Dengue Hemorrhagic Fever vulnerability indicators valuation due to climate change in Semarang City

Cahyorini, K Azhar and G Veridona
Center for Research and Development of Public Health, National Institute of Health Research and Development, Ministry of Health of Indonesia

Corresponding author: yorinix@gmail.com

Abstract. Information about the vulnerability of an area due to climate change is one of the supporters on the implementation of the early warning system which is carried out as one of the adaptation activities in the health sector in the face of climate change. Health vulnerability assessment research due to climate change was conducted to determine the level of vulnerability and influential indicators for adaptation planning. The study was conducted in the City of Semarang in 2015, to determine indicators of vulnerability for dengue disease due to climate change. Weighting vulnerability indicator variables was done using Principal Component Analysis. The results of the indicators valuation obtained were temperature classification and flood for the exposure component; population density and cases of dengue disease for the sensitivity component; number of health care facilities, number of health workers, clean and healthy living behaviour programme, and healthy houses for adaptive capacity components. The Exposure Index for Dengue Hemorrhagic Fever (DHF) was found at low and moderate levels, the Sensitivity Index for DHF was at moderate and high levels, while the Adaptive Capacity Index was at very low and low levels. It is necessary to plan and implement proactive policies so as to increase the adaptive capacity of local communities and reduce sensitivity to DHF.

1. Introduction
The Intergovernmental Panel on Climate Change (IPCC) in 2007 defines vulnerability to climate change as the level of sensitivity of a system, or the inability to overcome the adverse effects of variability and climate change. Climate change occurs scientifically over a long period, involving internal and external factors from the world climate system. Climate change is also the result of interactions between dynamic and complex climate components and external factors such as solar radiation, volcanic eruptions and human activities.

The occurrence of climate change will deliver health effects both directly and indirectly (through intermediate factors) [1]. The World Health Organisation (WHO) has identified several diseases that are sensitive to climate change, namely malaria, dengue hemorrhagic fever (DHF) and diarrhoea (WHO, 2004). The implication is that there are communities or populations that are susceptible to these diseases. The magnitude of the impact is determined by the changes that occur in the climate and on non-climatic factors that occur together [2].

According to Hahn et al., 2008 in Fullerton et al. 2014, the challenge in compiling and assessing vulnerability is how to synthesise various social and environmental determinants for further communication, and calculate the implications of certain hazards [3]. For examples, there are relevant factors that react on a multi-spatial and temporal scale which are represented by a series of qualitative and quantitative data. This is because the size of the variables of exposure and susceptibility are often...
multi-dimensional, so the approach is through indicators that can simplify and combine various sizes into a composite index (index of vulnerability). Some of these indicators will later facilitate decision makers in understanding large data [4].

The impact of climate change is a consequence of changes that occur in and interactions between nature and humans that form a system. The impact depends on the vulnerability of the system, where vulnerability is a function of exposure (character, magnitude and rate of climate variation) as well as sensitivity and adaptive capacity of a system [5]. Vulnerability represents an illustration of the ease or difficulty of a system in overcoming the negative impacts of climate change, including those caused by extreme climate and climate variability. Vulnerability is a dynamic phenomenon that involves social and biophysical processes [6]. The greater the exposure or sensitivity, the higher the vulnerability of a system. Conversely, if the adaptation capacity gets bigger, the vulnerability will decrease.

Adaptation in health sector due to climate change is essential, especially related to cases of DHF, diarrhoea and malaria. In carrying out adaptations, the supports and involvement of many parties are needed, starting from individuals, households, communities and the government. Adaptation strategies must be designed in order to increase the adaptive capacity and climate resilience of the community[7] because regions with low adaptive capacity will be more affected by the negative impacts of climate change. Usually, the obstacles encountered at the individual and community level are the lack of understanding of and knowledge about the effects of climate change, so that in developing the adaptation strategies, it is necessary to consider aspects of local people's knowledge and conditions that can be justified through scientific research results.

Semarang City is geographically located adjacent to the coastline, thus it will be more exposed to the effects of climate change. From the years 2008 to 2012, the city was ranked first in the highest number of dengue cases in Central Java Province. Even in 2014, the dengue morbidity rate (IR) has reached 97.31 per 100,000 populations, which placed this city in the first rank of dengue morbidity rates in Central Java Province. Today, the DHF cases in Semarang City have increased from 1628 cases (2014) to 1729 cases (2015), especially in Tembalang, Banyumanik and Ngaliyan areas. Based on the 2014 report, the number of deaths from DHF in Central Java Province was still high, namely 159 deaths or second highest after West Java Province (178) and followed by East Java (107).

Based on the conditions mentioned above, it is necessary to establish and evaluate the indicators of vulnerability to dengue in all sub-districts in the City of Semarang. This article has the objective to explain the indicators that are expected to affect the vulnerability of a region so that it can be used as information material for climate change adaptation that is required to form an adaptation programme in Semarang City to face the potential impacts of climate change, especially those related to dengue disease.

2. Methodology

The analysis of indicators of dengue vulnerability in Semarang City mostly uses secondary data in the periods of 2010–2014, originating from several sources. The data collected consisted of DHF incidence data, health care facilities, health workers, Clean and Healthy Living Behaviour Programme (PHBS), healthy houses, population density, climate and disasters, all of which are constituent variables and components of sensitivity, exposure and adaptive capacity.

The steps taken in preparing the vulnerability index are as follows:

- Data collection from health sector (District/City Health Office), Meteorological, Climatological, and Geophysical Agency (BMKG), Development Planning Agency at Sub-National Level (Bappeda), and the Regional Disaster Management Agency (BPBD). The objectives to obtain an overview of the condition of all sub-districts in Semarang City from the aspects of health, demography, climate, programmes and policies of the city government, as well as disasters in the past five years.
- Selection of indicators based on the completeness of the data collected. The indicators were grouped into three components of vulnerability, namely the components of exposure, sensitivity, and adaptive capacity. Exposure refers to the disturbance that comes from
environmental and social political pressure, which includes the magnitude of the problem, frequency, duration and area affected. Sensitivity is the sensitivity of a system to incoming disturbances, while the ability to adapt and deal with the dangers present from the surrounding environment is called adaptive capacity. Adaptive capacity is the ability to overcome the consequences of climate change.

- Scoring was applied to each variable of each indicator with regards to the relevant reference. Scoring is given by considering the resulting impacts, where impacts with higher influences on vulnerability would obtain higher values. The next process was weighting the indicator using the main component analysis technique or Principal Component Analysis (PCA) with the help of the Minitab programme.
- Calculation of the value of vulnerability is illustrated through the relationship of vulnerability-exposure-sensitivity-adaptation ability as follows:

\[ \text{Vulnerability} = f(\text{Exposure}, \text{Sensitivity}, \text{Adaptive Capacity}) \]

The greater the exposure value or sensitivity, the greater the value of vulnerability. But adaptive capacity inversely proportional to vulnerability. The greater the value of adaptation capacity, the smaller the value of vulnerability.

### 3. Results

Based on the completeness of the data, the 2014 data was set as the baseline. The indicators set for the components of vulnerability are: 1. Indicators of temperature trends, and flood events for the exposure component; 2. Indicator of population density, and data on the number of dengue cases in each sub-district for the sensitivity component; 3. Indicators of the availability of health service facilities, health workers (doctors and nurses), clean and healthy living behaviour (PHBS), and healthy homes for components of adaptive capacity.

#### Table 1. Components for compiling the DHF vulnerability index in Semarang City.

| Vulnerability Component | Indicator                          | Weight | Categories                                  | Scoring |
|-------------------------|------------------------------------|--------|---------------------------------------------|---------|
| **Exposure**            | 1 Temperature classification*      | 0.5    | T < 10°C or T > 40°C                        | 1       |
|                         |                                    |        | 10°C ≤ T or 35 < T ≤ 40°C                   | 2       |
|                         |                                    |        | 10°C ≤ T < 20°C or 30°C < T ≤ 35°C          | 3       |
|                         |                                    |        | 20°C ≤ T < 25°C or 27°C < T ≤ 30°C          | 4       |
|                         |                                    |        | 25°C ≤ T ≤ 27°C                             | 5       |
| 2 Flood                 |                                    | 0.5    | Not the location of the disaster            | 1       |
|                         |                                    |        | the location of the disaster                | 2       |
| **Sensitivity**         | 1 population density (per km²)     | 0.5    | Very low population density (<100)          | 1       |
|                         |                                    |        | low population density (100–199)            | 2       |
|                         |                                    |        | Average population density (200–799)        | 3       |
|                         |                                    |        | High population density (800–1199)          | 4       |
|                         |                                    |        | Very high population density (>1200)        | 5       |
| 2 Data on the number of cases of DHF | 0.5 | Data = 0 case | 1 | Data > 0 case | 2 | No data | 3 |
| Vulnerability Component | Indicator                                           | Weight | Categories                                                                 | Scoring |
|-------------------------|-----------------------------------------------------|--------|---------------------------------------------------------------------------|---------|
| Adaptive Capacity       | Number of health care facilities (Primary health care) | 0.23   | Insufficient (< 1 Primary health care /n30,000 population)                | 1       |
|                         |                                                     |        | Sufficient (≥ 1 Pkm/30,000 population)                                    | 2       |
|                         | Number of health workers (doctors and nurses)       | 0.31   | Insufficient (< 1 doctors/4000 population, ≤ 4 nurses /4000 population)   | 1       |
|                         |                                                     |        | Sufficient (≥ 1 doctors/4000 population, ≥ 4 nurses/4000 population)       | 2       |
|                         | Clean and Healthy Living Behaviour program (PHBS)    | 0.19   | Less than 100%                                                            | 1       |
|                         | Healthy house                                       | 0.26   | Achieve 100%                                                               | 2       |
|                         |                                                     |        | Deficient (0–60%)                                                          | 1       |
|                         |                                                     |        | Sufficient (61–80%)                                                        | 2       |
|                         |                                                     |        | Decent (81–100%)                                                           | 3       |

*Data analysed by BMKG*

Each indicator in Table 1 has a category division based on reference or data availability. The category has a scoring value based on the level or degree of influence on vulnerability. Scoring for the exposure component was the same as sensitivity, where the greater the score, the higher was the effect of the negative impact meaning that the high score given to a potentially high condition has a negative/unfavourable impact. Conversely, a high score on the component of adaptation capacity was given for conditions that were closer to the development target, for example the area of dengue cases gets a score of 2, areas without cases with a score of 1. A score of 2 is given when adequate health facilities available, while a score of 1 is given when there are no available facilities.

In the sensitivity component there was an indicator of population density which showed the number of population for each square kilometre of area, grouped into 5 categories. The denser the population living in an area, the higher was the score given assuming an infectious disease in the region. For dengue cases grouping was divided into 3 where the highest value was given to areas that did not have DHF case data because it was assumed that if there was no recorded data, it would mean that the area had the potential to be more susceptible to disease due to poor surveillance activities.

The adaptation capacity component part consisted of 4 indicators. Scoring in this component would be even greater if the indicator was considered to have a stronger influence on the vulnerability of the region. Indicators of the number of health care facilities, as well as the number of health workers were divided into 2 groups, namely sufficient and insufficient. The group was based on the availability of the number of health care facilities or health workers in the region.

In Table 1, we could also see the weight of each indicator. The weight was obtained using statistical analysis based on the Principal Component Analysis (PCA) method. For the component of exposure and sensitivity, each indicator has a weight of 0.5. For the adaptation capacity component, each indicator has a different weight. The number of health workers achieved the highest weight, with 0.31, followed by healthy homes with a weight of 0.26, the number of health facilities with 0.23, and PHBS with the lowest weight of 0.19. Climate data originated from BMKG comprised of data observed since 1981 to 2014, while the indicators of the disaster were sourced from the BPBD data from Semarang City from 2010–2014. Weather conditions and disaster events related to hydrometeorology in each
sub-district were analysed by a team from BMKG. A description of the exposure index of these sub-districts was worth between 2 or 3 can be seen in Figure 1. In the exposure component, there were 9 sub-districts which scored 3, while the rest obtained a score of 2 (7 sub-districts). Thus, more than half of Semarang City has the potential for disasters related to flooding.

Figure 1. The weight of E, S, AC components in Semarang City.

Figure 1 showed that almost all sub-districts obtained a value of sensitivity of 3.5 which means very high vulnerability. Only Ngaliyan sub-district has a value of 3 (high vulnerability). Components of adaptation capacity were composed of 4 indicators consisted of the number of health care facilities (health facilities), number of health workers (health workers), Clean and Healthy Living Behaviour Programme (PHBS) and healthy houses. In the assessment of the healthy houses, there were several criteria that must be met, for example free from mosquito larvae, especially the *Aedes aegypti* mosquito, having healthy latrines and the availability of household sewage treatment channels.

In the adaptation capacity component, the East Semarang and Ngaliyan sub-districts acquired a score of 1, while the other sub-districts acquired a score of 2. Low scores for East Semarang and Ngaliyan sub-district adaptation capacities were caused by the lack of health facilities and achievement of a healthy home below 100%, unlike the other surrounding sub-districts where the performances of the two parameters were found to be better.
Figure 2. DHF vulnerability index in Semarang City.

To obtain the vulnerability index value, the results of sensitivity multiplication and exposure were then divided by adaptive capacity. A total of 16 sub-districts in Semarang City had different levels of exposure, sensitivity, and adaptive capacity. Based on the results of the analysis, the sub-districts with the highest level of vulnerability to DHF was the East Semarang sub-district (2.1), while the sub-districts with the lowest index was Tugu sub-district (1.5).

4. Discussion
This research on vulnerability seeks to identify the problems faced by all sub-districts in Semarang City related to dengue disease and climate change. Vulnerability assessment is a step that must be passed in preparing adaptation actions in accordance with PP No. 33 MenLHK in 2016. The next stage was the preparation of choice of adaptation actions, priority setting and integration of adaptation actions into development policies, plans and/or programmes.

Although some approaches to regional vulnerability were very useful, in general they were very dependent on global data sets and climate prediction models strongly influenced by variations in local conditions, which makes it difficult to interpret. The indicator-based approach was also very limited in the quality and quantity of available data [8]. The types of variables that could be used as indicators should meet several requirements, among others [9]:

- Available and not limited by fees
- Easy to understand
- Accurate, comes from reliable sources
- Measured so that it can be used at several levels of analysis
- Relevant
- The data is updated regularly
- Can be integrated with other sectors

The limitations of this study were the unavailability of complete DHF incidence rate data that could specifically indicate the magnitude of DHF problems in all sub-districts in the periods of 2010–2014. As a solution, an approach was taken to refer to whether there were reports of dengue cases in each sub-district. The method of evaluation based solely on the report, on the number of dengue cases, and might not reflect the actual condition. The possibility of under-reporting of DHF cases related to the results of diagnosis and how to categorise DHF cases could affect the scoring of each sub-district. As a result, the value of sub-components of DHF cases was not varied so that it influenced the calculation of sensitivity component weights.
In addition, it would be better if there were other parameters such as larva free numbers (ABJ) which is one measure of the success rate of mosquito nest eradication (PSN). The ABJ variable can give an idea of the condition of the environment around the residence. According to 2014 data, the national ABJ had only reached 24.06%, which was a sharp decline compared to the 2013 data of 80.09%, meaning that it is far from the programme target of 95%. If ABJ is 95%, it is expected that the transmission of DHF could be prevented or reduced. The low ABJ was caused not only by the absence of ABJ in all districts/cities, but also due to the failure of periodic larva monitoring programmes and jumantik (larvae monitoring specialist) programmes in most regions due to limited budget allocation [10].

With the integration of the values of exposure, sensitivity, and adaptive capacity, it is expected that decision makers can explore various components of vulnerability at the district/city level or sub-district levels. Both of these sub-districts were directly adjacent to East Semarang. The opposite was true for the Central Semarang and South Semarang villages which had a lower index of 1.6 and 1.7, although it was directly adjacent to East Semarang.

Infectious diseases know no administrative borders. For example, high population mobility was partly due to the availability of good means of transportation infrastructure between regions, contributing to the spread of the disease. If there were two bordering regions with the same disease problem, the programme must be synchronised. The aim was to eradicate disease by using the resources of each region, both involving the health sector and other sectors.

Population factors affect the disease transmission process because it will facilitate the proliferation of viruses so that it can lead to an increase in cases. Areas with high population density are usually followed by a high number of DHF cases. Ecological studies conducted in Tanah Datar showed a strong relationship between population density and dengue cases (p = 0.001) [11].

Research conducted in Surabaya found that in addition to population density, the characteristics of a city also influenced the number of cases [12]. Each city had a variety of characteristics and could be grouped into four types. The first type represented an area that had been transformed from a rural area into an industrial area, the characteristic of which human movement occurred between sub-districts, allowing infected people to come from other sub-districts. The second type reflected the new area with the upper middle class economic community. The community moved throughout the working day, infected in other sub-districts then spreads the virus in their homes. Furthermore, the third type was a densely populated area where human movement mostly occurs within the sub-district itself. DHF cases encountered were low due to good disease control. Finally, the fourth type represents slums and densely populated area. Here there was the complexity of human movements, both in sub-districts and between sub-districts, and socio-cultural factors. These factors have caused the high number of dengue cases encountered.

The level of vulnerability of a region can be reduced by reducing the exposure and sensitivity, and increasing adaptive capacity, both in the short and long terms. For this reason, an adaptation strategy is needed, in this case include the improvement of health services and treatment, improvement of surveillance activities and control of dengue disease, clean water and sanitation, and cooperation between regions so as to increase resilience of all sub-districts.

5. Conclusion
The level of sensitivity in all the sub-districts within the City of Semarang was similar, namely 3.5. Exposure levels ranged from 2 to 3, and the level of adaptation capacity was 1.31–2.07. Based on the results of calculations, as many as nine sub-districts had very high levels of vulnerability to DHF and seven sub-districts in the high category. The district with the highest level of vulnerability was East Semarang (2.1) and the lowest was Tugu sub-district (1.5). There is a need to implement various strategies for each community or location in order to effectively reduce health vulnerability due to climate change.
6. Suggestions
DHF is influenced by multiple factors such as population density, climate/weather variability and social factors. Some efforts that can be made to reduce the level of vulnerability to DHF in each region include:

- Planning and implementing proactive policies so as to increase the adaptive capacity of local communities and reduce sensitivity to DHF, for example the provision of clean water facilities, drainage systems and PSN programmes on a regular basis.
- Development of public service infrastructure as population growth includes an increase in the number of health facilities and health workers.
- Increased coordination between sub-districts in order to control dengue cases.
- Improvement of people’s understanding of Clean and Healthy Living Behaviour programme (PHBS) and sanitation through information and education studies.

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