Climate Change Risk and Adaptation Assessment

Tarakan

Sectoral Report
Health

June 2012

Ministry of Environment

Climate Risk and Adaptation Assessment for the Health Sector – Tarakan

FINAL DRAFT

Published by:

Ministry of Environment

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The development of this document was supported by:

Climate Risk and Adaptation Assessment for the Health Sector – Tarakan

Draft Final Report

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June 2012

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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).

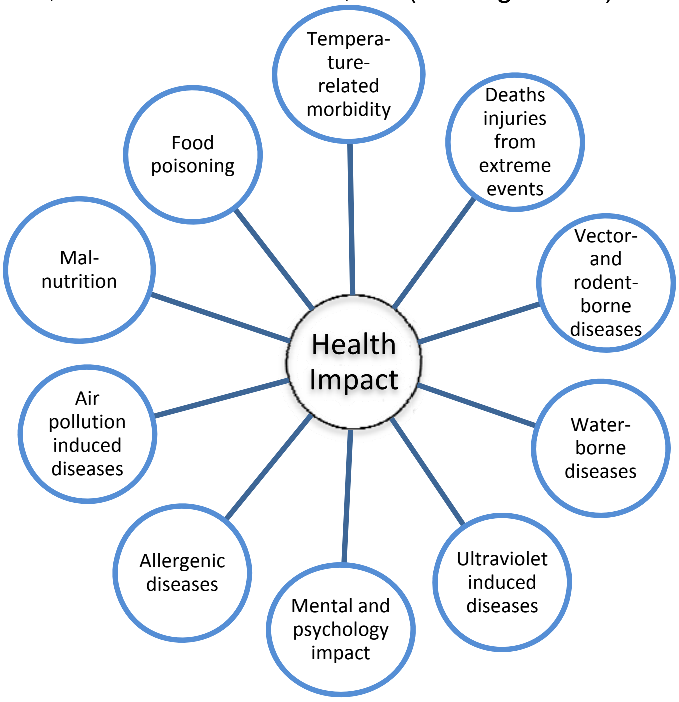


Figure 1-1 Climate Change Impact on Human Health

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.

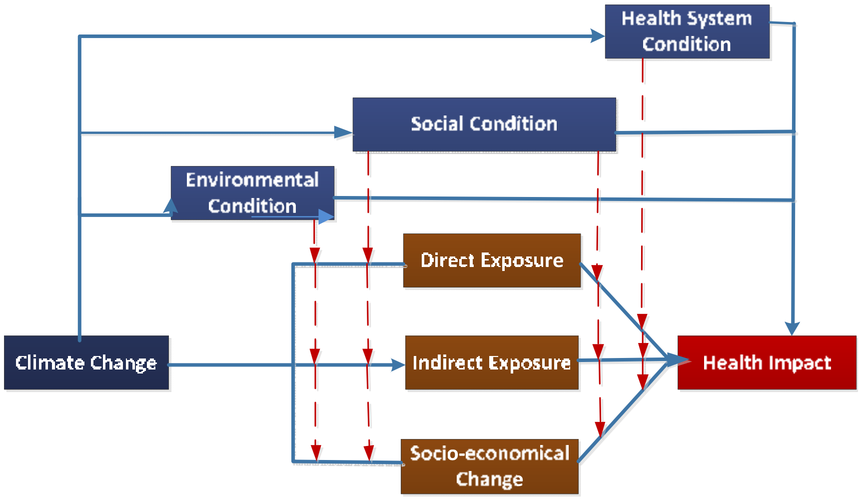


Figure 1-2 Schematic Diagram of Relationship Pattern of Climate Influence on Health, Impacting Directly as well as Influenced by the Modification of the Environmental Conditions, Social, and Health System (IPCC, Working Group II, 2008)

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: - Floods - Disturbance of water	- Flood and water balance disturbance could affect sanitation condition and bring water borne disease such as

Climate change	Direct Hazard	Non-direct Hazard
	balance - Landslides Together with increase in temperature, will decrease surface stream, causing: - Decrease of water availability - Droughts	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.

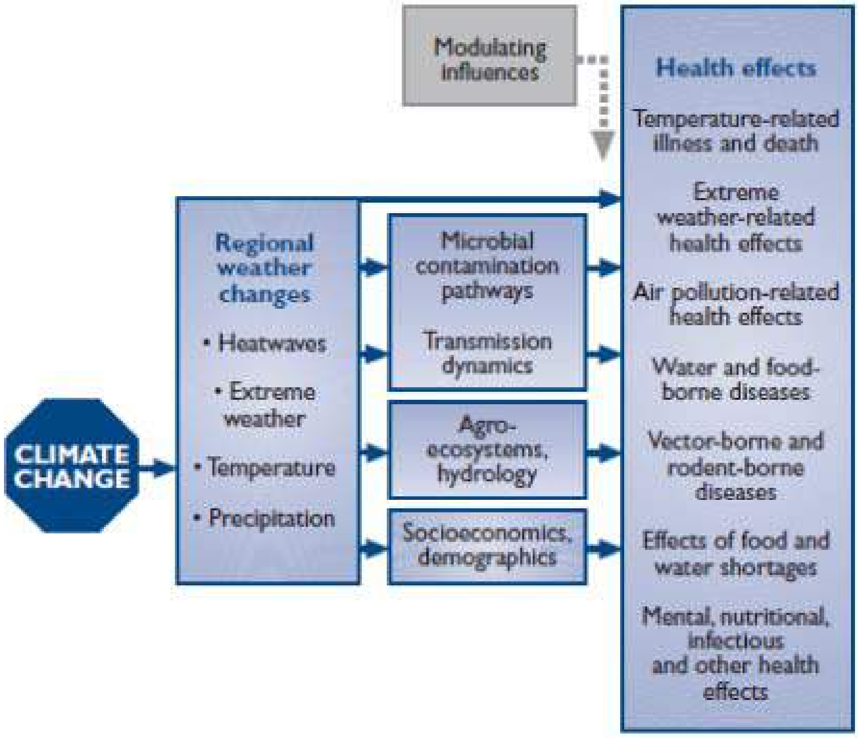


Figure 1-3 Pathways by which Climate Change Affect Human Health (Patz et al, 2000)

This assessment will look into the analysis of vulnerability and risk to climate change in the health sector in Tarakan, an island with total land area of 250.8 km^2 (Buku Saku Statistik Kota Tarakan, 2006) which located in East Kalimantan province. In general, small islands, especially in tropical developing countries, are the least responsible for climate change but are the most likely to suffer from its impact (UNFCCC, 2005). Temperature rise will change weather pattern, therefore increasing intensity and frequency of extreme weather events, such as tropical storms. Sea level rise and increasing vulnerability of natural disasters had been reported as impacts of extreme weather events on small islands, along with its various health effects. Moreover, rapid population growth on small islands will intensify the effect, especially due to water shortages. High number of population will require more fresh water, while availability of water supplies is limited. Many small islands rely entirely on a single source of water supply, such as rainwater, making them highly sensitive to climatic patterns (UNFCCC, 2005). For example, reduction and changes in precipitation and sea-level rise will decrease fresh water supply through rise of flood risks, impeded drainage system, and sea water intrusion. The disrupted water supplies and sanitation system will enhance water-borne diseases, e.g. diarrhea. In addition, changes in temperature and rainfall can elicit some vectors to extend their current range. The interior highlands of many islands are currently free of vectors these tropical diseases, could become favorable breeding sites due to temperature warming, therefore causing wider transmission of some diseases, for example, malaria and DHF (UNFCCC, 2005).

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 the Tarakan study 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 of Tarakan and analysis of risk to climate change in Tarakan island, 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 and Adaptation of the Health Sector to the Climate Change Adaptation and Vulnerability Database to be used by local governments and stakeholders in Tarakan
- To contribute Risk Analysis and Adaptation Options for the Health Sector to the Final Document for the local governments of Tarakan (BAPEDA and Pemda), 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 Predictive “Health Sector” Model as part of the national VA Guidelines based on the lessons drawn from the VA exercise in Tarakan.

This assessment also serve as a pilot project of vulnerability assessment in health sector conducted in a small island which methods, tools and concepts can potentially be used in other island in Indonesia with similar characteristic to Tarakan island 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 Tarakan municipality.

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, AND CLIMATE CHANGE ISSUES OF THE TARAKAN

2.1 Regional Description

In local term, Tarakan means 'a meeting place for fishermen to eat together and practice barter economy'. This area is crossed by Kayan, Sesayap, and Malinau River. Tarakan is famous as 'oil city', started in 1896 when Bataavishe Petroleum Maatchapij, a Ducth oil company, found that the island is rich in oil and dotted it with oil field pumps and tower rigs. This area had rapidly developed since the exploitation activities took place, attracting immigrants from other part of the country. Its strategic position had brought Tarakan as one of industrial centers in East Kalimantan.

2.1.1 Geographic and Topographic Profile of Tarakan Island

Tarakan Island is located in northern part of East Kalimantan Province, particularly between $3^o14'23"$-$3^o26'37"$ North Latitude and $117^o30'50"$-$117^o40'12"$ East Longitude with $\pm$ 250.80 km^2 of land area and $\pm$ 406.53 km^2 of vast ocean from $\pm$ 657.13 km^2 of total area of Tarakan Island. An average minimum temperature on this island is 24.8 ^oC and average maximum temperature is 31.4 ^oC with 85% of an average humidity (www.tarakankota.go.id).

Figure 2-1 Location of Tarakan Island

Geographical borders of Tarakan Island are as follow:
North : Coastal area of Bunyu Island sub district
East : Bunyu Island sub district and Sulawesi Sea
South : Coastal area of Tanjung Palas sub district
West : Coastal area of Sesayap sub district

As an Island, Tarakan consists of mostly lowland with high variation of elevation between 0-110 m above sea level (see Figure 2.2). The lowest part is the area along the coast, while the highest is around the hills. As mentioned before, there are still many towering and rugged hills in the area of Tarakan Island. Figure 2.2 shows that highlands area are spread from the southern to the northern part of the island, while the lowlands area are located along the coastal plains.

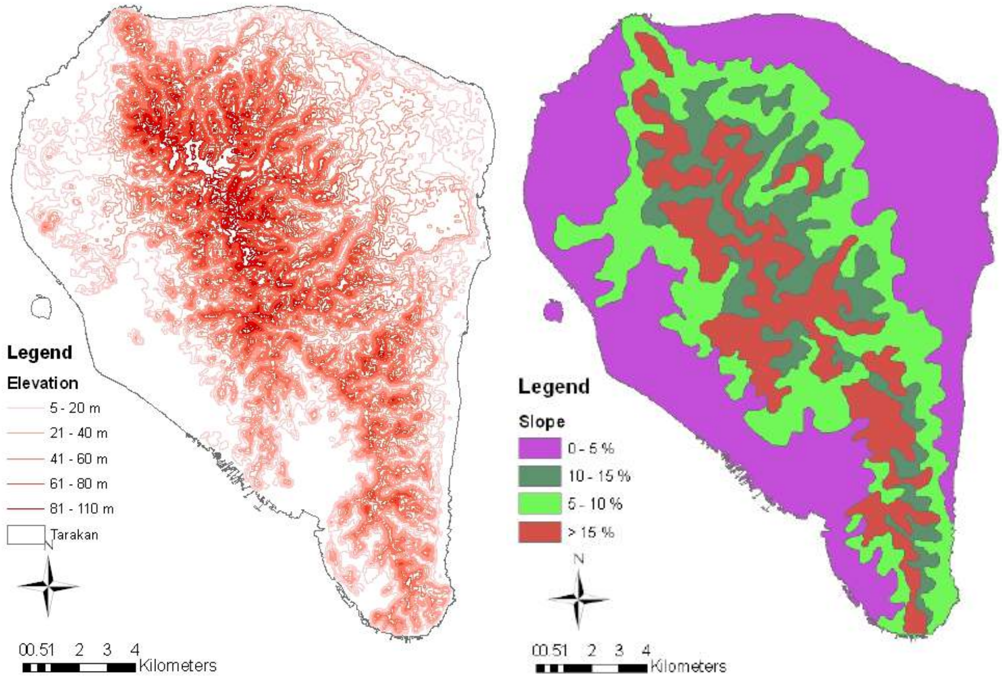


Figure 2-2 Topography of Tarakan Island

Tarakan Island consists of 4 sub districts and 20 villages (see Figure 2.3). Tarakan Utara (North Tarakan) sub district consists of 3 villages (Juata Laut, Juata Permai, and Juata Kerikil); Tarakan Barat (West Tarakan) consists of 5 villages (Karang Anyar, Karang Balik, Karang Anyar Pantai, Karang Rejo, and Karang Harapan); Tarakan Tengah (Central Tarakan) consists of 5 villages (Skip Kampung 1, Pamusian, Sebengkok, Selumit, and Pantai Selumitan); Tarakan Timur (East Tarakan) consists of 7 villages (Lingkas Ujung, Gunung Lingkas, Kampung 4, Kampung 6, Mamburungan, Mamburungan Timur, and Pantai Amal). Among the four subdistricts, Tarakan Utara has the largest area with an area of 109.32 km^2, followed by Tarakan Timur (58.01 km^2), Tarakan Tengah (55.54 km^2), and Tarakan Barat (27.89 km^2) (see Figure 2.4). In addition, to support the administration and improvement of services for community, Tarakan has established several institutions or office based on local regulations.

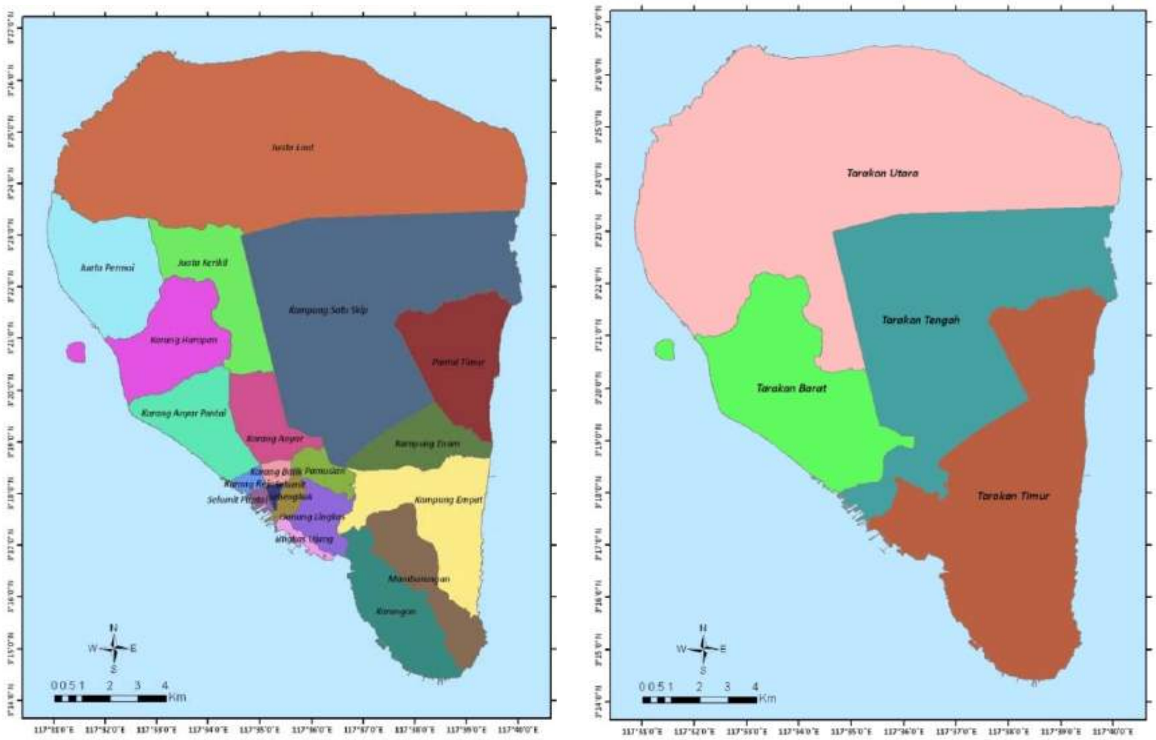


Figure 2-3 Administration Map of Villages and Subdistricts in Tarakan Island, 2009

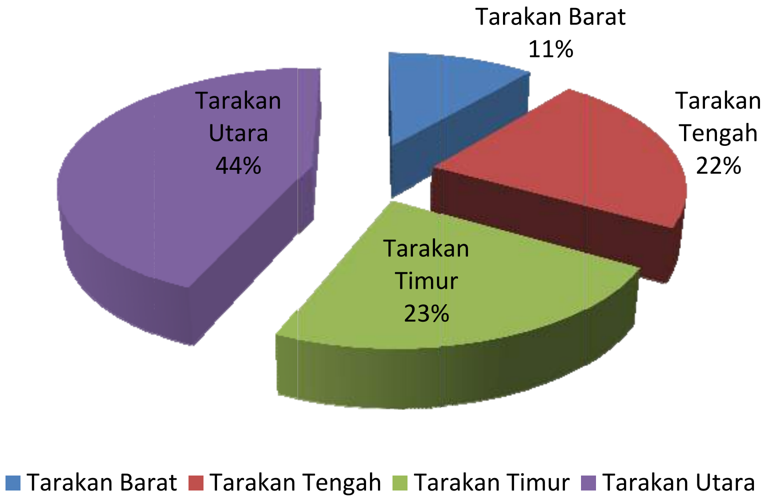


Figure 2-4 Tarakan Island Subdistricts Area, 2009

According to data from the Department of Forestry and Plantation of Tarakan, Tarakan Island has different land usages such as forest, industry, settlement, etc (see Figure 2.5). The most extensive land use in Tarakan Island is protected forest areas with 6,860 hectares or 27.35% of total land use areas, 2,797 hectares (11.15%) of urban forest,766 hectares (3.05%) of mangrove, 289 hectares (1.15%) of local conservation area, 910 hectares (3.63%) of commerce and services area, 1,934 hectares (7.71%) of industries area, 7,169 hectares (28.58%) settlements, 1,321 hectares (5.27%) of mining area, 1,282 hectares (5.11%) tourism, special regions 1,149 hectares or 4.58%, infrastructure facility 488 hectares or 1.95%, and livestock with 115 hectares or 0.46% of total land area of Tarakan.

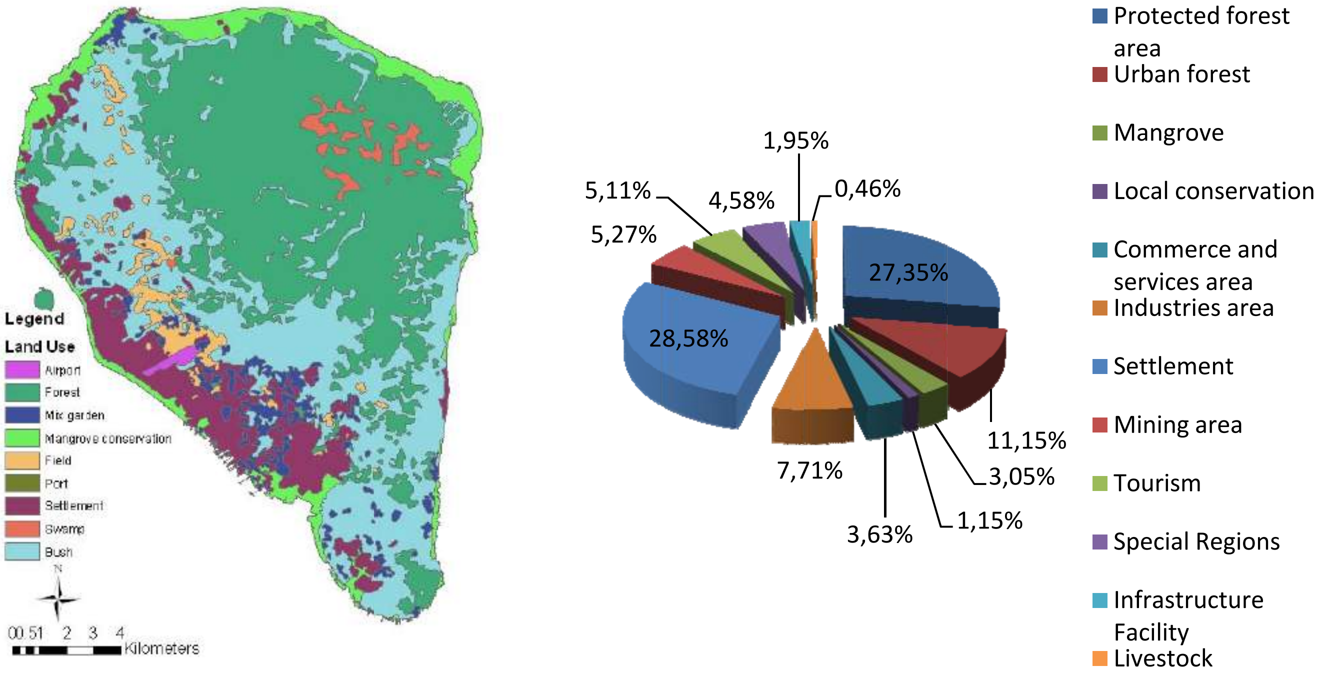
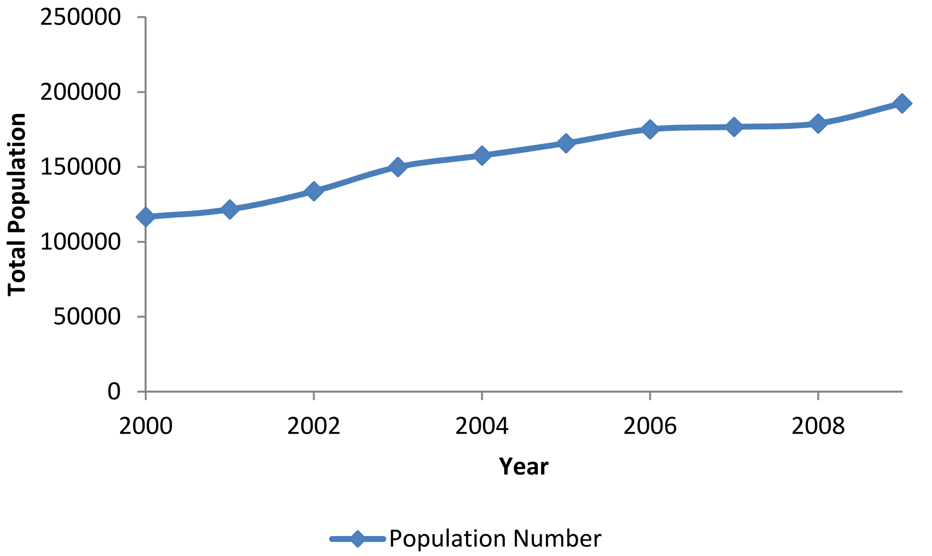


Figure 2-5 Land Use of Tarakan Island, 2008
Source: Department of Forestry and Plantation of Tarakan Island

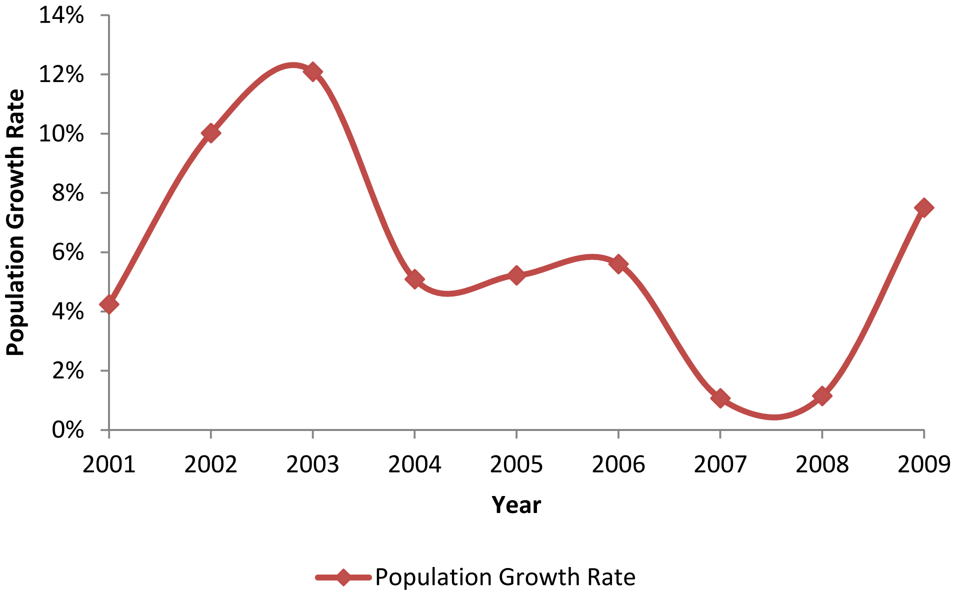
2.1.2 Demography of Tarakan Island

Figure 2.6a indicates that Tarakan Island population increased at an average of more than 2 percent annually (Civil Registration Agency of Tarakan, 2009). The current total number of population of Tarakan (2009) is around 192,430 peoples with growth rate increase fluctuating from 1% to 7.5% annually. Tarakan noted a peak growth rate of around 12% in 2003 (Figure 2.6b), although it subsided in the following years, reaching a minimum low in 2008, which is around 1.15%. In 2009, growth rate of Tarakan Island increased, surpassing national average population growth rate of 2.4% in the same year.

Health status of a community depends upon the dynamic relationship between number of people, their composition and distribution. Increasing population number and high annual growth rate of Tarakan require special attention from social and health aspect. 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. Slum areas with poor infrastructure and sanitation will emerge due to population explosion, which in turn will bring hazard should extreme climate occur.



(a)



(b)

Figure 2-6 Tarakan Island (a) Population Number and (b) Population Growth Rate Source: Civil Registration Agency of Tarakan City

Moreover, population density plays important factor for determining the health status in a region and for the provision of health facility. Densely populated and crowded areas with low health facility tend to ease on spread of infectious disease in the area. Table 2.1 shows the population distribution by sub districts and its annual increase. Obviously, the sub district of Tarakan Barat has higher risk in term of health condition since the area has the highest population density, but served by only one Puskesmas (Public Health Center or PHC).

Table 2.1: Recapitulation of Tarakan Island Population 2009

Sub district	Number of Population				PHC*)
	2006	2007	2008	2009	
Tarakan Barat	61,965	61,220	59,423	64,610	1
Tarakan Timur	37,494	37,914	39,325	44,346	3
Tarakan Tengah	54,109	55,092	60,651	63,774	1
Tarakan Utara	21,524	22,470	19,603	19,700	2
Total	175,092	176,696	179,002	192,430	7

Source : BPS and Public Health Service of Tarakan

Note *) = number of Primary Health Center (Puskesmas)

Figure 2.7 below shows a different aspect of the population growth in each sub district in term of social and health aspect. While Tarakan Barat has a constant population growth, it is the Tarakan Tengah which require better health concern as the average annual population growth is the fastest as compared to the other three sub districts. Moreover, only one Puskesmas is currently available to serve the Tarakan Tengah sub district.

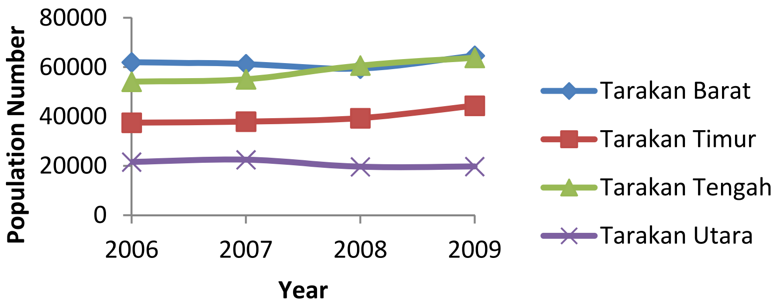


Figure 2-7 Population Number of Tarakan by Subdistrict
Source: BPS and Public Health Service of Tarakan, 2010

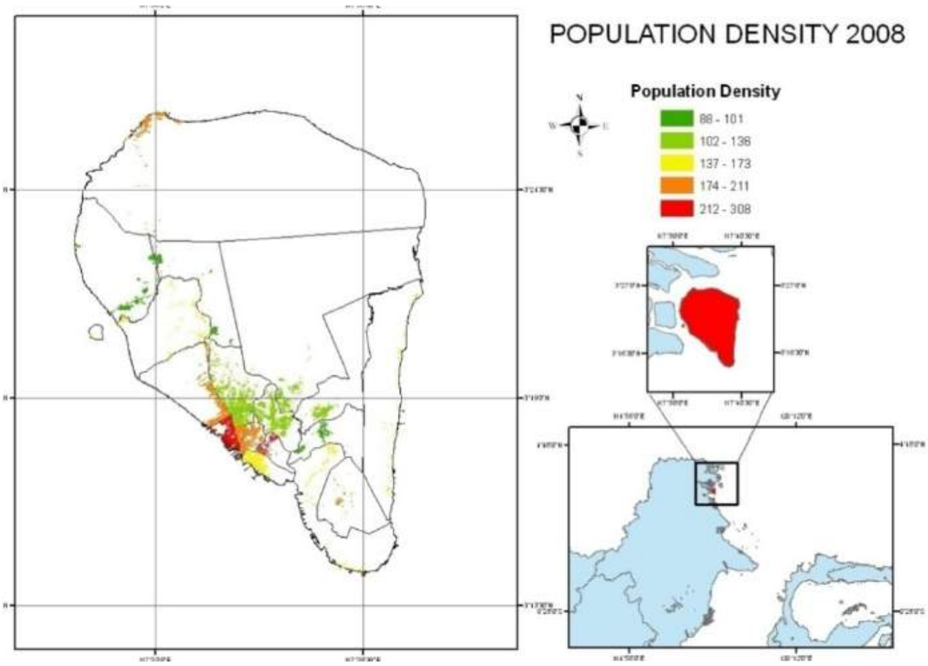


Figure 2-8 Population Density (people/Ha) of Tarakan, 2008
Source: Civil Registration Agency of Tarakan Island

Table 2.2: Number of Tarakan Population by Sex

Year	Number of Male Population	Number of Female Population
2003	83,174	66,769
2004	85,529	72,045
2005	89,608	76,193
2006	94,086	81,006
2007	96,492	80,489
2008	94,262	84,740
2009	102,094	90,336

Source: Civil Registration Agency of Tarakan Island

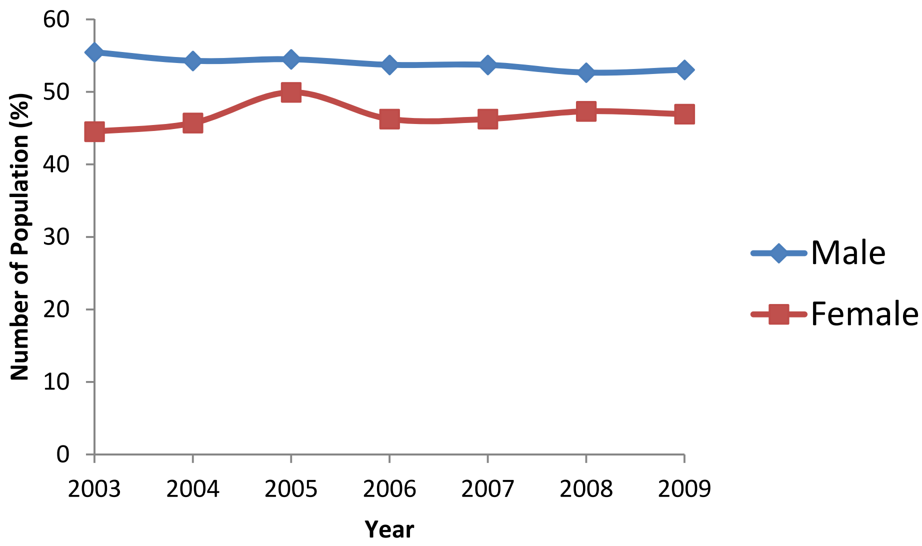


Figure 2-9 Proportion of Male and Female Occupant in Tarakan City
Source: Civil Registration Agency of Tarakan Island, 2010

Gender-based population ratio of Tarakan indicates a healthy population balance (see Figure 2.9). Male to female ratio of the population as shown on Figure 2.9 is similar to other developing area of the country. It is the age ratio shown in Figure 2.10, which requires attention as the number of young adults within the age group of 0 – 14 years are dwindling. The productive age group (15 – 64 years old) may understandably increases, as Tarakan is an open and a transit city where migrant workers may come and go, but the decrease of young adult population may create a slow growth on population, such in Singapore.

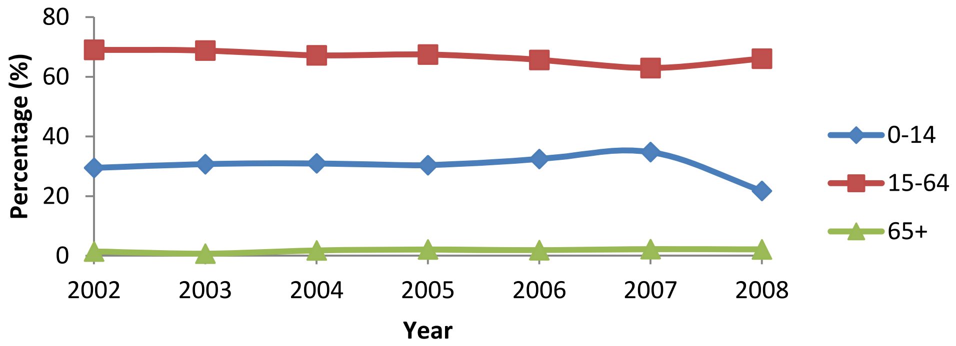


Figure 2-10 Tarakan Island Population by Age
Source: Civil Registration Agency of Tarakan Island, 2009

2.2 Health Profile of Tarakan Island

2.2.1 National and Regional Strategic Issues of Health Sector

Health Act no. 36/2009 defines health covers physical, mental, spiritual, and social health; therefore enable people to live socially and economically productive. Sustainable health development has been started since the introduction of the First Five-Year Development Plan (REPELITA) in 1969, which obviously has successfully developed various health resources and to implement health measures that have an impact on improving community health status. 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. Development in health is aimed to increase awareness, willingness and ability to live a healthy life for everyone in regards to manifestation of optimum community health.

In order to achieve a healthy community in certain level, some organized efforts must be established, particularly in health care, health improvement (promotion), disease prevention (preventive), cure (curative) and health recovery (rehabilitation), and it must be carried out in comprehensive, integrated and sustainable manners. 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.

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.

2.2.2 Health Status of Tarakan Island

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.

Official vision of Tarakan Island is ‘Tarakan Island as trade and service center; and healthy, fair, prosperous, and sustainable city while maintaining its cultural heritage’. It is clear that health aspect is one of priority area of Tarakan Island. Basically, health sector development is aimed to provide easier and affordable health service, as well as to improve health equity. Health Department of Tarakan has focused in aiming the improvement of public health status in self-supporting and integrated manner, therefore enhancing productivity and healthy competition among community members. In order to achieve its goals, Health Department of Tarakan has set several health policies as follow:

- Mutual improvement of human resource and environmental quality in enhancing health attempts that comprise preventive, curative, recovery, and rehabilitative action to maintain health condition, from maternal stages to old ages.
- Improvement of institutional capacity and health service through sustainable empowerment of human resources and medical facilities, including availability of affordable of medical supplies.
- Improvement of community quality through birth control program and reduce of mortality and morbidity.
- Promoting healthy behavior in society in order to achieve optimum health status.
- Tackling abusive uses of drugs additives, and other hazardous substances through peer counseling aimed to high risk groups and increasing rehabilitation centers for drugs victims.
- Partnership improvement with Municipal Government, NGOs, and other stakeholders.
- Improvement of occupational and public environment quality through air, water, and soil quality monitoring and pollution control.

Health condition will be represented by the capability of local government to provide a good environment, infrastructure, and education. Health condition in Tarakan is well-managed. Based on 2009 morbidity and mortality report available, only 2 maternal deaths were reported out of 4,552 pregnancies. The number of birth annually fluctuates between 4,000 to 5,000 births, for example the number of birth annually are 4,640, 4,669, 4,965, 4,552, and 4,552 for year 2005, 2006, 2007, 2008, and 2009, respectively. In the mean while, prevalence case of infectious diseases is low. In Tarakan, there are two climate-change related infectious diseases that should be noted. The first one is diarrhea, in which Tarakan has 4,098 cases reported in 2009. The second one is Dengue Hemorrhagic Fever (DHF) with 706 cases in the same year. Malaria is very small cases in Tarakan, but it is need to be evaluated due to prevention action.

Both malaria and DHF are mosquito borne diseases, which tend to increase as temperature, humidity and precipitation increase. Nevertheless, there has been no major health catastrophe for five consecutive years starting from 2004. The 10 highest diseases cases reported in Tarakan Island are shown in Table 2.3. As can be seen on the Table 2.3, DHF and upper respiratory infection are diseases with highest prevalence.

2.2.2.1 Malnutrition

Malnutrition is one of main concern in Millenium Development Goals. Indonesia MDGs also provide future expectation on decreasing malnutrition occurred on children under-five. Prevalence of malnutrition among children under-five in Indonesia has declined from 31% in 1989 to 18.4 % in 2007, so that Indonesia is expected to reach the MDG target of 15.5 % in year 2015. Moreover, malnutrition is a health hazard strongly related to the impact of climate change. Sea level rise, extreme weather, flood and drought could cause crop failure. Together with fisheries failure, the impact of climate change to the island of Tarakan will manifest in the form of malnutrition and famine.

Currently, based on data shown in Table 2.4, the number of children under-five in Tarakan Island in 2008 were 22,036 children, where 11 (0.05%) of them were malnourished. While, according to Riskesdas (Basic Health Research) data in 2007, 18.5% of childrenunder-five in Kalimantan Timur Province suffered from malnutrition. From the data alone, it can be concluded that malnutrition problem in Tarakan Island was much lower than Kalimantan Timur Province and that Tarakan has good food supply and distribution. In addition, as shown in Table 2.4, Tarakan Tengah sub district malnutrition data only available in 2008 because Sebengkok Public Health Center (PHC) was established in 2008.

Table 2.3: Diseases reported from Tarakan and its Relevance to Climate Change and Environmental Pollution

Disease	Type of Disease	Relevance to Climate	Degree of Relevance (IPCC)	Prevalence in Tarakan*	National Prevalence **
DHF (P)	Vector-borne	Temperature, Precipitation, Humidity	+++	12.1	0.6
Malaria (P)	Vector-borne	Sea level rise	+++	?	2.9
Filariasis (P)	Vector-borne	Temperature, Precipitation, Humidity	++	?	0.1
Diarrhea	Water-borne	Flood, drought	+++	6.8	9.0
Typhoid	Water-borne	Flood, Water pollution	++	8.4	1.6
URTI (***)	Air-borne	Air pollution, smoke hazard	++	37.3	25.5
Pneumonia	Air-borne	Droplet Infection	+	3.9	2.1
Lung TB (P)	Air-borne	Droplet Infection	+	5.8	1.0
Bronchitis	Air-borne	Droplet Infection	±	3.9	?
Hepatitis	Environmental sanitation	Food-borne Infection	–	–	0.6
Measles	Community Hygiene	Skin contact infection	–	–	1.2

* Source: *Kota Tarakan Dalam Angka* (2006)
** Source : MoH – Basic Health Research RISKESDAS (2007)
*** URTI = Upper Respiratory Tract Infection
(P) designated by WHO as 'Infectious Disease of Poverty"

Table 2.4: Tarakan Malnutrion Status on Underfive Year Children

No	Sub district	PHC	2006		2007		2008	
			Existed under-five	Mal-nutrition	Existed under-five	Mal-nutrition	Existed under-five	Mal-nutrition
1	**Tarakan Timur**	Mamburungan	11,558	0	2,121	0	2,162	0
		Gunung Lingkas	2,127	0	1,638	0	1,427	0
		Pantai Amal	4,031	0	4,159	2	3,856	2
2	**Tarakan Barat**	Karang Rejo	1,336	0	11,619	3	6,707	3
3	**Tarakan Utara**	Juata Laut	2,115	0	1,582	3	1,234	3
		Juata Permai	1,550	0	2,167	0	1,993	0
4	**Tarakan Tengah**	Sebengkok	*	*	*	*	4,657	3
Total			22,717	0	23,286	8	22,036	11

Source: Health Service of Tarakan Island

Note: *) No data because Sebengkok Public Health Center (PHC) was start established in 2008.

Public health status depends on many indicators, one of them is drugs supply and distribution, especially for high risk population such as old ages populations and pregnant women. For example, iron is a essential nutrient required by pregnant women in their daily diet, lack of iron can cause many health problems during pregnancy and post-delivery phase, such as iron-deficiency anemia both in mother and baby. The availability and distribution of Fe tablets is shown in Table 2.5. From the data, the coverage of Fe tablets for pregnant mothers is fluctuative year by year. As for Central Tarakan sub district, the data are only available in 2008 and 2009 because Sebengkok Public Health Center (PHC) was established in 2008.

Table 2.5: Fe Tablets Coverage for Pregnant Mothers in Tarakan

No	Subdistricts	PHC	2007		2008		2009	
			Fe1 (%)	Fe3 (%)	Fe1 (%)	Fe3 (%)	Fe1 (%)	Fe3 (%)
1	Tarakan Timur	Gunung Lingkas	92.3	136.2	39.6	25.0	64.1	59.2
		Pantai Amal	59.8	68.8	103.7	87.0	89.6	84.1
		Mamburugan	95.6	113.9	96.6	118.8	71.1	67.2
2	Tarakan Barat	Karang Rejo	43.4	20.6	74.9	80.5	50.3	35.7
3	Tarakan Utara	Juata Laut	80.7	79.1	109.3	64.1	104.3	74.2
		Juata Permai	115.5	71.4	99.4	78.6	97.5	64.6
4	Tarakan Tengah	Sebengkok	*	*	25.2	12.5	39.1	43.4

Source: Health Service of Tarakan Island

Note: *) No data because Sebengkok Public Health Center (PHC) was start operated in 2008.

2.2.2.2 UCI (Universal Child Immunization) and Nutrition Program

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.

Table 2.6: Percentage of Under-five Immunization Coverage in 2007 and 2008

No	Sub district	PHC	Coverage 2007 (%)					
			BCG	DPT1+HB1	DPT3+HB3	POLIO3	CAMPAK	HB3
1	Tarakan Timur	Mamburungan	97.4	132.4	106.9	108.7	99.7	107.7
		Gunung Lingkas	99.7	106.0	107.0	92.4	95.3	112.6
		Pantai Amal	102.7	130.9	105.2	91.6	98.4	106.9
2	Tarakan Barat	Karang Rejo	99.3	131.1	98.5	99.6	97.8	98.5
3	Tarakan Utara	Juata Laut	90.4	103.4	100.3	83.2	96.6	95.2
		Juata Permai	110.5	152.0	115.0	113.5	117.3	104.3
4	Tarakan Tengah	Sebengkok*						
No	Sub district	PHC	Coverage 2008 (%)					
			BCG	DPT1+HB1	DPT3+HB3	POLIO3	CAMPAK	HB3
1	Tarakan Timur	Mamburungan	111.2	112.6	110.7	102.2	104.1	110.7
		Gunung Lingkas	86.1	84.2	78.9	73.9	82.8	78.9
		Pantai Amal	96.6	87.2	88.1	82.8	80.2	88.1
2	Tarakan Barat	Karang Rejo	106.0	102.4	105.3	96.5	93.1	105.3
3	Tarakan Utara	Juata Laut	92.4	101.0	103.9	93.4	110.5	103.9
		Juata Permai	108.4	112.8	109.6	109.6	97.8	109.6
4	Tarakan Tengah	Sebengkok	105.5	98.1	91.8	91.8	82.1	91.8

Source: Health Service of Tarakan Island

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 vaccination coverage of Tarakan Island in 2007 and 2008 is shown in Table 2.6. Data in Table 2.6 indicates high coverage of infant immunization in almost every Tarakan's sub district, suggesting that immunization program was quite a success.

Table 2.7 shows the percentage of householder receive the immunization. It indicates that annual increase of vaccination rate did not occur, but in general, coverage of vaccination in Tarakan Island is quite high, with more than 50% coverage each year.

Table 2.7: Universal Child Immunization (UCI)

Year	Amount of Villages	UCI (villages)	
		UCI	UCI (%)
2004	20	16	80%
2005	20	13	65%
2006	20	na	na
2007	20	19	95%
2008	20	12	60%

Source: Health Service of Tarakan Island

Based on vision and mission statement of the government of Tarakan, Tarakan has developed a program to accomodate all its citizens to be in a good health condition. Tarakan nutrition program is divided into several main indicators (see Table 2.8). Almost none of the indicators in that program have met its designated target and therefore the local government had to solve this problem by using several appropriate means of alternatives.

Table 2.8: Related Indicators for Tarakan Nutrition Program

Indicators	Target	Year			
		2005	2006	2007	2008
Weight Increment of under-five	80.0%	84.0%	78.7%	62.4%	63.6%
Under-five with low weight	5.0%	2.9%	0.4%	1.8%	1.4%
Number of Under-five receiving vitamin A	90.0%	43.4%	80.5%	115.0%	88.3%
Pregnant woman receiving Fe tablets	90.0%	68.6%	67.7%	59.9%	52.5%
Provision of supplementary food with breastmilk for low weight babies of Poor Families (Gakin)	100.0 %	100.0%	100.0%	100.0%	100.0%
Treatment of Under-five with severe malnutrition	100.0 %	100.0%	100.0%	100.0%	100.0%

Source: Health Service of Tarakan Island

2.2.3 Health Facilities and Its Management

Health facilities play an important role in maintaining and improving the quality of public health. Without health facilities, both quantity and quality, it would be impossible to achieve the vision and mission of Tarakan Government. Health facilities include health infrastructure (such as health centers, intergrated health center, and hospitals), health professionals (such as doctors, nurses, midwives, nutritionists, etc.), and sanitation facilities (such as clean water facilities, drainage, etc.). In anticipation of future climate change's influence on health condition, health emergency facilities for climate hazards should be adequately prepared.

2.2.3.1 PHC (Public Health Center/Puskesmas)

Public Health Center (PHC) have important role in maintaining and improving the condition of population health. Tarakan has 7 PHCs which are distributed in 4 sub districts (see Table. 2.9). Data from Table 2.9 show that utility level of PHC was in low percentage. It might be due to people who tend to visit hospital if they were sick rather than going to a PHC. Based on Kalimantan Timur Riskesdas data of 2007, hospitals remain the most visited place for both in-patients and out-patients.

Table 2.9: Utilization rate of PHC in 2008

Sub districts	Name of PHC	Visit PHC level in 2008	
		Visit (person)	Utility level
Tarakan Timur	Gunung Lingkas	29,414	17.8%
	Pantai Amal	5,709	3.5%
	Mambrungan	26,621	16.1%
Tarakan Barat	Karang Rejo	55,517	33.7%
Tarakan Utara	Juata Laut	11,531	7.0%
	Juata Permai	27,607	16.7%
Tarakan Tengah	Sebengkok	8,761	5.3%

Source : Health Service of Tarakan Island

Figure 2-11 PHC Gunung Lingkas in Tarakan Island

PHC/Puskesmas Gunung Lingkas (Figure 2.11) is a newly built modern health facility operating 24 hours a day in anticipation of health emergency.

2.2.3.2 IHC (Integrated Health Center/Posyandu)

Tarakan has IHCs whose numbers continue to increase every year. Table 2.10 shows the increase in IHCs from the year of 2006 until 2008.

Table 2.10: IHC (Integrated Health Center/Posyandu)

Subdistrict	PHC	IHC		
		2006	2007	2008
Tarakan Timur	Gunung Lingkas	13	24	24
	Pantai Amal	12	13	13
	Mamburungan	24	12	12
Tarakan Barat	Karang Rejo	76	63	43
Tarakan Utara	Juata Laut	11	11	12
	Juata Permai	16	17	19
Tarakan Tengah	Sebengkok	*	*	20
Total Number		127	140	143

Source: Health Service of Tarakan Island

Note: *) No data because Sebengkok Public Health Center (PHC) was start operated in 2008.

2.2.3.3 Health professionals

Capacity and support of health professionals, such as doctors, dentists, nurses, midwives, and others, are other main factors which contribute to public health status. Current number of health staff providing health services for the whole 180,000 population of Tarakan is 74 health professionals, of which 24 are medical specialists, 33 are general practitioners and 17 are dentists. Tarakan also has 244 nurses in active service, but only one is a university graduate nurse. Compared to the national health staff distribution, the number of health professionals in Tarakan is considered sufficient. As a growing city with strong potential for educated workers, Tarakan also attracts fresh medical graduates.

Table 2.11: Health Human Resources in Tarakan

Health Indicators	Year	
	2007	2008
The ratio of doctors per 100,000 population	37	40
The ratio of specialist physicians per 100,000 population	14	16
The ratio of family doctors per 100,000 population	0	na
Rasio dentists per 100,000 population	11	15
The ratio of pharmacists per 100,000 population	9	16
The ratio of midwives per 100,000 population	42	55
The ratio of nurses per 100,000 population	217	280
Nutritionists ratio per 100,000 population	7	6
The ratio of sanitation specialists per 100,000 population	10	7
The ratio of public health professionals per 100,000 population	12	13

Source: Health Service of Tarakan Island

2.2.3.4 Other facilities and infrastructures

There are other facilities that may determine the level of health of the population. They are:

a. Number of Healthy Houses

House, as the place where the residents perform their daily activities, must be healthy. A healthy house is a house that is free from vector breeding nest, have good air circulation, receive adequate sun lights, etc. In other word, a healthy house is also an indicator of population/occupants health. Table 2.12 shows the percentage of healthy house in Tarakan City year 2007 and 2008. From these data, the distribution of healthy houses in Tarakan island are not well-distribute. Tarakan Timur sub district has the highest percentage of healthy house than the other sub districts.

Table 2.12: Percentage of Healthy House in Tarakan Island, 2007 and 2008

Sub district	PHC	Houses (2007)				
		Total Number	Number observed	%Observed	Number of healthy house	% Healthy
Tarakan Timur	Gunung Lingkas	4,308	500	11.6	285	57.0
	Pantai Amal	2,564	505	19.6	486	96.2
	Mamburu-ngan	6,304	904	14.3	306	33.8
Tarakan Barat	Karang Rejo	16,686	454	2.7	363	80.0
Tarakan Utara	Juata Laut	1,647	357	21.6	90	25.2
	Juata Permai	3,627	0	0	0	0
Tarakan Tengah	Sebengkok*	na	na	na	na	na
Total		35,136	2,720	7.7	1,530	56.3

Note: *) No data because Sebengkok Public Health Center (PHC) was start operated in 2008.

Sub district	PHC	Houses (2008)				
		Total Number	Number observed	%Observed	Number of healthy house	% Healthy
Tarakan Timur	Gunung Lingkas	2,641	222	8.4	128	57.7
	Mamburu-ngan	2,982	487	16.3	300	61.6
	Pantai Amal	6,304	5,289	83.9	4,794	90.6
Tarakan Barat	Karang Rejo	10,766	2,440	22.7	1,789	73.3
Tarakan Utara	Juata Laut	1,647	657	39.6	173	26.5
	Juata Permai	3,627	379	10.4	0	0
Tarakan Tengah	Sebengkok	5,922	0	0	0	0
Total		33,889	9,474	27.9	7,184	75.9

Source: Health Service of Tarakan Island

b. Provision of clean water from WTP (Water Treatment Plant)

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 wheather-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.

Tarakan city has water treatment facilities to support the health of population. This facility should serve the entire population with 400 L/sec processing capacity (see Table 2.13). Raw water source for drinking water in the Tarakan comes from surface water (river). Types of clean water used in Tarakan sub districts are described in each sub district. Total PDAM water production and distribution of Tarakan City in 2008 are shown in Figure 2.12. From those figure, total water losses are quite high so it is necessary to improve and develop maintenance regular program. Types of clean water used in Tarakan sub districts are described in each sub district.

Table 2.13: Water Treatment Plant (WTP) PDAM Tarakan 2008

Description		
Tarakan City Population		179,002 citizen
Total IPA taps	400 L / s	
Region		
* Kampung Bugis	120 L / s	
* Persemaian	155 L / s	
* Juata Permai	35 L / s	
* Kampung Satu	90 L / s	
Type of source water	Water surface	
Drainage system	Pumping and gravity	

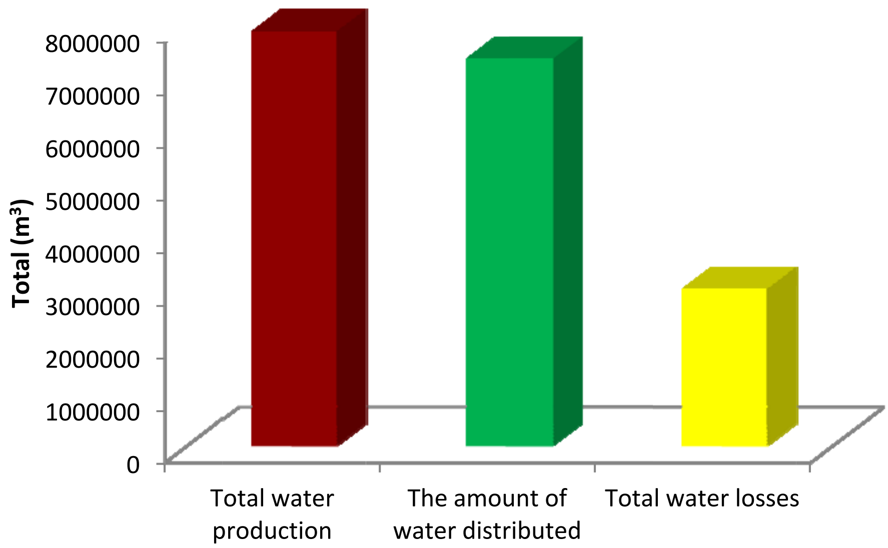
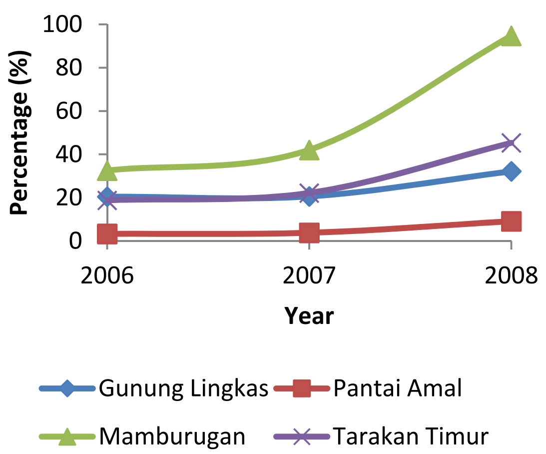


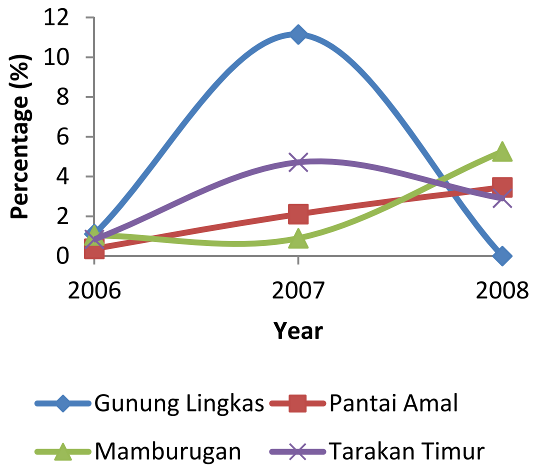
Figure 2-12 PDAM Water Production and Distribution of Tarakan Island 2008 (Source: Tarakan in Figures 2008)

b.1 Tarakan Timur Sub district

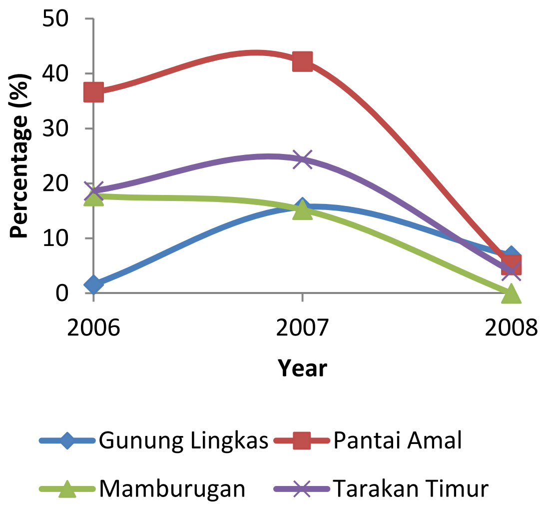
Types of clean water used in Tarakan Timur sub district are shown in Figure 2.13. Usage of tap water as clean water increased every year but Pantai Amal has highest risk since its tap water percentage is very low (see Figure 2.13a). The percentage of rainwater usage as clean water is not different compared by previous year (data in 2006 until 2008). From Figure 2.13, about 40% of Tarakan Timur population use tap water and rainwater in 2008 as clean water, and the rest of it are from deep wells and shallow wells.



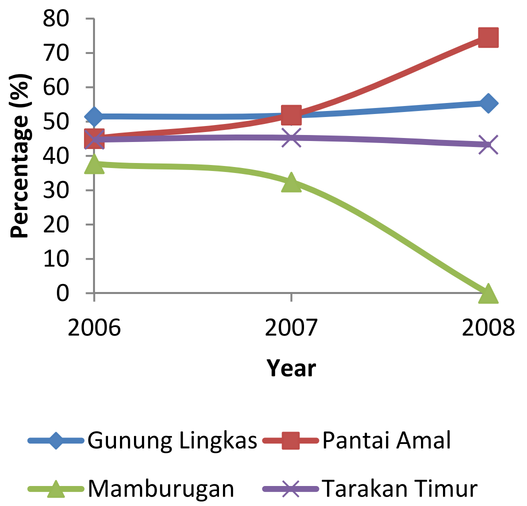
(a) Tap water



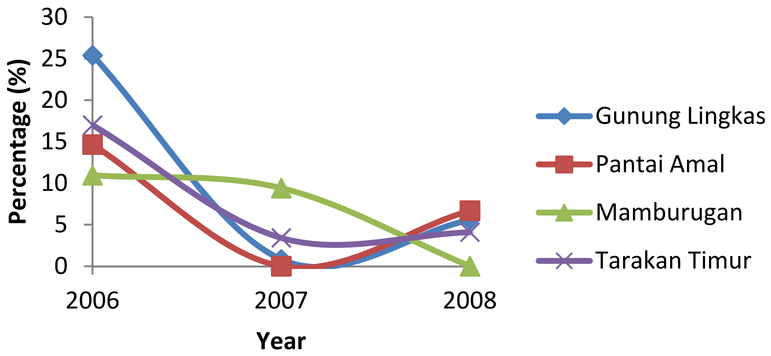
(b) Deep well water



(c) Shallow well water



(d) Rainwater



(e) Others

Figure 2-13 (a) Tap water, (b) Deep Well Water, (c) Shallow Well Water, (d) Rainwater, (e) Others Types of Clean Water Used by Population in Tarakan Timur (source: Health Service of Tarakan)

Table 2.14: Recapitulation of Clean Water Used in Tarakan Timur

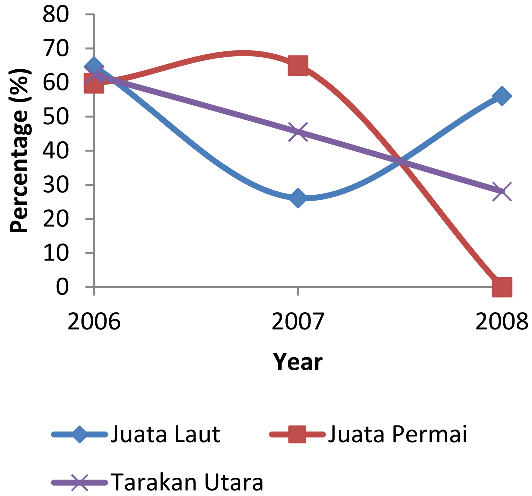
Sub district	PHC	Tap water (%)			Deep Well Water (%)		
		2006	2007	2008	2006	2007	2008
Tarakan Timur	Gunung Lingkas	20.5	20.6	32.2	1.1	11.1	0.0
	Pantai Amal	3.3	3.8	9.1	0.4	2.1	3.5
	Mamburungan	32.5	42.1	94.7	1.0	0.9	5.3

Sub district	PHC	Shallow Well Water (%)			Rain water (%)			Others (%)		
		2006	2007	2008	2006	2007	2008	2006	2007	2008
Tarakan Timur	Gunung Lingkas	1.6	15.7	6.9	51.5	51.8	55.4	25.4	0.8	5.6
	Pantai Amal	36.6	42.2	5.2	45.1	51.9	74.5	14.7	0.0	6.7
	Mamburungan	17.7	15.2	0.0	37.7	32.4	0.0	11.0	9.4	0.0

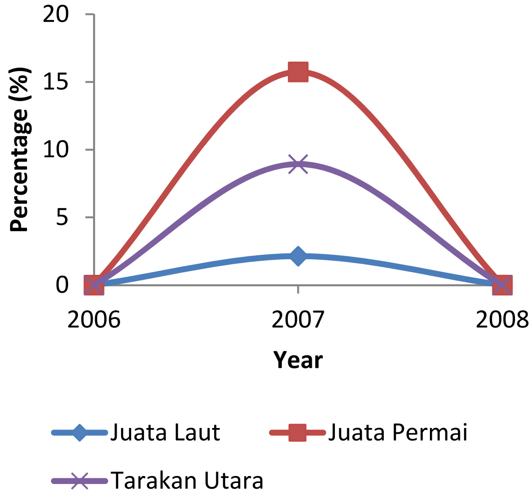
Source: Health Service of Tarakan

b.2 Tarakan Utara

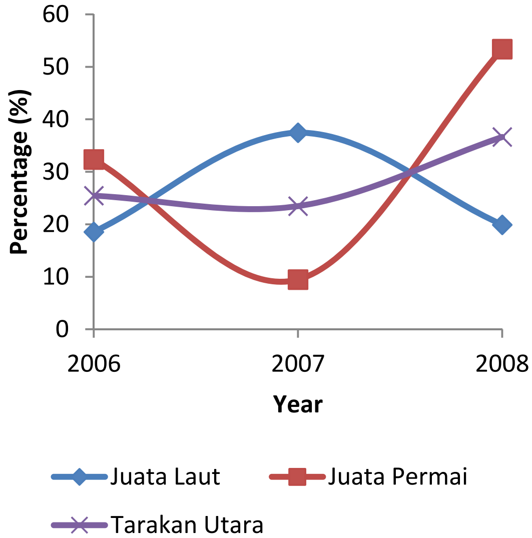
Types of clean water used in Tarakan Utara sub district are shown in Figure 2.14. From Figure 2.14a, usage of tap water as clean water decreased every year (2006-2008). Percentage of rainwater and shallow well water usage as clean water are increased compared to the previous years (data in 2006 until 2008). From Figure 2.14, about 30% of Tarakan Utara population use tap water as clean water in 2008, while 35 % use shallow well water and 20% use the rainwater, and the rest of them are from deep wells.



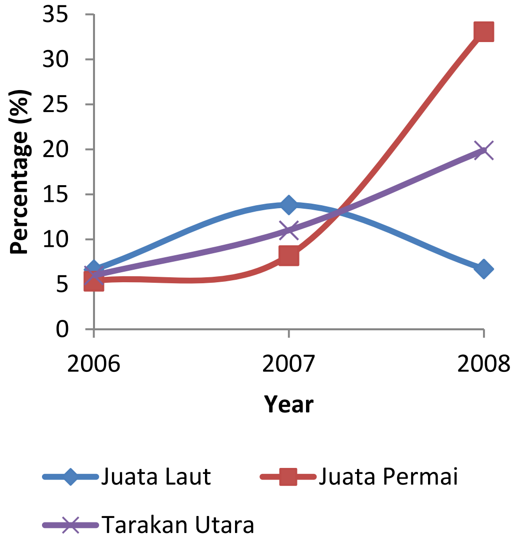
(a) Tap water



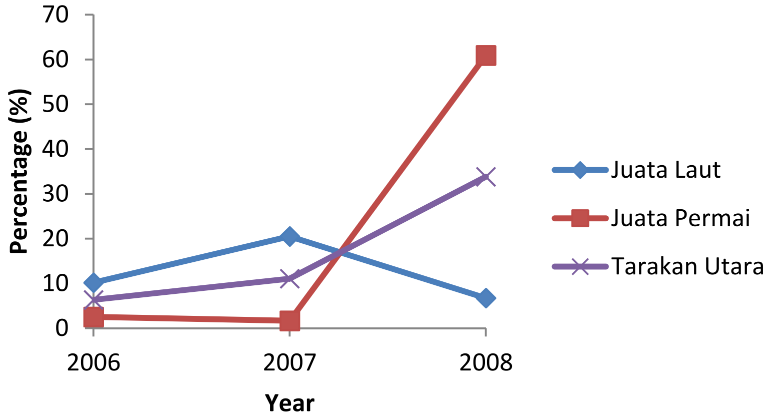
(b) Deep well water



(c) Shallow well water



(d) Rainwater



(e) Others

Figure 2-14 (a) Tap water, (b) Deep Well, (c) Shallow Well, (d) Rainwater, (e) Others Types of Clean Water Used by Population in Tarakan Utara (source: Health Service of Tarakan)

Table 2.15: Recapitulation of Clean Water Used in Tarakan Utara

Sub district	PHC	Tap water (%)			Deep Well Water (%)			Shallow Well Water (%)		
		2006	2007	2008	2006	2007	2008	2006	2007	2008
Tarakan Utara	Juata Laut	64.7	26.1	56.1	0.0	2.1	0.0	18.6	37.5	19.9
	Juata Permai	59.8	65.0	0.0	0.0	15.7	0.0	32.4	9.5	53.4

Sub district	PHC	Rain water (%)			Others (%)		
		2006	2007	2008	2006	2007	2008
Tarakan Utara	Juata Laut	6.6	13.8	6.7	10.1	20.5	6.7
	Juata Permai	5.4	8.2	33.1	2.5	1.6	60.9

Source: Health Service of Tarakan

b.3 Tarakan Barat

Types of clean water used in Tarakan Barat sub district are shown in Figure 2.15. From Figure 2.15, about 60% of Tarakan Barat population use tap water as clean water and 30% of them use rainwater, and the rest are from deep well and shallow well in 2008.

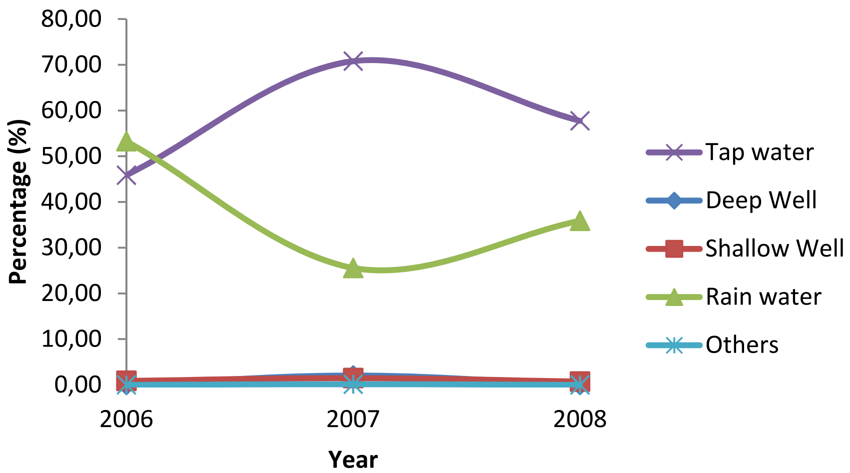


Figure 2-15 Tap water, Deep Well, Shallow Well, Rainwater, and Others Types of Clean Water Used by Population in Karang Rejo, Tarakan Barat

Table 2.16: Recapitulation of Clean Water Used in Tarakan Barat

Sub district	PHC	Tap water (%)			Deep Well Water (%)			Shallow Well Water (%)		
		2006	2007	2008	2006	2007	2008	2006	2007	2008
Tarakan Barat	Karang Rejo	45.8	70.8	57.7	0.0	2.0	0.0	0.9	1.5	0.7

Sub district	PHC	Rain water (%)			Others (%)		
		2006	2007	2008	2006	2007	2008
Tarakan Barat	Karang Rejo	53.3	25.6	35.9	0.0	0.1	0.0

Source: Health Service of Tarakan

b.4 Tarakan Tengah
Data of clean water usage in Tarakan Tengah Sub district are not available.

c. Functioning solid waste treatment (Sanitary Landfill)

Landfill is a place of final processing of the waste produced from households, markets, residential areas, industrial, and others. This facility plays crucial role in management of solid waste, and it is expected to functioning well in order to prevent vector breeding, therefore reducing incidence of vector-borne infectious diseases.

Tarakan as one of developing and high economic cities also has landfill facility, particularly Sanitary Landfill as it is known to be a sound landfill processing. Figure 2.16 shows the Akibabu sanitary landfill processes.

Figure 2-16 Akibabu Sanitary Landfill, Tarakan

2.3 Sensitive Population

Sensitive population is receptor who receives the highest impact of climate change. Sensitivity is one of climate change vulnerability factor. Therefore, human classification by different level of sensitivity is needed. The results of research from experts in the field of health and medicine indicate that the most sensitive 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. Table 2.17 displayed the mortality rate of infants, under-five, and maternal death rate in Tarakan from 2000 to 2009. To see the trend of its value, see Figure 2.17.

Table 2.17: Mortality Rate of Infant, Under-five, and Maternal in Tarakan

Year	Per 1,000 Population			
	Crude Death Rate (CDR)	Maternal Mortality Rate	Infant Mortality Rate	Under-five Mortality Rate
2000	8.9	0.1	0.4	0.1
2001	4.5	0.9	3.0	0.1
2002	2.0	0.4	8.0	0.7
2003	1.6	0.6	26.2	0.8
2004	0.4	0.0	15.1	1.0
2005	0.4	0.9	19.2	1.2
2006	0.4	1.3	15.5	0.5
2007	0.4	0.8	11.7	0.5
2008	0.5	0.7	11.8	0.8
2009	0.0	0.4	18.1	0.7
Average	1.91	0.61	12.9	0.64
Indonesia	19	230	31	41

Source: Health Service of Tarakan

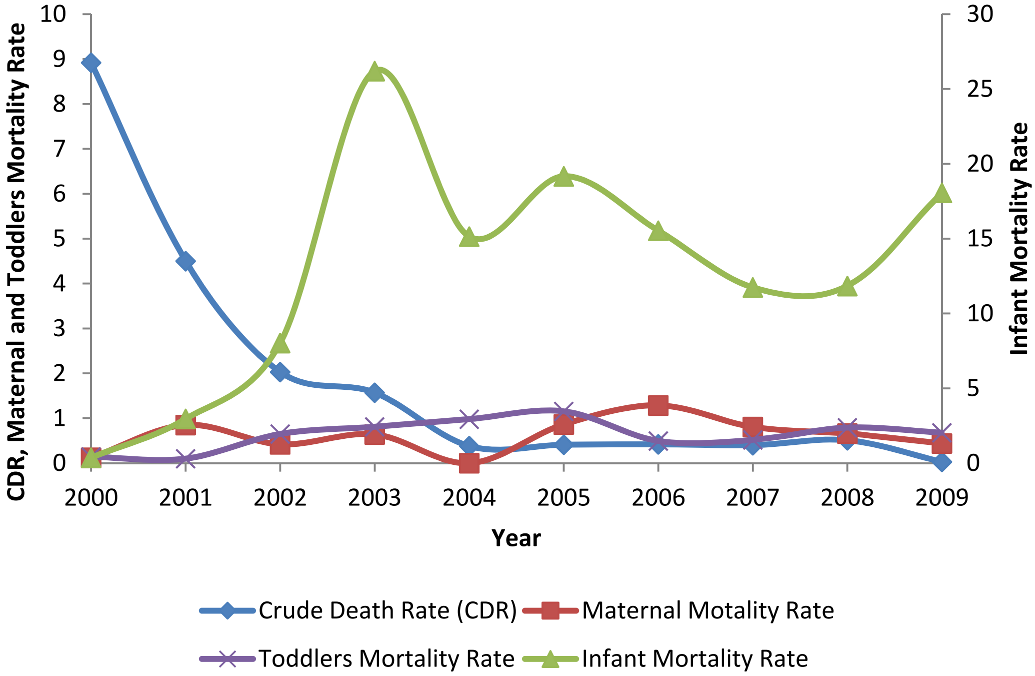


Figure 2-17 Rate of Crude Death, Maternal Mortality, Under-five Mortality, and Infant Mortality in Tarakan (Source: Health Service of Tarakan)

From Table 2.17 , it is clear that average CDR, MMR, IMR, and U5MR in Tarakan Island were much lower than CDR, MMR, IMR, and U5MR in Indonesia as a whole. It suggests that health status of Tarakan Island is better than in some other area in Indonesia.

Definition of CDR, MMR, IMR, and U5MR are described below:

- 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 child bearing 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.
- Infant mortality rate (IMR) is defined as the number of infant deaths (one year of age or younger) per 1000 live births. IMR is the basic indicator for population health and quality of health care services, since it measures longer term consequences of perinatal events.
- Under-five mortality rate (U5MR) is defined as the probability of dying between birth and exactly five years of age per 1,000 live births.

2.4 Strategic issues of the Health Sector, Climate Change and Development

Tarakan City is a small island with high potential impacts due to climate change, especially in human 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. However, based on health condition analysis in Tarakan, the major health impacts discussed in this report are vector-borne diseases (DHF and malaria) and water-borne diseases (diarrhea). Malnutrition will not be included in the analysis because it only occurred in small percentages.

In addition, the city of Tarakan is also a transit city. It gives effects on spreading the diseases including vector and water borne diseases. These issues are the important factors why Tarakan Island is chosen to be the assessment/study location.

As a conclusion to the report and discussion of the health condition in Tarakan, it may be drawn to our attention the following strategic issues (which will be further analyzed, discussed and elaborated in Chapter IV):

1) On the geographic (dis-) advantages of Tarakan as a small island – as a small island, Tarakan is prone to climate changes namely sea level rise, tropical monsoon, torrential flooding and prolonged drought. The isolation of Tarakan from mainland Kalimantan Timur province has also the disadvantage of being cut off from livelihood supplies should climate emergency occur.
2) On the population and socio-health aspects – population density made worse by influx of job seeking incoming migrant will burden the health infrastructures. Socially there will be tension between the slum-dwelling migrants and the local inhabitant. Racial tension may soar.
3) On the availability of health-related facilities – currently medical facilities and health supplies are adequate. But its availability is not yet geared to facing climate hazard in the future.
4) On the incidence and prevalence of climate related diseases – influx of migrant, whether permanent or temporary, will expose Tarakan with diseases not known

previously. Chikungunya, one of the climate dependent vector borne disease, commonly found in Java should be closely monitored. Incidence may increase during rainy season.

CHAPTER 3 METHODOLOGY OF ASSESSMENT

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

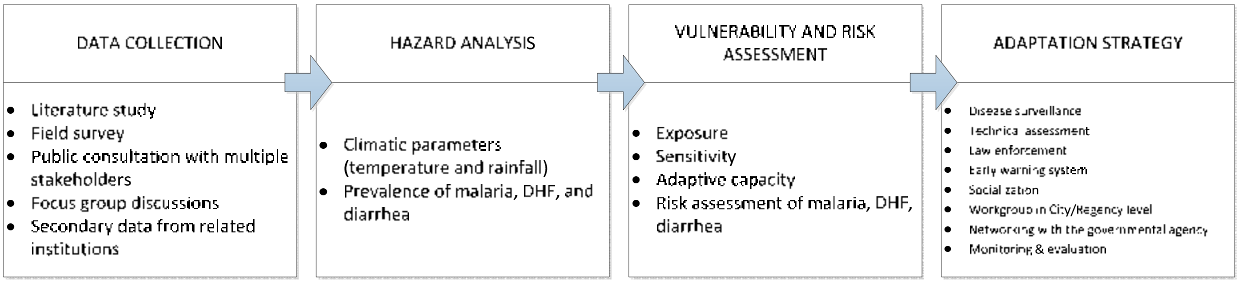


Figure 3-1 Assessment Framework

The methodology is divided into 8 sub chapter as follow:

- Sub-chapter 3.1 explains both primary and secondary data collection method
- Sub-chapter 3.2 describes method to calculate relation between climate change stimuli and health hazard, such as appliscation of statistical method in hazard analysis. Sub-chapter 3.2 also describes summary of climate analysis both baseline and future projection.
- Sub-chapter 3.3 describes health hazard projection method including DHF, malaria and diarrhea.
- Sub-chapter 3.4 describes method of vulnerability analysis, including terms used in vulnerability analysis and factors affecting vulnerability.
- Sub-chapter 3.5 describes method of projection of vulnerability, including assumptions about future conditions affecting vulnerability.
- Sub-chapter 3.6 describes method of risk analysis, emphasizes on definition of risk that is constructed from interaction of hazard and vulnerability
- Sub-chapter 3.7 describes method of projection of risk including assumptions about future conditions affecting risk.
- Sub-chapter 3.8 describes method of adaptation strategy formulation both existing condition and future projection.

3.1 Data Collection Method

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 during 2010-2011 in Tarakan, Jakarta and Bandung city. Field surveys were conducted in Aug 27 – Oct 1, 2010 (6 days) and Jan 31 – Feb 3, 2011 (4 days) in Tarakan to investigate health, disease, mosquitos, and sanitation condition in Tarakan island.

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

3.2.1 Vector-borne disease

The temporal and spatial changes in temperature, rainfall 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.

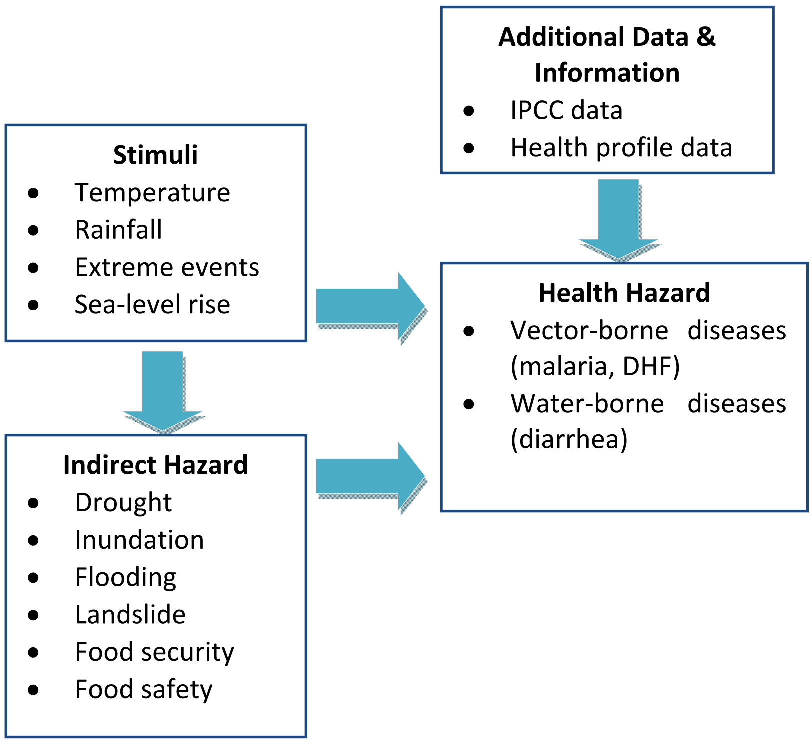


Figure 3-2 Relation between Climate Change Stimuli and Health Hazard

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 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 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, rainfall, 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. This effect is predicted to be greater in small islands area where water supply is scarce, such in Tarakan Island. 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.

3.2.3 Hazard Data Availability in Tarakan

As a small island vulnerable to change of climatic factors, Tarakan Island has high potential in exposed to health hazard. According to previous discussion in Chapter II regarding top ten diseases in Tarakan Island, 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), which occur in high prevalence in Tarakan (3,782 cases in 2008 and 4,098 cases in 2009). 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, rainfall, and humidity.

In order to evaluate DHF and malaria cases, data regarding population, density, and types of mosquito as vector in DHF and malaria should be investigated. However, 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 and it is no vector data in Tarakan island. Therefore, 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 prevalence data of three infectious diseases that are dengue fever, malaria, and diarrhea. Collected data were elaborated for assessment and selection as input in the study, including quality and relevance of the data with a specified level of accuracy. 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 Tarakan, there are only monthly DHF data for 1998-2010 is available. The monthly malaria and diarrhea data are not available and those only present in annual data.

3.2.4 Baseline Climate Analysis in Tarakan

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 Tarakan Island. The summary of Dr. Tri Wahyu Hadi's work is described as follow.

a. Mean Annual Pattern of Rainfall and Temparature in Tarakan

Generally speaking, Tarakan belongs to humid tropical climate with relative humidity as high as 87% during the driest month. Tarakan also lies in the monsoon region where near surface winds generally reverse direction about every six months, preceding the onset of alternating drier and wetter seasons. Although affected by such annual variation of monsoon circulation, the rainfall in Tarakan is normally always higher than 240 mm for each month with an average value of about 310 mm (Figure 3.4). In Tarakan, the dry season does not well develop in normal years because rainfall amount in the "driest" month of February is still typically as high as about 250 mm. The rainfall in Tarakan is of equatorial-type, which can be identified from the two peaks around April (boreal spring) and November (the end of boreal fall).

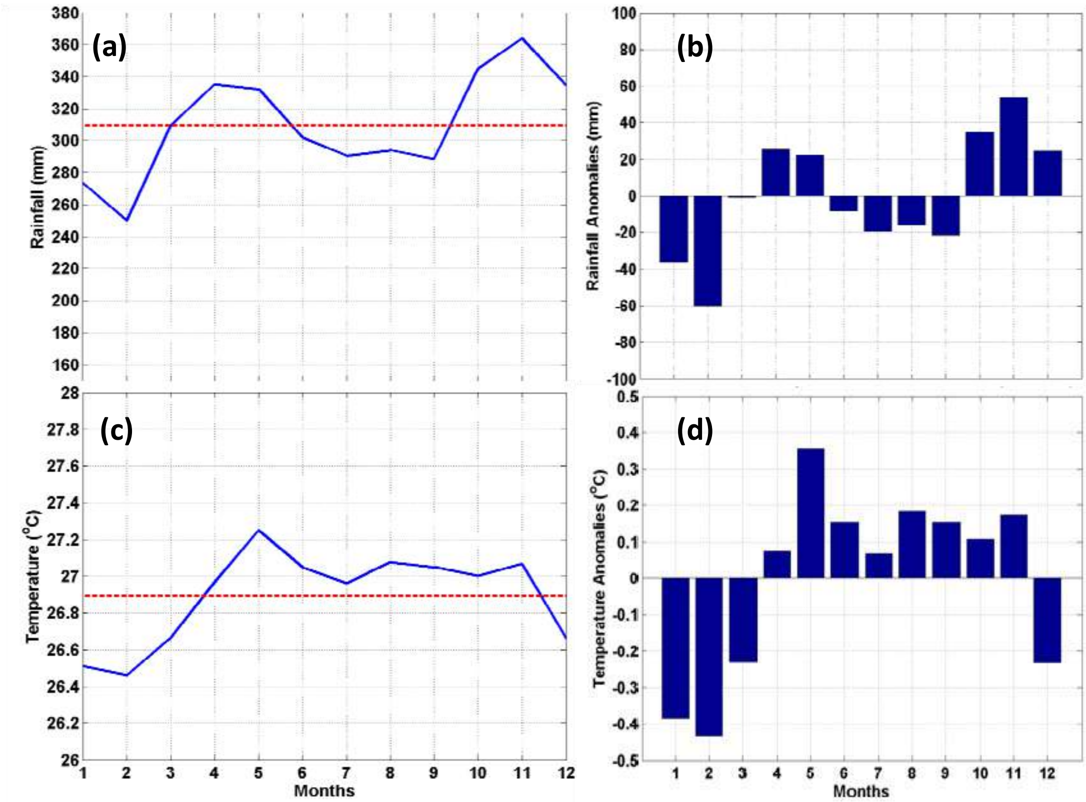


Figure 3-4 Mean annual variation of monthly (a)rainfall and (c)temperature, while (b) and (c) show the corresponding anomalies relative to long-term average as indicated by the red dashed lines.

From Figure 3.4, it can also be seen that the long-term mean temperature in Tarakan is around 26.9° C with less than 1° C variations between different months. Peaks in temperature data that are supposed to be corresponding to March and September equinoxes, are less clear probably due to the effects of cloud shading on surface temperature measurements. It is of interest to note that February is the “coldest” as well as “driest” month in Tarakan probably because there are predominant easterly winds that bring cooler air originated from the winter hemisphere.

b. Historical Climatic Hazards: Trend, Variabilites, and Extremes

Climatic change may be manifested by the changes in two main statistical parameters, namely *mean* and *variance*, of any weather/climate variables observed throughout at least two consecutive climatic periods. By WMO definition, a climatic period is defined as 30 years time span. In addition, secular change in surface temperature is always of interest to analyze in conjunction with global warming issue. Figure 3.5 shows long-term fluctuations in surface temperature observed over Tarakan with three trend lines calculated for the last 25, 50, and 100 years. During the last 25 years, there is a significant increase of about 0.63° C but for the last 50 and 100 years, the linear increase is only about 0.2° C/century.

Table 3.1 shows the trend of surface temperature change in Tarakan throughout the last century calculated for every month of the year. It can be seen that the trend of temperature change is different for each month with the highest value of about 0.35° C in March-April-May for 100-year period. The increasing trend of surface temperature is, in general, well defined for the months of February to June with values between 0.2 and 0.35 ° C/century. During these months, temperature measurements may be less affected by cloud shading because cloud formation is more dominated by local processes. Thus, temperature changes in March to May are likely influenced by the effect of urban heat island. During the other months (July-January), larger-scale cloud systems seem to more frequently develop due to stronger effect of the Asian monsoon.

Statistically speaking, across the climatic periods, the average trend of observed surface temperature change in Tarakan is around 0.2° C/century. For the last 25 years (less than one climatic period), trends of temperature increase are in the excess of 0.4° C for all months with the highest value of about 0.84° C in July and November. Linear extrapolation of the temperature trend to the future is subject to uncertainty because there was more than 1° C fluctuation in the past data. Moreover, there is only one single station in Tarakan that provides long-term record of temperature. Nevertheless, these data show that warming has possibly been intensified during the last several decades.

Different from temperature, trend analysis is not suitable for identifying the hazard of rainfall change because long-term fluctuation in rainfall data is much larger compared to the secular trend. In the case of Tarakan, the calculated trend is only about 10 mm/century, which is insignificant compared to the total variance of rainfall data. Therefore, the hazard of rainfall change is better analyzed in terms of inter-annual and inter-decadal variabilites as discussed below.

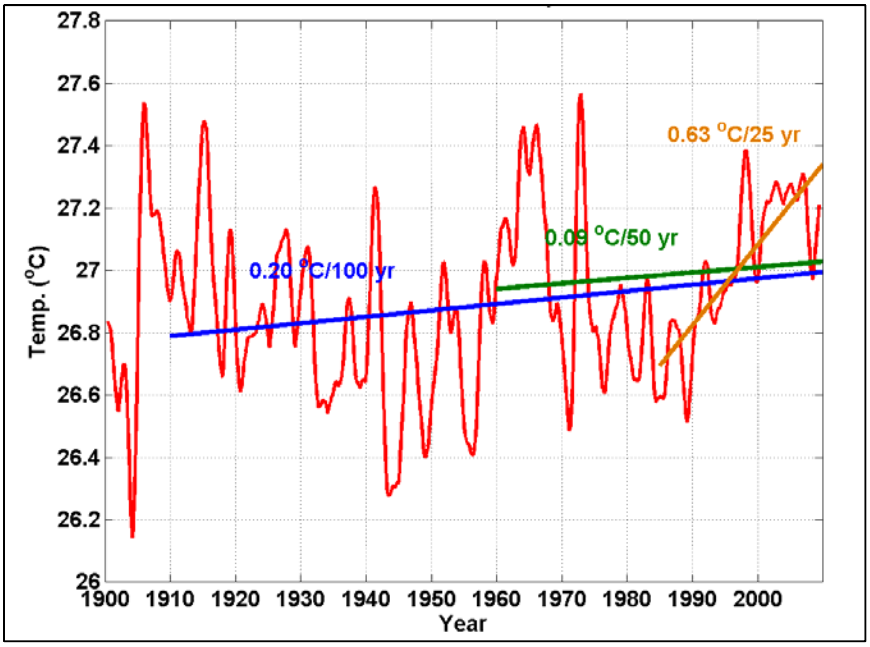


Figure 3-5 Trends in temperature changes in Tarakan over the past century. Red solid line is smoothed monthly temperature data, while blue, green, and orange lines indicate linear trends for the last 100, 50, and 25 years respectively.

Table 3.1 Trends of surface temperature change in Tarakan throughout the last century.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Trend (°C/100 yr)	0.17	0.15	0.33	0.35	0.37	0.24	0.11	-0.01	0.12	0.15	-0.06	0.10
Trend (°C/50 yr)	0.19	0.45	0.13	0.12	0.33	0.07	-0.08	-0.03	-0.33	0.01	-0.24	0.08
Trend (°C/25 yr)	0.80	0.82	0.45	0.46	0.56	0.44	0.84	0.75	0.67	0.56	0.84	0.65

c. Inter-annual Rainfall Variabilities

In the tropics, rainfall variations at inter-annual time scale are known to be largely affected by global climatic phenomena known as *El Niño Southern Oscillation* (ENSO) and *Indian Ocean Dipole* (IOD). These phenomena are related to the dynamical behavior of the Pacific and Indian Ocean, which are manifested as temporal and spatial variations in Sea Surface Temperature (SST). Indices that represent the climatic events associated with ENSO and IOD have been developed based on SST measurements. Scatter plots in Figure 3.6 show the correlation between ENSO and IOD indices with Standard Precipitation Index (SPI) of Tarakan. SPI is one of the simplest indeces to represent drought level based on certain statistical distribution of rainfall observed at specific location. Thus, SPI signifies the deviation of rainfall amount during a period of time (one-, three-, six-, twelve-monthly, and so on) from its local long-term mean. In Figure 3.6, six-monthly SPI values are presented with more negative (less than -0.9) SPI means more severe drought event.

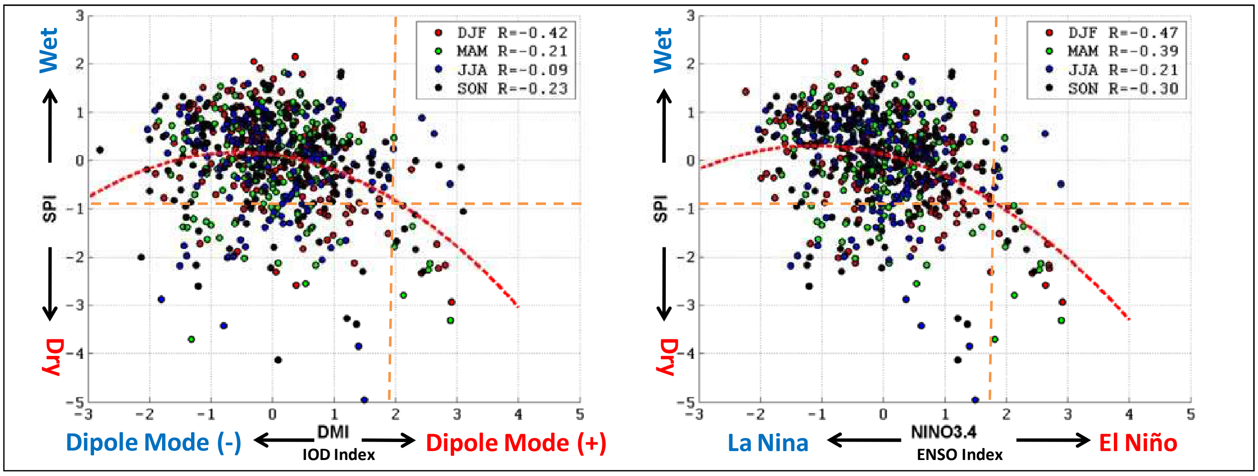


Figure 3-6 Correlation between 6-monthly Standardized Precipitation Index (SPI) calculated from rainfall of Tarakan and Dipole Mode Index (DMI)(left) as well as ENSO index (Nino3.4 sea surface anomaly)(right).

From the trend of SPI versus ENSO and IOD indices, it can be seen in Figure 3.6 that drought events at Tarakan are mostly attributed to strong El Niño, while correlation between SPI and IOD is much weaker especially for the months of June-July-August. This result is consistent with the fact that Tarakan is close to the Western North Pacific Monsoon (WNPM) region so that effects of dynamic processes in the Pacific Ocean on the climate of Tarakan are naturally stronger compared to that of Indian Ocean. In this case, it is assumed that the strength of ENSO is represented by the absolute value of its index. However, it should be noted that stronger La Nina events are not necessarily associated with the wettest climate condition. When both ENSO and IOD are weak, the climatic state spreads between dry and wet condition indicating higher uncertainty. To summarize, strong El Niño event is one of the potential climatic hazards for Tarakan that are associated with the occurrence of drought. On the other hand, strong La Nina events do not clearly signify extreme “wetness” level. In addition, neutral (weak ENSO and IOD) events imply more uncertainties on rainfall.

ENSO is a quasi-periodic phenomenon, by which the state of the Pacific Ocean swings between cool (La Nina) and warm (El Niño) phases. El Niño may occur in every two to five years and recent investigations suggest that El Nino frequency tends to be higher. However, data of the past one and a half century indicate that strong El Niño events, which may cause severe, drought only reoccur about once in every 20 years. The impact of more frequent changes between El Nino and La Nina will be more likely associated with frequent occurrence of neutral state, in which rainfall condition of Tarakan maybe more unpredictable.

d. Inter-decadal Variations of Rainfall and Temperature

Rainfall variations at inter-decadal time scale are quite important because, as previously mentioned, climatological period is defined by WMO as a 30-year time window. Recent studies indicate that two oceanic variations known as Pacific Decadal Oscillation (PDO) and North Atlantic Oscillation (NAO) may influence the climate in Asia and Australia at interdecadal time scale. Figure 3.7 shows the time series of smoothed monthly rainfall observed at Tarakan from 1911 to 2009. The interdecadal variation in Tarakan rainfall is quite pronounced during 1950 to 1980 period, which is marked by a significant decrease in decadal average rainfall during 1960 to 1970. This decreasing pattern of rainfall was not only found in Tarakan, but also appeared in most regions of East Kalimantan.

Scientific explanation for the decadal rainfall anomaly is beyond the objectives of this study but it is of interest to note that the decrease of rainfall during 1960 to 1970 only occurred in particular season. As it is shown in Figure 3.8, results of further analysis of rainfall and temperature data indicate that the decadal scale reduction of rainfall in Tarakan occurred most significantly in the months of June-July-August (JJA), while there were only relatively little changes in the rainfall of December-January-February (DJF). Figure 3.8 also indicates the correlation between temperature and rainfall data. When rainfall decreases, temperature tends to increase because there are less effects of cloud shading.

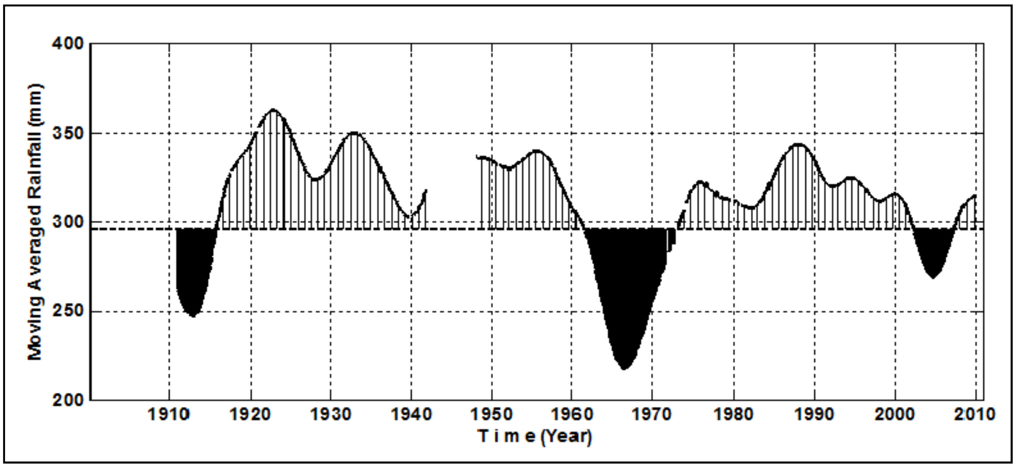


Figure 3-7 Smoothed time series of monthly rainfall observed in Tarakan from 1911 to 2009. Large gap between 1940 and 1950 indicates missing data.

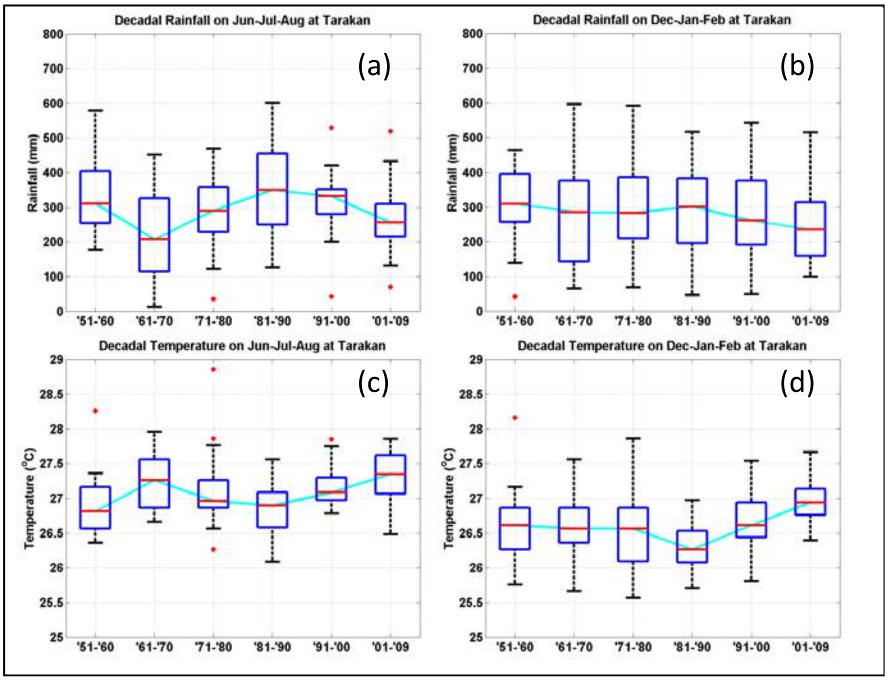


Figure 3-8 Box-plot diagrams showing statistics of monthly rainfall and temperature for June-July-August and December-January-February periods in every decades since 1951. Upper and lower ends of the boxes designate lower and upper quartiles, while red lines indicate median values. In addition, dotted lines represent minima and maxima, whereas red dots indicate outliers.

3.2.5 Projection of Future Climate in Tarakan

Scientific basis team (Dr. Tri Wahyu Hadi and team) has also developed projection of future climate analysis that the work is summarized as follow.

a. Projection of Future Rainfall and Temperature Changes

Although there is a high degree of uncertainty, climate projection into several decades in the future is a fundamental element of climate change impact assessment. Two approaches may be used for climate projections : (i) projection based on empirical regression model, and (ii) projection based on the output of Global Circulation Models (GCMs). In this study, the former is only applied for rainfall projection, while the latter is used for both rainfall and temperature projection.

b. Empirical Projection of Interdecadal Rainfall Variations

As previously mentioned (see Chapter 3.2.4), interdecadal rainfall variability may be associated with global oceanic variations known as PDO and NAO. Thus, an empirical regression between PDO and NAO indices and smoothed (or low-pass filtered) rainfall model can be developed to predict the trend of rainfall changes in the next couple of decades. Result of the empirical regression is presented in Figure 3.9. The regression parameters were chosen so as to obtain the best fit the testing the observation during the testing period, although there may be large differences between model and observations during the training (development) period. The empirical projection is mainly for obtaining qualitative view of future trend in rainfall changes.

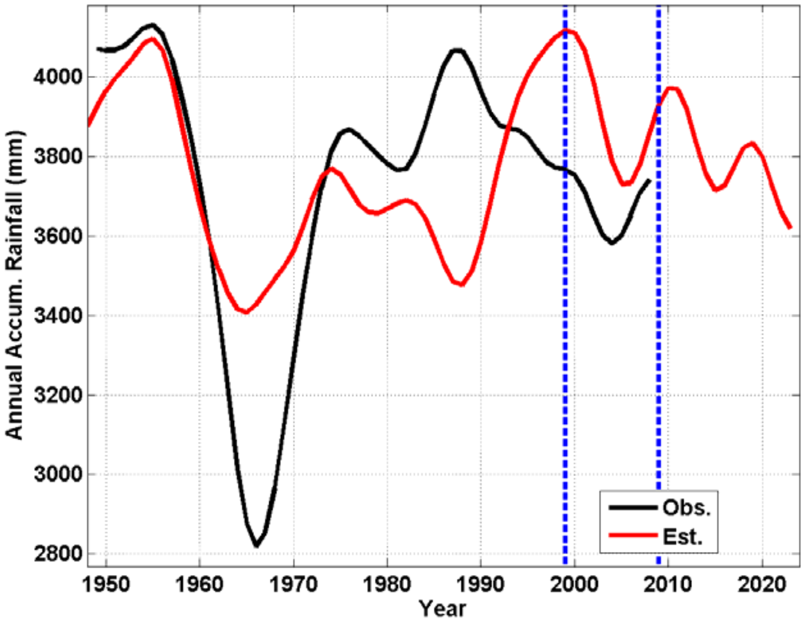


Figure 3-9 Result of empirical regression between PDO and NAO indices and smoothed annual rainfall observed over Tarakan (black line). Time window between blue dashed lines indicate "testing" period and red line shows projected rainfall 2010.

It can be seen from Figure 3.9 that there is a trend of decreasing rainfall from 2010 to 2020 with marked interannual variations. It should be noted that the correlation between rainfall and global climate indices may change phases so that the regression model fits well with observations during 1950s to 1960s but it shows large discrepancy for the 1970s to 1990s. However, the decreasing trend of rainfall is of primary interest and will be compared with the result of rainfall projection based on GCM outputs as described below.

c. Rainfall Projection Based on GCM Outputs

Global Circulation Models (GCMs) are the only tool that we can use to study the possible states of Earth's climate in the far future. Outputs of seven GCMs contributed for the IPCC AR-4 (the 4^{th} Assessment Report) are used in this study to obtain projections of rainfall in Tarakan. Three carbon emission (SRES) scenarios i.e. B1 (low), A1B (moderate), and A2 (high) were chosen. The common problems with these GCM data for regional or local climate change risk assessment are the low horizontal grid resolution and the diverse results of rainfall estimation, especially in the tropical regions. In this study, a simple ensemble averaging and bias correction method have been applied to the GCM outputs to produce the rainfall projections as shown in Figure 3.10.

Although the models cannot perfectly match observations, Figure 3.10 shows that projected rainfall of Tarakan partially follows an observed interdecadal variations. More importantly, there is also a decreasing trend from 2010 to 2030, which is consistent with the result of empirical regression as discussed previously (Figure 3.9). It should also be noted that, although the long-term trend is quite similar, there are also significant differences in the year to year variations between different scenarios.

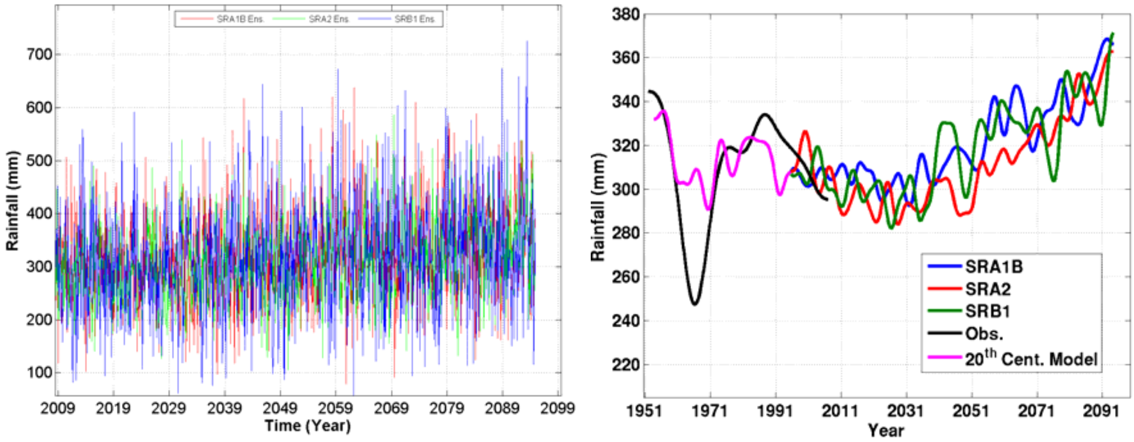


Figure 3-10 The GCM out based projected monthly rainfall of Tarakan for the 21st century (left) and the smoothed version with an extension back to 1951 (20th century) (right).

d. Temperature Projection

Temperature projection has been made based on GCM output similar to that of rainfall as discussed previously. As it is shown in Figure 3.11, the models show uniform increase of temperature from 1990s to 2030 for all scenarios. After 2030 the trend splits between B1 (low emission) and other (A1B and A2) scenarios. This result, is in general, agree with the global trend of temperature for the tropical region.

Note that, although models seem to fit the trend of temperature increase, they cannot actually follow observed interdecadal variations. This is one of the weaknesses of the GCMs contributing to the IPCC AR-4. Developments of better GCMs are on progress and the results are planned for contribution to IPCC AR-5 but published materials are still limited.

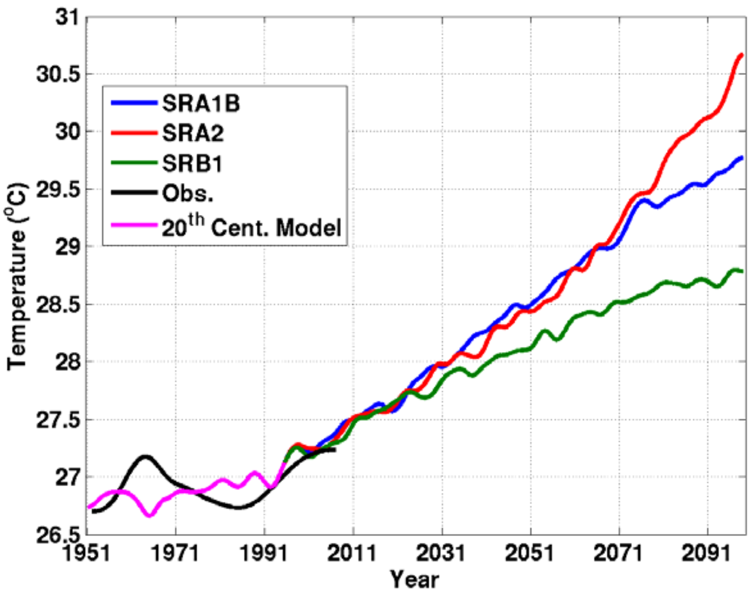


Figure 3-11 The GCM out based projected temperature of Tarakan for the 21st century with an extension back to 1951 (20th century). Data has been smoothed to show only the long-term trend.

e. Analysis of Extreme Events

Information of extreme events is important in climate change risk assessments. Analysis and projection of extreme events are, however, more difficult to perform because it requires more detailed and accurate data. Long records of observed daily temperature and rainfall are at least needed to analyze the extreme events, while GCM outputs with daily time resolution are also required for the projection. In tropical region, extreme temperature events such as heat wave are very rare events. Therefore, only several aspects of extreme rainfall events at Tarakan are briefly discussed below.

The best data for analysis of extreme events obtained in this study is probably daily rainfall data observed by BMKG station in Tarakan (Juwata). However, the record only spans from 2004 to 2009, which is not representative for climate analysis. Another data set show maximum daily rainfall in each year from 1984 to 2001. Figure 3.12 shows the yearly maximum rainfall data of 1984 to 2001 combined with those derived from more recent data up to 2009. This is incomplete information of extreme events because the data samples cannot be used to construct probability of exceedance (PoE), which is a measure of the probability of an extreme event to occur in certain period of time.

From Figure 3.12, it can be seen that 100 mm/day seems to be the minimum threshold for extreme rainfall event and the most extreme rainfall occurred on 7 August 1998 with a record of 295 mm/day. Correlation between the probability of extreme monthly and daily rainfall has been investigated in this study using daily rainfall data of Singapore, which is considered to be the most representative data that can be obtained. Figure 3.13(a) shows a three curves fitted to some pairs of probability of monthly rainfall data with a certain threshold (400 mm/month for Singapore) against that of daily rainfall (60, 80, and 100 mm/day). Data of Tarakan and Kenten (South Sumatra) are also plotted with adjusted threshold of monthly rainfall (433 mm/month in the case of Tarakan). It can be seen that data of all sites roughly follow the same trend. Hence, changes in the probability of monthly rainfall with certain threshold is an indicator for the probability of extreme daily rainfall.

As it is shown in Figure 3.13(b), the projected probability of monthly rainfall above 433 mm differs with the B1, A1B, and A2 scenarios. Although the magnitudes are also different from observations, A2 scenario gives quite similar trend with that of observations. It is inferred from this results that, until 2030s, the probability of occurrence of extreme daily will likely decrease or stay the same as present. However, it should be noted that after 2050s probability of extreme rainfall is projected to increase in all scenarios.

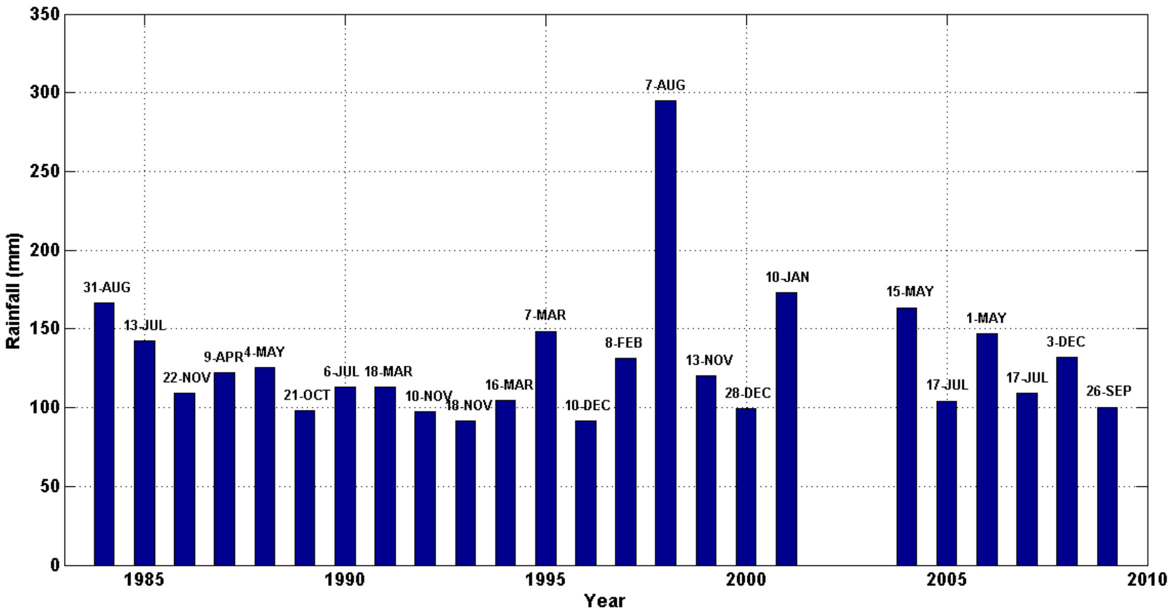


Figure 3-12 Records of maximum rainfall observed in Tarakan for each year from 1984 to 2009.

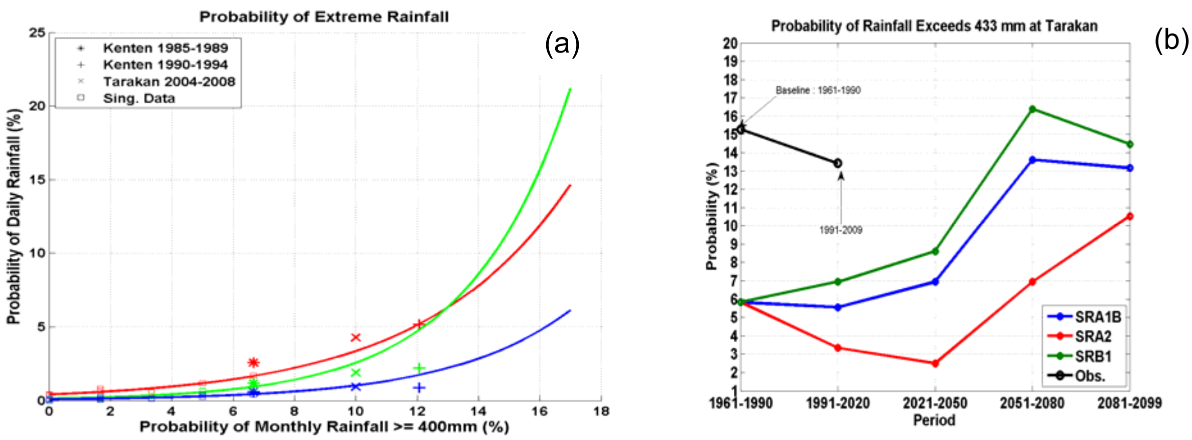


Figure 3-13 (a) Correlation between the probability of monthly rainfall exceeding certain threshold and the probability of daily rainfall exceeding 60 (blue), 80 (green) and 100 mm/day (red) with square symbol designates data of Singapore (threshold of monthly rainfall is 400 mm), while asterisk, cross, and plus symbols indicate data of Kenten (1985-1989), Kenten (1990 – 1994) and Tarakan respectively (see text);m (b)projected trend of the probability of extreme events (rainfall exceeding 433 mm).

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:

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

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

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

  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 ∆QICu ≤ 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:

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

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:

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

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 3.2 below.

Table 3.2: 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.

Study	Parameter	Methods
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:

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

Where

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

$$g = r_1 \sum_{i=\tau_1}^{\tau_{min}} T_{min}(i) + r_2 \sum_{i=\tau_2}^{\tau_{max}} T_{max} + r_3 \sum_{i=\tau_3}^{\tau_R} R_{ain}(i) + r_4 \sum_{i=\tau_1}^{\tau_{min}} T_{min}(i) \times \sum_{i=\tau_3}^{\tau_R} R_{ain}(i) + r_5 \sum_{i=\tau_2}^{\tau_{max}} T_{max}(i) \times \sum_{i=\tau_3}^{\tau_R} R_{ain}(i).$$ (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 3.3 below.

Table 3.3: 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) 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. This effect is predicted to be greater in small islands area where water supply is scarce, such in Tarakan Island. 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 Tarakan 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 Tarakan

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 Tarakan Island.

First, some exercises to discover the correlation between DHF cases and rainfall and between DHF cases and temperature in Tarakan Island 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:

$$\text{Ln (Yt)} = \beta0 + \beta1\ \text{Ln(Yt-1)} + \beta2T2 + \beta3Rt + \beta4Pt + \hat{P}$$

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

$$\text{Yt} \sim \text{Poisson } (\mu t)$$

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 3.4, 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 3.4: 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

MODEL	EQUATION	REMARK
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.

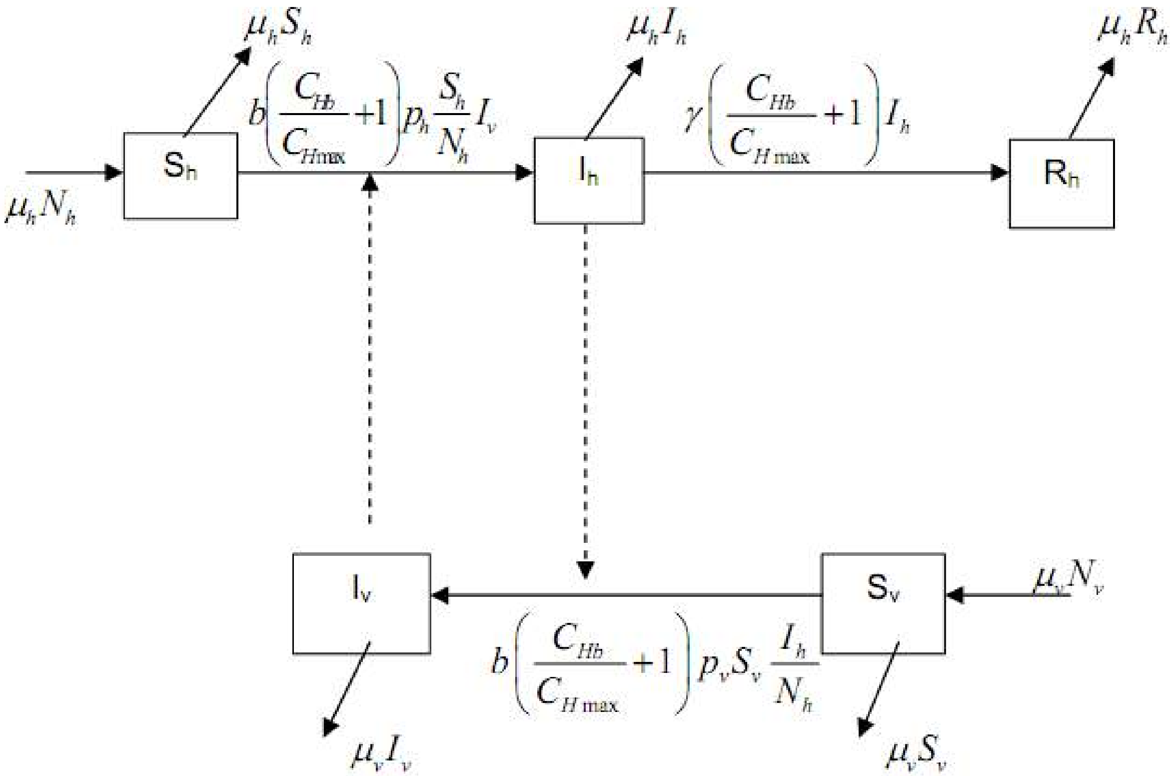


Figure 3-14 Schematic of the compartment modeling of DHF (Jafaruddin and Sofyan, 2011)

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

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

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 Appendix 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.

Poisson regression model has been used wider by public health researcher in the world compare than residual method. Therefore, in Tarakan case, the relationship between weather and dengue transmission have been conducted by Poisson regression model. The result can be seen in Appendix B.

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 and length of DHF, malaria, and diarrhea incident data. Thus, we found several difficulties to conduct those methods in Tarakan case since DHF, malaria, and diarrhea incident data availability are quite short (under 10 years data). Thus, both residual method and Poisson regression model is not 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 length of data are quite short (under 10 years data). However, compartment model need verification. In this study verification of the parameters and coefficient of compartment model are carried out by using wide study literature from both local and international journal. Moreover, before conducting model for future case firstly the model is conducted for recent case, for example DHF incident in Tarakan for 2003-2010. The aim of this method is to elucidate the performance of model compared with recent data and to verify the model accuracy. Detail description about compartment model is explained in Appendix C.

Based on those reason, we choose compartment model as prediction method for future DHF, malaria, and diarrhea in Tarakan. 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 Tarakan. 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.

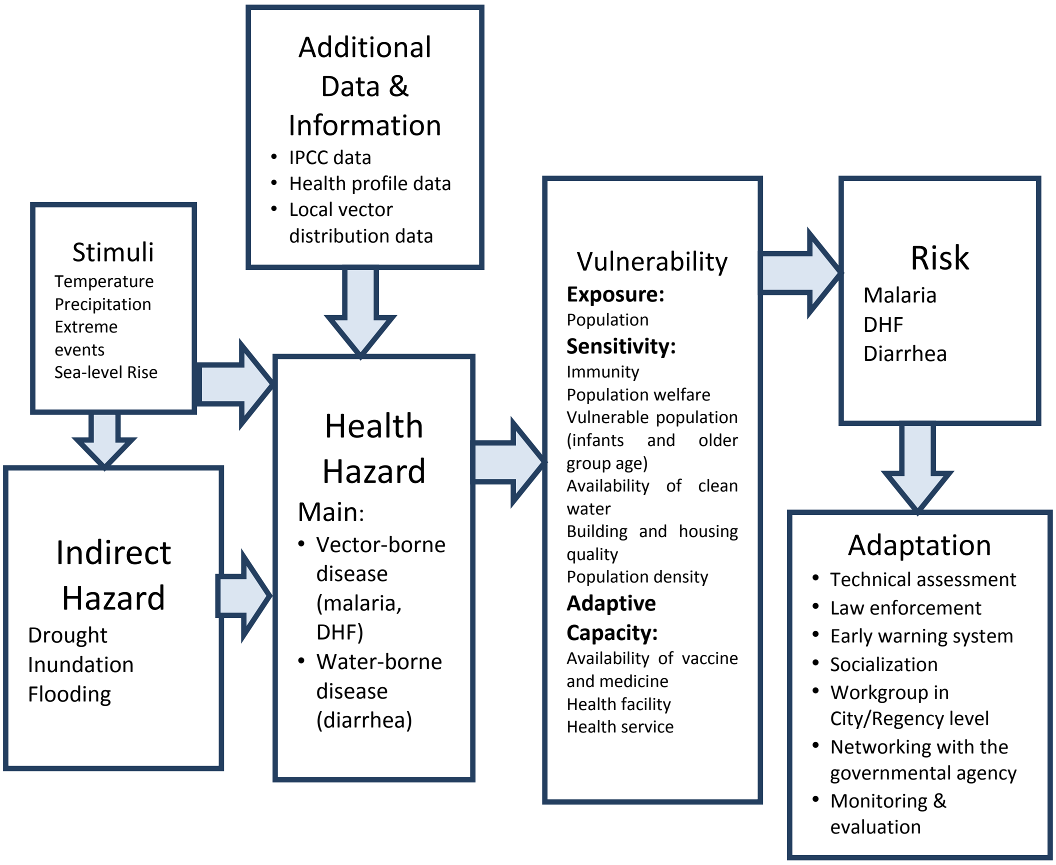


Figure 3-15 General Schematic of Vulnerability and Risk Assessment in Health Sector

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 3.15. In Figure 3.15 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 3.15 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 indicators for DHF is indicated by several parameters outlined in the Table 3.5.

Table 3.5: 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

Component	Indicators	Remarks
		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 indicators for malaria is indicated by several parameters outlined in the Table 3.6.

Table 3.6: 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 indicators for diarrhea is indicated by several parameters outlined in the Table 3.7 below.

Table 3.7: 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	Peoples who live in a house with no toilet

Component	Parameter/Variable	Remarks
	facility: Houses with toilet and without 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 3.8. AHP scores is recalculated based on available variable.

Table 3.8: 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 Tarakan 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:

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

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:

1) 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

2) 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

3) 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

4) 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:

1) 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

2) 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

3) 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

4) 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:

1) 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

2) 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

3) 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

4) 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 Tarakan) 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 of Tarakan 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 3.9: 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 3.16 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 3-16 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 Tarakan 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 ANALYSIS OF HAZARDS TO CLIMATE CHANGE

This chapter discusses results of hazard analysis related to climatic factors and diseases, including vector and water-borne disease. Climatic factors utilized in analysis cover temperature and rainfall, in which this study tries to assess their relationships with DHF, malaria, and diarrhea incidences in Tarakan Island.

4.1 Existing DHF Hazard Analysis in Correlation with Climate Condition

4.1.1 Description of Available Data

Analysis is conducted both for city and district level in Tarakan, that includes 4 sub districts in Tarakan namely Tarakan Utara, Tarakan Tengah, Tarakan Barat, and Tarakan Timur. Required data in this assessment are monthly DHF case, monthly rainfall and temperature, and population. Population data and monthly dengue cases were collected from Health Department of Tarakan for years 2003 – 2009. Data on temperature and rainfall were obtained from Scientific Basis Team. Figure 4.1, 4.2, 4.3, 4.4, and 4.5 illustrate the dengue fever incidence in Tarakan and its sub districts.

Table 4.1: CFR and IR DHF cases in Tarakan Island 2001-2009

Year	Population	DHF Cases		CFR	IR
		Patient	Death	(%)	/100,000
2001	115,959	42	4	9.52	36.21
2002	115,949	86	4	4.65	74.17
2003	121,588	58	3	5.17	47.70
2004	149,943	104	4	3.84	69.35
2005	157,574	323	12	3.71	204.98
2006	165,801	272	12	4.41	164.05
2007	175,092	368	11	2.98	210.17
2008	176,696	471	11	2.33	266.55
2009	162,189	706	12	1.69	435.29

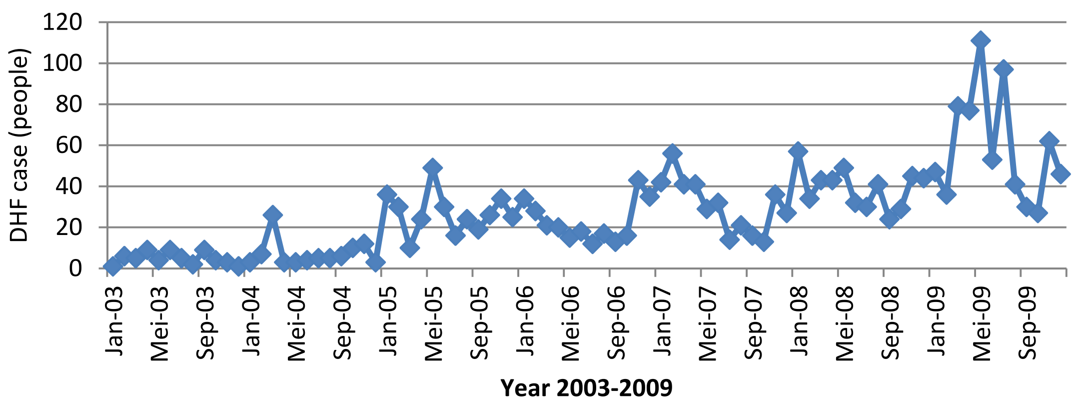


Figure 4-1 Monthly Dengue Fever Cases in Tarakan City for Year 2003-2009

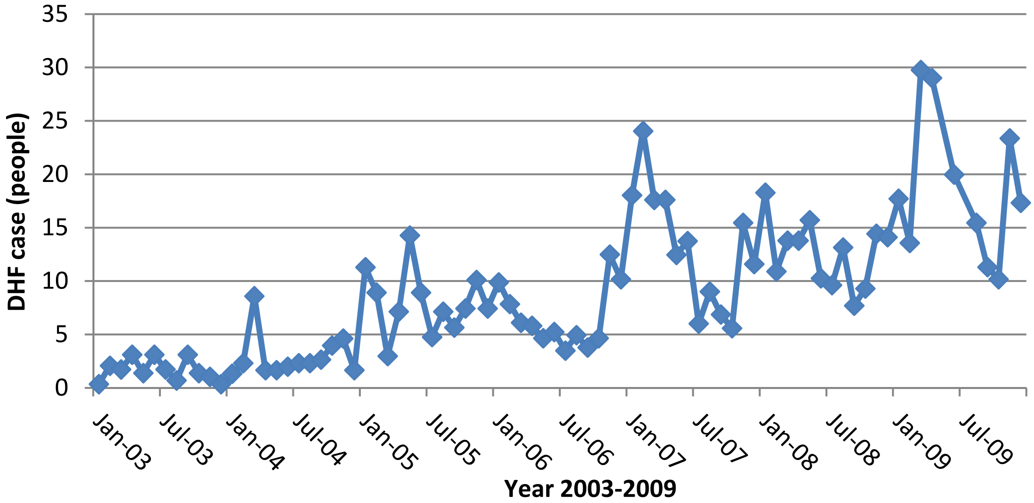


Figure 4-2 Monthly Dengue Fever Cases in Tarakan Barat for Year 2003-2009

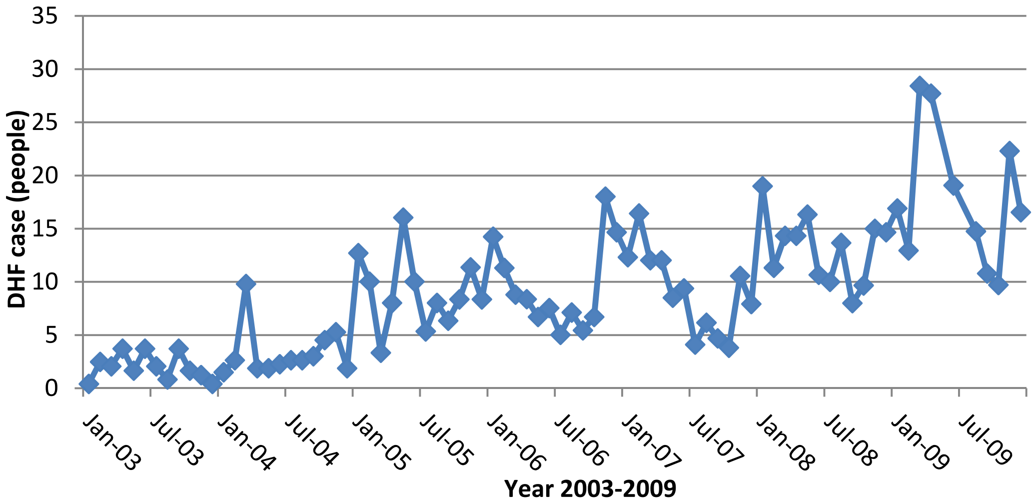


Figure 4-3 Monthly Dengue Fever Cases in Tarakan Tengah for Year 2003-2009

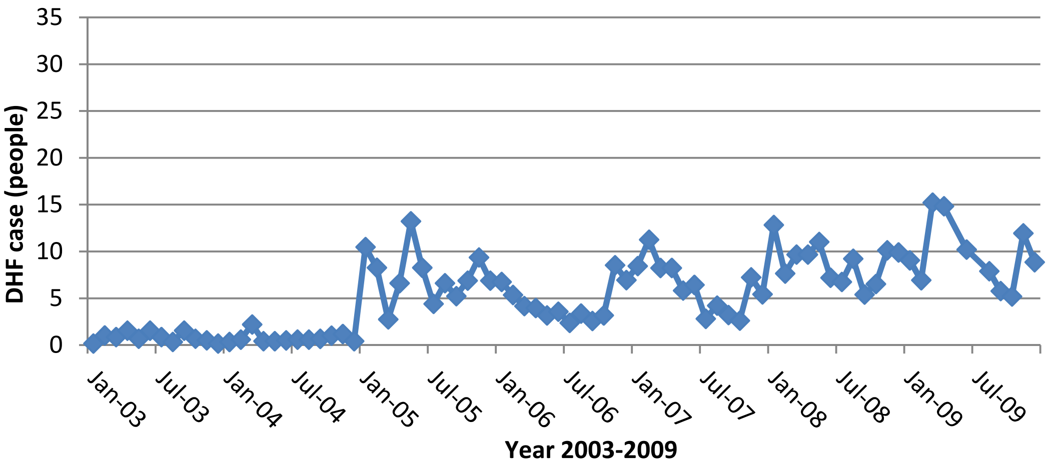


Figure 4-4 Monthly Dengue Fever Cases in Tarakan Timur for Year 2003-2009

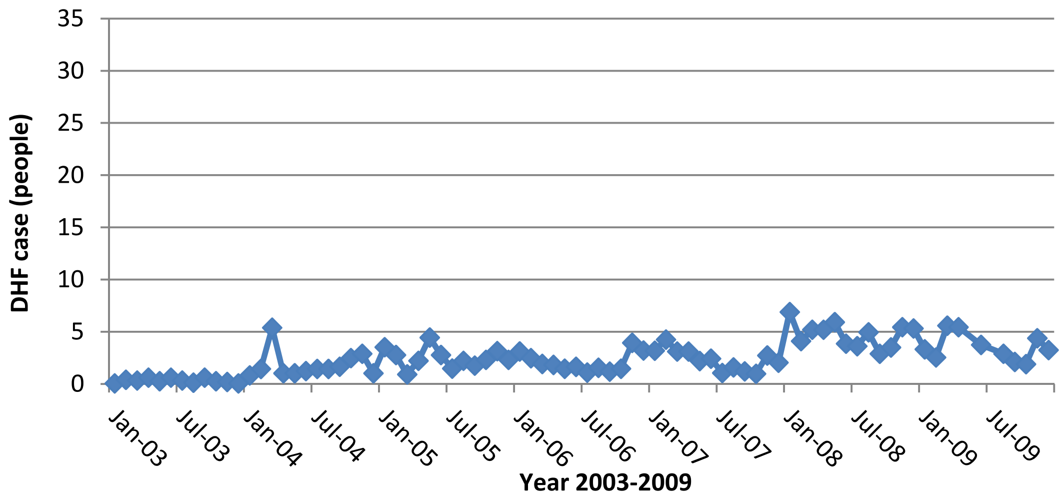


Figure 4-5 Monthly Dengue Fever Cases in Tarakan Utara for Year 2003-2009

According to Figure 4.1 to Figure 4.5, the trend of dengue fever cases in Tarakan Island and in each sub district of Tarakan increased from 2003 to 2009. However, whether the increases were mostly caused by climatic factors or other factors, such as population increase that is not followed by improvement of sanitation and health facilities, is the main problem that we try to address in this study.

4.1.2 Associations between DHF Incidence, Rainfall and Temperature

Previous studies have shown that there are biological relationships between temperature, rainfall and dengue transmission, but empirical evidence of these relationships is inconsistent. It also suggests that the effects of global climate change on dengue transmission will be local rather than global (Johansson, 2009).

Figure 4.6 and 4.7 describe the variability of weather in 2003 – 2009. Rainfall is collected as cumulative quantity per month whereas temperature is defined as average temperature per month.

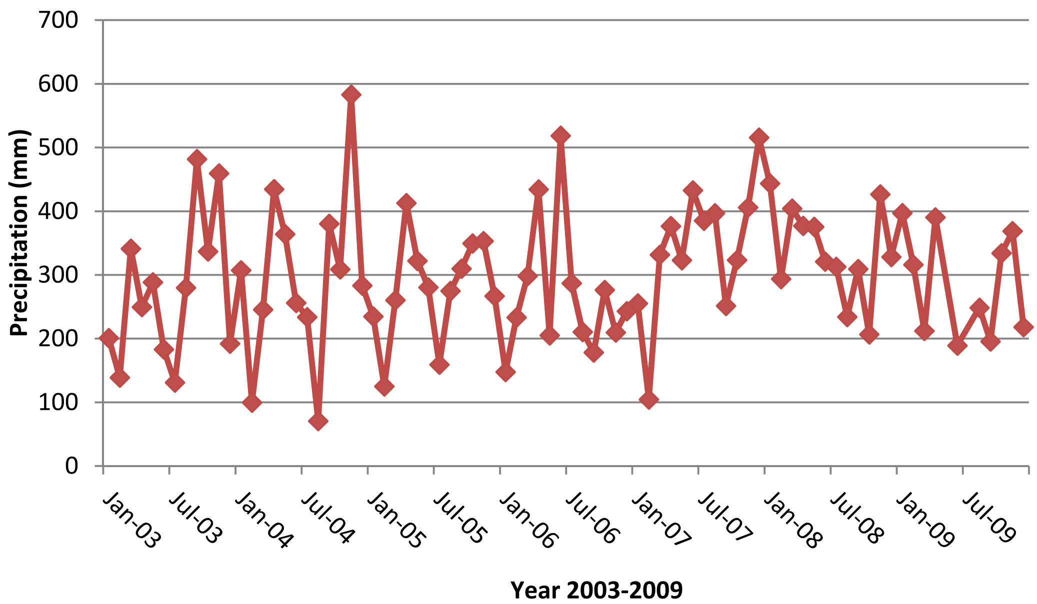


Figure 4-6 Cumulative Monthly Precipitations in Tarakan City for year 2003-2009

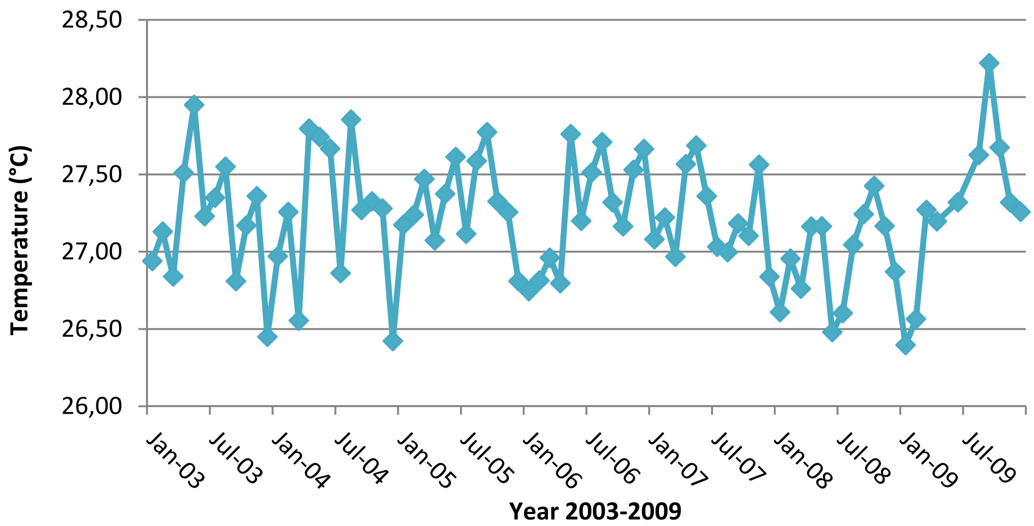


Figure 4-7 Monthly Average Temperatures in Tarakan City for Year 2003-2009

Meanwhile the association between monthly rainfall and monthly temperature to DHF cases in Tarakan is shown in Figure 4.8 and Figure 4.9.

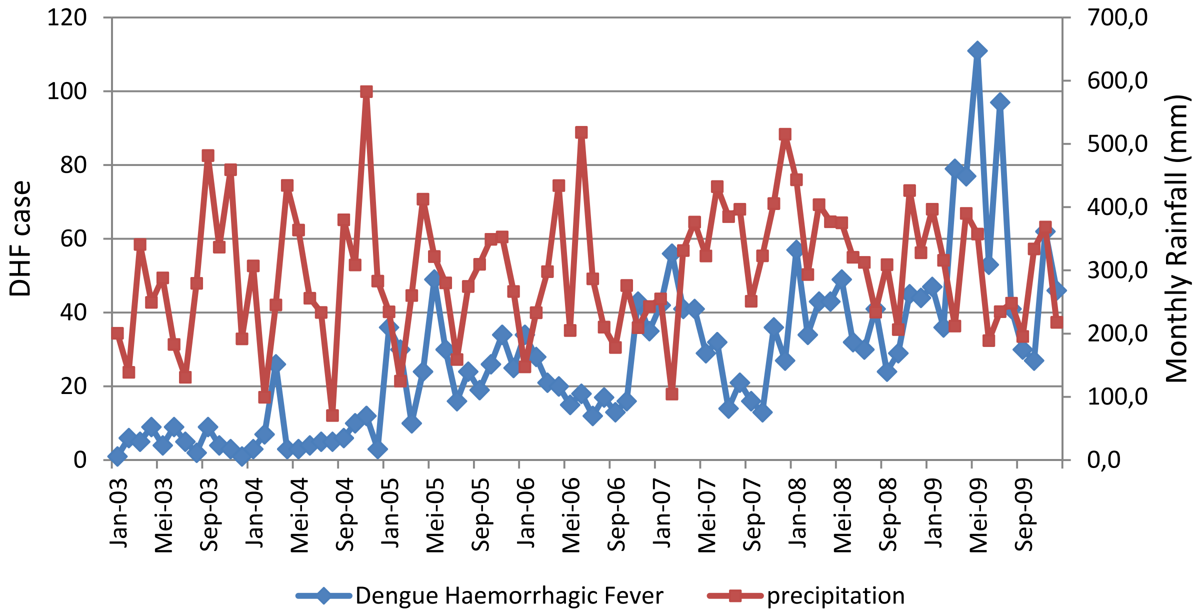


Figure 4-8 Monthly DHF and Monthly Precipitation in Tarakan

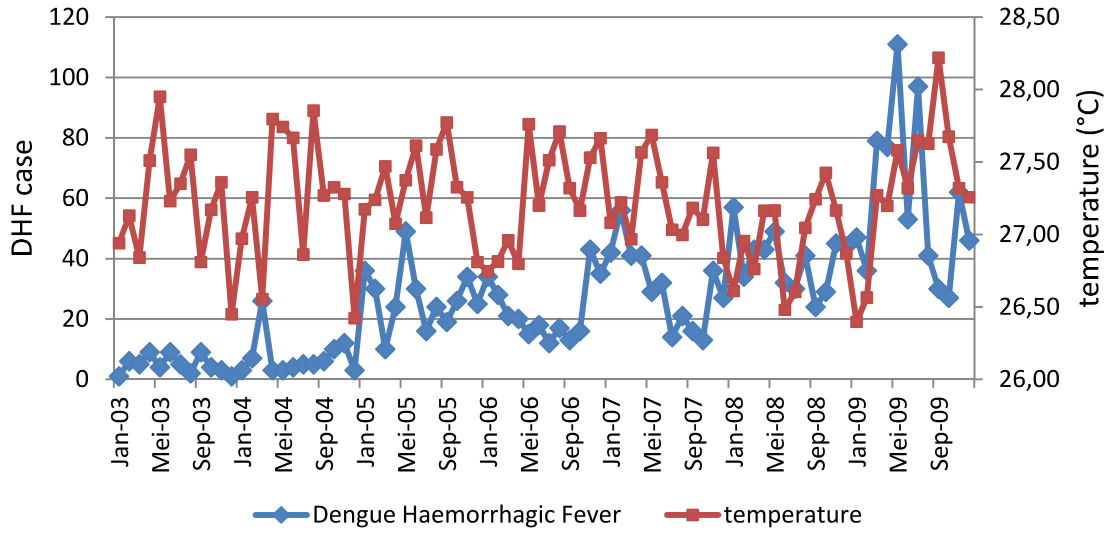


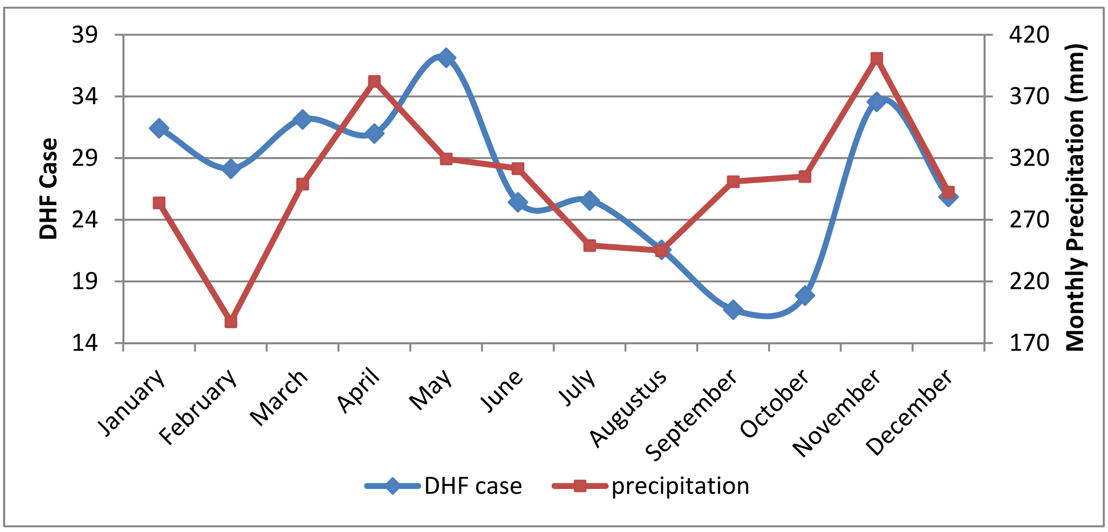
Figure 4-9 Monthly DHF and Monthly Temperature in Tarakan

In order to see association between precipitations (rainfall) and DHF cases, monthly average of DHF and rainfall 2003-2009 are calculated. By this, the relationship between rainfall and DHF cases is shown in Figure 4.10a. The Figure 4.10a indicates that the increase of rainfall in February-April is highly related with the increase of DHF cases in March-May which means that there is 1 month lag between the increase of rainfall and DHF cases. Furthermore, the decrease of rainfall in May-August is followed by the decrease of DHF cases in June-September which means that there is 1 month lag between the decrease of rainfall and the decrease of DHF cases.

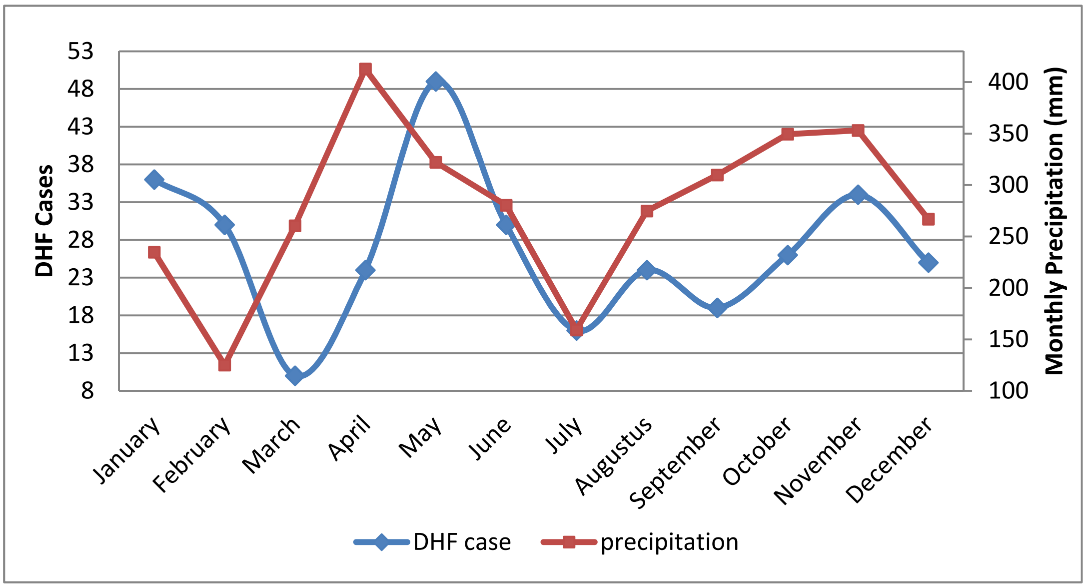
The association with lag-0 and lag-1 is also shown in August-February. The increase of rainfall in September-November is related with the increase of DHF cases in October-November and the decrease of rainfall in December-February is related with the decrease of DHF cases in December-February.

Figure 4.10b and c show data of year 2005 and 2008, respectively. As shown in Figure 4.10b and c, the increase of rainfall is related with the increase of DHF cases with lag-0 or lag-1 month.

a) Average of Year 2003-2009



b) Year 2005 data only



c) Year of 2008 data only

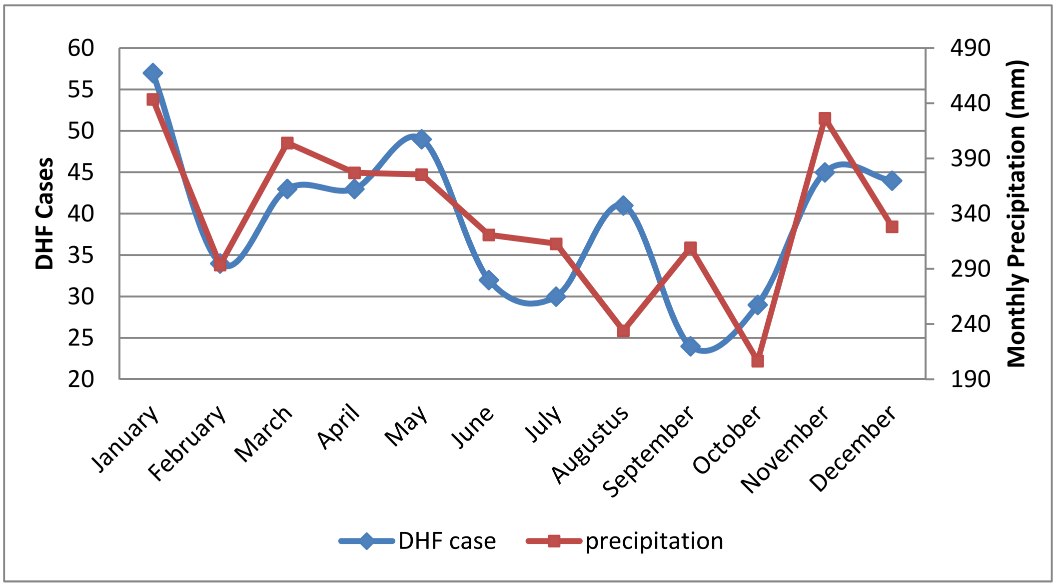


Figure 4-10 Relationship between monthly rainfall with DHF Cases for (a) average 2003-2009, (b) 2005, and (c) 2008 in Tarakan

4.1.3 Associations between DHF Incidence and Population Growth

In order to understand the correlation between DHF cases and population (see Figure 4.11), Spearman rank correlation is used as shown in Table 4.2 with correlation coefficient between population and DBD cases in Tarakan is 0.784. Figure 4.11 and Table 4.2 show that population number is positively associated with the number of notified dengue cases.

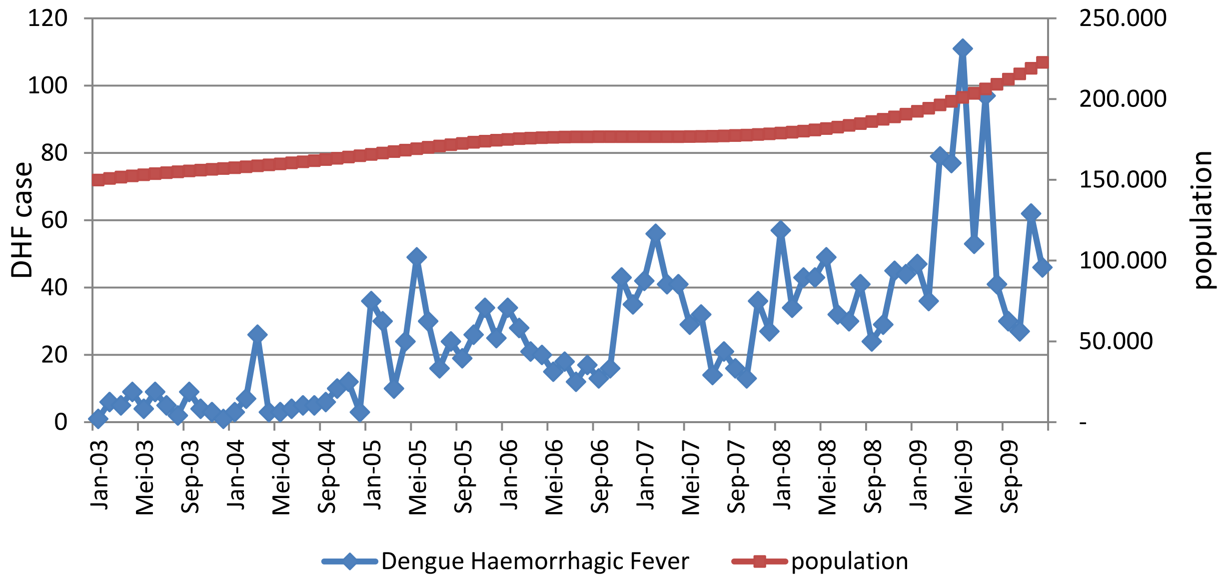


Figure 4-11 Monthly DHF cases in Tarakan increase following the population

Table 4.2: Coefficients of Spearman rank correlation between dengue fever cases and population number for data years 2003 - 2009

Data	Coefficient of Spearman Correlation
Dengue fever case in Tarakan	0.784
Dengue fever case in Tarakan Barat	0.796
Dengue fever case in Tarakan Tengah	0.745
Dengue fever case in Tarakan Timur	0.734
Dengue fever case in Tarakan Utara	0.15

4.1.4 Results of Existing DHF Hazard Analysis

The eight years average of prevalence (2003-2010) is used to categorize the hazard in sub district level as shown in table below.

Table 4.3: Existing Hazard Categorization for DHF in Tarakan City

Sub district	Villages	Hazard (DHF)	
		Average Prevalence (2003-2010) /10,000 Occupants	Level (2003-2010)
Tarakan Timur	Lingkas Ujung	19.81	Moderate
	Gunung Lingkas	23.09	High
	Mamburungan	13.94	Low
	Mamburungan Timur	14.31	Low
	Kampung Empat	28.47	Very High
	Kampung Enam	20.67	High
	Pantai Amal	6.52	Very Low
Tarakan Tengah	Selumit Pantai	20.20	Moderate
	Selumit	23.76	Very High
	Sebengkok	19.91	Moderate
	Pamusian	17.91	Moderate
	Kampung Satu Skip	21.60	High

Sub district	Villages	Hazard (DHF)	
		Average Prevalence (2003-2010) /10,000 Occupants	Level (2003-2010)
Tarakan Barat	Karang Rejo	17.08	Low
	Karang Balik	20.64	High
	Karang Anyar	24.85	Very High
	Karang Anyar Pantai	12.89	Very Low
	Karang Harapan	13.52	Very Low
Tarakan Utara	Juata Permai	24.67	Very High
	Juata Kerikil	17.14	Low
	Juata Laut	11.75	Very Low

Figure below shows the hazard categorization in spatial view. It is seen that most of Tarakan villages have high level of DHF hazard, means that naturally this disease is occurred in high prevalence. This condistion may caused by the existence of natural inhabitant mosquitoes in large number.

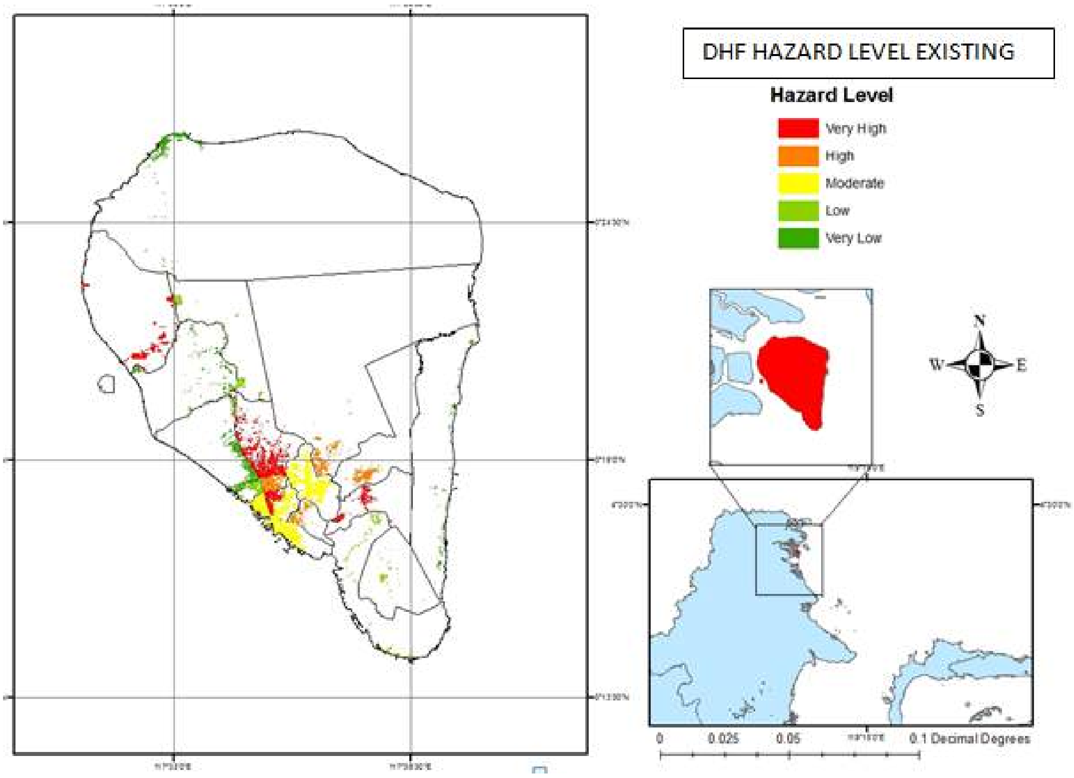


Figure 4-12 Hazard Map of Existing DHF in Tarakan

4.2 Future Projection of DHF Hazard in Correlation with Climate Change

As described in sub-chapter 3.3.4, we choose compartment model as prediction method for future DHF, malaria, and diarrhea in Tarakan.

4.2.1 Estimation of Existing DHF Hazard by Using Compartment Model

Compartment model is used to analysis the relation between disease and climatic factor such as rainfall and temperature. Compartment model use deterministic approach. 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 villages level. Therefore, the number of case in 4 sub districts level of Tarakan is based on the summation of each villages in the corresponding sub district area. Figure 4.13 shows DHF compartment model result in city level and Figure 4.14 - 4.17 show those in sub-district levels, i.e. Tarakan Timur, Tarakan Tengah, Tarakan Barat, and Tarakan Utara, respectively.

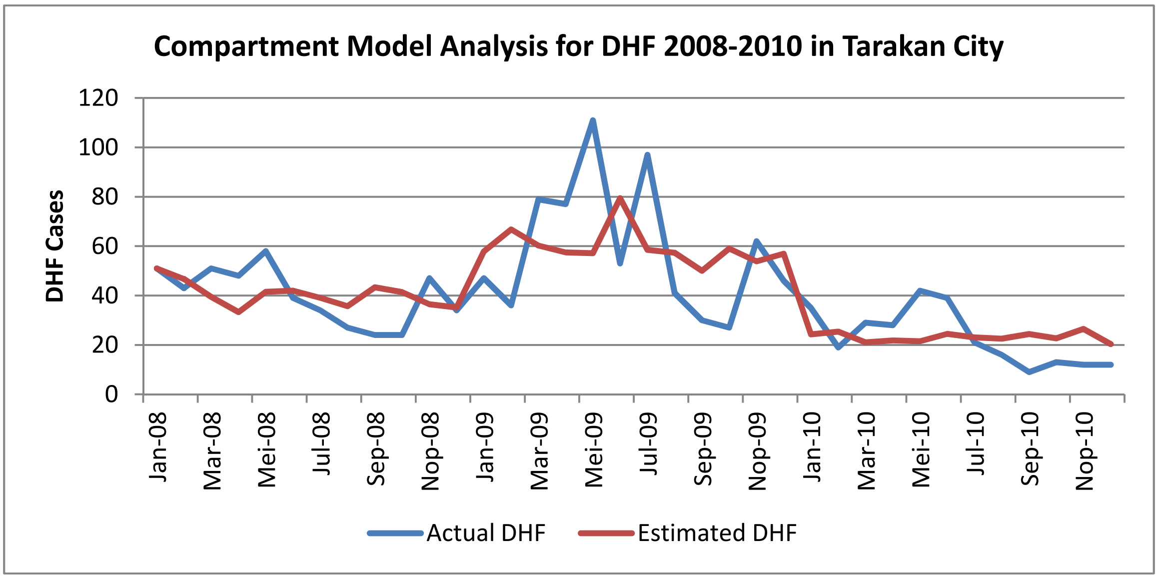


Figure 4-13 Compartment Model Analysis for DHF 2008-2010 in Tarakan City

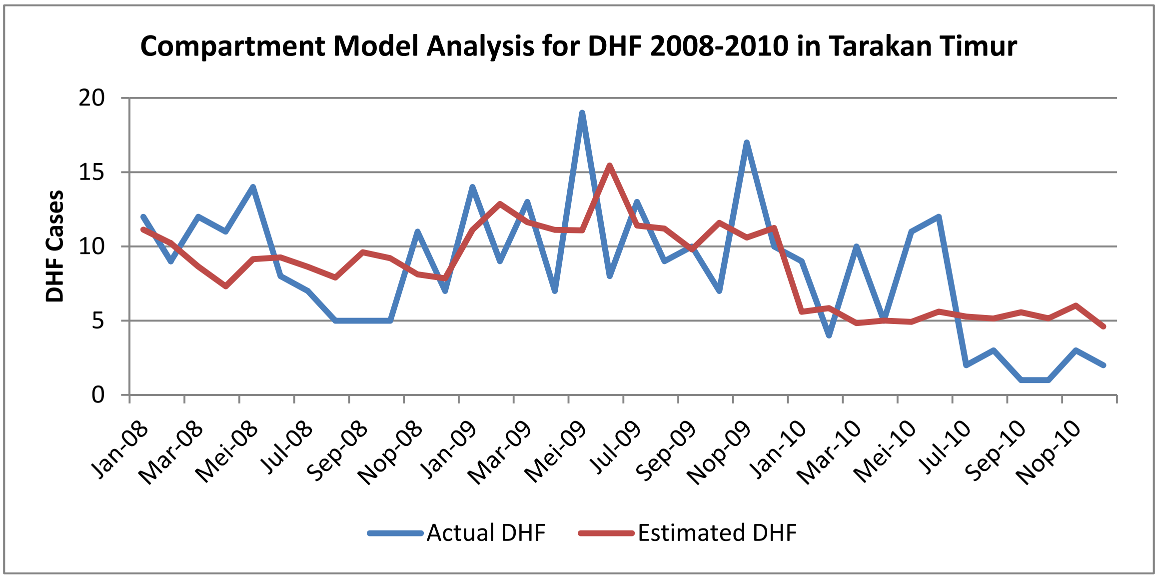


Figure 4-14 Compartment Model Analysis for DHF 2008-2010 in Tarakan Timur

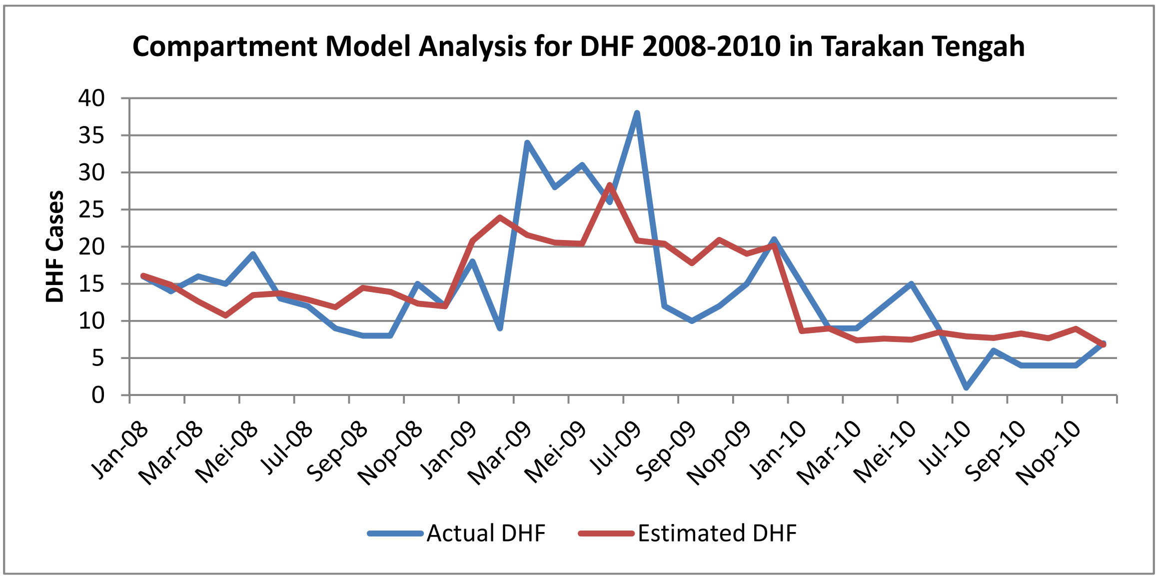


Figure 4-15 Compartment Model Analysis for DHF 2008-2010 in Tarakan Tengah

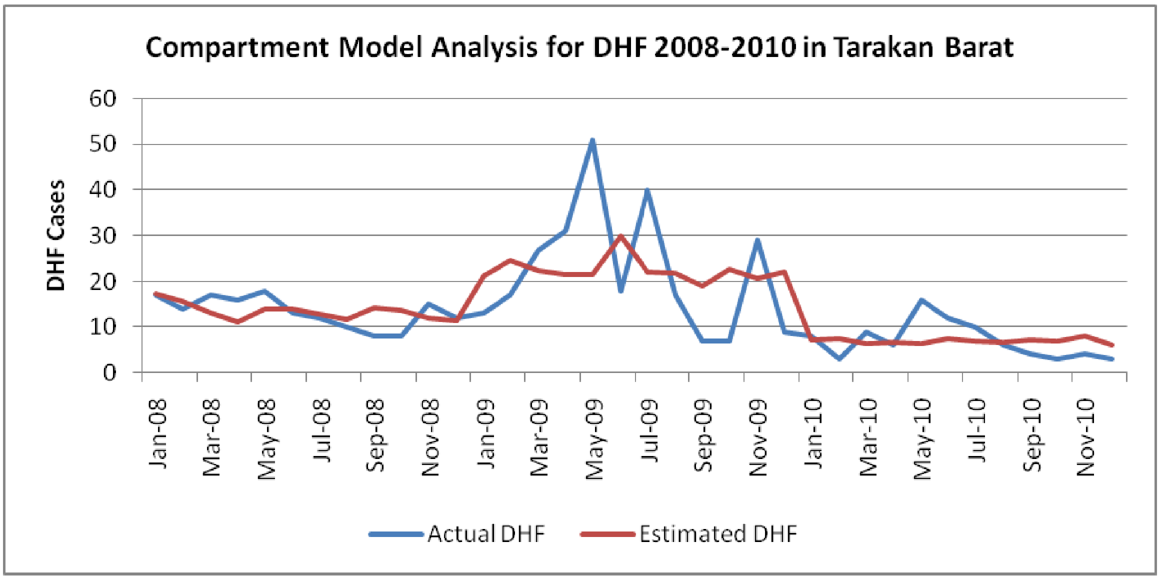


Figure 4-16 Compartment Model Analysis for DHF 2008-2010 in Tarakan Barat

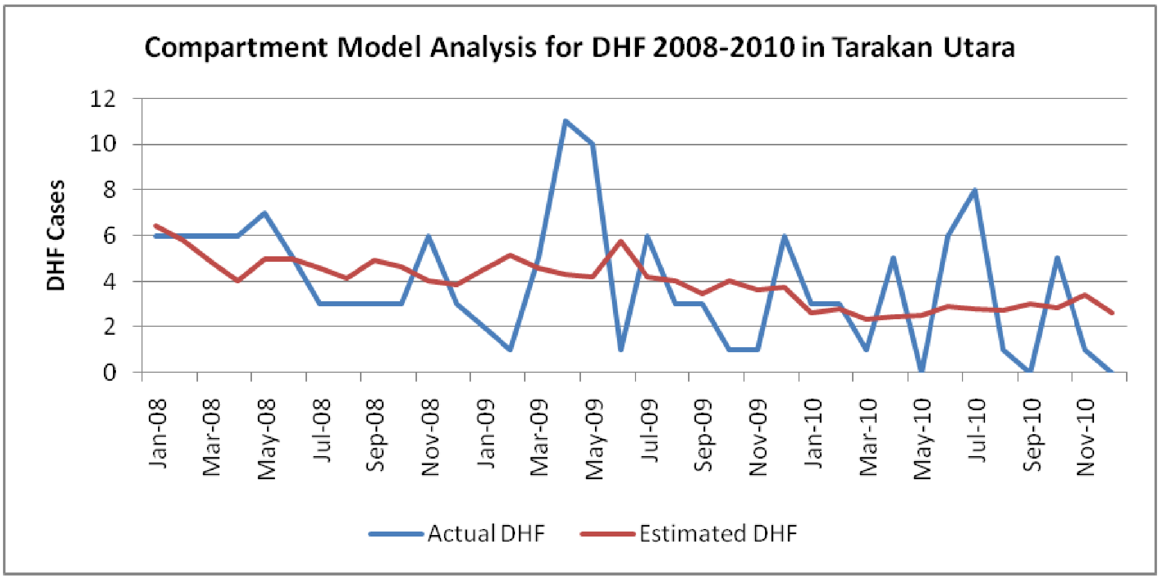


Figure 4-17 Compartment Model Analysis for DHF 2008-2010 in Tarakan Utara

4.2.2 Results of DHF Hazard Projection 2030 by Compartment Model

DHF cases 2011-2030 is projected by using compartment model method. Compartment method is selected because it has better accuracy than Poisson regression analysis method. As shown in Figure 4.18 – 4.22, DHF projection 2011-2030 were calculated both in city level and sub-district level.

DHF cases 2011-2030 for Tarakan City was calculated by using compartment model method and it is illustrated in Figure 4.18. As shown in Figure 4.18, DHF trend increase and each year has fluctuating number following the rainfall pattern.

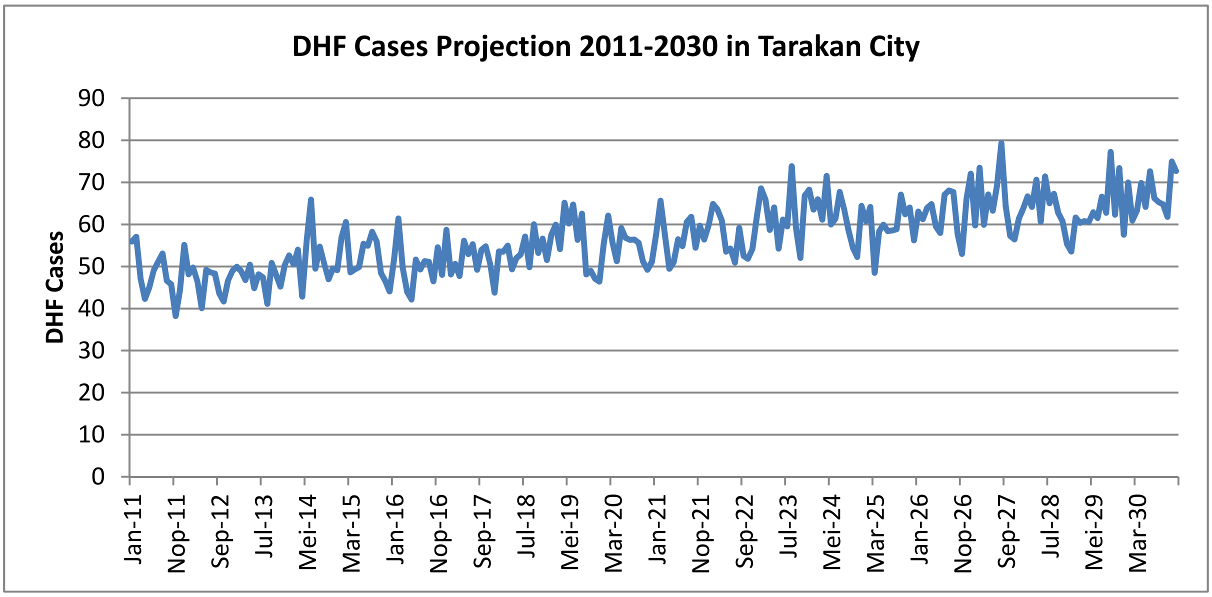


Figure 4-18 DHF Hazard Projection 2011-2030 for Tarakan City

Figure 4.19 shows DHF cases for 2011-2030 in Tarakan Timur subdistrict. The projection method is compartment model. As shown in Figure 4.18, DHF trend increase and each year fluctuated following the rainfall pattern.

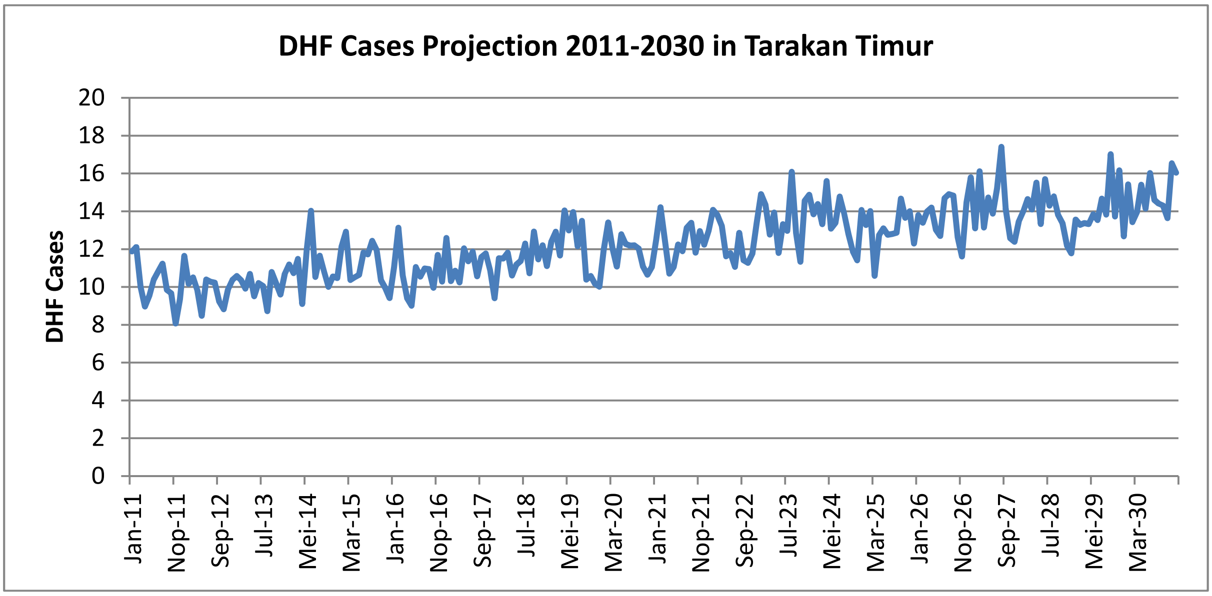


Figure 4-19 DHF Hazard Projection 2011-2030 for Tarakan Timur

Figure 4.20 shows DHF projection cases for 2011-2030 in Tarakan Tengah subdistrict that calculated by using compartment model. Similar with Tarakan Timur subdistrict, DHF trend in Tarakan Tengah subdistrict increase and has monthly fluctuated pattern following the rainfall pattern.

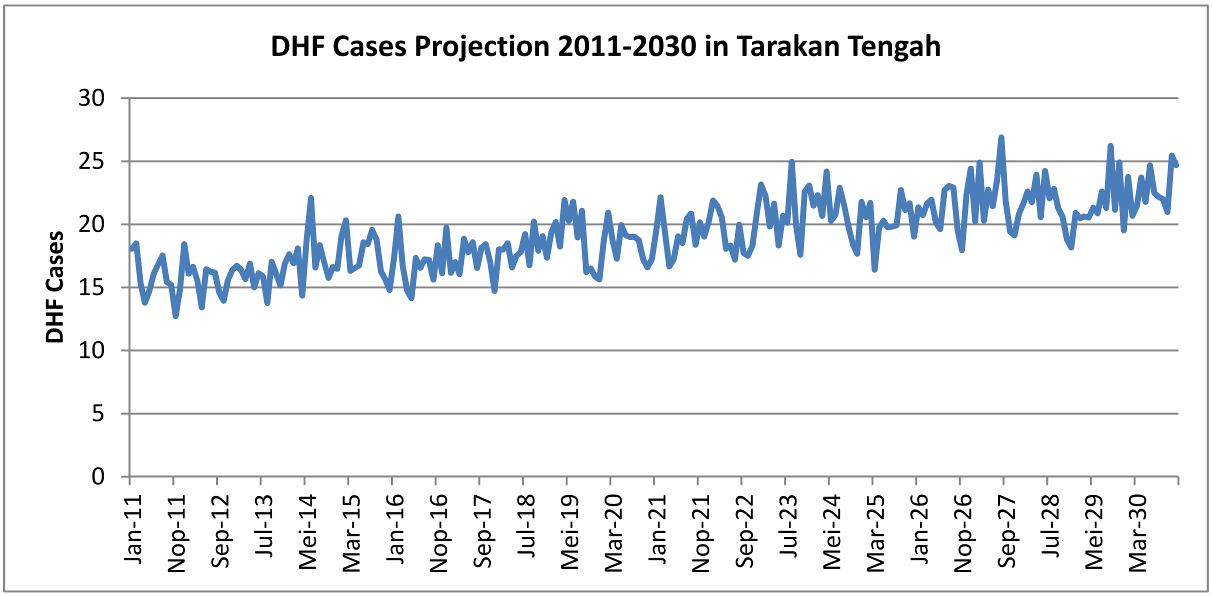


Figure 4-20 DHF Hazard Projection 2011-2030 for Tarakan Tengah

Figure 4.21 shows DHF cases projection for 2011-2030 in Tarakan Barat subdistrict that calculated by using compartment model. As shown in Figure 4.20, DHF trend has monthly fluctuating pattern following the rainfall pattern.

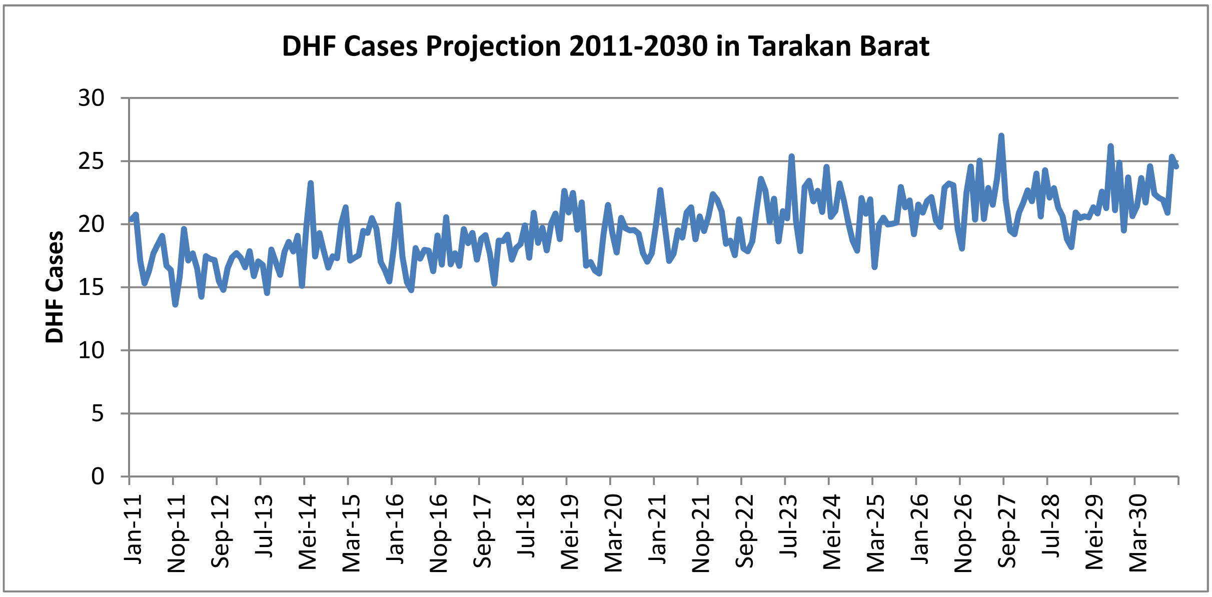


Figure 4-21 DHF Hazard Projection 2011-2030 for Tarakan Barat

Figure 4.22 shows DHF projection cases for 2011-2030 in Tarakan Utara subdistrict that calculated by using compartment model.

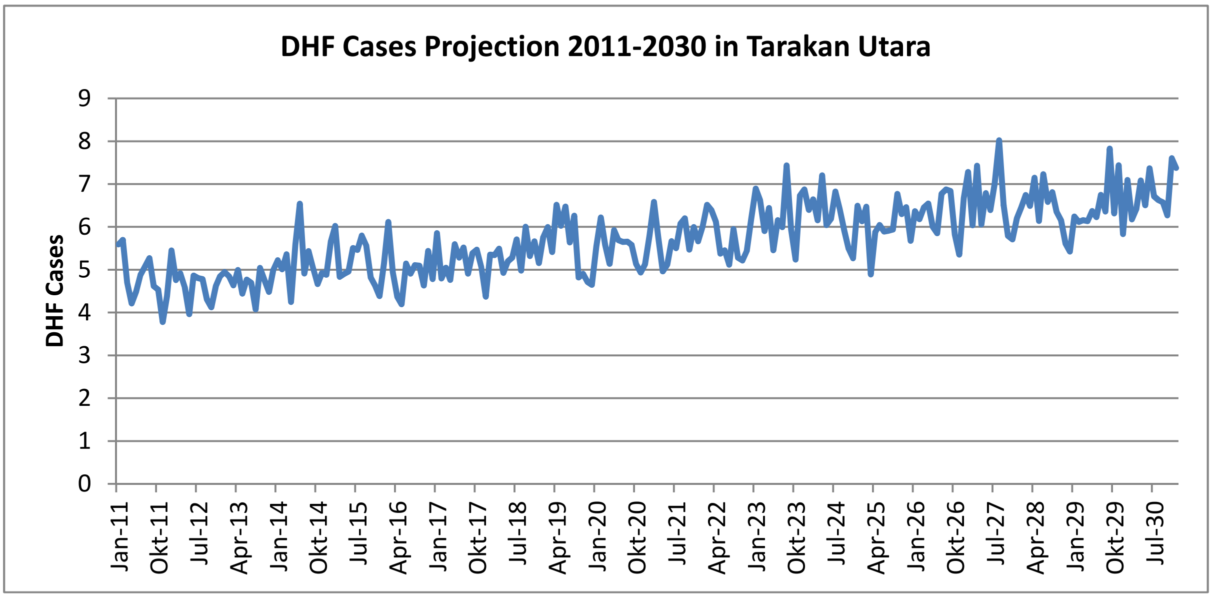


Figure 4-22 DHF Hazard Projection 2011-2030 for Tarakan Utara

Based on compartment model calculation, hazard level of DHF projection in 2030 was defined as shown in Table 4.4. There are 15 villages that will have very high DHF level. The levels are plotted in Figure 4.23.

Table 4.4: Categories of DHF Hazard in 2030

Sub Districts	Villages	Hazard	
		Prevalence (2030) /10,000 Occupants	Categories
Tarakan Timur	Lingkas Ujung	31.90	Very High
	Gunung Lingkas	38.33	Very High
	Mamburungan	27.48	Very High
	Mamburungan Timur	15.69	Low
	Kampung Empat	40.21	Very High
	Kampung Enam	25.03	Very High
	Pantai Amal	8.91	Very Low
Tarakan Tengah	Selumit Pantai	28.40	Very High
	Selumit	37.08	Very High
	Sebengkok	30.22	Very High
	Pamusian	28.23	Very High
	Kampung Satu Skip	38.92	Very High
Tarakan Barat	Karang Rejo	31.07	Very High
	Karang Balik	35.66	Very High
	Karang Anyar	42.11	Very High
	Karang Anyar Pantai	18.63	Moderate
	Karang Harapan	20.06	Moderate
Tarakan Utara	Juata Permai	32.79	Very High
	Juata Kerikil	22.56	High
	Juata Laut	24.41	Very High

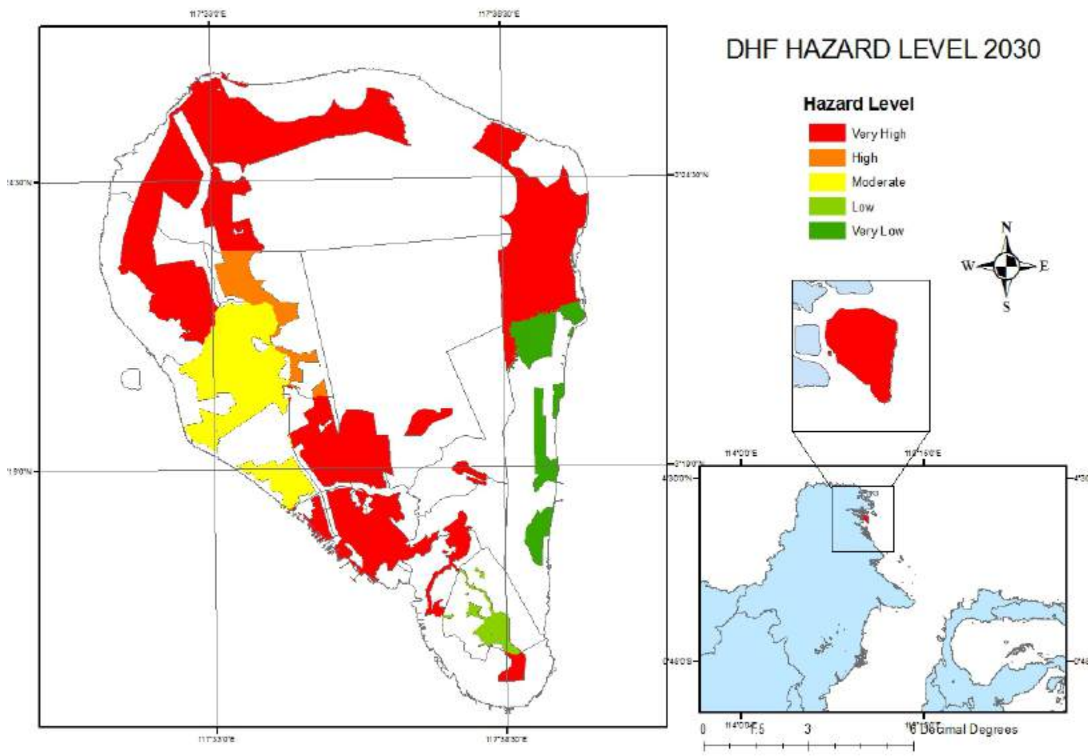


Figure 4-23 Hazard Map of DHF Projection 2030

4.3 Comparison of DHF Hazard Levels in 2008 and 2030

Average prevalence of DHF in 2003-2010 is used to categorize the existing hazard in sub district level as shown in table below. Moreover, predicting hazard for 2030 is used as comparator whether the hazard in 2030 is increase or decrease. Several sub-district is increase, there are marked by +1, +2, +3, and +4, and several sub-district have same level, there are marked by 0. As shown in Table 8.1, Juata Laut will increase sharply that it will increase for 4 level. Mamburungan and Karang Rejo will increase for 3 level.

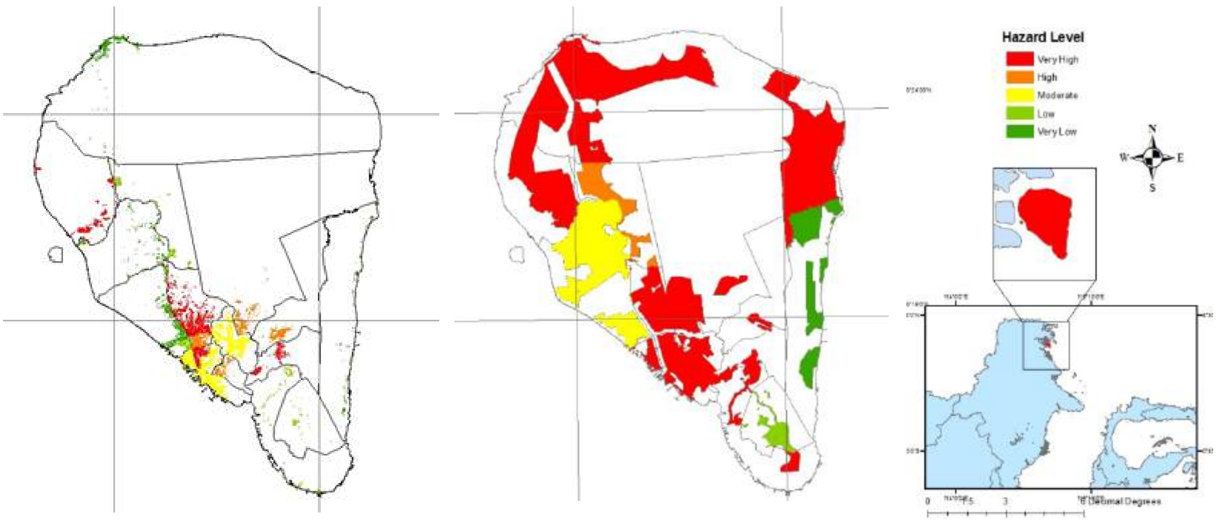
Table 4.5: Comparison of Existing and Future Hazard Categorization for DHF in Tarakan City

Sub district	Villages	Hazard (DHF)				Compa-rison
		Average Prevalence (2003-2010) /10,000 Occupants	Level (2003-2010)	Prevalence (2030) /10,000 Occupants	Level (2030)	
Tarakan Timur	Lingkas Ujung	19.81	Moderate	31.90	Very High	+2
	Gunung Lingkas	23.09	High	38.33	Very High	+1
	Mamburungan	13.94	Low	27.48	Very High	+3
	Mamburungan Timur	14.31	Low	15.69	Low	0
	Kampung Empat	28.47	Very High	40.21	Very High	0
	Kampung Enam	20.67	High	25.03	Very High	+1
	Pantai Amal	6.52	Very Low	8.91	Very Low	0
Tarakan Tengah	Selumit Pantai	20.20	Moderate	28.40	Very High	+2
	Selumit	23.76	Very High	37.08	Very High	0

Sub district	Villages	Hazard (DHF)				Compa-rison
		Average Prevalence (2003-2010) /10,000 Occupants	Level (2003-2010)	Prevalence (2030) /10,000 Occupants	Level (2030)	
	Sebengkok	19.91	Moderate	30.22	Very High	+2
	Pamusian	17.91	Moderate	28.23	Very High	+2
	Kampung Satu Skip	21.60	High	38.92	Very High	+1
Tarakan Barat	Karang Rejo	17.08	Low	31.07	Very High	+3
	Karang Balik	20.64	High	35.66	Very High	+1
	Karang Anyar	24.85	Very High	42.11	Very High	0
	Karang Anyar Pantai	12.89	Very Low	18.63	Moderate	+1
	Karang Harapan	13.52	Very Low	20.06	Moderate	+2
Tarakan Utara	Juata Permai	24.67	Very High	32.79	Very High	0
	Juata Kerikil	17.14	Low	22.56	High	+2
	Juata Laut	11.75	Very Low	24.41	Very High	+4

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

Figure below shows the hazard categorization in spatial view. It is seen that most of Tarakan villages have high level of DHF hazard, means that naturally this disease is occurred in high prevalence. This condistion may caused by the existence of natural inhabitant mosquitoes in large number.



DHF Hazard Map 2008 DHF Hazard Map 2030

Figure 4-24 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

Monthly malaria cases data is not available in Tarakan but yearly data 2007-2009 is available. The malaria cases yearly data are shown in Table 4.6 and it is illustrated in Figure 4.25.

Table 4.6: Malaria cases in Tarakan City 2007-2009

No.	PHC	2007	2008	2009
1	Karang Rejo	0	0	0
2	Gunung Lingkas	2	3	2
3	Sebengkok	0	0	0
4	Mamburungan	1	0	0
5	Pantai Amal	0	1	2
6	Juata Permai	24	0	0
7	Juata Laut	1	0	1
	Total	28	4	5

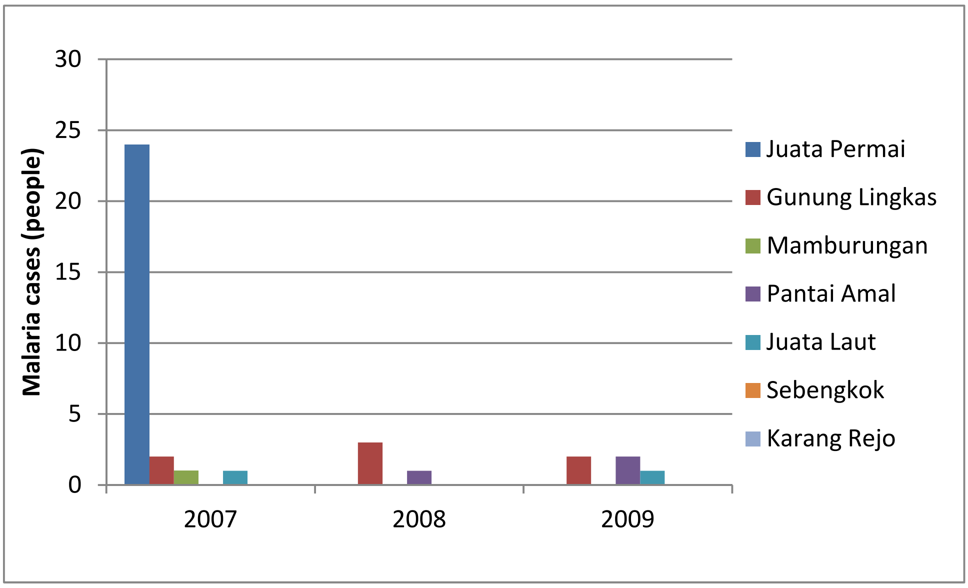


Figure 4-25 Malaria Cases in Tarakan City 2007-2009

4.4.2 Associations between Malaria Incidence, Rainfall and Temperature

Association between malaria incidence and annual average rainfall is illustrated in Figure 4.26. There are no monthly malaria data, therefore monthly analysis was not conducted.

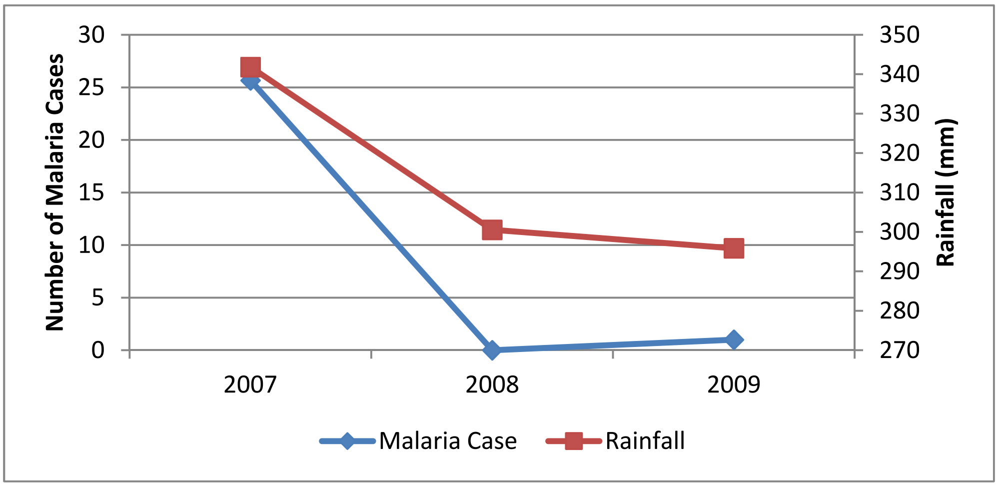


Figure 4-26 Malaria Case and Annual Average Rainfall in Tarakan City for 2007-2009

Association between malaria incidence and annual average temperature is illustrated in Figure 4.27.

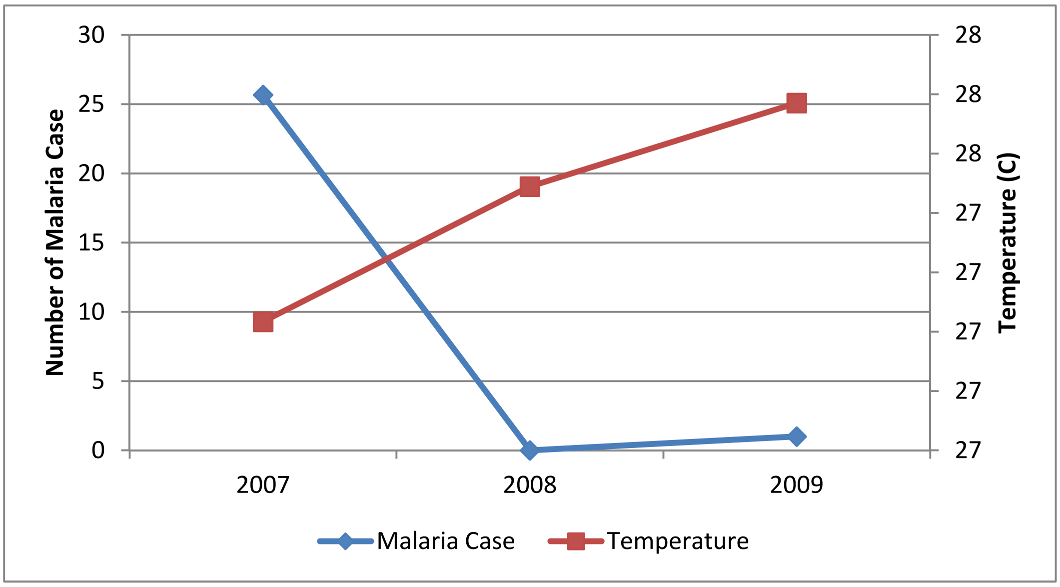


Figure 4-27 Malaria Case and Annual Average Temperature in Tarakan City for 2007-2009

4.4.3 Associations between Malaria Incidence and Population Number

Association between malaria incidence and population number is illustrated in Figure 4.28.

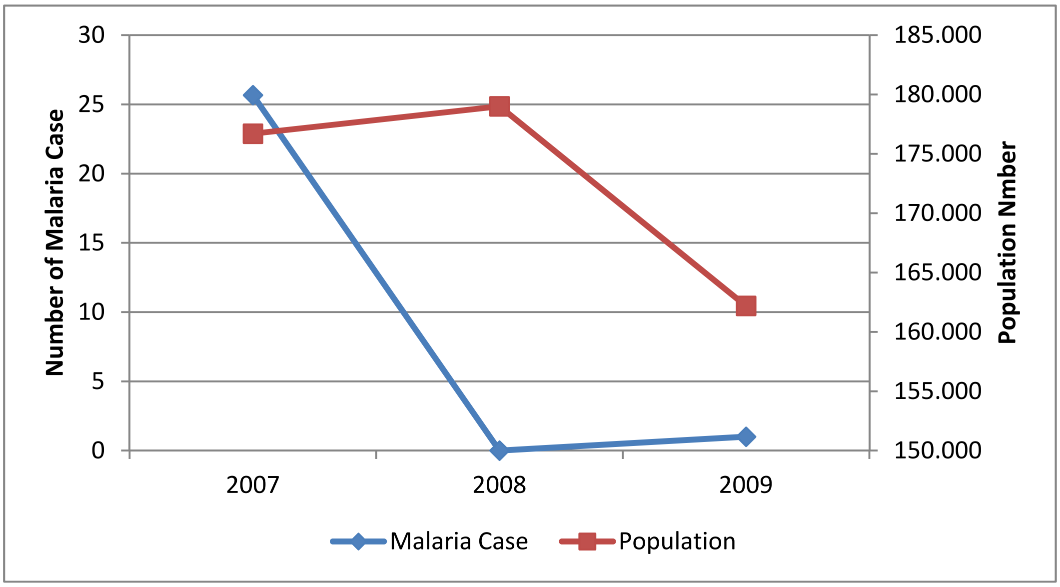


Figure 4-28 Malaria Case and Annual Population Number in Tarakan City for 2007-2009

4.4.4 Results of Existing Malaria Hazard Analysis

The three years average of prevalence (2007-2009) is used to categorize the hazard in sub district level as shown in table below.

Table 4.7: Existing Hazard Categories of Malaria in Tarakan

Sub districts	Villages	Average Prevalence (2007-2009) /100,000 Occupants	Hazard Level (2007-2009)
Tarakan Timur	Lingkas Ujung	15.24	Very High
	Gunung Lingkas	15.24	Very High
	Mamburungan	0.52	Low
	Mamburungan Timur	0.52	Low
	Kampung Empat	12.30	High
	Kampung Enam	12.30	High
	Pantai Amal	12.30	High
Tarakan Tengah	Selumit Pantai	0.00	Very Low
	Selumit	0.00	Very Low
	Sebengkok	0.00	Very Low
	Pamusian	0.52	Low
	Kampung Satu Skip	0.52	Low
Tarakan Barat	Karang Rejo	0.00	Very Low
	Karang Balik	0.00	Very Low
	Karang Anyar	0.00	Very Low
	Karang Anyar Pantai	0.00	Very Low
	Karang Harapan	44.44	Very High
Tarakan Utara	Juata Permai	44.44	Very High
	Juata Kerikil	44.44	Very High
	Juata Laut	6.93	Moderate

Hazard level of malaria existing is plotted in Figure 4.29. As shown in Figure 4.29, malaria is more prominent in southern and northern area of Tarakan.

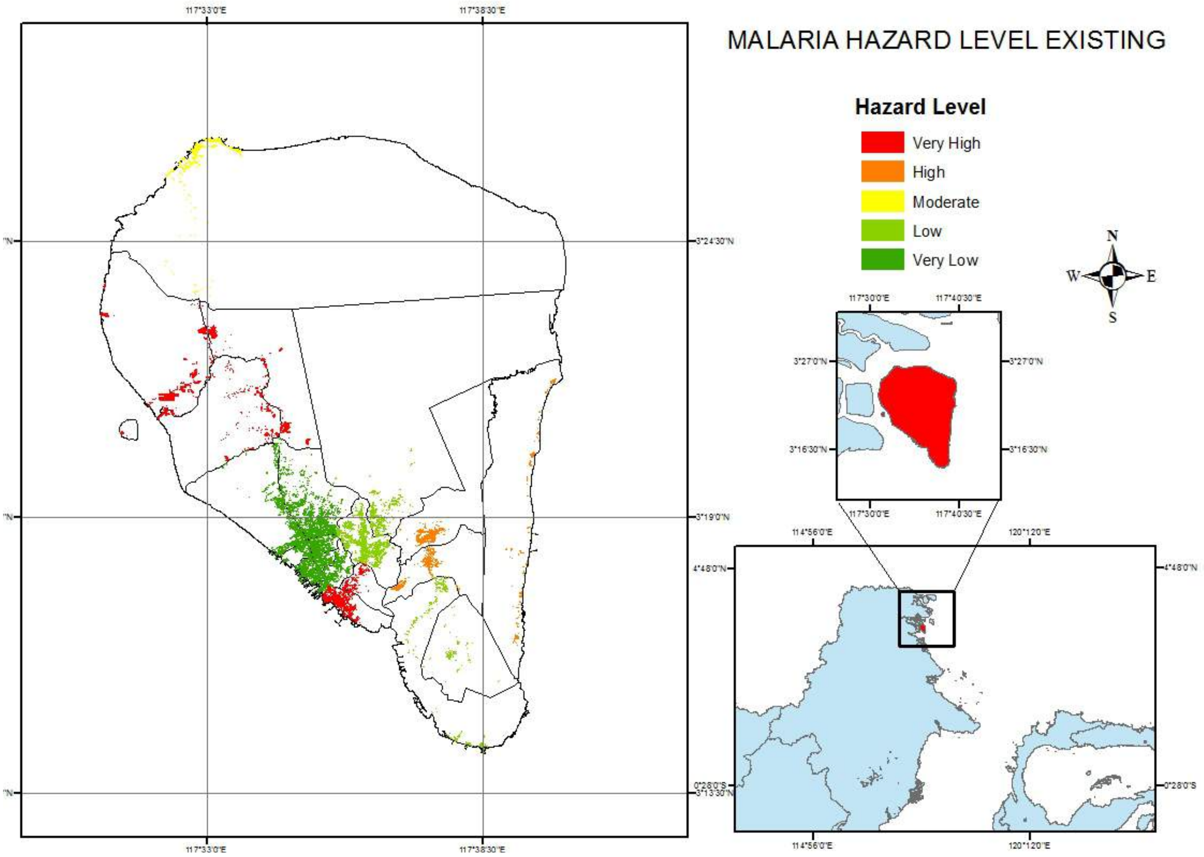
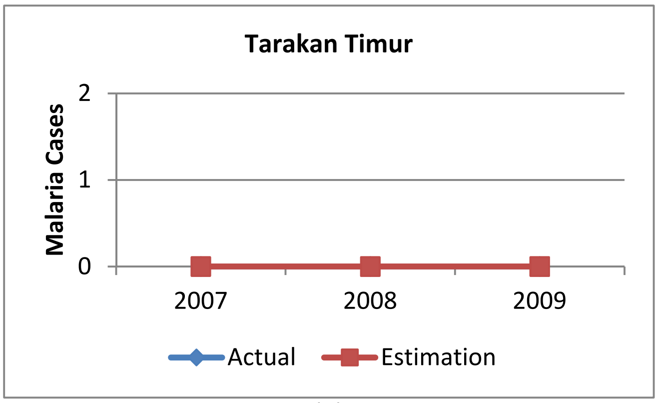


Figure 4-29 Hazard Map of Existing Malaria in Tarakan

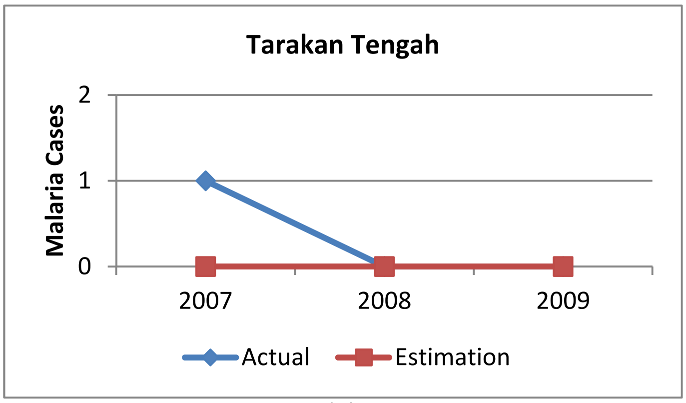
4.5 Future Projection of Malaria Hazard in Correlation with Climate Change

Since malaria only present in annual data form, the poisson regression is unable to be calculated. However, compartment model is used and its result is shown in Figures 4.30(a) – 4.30(e).

4.5.1 Estimation of Existing Malaria Hazard by Using Compartment Model



(a)



(b)

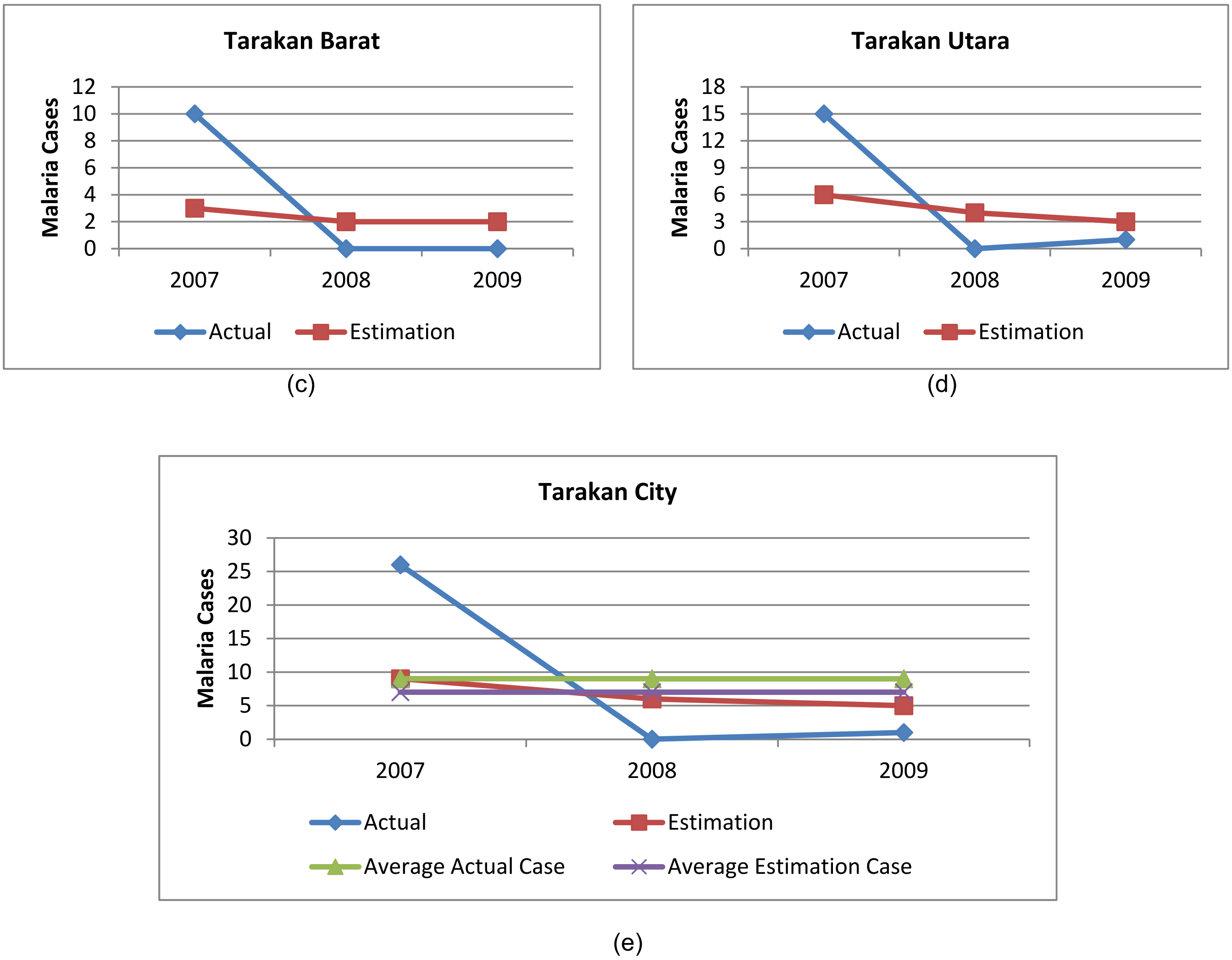


Figure 4-30 Compartment Model Analysis for Malaria Cases 2007-2009

4.5.2 Results of Malaria Hazard Projection 2030 by Compartment Model

Malaria incidence for 2010-2030 is projected by using compartment model and its result is shown in Figure 4.31. Malaria incidence in 2030 is classified by using 5 hazard level as shown in Table 4.8 and Figure 4.32.

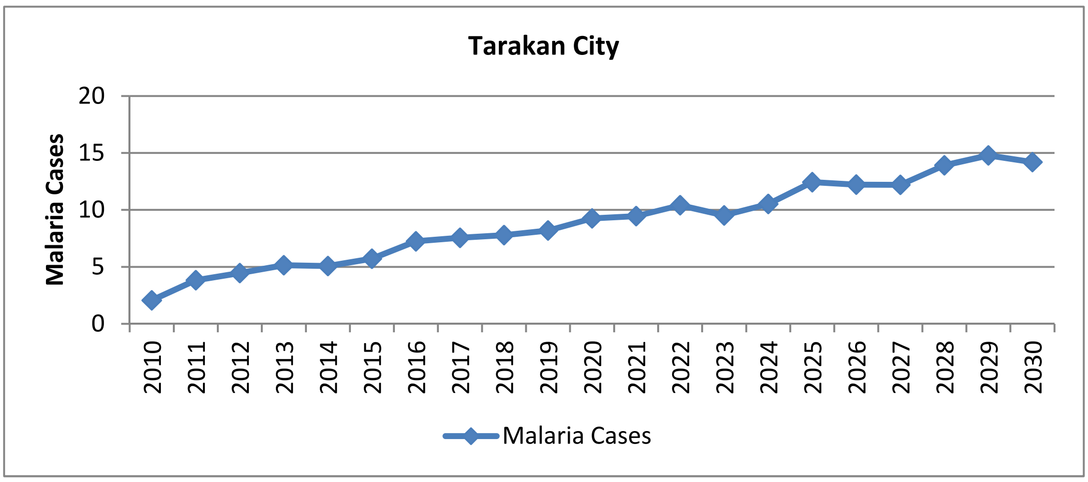


Figure 4-31 Malaria Hazard Projection 2030 in Tarakan City Using Compartment Model

Table 4.8 shows hazard categories of malaria in Tarakan city in 2030. Hazard level of Tarakan city is very low until very high. Hazard level of Tarakan Timur, Tarakan Tengah, Tarakan Barat, and Tarakan Utara subdistrict are moderate, very low, very low, and very high, respectively.

Table 4.8: Hazard Categories of Malaria in Tarakan City for 2030

Sub districts	Villages	Hazard	
		Prevalence (2030) /100,000 Occupants	Hazard Level (2030)
Tarakan Timur	Lingkas Ujung	11.02	Moderate
	Gunung Lingkas	11.02	Moderate
	Mamburungan	11.02	Moderate
	Mamburungan Timur	11.02	Moderate
	Kampung Empat	11.02	Moderate
	Kampung Enam	11.02	Moderate
	Pantai Amal	11.02	Moderate
Tarakan Tengah	Selumit Pantai	0.00	Very Low
	Selumit	0.00	Very Low
	Sebengkok	0.00	Very Low
	Pamusian	0.00	Very Low
	Kampung Satu Skip	0.00	Very Low
Tarakan Barat	Karang Rejo	0.00	Very Low
	Karang Balik	0.00	Very Low
	Karang Anyar	0.00	Very Low
	Karang Anyar Pantai	0.00	Very Low
	Karang Harapan	0.00	Very Low
Tarakan Utara	Juata Permai	64.94	Very High
	Juata Kerikil	64.94	Very High
	Juata Laut	64.94	Very High

The hazard level of each villages in Tarakan city in 2030 is illustrated in Figure 4.32.

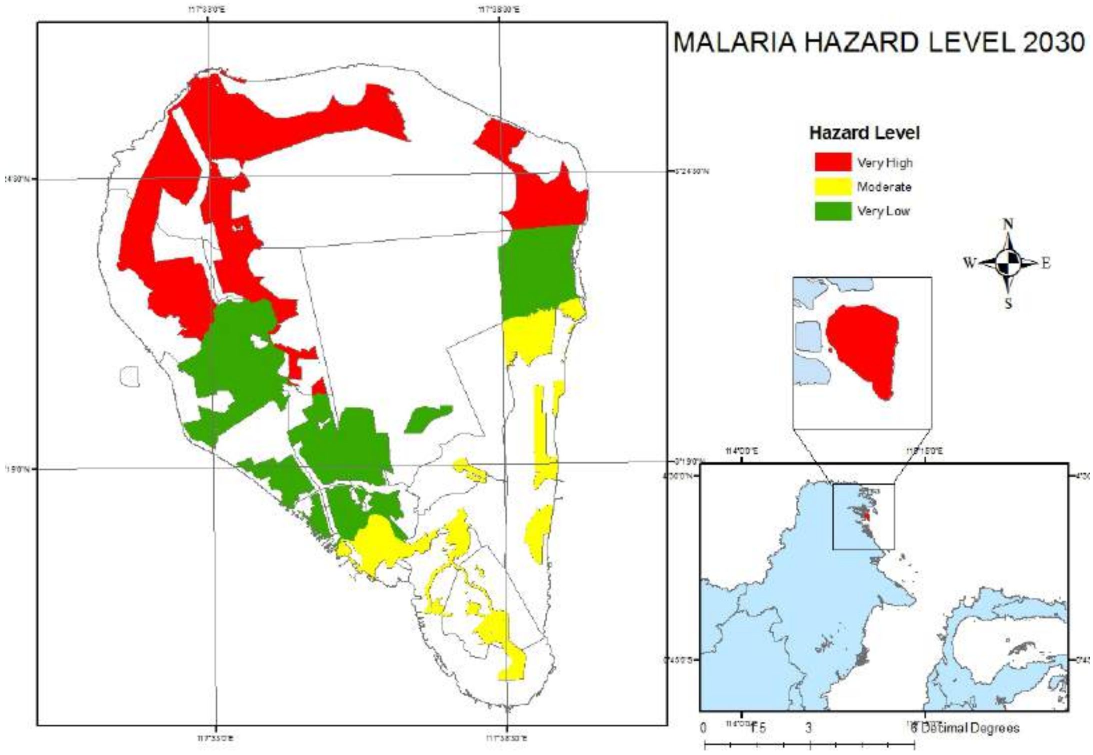


Figure 4-32 Hazard Level Map of Malaria in Tarakan in 2030

4.6 Comparison of Malaria Hazard Levels in 2008 and 2030

Comparison of Malaria hazard levels in Tarakan in 2008 and 2030 is described in Table 4-9 below.

Table 4.9: Comparison of Existing and Future Hazard Categorization for Malaria in Tarakan City

Sub district	Villages	Hazard (Malaria)				Compa-rison
		Average Prevalence (2007-2009) /100,000 Occupants	Level (2007-2009)	Prevalence (2030) /100,000 Occupants	Level (2030)	
Tarakan Timur	Lingkas Ujung	15.24	Very High	11.02	Moderate	-2
	Gunung Lingkas	15.24	Very High	11.02	Moderate	-2
	Mamburungan	0.52	Low	11.02	Moderate	+1
	Mamburungan Timur	0.52	Low	11.02	Moderate	+1
	Kampung Empat	12.30	High	11.02	Moderate	-1
	Kampung Enam	12.30	High	11.02	Moderate	-1
	Pantai Amal	12.30	High	11.02	Moderate	-1
Tarakan Tengah	Selumit Pantai	0.00	Very Low	0.00	Very Low	0
	Selumit	0.00	Very Low	0.00	Very Low	0
	Sebengkok	0.00	Very Low	0.00	Very Low	0
	Pamusian	0.52	Low	0.00	Very Low	-1
	Kampung Satu Skip	0.52	Low	0.00	Very Low	-1

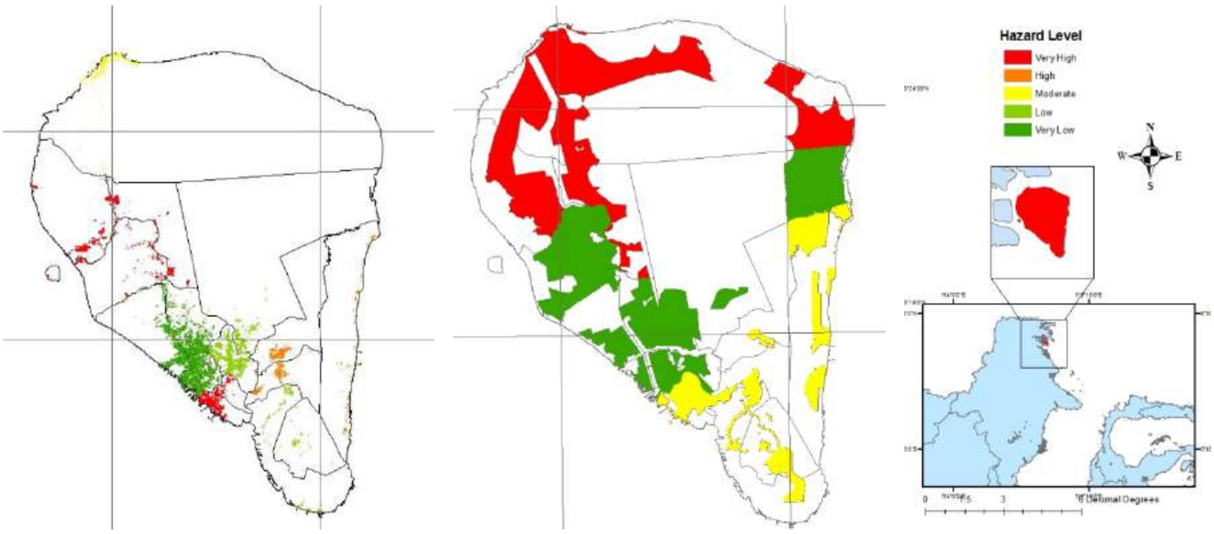
Sub district	Villages	Hazard (Malaria)				Compa-rison
		Average Prevalence (2007-2009) /100,000 Occupants	Level (2007-2009)	Prevalence (2030) /100,000 Occupants	Level (2030)	
Tarakan Barat	Karang Rejo	0.00	Very Low	0.00	Very Low	0
	Karang Balik	0.00	Very Low	0.00	Very Low	0
	Karang Anyar	0.00	Very Low	0.00	Very Low	0
	Karang Anyar Pantai	0.00	Very Low	0.00	Very Low	0
	Karang Harapan	44.44	Very High	0.00	Very Low	-4
Tarakan Utara	Juata Permai	44.44	Very High	64.94	Very High	0
	Juata Kerikil	44.44	Very High	64.94	Very High	0
	Juata Laut	6.93	Moderate	64.94	Very High	+2

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 hazard map in 2008 and 2030 is described in Figure 4-33 below.



Malaria Hazard Map 2008 Malaria Hazard Map 2030

Figure 4-33 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

Similar with malaria cases, there are not diarrhea monthly data in Tarakan city. Thus, yearly data was used for analysis. Table 4.10 shows yearly diarrhea cases data for each PHC in Tarakan city for 2000-2010.

Table 4.10: Diarrhea cases in Tarakan City in 2000-2010

No.	PHC	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1	Karang Rejo	796	840	861	1,071	1,101	843	1,344	1,176	1,306	1,304	2,086
2	Gunung Lingkas	537	504	422	439	524	683	1,027	711	913	1,085	1,336
3	Mamburungan	626	627	541	600	607	426	793	813	807	778	1,057
4	Juata Laut	377	350	475	490	387	301	348	370	370	475	358
5	Juata Permai	*	184	234	415	692	770	907	671	1,030	1,084	1,377
6	Pantai Amal	*	44	42	67	77	112	163	183	296	457	374
7	Sebengkok	*	*	*	*	*	*	*	*	254	785	391
Total			2,549	2,575	3,082	3,388	3,135	4,582	3,924	4,976	5,968	6,979

*Data is unavailable

Figure 4.34 shows yearly diarrhea cases data for each PHC in Tarakan city for 2000-2010. As shown in Figure 4.34, the highest case occurs in Karang Rejo PHC (Public Health Center/puskesmas).

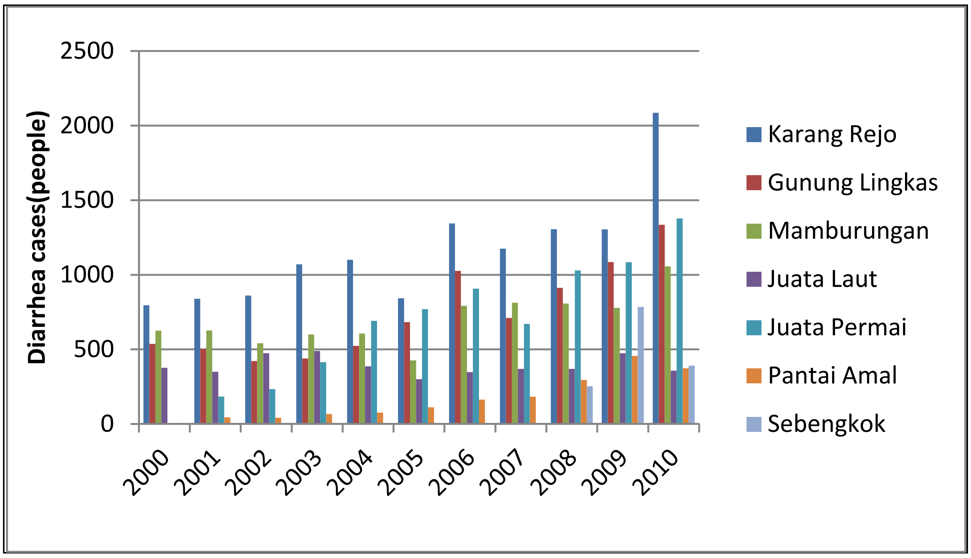


Figure 4-34 Diarrhea Cases In Tarakan Island 2000-2010

4.7.2 Results of Existing Diarrhea Hazard Analysis

The eight years average of prevalence (2003-2010) is used to categorize the hazard in villages level as shown in Table 4.11 below. Figures 4.35 show areas with different levels of diarrhea disease hazard.

Table 4.11: Existing Hazard Categories of Diarrhea in Tarakan City

Sub-district	Villages	Average Prevalence (2003-2010) /1,000 Occupants	Level (2003-2010)
Tarakan Timur	Lingkas Ujung	53.30	Very High
	Gunung Lingkas	53.30	Very High
	Mamburungan	17.00	Low
	Mamburungan Timur	17.00	Low
	Kampung Empat	16.52	Very Low

Sub-district	Villages	Average Prevalence (2003-2010) /1,000 Occupants	Level (2003-2010)
	Kampung Enam	16.52	Very Low
	Pantai Amal	16.52	Very Low
Tarakan Tengah	Selumit Pantai	13.63	Very Low
	Selumit	13.63	Very Low
	Sebengkok	13.63	Very Low
	Pamusian	17.00	Low
	Kampung Satu Skip	17.00	Low
Tarakan Barat	Karang Rejo	24.22	Moderate
	Karang Balik	24.22	Moderate
	Karang Anyar	24.22	Moderate
	Karang Anyar Pantai	24.22	Moderate
	Karang Harapan	50.60	Very High
Tarakan Utara	Juata Permai	50.60	Very High
	Juata Kerikil	50.60	Very High
	Juata Laut	40.70	High

As shown in Table 4.11, the villages that have very high hazard level are Lingkas Ujung, Gunung Lingkas, Karang Harapan, Juata Permai, and Juata Kerikil.

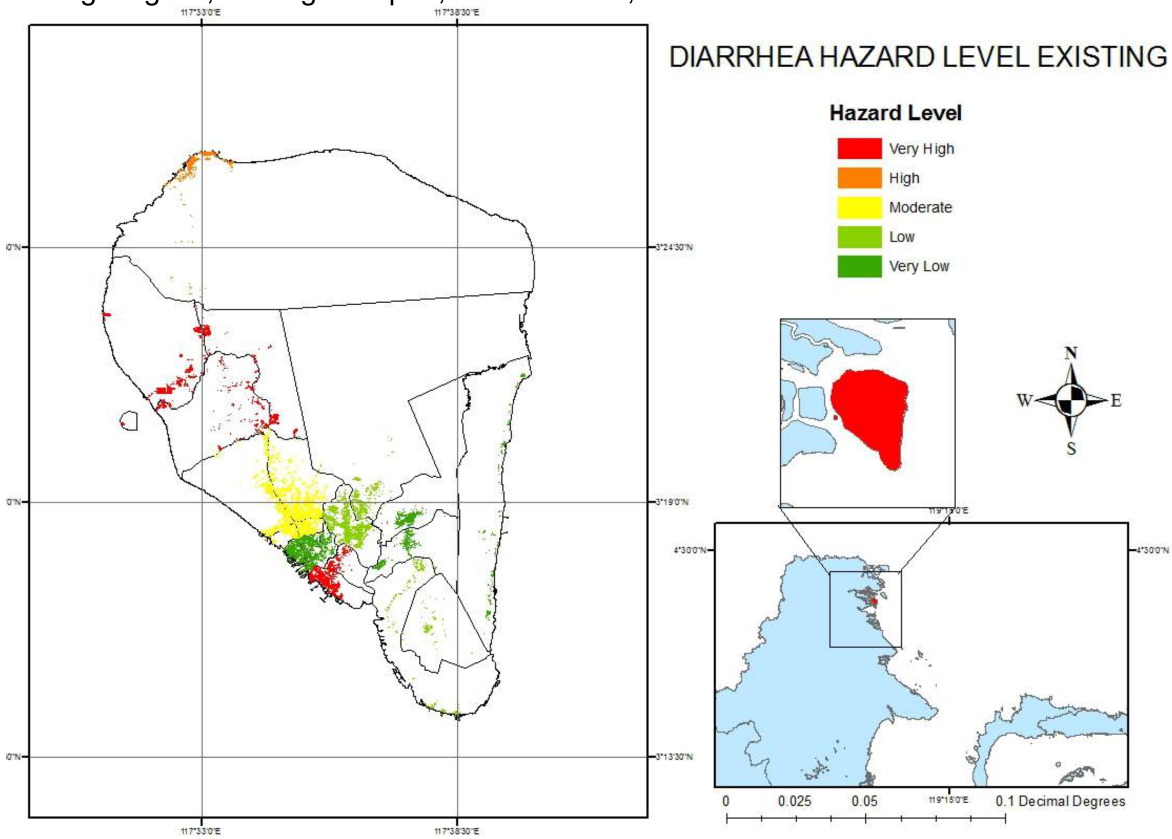


Figure 4-35 Hazard Map of Existing Diarrhea in Tarakan

4.8 Future Projection of Diarrhea Hazard in Correlation with Climate Change

4.8.1 Estimation of Existing Diarrhea Hazard by Using Compartment Model

Compartment model is used to estimate diarrhea case both in Tarakan city and each sub district. The results are shown in Figure 4.36 – 4.40.

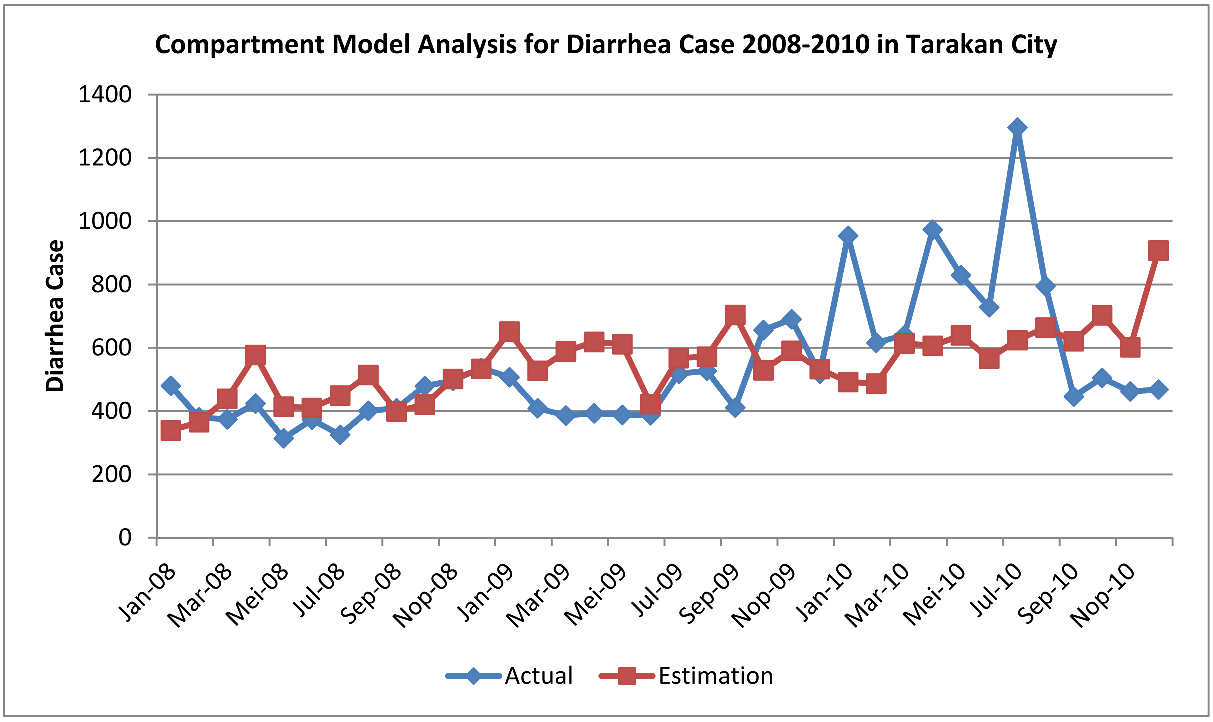


Figure 4-36 Compartment Model Analysis for Diarrhea Case 2008-2010 in Tarakan City

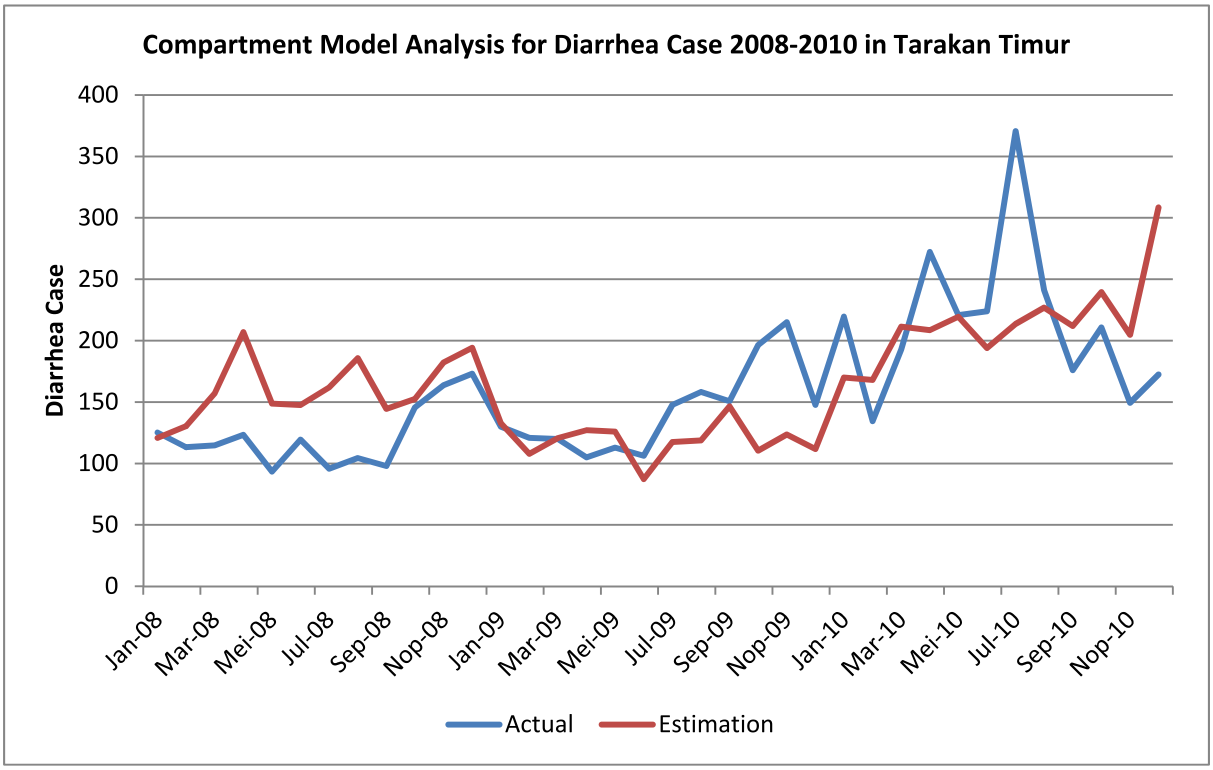


Figure 4-37 Compartment Model Analysis for Diarrhea Case 2008-2010 in Tarakan Timur

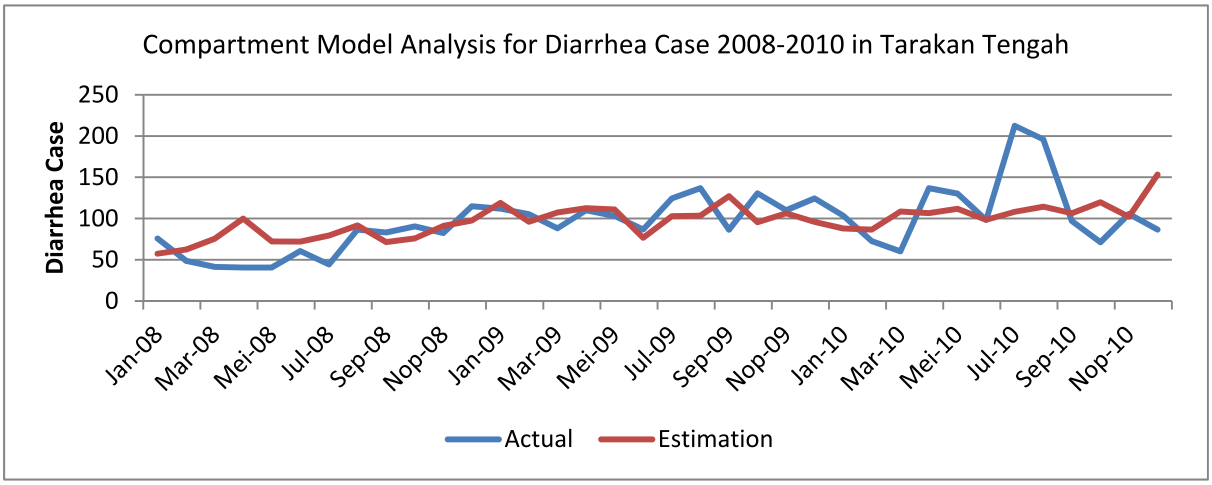


Figure 4-38 Compartment Model Analysis for Diarrhea Case 2008-2010 in Tarakan Tengah

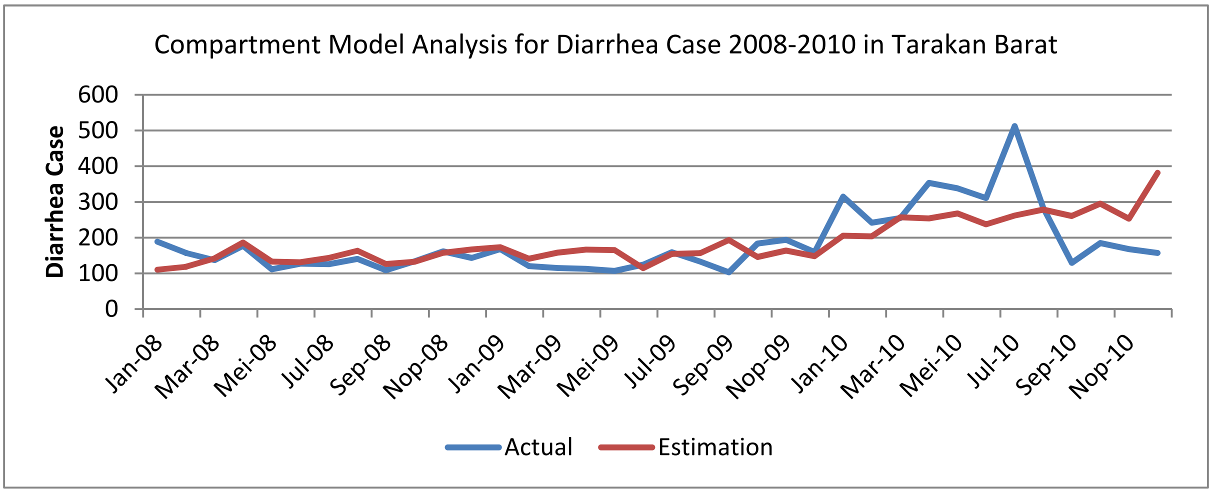


Figure 4-39 Compartment Model Analysis for Diarrhea Case 2008-2010 in Tarakan Barat

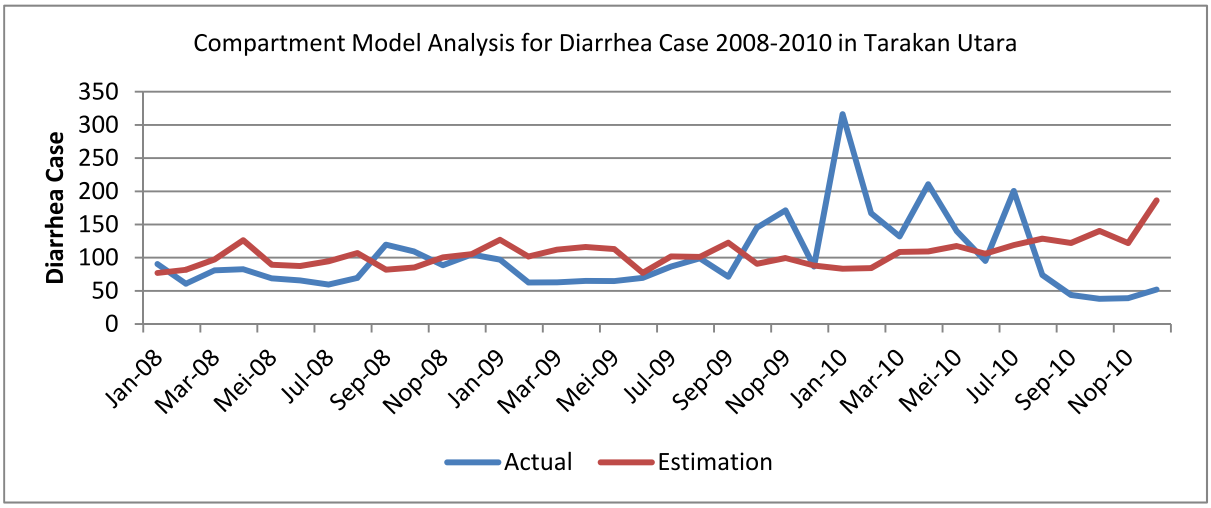


Figure 4-40 Compartment Model Analysis for Diarrhea Case 2008-2010 in Tarakan Utara

4.8.2 Results of Diarrhea Hazard Projection 2030 by Compartment Model

Projection of diarrhea case for 2030 is calculated by using compartment model. The result is categorized to 5 hazard level as shown in Table 4.12 and its area is plotted in Figure 4.41.

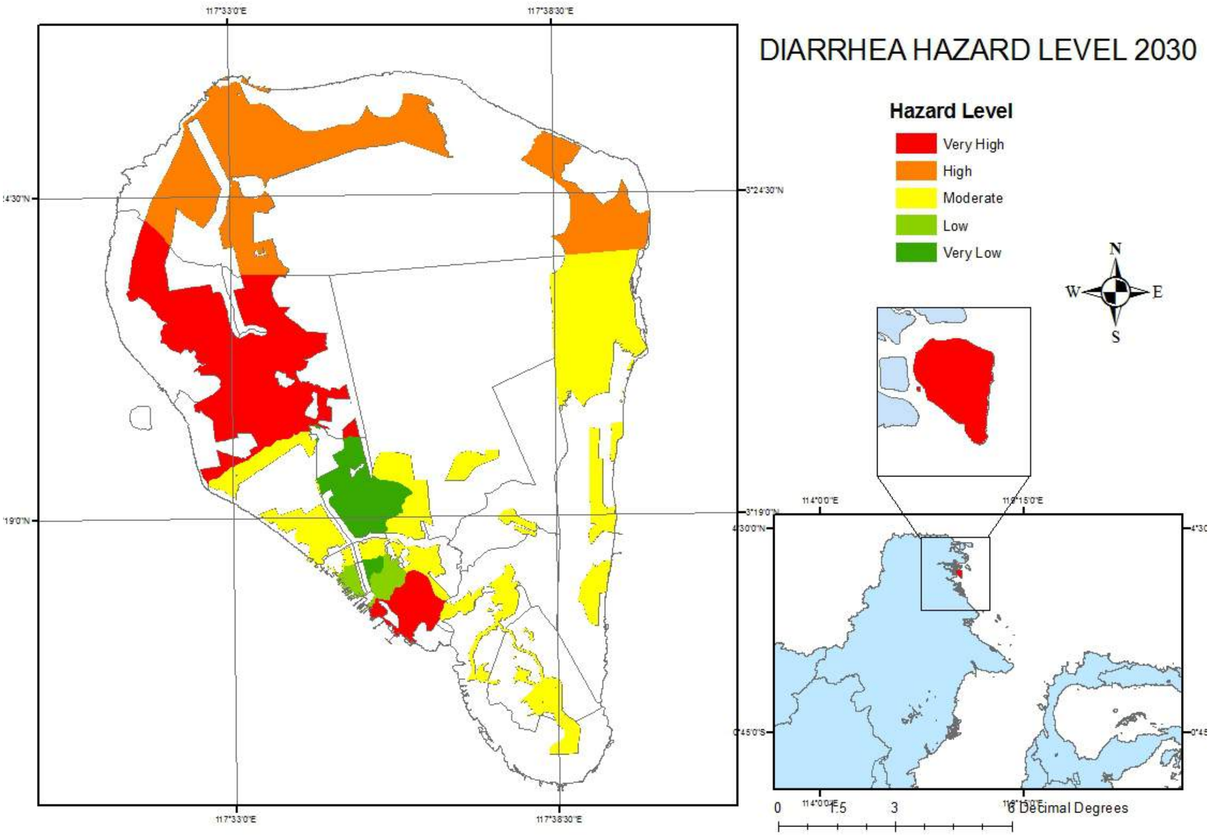


Figure 4-41 Hazard Map of Diarrhea Cases Projection 2030

Table 4.12: Categories of Diarrhea Hazard in 2030

Sub districts	Villages	Hazard	
		Prevalence (2030) /1,000 Occupants	Level
Tarakan Timur	Lingkas Ujung	60.54	Very High
	Gunung Lingkas	61.09	Very High
	Mamburungan	26.50	Moderate
	Mamburungan Timur	24.18	Moderate
	Kampung Empat	24.84	Moderate
	Kampung Enam	27.05	Moderate
	Pantai Amal	27.47	Moderate
Tarakan Tengah	Selumit Pantai	16.82	Low
	Selumit	14.56	Very Low
	Sebengkok	17.70	Low
	Pamusian	21.01	Moderate
	Kampung Satu Skip	32.97	Moderate
Tarakan Barat	Karang Rejo	30.32	Moderate
	Karang Balik	28.52	Moderate

Sub districts	Villages	Hazard	
		Prevalence (2030) /1,000 Occupants	Level
	Karang Anyar	15.67	Very Low
	Karang Anyar Pantai	31.14	Moderate
	Karang Harapan	54.30	Very High
Tarakan Utara	Juata Permai	113.23	Very High
	Juata Kerikil	57.72	Very High
	Juata Laut	43.04	High

4.9 Comparison of Diarrhea Hazard Levels in 2008 and 2030

Comparison of diarrhea hazard levels in Tarakan in 2008 and 2030 is described in Table 4-13 below.

Table 4.13: Comparison of Existing and Future Hazard Categorization for Diarrhea in Tarakan City

Sub district	Villages	Hazard (Diarrhea)				Compa-rison
		Average Prevalence (2003-2010) /1,000 Occupants	Level (2003-2010)	Prevalence (2030) /1,000 Occupants	Level (2030)	
Tarakan Timur	Lingkas Ujung	53.30	Very High	60.54	Very High	0
	Gunung Lingkas	53.30	Very High	61.09	Very High	0
	Mamburungan	17.00	Low	26.50	Moderate	+1
	Mamburungan Timur	17.00	Low	24.18	Moderate	+1
	Kampung Empat	16.52	Very Low	24.84	Moderate	+2
	Kampung Enam	16.52	Very Low	27.05	Moderate	+2
	Pantai Amal	16.52	Very Low	27.47	Moderate	+2
Tarakan Tengah	Selumit Pantai	13.63	Very Low	16.82	Low	+1
	Selumit	13.63	Very Low	14.56	Very Low	0
	Sebengkok	13.63	Very Low	17.70	Low	+1
	Pamusian	17.00	Low	21.01	Moderate	+1
	Kampung Satu Skip	17.00	Low	32.97	Moderate	+1
Tarakan Barat	Karang Rejo	24.22	Moderate	30.32	Moderate	0
	Karang Balik	24.22	Moderate	28.52	Moderate	0
	Karang Anyar	24.22	Moderate	15.67	Very Low	-2
	Karang Anyar Pantai	24.22	Moderate	31.14	Moderate	0
	Karang Harapan	50.60	Very High	54.30	Very High	0
Tarakan Utara	Juata Permai	50.60	Very High	113.23	Very High	0
	Juata Kerikil	50.60	Very High	57.72	Very High	0
	Juata Laut	40.70	High	43.04	High	0

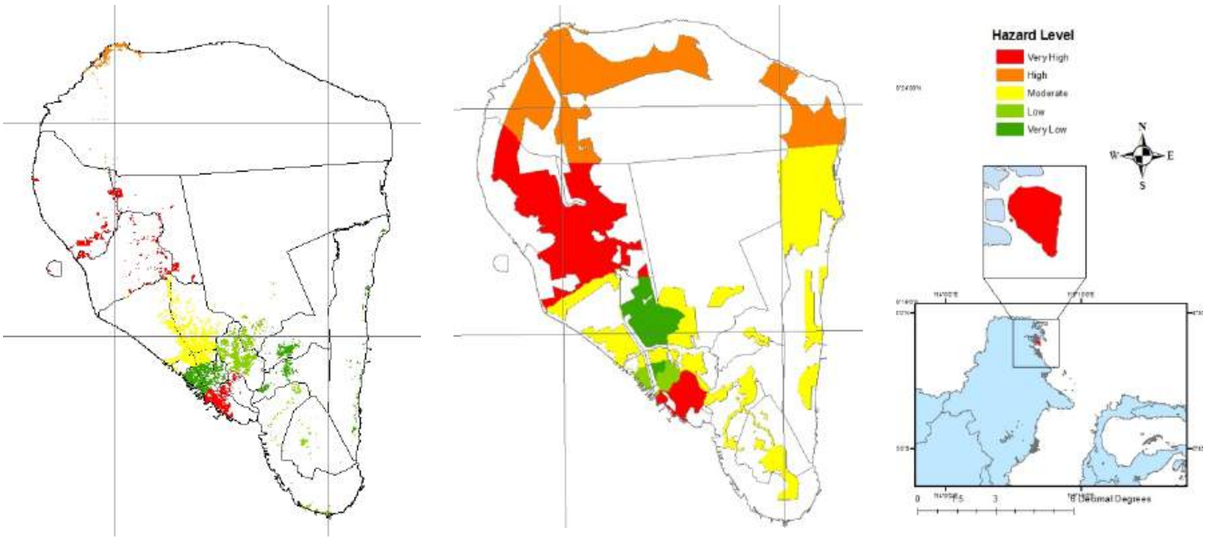
Note:

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

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

0 : same level

Comparison of Diarrhea hazard map in 2008 and 2030 is described in Figure 4-42 below.



Diarrhea Hazard Map 2008 Diarrhea Hazard Map 2030

Figure 4-42 Comparison between Diarrhea Hazard Map 2008 and 2030

CHAPTER 5 VULNERABILITY ASSESSMENT

This chapter discusses vulnerability assessment to climate change on health sector in 4 sub districts on Tarakan Island. Methodology of vulnerability assessment is described in Chapter 3.4.

5.1 DHF Vulnerability Analysis Existing

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 villages in Tarakan is also calculated and categorized; its result is shown in Table 5.1.

Table 5.1: Results of Existing Vulnerability Score to DHF in Tarakan

Sub District	Villages	Vp	Vpd	Vnp	Vhf	Vtotal	Levels
Tarakan Timur	Lingkas Ujung	0.08	0.12	0.06	0.02	0.25	High
	Gunung Lingkas	0.07	0.25	0.07	0.08	0.31	High
	Mamburungan	0.07	0.12	0.11	0.05	0.25	High
	Mamburungan Timur	0.02	0.12	0.12	0.03	0.23	Moderate
	Kampung Empat	0.04	0.06	0.08	0.02	0.15	Very Low
	Kampung Enam	0.05	0.06	0.10	0.02	0.20	Low
	Pantai Amal	0.05	0.12	0.12	0.07	0.22	Moderate
Tarakan Tengah	Selumit Pantai	0.09	0.25	0.08	0.02	0.40	Very High
	Selumit	0.05	0.25	0.07	0.05	0.32	Very High
	Sebengkok	0.09	0.25	0.06	0.03	0.36	Very High
	Pamusian	0.09	0.06	0.05	0.05	0.15	Very Low
	Kampung Satu Skip	0.05	0.06	0.05	0.09	0.07	Very Low
Tarakan Barat	Karang Rejo	0.04	0.25	0.02	0.04	0.26	High
	Karang Balik	0.04	0.06	0.04	0.04	0.10	Very Low
	Karang Anyar	0.14	0.06	0.05	0.02	0.23	Moderate
	Karang Anyar Pantai	0.11	0.12	0.04	0.07	0.20	Low
	Karang Harapan	0.05	0.12	0.07	0.03	0.21	Low
Tarakan Utara	Juata Permai	0.10	0.06	0.12	0.05	0.23	Moderate
	Juata Kerikil	0.07	0.06	0.11	0.04	0.20	Low
	Juata Laut	0.20	0.12	0.09	0.01	0.40	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 in Tarakan Island 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. Figure 5.1 indicates that population density vary across the region. The very high population density occurs in several villages, namely Gunung Lingkas, Selumit Pantai, Selumit, Sebengkok, and Karang Rejo.

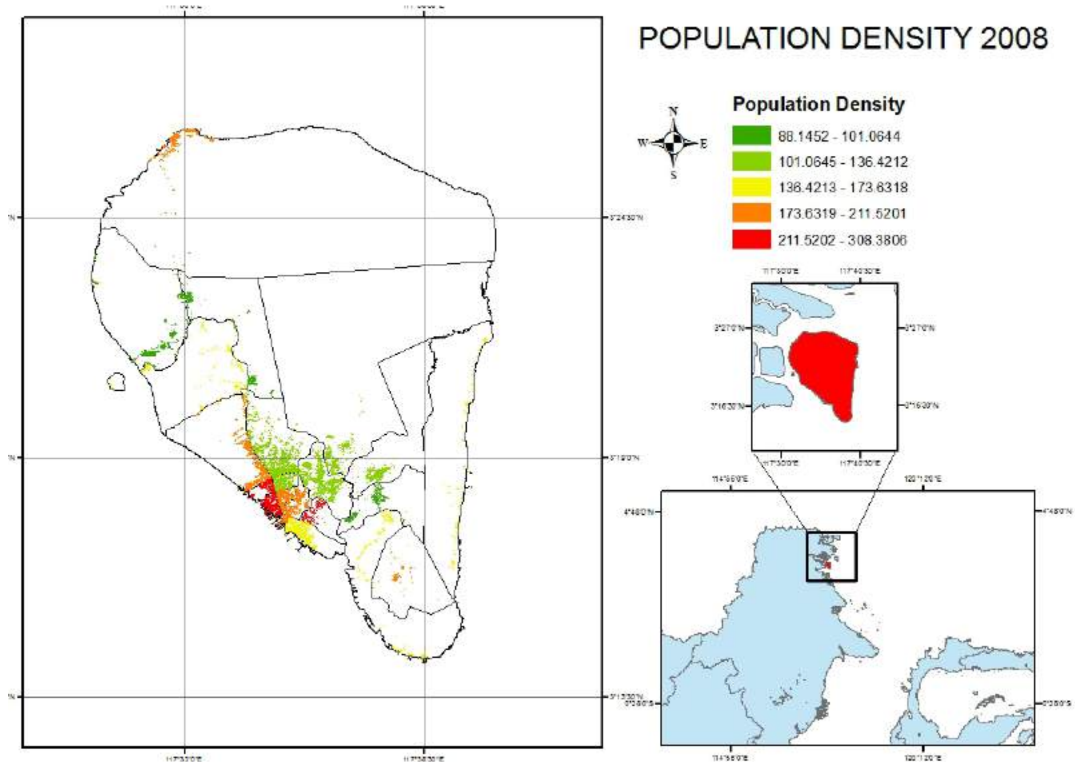


Figure 5-1 Existing Population Density in Tarakan for 2008 (peoples/Ha)

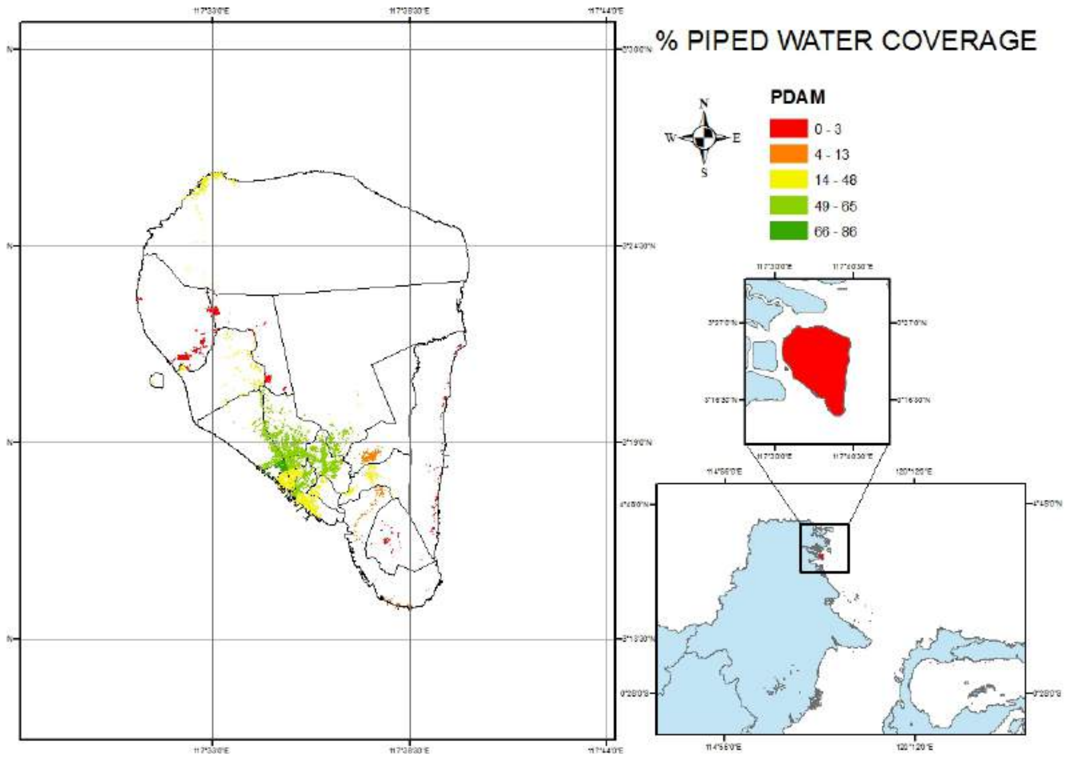


Figure 5-2 Percentage Existing Piped Water Coverage in Tarakan for 2008

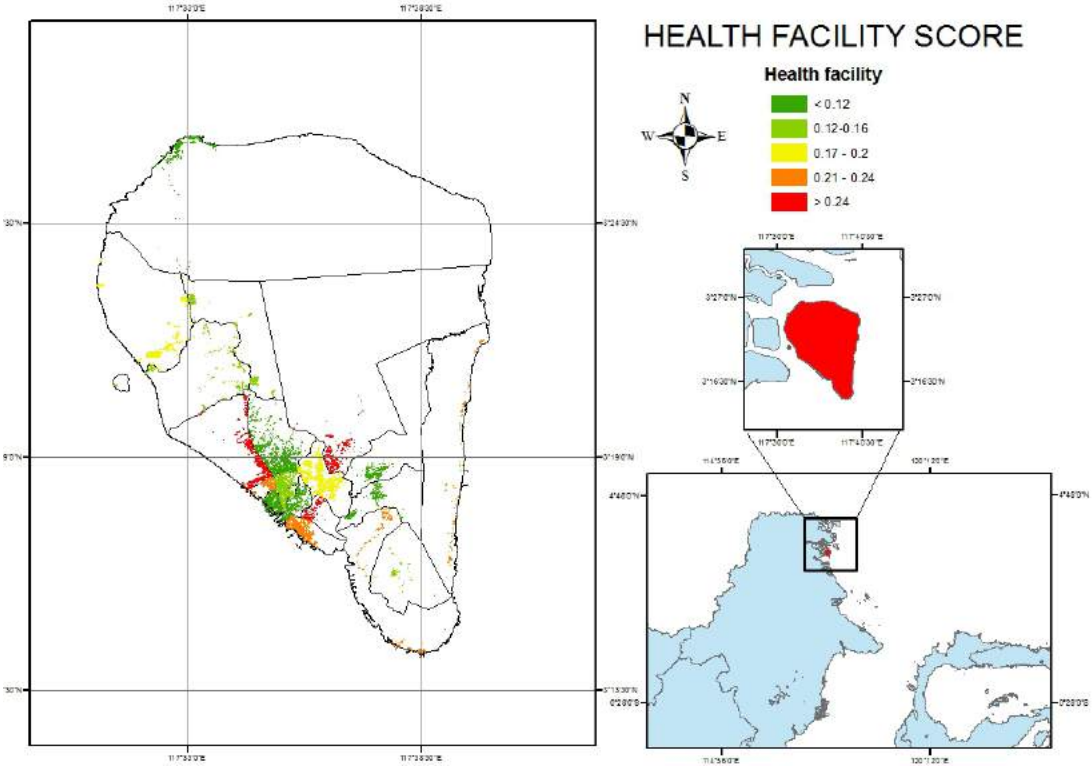


Figure 5-3 Existing Health Facility Score in Tarakan for 2008

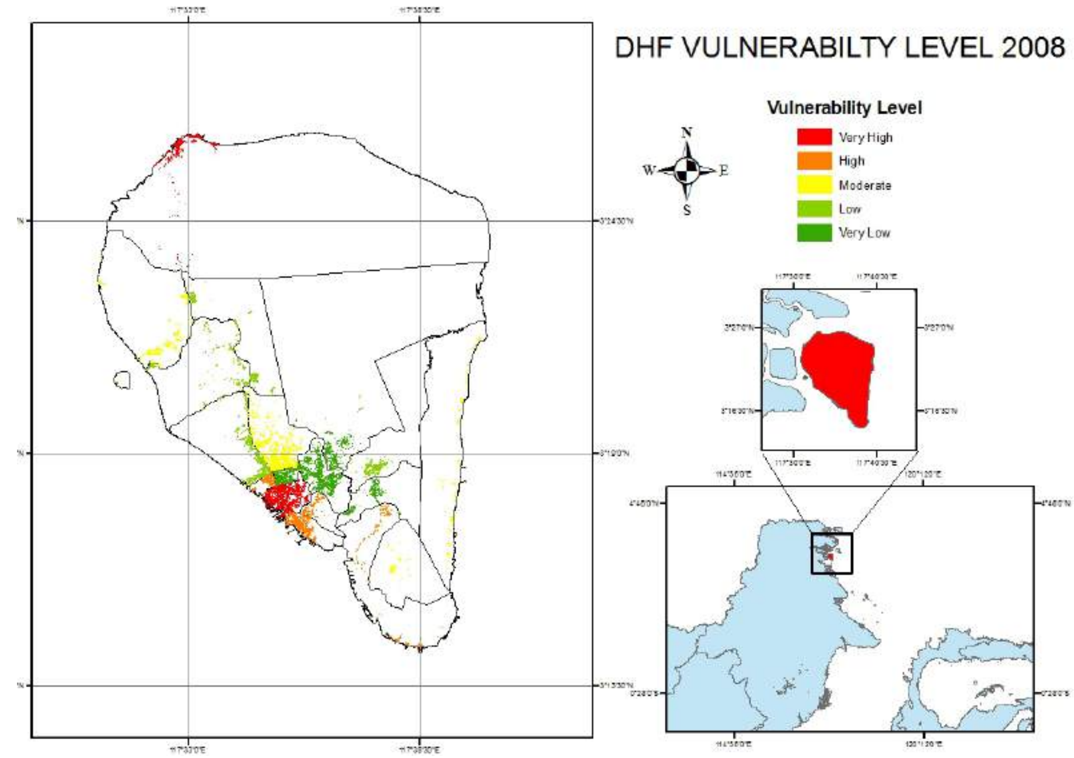


Figure 5-4 Existing Vulnerability Level to DHF in Tarakan for 2008

5.2 DHF Vulnerability Analysis Projection 2030

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

Table 5.2: Results of Vulnerability Score to DHF in Tarakan 2030

Sub Districts	Villages	Vp	Vpd	Vnp	Vhf	Vtotal	Levels
Tarakan Timur	Lingkas Ujung	0.09	0.2	0.05	0.01	0.39	Very High
	Gunung Lingkas	0.07	0.1	0.05	0.03	0.16	Very Low
	Mamburungan	0.07	0.1	0.05	0.02	0.17	Very Low
	Mamburungan Timur	0.04	0.1	0.08	0.01	0.18	Very Low
	Kampung Empat	0.05	0.1	0.06	0.01	0.17	Very Low
	Kampung Enam	0.04	0.1	0.04	0.01	0.13	Very Low
	Pantai Amal	0.02	0.1	0.00	0.05	0.03	Very Low
Tarakan Tengah	Selumit Pantai	0.10	0.3	0.05	0.01	0.43	Very High
	Selumit	0.04	0.2	0.05	0.07	0.27	High
	Sebengkok	0.09	0.2	0.05	0.01	0.38	Very High
	Pamusian	0.09	0.1	0.05	0.02	0.18	Very Low
	Kampung Satu Skip	0.05	0.1	0.05	0.03	0.14	Very Low
Tarakan Barat	Karang Rejo	0.04	0.3	0.05	0.02	0.36	Very High
	Karang Balik	0.04	0.2	0.05	0.01	0.33	Very High
	Karang Anyar	0.10	0.1	0.02	0.01	0.17	Very Low
	Karang Anyar Pantai	0.15	0.1	0.08	0.02	0.27	High
	Karang Harapan	0.04	0.1	0.05	0.06	0.10	Very Low
Tarakan Utara	Juata Permai	0.12	0.1	0.05	0.02	0.22	Moderate
	Juata Kerikil	0.08	0.1	0.05	0.09	0.10	Very Low
	Juata Laut	0.18	0.1	0.05	0.01	0.29	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 in Tarakan Island 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.

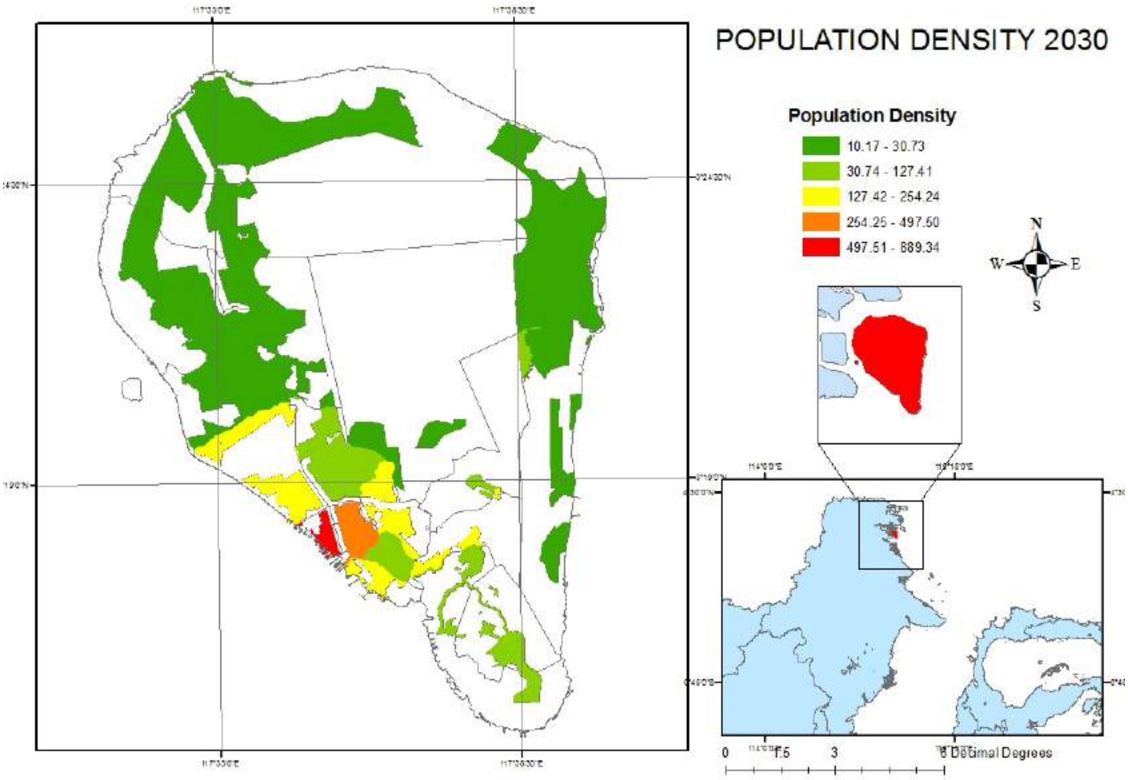


Figure 5-5 Projection of Population Density (people/Ha) in Tarakan for 2030

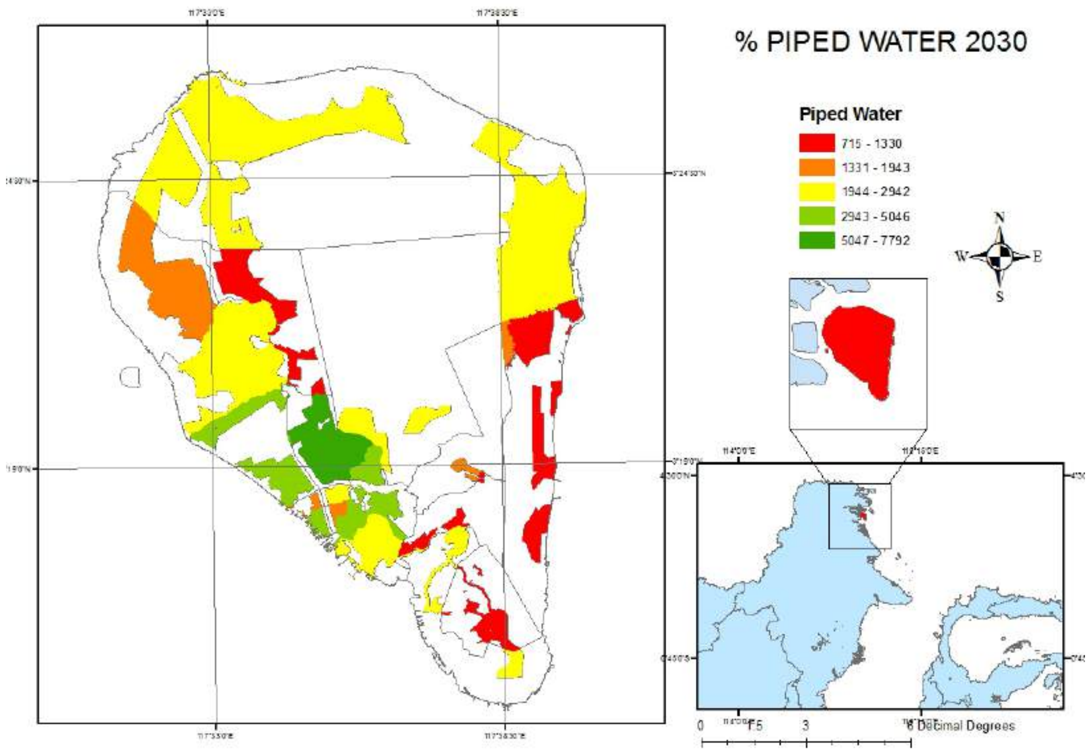


Figure 5-6 Projection of Percentage Piped Water Coverage in Tarakan for 2030

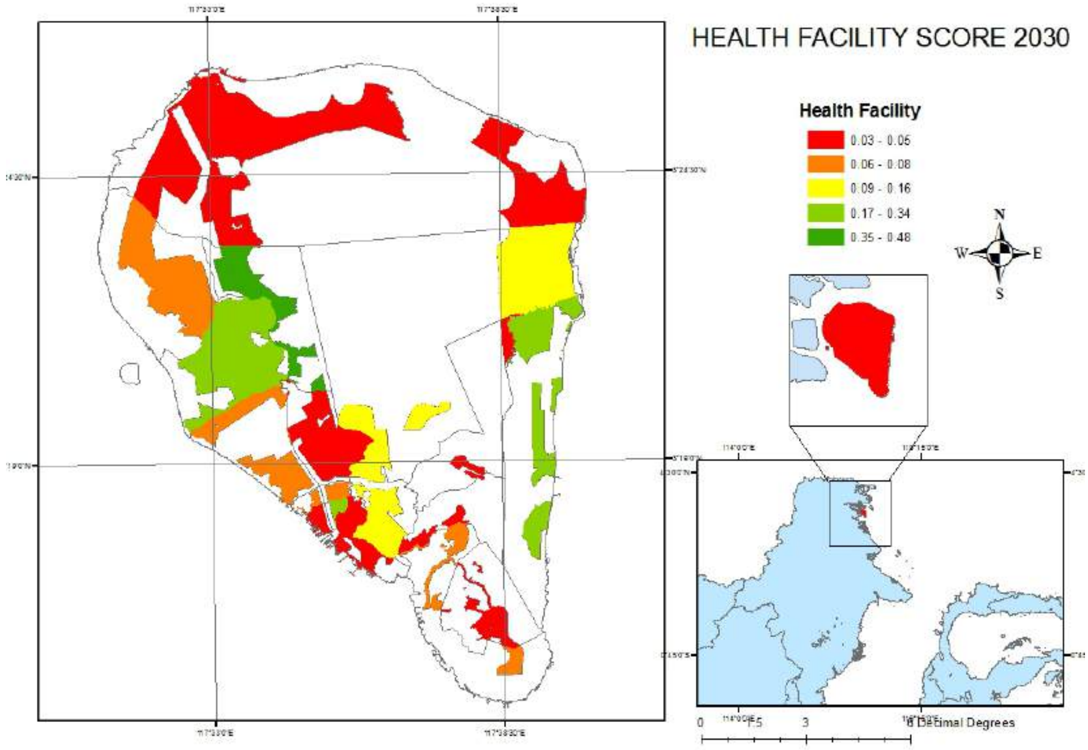


Figure 5-7 Projection of Health Facility Score in Tarakan for 2030

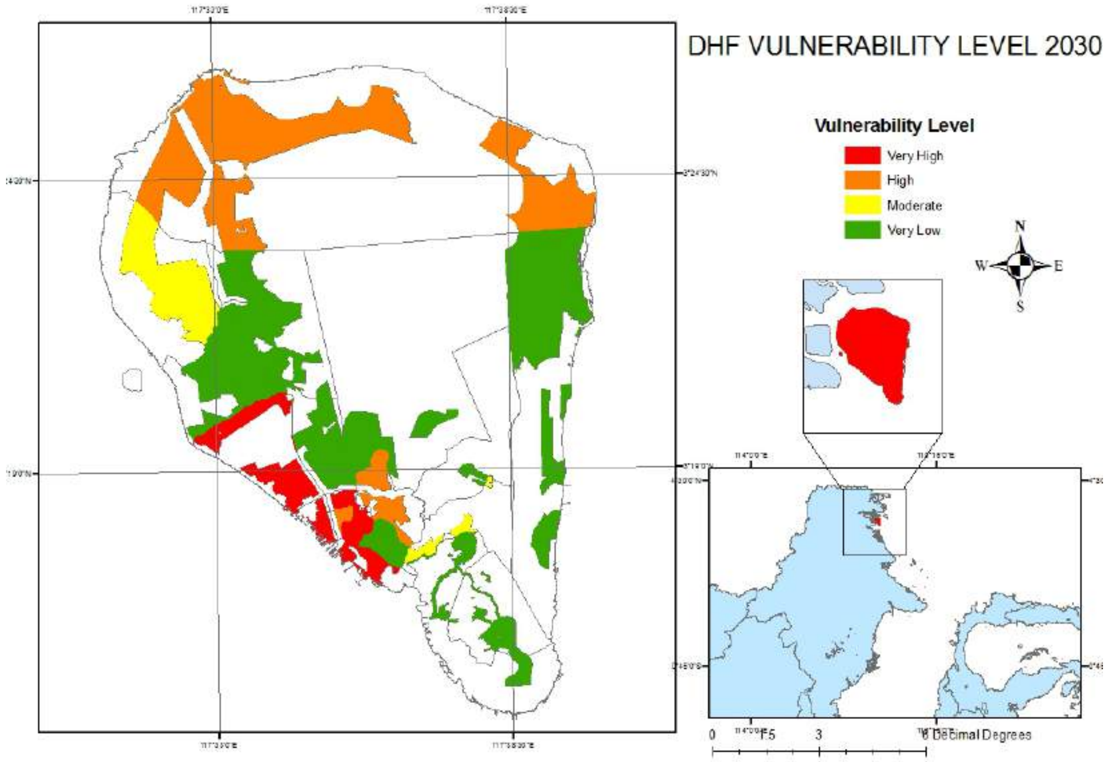


Figure 5-8 Projection Vulnerability Level to DHF in Tarakan for 2030

5.3 Comparison of DHF Vulnerability Levels in 2008 and 2030

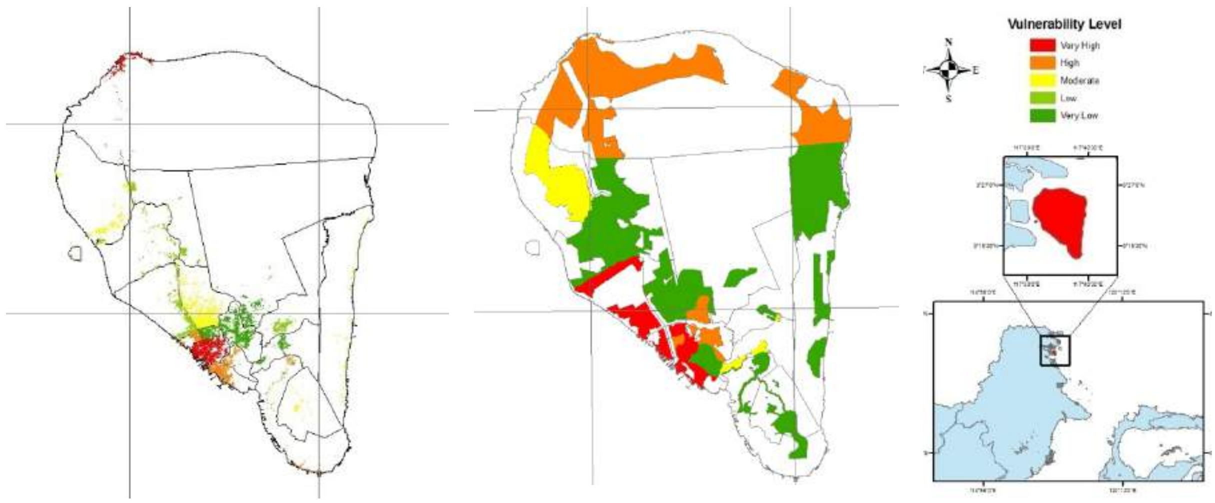
Comparison of DHF vulnerability in Tarakan in 2008 and 2030 is described in Table 5-3 below.

Table 5.3: Results of Existing Vulnerability Score to DHF in Tarakan

Sub District	Villages	Levels 2008	Levels 2030	Comparison
Tarakan Timur	Lingkas Ujung	High	Very High	+1
	Gunung Lingkas	High	Very Low	-3
	Mamburungan	High	Very Low	-3
	Mamburungan Timur	Moderate	Very Low	-2
	Kampung Empat	Very Low	Very Low	0
	Kampung Enam	Low	Very Low	-1
	Pantai Amal	Moderate	Very Low	-2
Tarakan Tengah	Selumit Pantai	Very High	Very High	0
	Selumit	Very High	High	-1
	Sebengkok	Very High	Very High	0
	Pamusian	Very Low	Very Low	0
	Kampung Satu Skip	Very Low	Very Low	0
Tarakan Barat	Karang Rejo	High	Very High	+2
	Karang Balik	Very Low	Very High	+4
	Karang Anyar	Moderate	Very Low	-2
	Karang Anyar Pantai	Low	High	+2
	Karang Harapan	Low	Very Low	-1
Tarakan Utara	Juata Permai	Moderate	Moderate	0
	Juata Kerikil	Low	Very Low	-1
	Juata Laut	Very High	High	-1

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 DHF vulnerability map in 2008 and 2030 is described in Figure 5-9 below.



Vulnerability 2008 Vulnerability 2030

Figure 5-9 Comparison between DHF Vulnerability Map 2008 and 2030

5.4 Malaria Vulnerability Analysis Existing

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

Table 5.4: Results of Existing Vulnerability Score to Malaria in Tarakan in 2008

Sub District	Villages	Vpb	Vhb	Vnp	Vhf	Vtotal	Levels
Tarakan Timur	Lingkas Ujung	0.47	0.28	0.11	0.01	0.84	Very High
	Gunung Lingkas	0.30	0.17	0.06	0.05	0.49	Moderate
	Mamburungan	0.34	0.20	0.11	0.03	0.63	High
	Mamburungan Timur	0.06	0.03	0.13	0.02	0.20	Low
	Kampung Empat	0.16	0.10	0.04	0.01	0.28	Low
	Kampung Enam	0.15	0.09	0.05	0.01	0.28	Low
	Pantai Amal	0.35	0.21	0.13	0.04	0.65	High
Tarakan Tengah	Selumit Pantai	0.47	0.28	0.13	0.01	0.86	Very High
	Selumit	0.47	0.28	0.07	0.03	0.79	Very High
	Sebengkok	0.37	0.22	0.07	0.02	0.64	High
	Pamusian	0.09	0.05	0.05	0.03	0.15	Very Low
	Kampung Satu Skip	0.10	0.06	0.04	0.05	0.15	Very Low
Tarakan Barat	Karang Rejo	0.47	0.28	0.10	0.02	0.82	Very High
	Karang Balik	0.13	0.07	0.06	0.02	0.24	Low
	Karang Anyar	0.07	0.04	0.05	0.01	0.15	Very Low
	Karang Anyar Pantai	0.40	0.23	0.10	0.04	0.70	High
	Karang Harapan	0.18	0.10	0.08	0.02	0.34	Moderate
Tarakan Utara	Juata Permai	0.10	0.06	0.03	0.03	0.16	Very Low
	Juata Kerikil	0.17	0.10	0.04	0.02	0.28	Moderate
	Juata Laut	0.32	0.19	0.11	0.01	0.61	Moderate

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 5.10-5.14 show malaria vulnerability score for each variable in Tarakan Island for 2008 in GIS format. Figure 5.10 shows population near breeding site, Figure 5.11 shows amount of house near breeding site, Figure 5.12 shows percentage non permanent housing, Figure 5.13 shows coverage of health facility, and Figure 5.14 shows total vulnerability level of malaria.

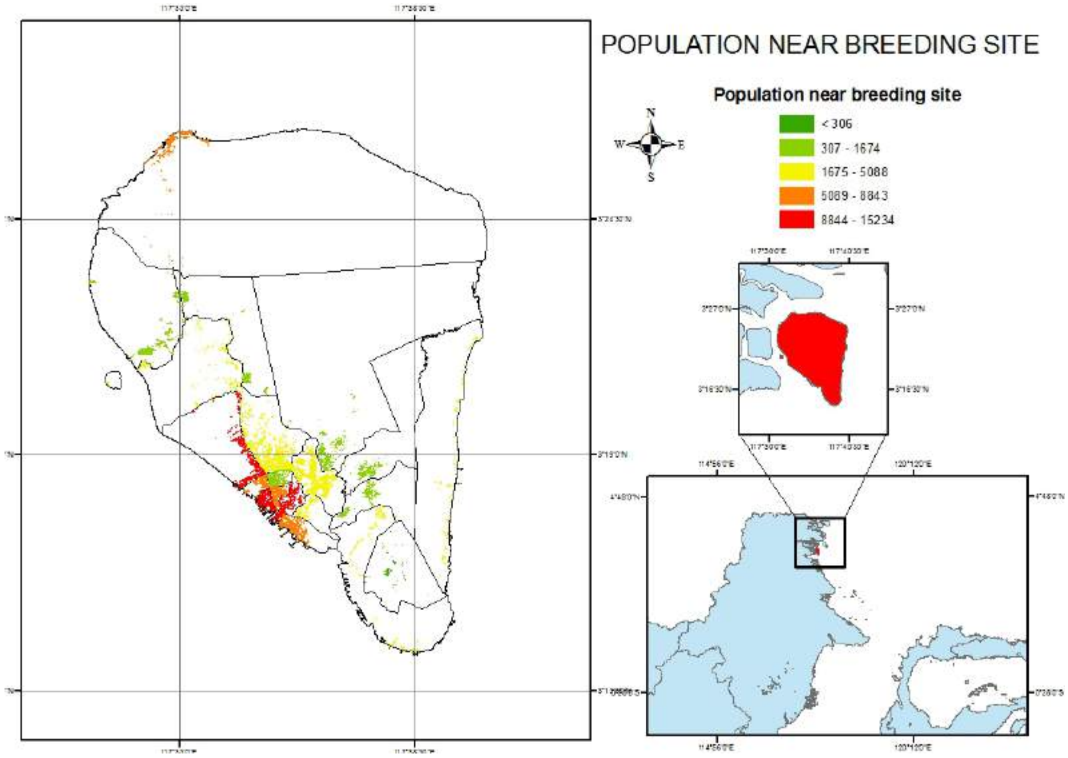


Figure 5-10 Existing Population Near Breeding Site in Tarakan for 2008

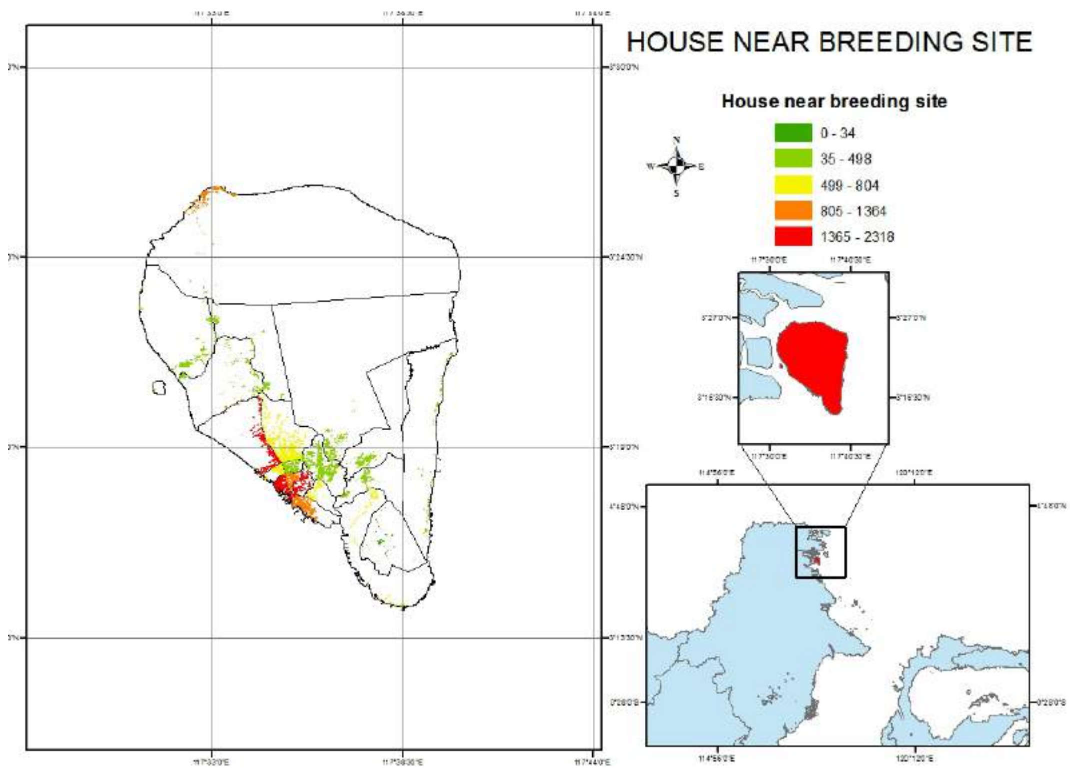


Figure 5-11 Existing House Near Breeding Site in Tarakan for 2008

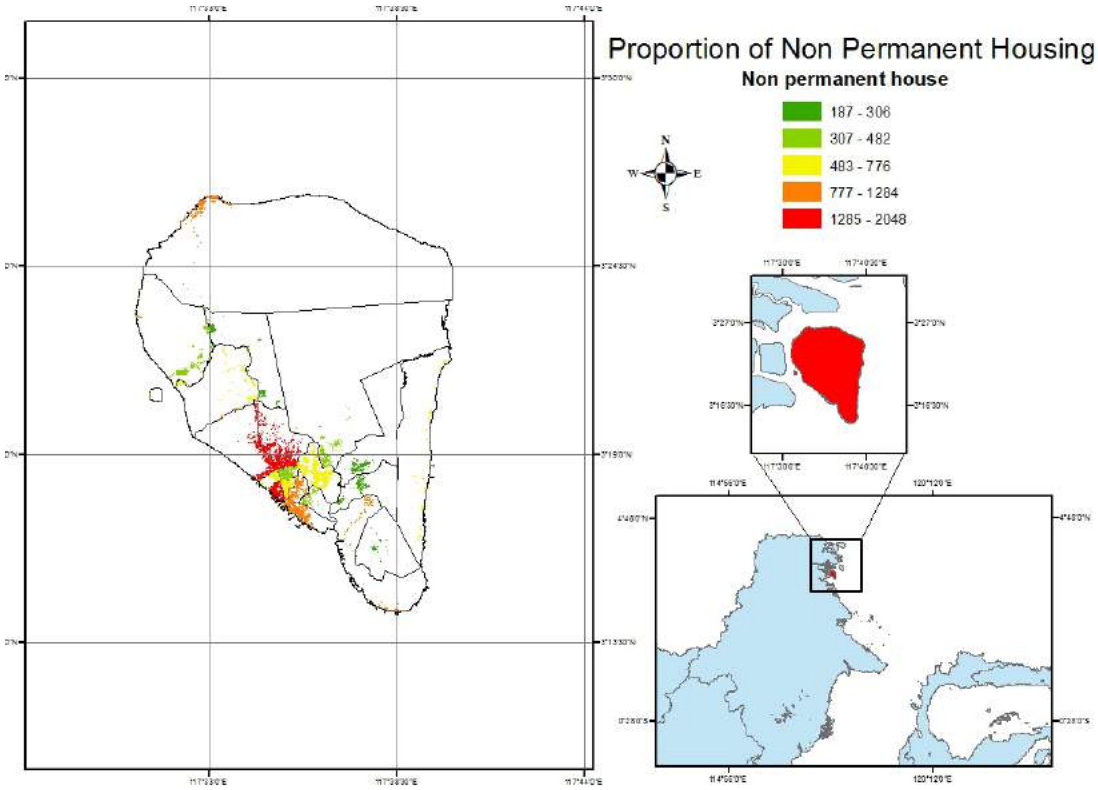


Figure 5-12 Existing Non Permanent Housing in Tarakan for 2008

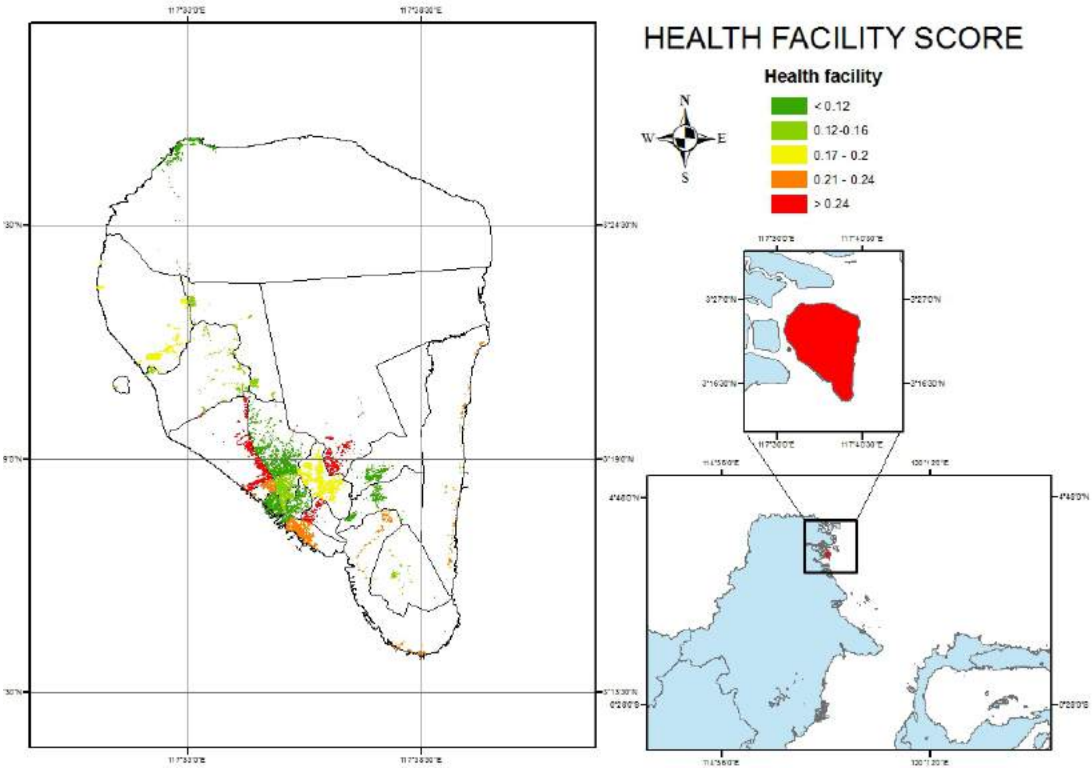


Figure 5-13 Existing Health Facility Score in Tarakan for 2008

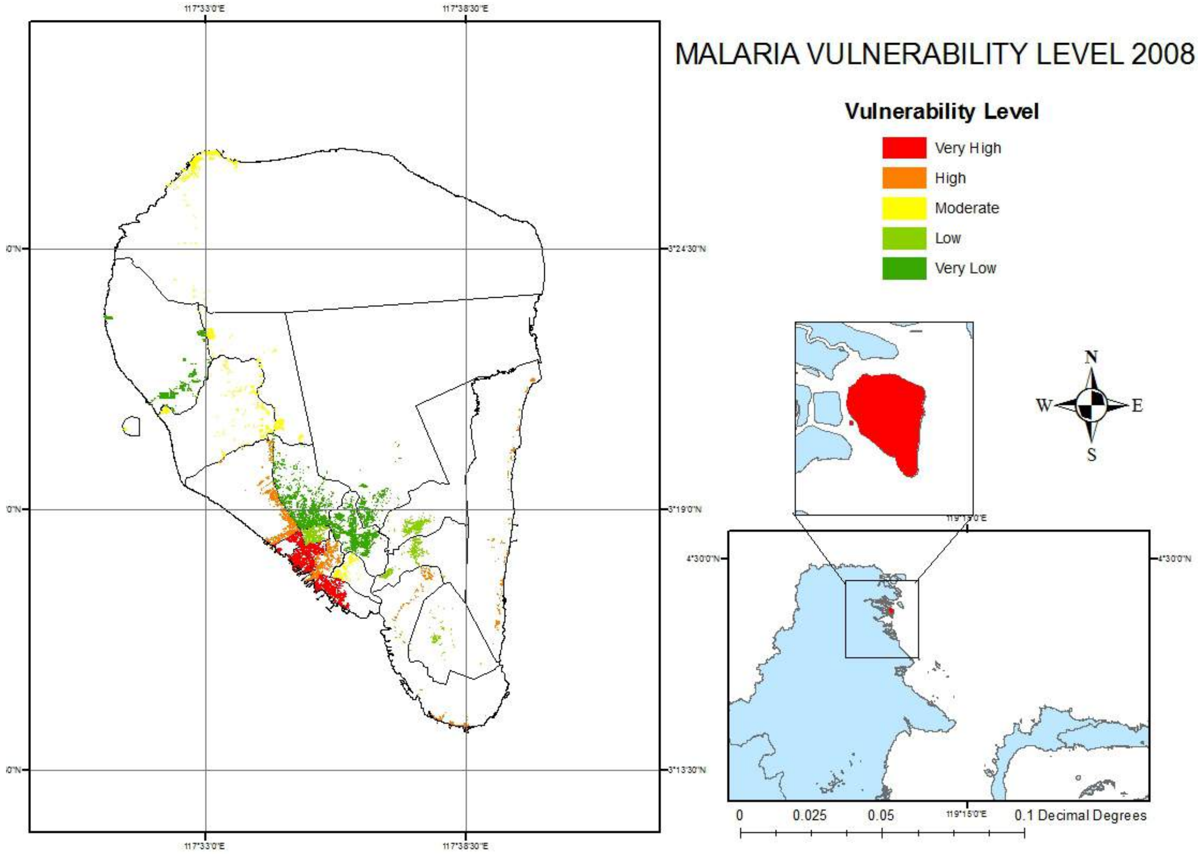


Figure 5-14 Existing Vulnerability Level to Malaria in Tarakan for 2008

5.5 Malaria Vulnerability Analysis Projection 2030

Malaria vulnerability score for 2030 is calculated and its result is shown in Table 5.5.

Table 5.5: Results of Vulnerability Score to Malaria in Tarakan 2030

Villages	Vpb	Vhb	Vnp	Vhf	Vtotal	Levels
Tarakan Timur						
Lingkas Ujung	0.00	0.00	0.05	0.00	0.05	Very Low
Gunung Lingkas	0.04	0.03	0.03	0.02	0.08	Very Low
Mamburungan	0.02	0.01	0.06	0.01	0.08	Very Low
Mamburungan Timur	0.04	0.02	0.03	0.00	0.09	Very Low
Kampung Empat	0.12	0.07	0.02	0.00	0.21	Low
Kampung Enam	0.25	0.14	0.03	0.00	0.42	Moderate
Pantai Amal	0.22	0.13	0.12	0.03	0.44	Moderate
Tarakan Tengah						
Selumit Pantai	0.28	0.16	0.06	0.00	0.50	Moderate
Selumit	0.15	0.09	0.04	0.04	0.24	Low
Sebengkok	0.20	0.12	0.04	0.01	0.35	Moderate
Pamusian	0.30	0.17	0.03	0.01	0.48	Moderate
Kampung Satu Skip	0.11	0.06	0.02	0.02	0.18	Very Low
Tarakan Barat						
Karang Rejo	0.47	0.28	0.04	0.01	0.78	Very High
Karang Balik	0.47	0.27	0.03	0.01	0.77	Very High

Villages	Vpb	Vhb	Vnp	Vhf	Vtotal	Levels
Karang Anyar	0.16	0.09	0.04	0.01	0.29	Moderate
Karang Anyar Pantai	0.23	0.13	0.03	0.01	0.38	Moderate
Karang Harapan	0.10	0.06	0.04	0.03	0.17	Very Low
Tarakan Utara						
Juata Permai	0.14	0.08	0.03	0.01	0.24	Low
Juata Kerikil	0.24	0.14	0.02	0.05	0.34	Moderate
Juata Laut	0.06	0.04	0.06	0.00	0.16	Very Low

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 5.15-5.19 show malaria vulnerability score for each variable in Tarakan Island for 2030 in GIS format. Figure 5.15 shows population near breeding site, Figure 5.16 shows amount of house near breeding site, Figure 5.17 shows percentage non permanent housing, Figure 5.18 shows coverage of health facility, and Figure 5.19 shows total vulnerability level of malaria.

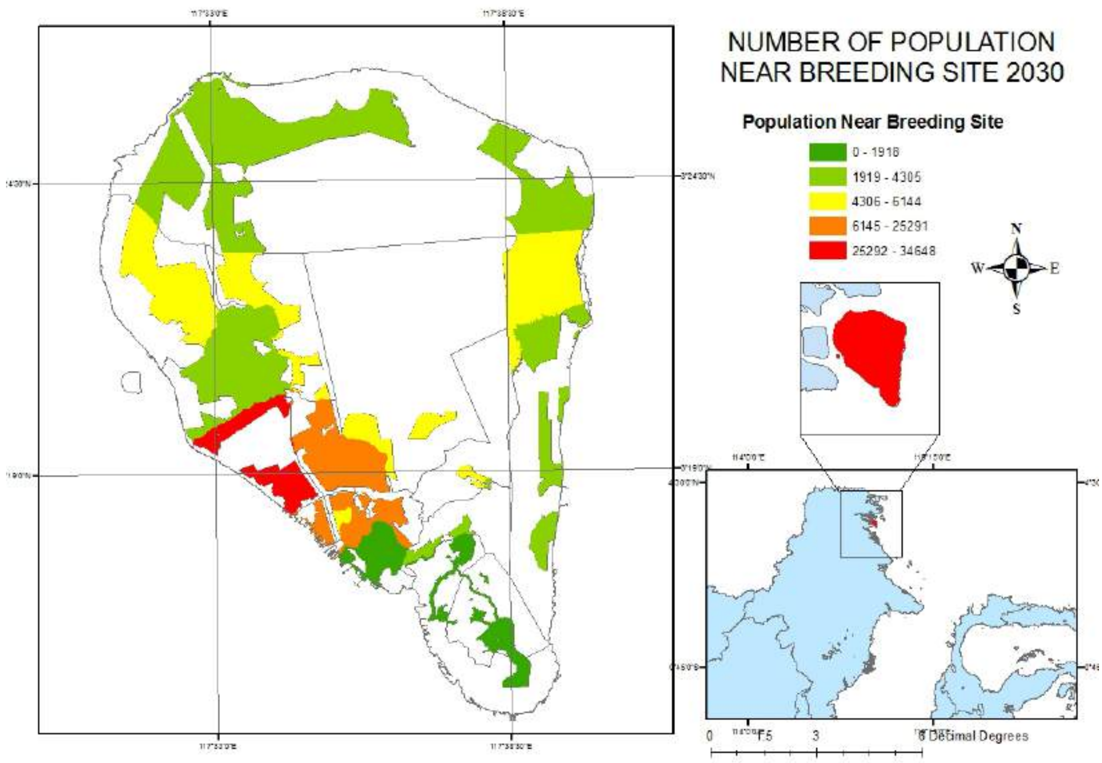


Figure 5-15 Projection of Population Near Breeding Site in Tarakan for 2030

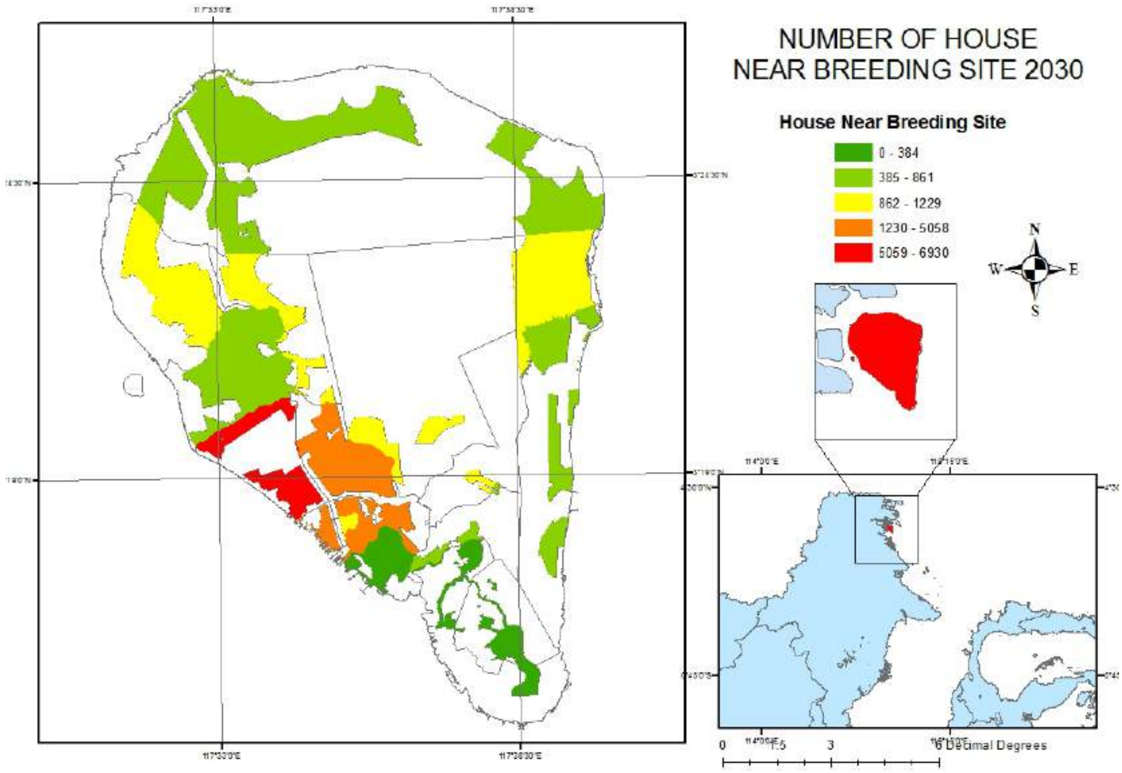


Figure 5-16 Projection of House Near Breeding Site in Tarakan for 2030

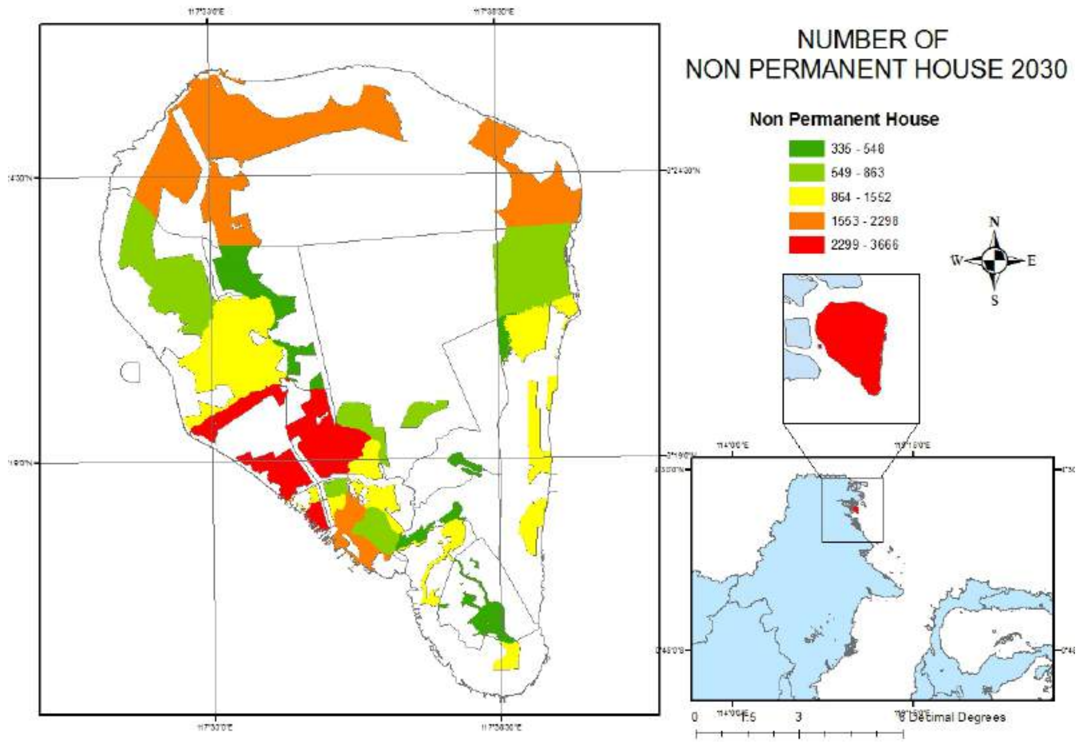


Figure 5-17 Projection of Non Permanent Housing in Tarakan for 2030

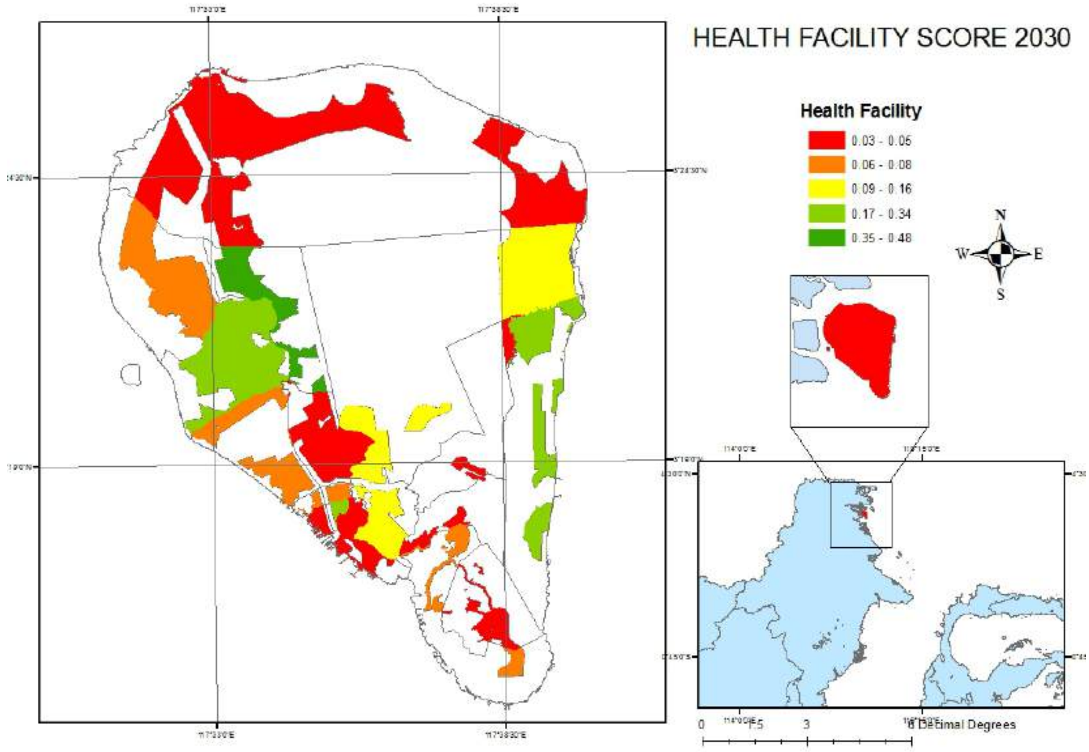


Figure 5-18 Projection of Health Facility Score in Tarakan for 2030

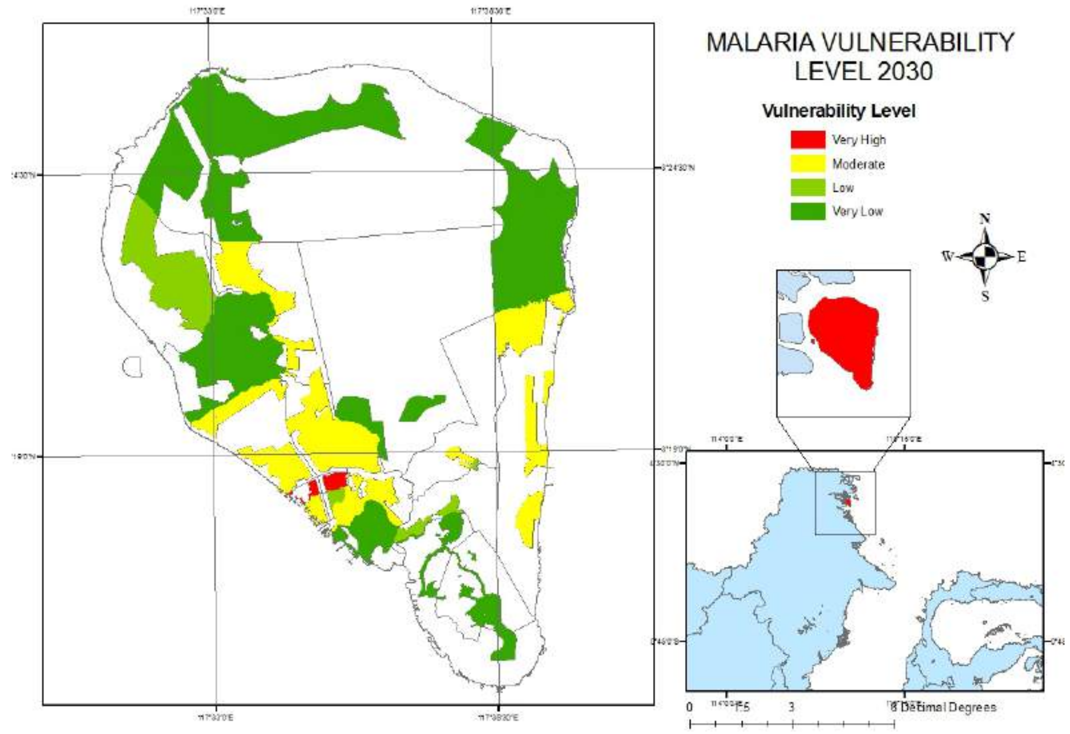


Figure 5-19 Projection of Malaria Vulnerability Level in Tarakan for 2030

5.6 Comparison of Malaria Vulnerability Levels in 2008 and 2030

Comparison of Malaria vulnerability in Tarakan in 2008 and 2030 is described in Table 5-6 below.

Table 5.6: Results of Existing Vulnerability Score to Malaria in Tarakan

Sub District	Villages	Levels 2008	Levels 2030	Comparison
Tarakan Timur	Lingkas Ujung	Very High	Very Low	-4
	Gunung Lingkas	Moderate	Very Low	-2
	Mamburungan	High	Very Low	-3
	Mamburungan Timur	Low	Very Low	-1
	Kampung Empat	Low	Low	0
	Kampung Enam	Low	Moderate	+1
	Pantai Amal	High	Moderate	-1
Tarakan Tengah	Selumit Pantai	Very High	Very High	0
	Selumit	Very High	Very High	0
	Sebengkok	High	Moderate	-1
	Pamusian	Very Low	Moderate	+2
	Kampung Satu Skip	Very Low	Very Low	0
Tarakan Barat	Karang Rejo	Very High	Very High	0
	Karang Balik	Low	Very High	+3
	Karang Anyar	Very Low	Moderate	+2
	Karang Anyar Pantai	High	Moderate	-1
	Karang Harapan	Moderate	Very Low	-2
Tarakan Utara	Juata Permai	Very Low	Low	+1
	Juata Kerikil	Low	Moderate	+1
	Juata Laut	Very High	Very Low	-4

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 2008 and 2030 is described in Figure 5-20 below.

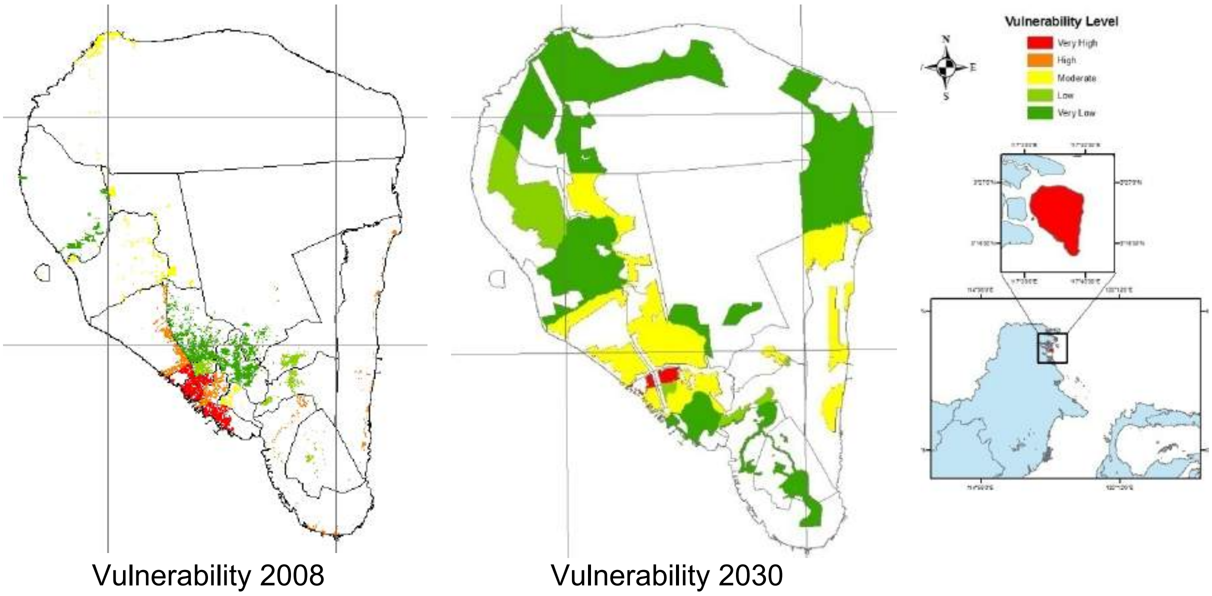


Figure 5-20 Comparison between Malaria Vulnerability Map 2008 and 2030

5.7 Diarrhea Vulnerability Analysis Existing

Vulnerability score of diarrhea in 2008 is calculated and its result is shown in Table 5.7.

Table 5.7: Results of Existing Vulnerability Score to Diarrhea in Tarakan

Villages	Vp	Vht	Vpw	Vhf	Vtotal	Levels
Tarakan Timur						
Lingkas Ujung	0.06	0.19	0.11	0.03	0.33	High
Gunung Lingkas	0.05	0.10	0.13	0.11	0.18	Very Low
Mamburungan	0.05	0.19	0.20	0.06	0.38	High
Mamburungan Timur	0.02	0.23	0.22	0.04	0.42	Very High
Kampung Empat	0.03	0.06	0.14	0.03	0.20	Low
Kampung Enam	0.04	0.08	0.19	0.02	0.29	High
Pantai Amal	0.03	0.22	0.22	0.10	0.38	Very High
Tarakan Tengah						
Selumit Pantai	0.07	0.22	0.14	0.02	0.41	Very High
Selumit	0.04	0.12	0.12	0.06	0.21	Low
Sebengkok	0.07	0.12	0.10	0.04	0.25	Moderate
Pamusian	0.07	0.08	0.09	0.07	0.17	Very Low
Kampung Satu Skip	0.04	0.07	0.09	0.12	0.09	Very Low
Tarakan Barat						
Karang Rejo	0.03	0.18	0.03	0.06	0.18	Low
Karang Balik	0.03	0.10	0.08	0.06	0.15	Very Low
Karang Anyar	0.11	0.08	0.09	0.03	0.25	Moderate
Karang Anyar Pantai	0.08	0.18	0.08	0.09	0.24	Low
Karang Harapan	0.03	0.13	0.13	0.04	0.26	Moderate
Tarakan Utara						
Juata Permai	0.08	0.05	0.22	0.07	0.28	Moderate

Villages	Vp	Vht	Vpw	Vhf	Vtotal	Levels
Juata Kerikil	0.05	0.07	0.21	0.05	0.28	High
Juata Laut	0.15	0.19	0.16	0.02	0.48	Very 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 5.21-5.24 show diarrhea vulnerability score for each variable in Tarakan Island for 2008 in GIS format. Figure 5.21 shows proportion of houses without toilet, Figure 5.22 shows coverage of piped water, Figure 5.23 shows coverage of health facility, and Figure 5.24 shows total vulnerability level of diarrhea in 2008.

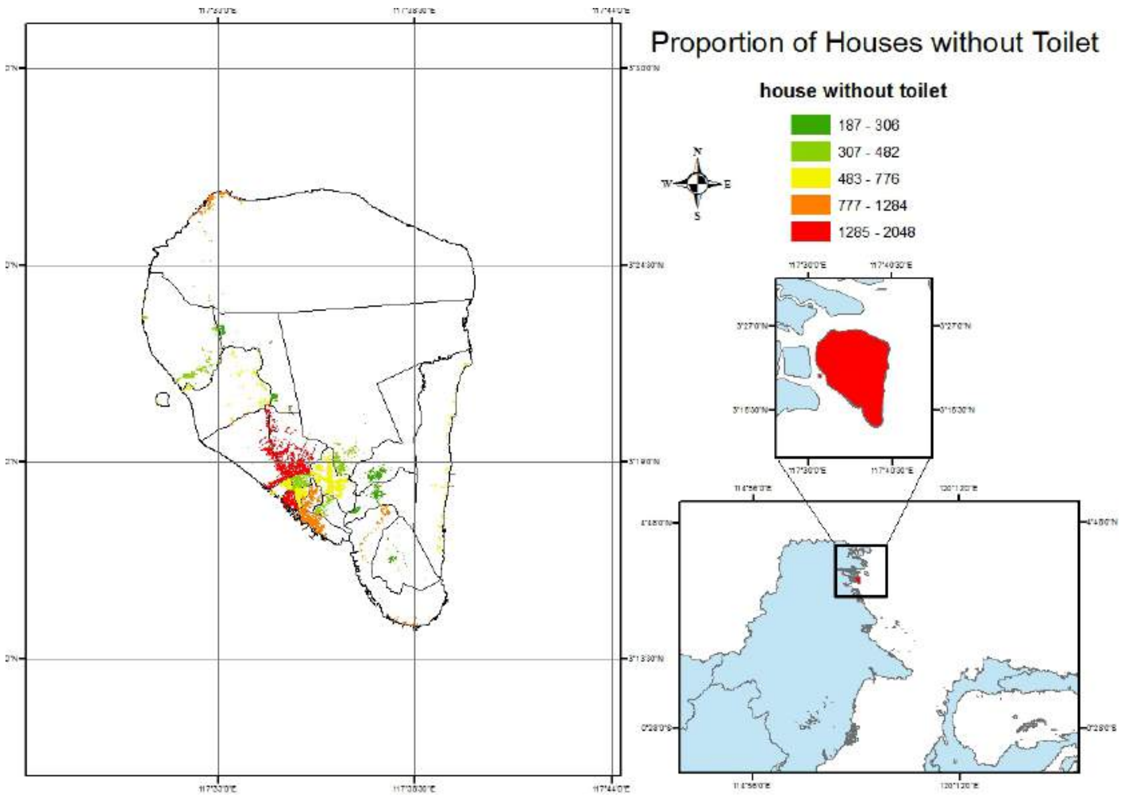


Figure 5-21 Existing Houses without Toilet in Tarakan for 2008

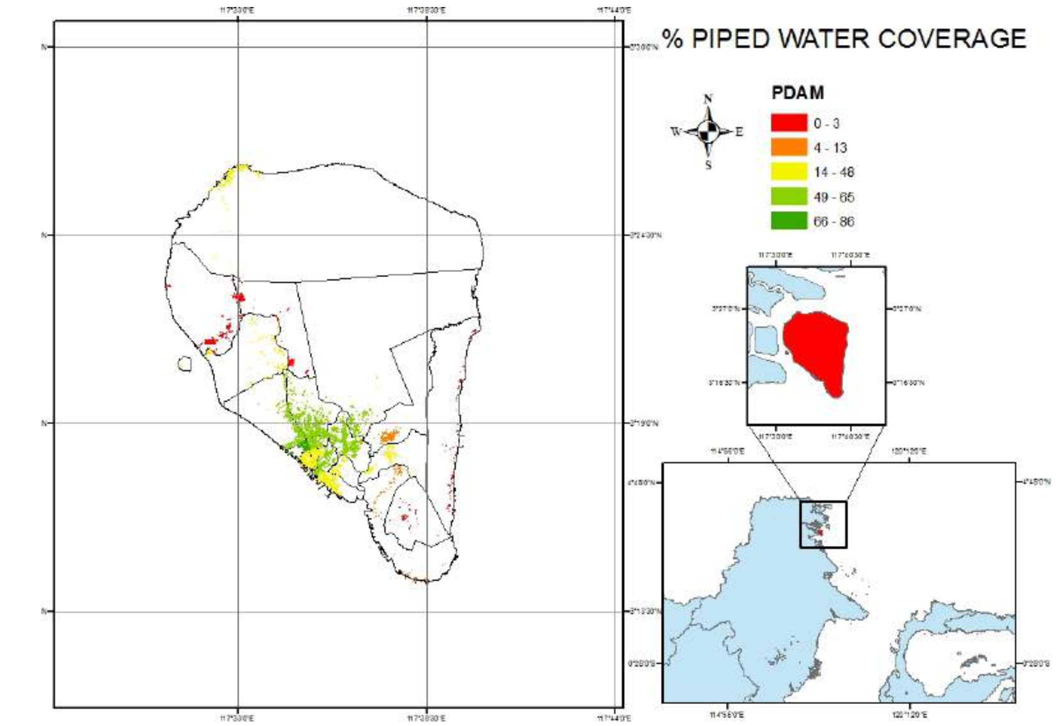


Figure 5-22 Existing Piped Water Coverage in Tarakan for 2008

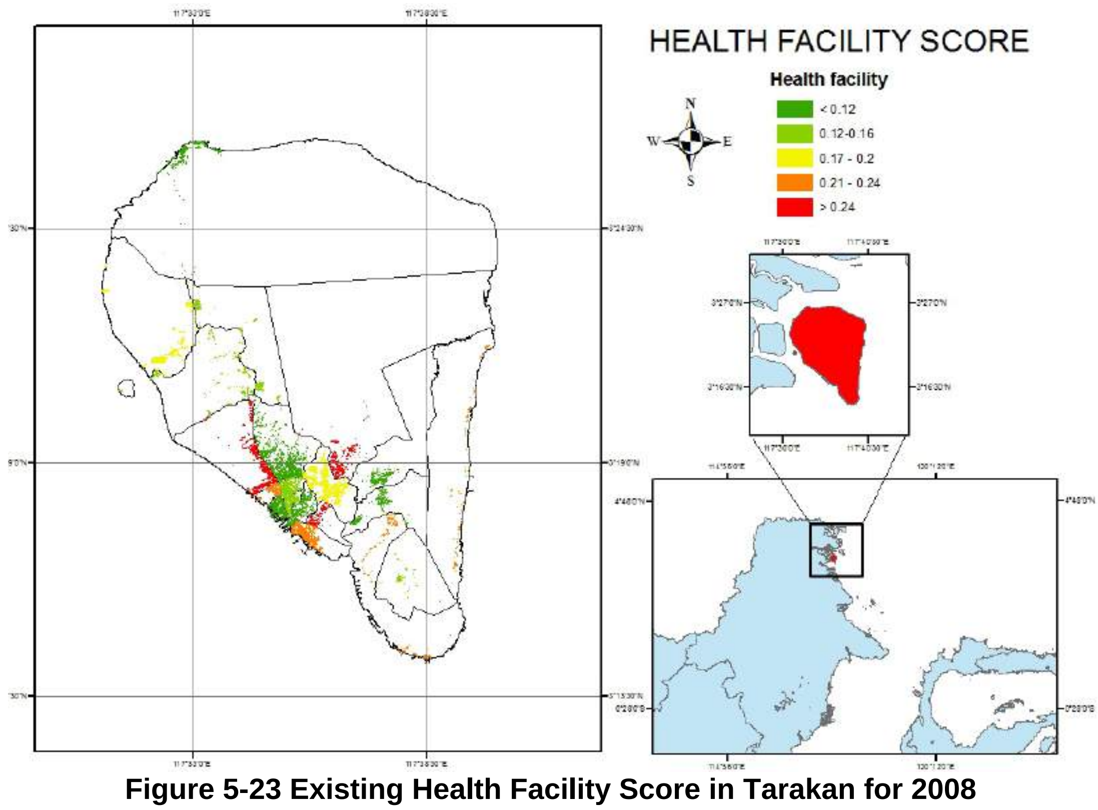


Figure 5-23 Existing Health Facility Score in Tarakan for 2008

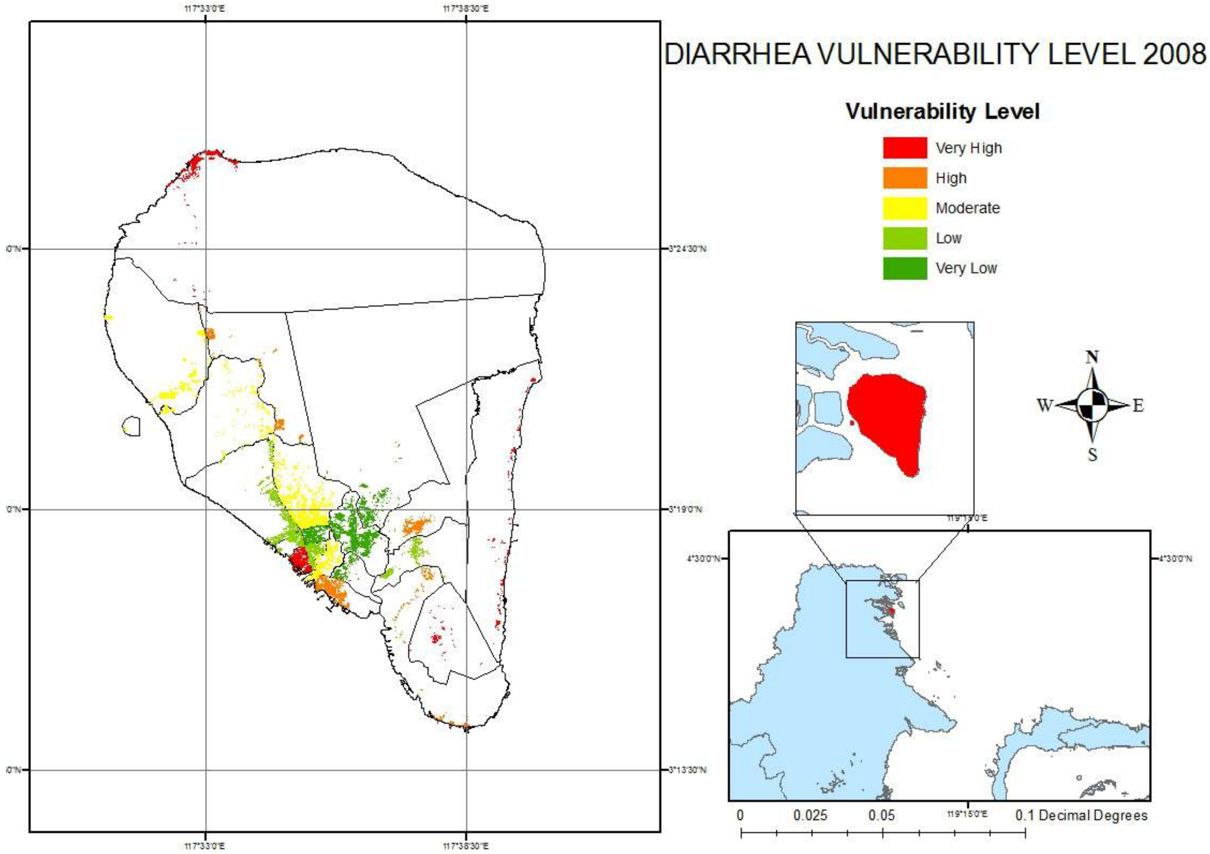


Figure 5-24 Existing Vulnerability Level to Diarrhea in Tarakan for 2008

5.8 Diarrhea Vulnerability Analysis Projection 2030

Vulnerability score of projected diarrhea 2030 is calculated and its result is shown in Table 5.8.

Table 5.8: Results of Vulnerability Score to Diarrhea in Tarakan 2030

Villages	Vp	Vht	Vpw	Vhf	Vtotal	Levels
Tarakan Timur						
Lingkas Ujung	0.00	0.00	0.05	0.00	0.05	Very Low
Gunung Lingkas	0.04	0.03	0.03	0.02	0.08	Very Low
Mamburungan	0.02	0.01	0.06	0.01	0.08	Very Low
Mamburungan Timur	0.04	0.02	0.03	0.00	0.09	Very Low
Kampung Empat	0.12	0.07	0.02	0.00	0.21	Low
Kampung Enam	0.25	0.14	0.03	0.00	0.42	Moderate
Pantai Amal	0.22	0.13	0.12	0.03	0.44	Moderate
Tarakan Tengah						
Selumit Pantai	0.28	0.16	0.06	0.00	0.50	Moderate
Selumit	0.15	0.09	0.04	0.04	0.24	Low
Sebengkok	0.20	0.12	0.04	0.01	0.35	Moderate
Pamusian	0.30	0.17	0.03	0.01	0.48	Moderate
Kampung Satu Skip	0.11	0.06	0.02	0.02	0.18	Very Low
Tarakan Barat						
Karang Rejo	0.47	0.28	0.04	0.01	0.78	Very High

Villages	Vp	Vht	Vpw	Vhf	Vtotal	Levels
Karang Balik	0.47	0.27	0.03	0.01	0.77	Very High
Karang Anyar	0.16	0.09	0.04	0.01	0.29	Moderate
Karang Anyar Pantai	0.23	0.13	0.03	0.01	0.38	Moderate
Karang Harapan	0.10	0.06	0.04	0.03	0.17	Very Low
Tarakan Utara						
Juata Permai	0.14	0.08	0.03	0.01	0.24	Low
Juata Kerikil	0.24	0.14	0.02	0.05	0.34	Moderate
Juata Laut	0.06	0.04	0.06	0.00	0.16	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 5.25-5.28 show diarrhea vulnerability score for each variable in Tarakan Island for 2030 in GIS format. Figure 5.25 shows proportion of houses without toilet, Figure 5.26 shows coverage of piped water, Figure 5.27 shows coverage of health facility, and Figure 5.28 shows total vulnerability level of diarrhea in 2030.

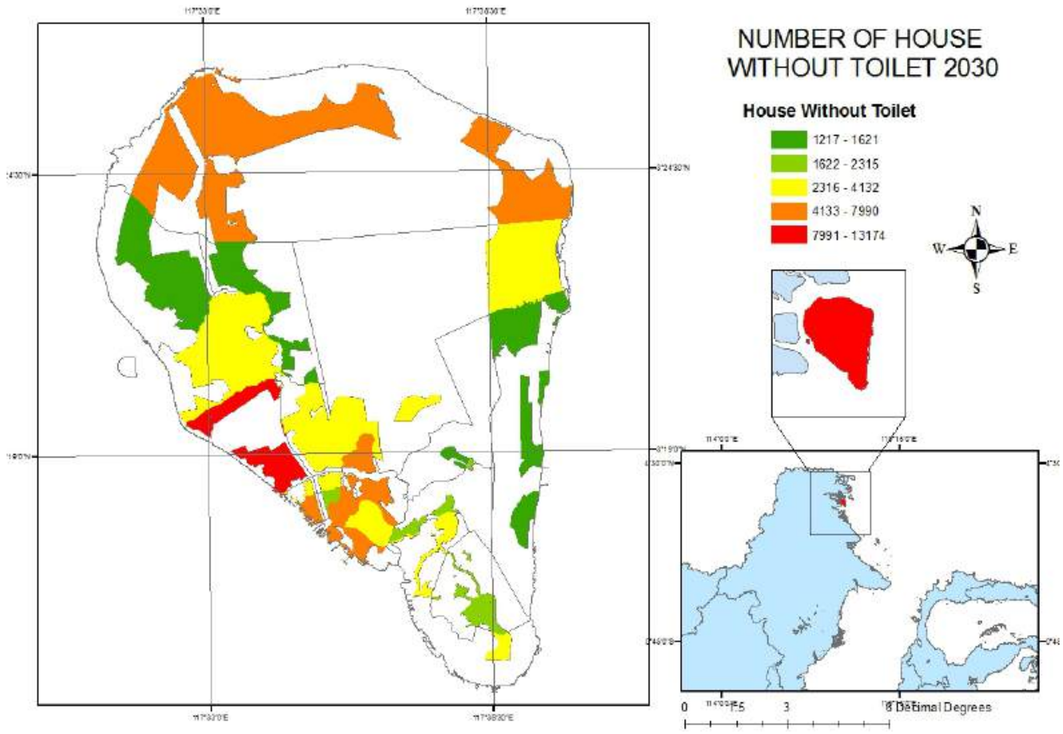


Figure 5-25 Projection of House without Toilet in Tarakan for 2030

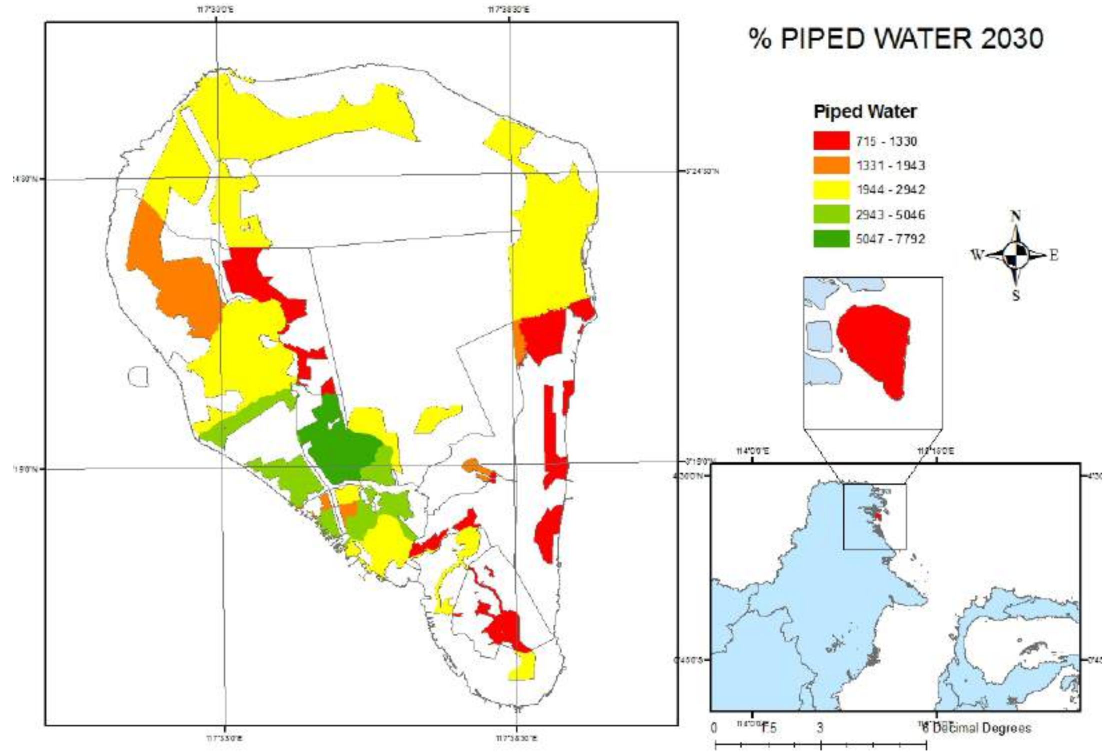


Figure 5-26 Projection of Piped Water Coverage in Tarakan for 2030

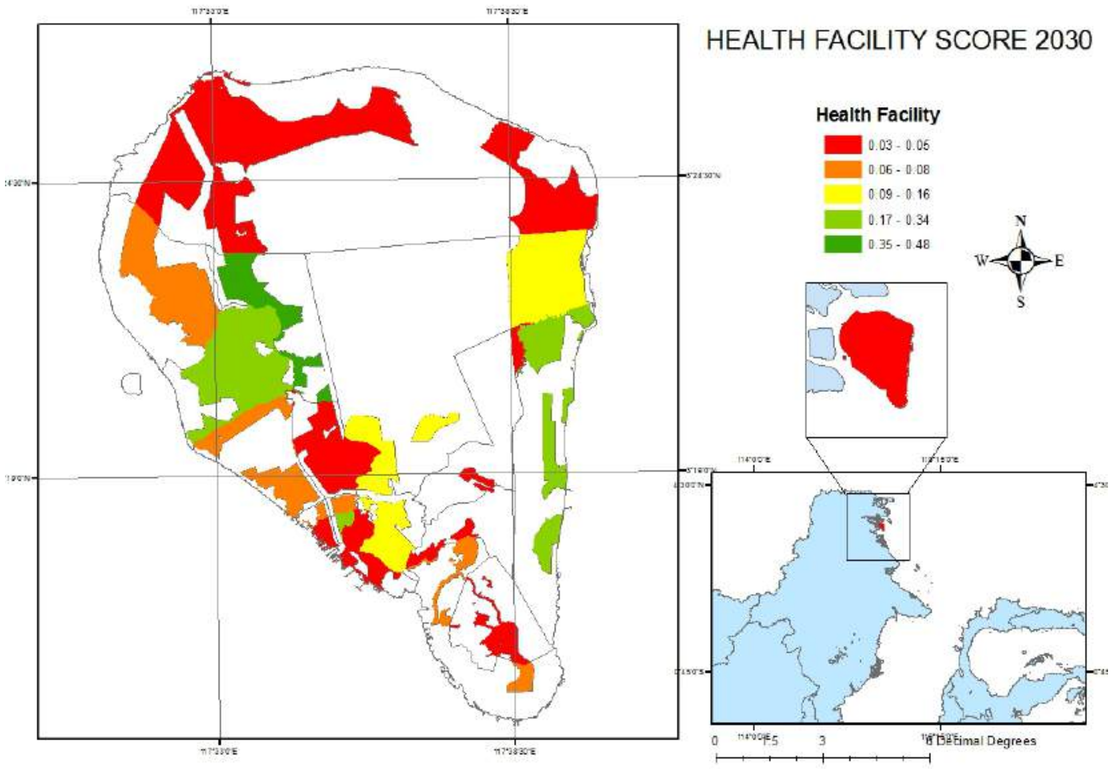


Figure 5-27 Projection of Health Facility Scores in Tarakan for 2030

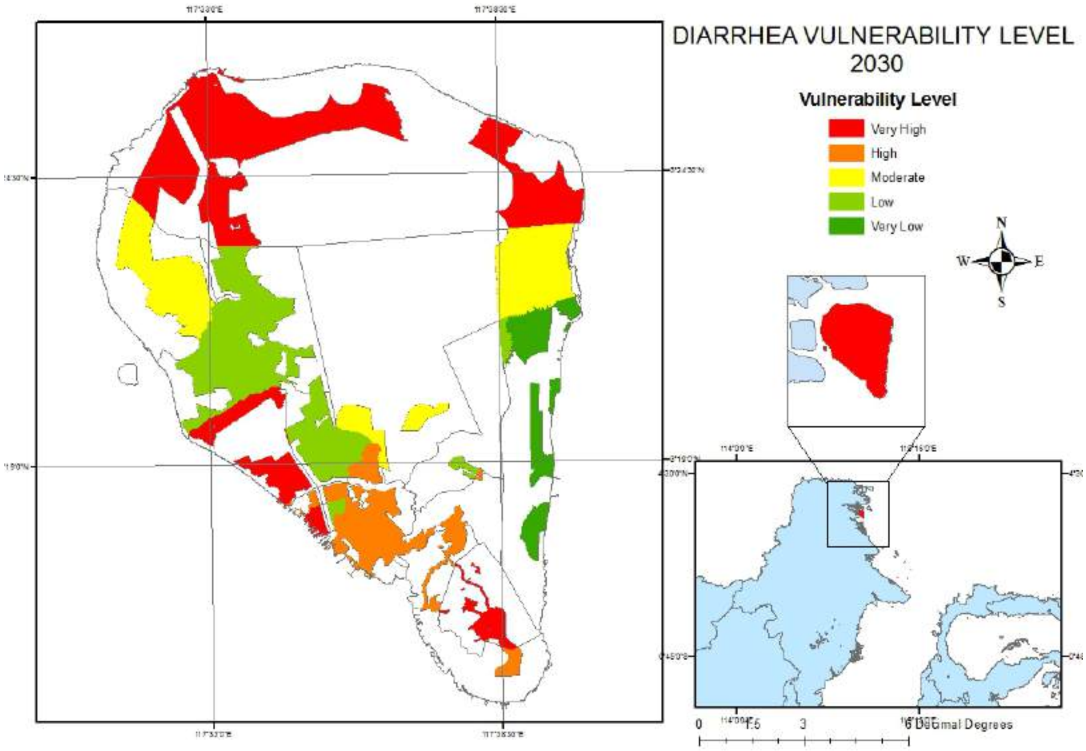


Figure 5-28 Projection of Diarrhea Vulnerability Level in Tarakan for 2030

5.9 Comparison of Diarrhea Vulnerability Levels in 2008 and 2030

Comparison of Diarrhea vulnerability levels in Tarakan in 2008 and 2030 is described in Table 5-9 below.

Table 5.9 : Results of Existing Vulnerability Score to Diarrhea in Tarakan

Sub District	Villages	Levels 2008	Levels 2030	Comparison
Tarakan Timur	Lingkas Ujung	High	Very Low	-3
	Gunung Lingkas	Very Low	Very Low	0
	Mamburungan	High	Very Low	-3
	Mamburungan Timur	Very High	Very Low	-4
	Kampung Empat	Low	Low	0
	Kampung Enam	High	Moderate	-1
	Pantai Amal	Very High	Moderate	-2
Tarakan Tengah	Selumit Pantai	Very High	Moderate	-2
	Selumit	Low	Low	0
	Sebengkok	Moderate	Moderate	0
	Pamusian	Very Low	Moderate	+2
	Kampung Satu Skip	Very Low	Very Low	0
Tarakan Barat	Karang Rejo	Low	Very High	+3
	Karang Balik	Very Low	Very High	+4
	Karang Anyar	Moderate	Moderate	0
	Karang Anyar Pantai	Low	Moderate	+1
	Karang Harapan	Moderate	Very Low	-2
Tarakan Utara	Juata Permai	Moderate	Low	-1

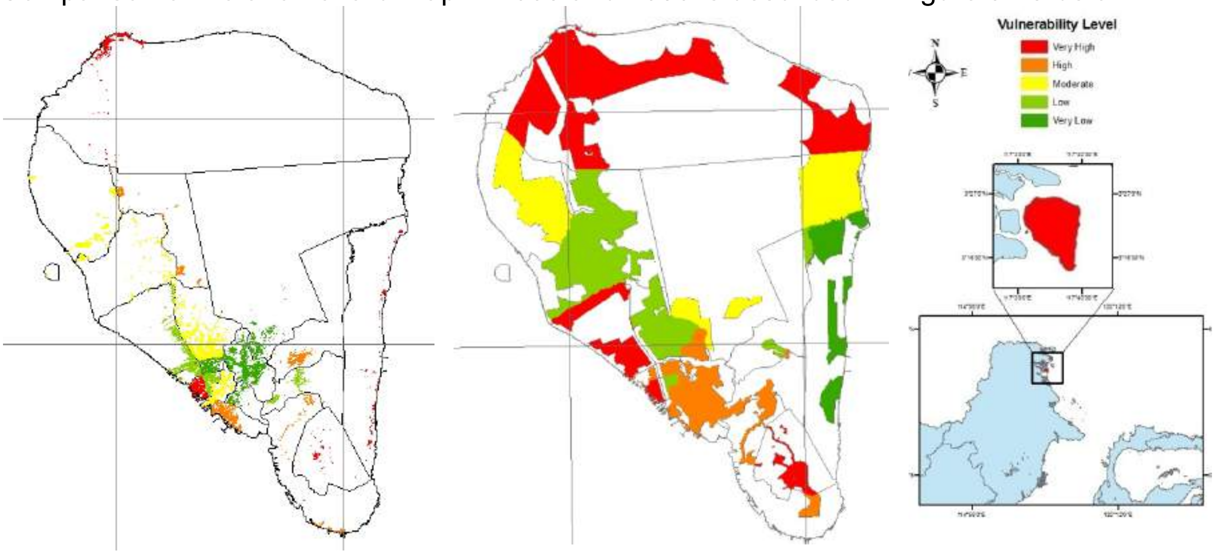
Sub District	Villages	Levels 2008	Levels 2030	Comparison
	Juata Kerikil	High	Moderate	-1
	Juata Laut	Very High	Very Low	-4

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 hazard map in 2008 and 2030 is described in Figure 5-29 below.



Vulnerability 2008 Vulnerability 2030

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:

$$R = H \times V \tag{6.1}$$

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 Existing 2008

Risk of DHF existing in corresponding sub 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 Tarakan 2008

Sub districts	Villages	Hazard		Vulnerability		Risk
		Average prevalence (2003-2010) /10,000 Occupants	Level	Score	Level	
Tarakan Timur	Lingkas Ujung	19.81	Moderate	0.25	High	High
	Gunung Lingkas	23.09	High	0.31	High	High
	Mamburungan	13.94	Low	0.25	High	Moderate
	Mamburungan Timur	14.31	Low	0.23	Moderate	Low
	Kampung Empat	28.47	Very High	0.15	Very Low	Moderate
	Kampung Enam	20.67	High	0.20	Low	Moderate
	Pantai Amal	6.52	Very Low	0.22	Moderate	Low
Tarakan Tengah	Selumit Pantai	20.20	Moderate	0.40	Very High	High
	Selumit	23.76	Very High	0.32	Very High	Very High
	Sebengkok	19.91	Moderate	0.36	Very High	High
	Pamusian	17.91	Moderate	0.15	Very Low	Low
	Kampung Satu Skip	21.60	High	0.07	Very Low	Low
Tarakan Barat	Karang Rejo	17.08	Low	0.26	High	Moderate
	Karang Balik	20.64	High	0.10	Very Low	Low
	Karang Anyar	24.85	Very High	0.23	Moderate	High
	Karang Anyar	12.89	Very Low	0.20	Low	Very Low

Sub districts	Villages	Hazard		Vulnerability		Risk
		Average prevalence (2003-2010) /10,000 Occupants	Level	Score	Level	
	Pantai					
	Karang Harapan	13.52	Very Low	0.21	Low	Very Low
Tarakan Utara	Juata Permai	24.67	Very High	0.23	Moderate	High
	Juata Kerikil	17.14	Low	0.20	Low	Low
	Juata Laut	11.75	Very Low	0.40	Very High	Moderate

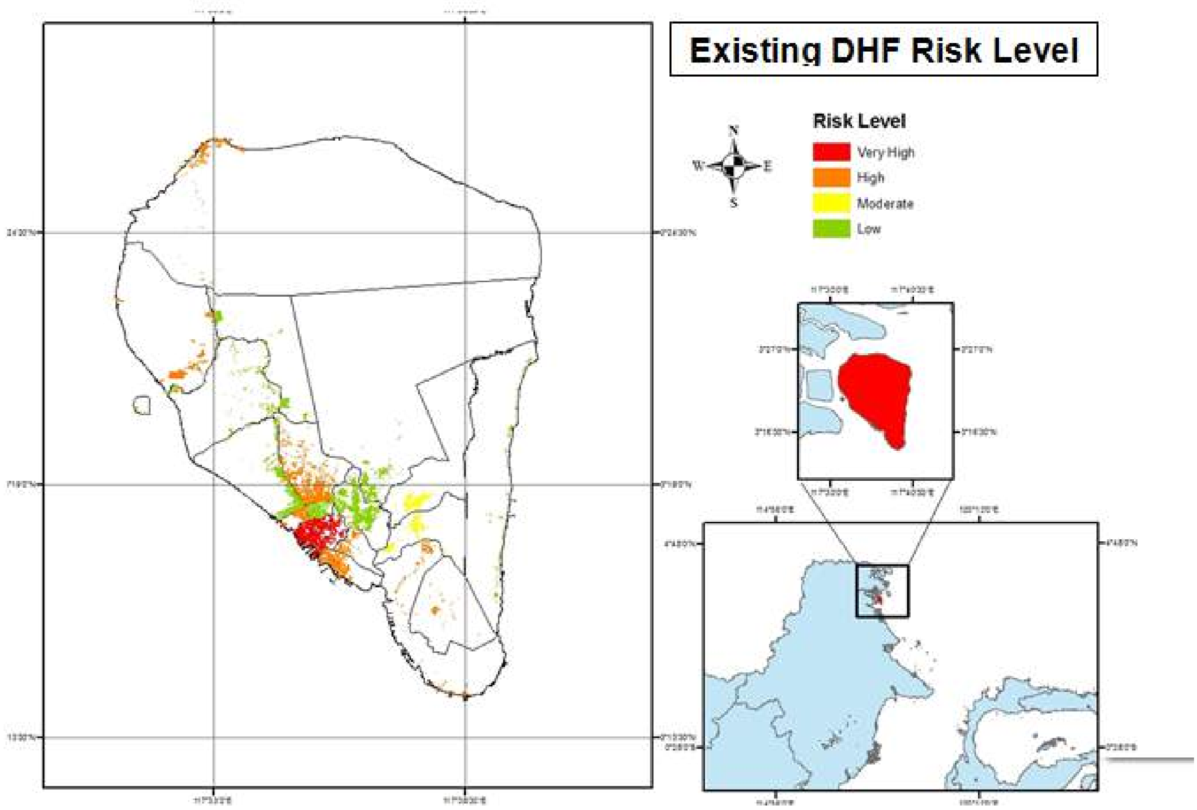


Figure 6-1 Existing Risk of DHF in Tarakan

Figure 6.1 shows that very high risk of DHF occurred in Selumit, while Karang Anyar Pantai and Karang Harapan elicit very low risk of DHF. Table 6.2 mentioned the major factor influence the very high risk score of DHF in villages of Tarakan. For general, very high risk of DHF in north area of Tarakan is more caused by low piped water coverage and number of population, while in middle area is caused by population density. Moreover, all the very high risk areas has high annual prevalence rate of DHF.

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

Villages with High Risk of DHF	Component	Main Causal Factors
Tarakan Tengah		
Selumit Pantai	Hazard	High prevalence rate of DHF
	Vulnerability	High population density
		Low availability of health facility
Selumit	Hazard	High prevalence rate of DHF
	Vulnerability	High population density
Sebengkok	Hazard	High prevalence rate of DHF
	Vulnerability	High population density
		Low piped water coverage
Tarakan Utara		
Juata Permai	Hazard	High prevalence rate of DHF
	Vulnerability	Low piped water coverage
Tarakan Timur		
Lingkas Ujung	Vulnerability	High population density
		Low availability of health facility
Gunung Lingkas	Hazard	High prevalence rate of DHF
	Vulnerability	High population density
Tarakan Barat		
Karang Anyar	Hazard	High prevalence rate of DHF

6.2 Risk Assessment of DHF Projection 2030

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 Tarakan 2030

Sub districts	Villages	Hazard		Vulnerability		Risk
		Average prevalence (2003-2010) /10,000 Occupants	Level	Score	Level	
Tarakan Timur	Lingkas Ujung	31.90	Very High	0.39	Very High	Very High
	Gunung Lingkas	38.33	Very High	0.16	Very Low	Moderate
	Mamburungan	27.48	Very High	0.17	Very Low	Moderate
	Mamburungan Timur	15.69	Low	0.18	Very Low	Very Low
	Kampung Empat	40.21	Very High	0.17	Very Low	Moderate
	Kampung Enam	25.03	Very High	0.13	Very Low	Moderate
	Pantai Amal	8.91	Very Low	0.03	Very Low	Very Low
Tarakan Tengah	Selumit Pantai	28.40	Very High	0.43	Very High	Very High
	Selumit	37.08	Very High	0.27	High	Very High
	Sebengkok	30.22	Very High	0.38	Very High	Very High
	Pamusian	28.23	Very High	0.18	Very Low	Moderate

Sub districts	Villages	Hazard		Vulnerability		Risk
		Average prevalence (2003-2010) /10,000 Occupants	Level	Score	Level	
	Kampung Satu Skip	38.92	Very High	0.14	Very Low	Moderate
Tarakan Barat	Karang Rejo	31.07	Very High	0.36	Very High	Very High
	Karang Balik	35.66	Very High	0.33	Very High	Very High
	Karang Anyar	42.11	Very High	0.17	Very Low	Moderate
	Karang Anyar Pantai	18.63	Moderate	0.27	High	High
	Karang Harapan	20.06	Moderate	0.10	Very Low	Low
Tarakan Utara	Juata Permai	32.79	Very High	0.22	Moderate	High
	Juata Kerikil	22.56	High	0.10	Very Low	Low
	Juata Laut	24.41	Very High	0.29	High	Very High

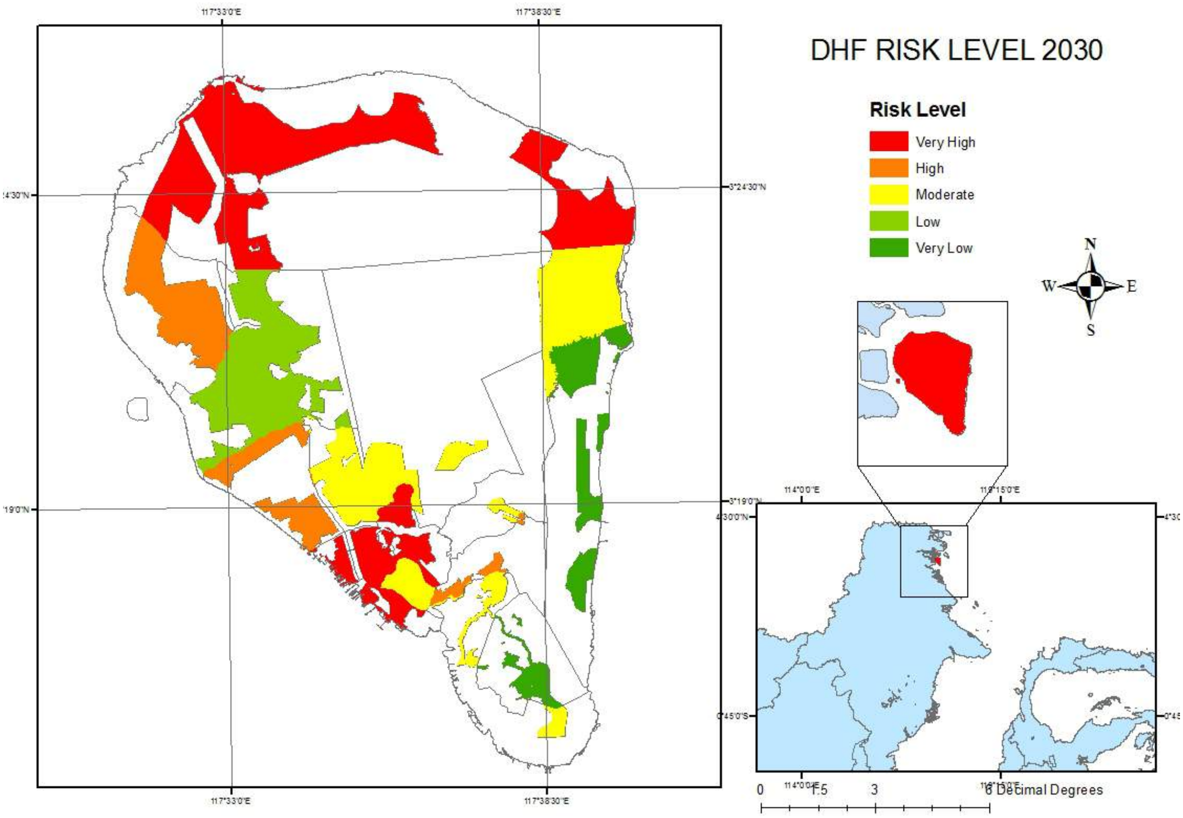


Figure 6-2 Projection Risk of DHF in Tarakan 2030

Table 6.4 describes the major factor influence the very high risk score of DHF in villages of Tarakan in 2030.

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

Villages with High Risk of DHF	Component	Main Causal Factors
Tarakan Tengah		
Selumit Pantai	Hazard	High prevalence rate of DHF

Villages with High Risk of DHF	Component	Main Causal Factors
	Vulnerability	High population density
		Low availability of health facility
Selumit	Hazard	High prevalence rate of DHF
	Vulnerability	High population density
Sebengkok	Hazard	High prevalence rate of DHF
	Vulnerability	High population density
		Low piped water coverage
Tarakan Utara		
Juata Laut	Hazard	High prevalence rate of DHF
	Vulnerability	Low piped water coverage
Tarakan Timur		
Lingkas Ujung	Vulnerability	High population density
		Low availability of health facility
Tarakan Barat		
Karang Rejo	Hazard	High prevalence rate of DHF
	Vulnerability	High population density
Karang Balik	Hazard	High prevalence rate of DHF
	Vulnerability	High population density

6.3 Comparison of DHF Risk Levels in 2008 and 2030

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

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

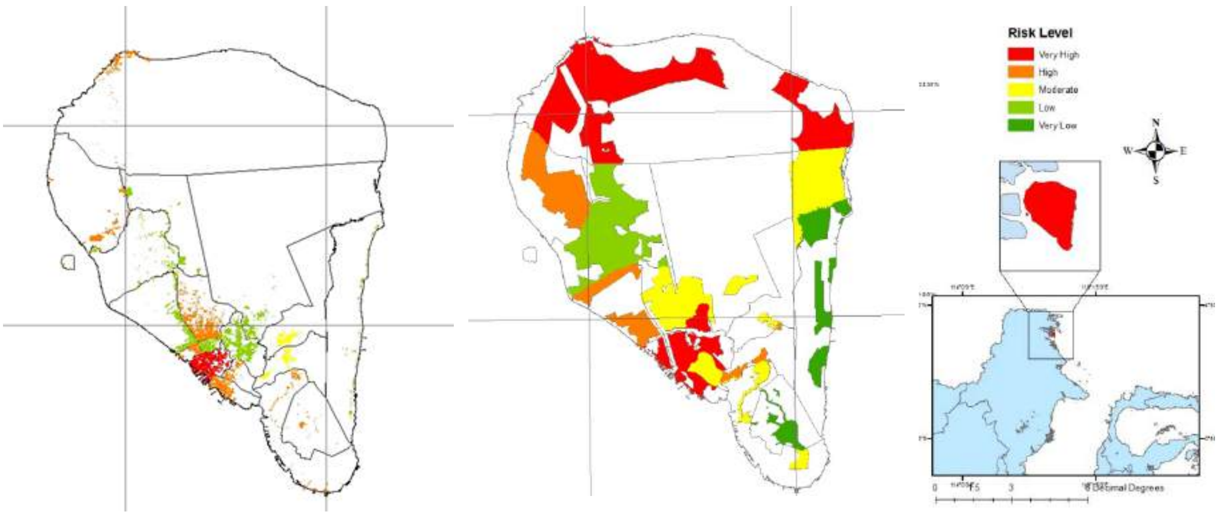
Sub districts	Villages	Risk 2008	Risk 2030	Comparison
Tarakan Timur	Lingkas Ujung	High	Very High	+1
	Gunung Lingkas	High	Moderate	-1
	Mamburungan	Moderate	Moderate	0
	Mamburungan Timur	Low	Very Low	-1
	Kampung Empat	Moderate	Moderate	0
	Kampung Enam	Moderate	Moderate	0
	Pantai Amal	Low	Very Low	-1
Tarakan Tengah	Selumit Pantai	High	Very High	+1
	Selumit	Very High	Very High	0
	Sebengkok	High	Very High	+1
	Pamusian	Low	Moderate	+1
	Kampung Satu Skip	Low	Moderate	+1
Tarakan Barat	Karang Rejo	Moderate	Very High	+2
	Karang Balik	Low	Very High	+3
	Karang Anyar	High	Moderate	-1
	Karang Anyar Pantai	Very Low	High	+3
	Karang Harapan	Very Low	Low	+1

Sub districts	Villages	Risk 2008	Risk 2030	Comparison
Tarakan Utara	Juata Permai	High	High	0
	Juata Kerikil	Low	Low	0
	Juata Laut	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 DHF risk map in 2008 and 2030 is described in Figure 6.3 below.



Risk 2008 Risk 2030

Figure 6-3 Comparison of DHF Risk Map in 2008 and 2030

6.4 Risk Assessment of Malaria Existing 2008

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 6.6, while Risk Map is shown in Figure 6.4

Table 6.6: Existing Risk Levels of Malaria in Tarakan in 2008

Sub districts	Villages	Hazard		Vulnerability		Risk
		Average prevalence (2003-2010) /100,000 Occupants	Level	Score	Level	
Tarakan Timur	Lingkas Ujung	15.24	Very High	0.84	Very High	Very High
	Gunung Lingkas	15.24	Very High	0.49	Moderate	High
	Mamburungan	0.52	Low	0.63	High	Moderate
	Mamburungan Timur	0.52	Low	0.20	Low	Low
	Kampung Empat	12.30	High	0.28	Low	Moderate

Sub districts	Villages	Hazard		Vulnerability		Risk
		Average prevalence (2003-2010) /100,000 Occupants	Level	Score	Level	
	Kampung Enam	12.30	High	0.28	Low	Moderate
	Pantai Amal	12.30	High	0.65	High	High
Tarakan Tengah	Selumit Pantai	0.00	Very Low	0.86	Very High	Moderate
	Selumit	0.00	Very Low	0.79	Very High	Moderate
	Sebengkok	0.00	Very Low	0.64	High	Low
	Pamusian	0.52	Low	0.15	Very Low	Very Low
	Kampung Satu Skip	0.52	Low	0.15	Very Low	Very Low
Tarakan Barat	Karang Rejo	0.00	Very Low	0.82	Very High	Moderate
	Karang Balik	0.00	Very Low	0.24	Low	Very Low
	Karang Anyar	0.00	Very Low	0.15	Very Low	Very Low
	Karang Anyar Pantai	0.00	Very Low	0.70	High	Low
	Karang Harapan	44.44	Very High	0.34	Moderate	High
Tarakan Utara	Juata Permai	44.44	Very High	0.16	Very Low	Moderate
	Juata Kerikil	44.44	Very High	0.28	Moderate	High
	Juata Laut	6.93	Moderate	0.61	Moderate	Moderate

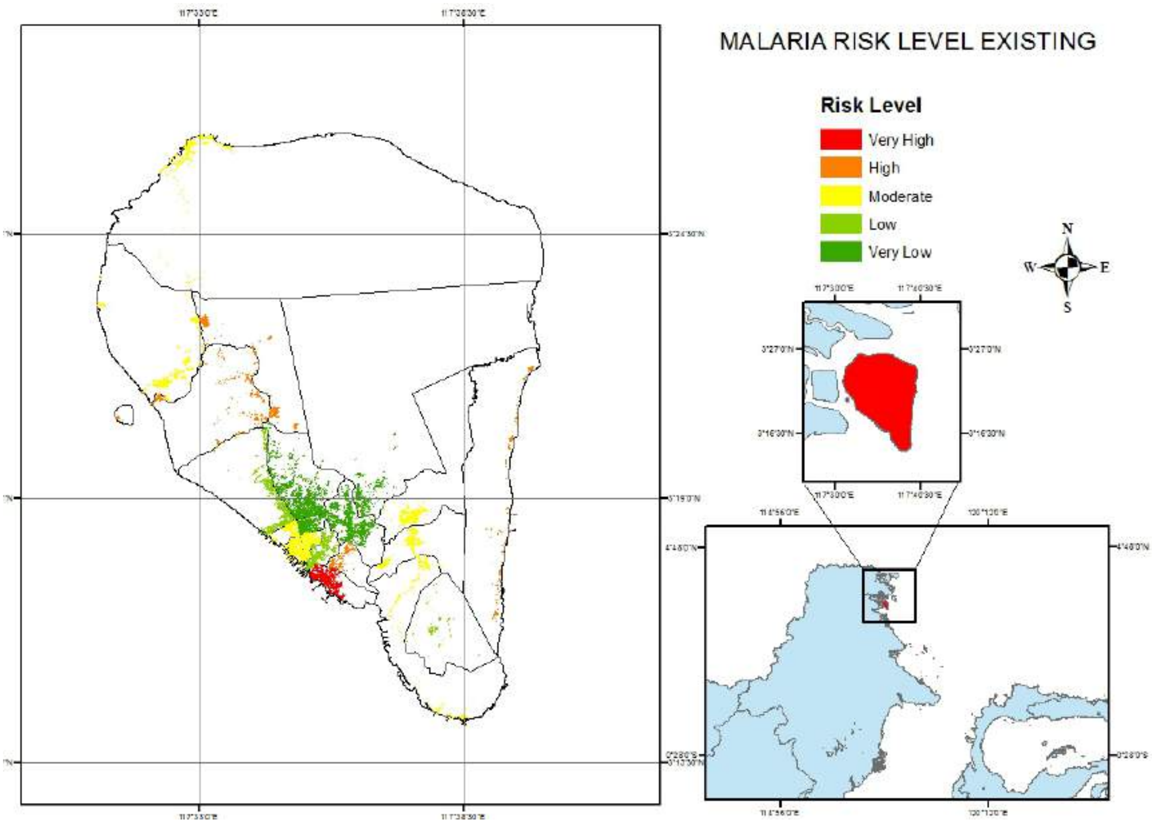


Figure 6-4 Existing Risk of Malaria in Tarakan in 2008

Figure 6.4 shows that southern region of Tarakan elicit higher risk to develop malaria disease incidence. Two main components responsible for the higher risk in certain area are the hazard and vulnerability of malaria. Table 6.6 shows the major factors of those two components 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. The major causal of high risk area seems to be multi factorial.

Table 6.7: Factors Influence the Risk Score 2008 in Tarakan villages with High Risk Score of Malaria

Villages with High Risk of Malaria	Component	Main Causal Factors
Tarakan Timur		
Lingkas Ujung	Hazard	High prevalence rate of malaria
	Vulnerability	Large population run their activity near the breeding site
		Most houses located near the breeding site
		Most people live in non permanent housing
		Low availability of Health Facility
Gunung Lingkas	Hazard	High prevalence rate of malaria
Pantai Amal	Hazard	High prevalence rate of malaria
	Vulnerability	Most people live in non permanent housing
Tarakan Barat		
Karang Harapan	Hazard	High prevalence rate of malaria
Tarakan Utara		
Juata Kerikil	Hazard	High prevalence rate of malaria

6.5 Risk Assessment of Malaria Projection 2030

Risk of malaria projection in 2030 in corresponding sub districts is determined according to the Risk Assessment Matrix. The results in tabular form are shown in Table 6.8, while Risk Map is shown in Figure 6.5.

Table 6.8: Projection Risk Levels of Malaria in Tarakan 2030

Sub districts	Villages	Hazard		Vulnerability		Risk
		Average prevalence (2003-2010) /100,000 Occupants	Level	Score	Level	
Tarakan Timur	Lingkas Ujung	11.02	High	0.05	Very Low	Low
	Gunung Lingkas	11.02	High	0.08	Very Low	Low
	Mamburungan	11.02	High	0.08	Very Low	Low
	Mamburungan Timur	11.02	High	0.09	Very Low	Low
	Kampung Empat	11.02	High	0.21	Low	Low
	Kampung Enam	11.02	High	0.42	Moderate	Moderate
	Pantai Amal	11.02	High	0.44	Moderate	Moderate
Tarakan Tengah	Selumit Pantai	0.00	Very Low	0.50	Moderate	Low
	Selumit	0.00	Very Low	0.24	Low	Very Low
	Sebengkok	0.00	Very Low	0.35	Moderate	Low

Sub districts	Villages	Hazard		Vulnerability		Risk
		Average prevalence (2003-2010) /100,000 Occupants	Level	Score	Level	
	Pamusian	0.00	Very Low	0.48	Moderate	Low
	Kampung Satu Skip	0.00	Very Low	0.18	Very Low	Very Low
Tarakan Barat	Karang Rejo	0.00	Very Low	0.78	Very High	Moderate
	Karang Balik	0.00	Very Low	0.77	Very High	Moderate
	Karang Anyar	0.00	Very Low	0.29	Moderate	Low
	Karang Anyar Pantai	0.00	Very Low	0.38	Moderate	Low
	Karang Harapan	0.00	Very Low	0.17	Very Low	Very Low
Tarakan Utara	Juata Permai	64.94	Very High	0.24	Low	High
	Juata Kerikil	64.94	Very High	0.34	Moderate	High
	Juata Laut	64.94	Very High	0.16	Very Low	Moderate

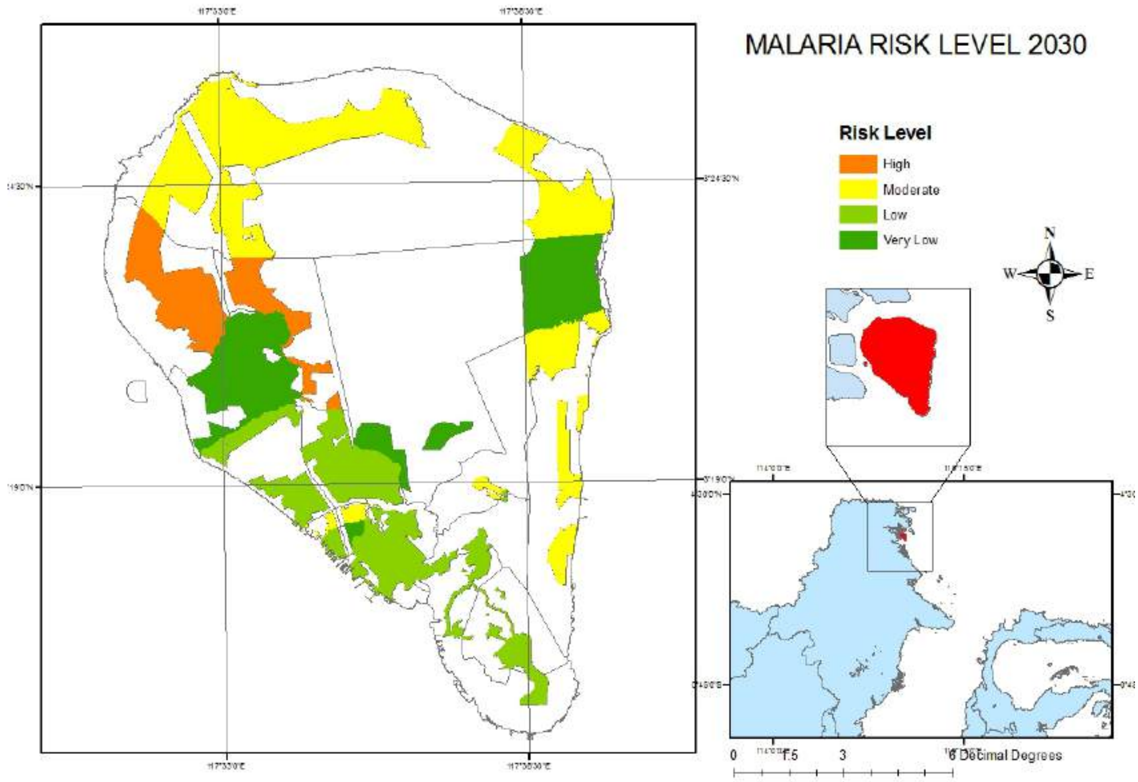


Figure 6-5 Projection Risk of Malaria in Tarakan 2030

Table 6.9 describes the major factor influence the high risk score of malaria in villages of Tarakan in 2030.

Table 6.9: Factors Influence the Risk Score 2030 in Tarakan villages with High Risk Score of Malaria

Villages with High Risk of Malaria	Component	Main Causal Factors
Tarakan Utara		
Juata Kerikil	Hazard	High prevalence rate of malaria
Juata Permai	Hazard	High prevalence rate of malaria

6.6 Comparison of Malaria Risk Levels in 2008 and 2030

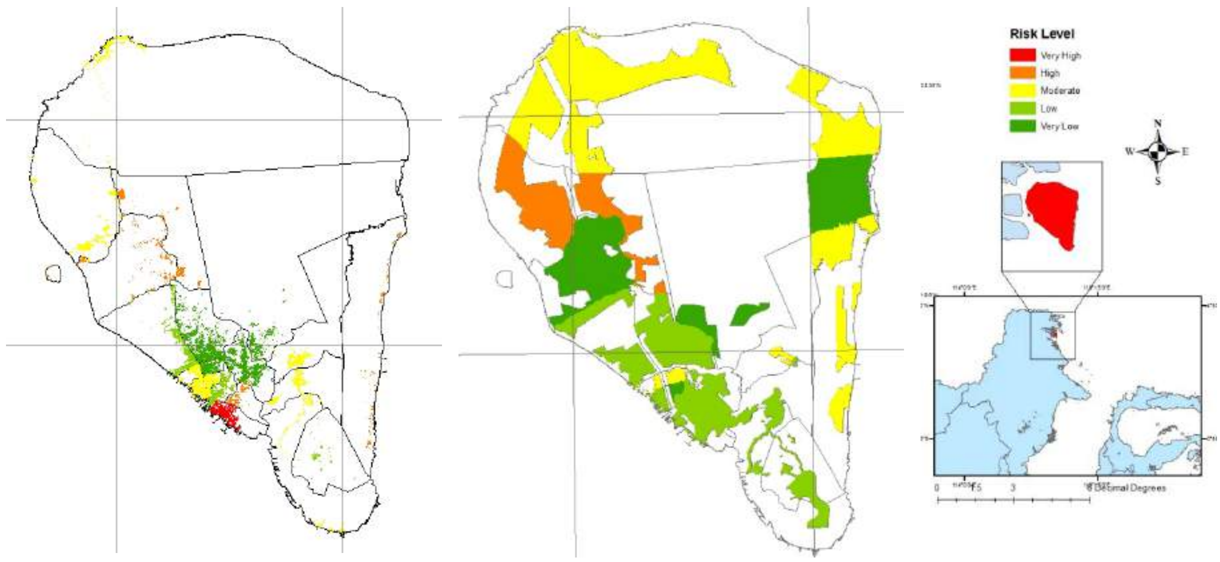
Comparison of Malaria risk levels in 2008 and 2030 is described in Table 6-10 below.

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

Sub districts	Villages	Risk 2008	Risk 2030	Comparison
Tarakan Timur	Lingkas Ujung	Very High	Low	-3
	Gunung Lingkas	High	Low	-2
	Mamburungan	Moderate	Low	-1
	Mamburungan Timur	Low	Low	0
	Kampung Empat	Moderate	Low	-1
	Kampung Enam	Moderate	Moderate	0
	Pantai Amal	High	Moderate	-1
Tarakan Tengah	Selumit Pantai	Moderate	Low	-1
	Selumit	Moderate	Very Low	-2
	Sebengkok	Low	Low	0
	Pamusian	Very Low	Low	+1
	Kampung Satu Skip	Very Low	Very Low	0
Tarakan Barat	Karang Rejo	Moderate	Moderate	0
	Karang Balik	Very Low	Moderate	+2
	Karang Anyar	Very Low	Low	+1
	Karang Anyar Pantai	Low	Low	0
	Karang Harapan	High	Very Low	-3
Tarakan Utara	Juata Permai	Moderate	High	+1
	Juata Kerikil	High	High	0
	Juata Laut	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 2008 and 2030 is described in Figure 6.6 below.



Risk 2008 Risk 2030

Figure 6-6 Comparison of Malaria Risk Map in 2008 and 2030

6.7 Risk Assessment of Diarrhea Existing 2008

Risk of diarrhea existing in 2008 in corresponding sub districts is determined according to the Risk Assessment Matrix. The results in tabular form are shown in Table 6.11, while Risk Map is shown in Figure 6.7.

Table 6.11: Existing Risk Levels of Diarrhea in Tarakan

Sub districts	Villages	Hazard		Vulnerability		Risk
		Average prevalence (2003-2010) /1,000 Occupants	Level	Score	Level	
Tarakan Timur	Lingkas Ujung	53.30	Very High	0.33	High	Very High
	Gunung Lingkas	53.30	Very High	0.18	Very Low	Moderate
	Mamburungan	17.00	Low	0.38	High	Moderate
	Mamburungan Timur	17.00	Low	0.42	Very High	High
	Kampung Empat	16.52	Very Low	0.20	Low	Very Low
	Kampung Enam	16.52	Very Low	0.29	High	Low
	Pantai Amal	16.52	Very Low	0.38	Very High	Moderate
Tarakan Tengah	Selumit Pantai	13.63	Very Low	0.41	Very High	Moderate
	Selumit	13.63	Very Low	0.21	Low	Very Low
	Sebengkok	13.63	Very Low	0.25	Moderate	Low
	Pamusian	17.00	Low	0.17	Very Low	Very Low
	Kampung Satu Skip	17.00	Low	0.09	Very Low	Very Low
Tarakan Barat	Karang Rejo	24.22	Moderate	0.18	Low	Low
	Karang Balik	24.22	Moderate	0.15	Very Low	Low
	Karang Anyar	24.22	Moderate	0.25	Moderate	Moderate
	Karang Anyar	24.22	Moderate	0.24	Low	Low

Sub districts	Villages	Hazard		Vulnerability		Risk
		Average prevalence (2003-2010) /1,000 Occupants	Level	Score	Level	
	Pantai					
	Karang Harapan	50.60	Very High	0.26	Moderate	High
Tarakan Utara	Juata Permai	50.60	Very High	0.28	Moderate	High
	Juata Kerikil	50.60	Very High	0.28	High	Very High
	Juata Laut	40.70	High	0.48	Very High	Very High

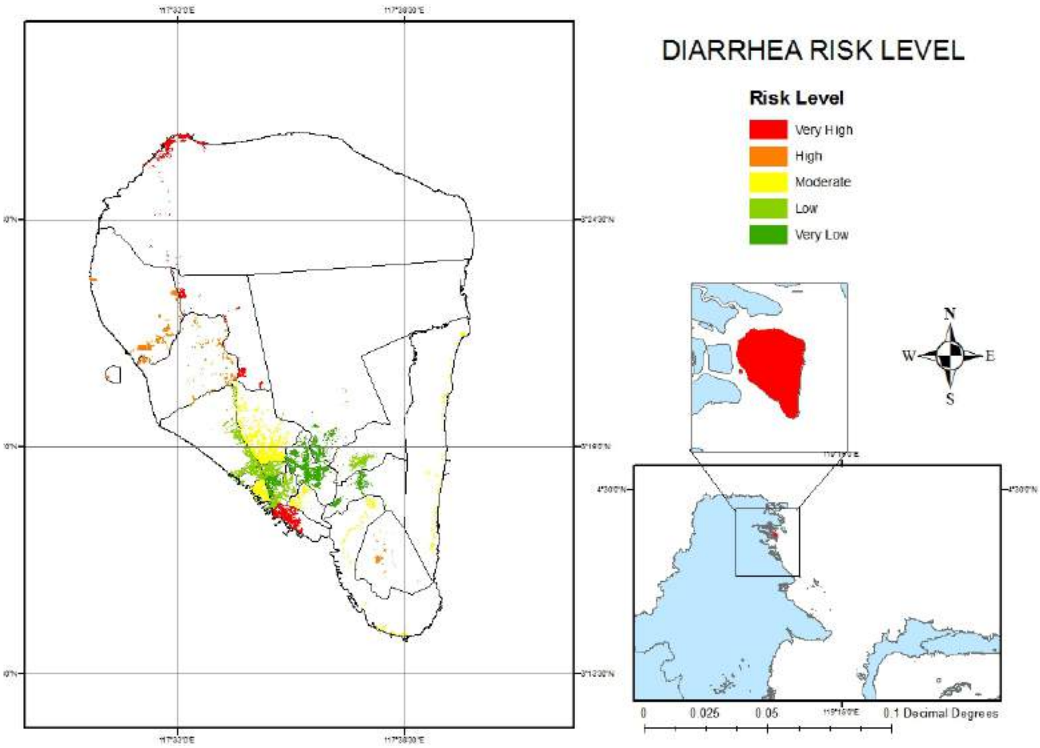


Figure 6-7 Existing Risk of Diarrhea in Tarakan in 2008

Figure 6.7 show that Lingkas have the highest risk of diarrhea. 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 6.11).

Table 6.12: Factors Influence the Risk Score 2008 in Sub districts with Very High Risk Score of Diarrhea

Sub districts with High Risk of Diarrhea	Component	Main Causal Factors
Tarakan Timur		
Lingkas Ujung	Hazard	High prevalence rate of Diarrhea
	Vulnerability	High population density
		Low piped water coverage
Mamburungan Timur	Vulnerability	Low piped water coverage
		Low availability of toilet
Tarakan Barat		
Karang Harapan	Hazard	High prevalence rate of

Sub districts with High Risk of Diarrhea	Component	Main Causal Factors
		Diarrhea
Tarakan Utara		
Juata Permai	Hazard	High prevalence rate of Diarrhea
Juata Kerikil	Hazard	High prevalence rate of Diarrhea
	Vulnerability	Low piped water coverage
Juata Laut	Hazard	High prevalence rate of Diarrhea
	Vulnerability	High population density
		Low availability of toilet

6.8 Risk Assessment of Diarrhea Projection 2030

Risk of diarrhea projection in 2030 in corresponding sub districts is determined according to the Risk Assessment Matrix. The results in tabular form are shown in Table 6.13, while Risk Map is shown in Figure 6.8.

Table 6.13: Projection Risk Levels of Diarrhea in Tarakan 2030

Sub districts	Villages	Hazard		Vulnerability		Risk
		Average prevalence (2003-2010) /1,000 Occupants	Level	Score	Level	
Tarakan Timur	Lingkas Ujung	60.54	Very High	0.37	High	Very High
	Gunung Lingkas	61.09	Very High	0.29	High	Very High
	Mamburungan	26.50	Moderate	0.34	High	High
	Mamburungan Timur	24.18	Moderate	0.41	Very High	Moderate
	Kampung Empat	24.84	Moderate	0.30	High	High
	Kampung Enam	27.05	Moderate	0.23	Low	Low
	Pantai Amal	27.47	Moderate	0.18	Very Low	Low
Tarakan Tengah	Selumit Pantai	16.82	Low	0.40	Very High	High
	Selumit	14.56	Very Low	0.20	Low	Very Low
	Sebengkok	17.70	Low	0.33	High	Moderate
	Pamusian	21.01	Moderate	0.29	High	High
	Kampung Satu Skip	32.97	Moderate	0.25	Moderate	Moderate
Tarakan Barat	Karang Rejo	30.32	Moderate	0.33	High	High
	Karang Balik	28.52	Moderate	0.28	High	High
	Karang Anyar	15.67	Very Low	0.20	Low	Very Low
	Karang Anyar Pantai	31.14	Moderate	0.46	Very High	High
	Karang Harapan	54.30	Very High	0.24	Low	High
Tarakan Utara	Juata Permai	113.23	Very High	0.26	Moderate	High
	Juata Kerikil	57.72	Very High	0.20	Low	High
	Juata Laut	43.04	High	0.44	Very High	Very High

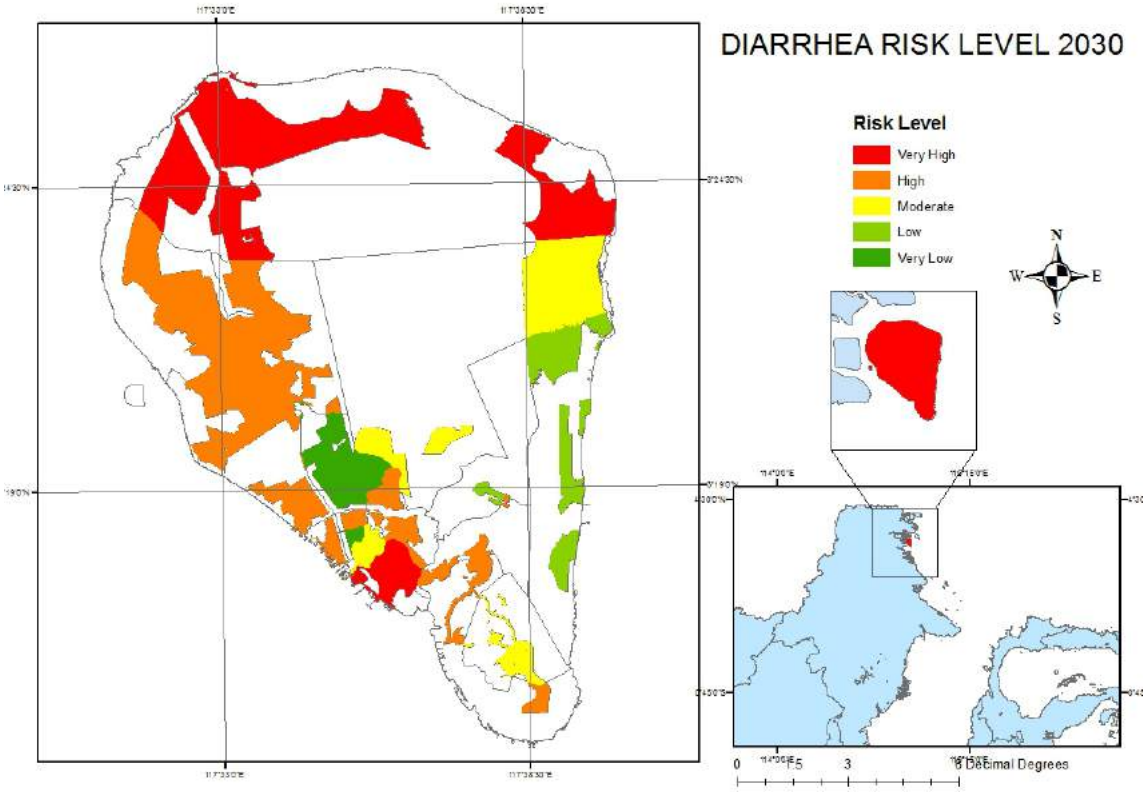


Figure 6-8 Projection Risk Map of Diarrhea in Tarakan 2030

Table 6.14 describes the major factor influence the very high risk score of diarrhea in villages of Tarakan in 2030.

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

Sub districts with High Risk of Diarrhea	Component	Main Causal Factors
Tarakan Timur		
Lingkas Ujung	Hazard	High prevalence rate of Diarrhea
	Vulnerability	High population density
		Low piped water coverage
Gunung Lingkas	Hazard	High prevalence rate of Diarrhea
	Vulnerability	Low piped water coverage
		Low availability of toilet
Tarakan Utara		
Juata Laut	Hazard	High prevalence rate of Diarrhea
	Vulnerability	High population density
		Low availability of toilet

6.9 Comparison of Diarrhea Risk Levels in 2008 and 2030

Comparison of diarrhea risk levels in 2008 and 2030 is described in Table 6.15 below.

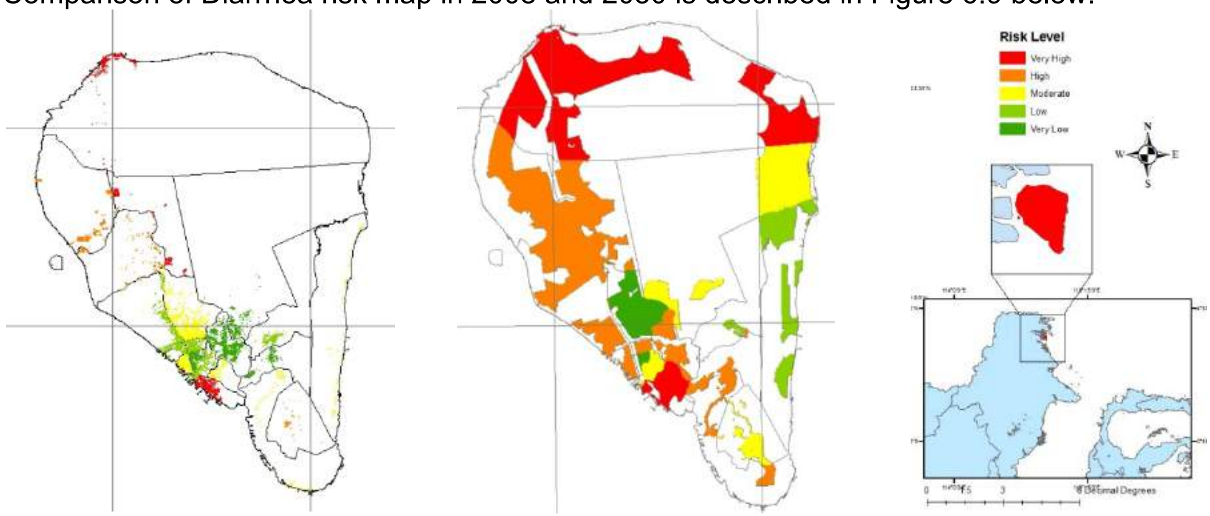
Table 6.15: Comparison of Diarrhea Risk Level in 2008 and 2030

Sub districts	Villages	Risk 2008	Risk 2030	Comparison
Tarakan Timur	Lingkas Ujung	Very High	Very High	0
	Gunung Lingkas	Moderate	Very High	+2
	Mamburungan	Moderate	High	+1
	Mamburungan Timur	High	Moderate	-1
	Kampung Empat	Very Low	High	+3
	Kampung Enam	Low	Low	0
	Pantai Amal	Moderate	Low	-1
Tarakan Tengah	Selumit Pantai	Moderate	High	+1
	Selumit	Very Low	Very Low	0
	Sebengkok	Low	Moderate	+1
	Pamusian	Very Low	High	+3
	Kampung Satu Skip	Very Low	Moderate	+2
Tarakan Barat	Karang Rejo	Low	High	+2
	Karang Balik	Low	High	+2
	Karang Anyar	Moderate	Very Low	-2
	Karang Anyar Pantai	Low	High	+3
	Karang Harapan	High	High	0
Tarakan Utara	Juata Permai	High	High	0
	Juata Kerikil	Very High	High	-1
	Juata Laut	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 Diarrhea risk map in 2008 and 2030 is described in Figure 6.9 below.



Risk 2008 Risk 2030

Figure 6-9 Comparison of Diarrhea Risk Map in 2008 and 2030

CHAPTER 7 HEALTH ADAPTATION STRATEGY

7.1 Introduction

In term of human health, Tarakan Island is unique in the sense that its general health condition is above the national health standard in many respects. It is known that human health is the results of three synergistic factors, namely genetic, environment and behavior. Recent issues of climate change brought specific alteration in environmental condition. Specifically, the increment of rainfall and temperature will affect the nature of disease agents. The three guiding principles for the adaptation strategies in the health sector of Tarakan Island include:

- A policy switch from curative dominance to preventive and promotive activity in the long run.
- Based on the conclusion and prediction drawn by the science basis which stated that Tarakan's climate as equatorial type and ENSO influenced, all health planning and adaptation strategy for Tarakan should include Tarakan's future climate changes into consideration.
- Health sector should not be working alone in tackling the situation. A concerted and integrated effort should include other relevant departments. 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 (see Appendix D for detail explanation).

Many diseases and health problems that may be exacerbated by climate change in Tarakan 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 Tarakan

Based on analyzing the hazard, vulnerability and risk level both in 2008 and 2030, adaptation strategy categories of DHF for each villages in Tarakan 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 Tarakan City

Sub district	Villages	Hazard			Vulnerability			Risk			Adap Str.
		2008	2030	Comp.	2008	2030	Comp.	2008	2030	Comp.	
Tarakan Timur	Lingkas Ujung	M	VH	+2	H	VH	+1	H	VH	+1	A
	Gunung Lingkas	H	VH	+1	H	VL	-3	H	M	-1	B
	Mamburungan	L	VH	+3	H	VL	-3	M	M	0	B
	Mamburungan Timur	L	L	0	M	VL	-2	L	VL	-1	D
	Kampung Empat	VH	VH	0	VL	VL	0	M	M	0	B
	Kampung Enam	H	VH	+1	L	VL	-1	M	M	0	B
	Pantai Amal	VL	VL	0	M	VL	-2	L	VL	-1	D
Tarakan Tengah	Selumit Pantai	M	VH	+2	VH	VH	0	H	VH	+1	A
	Selumit	VH	VH	0	VH	H	-1	VH	VH	0	A
	Sebengkok	M	VH	+2	VH	VH	0	H	VH	+1	A
	Pamusian	M	VH	+2	VL	VL	0	L	M	+1	B
	Kampung Satu Skip	H	VH	+1	VL	VL	0	L	M	+1	B
Tarakan Barat	Karang Rejo	L	VH	+3	H	VH	+2	M	VH	+2	C
	Karang Balik	H	VH	+1	VL	VH	+4	L	VH	+3	A
	Karang Anyar	VH	VH	0	M	VL	-2	H	M	-1	B

Sub district	Villages	Hazard			Vulnerability			Risk			Adap Str.
		2008	2030	Comp.	2008	2030	Comp.	2008	2030	Comp.	
	Karang Anyar Pantai	VL	M	+1	L	H	+2	VL	H	+3	C
	Karang Harapan	VL	M	+2	L	VL	-1	VL	L	+1	D
Tarakan Utara	Juata Permai	VH	VH	0	M	M	0	H	H	0	B
	Juata Kerikil	L	H	+2	L	VL	-1	L	L	0	B
	Juata Laut	VL	VH	+4	VH	H	-1	M	VH	+2	A

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 Tarakan

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
(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 Tarakan Timur

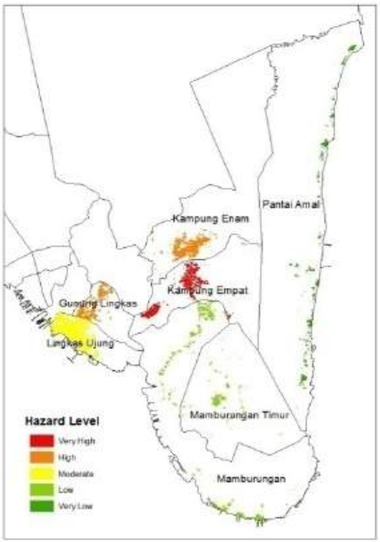
Table 7-3 show hazard, vulnerability and risk in each village in Tarakan Timur both in 2008 and 2030. Moreover, visualization of each hazard, vulnerability and risk in each village in Tarakan Timur both in 2008 and 2030 are drew in Figure 7-1. After analyzing the hazard, vulnerability and risk adaptation strategy, the category of adaptation strategy of each village in Tarakan Timur can be defined as shown in Table 7-4.

Table 7.3: Hazard, Vulnerability and Risk of DHF in Tarakan Timur

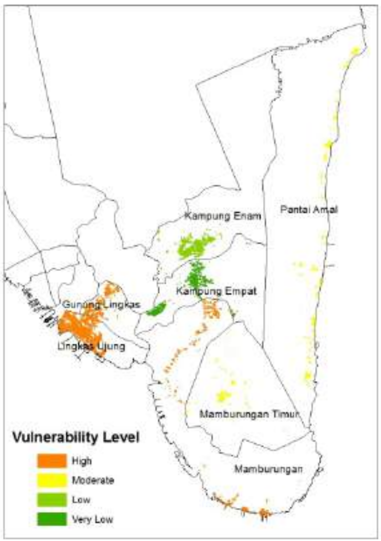
Sub district	Villages	Hazard			Vulnerability			Risk			Adap Str.
		2008	2030	Comp.	2008	2030	Comp.	2008	2030	Comp.	
Tarakan Timur	Lingkas Ujung	M	VH	+2	H	VH	+1	H	VH	+1	A
	Gunung Lingkas	H	VH	+1	H	VL	-3	H	M	-1	B
	Mamburungan	L	VH	+3	H	VL	-3	M	M	0	B
	Mamburungan Timur	L	L	0	M	VL	-2	L	VL	-1	D
	Kampung Empat	VH	VH	0	VL	VL	0	M	M	0	B
	Kampung Enam	H	VH	+1	L	VL	-1	M	M	0	B
	Pantai Amal	VL	VL	0	M	VL	-2	L	VL	-1	D

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

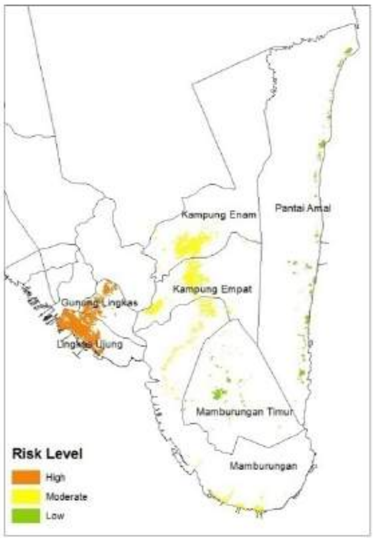
As shown in Table 7-3 and Figure 7-1, villages that have high hazard in 2008 are Gunung Lingkas, Kampung Empat and Kampung Enam. In 2030, Gunung Lingkas, Kampung Empat, and Kampung Enam may still have high hazard. Moreover, Mamburungan is predicted to be high hazard in 2030. Therefore, four villages are defined as category B, there are Gunung Lingkas, Kampung Empat, Kampung Enam, and Mamburungan. Lingkas Ujung is defined as category A because Lingkas Ujung has not only high hazard but also high vulnerability. Lingkas Ujung has high vulnerability because its health facility is limited. Therefore, in Tarakan Timur, Lingkas Ujung is most priority area that have to be improved both hazard and vulnerability control. Two villages have low hazard and vulnerability therefore there are defined as category D, namely Mamburungan Timur and Pantai Amal. Based on this classification, in general Tarakan Timur has high hazard but low vulnerability. In detail, adaptation strategy for each village in Tarakan Timur is described in Table 7-4 below.



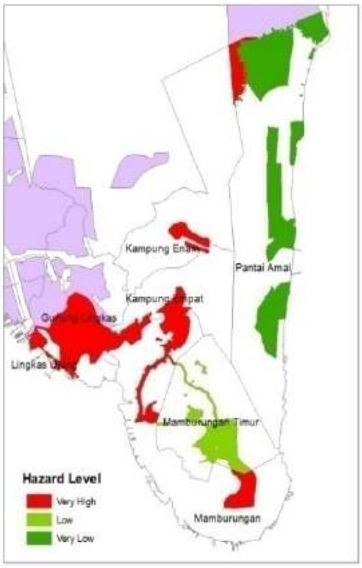
Hazard 2008



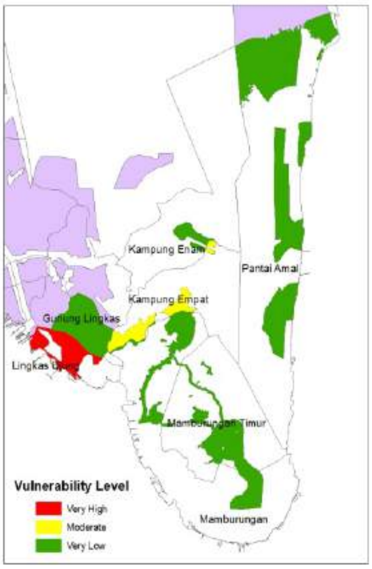
Vulnerability 2008



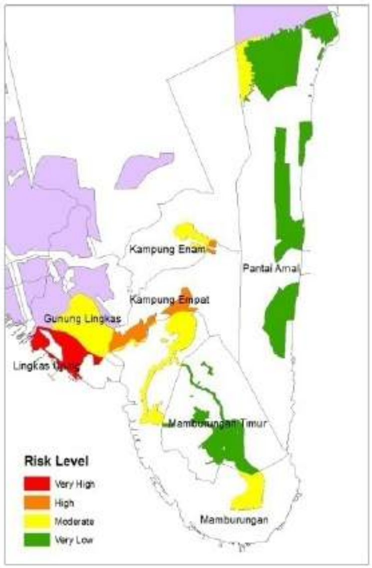
Risk 2008



Hazard 2030



Vulnerability 2030



Risk 2030

Figure 7-1 Map of Hazard, Vulnerability and Risk of DHF in Tarakan Timur

Table 7.4: Adaptation Strategy Category of DHF for Each Village in Tarakan Timur

Category	Villages	Adaptation Strategy
A	• Lingkas Ujung	• 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 health facility
B	• Gunung Lingkas	• Mosquito source reduction

Category	Villages	Adaptation Strategy
	• Kampung Empat • Kampung Enam • Mamburungan	• 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	• None	
D	• Mamburungan Timur • Pantai Amal	• 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

7.2.2 Adaptation Strategy of DHF in Tarakan Tengah

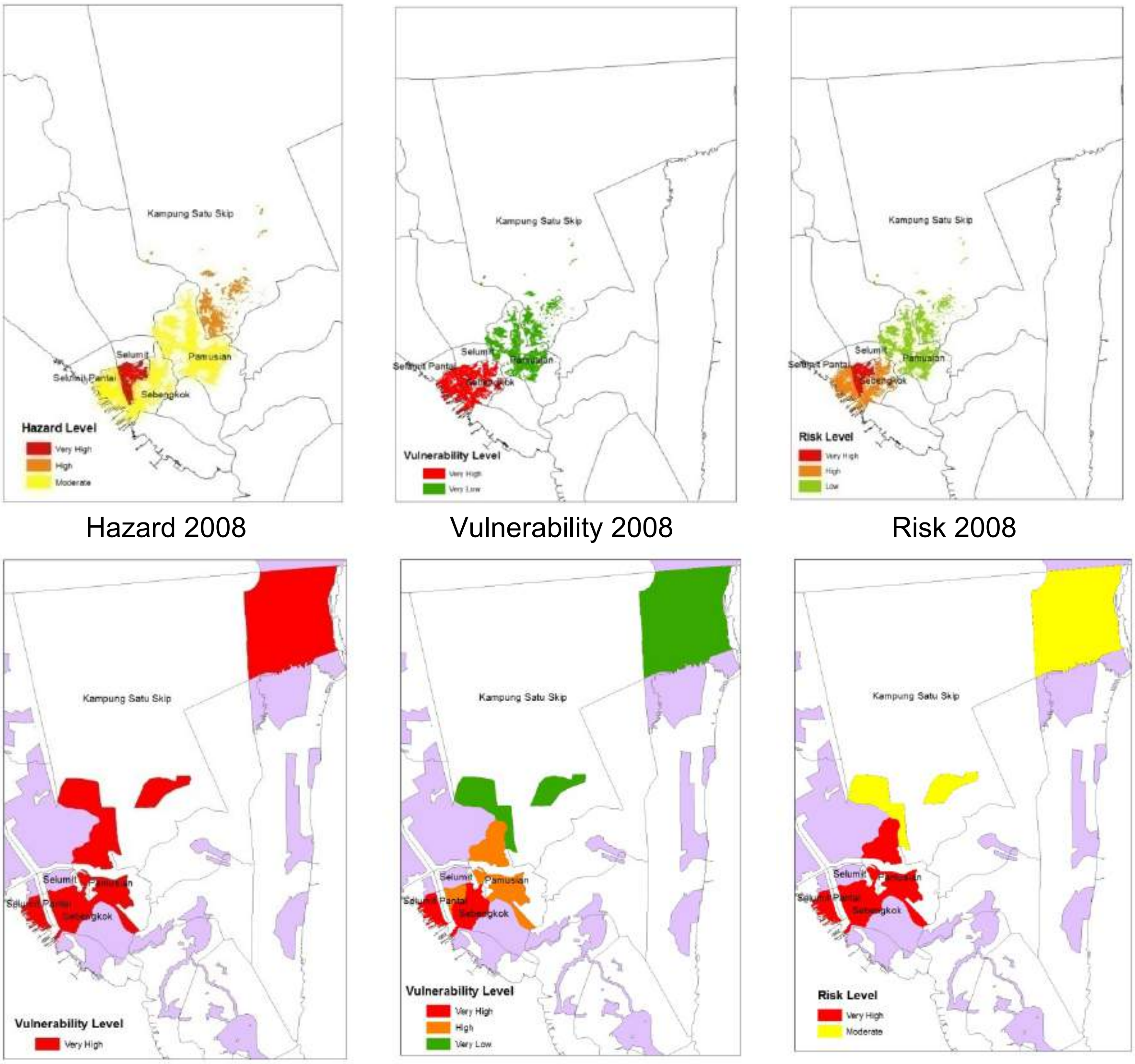
Table 7-5 show hazard, vulnerability and risk in each village in Tarakan Tengah both in 2008 and 2030. Moreover, visualization of each hazard, vulnerability and risk in each village in Tarakan Tengah both in 2008 and 2030 are drew in Figure 7-2. After analyzing the hazard, vulnerability and risk adaptation strategy, the category of adaptation strategy of each village in Tarakan Tengah can be defined as shown in Table 7-6.

Table 7.5: Hazard, Vulnerability and Risk of DHF in Tarakan Tengah

Sub district	Villages	Hazard			Vulnerability			Risk			Adap Str.
		2008	2030	Comp.	2008	2030	Comp.	2008	2030	Comp.	
Tarakan Tengah	Selumit Pantai	M	VH	+2	VH	VH	0	H	VH	+1	A
	Selumit	VH	VH	0	VH	H	-1	VH	VH	0	A
	Sebengkok	M	VH	+2	VH	VH	0	H	VH	+1	A
	Pamusian	M	VH	+2	VL	VL	0	L	M	+1	B
	Kampung Satu Skip	H	VH	+1	VL	VL	0	L	M	+1	B

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

As shown in Table 7-5, all villages in Tarakan Tengah have moderate until very high hazard level in 2008 and those be predicted increase in 2030 to become very high. Moreover, Selumit Pantai, Selumit and Sebengkok have high vulnerability, therefore Selumit Pantai, Selumit and Sebengkok are categorized as type A in adaptation strategy category. However, Pamusian and Kampung Satu Skip have very low vulnerability, therefore Pamusian and Kampung Satu Skip are categorized as type B in adaptation strategy category. Adaptation strategy in each village in Tarakan Tengah are described in detail in Table 7-6.



Hazard 2008 | Vulnerability 2008 | Risk 2008

Hazard 2030 | Vulnerability 2030 | Risk 2030

Figure 7-2 Map of Hazard, Vulnerability and Risk of DHF in 2008 and 2030 in Tarakan Tengah

Table 7.6: Adaptation Strategy Category of DHF for Each Village in Tarakan Tengah

Category	Villages	Adaptation Strategy
A	• Selumit Pantai • Selumit • Sebengkok	• 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 • Development of early warning method based on meteorogical surveillance • Selumit Pantai: control of population density and improve health facility • Selumit: control of population density • Sebengkok: control of population density and better

Category	Villages	Adaptation Strategy
		piped-water supply and covered water storage
B	• Pamusian • Kampung Satu Skip	• 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	• None	• None
D	• None	• None

7.2.3 Adaptation Strategy of DHF in Tarakan Barat

Similar with Tarakan Timur, hazard, vulnerability and risk of DHF in each village in Tarakan Barat 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 village in Tarakan Barat can be defined as shown in Table 7-8.

Table 7.7: Hazard, Vulnerability and Risk of DHF in Tarakan Barat

Sub district	Villages	Hazard			Vulnerability			Risk			Adap Str.
		2008	2030	Comp.	2008	2030	Comp.	2008	2030	Comp.	
Tarakan Barat	Karang Rejo	L	VH	+3	H	VH	+2	M	VH	+2	C
	Karang Balik	H	VH	+1	VL	VH	+4	L	VH	+3	A
	Karang Anyar	VH	VH	0	M	VL	-2	H	M	-1	B
	Karang Anyar Pantai	VL	M	+1	L	H	+2	VL	H	+3	C
	Karang Harapan	VL	M	+2	L	VL	-1	VL	L	+1	D

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

In Tarakan Barat, Karang Balik and Karang Anyar have high hazard in 2008 and those be predicted still high hazard in 2030. However, Karang Anyar has low vulnerability therefore Karang Anyar is categorized as type B of adaptation strategy. Karang Balik has high vulnerability therefore Karang Balik is category A. Vulnerability problem in Karang Balik is mainly caused by its limited health facility and low piped-water supply. In Tarakan Barat, in term of DHF control and eradication, Karang Balik should be treated as the most priority area.

Karang Rejo and Karang Anyar Pantai have low hazard but high vulnerability therefore Karang Rejo and Karang Anyar Pantai are categorized as type C of adaptation strategy. Karang Rejo has high vulnerability because its population density is too high. Karang Anyar Pantai has low piped-water supply and quite high population density. Eventhough Karang Rejo is predicted will have high hazard in 2030, type C is most appropriate because by maintaining its environment Karang Rejo may prevent the hazard increasing probability. Karang Harapan has low hazard and vulnerability therefore Karang Harapan is categorized as type D of adaptation strategy. Based on this classification, in general Tarakan Barat has low hazard but high vulnerability. In detail, adaptation strategy for each village in Tarakan Barat is described in Table 7-8 below.

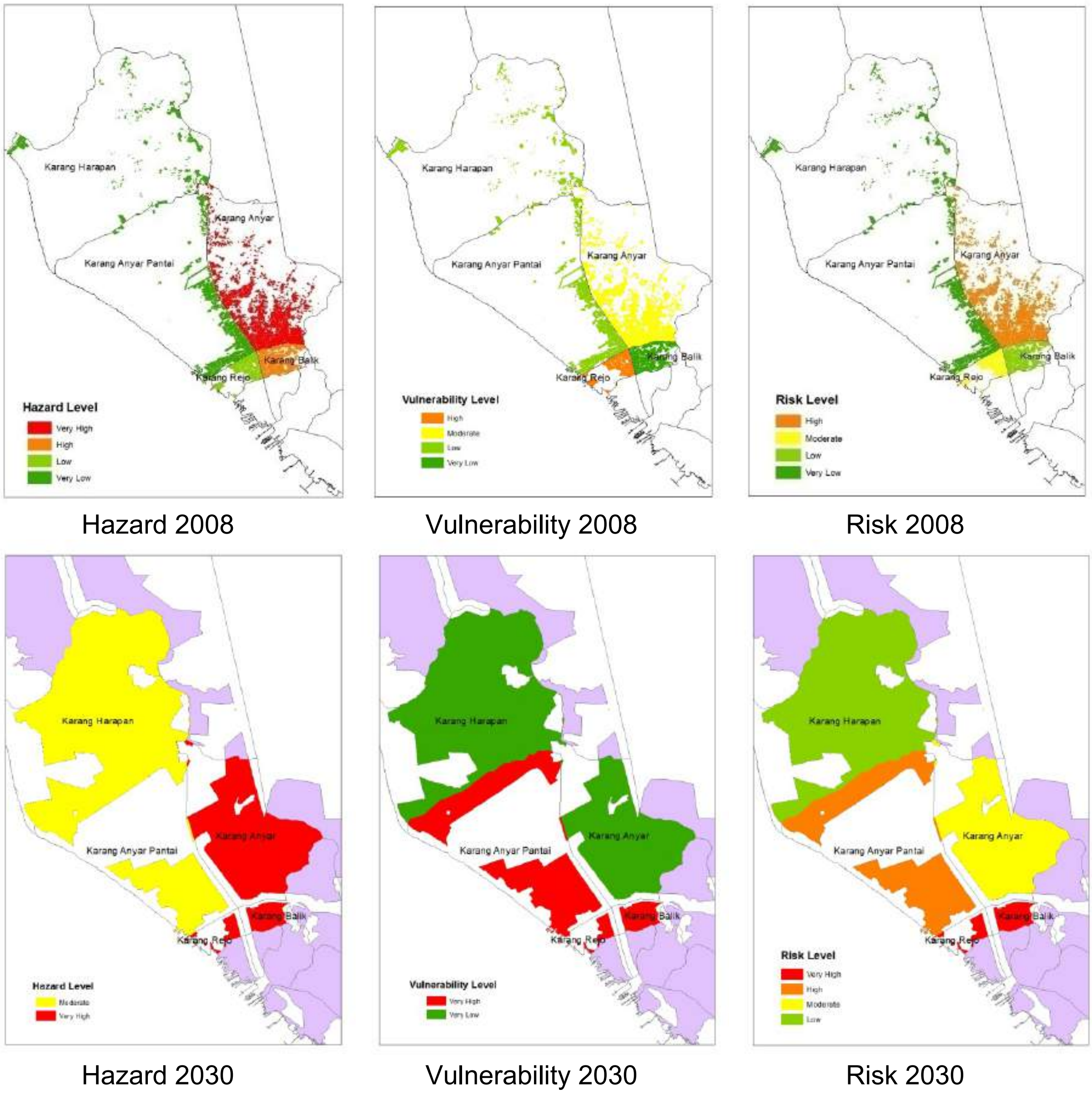


Figure 7-3 Map of Hazard, Vulnerability and Risk of DHF in 2008 and 2030 in Tarakan Barat

Table 7.8: Adaptation Strategy Category of DHF for Each Village in Tarakan Barat

Category	Villages	Adaptation Strategy
A	• Karang Balik	• 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 health facility • Better piped-water supply and covered water storage
B	• Karang Anyar	• Mosquito source reduction • Community and village level of vector management (pesticide fogging program at high incidence and

Category	Villages	Adaptation Strategy
		specific locations) • Vaccination on vulnerable population (still on trial) • Whole hospital and Puskesmas emergency alert • Increased Routine surveillance of DHF
C	• Karang Rejo	• Control of population density
	• Karang Anyar Pantai	• Better piped-water supply and covered water storage • Control of population density
D	• Karang Harapan	• 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

7.2.4 Adaptation Strategy of DHF in Tarakan Utara

Table 7-9 show hazard, vulnerability and risk in each village in Tarakan Utara both in 2008 and 2030. Moreover, visualization of each hazard, vulnerability and risk in each village in Tarakan Utara both in 2008 and 2030 are drew in Figure 7-4. After analyzing the hazard, vulnerability and risk adaptation strategy, the category of adaptation strategy of each village in Tarakan Utara can be defined as shown in Table 7-10.

Table 7.9: Hazard, Vulnerability and Risk of DHF in Tarakan Utara

Sub district	Villages	Hazard			Vulnerability			Risk			Adap Str.
		2008	2030	Comp.	2008	2030	Comp.	2008	2030	Comp.	
Tarakan Utara	Juata Permai	VH	VH	0	M	M	0	H	H	0	B
	Juata Kerikil	L	H	+2	L	VL	-1	L	L	0	B
	Juata Laut	VL	VH	+4	VH	H	-1	M	VH	+2	A

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

In Tarakan Utara, Juata Permai and Juata Kerikil have high hazard in 2008 and those be predicted still high hazard in 2030. However, Juata Permai and Juata Kerikil have low vulnerability therefore Juata Permai and Juata Kerikil are categorized as type B of adaptation strategy. Moreover, Juata Laut has high vulnerability therefore Juata Laut is defined as category A. Vulnerability problem in Juata Laut is mainly caused by its limited health facility. In Tarakan Utara, in term of DHF control and eradication, Juata Laut should be treated as the most priority area. In detail, adaptation strategy for each village in Tarakan Barat is described in Table 7-10 below.

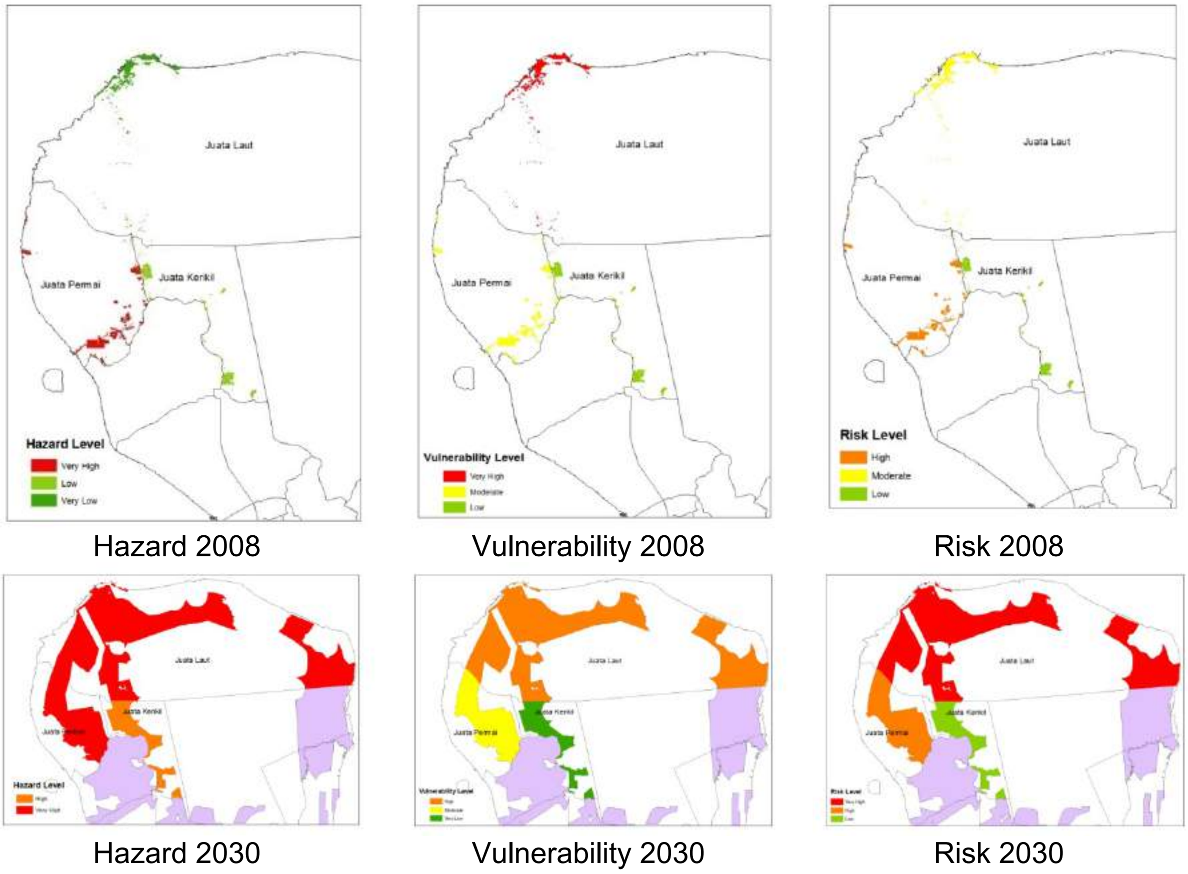


Figure 7-4 Map of Hazard, Vulnerability and Risk of DHF in 2008 and 2030 in Tarakan Utara

Table 7.10: Adaptation Strategy Category of DHF for Each Village in Tarakan Utara

Category	Villages	Adaptation Strategy
A	• Juata Laut	• 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 health facility • Development of early warning method based on meteorogical surveillance
B	• Juata Permai • Juata Kerikil	• 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	• None	• None
D	• None	• None

7.3 Adaptation Strategy for Malaria in Tarakan

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 villages in Tarakan are defined as shown in Table 7-11. 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 7.11: Adaptation Strategy Category of Malaria for Each Village in Tarakan

Sub district	Villages	Hazard			Vulnerability			Risk			Adap Str.
		2008	2030	Comp	2008	2030	Comp.	2008	2030	Comp.	
Tarakan Timur	Lingkas Ujung	VH	M	-2	VH	VL	-4	VH	L	-3	A
	Gunung Lingkas	VH	M	-2	M	VL	-2	H	L	-2	B
	Mamburungan	L	M	+1	H	VL	-3	M	L	-1	C
	Mamburungan Timur	L	M	+1	L	VL	-1	L	L	0	D
	Kampung Empat	H	M	-1	L	L	0	M	L	-1	B
	Kampung Enam	H	M	-1	L	M	+1	M	M	0	B
	Pantai Amal	H	M	-1	H	M	-1	H	M	-1	A
Tarakan Tengah	Selumit Pantai	VL	VL	0	VH	VH	0	M	L	-1	C
	Selumit	VL	VL	0	VH	VH	0	M	VL	-2	C
	Sebengkok	VL	VL	0	H	M	-1	L	L	0	C
	Pamusian	L	VL	-1	VL	M	+2	VL	L	+1	D
	Kampung Satu Skip	L	VL	-1	VL	VL	0	VL	VL	0	D
Tarakan Barat	Karang Rejo	VL	VL	0	VH	VH	0	M	M	0	C
	Karang Balik	VL	VL	0	L	VH	+3	VL	M	+2	C
	Karang Anyar	VL	VL	0	VL	M	+2	VL	L	+1	D
	Karang Anyar Pantai	VL	VL	0	H	M	-1	L	L	0	C
	Karang Harapan	VH	VL	-4	M	VL	-2	H	VL	-3	B
Tarakan Utara	Juata Permai	VH	VH	0	VL	L	+1	M	H	+1	B
	Juata Kerikil	VH	VH	0	M	M	0	H	H	0	B
	Juata Laut	M	VH	+2	M	VL	-2	M	M	0	D

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

Each category in Table 7-11 has different adaptation strategy as shown in Table 7-12.

Table 7.12: Adaptation Strategy for Malaria for Each Category in Tarakan

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)

Category	Adaptation Strategy
	• 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 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

7.3.1 Adaptation Strategy of Malaria in Tarakan Timur

Table 7-13 show hazard, vulnerability and risk of malaria in each village in Tarakan Timur both in 2008 and 2030. Moreover, visualization of each hazard, vulnerability and risk of malaria in each village in Tarakan Timur both in 2008 and 2030 are drew in Figure 7-5.

Table 7.13: Hazard, Vulnerability and Risk of Malaria in Tarakan Timur

Sub district	Villages	Hazard			Vulnerability			Risk			Adap Str.
		2008	2030	Comp	2008	2030	Comp.	2008	2030	Comp.	
Tarakan Timur	Lingkas Ujung	VH	M	-2	VH	VL	-4	VH	L	-3	A
	Gunung Lingkas	VH	M	-2	M	VL	-2	H	L	-2	B
	Mamburungan	L	M	+1	H	VL	-3	M	L	-1	C
	Mamburungan Timur	L	M	+1	L	VL	-1	L	L	0	D
	Kampung Empat	H	M	-1	L	L	0	M	L	-1	B

Sub district	Villages	Hazard			Vulnerability			Risk			Adap Str.
		2008	2030	Comp	2008	2030	Comp.	2008	2030	Comp.	
	Kampung Enam	H	M	-1	L	M	+1	M	M	0	B
	Pantai Amal	H	M	-1	H	M	-1	H	M	-1	A

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

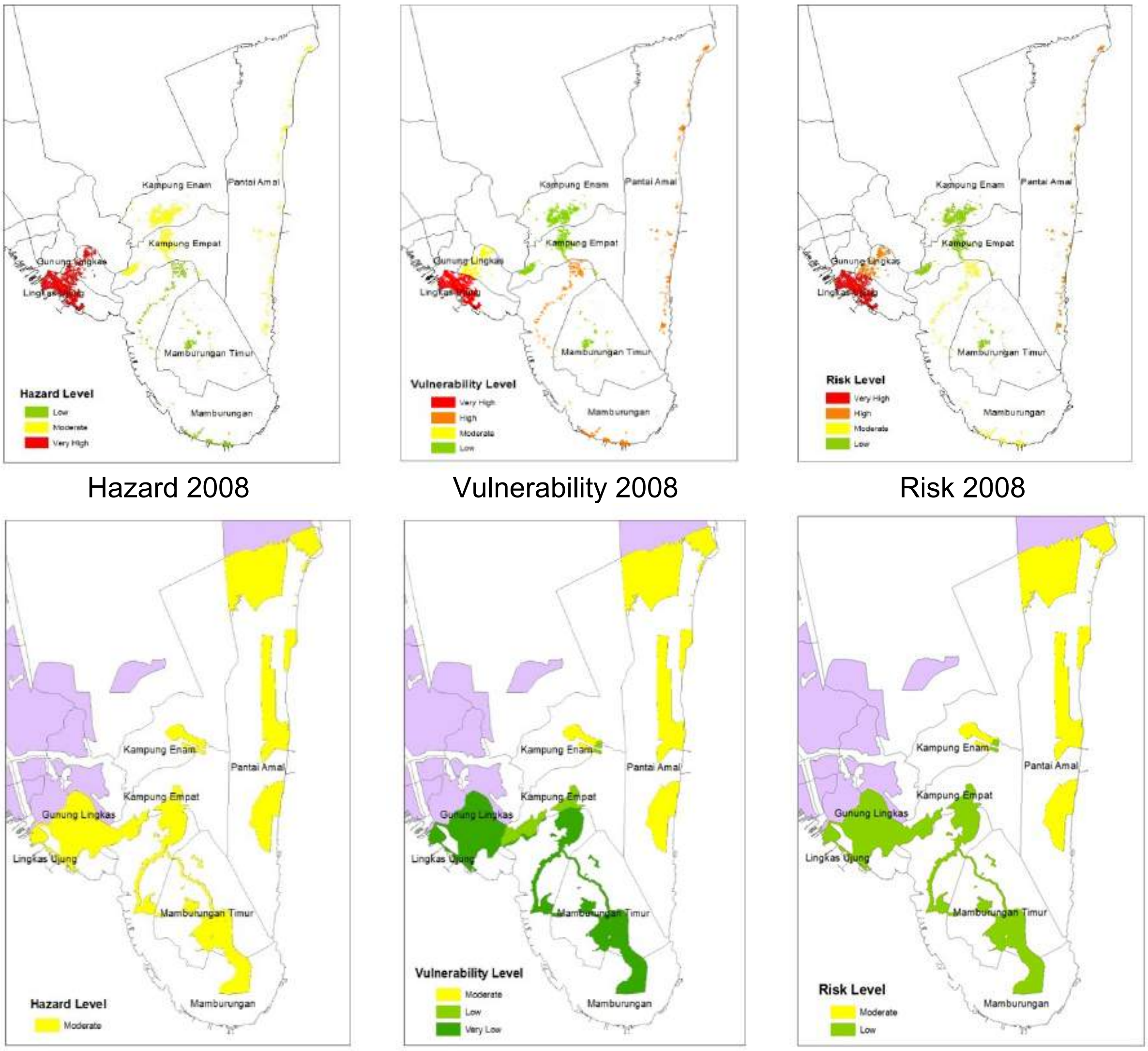


Figure 7-5 Map of Hazard, Vulnerability and Risk of Malaria 2008 and 2030 in Tarakan Timur

In Tarakan Timur, Gunung Lingkas, Kampung Empat, and Kampung Enam have high hazard in 2008 and those be predicted moderate hazard in 2030. However, those villages have low vulnerability therefore those villages are categorized as type B of adaptation strategy. In contrast, Mamburungan has high vulnerability but its hazard is low, therefore Mamburungan is defined as category C. Vulnerability problem in Mamburungan is mainly caused by housing quality; most people in Mamburungan live in non permanent house.

Lingkas Ujung and Pantai Amal have high hazard and vulnerability, therefore Lingkas Ujung and Pantai Amal are defined as category A. Vulnerability problem in Lingkas Ujung is mainly caused by its location; large population in Lingkas Ujung run their activities near the breeding site and most houses located near the breeding site. Moreover, vulnerability problem in Pantai Amal is mainly caused by housing quality; most people in Pantai Amal live in non permanent house. In Tarakan Timur, in term of malaria control and eradication, Lingkas Ujung and Pantai Amal should be treated as the most priority area.

Mamburungan Timur has low hazard and vulnerability therefore Mamburungan Timur is categorized as type D of adaptation strategy. In detail, adaptation strategy of malaria for each village in Tarakan Timur is described in Table 7-14 below.

Table 7.14: Adaptation Strategy Category of Malaria for Each Village in Tarakan Timur

Category	Villages	Adaptation Strategy
A	• Lingkas Ujung • Pantai Amal	• 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 regulation on environment and health)
B	• Gunung Lingkas • Kampung Empat	• 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	• Mamburungan	• Improvement of housing condition • Meteorological surveillance (rainfall, temperature) • Legislative measures (enforcement of existing regulation on environment and health)
D	• Mamburungan Timur	• 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

7.3.2 Adaptation Strategy of Malaria in Tarakan Tengah

Table 7-15 show hazard, vulnerability and risk of malaria in each village in Tarakan Tengah 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 malaria of each village in Tarakan Tengah can be defined as shown in Table 7-16.

Table 7.15: Hazard, Vulnerability and Risk of Malaria in Tarakan Tengah

Sub district	Villages	Hazard			Vulnerability			Risk			Adap Str.
		2008	2030	Comp	2008	2030	Comp.	2008	2030	Comp.	
Tarakan Tengah	Selumit Pantai	VL	VL	0	VH	VH	0	M	L	-1	C
	Selumit	VL	VL	0	VH	VH	0	M	VL	-2	C
	Sebengkok	VL	VL	0	H	M	-1	L	L	0	C
	Pamusian	L	VL	-1	VL	M	+2	VL	L	+1	D
	Kampung Satu Skip	L	VL	-1	VL	VL	0	VL	VL	0	D

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

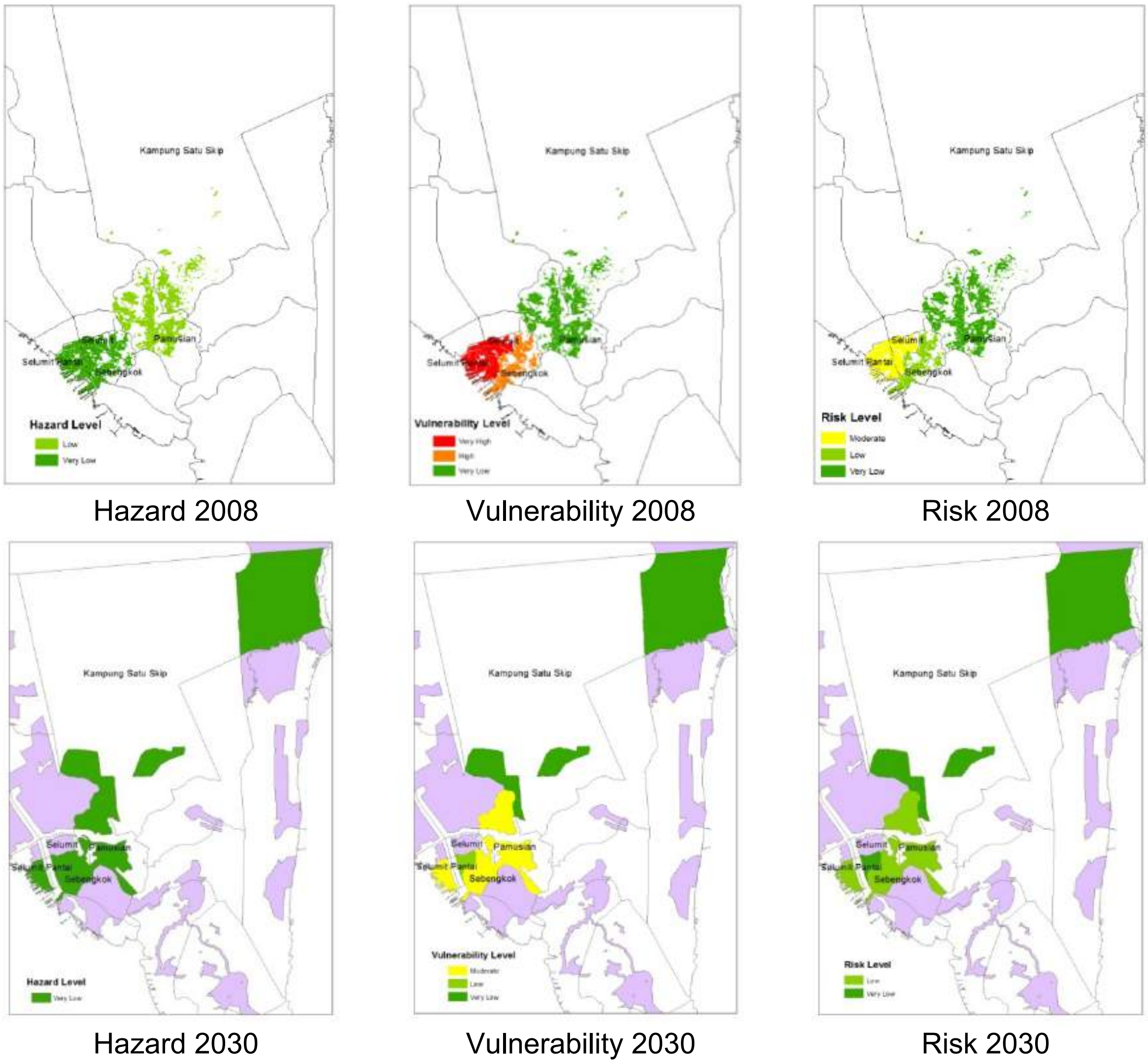


Figure 7-6 Map of Hazard, Vulnerability and Risk of Malaria 2008 and 2030 in Tarakan Tengah

In Tarakan Tengah Selumit Pantai, Selumit, and Sebengkok have low hazard but high vulnerability therefore Selumit Pantai, Selumit, and Sebengkok are categorized as type C of adaptation strategy. Vulnerability problems in Selumit Pantai are (a) large population run their activity near the breeding site, (b) most houses located near the breeding site, (c) most people live in non permanent housing, (d) low availability of health facility. Vulnerability problems in Selumit are (a) large population run their activity near the breeding site, and (b) most houses located near the breeding site. Moreover, vulnerability problems in Sebengkok is caused by its limited health facility.

Pamusian and Kampung Satu Skip have low both hazard and vulnerability therefore Pamusian and Kampung Satu Skip are categorized as type D of adaptation strategy. Based on this classification, in general Tarakan Tengah has low hazard and high vulnerability of malaria in partial area. In detail, adaptation strategy of malaria for each village in Tarakan Tengah is described in Table 7-16 below.

Table 7.16: Adaptation Strategy Category of Malaria for Each Village in Tarakan Tengah

Category	Villages	Adaptation Strategy
A	• None	• None
B	• None	• None
C	• Selumit Pantai • Selumit • Sebengkok	• Selumit Pantai and Selumit: improvement of housing condition especially that are located near breeding site of malaria mosquito • Sebengkok and Selumit Pantai: improve health facility • In coastal area: coastal reclamation (drying of swamps and lagoons) and mangrove reforestation
D	• Pamusian • Kampung Satu Skip	• 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

7.3.3 Adaptation Strategy of Malaria in Tarakan Barat

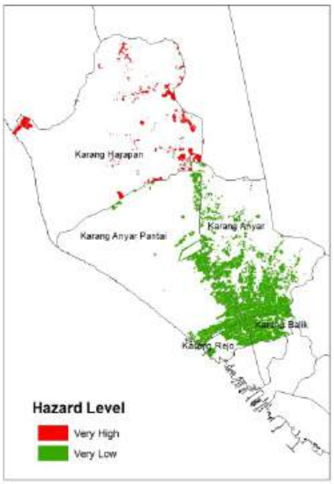
Table 7-17 show hazard, vulnerability and risk of malaria in each village in Tarakan Barat both in 2008 and 2030. Moreover, its visualizations are drew in Figure 7-7. After analyzing the hazard, vulnerability and risk adaptation strategy, the category of adaptation strategy of malaria in each village in Tarakan Barat can be defined as shown in Table 7-18.

Table 7.17: Hazard, Vulnerability and Risk of Malaria in Tarakan Barat

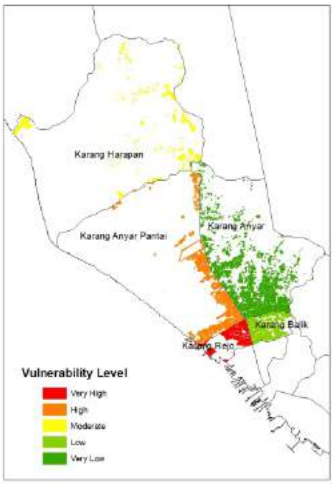
Sub district	Villages	Hazard			Vulnerability			Risk			Adap Str.
		2008	2030	Comp	2008	2030	Comp.	2008	2030	Comp.	
Tarakan Barat	Karang Rejo	VL	VL	0	VH	VH	0	M	M	0	C
	Karang Balik	VL	VL	0	L	VH	+3	VL	M	+2	C
	Karang Anyar	VL	VL	0	VL	M	+2	VL	L	+1	D

Sub district	Villages	Hazard			Vulnerability			Risk			Adap Str.
		2008	2030	Comp	2008	2030	Comp.	2008	2030	Comp.	
	Karang Anyar Pantai	VL	VL	0	H	M	-1	L	L	0	C
	Karang Harapan	VH	VL	-4	M	VL	-2	H	VL	-3	B

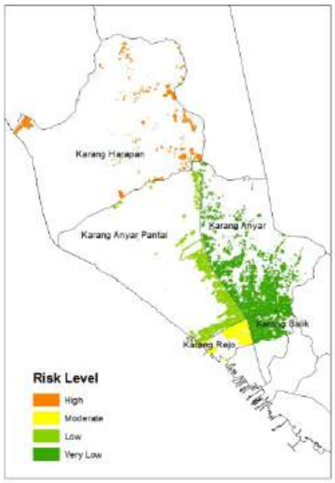
Note: Comp = comparison, Adap Str. = adaptation strategy category



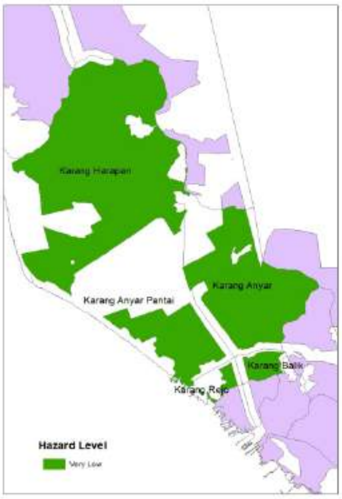
Hazard 2008



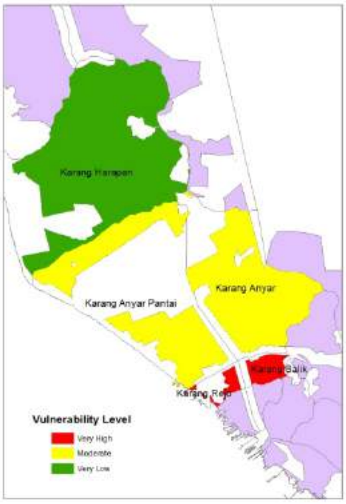
Vulnerability 2008



Risk 2008



Hazard 2030



Vulnerability 2030

Risk 2030

Figure 7-7 Map of Hazard, Vulnerability and Risk of Malaria 2008 and 2030 in Tarakan Barat

In Tarakan Barat, Karang Harapan has very high hazard in 2008 eventhough it is predicted to decrease in 2030. Karang Harapan has low vulnerability therefore Karang Harapan is categorized as type B of adaptation strategy for malaria. Karang Rejo, Karang Balik and Karang Anyar Pantai have very low hazard but high vulnerability therefore Karang Rejo, Karang Balik and Karang Anyar Pantai are categorized as type C of adaptation strategy for malaria. Vulnerability problems in Karang Rejo are (a) large population run their activity near the breeding site, and (b) most houses located near the breeding site. Vulnerability problems in Karang Balik in future probably has not sufficient of health facility. Moreover, vulnerability problems in Karang Anyar Pantai are low availability of health facility.

Karang Anyar has very low both hazard and vulnerability therefore Karang Anyar is categorized as type D of adaptation strategy for malaria. Based on this classification, in general Tarakan Barat has low hazard but high vulnerability in partial area. In detail, adaptation strategy for malaria in each village in Tarakan Barat is described in Table 7-18 below.

Table 7.18: Adaptation Strategy Category of Malaria for Each Village in Tarakan Barat

Category	Villages	Adaptation Strategy
A	• None	• None
B	• Karang Harapan	• 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	• Karang Rejo • Karang Balik • Karang Anyar Pantai	• Karang Rejo: improvement of housing condition especially that are located near breeding site of malaria mosquito • Karang Balik and Karang Anyar Pantai: improvement of health facility. • In coastal area: coastal reclamation (drying of swamps and lagoons) and mangrove reforestation
D	• Karang Anyar	• 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

7.3.4 Adaptation Strategy of Malaria in Tarakan Utara

Table 7-19 show hazard, vulnerability and risk of malaria in each village in Tarakan Utara both in 2008 and 2030. Moreover, its visualizations are drew in Figure 7-8. After analyzing the hazard, vulnerability and risk adaptation strategy, the category of adaptation strategy of malaria in each village in Tarakan Utara can be defined as shown in Table 7-20.

Table 7.19: Hazard, Vulnerability and Risk of Malaria in Tarakan Utara

Sub district	Villages	Hazard			Vulnerability			Risk			Adap Str.
		2008	2030	Comp	2008	2030	Comp.	2008	2030	Comp.	
Tarakan Utara	Juata Permai	VH	VH	0	VL	L	+1	M	H	+1	B
	Juata Kerikil	VH	VH	0	M	M	0	H	H	0	B
	Juata Laut	M	VH	+2	M	VL	-2	M	M	0	D

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

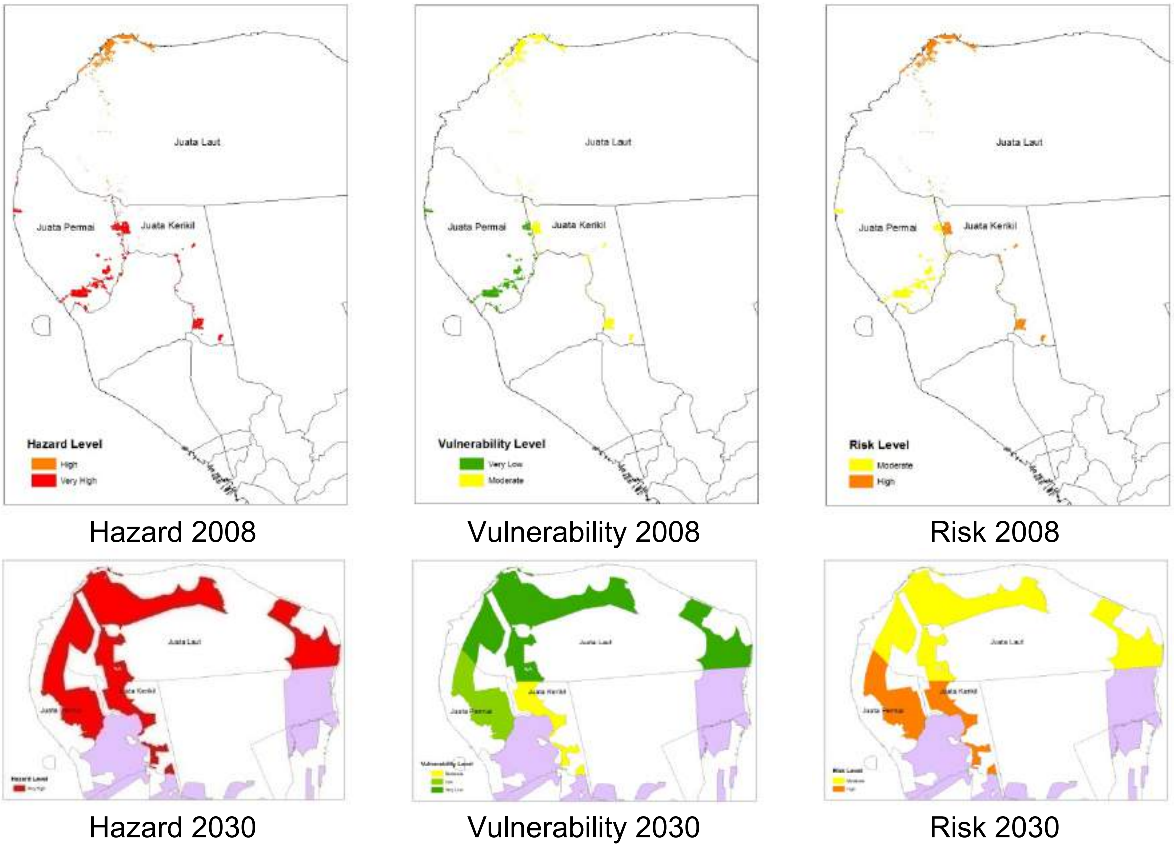


Figure 7-8 Map of Hazard, Vulnerability and Risk of Malaria 2008 and 2030 in Tarakan Utara

In Tarakan Utara, Juata Permai and Juata Kerikil have high hazard of malaria both in 2008 and those be predicted still high hazard in 2030. However, Juata Permai and Juata Kerikil have low vulnerability therefore Juata Permai and Juata Kerikil are categorized as type B of adaptation strategy for malaria. Moreover, Juata Laut has moderate hazard and vulnerability therefore Juata Laut is categorized as type D of adaptation strategy for malaria. However, hazard in Juata Laut may increase therefore health facility in Juata Laut should be improved. In general, Tarakan Utara has high hazard but low vulnerability. In detail, adaptation strategy for malaria in each village in Tarakan Utara is described in Table 7-20 below.

Table 7.20: Adaptation Strategy Category of Malaria for Each Village in Tarakan Utara

Category	Villages	Adaptation Strategy
A	• None	• None
B	• Juata Permai • Juata Kerikil	• 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	• None	• None
D	• Juata Laut	• Household level of mosquito bites prevention (Abate, spray cans, mosquito coils, repellents etc.) • Routine annual or twice per year seasonal spraying

Category	Villages	Adaptation Strategy
		• 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 Tarakan

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 villages in Tarakan are defined as shown in Table 7-21. Adaptation strategy of diarrhea is defined as A, B, C, and D category depend on its hazard and vulnerability level.

Table 7.21: Adaptation Strategy Category of Diarrhea for Each Village in Tarakan

Sub district	Villages	Hazard			Vulnerability			Risk			Adap Str.
		2008	2030	Comp.	2008	2030	Comp.	2008	2030	Comp.	
Tarakan Timur	Lingkas Ujung	VH	VH	0	H	VL	-3	VH	VH	0	A
	Gunung Lingkas	VH	VH	0	VL	VL	0	M	VH	+2	B
	Mamburungan	L	M	+1	H	VL	-3	M	H	+1	C
	Mamburungan Timur	L	M	+1	VH	VL	-4	H	M	-1	C
	Kampung Empat	VL	M	+2	L	L	0	VL	H	+3	D
	Kampung Enam	VL	M	+2	H	M	-1	L	L	0	C
	Pantai Amal	VL	M	+2	VH	M	-2	M	L	-1	C
Tarakan Tengah	Selumit Pantai	VL	L	+1	VH	M	-2	M	H	+1	C
	Selumit	VL	VL	0	L	L	0	VL	VL	0	D
	Sebengkok	VL	L	+1	M	M	0	L	M	+1	D
	Pamusian	L	M	+1	VL	M	+2	VL	H	+3	D
	Kampung Satu Skip	L	M	+1	VL	VL	0	VL	M	+2	D
Tarakan Barat	Karang Rejo	M	M	0	L	VH	+3	L	H	+2	D
	Karang Balik	M	M	0	VL	VH	+4	L	H	+2	D
	Karang Anyar	M	VL	-2	M	M	0	M	VL	-2	D
	Karang Anyar Pantai	M	M	0	L	M	+1	L	H	+3	D
	Karang Harapan	VH	VH	0	M	VL	-2	H	H	0	B
Tarakan Utara	Juata Permai	VH	VH	0	M	L	-1	H	H	0	B
	Juata Kerikil	VH	VH	0	H	M	-1	VH	H	-1	A
	Juata Laut	H	H	0	VH	VL	-4	VH	VH	0	A

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

Each category in Table 7-21 has different adaptation strategy as shown in Table 7-22

Table 7.22: Adaptation Strategy for Diarrhea for Each Category in Tarakan

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 Tarakan Timur

Table 7-23 show hazard, vulnerability and risk of diarrhea in each village in Tarakan Timur both in 2008 and 2030. Moreover, its visualization are drew in Figure 7-9. After analyzing the hazard, vulnerability and risk adaptation strategy, the category of adaptation strategy for diarrhea of each village in Tarakan Timur can be defined as shown in Table 7-24.

Table 7.23: Hazard, Vulnerability and Risk of Diarrhea in Tarakan Timur

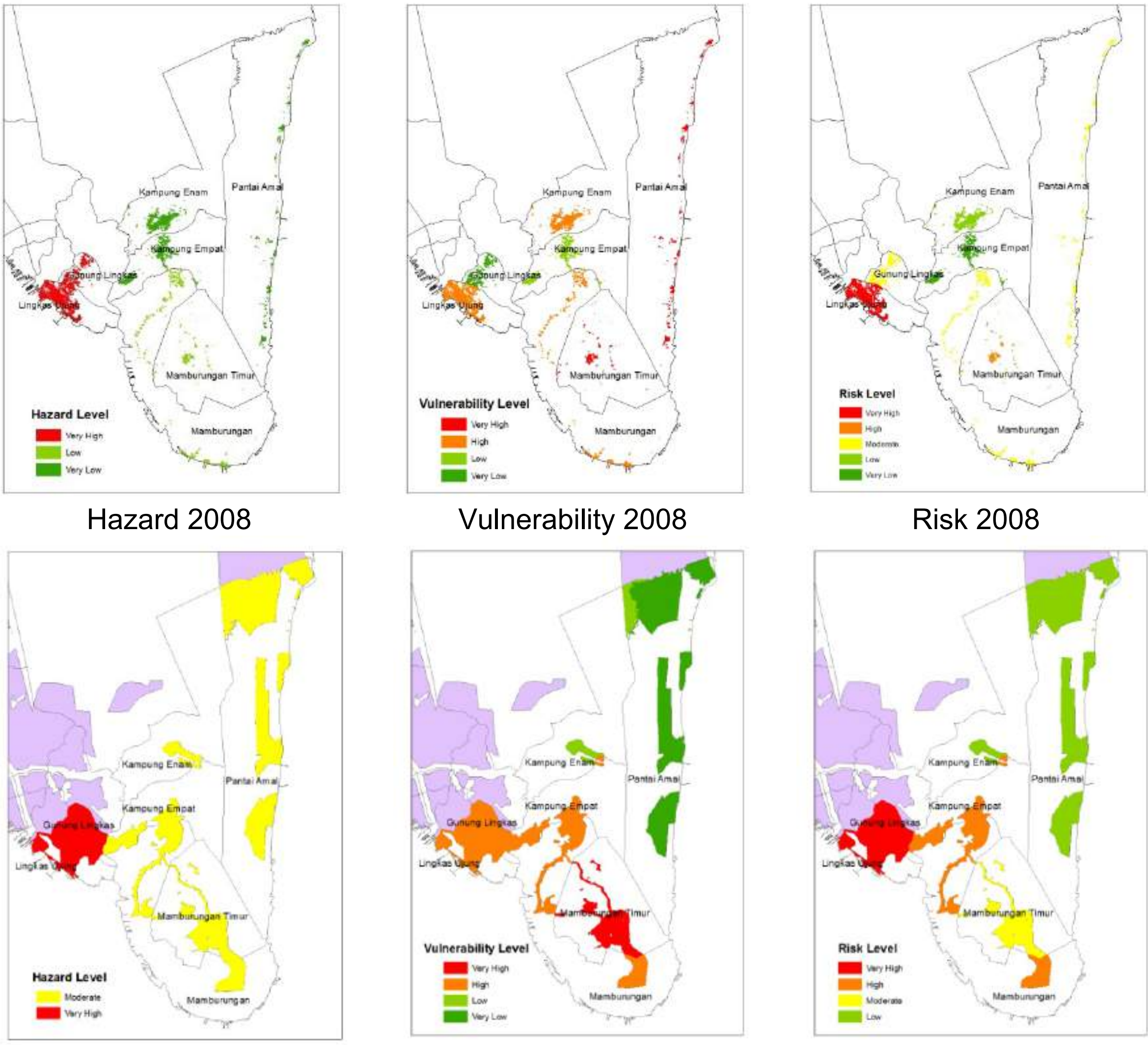
Sub district	Villages	Hazard			Vulnerability			Risk			Adap Str.
		2008	2030	Comp.	2008	2030	Comp.	2008	2030	Comp.	
Tarakan Timur	Lingkas Ujung	VH	VH	0	H	VL	-3	VH	VH	0	A
	Gunung Lingkas	VH	VH	0	VL	VL	0	M	VH	+2	B
	Mamburungan	L	M	+1	H	VL	-3	M	H	+1	C
	Mamburungan Timur	L	M	+1	VH	VL	-4	H	M	-1	C
	Kampung Empat	VL	M	+2	L	L	0	VL	H	+3	D
	Kampung Enam	VL	M	+2	H	M	-1	L	L	0	C
	Pantai Amal	VL	M	+2	VH	M	-2	M	L	-1	C

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

In Tarakan Timur, Lingkas Ujung and Gunung Lingkas has very high hazard in 2008 and those are predicted still very high hazard in 2030. Moreover, Lingkas Ujung has high vulnerability therefore Lingkas Ujung is categorized as type A of adaptation strategy for diarrhea. However, Gunung Lingkas has very low vulnerability therefore Gunung Lingkas is defined as category B. Vulnerability problem in Lingkas Ujung is caused by its limited health facility. In Tarakan Timur, in term of diarrhea control and eradication, Lingkas Ujung should be treated as the most priority area.

Mamburungan, Mamburungan Timur, Kampung Enam, and Pantai Amal have low hazard but high vulnerability therefore those villages are categorized as type C of adaptation strategy for diarrhea. Vulnerability problem in Mamburungan is low piped-water coverage, and vulnerability problem in Mamburungan Timur are (1) most of houses not equipped by toilet, (2) low piped-water coverage, and (3) low availability of health facilities. Moreover, vulnerability problem in Kampung Enam is low availability of health facilities and vulnerability problems in Pantai Amal are (1) most of houses not equipped by toilet and (2) low piped-water coverage.

Kampung Empat has low both hazard and vulnerability therefore Kampung Empat is categorized as type D of adaptation strategy. Based on this classification, in general Tarakan Timur has low hazard but high vulnerability. In detail, adaptation strategy for each village in Tarakan Timur is described in Table 7-24 below.



Hazard 2008 | Vulnerability 2008 | Risk 2008

Hazard 2030 | Vulnerability 2030 | Risk 2030

Figure 7-9 Map of Hazard, Vulnerability and Risk of Diarrhea 2008 and 2030 in Tarakan Timur

Table 7.24:Adaptation Strategy Category of Diarrhea for Each Village in Tarakan Timur

Category	Villages	Adaptation Strategy
A	• Lingkas Ujung	• 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

Category	Villages	Adaptation Strategy
		• If flood occur do better sanitation system in flood refugee camps • Legislative measures (enforcement of existing regulation on environment and health) • Improvement of health facility
B	• Gunung Lingkas	• 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	• Mamburungan • Mamburungan Timur • Kampung Enam • Pantai Amal	• Pantai Amal: Improvement of household sewer system and adaptation of greywater usage • Mamburungan, Mamburungan Timur and Pantai Amal : Extensive use of piped-water (PDAM) and increased of household piped-water • Kampung Enam: Improvement of health facility • Legislative measures (enforcement of existing regulation on environment and health)
D	• Kampung Empat	• 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

7.4.2 Adaptation Strategy of Diarrhea in Tarakan Tengah

Table 7-25 show hazard, vulnerability and risk of diarrhea in each village in Tarakan Tengah both in 2008 and 2030. Moreover, its visualizations are drew in Figure 7-10. After analyzing the hazard, vulnerability and risk adaptation strategy, the category of adaptation strategy of diarrhea of each village in Tarakan Tengah can be defined as shown in Table 7-26.

Table 7.25: Hazard, Vulnerability and Risk of Diarrhea in Tarakan Tengah

Sub district	Villages	Hazard			Vulnerability			Risk			Adap Str.
		2008	2030	Comp.	2008	2030	Comp.	2008	2030	Comp.	
Tarakan Tengah	Selumit Pantai	VL	L	+1	VH	M	-2	M	H	+1	C
	Selumit	VL	VL	0	L	L	0	VL	VL	0	D
	Sebengkok	VL	L	+1	M	M	0	L	M	+1	D
	Pamusian	L	M	+1	VL	M	+2	VL	H	+3	D
	Kampung Satu	L	M	+1	VL	VL	0	VL	M	+2	D

Sub district	Villages	Hazard			Vulnerability			Risk			Adap Str.
		2008	2030	Comp.	2008	2030	Comp.	2008	2030	Comp.	
	Skip										

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

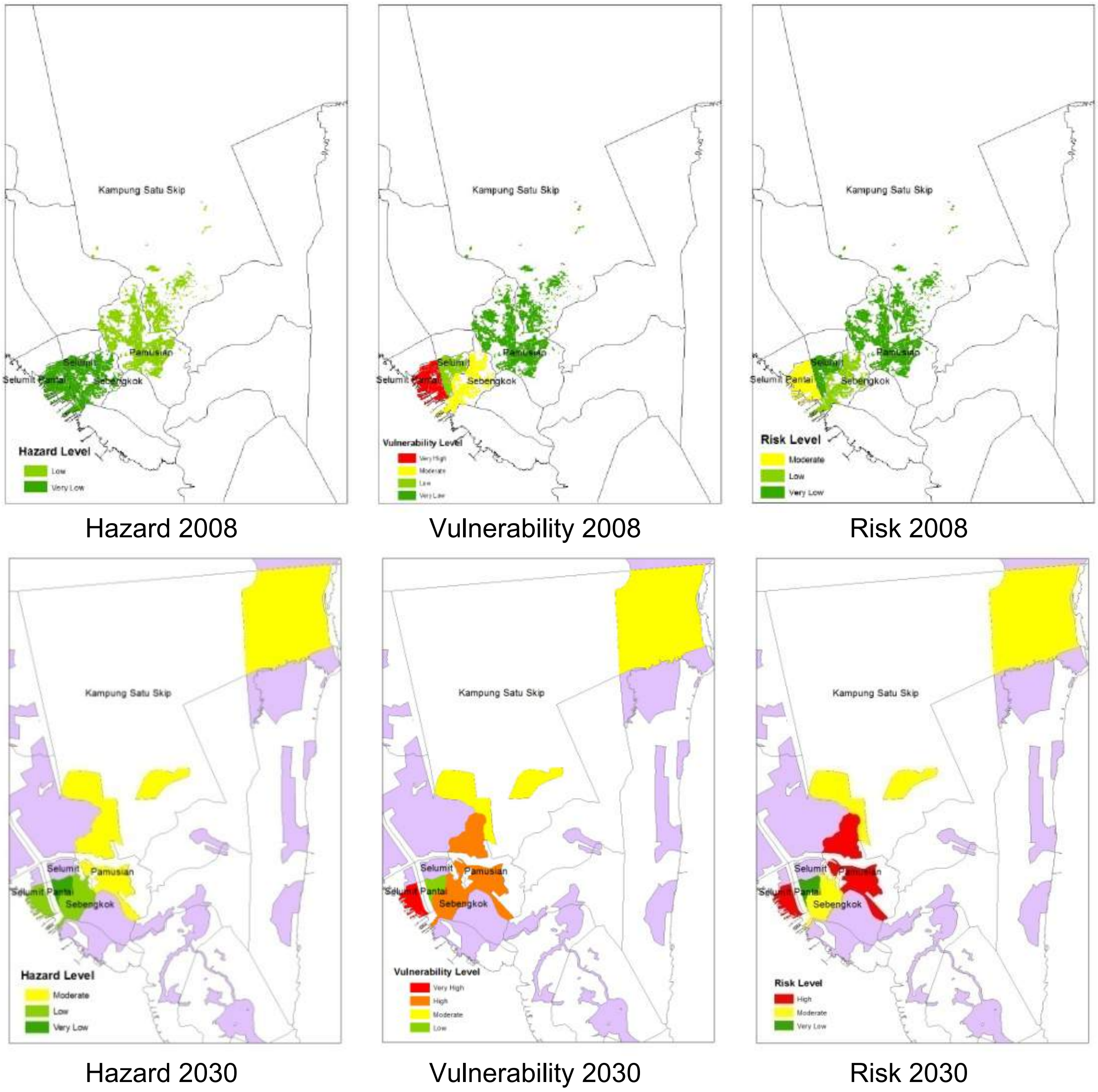


Figure 7-10 Map of Hazard, Vulnerability and Risk of Diarrhea 2008 and 2030 in Tarakan Tengah

In Tarakan Tengah, Selumit Pantai has very low hazard in 2008 and those be predicted low hazard in 2030. However Selumit Pantai has high vulnerability therefore Selumit Pantai is categorized as type C of adaptation strategy. Vulnerability problem in Selumit Pantai is mainly caused by most of houses not equipped by toilet and low piped-water coverage.

Selumit, Sebengkok, Pamusian and Kampung Satu Skip have low hazard and vulnerability therefore those villages are categorized as type D of adaptation strategy. Based on this classification, in general Tarakan Tengah has low hazard and low vulnerability. In detail, adaptation strategy for each village in Tarakan Tengah is described in Table 7-26 below.

Table 7.26: Adaptation Strategy Category of Diarrhea for Each Village in Tarakan Tengah

Category	Villages	Adaptation Strategy
A	• None	• None
B	• None	• None
C	• Selumit Pantai	• Improvement of health facility • Improvement of household sewer system and adaptation of greywater usage • Decrease the population density • Legislative measures (enforcement of existing regulation on environment and health)
D	• Selumit • Sebengkok • Pamusian • Kampung Satu Skip	• 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

7.4.3 Adaptation Strategy of Diarrhea in Tarakan Barat

Table 7-27 show hazard, vulnerability and risk in each village in Tarakan Barat both in 2008 and 2030. Moreover, visualization of each hazard, vulnerability and risk in each village in Tarakan Barat both in 2008 and 2030 are drew in Figure 7-11. After analyzing the hazard, vulnerability and risk adaptation strategy, the category of adaptation strategy of each village in Tarakan Barat can be defined as shown in Table 7-28.

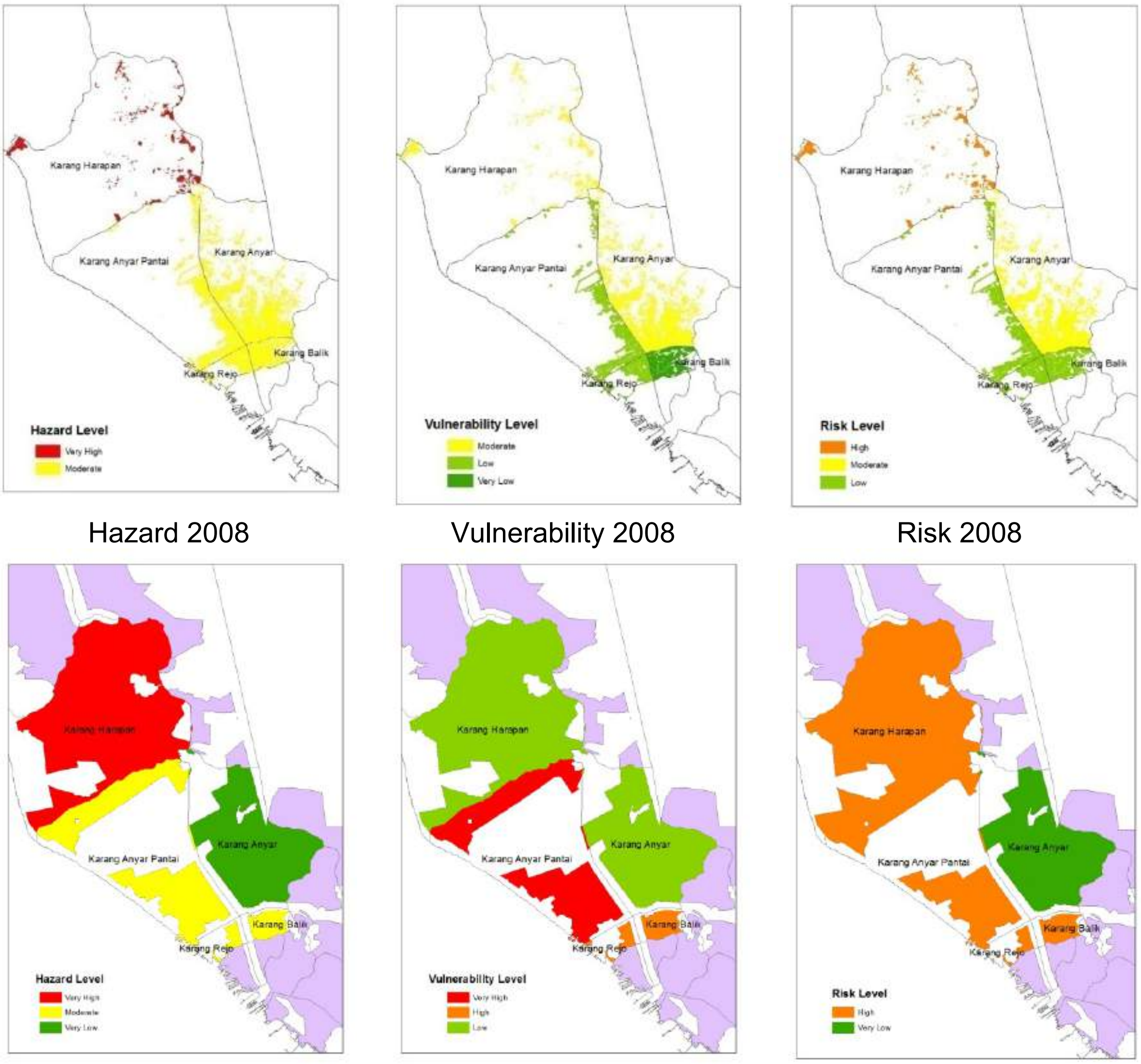
Table 7.27: Hazard, Vulnerability and Risk of Diarrhea in Tarakan Barat

Sub district	Villages	Hazard			Vulnerability			Risk			Adap Str.
		2008	2030	Comp.	2008	2030	Comp.	2008	2030	Comp.	
Tarakan Barat	Karang Rejo	M	M	0	L	VH	+3	L	H	+2	C
	Karang Balik	M	M	0	VL	VH	+4	L	H	+2	C
	Karang Anyar	M	VL	-2	M	M	0	M	VL	-2	D
	Karang Anyar Pantai	M	M	0	L	M	+1	L	H	+3	D
	Karang Harapan	VH	VH	0	M	VL	-2	H	H	0	B

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

In Tarakan Barat, Karang Harapan has very high hazard in 2008 and those be predict still very high hazard in 2030. However Karang Harapan has low vulnerability therefore Karang Harapan is categorized as type B of adaptation strategy.

Karang Anyar and Karang Anyar Pantai have low hazard and vulnerability therefore those villages are categorized as type D of adaptation strategy. Moreover, vulnerability of Karang Rejo and Karang Balik are predicted will increase to very high, therefore Karang Rejo and Karang Balik are categorized as type C of adaptation strategy. In detail, adaptation strategy for each village in Tarakan Barat is described in Table 7-28 below.



Hazard 2008 | Vulnerability 2008 | Risk 2008

Hazard 2030 | Vulnerability 2030 | Risk 2030

Figure 7-11 Map of Hazard, Vulnerability and Risk of Diarrhea 2008 and 2030 in Tarakan Barat

Table 7.28: Adaptation Strategy Category of Diarrhea for Each Village in Tarakan Barat

Category	Villages	Adaptation Strategy
A	• None	• None
B	• Karang Harapan	• 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

Category	Villages	Adaptation Strategy
		method based on meteorogical surveillance • Increased community participation • If flood occur do better sanitation system in flood refugee camps
C	• Karang Rejo • Karang Balik	• Continue improving environment and sanitation quality
D	• Karang Anyar • Karang Anyar Pantai	• 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

7.4.4 Adaptation Strategy of Diarrhea in Tarakan Utara

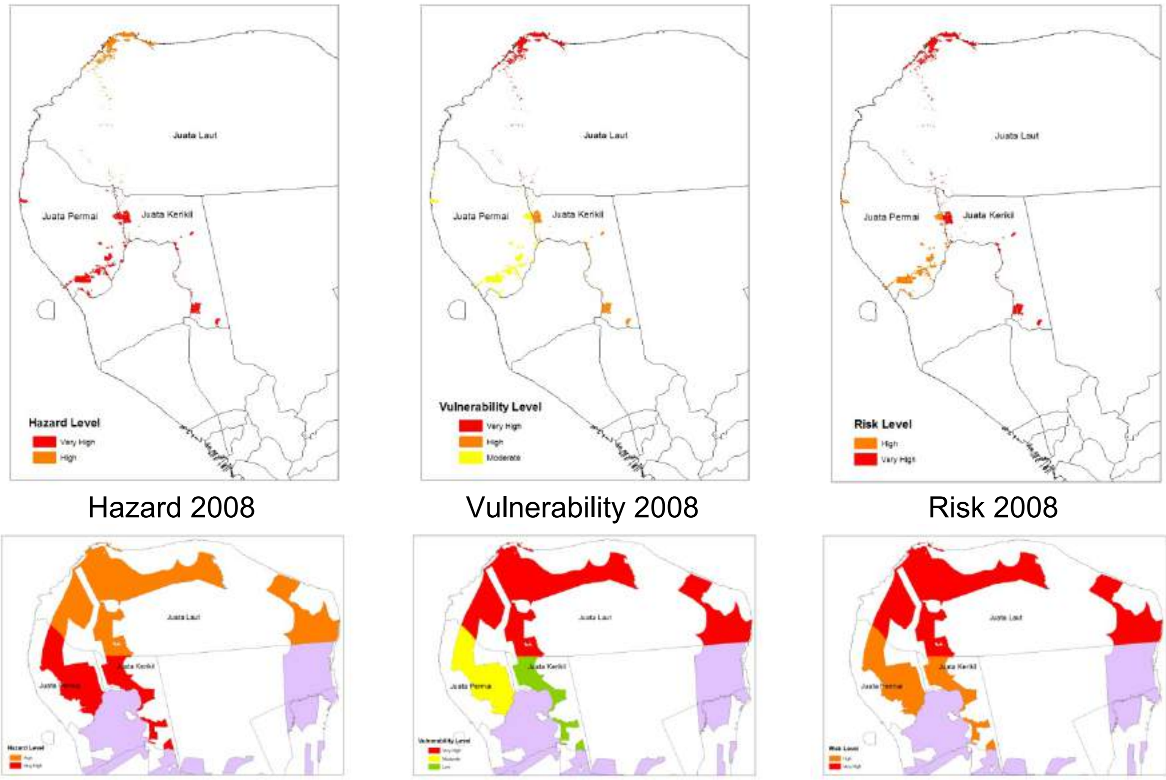
Table 7-29 show hazard, vulnerability and risk in each village in Tarakan Utara both in 2008 and 2030. Moreover, visualization of its hazard, vulnerability and risk in each village in Tarakan Utara both in 2008 and 2030 are drew in Figure 7-12. After analyzing the hazard, vulnerability and risk adaptation strategy, the category of adaptation strategy of each village in Tarakan Utara can be defined as shown in Table 7-30.

Table 7.29: Hazard, Vulnerability and Risk of Diarrhea in Tarakan Utara

Sub district	Villages	Hazard			Vulnerability			Risk			Str. Adp
		2008	2030	Comp.	2008	2030	Comp.	2008	2030	Comp.	
Tarakan Utara	Juata Permai	VH	VH	0	M	L	-1	H	H	0	B
	Juata Kerikil	VH	VH	0	H	M	-1	VH	H	-1	A
	Juata Laut	H	H	0	VH	VL	-4	VH	VH	0	A

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

In Tarakan Utara, Juata Kerikil and Juata Laut have high hazard and vulnerability therefore Juata Kerikil and Juata Laut are defined as category A of adaptation strategy. Moreover, Juata Permai has high hazard in 2008 and be predicted still high hazard in 2030. However, Juata Permai has low vulnerability therefore Juata Permai is categorized as type B of adaptation strategy. In Tarakan Utara, Juata Kerikil and Juata Laut should be treated as the most priority area. In detail, adaptation strategy for each village in Tarakan Utara is described in Table 7-30 below.



Hazard 2008 | Vulnerability 2008 | Risk 2008

Hazard 2030 | Vulnerability 2030 | Risk 2030

Figure 7-12 Map of Hazard, Vulnerability and Risk of Diarrhea 2008 and 2030 in Tarakan Utara

Table 7.30: Adaptation Strategy Category of Diarrhea for Each Village in Tarakan Timur

Category	Villages	Adaptation Strategy
A	• Juata Kerikil • Juata Laut	• 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 • Legislative measures (enforcement of existing regulation on environment and health) • Juata Kerikil: Extensive use of piped-water (PDAM) and increased of household piped-water • Juata Laut: Improvement of health facility

Category	Villages	Adaptation Strategy
B	• Juata Permai	• 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

In term of human health, Tarakan Island is unique in the sense that its general health condition is above the national health standard in many respects. It is known that human health is the results of three synergistic factors, namely genetic, environment and behavior. Recent issues of climate change brought specific alteration in environmental condition. Specifically, the increment of rainfall and temperature will affect the nature of disease agents. Therefore, to understand climate variability and climate change impact to health condition in Tarakan, the study for analysis hazard, vulnerability, risk and adaptation strategy for Tarakan were conducted.

8.1.1 Hazard Analysis

Hazard of DHF, malaria, and diarrhea in Tarakan island have been analyzed. For monthly incidence data there are only DHF data is available; malaria and diarrhea incidence data available only in yearly data. Thus, DHF data analysis is more detail than malaria and diarrhea. For example, it is found that the increase of monthly DHF cases is related with the increase of monthly rainfall with lag about 0 until 1 month (see Figure 8.1).

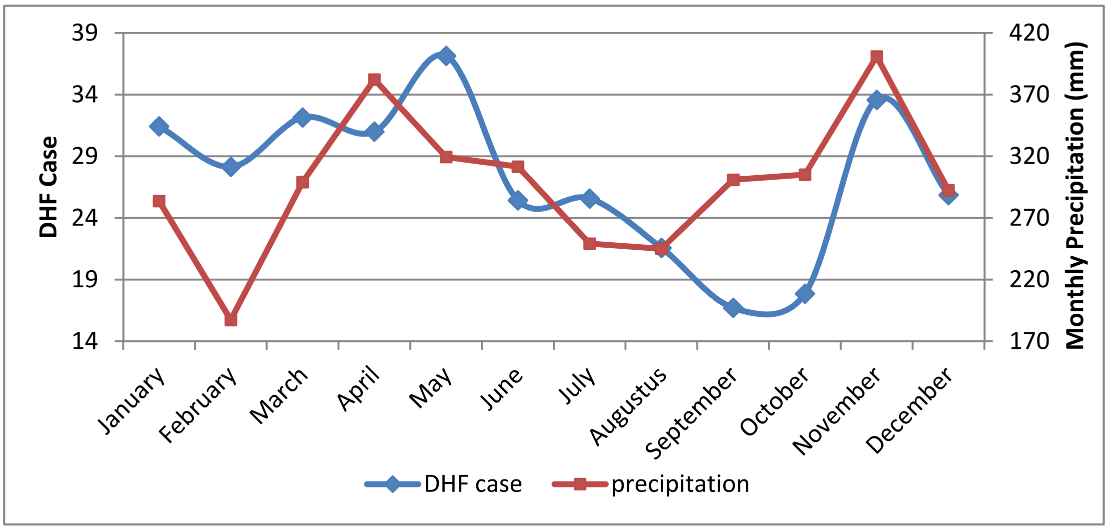


Figure 8-1 Relationship between monthly rainfall with DHF Cases for average 2003-2009.

Figure 8.1 shows association between monthly rainfall and DHF cases for 2003-2009. Figure 8.1 indicates that the increase of rainfall in February-April is highly related with the increase of DHF cases in March-May which means that there is 1 month lag between the increase of rainfall and DHF cases. Furthermore, the decrease of rainfall in May-August is followed by the decrease of DHF cases in June-September which means that there is 1 month lag between the decrease of rainfall and the decrease of DHF cases. The association with lag-0 and lag-1 is also shown in August-February. The increase of rainfall in September-November is related with the increase of DHF cases in October-November and the decrease of rainfall in December-February is related with the decrease of DHF cases in December-February.

Prediction of hazard for DHF, malaria, and diarrhea are calculated by compartment model method . For example, prediction of DHF case for 2011-2030 in Tarakan City is illustrated in Figure 8.2. As shown in Figure 8.2, DHF trend increase and each year has fluctuating number following the rainfall pattern.

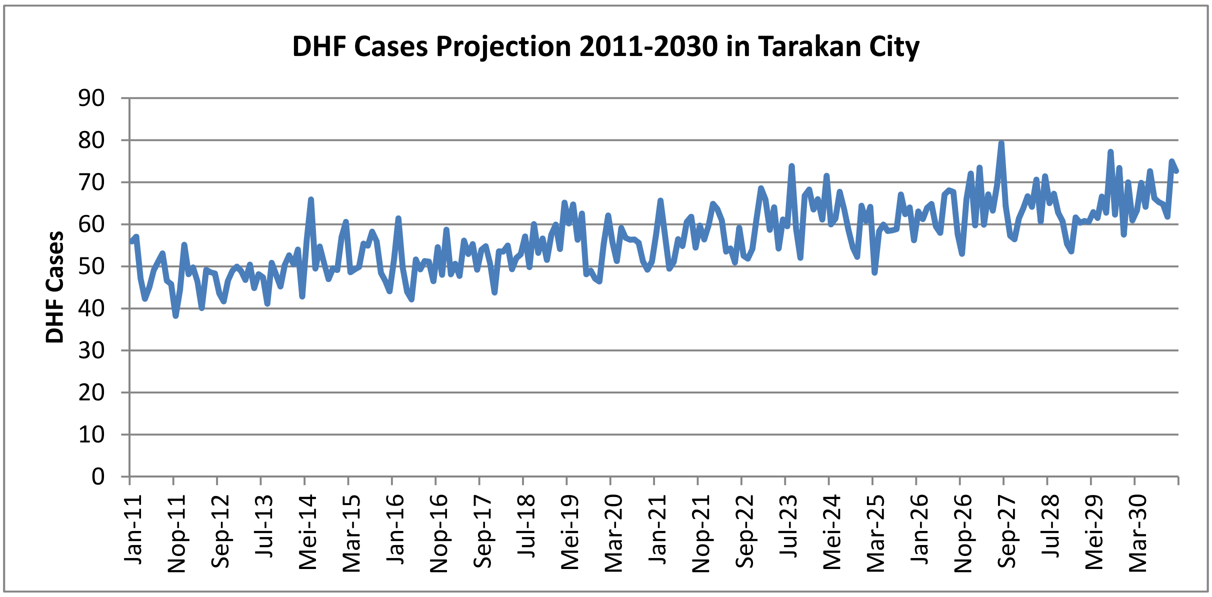


Figure 8-2 DHF Hazard Projection 2011-2030 for Tarakan City

Noted that 3 (three) method were elucidated for analyzing the relationship between weather and DHF, malaria, and diarrhea transmission, i.e. residual method, Poisson regression model, and compartment model. Thus, compartment model is chosen to predict both DHF, malaria, and diarrhea cases because compartment model can work well eventhough the length of data are quite short (under 10 years data).

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 villages that they have same level, they are marked by 0. As shown in Table 8.1, Juata Laut will increase sharply that it will increase for 4 level. Mamburungan and Karang Rejo will increase for 3 level (see Table 8.1).

Table 8.1: Existing and Future Hazard Categorization for DHF, Malaria and Diarrhea in Tarakan City

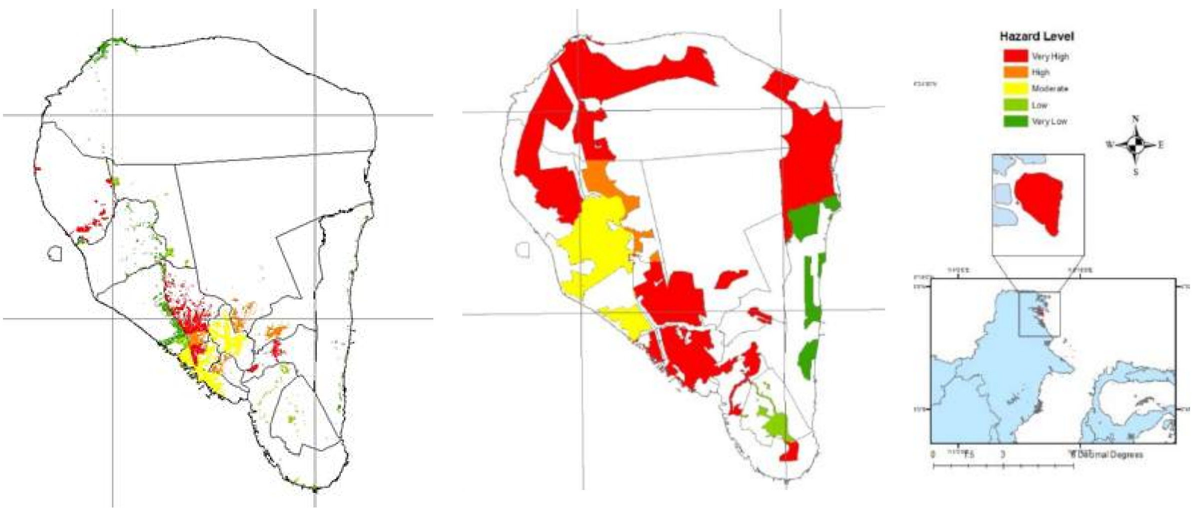
Sub district	Villages	Hazard DHF			Hazard Malaria			Hazard Diarrhea		
		2008	2030	Comp.	2008	2030	Comp.	2008	2030	Comp.
Tarakan Timur	Lingkas Ujung	M	VH	+2	VH	M	-2	VH	VH	0
	Gunung Lingkas	H	VH	+1	VH	M	-2	VH	VH	0
	Mamburungan	L	VH	+3	L	M	+1	L	M	+1
	Mamburungan Timur	L	L	0	L	M	+1	L	M	+1
	Kampung Empat	VH	VH	0	H	M	-1	VL	M	+2
	Kampung Enam	H	VH	+1	H	M	-1	VL	M	+2

Sub district	Villages	Hazard DHF			Hazard Malaria			Hazard Diarrhea		
		2008	2030	Comp.	2008	2030	Comp.	2008	2030	Comp.
	Pantai Amal	VL	VL	0	H	M	-1	VL	M	+2
Tarakan Tengah	Selumit Pantai	M	VH	+2	VL	VL	0	VL	L	+1
	Selumit	VH	VH	0	VL	VL	0	VL	VL	0
	Sebengkok	M	VH	+2	VL	VL	0	VL	L	+1
	Pamusian	M	VH	+2	L	VL	-1	L	M	+1
	Kampung Satu Skip	H	VH	+1	L	VL	-1	L	M	+1
Tarakan Barat	Karang Rejo	L	VH	+3	VL	VL	0	M	M	0
	Karang Balik	H	VH	+1	VL	VL	0	M	M	0
	Karang Anyar	VH	VH	0	VL	VL	0	M	VL	-2
	Karang Anyar Pantai	VL	M	+1	VL	VL	0	M	M	0
	Karang Harapan	VL	M	+2	VH	VL	-4	VH	VH	0
Tarakan Utara	Juata Permai	VH	VH	0	VH	VH	0	VH	VH	0
	Juata Kerikil	L	H	+2	VH	VH	0	VH	VH	0
	Juata Laut	VL	VH	+4	M	VH	+2	H	H	0

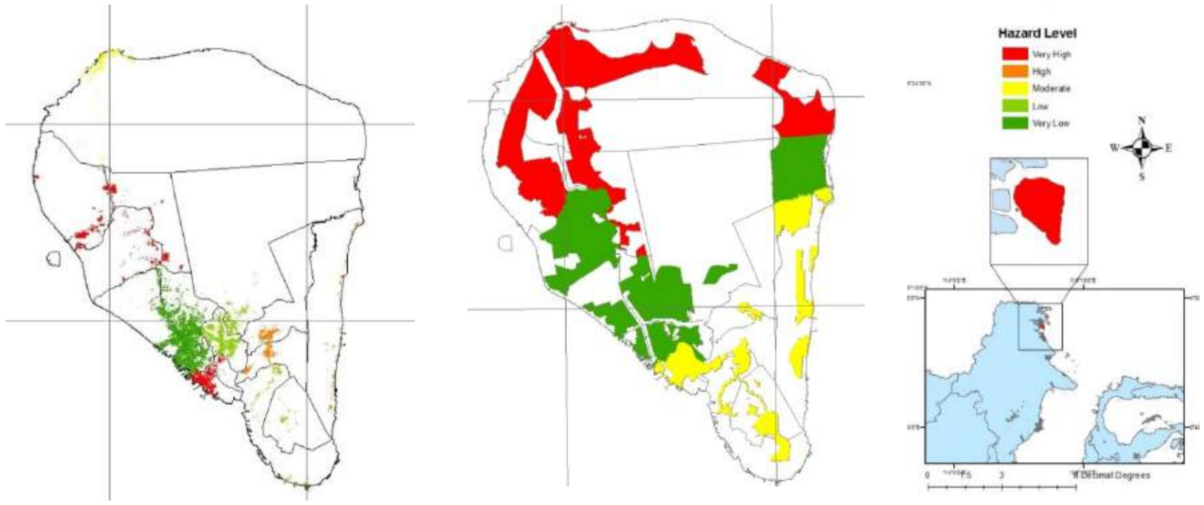
Note: Comp = comparison between 2008 and 2030

+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

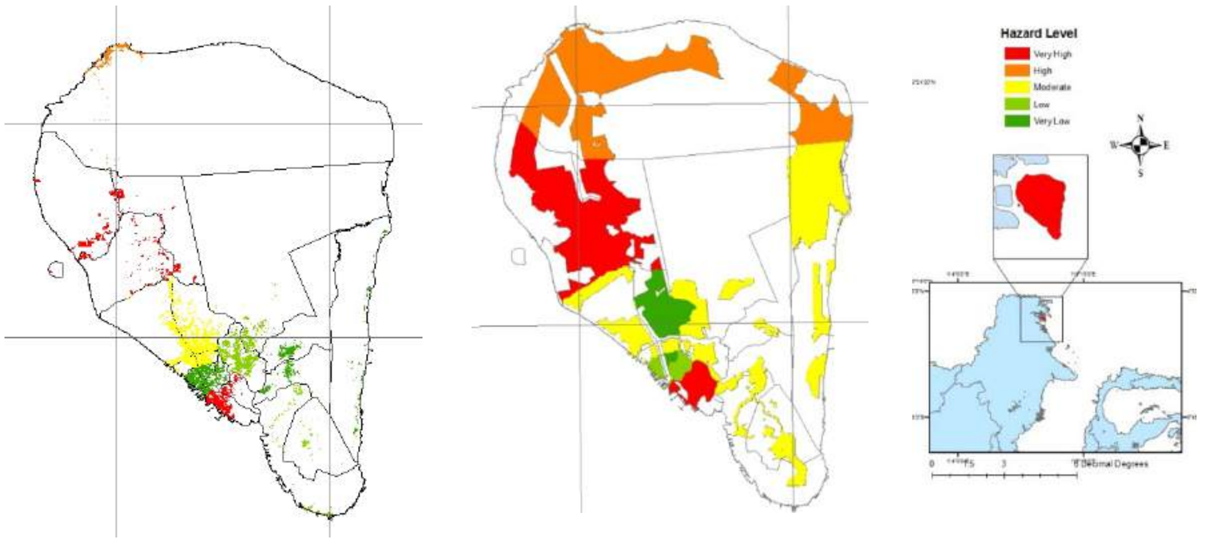
Existing and future hazards are also illustrated in spatial view. Figure 8.3 shows existing and future DHF, malaria, and diarrhea hazard in spatial view. By comparing two figure, trend of future hazard can be analyzed. For example, it is seen that most of villages in Tarakan have high level of DHF hazard both in 2008 and 2030, means that naturally this disease is occurred in high prevalence. This condistion may caused by the existence of natural inhabitant mosquitoes in large number.



(a) DHF Hazard Map 2008 DHF Hazard Map 2030



(b) Malaria Hazard Map 2008 Malaria Hazard Map 2030



(c) Diarrhea Hazard Map 2008 Diarrhea Hazard Map 2030

Figure 8-3 Comparison between (a) DHF, (b) Malaria and (c) Diarrhea Hazard Map 2008 and 2030

8.1.2 Vulnerability Analysis

Vulnerability analysis for health sector was conducted in Tarakan by using vulnerability indicators. Noted that Analytic Hierarchy Process (AHP) was used to refine the vulnerability indicators. Analytic Hierarchy Process (AHP), a decision-making technique, is used to determine the most suitable indicators and its rank weight. By using AHP method, vulnerability analysis for health sector in Tarakan was conducted and its result is resumed in Table 8.2 as follow. Table 8.2 shows DHF, malaria and diarrhea vulnerability levels in Tarakan in 2008 and 2030.

Table 8.2: Vulnerability Categorization for DHF, Malaria and Diarrhea in Tarakan

Sub district	Villages	Vulnerability DHF			Vulnerability Malaria			Vulnerability Diarrhea		
		2008	2030	Comp.	2008	2030	Comp.	2008	2030	Comp.
Tarakan Timur	Lingkas Ujung	H	VH	+1	VH	VL	-4	H	VL	-3
	Gunung Lingkas	H	VL	-3	M	VL	-2	VL	VL	0
	Mamburungan	H	VL	-3	H	VL	-3	H	VL	-3
	Mamburungan Timur	M	VL	-2	L	VL	-1	VH	VL	-4
	Kampung Empat	VL	VL	0	L	L	0	L	L	0
	Kampung Enam	L	VL	-1	L	M	+1	H	M	-1
	Pantai Amal	M	VL	-2	H	M	-1	VH	M	-2
Tarakan Tengah	Selumit Pantai	VH	VH	0	VH	VH	0	VH	M	-2
	Selumit	VH	H	-1	VH	VH	0	L	L	0
	Sebengkok	VH	VH	0	H	M	-1	M	M	0
	Pamusian	VL	VL	0	VL	M	+2	VL	M	+2
	Kampung Satu Skip	VL	VL	0	VL	VL	0	VL	VL	0
Tarakan Barat	Karang Rejo	H	VH	+2	VH	VH	0	L	VH	+3
	Karang Balik	VL	VH	+4	L	VH	+3	VL	VH	+4
	Karang Anyar	M	VL	-2	VL	M	+2	M	M	0
	Karang Anyar Pantai	L	H	+2	H	M	-1	L	M	+1
	Karang Harapan	L	VL	-1	M	VL	-2	M	VL	-2
Tarakan Utara	Juata Permai	M	M	0	VL	L	+1	M	L	-1
	Juata Kerikil	L	VL	-1	M	M	0	H	M	-1
	Juata Laut	VH	H	-1	M	VL	-2	VH	VL	-4

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

Vulnerability level is also illustrated in spatial view as shown in Figure 8.4.

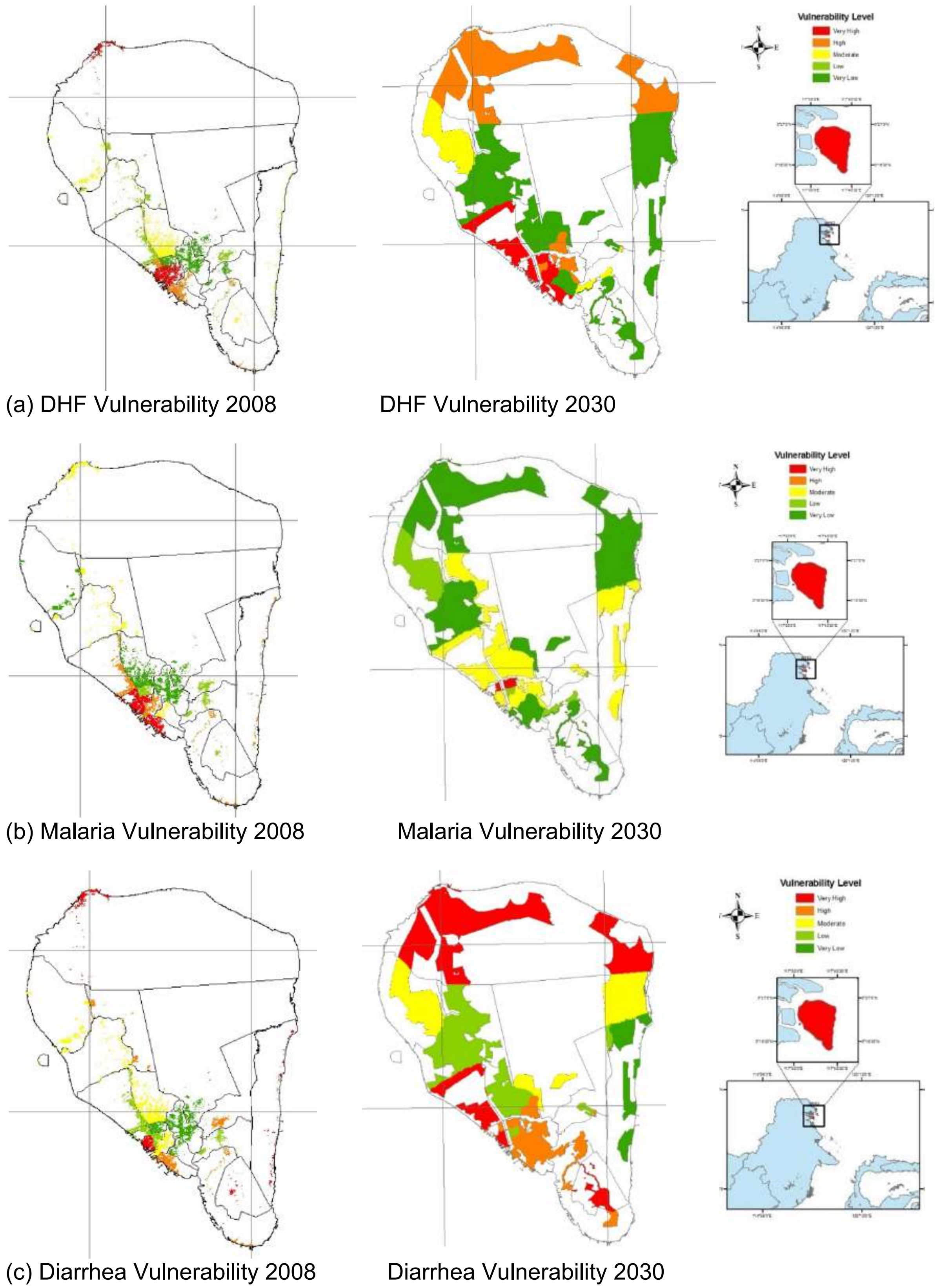


Figure 8-4 Vulnerability Map of (a) DHF, (b) Malaria and (c) Diarrhea in 2008 and 2030

8.1.3 Risk Analysis

By using risk matrix assessment approach, risk of DHF, malaria and diarrhea were calculated and its result for 2008 and 2030 are described in Table 8.3 below.

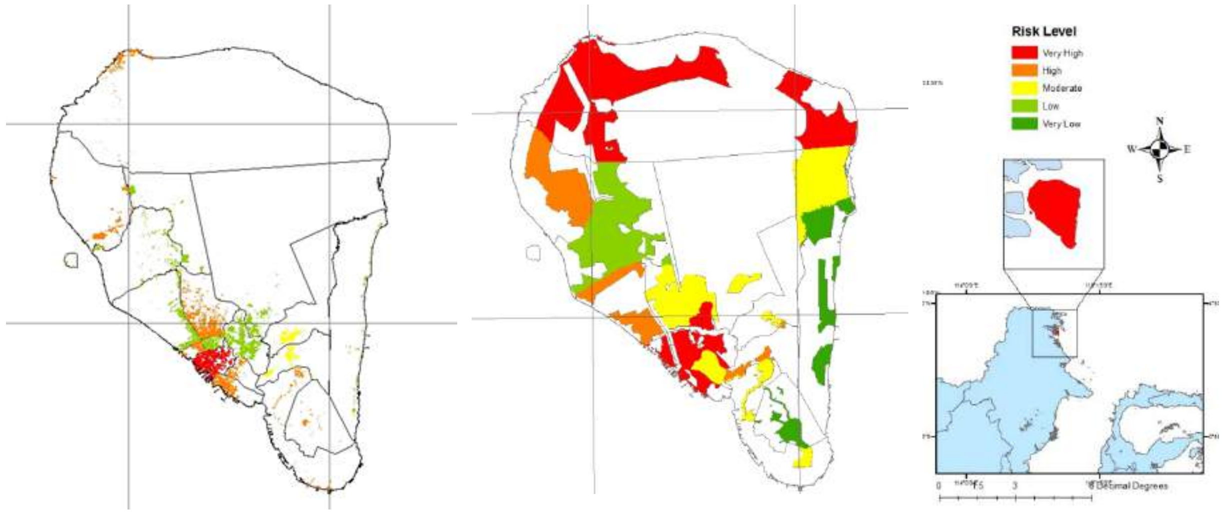
Table 8.3: Existing and Future Risk Categorization for DHF, Malaria and Diarrhea in Tarakan

Sub district	Villages	Risk DHF			Risk Malaria			Risk Diarrhea		
		2008	2030	Comp.	2008	2030	Comp.	2008	2030	Comp.
Tarakan Timur	Lingkas Ujung	H	VH	+1	VH	L	-3	VH	VH	0
	Gunung Lingkas	H	M	-1	H	L	-2	M	VH	+2
	Mamburungan	M	M	0	M	L	-1	M	H	+1
	Mamburungan Timur	L	VL	-1	L	L	0	H	M	-1
	Kampung Empat	M	M	0	M	L	-1	VL	H	+3
	Kampung Enam	M	M	0	M	M	0	L	L	0
	Pantai Amal	L	VL	-1	H	M	-1	M	L	-1
Tarakan Tengah	Selumit Pantai	H	VH	+1	M	L	-1	M	H	+1
	Selumit	VH	VH	0	M	VL	-2	VL	VL	0
	Sebengkok	H	VH	+1	L	L	0	L	M	+1
	Pamusian	L	M	+1	VL	L	+1	VL	H	+3
	Kampung Satu Skip	L	M	+1	VL	VL	0	VL	M	+2
Tarakan Barat	Karang Rejo	M	VH	+2	M	M	0	L	H	+2
	Karang Balik	L	VH	+3	VL	M	+2	L	H	+2
	Karang Anyar	H	M	-1	VL	L	+1	M	VL	-2
	Karang Anyar Pantai	VL	H	+3	L	L	0	L	H	+3
	Karang Harapan	VL	L	+1	H	VL	-3	H	H	0
Tarakan Utara	Juata Permai	H	H	0	M	H	+1	H	H	0
	Juata Kerikil	L	L	0	H	H	0	VH	H	-1
	Juata Laut	M	VH	+2	M	M	0	VH	VH	0

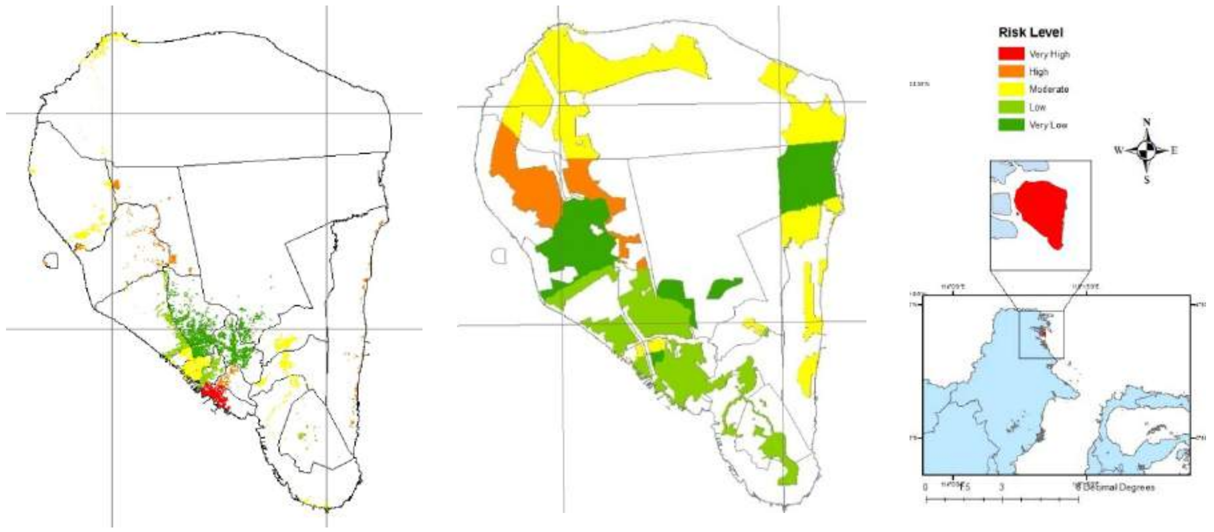
Note: Comp = comparison between 2008 and 2030

+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

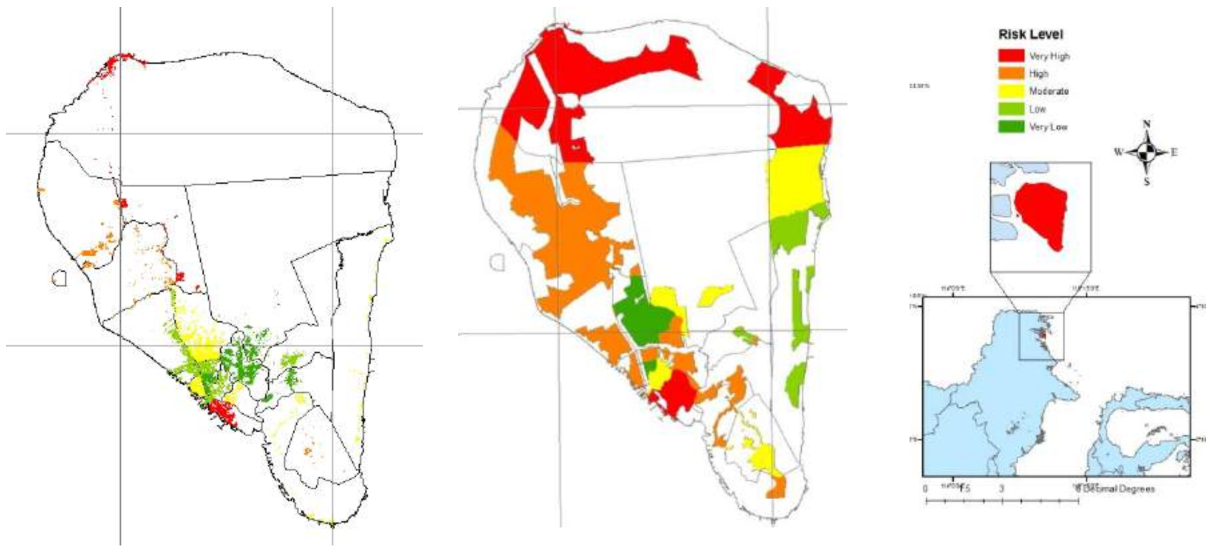
Risk of DHF, malaria and diarrhea in spatial view are drew in Figure 8.5 below.



(a) DHF Risk 2008 DHF Risk 2030



(b) Malaria Risk 2008 Malaria Risk 2030



(c) Diarrhea Risk 2008 Diarrhea Risk 2030

Figure 8-5 Risk Map of (a) DHF, (b) Malaria and (c) Diarrhea in 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 village in Tarakan was defined as shown in Table 8.4 as follow.

Table 8.4: Adaptation Strategy Category of DHF Malaria and Diarrhea for Each Village in Tarakan

Sub district	Villages	Adaptation Strategy for DHF	Adaptation Strategy for Malaria	Adaptation Strategy for Diarrhea
Tarakan Timur	Lingkas Ujung	A	A	A
	Gunung Lingkas	B	B	B
	Mamburungan	B	C	C
	Mamburungan Timur	D	D	C
	Kampung Empat	B	B	D
	Kampung Enam	B	B	C
	Pantai Amal	D	A	C
Tarakan Tengah	Selumit Pantai	A	C	C
	Selumit	A	C	D
	Sebengkok	A	C	D

Sub district	Villages	Adaptation Strategy for DHF	Adaptation Strategy for Malaria	Adaptation Strategy for Diarrhea
	Pamusian	B	D	D
	Kampung Satu Skip	B	D	D
Tarakan Barat	Karang Rejo	C	C	C
	Karang Balik	A	C	C
	Karang Anyar	B	D	D
	Karang Anyar Pantai	C	C	D
	Karang Harapan	D	B	B
Tarakan Utara	Juata Permai	B	B	B
	Juata Kerikil	B	B	A
	Juata Laut	A	D	A

As shown in Table 8.4, villages that have many A category are the highest priority areas, following by B and C category. In the other hand, the villages that have many D category are the lowest priority areas. Therefore the highest priority areas are Lingkas Ujung, Gunung Lingkas, Juata Permai, and Juata Kerikil.

8.2 Reccomendation

Based on this study, to gain better health condition in Tarakan, it may be drawn to our attention the following strategic issues:

1) On the geographic (dis-) advantages of Tarakan as a small island – as a small island, Tarakan is prone to climate changes namely sea level rise, tropical monsoon, torrential flooding and prolonged drought. The isolation of Tarakan from mainland Kalimantan Timur province has also the disadvantage of being cut off from livelihood supplies should climate emergency occur.
2) On the population and socio-health aspects – population density made worse by influx of job seeking incoming migrant will burden the health infrastructures. Socially there will be tension between the slum-dwelling migrants and the local inhabitant. Racial tension may soar.
3) On the availability of health-related facilities – currently medical facilities and health supplies are adequate. But its availability is not yet geared to facing climate hazard in the future.
4) On the incidence and prevalence of climate related diseases – influx of migrant, whether permanent or temporary, will expose Tarakan with diseases not known previously. Chikungunya, one of the climate dependent vector borne disease, commonly found in Java should be closely monitored. Incidence may increase during rainy season.

The three guiding principles for the adaptation strategies in the health sector of Tarakan Island include:

- A policy switch from curative dominance to preventive and promotive activity in the long run.
- Based on the conclusion and prediction drawn by the science basis which stated that Tarakan's climate as equatorial type and ENSO influenced, all health planning and adaptation strategy for Tarakan should include Tarakan's future climate changes into consideration.

- Health sector should not be working alone in tackling the situation. A concerted and integrated effort should include other relevant departments. 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 (see Appendix D for detail explanation).

Many diseases and health problems that may be exacerbated by climate change in Tarakan 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.

There are several additional approach which can be taken by the Tarakan health administration to promote adaptation to climate change.

1) **Promote climate information applications on health**—Improving climate information applications for the whole Island through work with the 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 provincial level of Kalimantan Timur, which is currently quite low. The BMKG Meteorological Department should develope a forecasting system to facilitate early warning system for mosquito borne and waterborne diseases management. Its research center should also develope a drought risk map for the Island and setting up drought information centers to provide timely information to relevant organizations. Another program that should be developed to supports and increase the adaptive capacity of the island is flood forecasting system, which can provides weekly forecasts on a daily basis. BMKG also should publish flood data, flood hazard maps, and other information. The Tarakan health office should also plans to develop standard training programs covering health monitoring, health structural measures, flood preparedness, and health emergency response.
2) **Improve access to social welfare**—Increasing access to, and the quality of, health care and other social services will also reduce the island'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 island currently felt that non governmental 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.
3) **Promote local participation in environmental health management**—Promoting community awareness on climate change effect on health and empowerment in local administration and planning for development will better ensure Tarakan’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. Tarakan should also aims to preserve and rehabilitate its mangrove natural resources. For example, the mangrove forest reserves should cover an area at least 25% of the island’s coastal area. Rehabilitation of abandoned shrimp ponds by mangrove reforestation, will reduce mosquito breeding. Re-introduction of the local

silver-leaf monkey (Bekantan) will prevent blood-sucking malaria mosquitoes from seeking human victims. By 2030, measures should be undertaken along the coastal area to address the reclamation of mosquito infested swamps and lagoons, providing also indirectly healthy human habitat to ease the crowding in the city center.

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APPENDIX A DATA OF HAZARD

Table A. 1: Recapitulation Data of DHF in Tarakan

Year	Month	DHF Cases					Rainfall (mm)	Temperature (^{O}C)
		West Tarakan	Central Tarakan	East Tarakan	North Tarakan	Tarakan City		
2003	Jan	1	1	0	0	3	495.9	26.81
	Feb	2	2	1	0	5	219.9	26.58
	Mar	1	1	0	0	3	341.4	26.66
	Apr	0	0	0	0	1	296.0	27.38
	May	1	2	1	0	4	212.5	27.68
	Jun	2	3	1	1	7	233.9	27.22
	Jul	1	1	0	0	3	146.6	27.52
	Aug	0	0	0	0	1	263.4	27.67
	Sep	2	3	1	1	7	299.4	27.40
	Oct	1	1	0	0	3	500.3	27.08
	Nov	1	1	0	0	2	367.3	27.17
	Dec	1	1	0	0	3	204.4	26.87
2004	Jan	2	2	1	1	5	149.4	26.98
	Feb	7	5	2	2	16	114.3	26.96
	Mar	3	3	1	1	8	374.2	27.01
	Apr	4	3	1	1	9	265.7	27.31
	May	3	2	1	1	7	577.4	27.64
	Jun	0	0	0	0	0	298.1	27.02
	Jul	2	2	1	1	6	231.3	27.85
	Aug	1	1	0	0	2	367.8	27.23
	Sep	2	1	1	1	4	305.1	26.90
	Oct	4	3	1	1	9	247.5	27.80
	Nov	5	4	2	2	13	341.5	27.52
	Dec	3	3	1	1	8	337.6	27.14
2005	Jan	0	0	0	0	1	200.8	26.94
	Feb	2	2	1	0	6	138.9	27.13
	Mar	2	2	1	0	5	341.2	26.84
	Apr	3	4	2	1	9	249.6	27.51
	May	1	2	1	0	4	288.4	27.95
	Jun	3	4	2	1	9	183.1	27.23
	Jul	2	2	1	0	5	131.1	27.35
	Aug	1	1	0	0	2	279.8	27.55
	Sep	3	4	2	1	9	481.8	26.81
	Oct	1	2	1	0	4	336.9	27.17
	Nov	1	1	1	0	3	459.4	27.36
	Dec	0	0	0	0	1	192	26.45
2006	Jan	1	2	0	1	4	307.3	26.97
	Feb	2	3	1	1	7	99.6	27.26

Year	Month	DHF Cases					Rainfall (mm)	Temperature (^{O}C)
		West Tarakan	Central Tarakan	East Tarakan	North Tarakan	Tarakan City		
	Mar	9	10	2	5	26	245.6	26.55
	Apr	2	2	0	1	5	434.6	27.80
	May	2	2	0	1	5	364	27.74
	Jun	2	2	1	1	6	256.1	27.67
	Jul	2	3	1	1	7	233.7	26.86
	Aug	2	3	1	1	7	70.6	27.85
	Sep	3	3	1	2	8	380.3	27.27
	Oct	4	5	1	2	12	308.8	27.33
	Nov	5	5	1	3	14	583	27.28
	Dec	2	2	0	1	5	283.3	26.42
2007	Jan	11	13	10	4	38	234.7	27.17
	Feb	9	10	8	3	30	125	27.24
	Mar	3	3	3	1	10	260.4	27.47
	Apr	7	8	7	2	24	412.8	27.07
	May	14	16	13	4	48	322.1	27.37
	Jun	9	10	8	3	30	280.4	27.61
	Jul	5	5	4	1	16	159.2	27.12
	Aug	7	8	7	2	24	274.8	27.59
	Sep	6	6	5	2	19	309.8	27.77
	Oct	7	8	7	2	25	349.4	27.33
	Nov	10	11	9	3	34	353.1	27.26
	Dec	7	8	7	2	25	266.9	26.81
2008	Jan	10	14	7	3	34	147.7	26.75
	Feb	8	11	5	2	27	233.3	26.81
	Mar	6	9	4	2	21	298.3	26.96
	Apr	6	8	4	2	20	434.3	26.80
	May	5	7	3	1	16	205.2	27.76
	Jun	5	8	4	2	18	518.5	27.20
	Jul	3	5	2	1	12	286.9	27.51
	Aug	5	7	3	2	17	210.5	27.71
	Sep	4	5	3	1	13	178.3	27.32
	Oct	5	7	3	1	16	276.3	27.16
	Nov	12	18	9	4	43	209.7	27.53
	Dec	10	15	7	3	35	243	27.66
2009	Jan	18	12	8	3	42	255.2	27.08
	Feb	24	16	11	4	56	104.5	27.22
	Mar	18	12	8	3	41	331.6	26.97
	Apr	18	12	8	3	41	376.6	27.57
	May	12	9	6	2	29	323.1	27.69
	Jun	14	9	6	2	32	432.7	27.36
	Jul	6	4	3	1	14	385.2	27.03
	Aug	9	6	4	2	21	396.8	27.00

Year	Month	DHF Cases					Rainfall (mm)	Temperature (^{o}C)
		West Tarakan	Central Tarakan	East Tarakan	North Tarakan	Tarakan City		
	Sep	7	5	3	1	16	251.4	27.18
	Oct	6	4	3	1	13	323.3	27.10
	Nov	15	11	7	3	36	405.9	27.56
	Dec	12	8	5	2	27	515.6	26.84

Table A. 2: Interpolation of Population Number in Tarakan

Year	Month	Population Number				
		West Tarakan	Central Tarakan	East Tarakan	North Tarakan	Tarakan City
2003	Jan	53067	46339	32110	18434	149943
	Feb	53329	46569	32264	18503	150657
	Mar	53581	46789	32413	18575	151349
	Apr	53823	47002	32558	18648	152021
	May	54057	47206	32698	18723	152676
	Jun	54285	47405	32835	18800	153315
	Jul	54506	47598	32970	18878	153942
	Aug	54722	47787	33102	18958	154559
	Sep	54935	47973	33232	19039	155168
	Oct	55145	48155	33361	19121	155772
	Nov	55353	48337	33489	19204	156373
	Dec	55561	48517	33617	19288	156973
2004	Jan	55768	48698	33745	19372	157574
	Feb	55978	48881	33875	19458	158180
	Mar	56190	49065	34005	19543	158793
	Apr	56405	49253	34138	19629	159414
	May	56625	49445	34273	19714	160047
	Jun	56851	49642	34411	19800	160693
	Jul	57084	49844	34553	19885	161356
	Aug	57324	50054	34699	19970	162037
	Sep	57573	50272	34849	20055	162738
	Oct	57832	50498	35004	20138	163463
	Nov	58102	50735	35165	20221	164214
	Dec	58384	50982	35333	20303	164992
2005	Jan	58679	51240	35506	20383	165801
	Feb	58988	51511	35687	20463	166641
	Mar	59306	51790	35873	20542	167503
	Apr	59628	52073	36061	20622	168378
	May	59951	52356	36250	20703	169254
	Jun	60268	52635	36437	20787	170122
	Jul	60577	52905	36619	20874	170971
	Aug	60871	53162	36795	20966	171790
	Sep	61147	53403	36962	21063	172571

Year	Month	Population Number				
		West Tarakan	Central Tarakan	East Tarakan	North Tarakan	Tarakan City
	Oct	61398	53622	37118	21167	173302
	Nov	61622	53815	37260	21277	173972
	Dec	61813	53979	37386	21396	174573
2006	Jan	61965	54109	37494	21524	175092
	Feb	62077	54203	37583	21662	175524
	Mar	62149	54268	37654	21804	175874
	Apr	62183	54310	37709	21948	176149
	May	62183	54340	37751	22087	176359
	Jun	62150	54364	37783	22217	176512
	Jul	62087	54392	37806	22333	176616
	Aug	61997	54431	37824	22430	176681
	Sep	61881	54490	37838	22504	176713
	Oct	61744	54578	37852	22550	176723
	Nov	61586	54702	37868	22563	176717
	Dec	61411	54870	37888	22538	176706
2007	Jan	61220	55092	37914	22470	176696
	Feb	61018	55373	37950	22357	176698
	Mar	60809	55709	37996	22202	176715
	Apr	60597	56094	38054	22011	176754
	May	60388	56520	38125	21790	176820
	Jun	60186	56981	38211	21544	176920
	Jul	59998	57471	38312	21278	177058
	Aug	59827	57984	38430	21000	177240
	Sep	59680	58512	38567	20713	177471
	Oct	59561	59049	38724	20425	177757
	Nov	59475	59589	38901	20140	178104
	Dec	59428	60126	39102	19864	178518
2008	Jan	59423	60651	39325	19603	179002
	Feb	59468	61160	39574	19363	179565
	Mar	59566	61646	39850	19149	180210
	Apr	59722	62101	40153	18967	180943
	May	59943	62520	40485	18823	181770
	Jun	60232	62896	40847	18722	182696
	Jul	60595	63223	41242	18670	183728
	Aug	61037	63493	41669	18672	184870
	Sep	61563	63701	42130	18735	186128
	Oct	62179	63839	42628	18863	187507
	Nov	62888	63902	43162	19063	189014
	Dec	63697	63883	43734	19340	190653
2009	Jan	64610	63774	44346	19700	192430
	Feb	65633	63571	45000	20149	194352
	Mar	66771	63266	45695	20692	196422

Year	Month	Population Number				
		West Tarakan	Central Tarakan	East Tarakan	North Tarakan	Tarakan City
	Apr	68028	62852	46434	21335	198647
	Jun	70921	61674	48049	22943	203585
	Aug	74354	59984	49853	25019	209207
	Sep	76285	58931	50830	26246	212290
	Oct	78367	57731	51859	27608	215560
	Nov	80603	56376	52941	29108	219024
	Dec	83000	54861	54076	30754	222688

APPENDIX B RESULT OF HAZARD CALCULATIONS BY USING POISSON REGRESSION

B.1 Estimation of Existing DHF Hazard by Using Poisson Regression

Descriptive analysis shall be performed prior to subsequent calculation. The basic principle is to verify the distribution of the data by normality curve as shown on Figure B.1, B.2, and B.3. Normally distributed data can be described by the familiar, bell-shaped curve where most of the values fall around the mean with decreasing number of values at either extreme (Wassertheil-Smoller, 2003). As shown in Figure B.1 and B.2, the curve for precipitation and temperature data are considered as normal curve. However, the distribution of DHF incidence data is not normal curve (see Figure B.3).

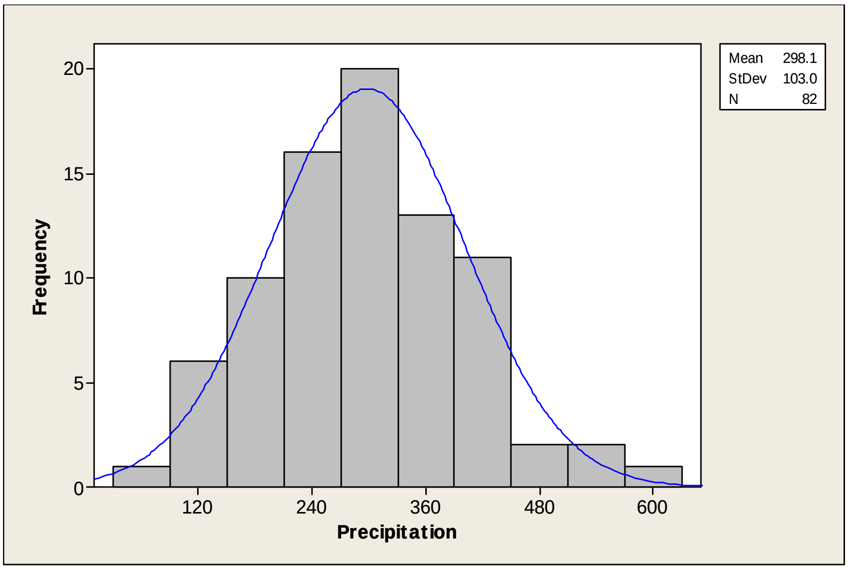

Figure B.1 Distribution of Precipitation Data

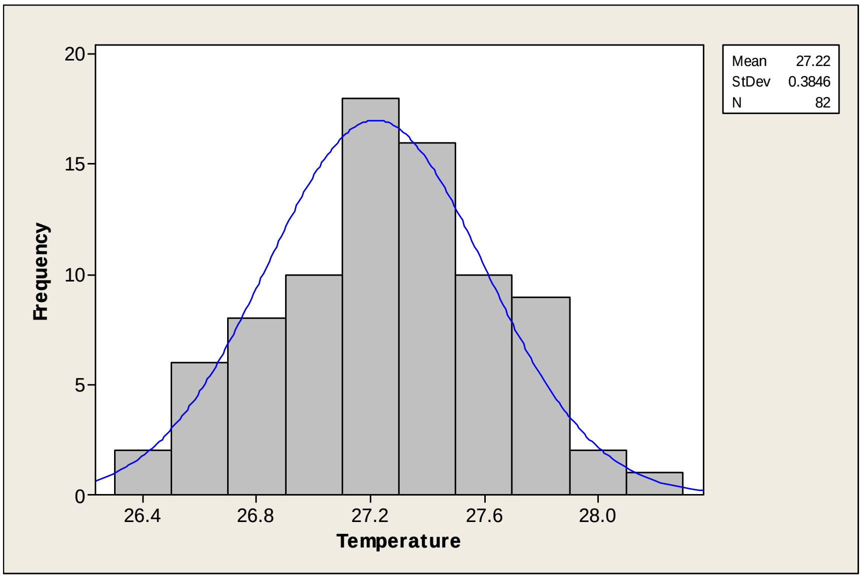

Figure B.2 Distribution of Temperature Data

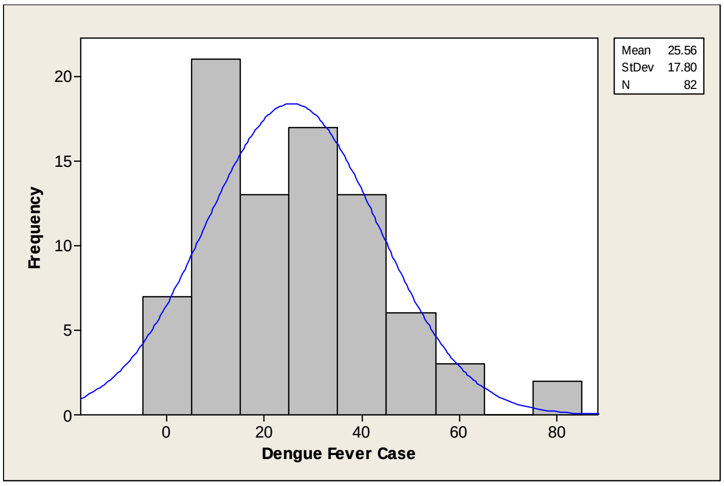

Figure B.3 Distribution of DHF Case Number Incidence

Because the distribution of DHF incidence data is not normal curve (see Figure B.3), therefore Poisson regression is used in the mathematical modeling and prediction.

B.1.1 Poisson Regression Calculation for Tarakan City

The result of calculation is given in the Table B.1 and the best model is illustrated in Figure B.4.

Table B. 1 Calculation of Dengue Fever Case Without Outliers Data for 2003-2009 in Tarakan

Parameter	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
β0	2,6146	2,7877	5,7162	5,2417	-51,4588	-41,5658	5,0937
β1	0,4345	0,1564	0,7034	0,2780	0,4019	0,1371	0,2830
β2	-0,1965	0,4017	-0,1822	0,5272	-0,1894	0,3839	0,5375
β3	0,0001	-0,1835	0,0002	-0,1735	0,0001	-0,1775	-0,1670
β4	2,5E-05	0,0001	1,9969	0,0001	4,8360	0,0001	0,00005
β5		2,00E-05		14,2232		3,9599	
RMSE	12,4425	11,9416	12,0008	11,9120	12,3076	11,9012	12,0625
SD	12,3089	11,8059	11,6841	11,6816	12,1765	11,7697	11,5898
AIC	774,3709	759,3665	768,5158	758,9702	772,6051	758,8242	7,5898

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

$$\ln(\mu_t) = -41{,}57 + 0.1371\ln(\mu_{t-1}) + 0.3839\ln(\mu_{t-2}) - 0.178T_t + 0.0001H_t + 3.96\ln(Pop_t) + e_t$$

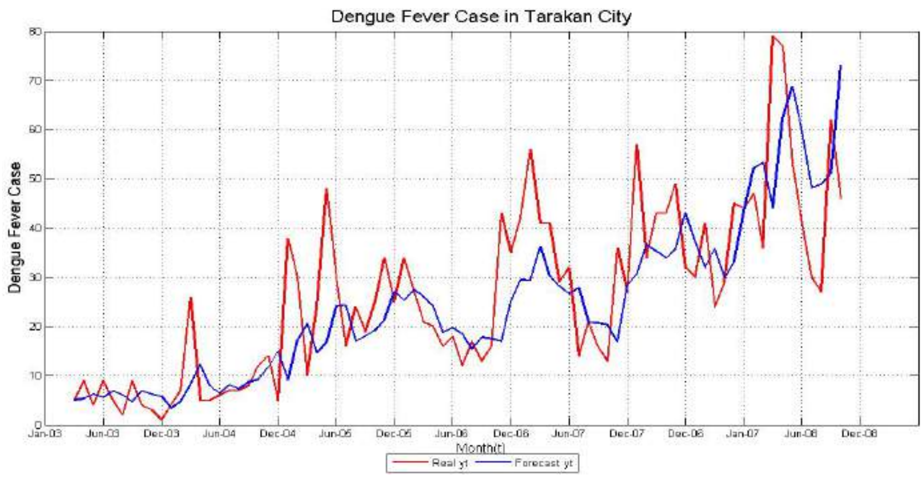

Figure B.4 Forecast Result from the Best Model (Model 6) in Tarakan City

B.1.2 Poisson Regression Calculation for Tarakan Barat

The result of calculation is given in the Table B.2 and the best model is illustrated in Figure B.5.

Table B. 2 : Calculation of Dengue Fever Case Without Outliers Data for 2003-2009 in Tarakan Barat

Parameter	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
β0	4,3635	4,2100	5,4670	5,0982	-32,6261	-24,6037	6,182
β1	0,5651	0,2097	0,7196	0,2770	0,5432	0,1980	0,270
β2	-0,2515	0,4754	-0,1847	0,5424	-0,2516	0,4659	0,540
β3	0,0003	-0,2253	0,0002	-0,1758	0,0003	-0,2257	-0,216
β4	5,30E-05	0,0002	9,8488	0,0001	3,6556	0,0003	0,0003
β5		4,06E-05		6,8821		2,8447	
RMSE	4,5419	4,2792	4,2875	4,2208	4,5128	4,2754	4,6970
SD	4,4720	4,2164	4,1708	4,1370	4,4437	4,2135	4,5990
AIC	611,1109	595,1657	601,7758	592,9678	610,0706	595,0222	6,0807

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

$$\ln(\mu_t) = 5.0982 + 0.277\ln(\mu_{t-1}) + 0.5424\ln(\mu_{t-2}) - 0.1758T_t + 0{,}0001H_t + 6.882RatePop_t + e_t$$

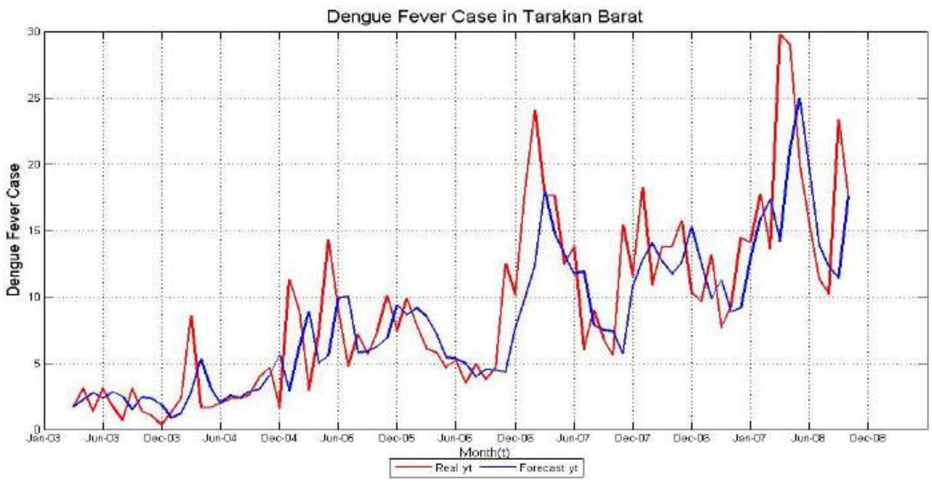

Figure B.5 Forecast Result from the Best Model (Model 4) in Tarakan Barat

B.1.3 Poisson Regression Calculation for Tarakan Tengah

The result of calculation is given in the Table B.3 and the best model is illustrated in Figure B.6.

Table B. 3 : Calculation of Dengue Fever Case Without Outliers Data for 2003-2009 in Tarakan Tengah

Parameter	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
β0	-1,7328	-0,4483	6,7686	6,2245	-41,3374	-32,4904	5,2199
β1	0,4027	0,1501	0,6618	0,2677	0,3801	0,1362	0,2846
β2	-0,0282	0,3829	-0,2247	0,5071	-0,0272	0,3700	0,5174
β3	-0,0003	-0,0563	0,0002	-0,2122	-0,0003	-0,0520	-0,1766
β4	6,80E-05	-0,0002	-17,3093	0,0002	3,9747	-0,0002	0,000005
β5		5,35E-05		-12,8446		3,2009	
RMSE	4,1185	4,0941	4,1997	4,1506	4,1048	4,0829	4,6795
SD	4,0513	4,0312	4,0911	4,0689	4,0382	4,0206	4,5828
AIC	595,2604	588,0886	598,4220	590,2842	594,7213	587,6530	6,0747

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

$$\ln(\mu_t) = -32.49 + 0.1362\ln(\mu_{t-1}) + 0.37\ln(\mu_{t-2}) - 0.052T_t - 0.0002H_t + 3.2\ln(Pop_t) + e_t$$

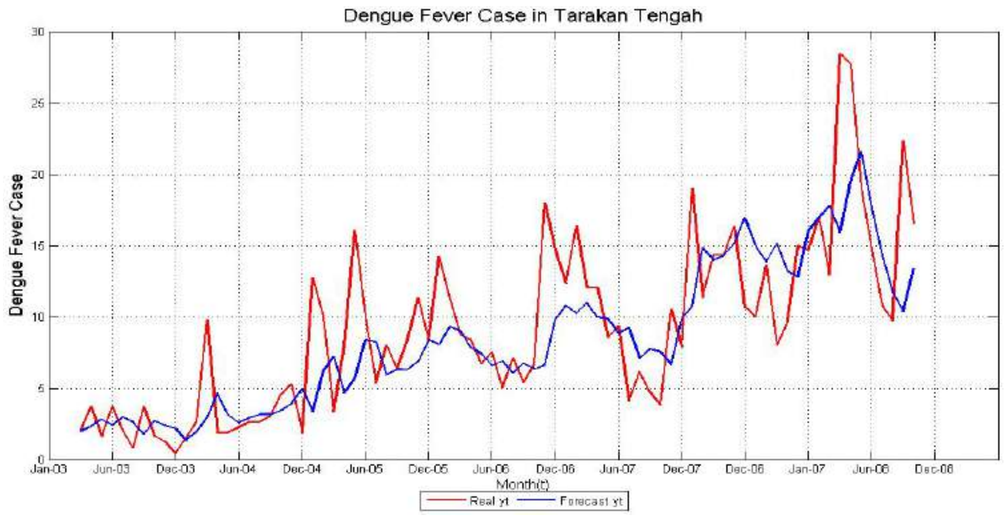

Figure B.6 Forecast Result from the Best Model (Model 6) in Tarakan Tengah

B.1.4 Poisson Regression Calculation for Tarakan Timur

The result of calculation is given in the Table B.4 and the best model is illustrated in Figure B.7.

Table B. 4 : Calculation of Dengue Fever Case Without Outliers for 2003-2009 in Tarakan Timur

Parameter	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
β0	-1,7328	-0,4483	6,7686	6,2245	-41,3374	-32,4904	3,0396
β1	0,4027	0,1501	0,6618	0,2677	0,3801	0,1362	0,3132
β2	-0,0282	0,3829	-0,2247	0,5071	-0,0272	0,3700	0,5596
β3	-0,0003	-0,0563	0,0002	-0,2122	-0,0003	-0,0520	-0,1045
β4	6,80E-05	-0,0002	-17,3093	0,0002	3,9747	-0,0002	0,00002
β5		5,35E-05		-12,8446		3,2009	2,8419
RMSE	4,1185	4,0941	4,1997	4,1506	4,1048	4,0829	2,7879
SD	4,0513	4,0312	4,0911	4,0689	4,0382	4,0206	5,2768
AIC	595,2604	588,0886	598,4220	590,2842	594,7213	587,6530	

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

$$\ln(\mu_t) = 6.7686 + 0.6618\ln(\mu_{t-1}) - 0.2247\,T_t + 0.0002H_t - 17.3093RatePop_t + e_t$$

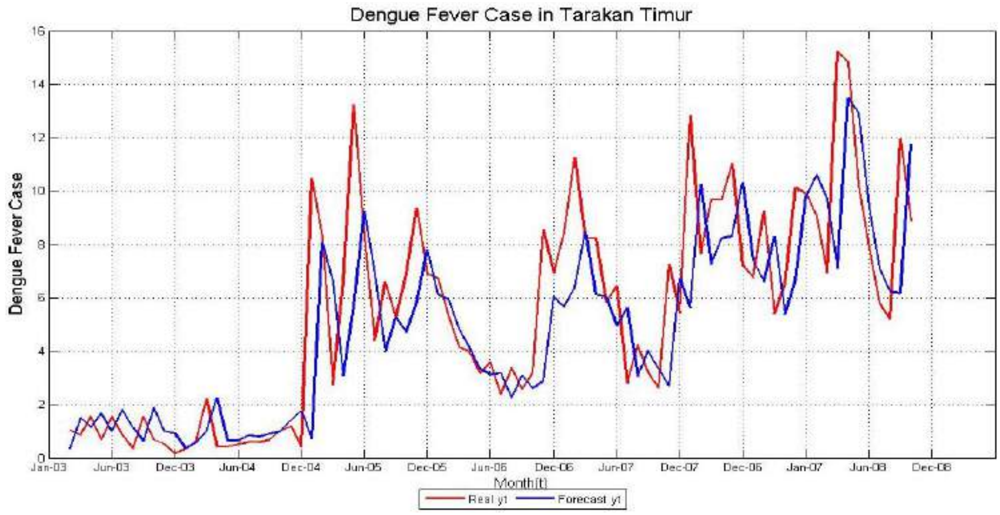

Figure B.7 Forecast Result from the Best Model (Model 3) in Tarakan Timur

B.1.5 Poisson Regression Calculation for Tarakan Utara

The result of calculation is given in the Table B.5 and the best model is illustrated in Figure B.8.

Table B. 5 : Calculation of Dengue Fever Case Without Outliers Data for 2003-2009 in Tarakan Utara

Parameter	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
β0	5,9956	5,3809	5,6861	5,1039	-3,6922	-2,0869	2,5385
β1	0,6666	0,2240	0,6900	0,2356	0,6654	0,2229	0,1946
β2	-0,2527	0,5327	-0,2045	0,5411	-0,2545	0,5330	0,5114
β3	0,0003	-0,2228	0,0003	-0,1838	0,0003	-0,2237	-0,088
β4	4,9E-05	0,0002	2,3568	0,0002	1,0832	0,0002	0,0001
β5		3,84E-05		1,4864		0,8341	1,7128
RMSE	1,2502	1,2325	1,2316	1,2233	1,2511	1,2336	1,6697
SD	1,2211	1,2087	1,2030	1,2004	1,2218	1,2097	4,466
AIC	402,1215	396,0038	399,6936	394,8054	402,2417	396,1460	

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

$$\ln(\mu_t) = 5.1039 + 0.2356\ln(\mu_{t-1}) + 0.541\ln(\mu_{t-2}) - 0.1838T_t + 0.0002H_t + 1.486RatePop_t + e_t$$

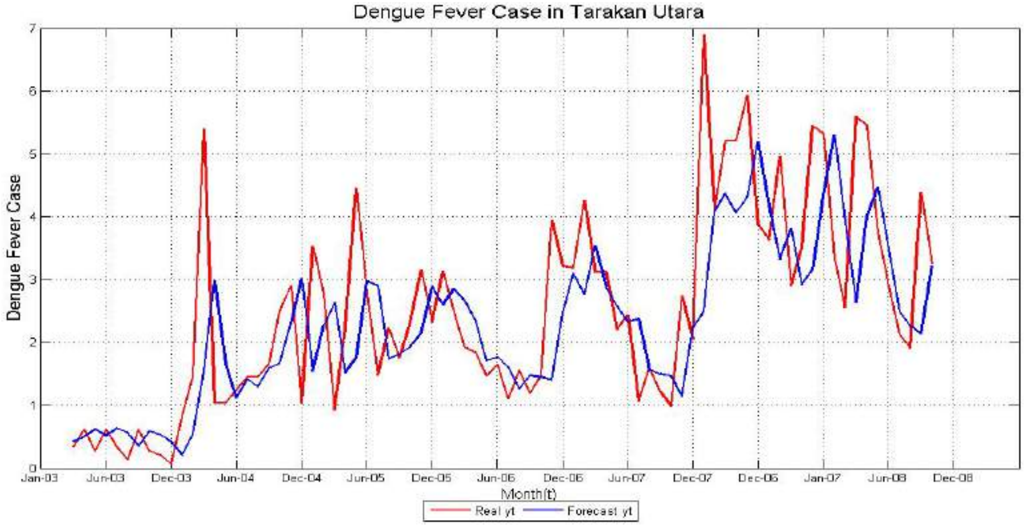

Figure B. 8 Forecast Result from the Best Model (Model 4) in Tarakan Utara

The result of calculations above can be summarized in Table B.6 below. The models can be utilized to predict number of DHF case for certain level of temperature or precipitation increase, or in other words forecasting health hazard level caused by change of climatic factors.

Table B. 6 : Summary of DHF and Climatic Factor Model for Tarakan

Area	Equation Model
Tarakan City	$\ln(\mu_t) = -41{,}57 + 0.1371\ln(\mu_{t-1}) + 0.3839\ln(\mu_{t-2}) - 0.178T_t + 0.0001H_t + 3.96\ln(Pop_t) + e_t$
Tarakan Barat	$\ln(\mu_t) = 0.50982 + 0.277\ln(\mu_{t-1}) + 0.5424\ln(\mu_{t-2}) - 0.1758T_t + 0{,}0001H_t + 6.882RatePop_t + e_t$
Tarakan Tengah	$\ln(\mu_t) = -32.49 + 0.1362\ln(\mu_{t-1}) + 0.37\ln(\mu_{t-2}) - 0.052T_t + 0.0002H_t + 3.2\ln(Pop_t) + e_t$
Tarakan Timur	$\ln(\mu_t) = 6.7686 + 0.6618\ln(\mu_{t-1}) - 0.2247T_t + 0.0002H_t + 17.3093RatePop_t + e_t$
Tarakan Utara	$\ln(\mu_t) = 5.1039 + 0.2356\ln(\mu_{t-1}) + 0.541\ln(\mu_{t-2}) - 0.1838T_t + 0.0002H_t + 1.486RatePop_t + e_t$

APPENDIX C COMPARTMENT 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

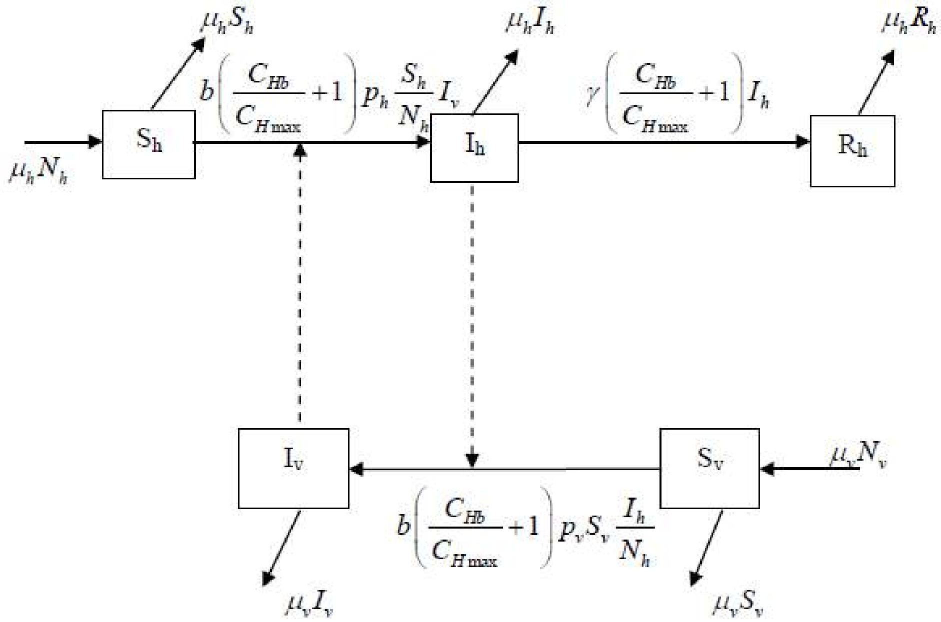

Figure C.1 Schematic model for dengue virus transmission with precipitation effect
(Jafaruddin and Sofyan, 2011)

Model transmission of the dengue virus in human and mosquito:

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

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

Effective reproductive ratio :

$$
\Re(C_b) = \sqrt{\frac{\left(\frac{C_{Hb}}{C_{H\max}}+1\right)^2 b^2 p_h p_v N_v}{\mu_v\left(\gamma\left(\frac{C_{Hb}}{C_{H\max}}+1\right)+\mu_h\right) N_h}}
$$

Force of infection of dengue in human

$$
\Lambda_v = b\left(\frac{C_{Hb}}{C_{H\max}}+1\right) p_h \frac{I_v}{N_h}
$$

Force of infection of dengue in vector

$$
\Lambda_v = b\left(\frac{C_{Hb}}{C_{H\max}}+1\right) p_h \frac{I_v}{N_h}
$$

C.3.2 Construction Model the Transmission Dynamics of the Dengue Virus with Temperature Effect

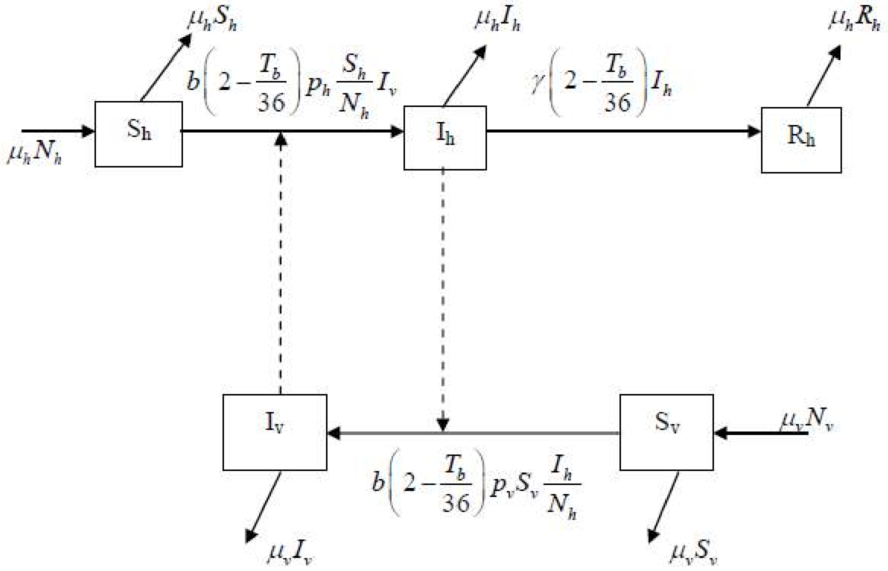

Figure C.2 Schematic model for dengue virus transmission with temperature effect
(Jafaruddin and Sofyan, 2011)

Model transmission of the dengue virus in human and mosquito:

Model transmission of the dengue virus in human

$$\begin{cases} \frac{dS_h}{dt} = \mu_h N_h - b\left(2-\frac{T_b}{36}\right)p_h\frac{S_h}{N_h}I_v - \mu_h S_h \\ \frac{dI_h}{dt} = b\left(2-\frac{T_b}{36}\right)p_h\frac{S_h}{N_h}I_v - \left(\gamma\left(2-\frac{T_b}{36}\right)+\mu_h\right)I_h \\ \frac{dR_h}{dt} = \gamma\left(2-\frac{T_b}{36}\right)I_h - \mu_h R_h \end{cases}$$

Model transmission of the dengue virus in mosquito

$$\begin{cases} \frac{dS_v}{dt} = \mu_v N_v - b\left(2-\frac{T_b}{36}\right)p_v S_v\frac{I_h}{N_h} - \mu_v S_v \\ \frac{dI_v}{dt} = b\left(2-\frac{T_b}{36}\right)p_v S_v\frac{I_h}{N_h} - \mu_v I_v \end{cases}$$

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

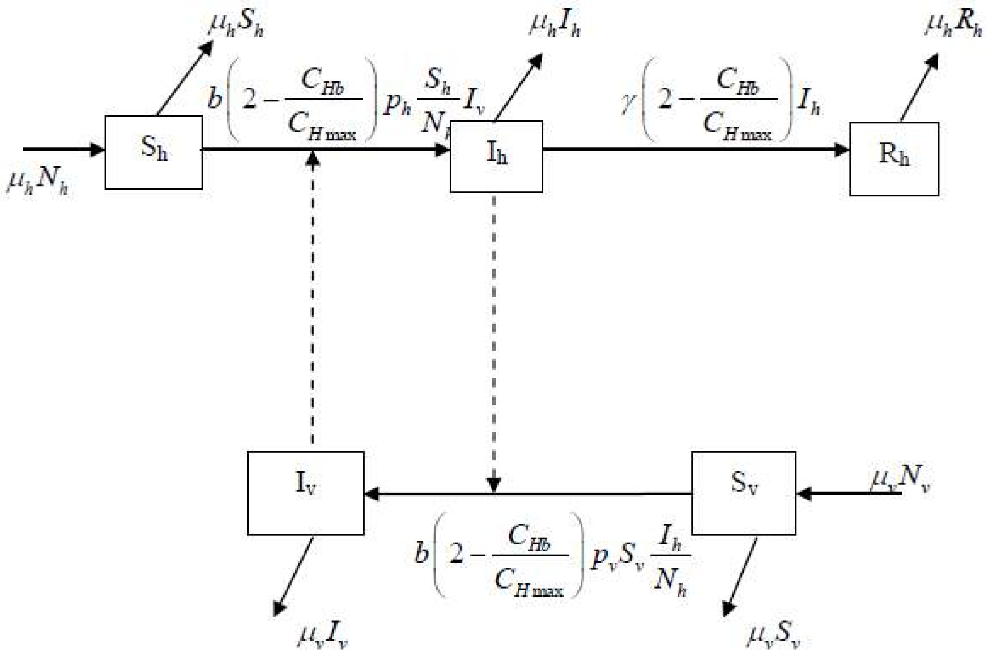

Figure C.3 Schematic model for malaria virus transmission with precipitation effect
(Jafaruddin and Sofyan, 2011)

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

$$\Lambda_v = b\left(2 - \frac{C_{Hb}}{C_{H\max}}\right) p_h \frac{I_v}{N_h}$$

Force of infection of Malaria in human

$$\Lambda_h = b\left(2 - \frac{C_{Hb}}{C_{H\max}}\right) p_v \frac{I_h}{N_h}$$

C.3.4 Construction Model the Transmission Dynamics of the Malaria Parasites with Temperature Effect

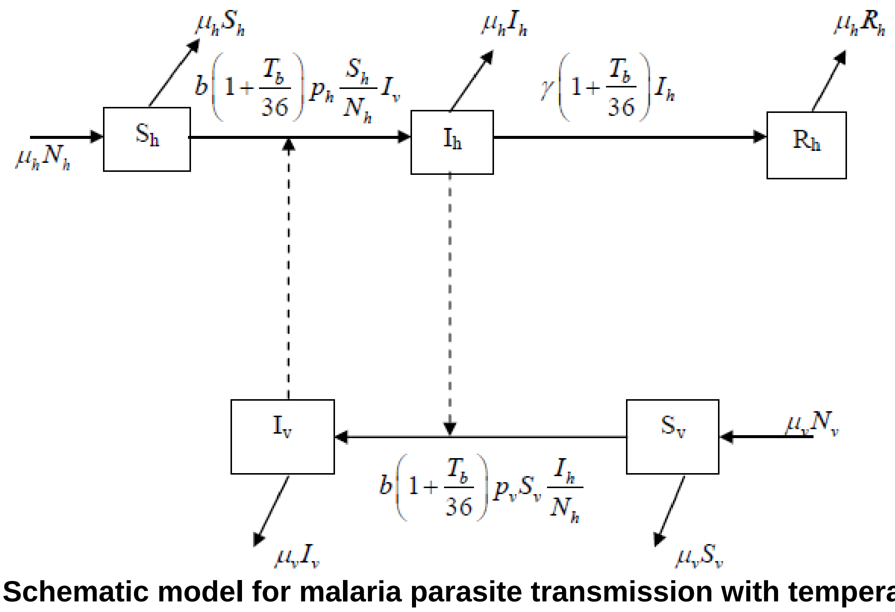

Figure C.4 Schematic model for malaria parasite transmission with temperature effect
(Jafaruddin and Sofyan, 2011)

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

$$\begin{cases} \frac{dS_v}{dt} = \mu_v N_v - b\left(1+\frac{T_b}{36}\right)p_v S_v \frac{I_h}{N_h} - \mu_v S_v \\ \frac{dI_v}{dt} = b\left(1+\frac{T_b}{36}\right)p_v S_v \frac{I_h}{N_h} - \mu_v I_v \end{cases}$$

Effective reproductive ratio :

$$\Re(T_b) = \sqrt{\frac{\left(1+\frac{T_b}{36}\right)^2 b^2 p_h p_v N_v}{\mu_v\left(\gamma\left(1+\frac{T_b}{36}\right)+\mu_h\right) N_h}}$$

Force of infection of Malaria in vector

$$\Lambda_v = b\left(1+\frac{T_b}{36}\right)p_h \frac{I_v}{N_h}$$

Force of infection of Malaria in human

$$\Lambda_h = b\left(1+\frac{T_b}{36}\right)p_v \frac{I_h}{N_h}$$

C.3.5 Construction Model the Transmission Dynamics of the Diarrhea bacterium (E. Colli) with Precipitation Effect

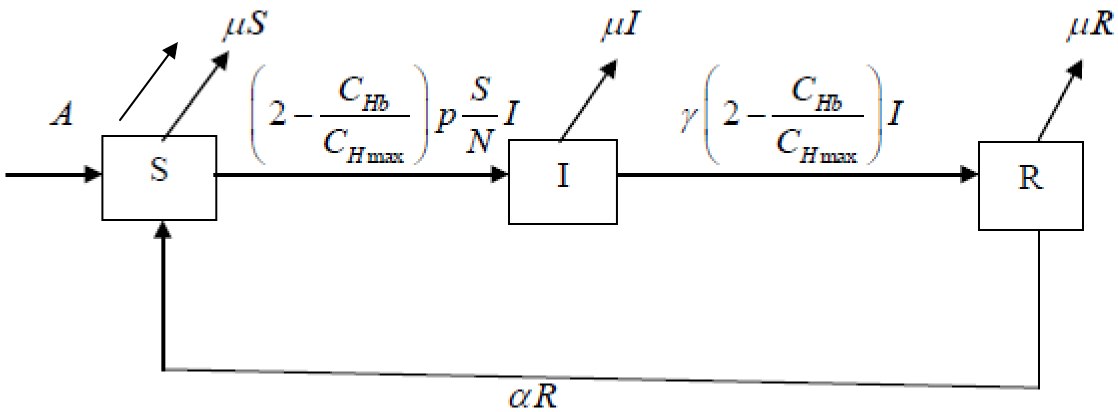

Figure C.5 Schematic model for diarrhea (bacterium E. coli) transmission with precipitation effect (Jafaruddin and Sofyan, 2011)

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

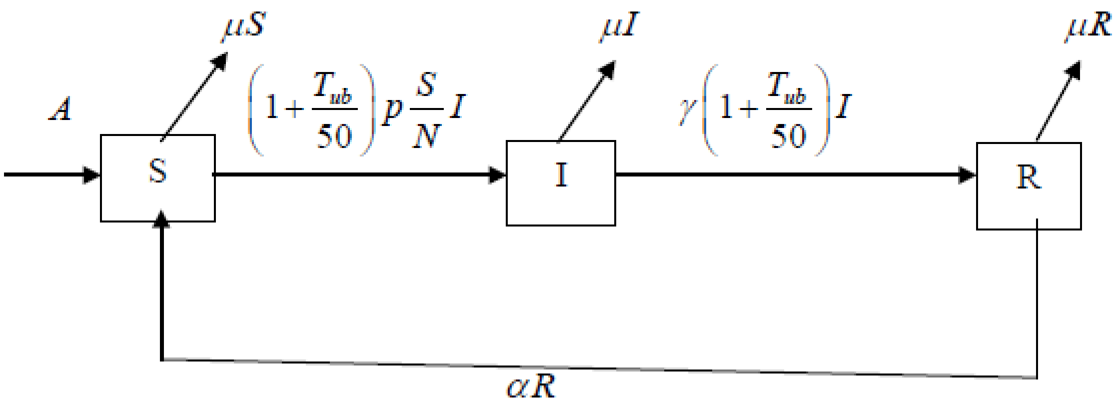

Figure C.6 Schematic model for diarrhea (bacterium E. coli) transmission with temperature effect (Jafaruddin and Sofyan, 2011)

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.

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APPENDIX D ADAPTATION STRATEGY FORMULATION

D.1 Adaptation Strategy for DHF Risk

Common adaptation strategy for DHF risk is shown in Table D.1 as follow. Areas with medium risk need to implement less strategy than higher risk areas. Combination of two or more strategy had proven to give good results in decreasing DHF incidence.

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 meteorological 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

The influence of climate change for DHF endemic area triggers an increase and the abundance of Aedes mosquito. Increase of rainfall frequency provides abundance of breeding sites. Warmer temperature increases the mating habit of the mosquito. Based on those findings, strategy for adaptation of DHF can be 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 vector-borne route. Therefore, the adaptation strategy covered the breaking of transmission chain through elimination of etiologies and its vectors. The following strategy of adaptation is based on the health and climate future projection and should be tailored to the different hazard, vulnerability and risk condition for each area.

Table D. 2: Adaptation Strategy to Various Risk of DHF

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	1. Lesser routine spraying (2-3 times annually, based on the	1. Development of inexpensive, less toxic and less resistant biological

TYPE OF STRATEGY	SHORT TERM (2010-2020)	MEDIUM TERM (2020-2030)	LONG TERM (2030-2050)
	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)	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	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 education	1. Better training of hospital personnel during emergency outbreak 2. To bring down the current incidence rate into halve by 2030	1. The long-term goal is to decrease incidence and mortality due to DHF infection by minimizing hazard, 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

Common adaptation strategy for malaria risk is shown in Table D.3 as follow. Areas with medium risk need to implement less strategy than higher risk areas. Combination of two or more strategy had proven to give good results in decreasing incidence.

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
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	1. **Whole Hospital** emergency alert	1. **Citywide** hospital alert 2. Decrease in morbidity and mortality

Based on implementation timeframe, strategy for adaptation of malaria can be divided into three terms as follow (1) Short term, (2) Medium term, and (3) Long term (see Table D.4).

Table D. 4: General Adaptation Strategy to Various Risk of Malaria

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)	3. Less routine spraying (2-3 times annually, based on the success of short-term program) 4. 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 of Tarakan Timur 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 2. Better malaria case reporting 3. Improve community awareness 4. Improve community education 5. Better availability of antimalarials	1. Better training of hospital personnel during malaria outbreak 2. Training of field malariologists	1. The long-term goal is to decrease incidence and mortality caused by severe falciparum malaria

D.3 Adaptation Strategy for Diarrhea Risk

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.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 concentrate toward behavioral change and long term prevention of diarrheal occurrence.

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	1. **Household level** water management	1. **Community level** of diseases management 3. Increased Community participation	1. **Citywide level** of diseases management	1. 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 agents	**Vaccination** on vulnerable population	Epidemic warning (KLB)
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 on diarrhea is based on the implementation timeframe. There are divided to three term, namely short, medium and long term as shown in Table D.6.

Table D. 6: General Adaptation Strategy to Various Risk of Diarrhea

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) and increased 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 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)