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A climate risk assessment of clean water supply in an urban area: A case study of South Tangerang city, Indonesia

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Abstract. The demand for clean water in South Tangerang, Indonesia, is very high. At present, this demand is mostly met by groundwater that is much influenced by climate variability, land cover change, and human activities. The local company on water services (PDAM) provides clean water services for only about 9% of the population. The climate risk assessment conducted by South Tangerang Government in 2016 indicates that several areas are potentially exposed to a high risk of climate change. Survey and in-depth interview with communities and sectoral officers suggest that a risk to clean water supply in this city is increasing. This study aims to assess climate potential risks on clean water supply based on the 2016 study. We adopted the method of that study by modifying some of the vulnerability indicators that can represent clean water access and supply. The results of the study demonstrate that many wards in South Tangerang would be exposed to high climate risks of clean water supply. By 2021, about 54% of wards would be exposed from high to the very very high risk of clean water supply. These results signify the tangible need of adaptation actions, to prevent the worsening impacts of climate on clean water supply.

1. Introduction

South Tangerang City is a neighbor and buffer zone to Jakarta Capital City. It is located downstream of three watersheds (Cisadane, Angke, and Pesanggrahan watershed) and is potentially vulnerable to climate disasters such as flood and drought. Based on interviews with the wards, sub-district officials and communities in several areas in South Tangerang from January to September 2017, each ward has drought-prone and flood-prone areas. The risk of drought and flood is felt increasing. The increasing risk of drought is mainly caused by the rapid increase of population and rapid growth of development process leading to the exceptionally high need for clean water, while the level of clean water supply does not much increase but becomes more uncertain. The increasing risk of flood is caused by increasing rainfall, narrowing and blocking of river's body by domestic solid waste leading to more frequent overflowing of the river of the upstream. It is reported that flood also causes the problem to clean water supply as many of community wells in the flood-prone areas are being contaminated by the flood water. In addition, the flood also causes the spread of various diseases, such as dengue fever in the city.

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In the future, the supply of clean water in South Tangerang City may pose a greater problem. It is not only due to climate change, but also high population growth. South Tangerang City has the highest population growth rate in 2010-2011 in Banten Province, which recorded 3.6% growth per year [1]. Thus, the demand for clean water will increase rapidly in the coming years. On the other hand, infrastructure for clean water services has not much improved. At present, only about 9% of the population in this city has access to clean water supply system or PDAM (Local Company of Drinking Water), while the rest depends on ground surface water (wells). Previous studies found that water shortage is a major problem in the South Tangerang City [2]. Boer *et al.* [3]indicate that Tangerang City will expose to the increased risk of water shortage even without climate change. By 2080, a water deficit will be more severe.

Ways of communities to cope with limited clean water supply during flood and drought occurrence are by deepening the groundwater wells, buy clean water, and ask for help from neighbors or from other parties such as the government. Considering the existing rapid increase of population and development in the urban areas of the South Tangerang, adequate availability of clean water becomes essential for sustainable growth of the city. However, the evidence of rapid growth and facts obtained in the field suggest that the future availability of clean water in South Tangerang is at a threatened level. To anticipate this condition, it is necessary to establish a clean water management policy considering climate change.

Based on the previous study, several of the city's environmental pillars are even categorized in vulnerable conditions [4]. On the other hand, spatial policies in the Local Spatial Plan (RTRW) regulation are not well defined in term of its relation to water management [5]. The South Tangerang City Government has had A Master Plan of Drinking Water Service System (RISPAM) in 2013. However, it is still in the preparation phase of its action plan [6]. The Assessment of Vulnerability and Risk for Climate Change in South Tangerang City has been prepared in 2016 by local government, but this does not include clean water aspects [7].

2. Objective

This study aims to assess the climate risks of water supply in South Tangerang City at present and in the near future. The result of this study is expected to be used as a reference for policymakers in designing strategy for sustainable water supply and avoiding greater losses in the future.

3. Method

Climate risk assessment of clean water supply is conducted to evaluate the level of risk of wards to clean water supply at South Tangerang City. The risk is measured by possible damage toward that can occur when threats become reality, including the anticipated severity of consequences. The City is situated in the western part of Java Islands, Indonesia (Figure 1a) consisting of 7 sub-districts and 54 wards (Figure 1b).

The assessment looks at to what extent awards are and going to be affected by the impacts of climate hazard (floods and drought) regarding clean water availability. The extent of the impact will be determined by the level of vulnerability of the wards, the degree to which award is unable to cope with the hazards.The occurrence of drought will limit the availability of clean water for household, particularly when the household relies very much on groundwater and is not connected to PDAM. Flood occurrence may also limit the availability of clean water as the flood may contaminate the quality of water in wells. Thus, the potential impact of the climate hazards on the household in the ward dealing with clean water will depend on the ward vulnerability or, in other words, the risk is defined as a function of hazard (H) and vulnerability (V) [8].

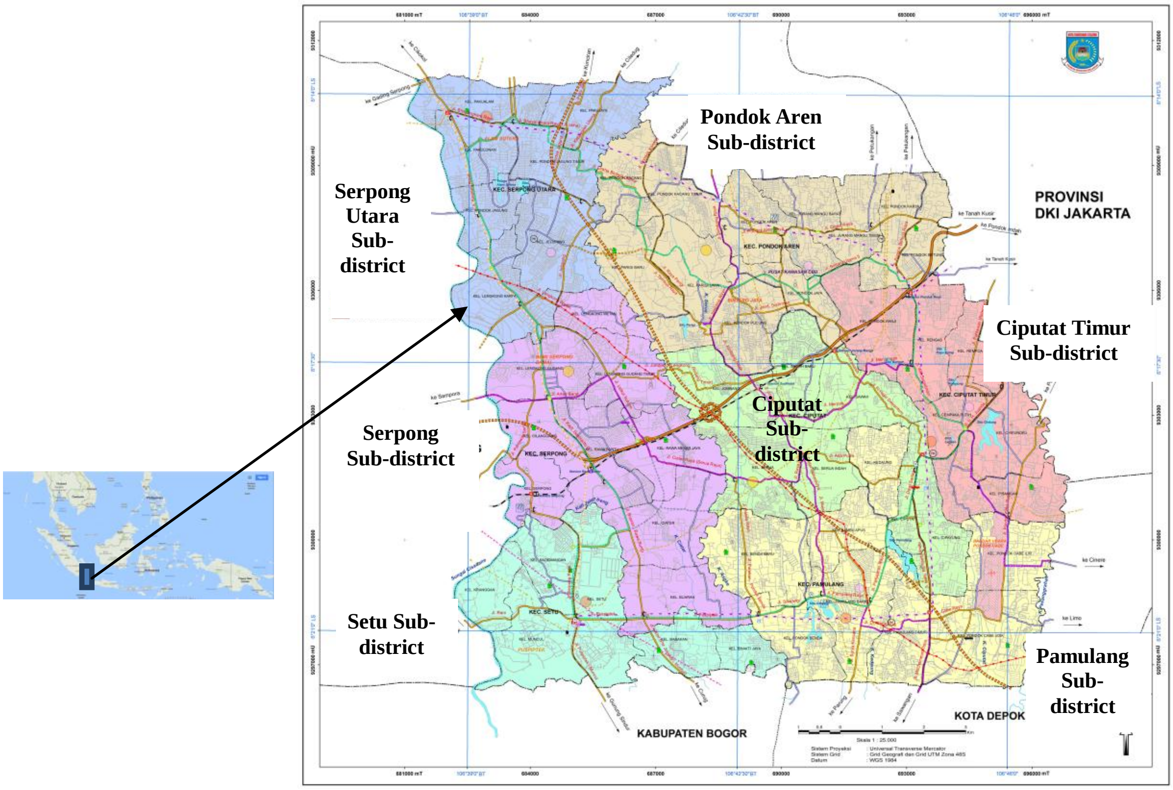

Figure 1. Map of South Tangerang city is divided into 7 sub-districts

Intergovernmental Panel on Climate Change (IPCC) formulates the vulnerability [9]as the following:

$$\text{Vulnerability} = f(\text{exposure, sensitivity, adaptive capacity}) \quad (1)$$

Exposure is the condition or level at which a system is exposed to significant climatic variations [10]. Sensitivity is defined as the degree/level of an affected system, either adversely or favorably, by climate-related stimuli, including all elements of climate change such as average climatic characteristics, climate variability, and extreme frequency and magnitude [10]. Adaptive capacity is defined as the ability of the system to adapt to climate change, to reduce potential damage from it, and to benefit or overcome its consequences [10].

Many studies developed approaches and methods to quantify the vulnerability as index [11][12]13]. A set of indicators have been used to represent exposure, sensitivity and adaptive capacity. In general, the index is developed by summing the multiplication of indicators values with their corresponding weights as the following:

$$\text{Index} = \Sigma w_i{*}I_i \quad (2)$$

where w_i and I_i is the weight and indicator value. The weight of an indicator is determined based on the importance level of the indicator in explaining the vulnerability which relies on expert opinion. However, there are many other approaches that can be used to define the weight. In this study, we used some indicators from the Government Study on the vulnerability of the Tangerang City conducted in 2016 [7] and introduced two new indicators that represent sensitivity and adaptive capacity related to clean water (Table 1a and 1b). These include clean water needs representing the sensitivity and PDAM's customers representing adaptive capacity. Clean water needs are classified as

sensitivity indicator as RWs (association of community) with high water needs will be more sensitive to clean water shortage than those with low water needs. Meanwhile, the number of PDAM customers is classified as adaptive capacity as the RW with the higher number of PDAM customers will have a higher capacity to adapt to water shortage than those with a lower number of PDAM customers.
The clean water needs of RW (CWN) are calculated using the following equation:

$$CWN = \text{population size} * \text{water consumption} \tag{3}$$

Water consumption is assumed to be about 175 liters/person/day (by using average amount based on the standard 150-200 liter/person/day) [14]. The value of CWN of an RW is normalized to make the value range between 0 and 1 by dividing the CWM with the CWM maximum. While the number of PDAM customer is also normalized by dividing the number of the customer with the population size of the RW.

Table 1a. New indicator of exposure and sensitivity

No	Data	Weighting
1	Population density	0.1
2	Clean water needs	0.25
3	Sensitive population	0.15
4	Low income family	0.15
5	Slump area	0.05
6	Developed area	0.1
7	Functional area	0.05
8	Unemployment	0.15
	Total weighting	**1**

Table 1b. New indicator of adaptive capacity

No	Data	Weighting
1	PDAM's customer	0.25
2	Education facilities capacity	0.20
3	Health facilities capacity	0.15
4	Source of income	0.15
5	Housing types	0.06
6	Sanitation types per family	0.10
7	Waste disposal method per family	0.05
8	Source of Energy	0.04
	Total weighting	**1**

Using the equation 1, we define two indices namely sensitivity and exposure index (IKS) and adaptive capacity index (IKA). The vulnerability index of the ward is defined using the quadrant system as suggested by the Permen LHK 33.2016 [15](Table 2).

Table 2. Category of vulnerability index

REQUIREMENT	QUADRANT	CATEGORY	COLOR
If Ano.IKS<0, Ano.IKA>0, Ano IKS-IKA<-0,25	1	Very Low	
If Ano.IKS>0, Ano.IKA>0, Ano IKS+IKA>0,25	2	Low	
If Ano IKS+IKA<0,25, Ano.IKS+IKA>-0,25, Ano IKS-IKA<0,25, Ano.IKS-IKA>-0,25	3	Medium	
If Ano.IKS<0, Ano.IKA<0, Ano IKS+IKA<-0,25	4	High	
If Ano.IKS>0, Ano.IKA<0, Ano IKS-IKA>0,25	5	Very High	

Source: CCROM, 2013 in PermenLHK 33, 2016[15]

While hazard index (HI) is also calculated following equation (1) in which the hazards include drought and floods. The level of flood and drought hazards is obtained based on the perception of respondent on the intensity of the hazards occurrence. The scores are 1, 2, 3, 4 or 5 representing very low, low, medium, high and very high intensity. The weight of the drought is 0.6, and the flood is 0.4. The drought has a higher weight, as the impact of the drought is regional wise while that of floods is a quite site-specific. The index of hazard is then classified into five, as shown in Table 3. The risk index is defined using the risk matrix as shown in Table 4.

Table 3. Category of hazard index

REQUIREMENT	CATEGORY	COLOR
IfHI< 1	Very Low	
If1< HI <=2	Low	
If2< HI <=3	Medium	
If3< HI <=4	High	
IfHI>4	Very High	

Source: Author’s calculation

Table 4. Category of risk level

PROBABILITY		HAZARD				
		Very High	High	Medium	Low	Very Low
VULNERABILITY	Very High	VVH	VVH	VH	H	M
	High	VVH	VH	H	M	L
	Medium	VH	H	M	L	VL
	Low	H	M	L	VL	VVL
	Very Low	M	L	VL	VVL	VVL

Source: Permen LHK 33, 2016[15]

Note:

VVH : Very Very High

VH : Very High

H :High

M :Medium

L :Low

VL : Very Low

VVL : Very Very Low

This study simulated 6 scenarios, which are:

- Scenario 1 describes the current situation;
- Scenario 2 describes projected situation in 2021 in which the number of PDAM costumer per year was increased 0.5% in every ward;
- Scenario 3 is similar to scenario 2, but ward that has no PDAM customer will start to have new PDAM access in 2017 for every ward;
- Scenario 4 describes projected situation in 2021 in which the number of wards affecting by flood was increased by 2% per year
- Scenario 5 describes projected situation in 2021 in which the number of RW as PDAM costumer were increased by 2% per year for every ward;
- Scenario 6 projected situation in 2021 with a combination of scenario 3, scenario 4, and scenario 5.

4. Results

At the current condition, the level of vulnerability of wards of South Tangerang City is mostly dominated by medium to very high level. Factors causing the vulnerability of the wards are influenced mainly by clean water needs, unemployment, education level and the percentage of households that have access to clean water system (PDAM customers). Wards that have very high vulnerability level are Paku Alam, Pakulonan, Serpong, Ciater, Pondok Kacang Timur, Pamulang Barat, Pamulang Timur, Pondok Benda, Kedaung, Benda Baru, Sawah, Jombang, Pondok, and Ranji, otherwise, award that has low vulnerability index is Cilenggang. It is found that the wards with very high vulnerability level are highly populated with high clean water demand, high unemployment rate, low education

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level and limited access of the household to clean water services (PDAM). These wards include Paku Alam, Ciater, Pondok Kacang Timur, Pamulang Timur, Sawah, Jombang and Pondok Ranji (Figure 2). In term of climate hazard, wards that are exposing to the high intensity of flood and drought are mostly situated in the north part of the city and a few in the south (Figure 2). Wards with very high vulnerability level and very high hazard index are considered to be very high risk. It is found that there are more than 20% of wards exposed to very high climate risk to the water supply. These wards include Lengkong Karya, Pondok Kacang Timur, Pondok Aren, Jurang Mangu Barat, Muncul, Kranggan, Pamulang Barat, Pamulang Timur, Kedaung, Cipayung, and Pondok Ranji (Figure 2).

With the scenario of increasing number of PDAM customer (scenario 2) and ward with PDAM access (scenario 3) with a low rate as well as increasing number of the ward of flood area (Scenario 4) will not change much the level risk (Figure 3). However, by increasing number of the ward with clean water service system (PDAM) at a high rate (2%; scenario 5 and 6), many of wards that currently have high risks will have lower risks. Under scenario 5 and 6, in the next five years (2021) the wards that have very low risks will increase significantly (Figure 3). The maps showing distribution of vulnerability index, hazards index, and risk index of wards under scenarios 2, 3, 4, 5 and 6 are presented in Figure 4.

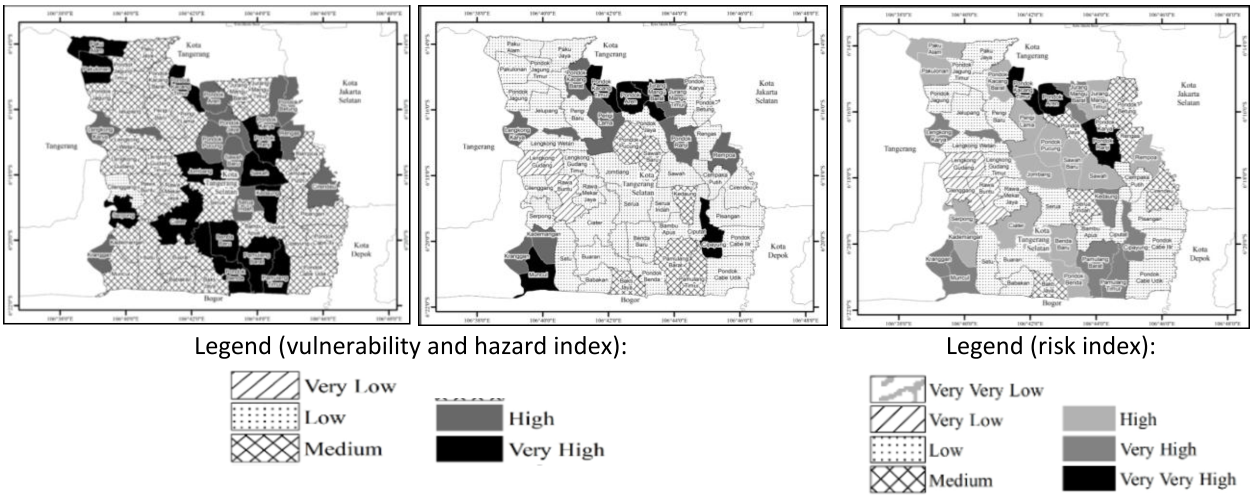


Figure 2. Map of vulnerability index (left), hazard index (middle) and risk index (right) of award under current conditions.

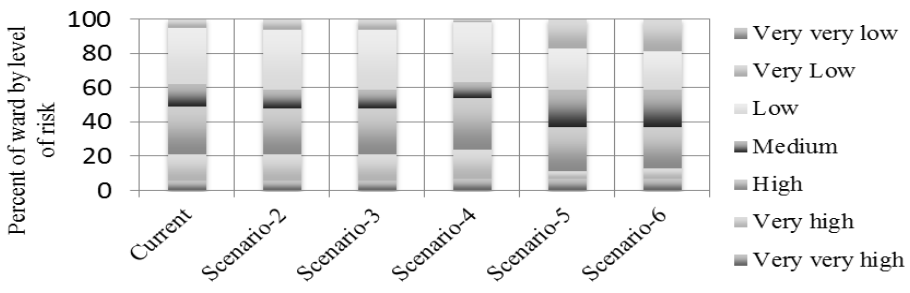


Figure 3. Percentage of ward based on risk level at current situation and under the scenarios

5. Discussion

Based on this study, it is shown that South Tangerang City has a potentially high risk of clean water supply caused by climate hazard, land cover changes, and human activities. It needs an adaptation action to reduce the worse impact by flood or drought that will potentially happen in the future. There is an option to build water reservoir as the water storage, as well as alternative water resources. Moreover, several river bodies are needed to be normalized, since these are occupied by buildings. The river normalization program may reduce the flood incidents in some areas. For preventing the worse drought condition in the future, South Tangerang City Government should also create many environments and water conservation by greening, bio pore hole, or rain harvesting. There should be a policy on sustainable groundwater management for preventing the water clean supply problems.

Besides climate hazards, the adaptation action should work on increasing the PDAM access throughout the city. The source of PDAM is not always from Cisadane River only, there are many other potential water resources in South Tangerang City since they have several lakes in the south and east part of the city. In 2013, RISPAM of South Tangerang is thought to be sufficient to provide the basis for the planning of water supply system from a variety of water sources according to the existing resources in South Tangerang. The action plan in the RISPAM can be improved by climate hazard consideration. Therefore, hopefully, the worse impact of climate hazards, population and development growth can be alleviated for more sustainable life.

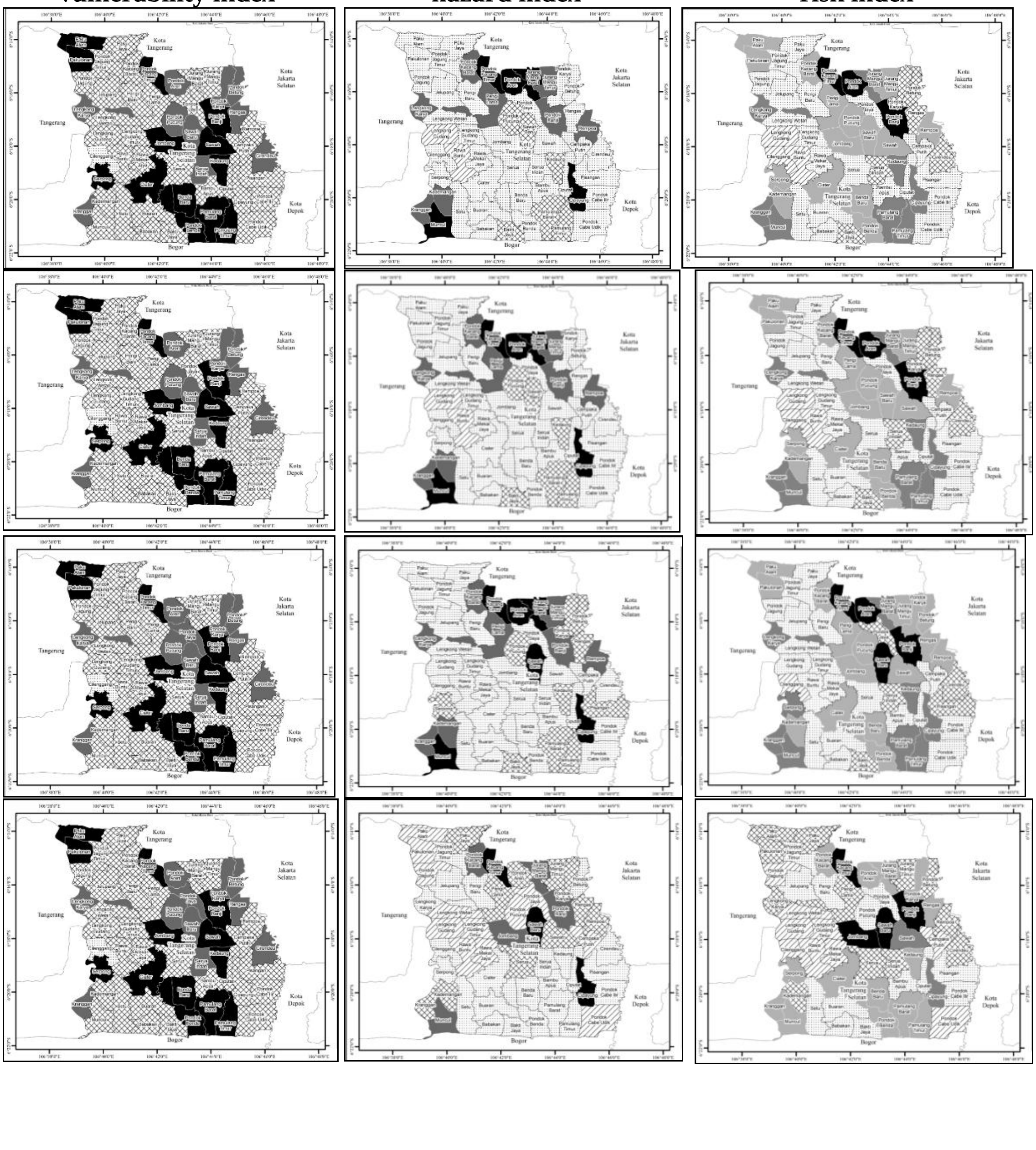
Scenario **vulnerability index** **hazard index** **risk index**

2

3

4

5



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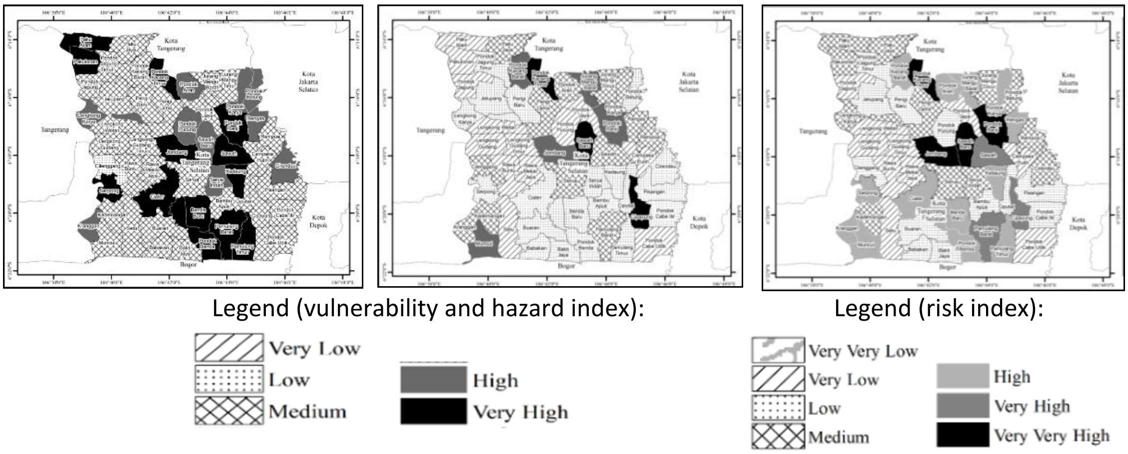

Figure 4. Map of vulnerability index (left), hazard index (middle) and risk index (right) of award under scenarios 2, 3, 4, 5 and 6.

6. Conclusion

South Tangerang City with its high population density and high clean water demand is also vulnerable to climate change. Since only about 9% population serviced by PDAM, most of them are highly dependent on groundwater that is very much influenced by climate variability, land cover changes, and human activities.

Based on this study, approximately 54% of the wards in South Tangerang have high risk until very very high-risk level and can be worse in the future if the climate hazards are not being anticipated as well as PDAM access is not being increased for all residents. It is necessary to develop a long-term adaptation strategy especially for clean water provision that takes into account aspects of climate change. Such strategy will enable the proponent to anticipate the possibility of worse risk and minimize the perceived loss.

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