The vulnerability of urban area on climate change and dengue haemorrhagic fever (DHF): Case study in Semarang City

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Abstract. Climate change affects the epidemiology of vector-borne diseases related to the increasing of Dengue Haemorrhagic Fever (DHF) cases, especially in the urban area. Semarang City is one of the urban areas in Indonesia that have experienced climate change. It is indicated by an increase in temperature and unpredicted rainfall pattern over the last few years, which is associated with high cases of DHF in Semarang City since 2005. This paper aims to explore the vulnerability of Semarang City to DHF due to climate change. This study was performed using qualitative research method approaches. Data collection was carried out through in-depth interviews and focus group discussions with the local government and Semarang City residents. We conducted a systematic review of peer-reviewed articles and gray literature analyzing the relation between climate change and DHF. A thematic network analysis was used to analyze and interpret the resulting data to describe Semarang City's vulnerability to DHF due to climate change. Data shows that Semarang City's vulnerability to climate change and DHF affect by geographical, social-demographic, and economic factors.

1. Introduction
Previous studies showed that climate change has occurred and affects human health [1–3]. The impacts of climate change on health can cause illness and death. Moreover, climate change affects the epidemiology of vector-borne diseases [4–6]. The concept of vulnerability depends on the environment and the group's sensitivity and adaptive capacity and place. The interactions between an environment and society are related to climate change, such as influenza, rodent-borne diseases, and vector-borne diseases [3]. For instance, Dengue Haemorrhagic Fever (DHF) is one disease that increases due to climate change [4].

Semarang city is one of Indonesia's urban areas that has experienced climate change [7]. It is indicated by the increase in temperature and changes in rainfall patterns over the last few years. The impact of climate change in Semarang City also demonstrated by high cases in DHF since 2005 [8]. In 2010, DHF cases in Semarang City were the highest in Central Java and the second highest in Indonesia [7]. Additionally, The incidence rate (IR) of DHF in Semarang from 2011 to 2015 exceeded the national IR of DHF, which was 55 per 100,000 per population. The high IR of DHF makes Semarang city more vulnerable to other regions in Central Java.

The local government has been implemented various policies to reduce DHF cases, such as the implementation of regional regulation Number 5 the year 2010 concerning the management of DHF in Semarang City. Additionally, using an information system via a short message service (SMS) gateway at the community health center (Puskesmas) was also carried out to refer the patient to the hospital to prevent delays in treatment.

However, the local government faced various obstacles to reduce incidence rate of DHF in Semarang City. Even though climate change is recognized as a factor that affects DHF, this problem
often considered to be responsibility of the health sector. This condition shows that the sector’s understanding of the vulnerability of cities to DHF from the geographical, climate, as well as socio demographic aspects is still limited. In addition, the obstacle also comes from the inadequate public awareness which often causes DHF cases to be late to be treated.

This paper aims to explore the vulnerability of Semarang City to DHF due to climate change. This paper will focus on the socio-demography characteristics, economic aspect, and health services to investigate the vulnerability of Semarang City on climate change and DHF.

2. Methods

This paper is a part of the study about Climate Change and Dengue Haemorrhagic Fever (DHF) Cases in Urban Areas: Responses from the Government and Civil Society in Semarang in 2012 conducted by Research Centre for Population Indonesian Institute of Sciences. The study was performed by using qualitative research method approaches. Data collection was carried out through in-depth interviews and focus group discussions with local government (district health offices, district planning development agency, meteorology, climatology, and geophysical agency) and local residents in Semarang City. In addition, we conducted a systematic review of peer-reviewed articles and gray literatures (published data and official report related to DHF in Semarang City) analysing the relation between climate change and DHF. A thematic network analysis was used to analyse and interpret the resulting data to describe the vulnerability of Semarang City to DHF due to climate change.

3. Results

3.1. Definitions of vulnerability

Bohle (1994) defined that vulnerability is a combination of exposure and coping strategy [9]. Turner et al (2003) stated that vulnerability as a combination of exposure, sensitivity and lack of resilience [10]. Moreover, Intergovernmental Panel on Climate Change (IPCC) investigated that vulnerability is the synthesis of four factors such as character, magnitude and rate of climate change, exposure, sensitivity and adaptive capacity [11].

Turner et al (2003) have considered the lack of resilience of the people to see the vulnerability [10]. There are several components that influence the vulnerability (Figure 1). The framework consists of linkages between the spacious human and environmental conditions and the operating processes on the combination system what it meant. Secondly, perturbations and stressors that emerge from these conditions and processes. The last one is the combination of the human-environment system that concern in which vulnerability exists including exposure and responses. The vulnerable system related to exposure, sensitivity and resilience of population, economy land use and development, infrastructure, and natural resources [10]. Also, the ability, resources or willingness to mitigate, prepare, respond and recover from disaster risks.

3.2. Climate change and dengue haemorrhagic fever (DHF)

In the Roadmap for Climate Change in the Health Sector, it is stated that the increase in temperature affects the reproduction, growth, age, and distribution of disease vectors, such as vectors of malaria, DHF and Chikungunya. Meanwhile, rainfall affects the type and number of habitat for disease vectors to reproduce. Changing in rainfall patterns, temperature and humidity can influence the population density of disease vectors [4].

Dengue Haemorrhagic Fever (DHF) is a disease that transmitted via vectors and exacerbated by climate change. DHF is an acute febrile disease caused by the dengue virus which attacks the human bloodstream through the bite of mosquitoes from the female Aedes genus, both Aedes aegypti and Aedes albopictus [12]. The increase in DHF cases because of population growth, population movement, regional development from villages to cities, urban arrangement and building structures that disobey health and climate change [13].
Furthermore, temperature greatly affects pathogen replication, maturation and the period of infectivity of the virus. Data shows that higher temperatures increase the extrinsic incubation period and the proportion of Aedes aegypti mosquitoes [14]. At temperature of 30 degrees Celsius, the incubation period of the dengue virus around 12 days, while at temperature of 32 - 35 degrees Celsius the incubation period for the virus only takes seven days [15]. Conversely, very low temperatures will kill larvae and eggs of Aedes aegypti [14]. Moreover, increasing rainfall and humid air also affect the density and transmission of the dengue virus [12]. The breeding of the Aedes aegypti is very sensitive and becomes faster against less drastic temperature changes [14]. This can be seen from the extraordinary cases (KLB) of DHF which generally spreads when the dry season changes to the rainy season.

3.3. The dengue haemorrhagic fever cases in Semarang City
Semarang city has experienced an increasing of temperature around 0.2°C Celsius every year from 1986 to 2006 [16]. In addition, the rainfall becomes unpredicted (abnormal), where the number of rainy days is getting shorter but the intensity of the rain increased significantly during the dry season [7]. This condition affects the increasing of the density and transmission of the dengue virus.

The highest cases and deaths from 1994 to 2019 occurred in 2010. The case is 5,556 and there is 47 of people died due to DHF. Likewise, The incidence rate in 2010 is 368.7 per 100,000. The cases of DHF decreases from 299 in 2017 to 103 in 2018 (Figure 2). The declining of the DHF cases is in line with the increasing of larva free number. There is also a massive DHF control in the societies through three ways, that are, eradication of mosquito nests (PSN), regularly larva checked and counselling to change the health behaviour of people. Besides that, the tidal flood that often occurred in Semarang City especially in coastal area is decreasing at that time.
Figure 2. The Cases, Incidence Rate (IR), Mortality and Case Fatality Rate (CFR) of DHF in Semarang City, 2011-2019

Source: Health office in Semarang, 2019

However, in 2019, the cases of DHF slightly increase to 440 and the incidence rate is rising to 26.37. The highest Case Fatality Rate (CFR) occurred in 2016 at 5.13%. In addition, the cases of DFH on male (63%) is higher than female (37%) in 2019. The highest DFH cases in 2019 occurred on the population aged 10-14 years (36%). The majority cases of DHF consistently dominated by age groups 0-14 years. The case fatality rate of DHF in Semarang City increase from 0.97% in 2018 to 3.18% in 2019. The mortality due to DHF in 2019 is 14 persons. Data also shows that population aged 5-9 years is a group with the highest mortality of DHF.

3.4. The vulnerability of semarang city on climate change and dengue haemorrhagic fever

3.4.1. Geographical aspect. Based on geographic aspect, Semarang City is located between 6º50'-7º10' South Latitude and 109º35'-110º50' East Longitude which borders the Java Sea to the north. The total area around 373.7 Km² and it is located between 0.75 – 348 meters under sea level [17]. The altitude location affects the vulnerability to DHF cases. The vector (Aedes aegypti and Aedes albopictus) that transmit the virus of DHF can live well at an altitude of less than 1000 meters under sea level [13].

Semarang, like several regions in Indonesia has tropical climate. There are two seasons, namely rainy season and dry season. The Average Rainfall in Semarang during 2019 is 181.83 mm. The rainfall caused the breeding grounds for the Aedes aegypti to become filling up after being dry. Also, vector that causes of DHF cannot reproduce at water that is directly contacted with the ground [18]. However, Semarang City is also known as the region which often occurred the tidal flood because of the climate change. It causes Semarang City is quite different with other regions. The high intensity of tidal flood affects the habitat of mosquitoes that cause DHF.

The vector that causes DHF has increased rapidly in transition seasons, during the rainy seasons and before the dry seasons [15]. The increasing of the Aedes aegypti population causes the rising of dengue virus transmission [18]. Moreover, the rainy season that accompanied by the increasing of temperature affect the DHF cases in a region [14]. As seen in Semarang City, the total cases of DHF are remain high although the highest cases occurred in 2010. Regions which have tropical climate tend to vulnerable of the increasing of DHF cases. The vector-borne disease that transmitted by the Aedes aegypti are commonly found in areas with tropical climate as a result of climate change [15]. Hot weather interspersed with the rain is a perfect environmental temperature for the breeding of Aedes aegypti as a spreader of the dengue virus [6]. It is more complicated with the tidal flood that often occurred in Semarang City.
The average of air temperature from 23.2°C to 34°C Celsius [17]. The period of virus incubation at 30°C Celsius is 12 days. However, it takes only seven days when the temperature around 32-35°C Celsius [15]. The temperature in coastal areas in Semarang is warmer than in the hill areas. Coastal areas which have hotter temperatures are more potential to become DHF endemic spot because the temperature of these areas accelerates the period of incubation for Aedes aegypti to breed. In addition, the air humidity in Semarang City is quite high, around 75% [17]. Aedes aegypti can adapt well in high humidity that increasing their population. It affects the vector to seek a damp and wet place outside the home to stay during the day so it can increase the spread of DHF. The vector that cause DHF do not like the humidity less than 60%. It is because the age of the vector will be short, so it is not enough time for the parasite in their body to growth [4].

3.4.2. Socio-demographic aspect. According to geographic aspects, Semarang City is vulnerable to DHF. This situation can be severed by socio-demography characteristics. High population density due to the population growth is susceptible to DHF. Regions with high population growth is related to high social vulnerability [19]. The high density of population will affect the availability of adequate housing facilities and social service networks that are not functioning properly. Also, regions with high population density have a higher social vulnerability than areas with low population density [20]. As the centre of industry area, Semarang city become a destination area for many migrants. This phenomenon does not only affect the population density in Semarang, but also increases the slum area considering the migrants who come for looking a job and staying temporarily. The slum area can trigger the transmission of DHF vector [21]. It can be related to the health behaviour of people. Based on research, some groups still have obstacles to live with healthy habits. It is more complicated for those who are living in congested areas and slum areas.

Table 1 shows the population growth in Semarang increases from 0.51% in 2018 to 1.57% in 2019. In 2019, the population density in Semarang reach at 4,854 person/km2. The increasing of the DFH transmission is influenced by the population density and it is increasing the temperature which accelerates the spread of DHF.

| Table 1. Characteristics of population in Semarang City |
|--------------------------------------------------------|
| **Variable** | **Data** |
| Population growth, 2019 | 1.57% |
| Population growth, 2018 | 0.51% |
| Population density (jiwa/km²) | |
| - 2019 | 4,854 person/Km² |
| - 2010 | 4,175 person/Km² |
| Sex: | |
| - Male | 49.02% |
| - Female | 50.98% |
| (n= 1,814,110) | |
| Age groups: | |
| - 0 – 14 year | 21.31% |
| - 15 – 49 year | 57.86% |
| - 50 – 64 year | 15.12% |
| - 65+ | 5.71% |
| (n= 1,814,110) | |

Source: Semarang Statistic Office, 2020
The age groups that consist of infants, toddlers and children are vulnerable to DHF. It means that 21.31% of population aged 0-14 years in Semarang City tend to be more vulnerable than the other age groups. In general, children aged 4-10 years are often to expose the DHF. However, there are also cases for babies less than a year. Aedes aegypti likes shady places that protected by the sun and smells of humans. Toddlers who need sleep in the morning have the propensity to be bitten by the vector. Besides home, school also vulnerable as a place where the vector or mosquito can spread the DHF virus. Likewise, a shady garden becomes a potential place where the Aedes albopictus is living.

Figure 3. The Percentage of Population Aged 15 Years Old and Above in Semarang City by Level of Education
Source: Semarang Statistics Office, 2019

Moreover, education level play an important role on health behaviour. Data shows that around 46.55% of population has low education, namely junior high school level and below (Figure 3). Education is one of the important factors to increase public awareness on health behaviour. The higher the education of a person, the better of the ability to understand information about the disease. A person’s ability helps to understand the information about the disease that supported to encourage the healthy behaviour, especially in implementing prevention and control efforts. People with higher education is assumed more understand the actions that should do when they feel the symptoms in their bodies or family. Based on research, they usually seek the health services to have blood tests to confirm whether they are exposed to DHF [22].

3.4.3. Economic aspect. The economic aspect in this study is seen by livelihood and facilities infrastructure of Semarang City. Previous study stated that the more infrastructure built in a region, the higher of social vulnerability will be occurred [19]. Semarang as an urban area and the capital of Central Java Province become an epicentre of infrastructure development that causes the increasing of DHF transmission. This is in line with the research that stated the development in infrastructure of urban areas with the tropical climates also had an impact on increasing the transmission of DHF [23]. Also, the spread of DHF cases is mostly found in urban areas that have poor water and sewage systems [15,21]. Thus, as the centre of industry, Semarang City is classified as a fairly high level of susceptibility to DHF due to the massive infrastructure development. It more worse if the infrastructures that built are not environmentally friendly.

Moreover, more than 30% of the population works in the informal sector (Figure 4). The informal sector includes farmers, farm laborers, fishermen, construction workers, transportation and traders. Meanwhile, the formal sector includes civil servants and military/police, retirees, entrepreneurs and industrial workers. People who are working in the informal sector suspected to be more vulnerable to DHF that in the formal sector. Unlike those who work in the formal sector, informal sector workers are usually do not covered by health insurance so the access to health care is limited. It affects to their health behaviour for seeking the first aid to cure the diseases. Likewise, this group is known as a group
with unstable incomes. Because of the costs limitation, people in the informal sector usually ignore the symptoms of DHF in their bodies which results in handling the DHF cases often being late.

![Figure 4. Percentage of Population by the Type of Work in Semarang City, 2016](image)

**Table 2.** Health Care Facilities in Semarang City, 2019

| Health care facilities                          | Total |
|------------------------------------------------|-------|
| Hospital                                       | 27    |
| Community Health Centre (Puskesmas)            | 37    |
| Puskesmas (supporting)                         | 38    |
| Mobile health centre (Puskesling)              | 37    |
| Doctor                                         | 2,771 |
| Specialist doctor                              | 1,155 |

Source: Semarang Health Office, 2019

Furthermore, one of the adaptation strategy to maintain the health from the diseases is health insurance. Health insurance can be seen as a formal adaptation in regards to the climate change impacts [10]. There are several types of health insurance ownership in Semarang City. Five types of health insurance show in Figure 5. It is useful for seeking the medical treatment especially when people get the diseases. In general, the majority of population in Semarang has ‘BPJS Kesehatan’ non-subsidy. One of the reasons is because the budget limitation of the central government. It becomes more vulnerable for those who are working in the informal sector because of the unstable income to afford the premium. However, due to the high cases of DHF, there is a policy from the local government to give free medical costs for the Semarang residents at that time.
4. Conclusion
The high prevalence of DHF is suspected to be due to climate change in Semarang City. Geographical and socio-demographic factors are known as underlying causes of the vulnerability of Semarang City to DHF. For geographical factors, the location of Semarang is suitable with the breeding ground for the Aedes aegypti. In addition, the problem of tidal flooding causes DBD mosquitoes to breed rapidly. For socio-demographic factors, the rate of population growth which continues to increase that related to the density of settlements. It has an impact on increasing in DHF transmission. Children under the age of five years old is the group of the population were more vulnerable to DHF. It is because the young age has weaker antibody compare to other age groups.

Therefore, the categorisation of vulnerable districts based on geographic and socio-demographic characteristics will provide options for policymakers to formulate intervention strategies to reduce the prevalence of DHF in Semarang City. In addition, increase the public awareness of the danger of DHF also one effective way to prevent delays in DHF treatment. The DBD prevention requires close cooperation among multiple stakeholders and this should be done consistently for sustained effect.

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