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Impacts of Climate Change on the Sustainability of Water Supply in Indonesia

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Abstract

The water sector is one of the most important sectors to be influenced by climate change impacts, in the form of water shortage. Currently, for an example, the Java-Bali regions have already faced a deficit in its water balance. Based on climate projections, most regions in Indonesia will suffer from a gradual decrease of water supply due to temperature increase and rainfall changes that will affect the water balance. Combined with estimated population growth rates, increased water demand will cause severe water shortages to occur, especially in Java and Sumatra for the period of 2020-2030. This paper identifies several high risk regions throughout Indonesia based on the national level of climate risk study. It is found that areas which possess high risk on water shortage stretch in some parts of the Java-Bali region, especially in a few locations in the northern and southern of West Java, middle and southern of Central Java and East Java; as well as in the capital of the North Sumatra, West Sumatra, Bengkulu and Lampung (Sumatra), Nusa Tenggara Barat and South Sulawesi. This paper concludes with some possible actions to adapt to the impacts of climate change to water shortage.

Keywords: climate change impact, water supply shortage, adaptation

1. INTRODUCTION

The demand of freshwater in Indonesia significantly increases due to growth of population and economic activity. The current total amount of water demand in Indonesia is 175,179.29 x10^6 m^3 per year which consists of domestic use of 6,431 x10^6 m^3 per year, agricultural use of 141, 005 x10^6 m^3 per year, and industrial use of 27,741 x10^6 m^3 per year. More than fifty percent of water demand is supplied by ground water. Water demand in urban areas is usually supplied by groundwater, treated surface water and spring water, whereas in rural areas generally use springs, groundwater and surface water.

The water resources capacity in Indonesia generally depends on rainfall intensity as well as aspects of local geology, humidity, evapotranspiration, and evaporation rates. Water resources in Indonesia include surface water and ground water. The supply of surface water and ground water across Indonesia varies widely across islands in both quantity and quality. Besides regional variation, the availability of water varies seasonally, indeed monthly, and is influenced by climate. Therefore, one of the potential impacts of climate change would be the decrease of water availability. Such impacts are caused by temperature rise, change in rainfall patterns, increase of frequency and intensity of extreme weather, and sea level rise.

To illustrate, the potential severity of climate change impacts on water availability, as a baseline, we calculate current water balance as shown in Table 1. It can be seen that the water balance in Java-Bali region is already deficit. Whereas, the water balances in Nusa Tenggara, Sulawesi, Maluku and Sumatra are in critical or nearly critical.

Table 1 Indonesia's current Water Balance (2009)

No	Area	Supply *(S)*	Demand *(B)*	Balance *(S – B)*	Note
1.	*Sumatera*	111,077.65	37,805.55	73,272.10	near critical
2.	*Java-Bali*	31,636.50	100,917.77	-69,281.27	deficit
3.	*Kalimantan*	140,005.55	11,982.78	128,022.77	surplus
4.	*Sulawesi*	34,787.55	21,493.34	13,294.21	near critical
5.	*Nusa Tenggara*	7,759.70	2,054.04	5,705.66	critical
6.	*Mollucas*	15,457.10	540.23	14,916.87	near critical
7.	*Papua*	350,589.65	385.58	350,204.07	surplus
Indonesia		691,313.70	175,179.29	516,134.41	

As known that climate change has been characterized by increase of temperature, precipitation change, sea level rise and extreme events which in turn could influence the water availability in a region. For the Java-Bali region, as an example, the impacts of climate change would cause severe impacts to water availability, especially in areas which are projected to experience decrease of rain intensity as well as inundation due to sea level rise such as along the northern coast of Java.

An analysis from a limited number of stations show that a temperature increase of around 0.5°C has been occurring during the 20th century. This temperature increase is in line with the rate of average of global temperature increase as projected in IPCC AR-4 that is about 0.7°C ± 0.2 per century (Hadi, 2009).

Hadi (2009) also found that based on the analysis of Global Circulation Model (GCM), average temperature increase is projected to be 0.8° to 1°C for the period of 2020-2050, relative to the baseline period of 1961-1990.

Unlike the projection of temperature increase, the projected of rainfall pattern varies temporally and spatially. Indeed, for Indonesian precipitation, the monthly trend of rainfall change can be quite different. For an example, an analysis of observational rainfall data in Jakarta conducted by Hadi (2009) shows that the January's rainfall has increased of around 100 mm for the period of 1955-1985 (1970s) compared to that of 1885-1915 (1900s). He also projects that the rainfall of the December-January-February-March period is expected to increase for almost all seasons until 2020 over large regions of Java-Bali. On the other hand, rainfall of the July-August-September periods is projected to decrease for region of Java-Bali, It is expected then this precipitation change either decrease or increase could cause climate related hazards i.e. floods or water supply shortage or drought

This paper discusses the potential impacts of climate change on risk of the future of water supply shortage.

2. METHODOLOGY

The analysis applied in this paper is based on the risk assessment framework which defines risk as the function of hazards and vulnerability. The tool used for risk mapping is the Geographical Information Systems (GIS).

The climate change hazards for the **Water Supply Shortage (WSS)** is calculated based on two indicators, (1) physical (land cover) and geology and (2) climate condition. Total Runoff (TRO) is calculated from water balance analysis, that is rainfall (CH) and temperature. WSS is the decrease of total runoff at projection time to total run off at baseline time. Based on analysis of TRO and annual CH during normal condition (TRON), WSS hazard is likely to occur when the TRON value during the future projection period (TRON, Projection), is smaller than baseline TRON (TRON, Baseline).

The six indicators of vulnerability to water supply shortage are described as follows.

1. Population Density
   In this study, it is considered that the higher the population density of a region, the more vulnerable to the water supply shortage will be the region. In general, Indonesia has a high population but it is unevenly distributed among regions. For an example, the Java-Bali region has the highest population density. Therefore, the Java-Bali region will possess highest vulnerability to the WSS hazards.
2. Land Cover
   Under this indicator, for an area which is dominated by built up land cover, it is considered to have a high vulnerability to WSS.
3. Water demand
   Water demand is classified into agriculture use, industrial use and domestic use. It is estimated that the water demand for the Java-Bali region is over 50 billion m^3/year. The Sumatra region is the second biggest water demand that is more than 18 billion m^3/year.
4. Confined aquifer and Aquifers Potential
   Confined aquifers in Indonesia are relatively evenly distributed among regions. Confined aquifers significantly contribute to the water supply. The total water resource inflow to confined aquifers is estimated to be nearly 18.841,37 x 10^6 m^3/year contained by 465 aquifers (Danaryanto, 2005). Although the ground water potentials are not directly influenced by climate change, from the supply side, they provide significant contribution. Therefore, it is argued that for an area which has a low capacity of confined aquifer will possess high vulnerability to WSS as this area has a low capacity of ground water supply provided by confined aquifers.
5. Water infrastructures

Water infrastructures can be classified as one of indicators for adaptive capacity. They include irrigation systems, dams, water treatment facilities and pipelines. Information on the status of local irrigation systems is obtained from the Department of Public Work.

6. Water quality

   Water availability can not only be calculated based on the quantity of water but the water quality must also be considered. Recently, especially in urban areas, we have experienced water pollution caused by industrial and domestic activities. The decrease of water quality would exacerbate the threat on water supply shortage.

The risk on water supply shortage is obtained from the overlay between hazards and vulnerability maps and the results of risk analysis will be presented in the following section.

3. RESULT AND DISCUSSION

3.1. Hazards on Water Supply Shortage

Figure 1 shows the map of hazards on WSS which indicates that many parts of the Java-Bali would pose high to very high hazards.

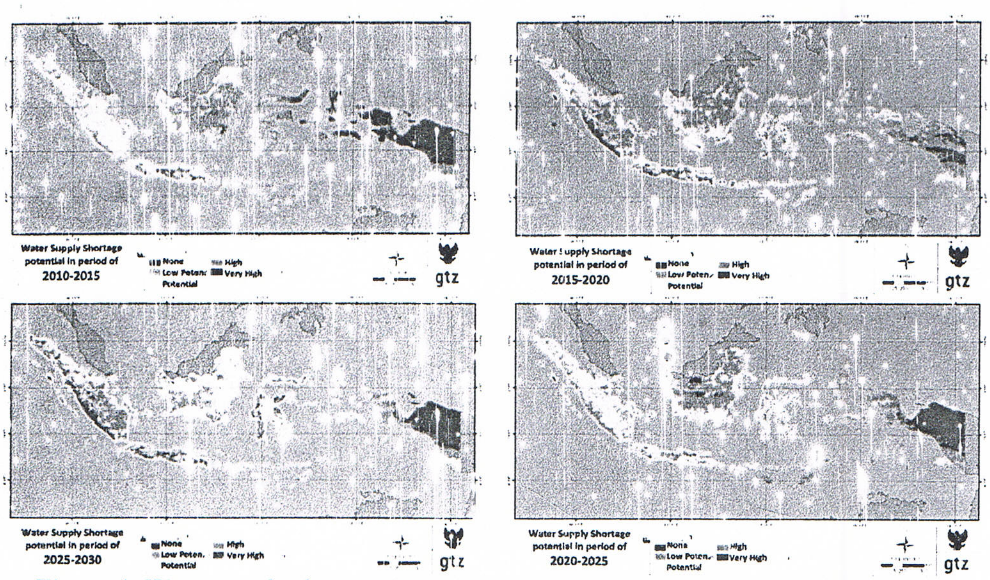

Figure 1. Water supply shortage hazards using SRA2 for the period of : 2010-2015 , 2015-2020, 2020-2025, and 2025-2030

3.2. Vulnerability to Water Supply Shortage

The level of vulnerability generally would increase from the period of 2010 to 2030 mainly caused by the increase of population and economic activities which in turn cause increase of water demand, and land use change (Figure 2).

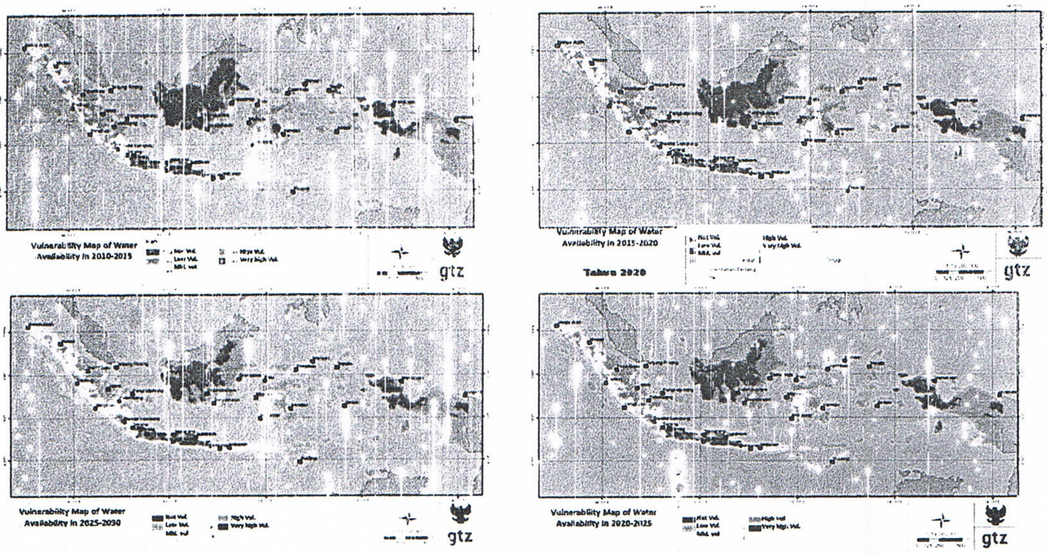

Figure 2 Map of vulnerability to water supply shortage, from the period of 2010-2015, 2015-2020, 2020-2025, and 2025-2030

As seen in Figure 2, more than half region of Java-Bali, small parts of Northern, Western, and Southern of Sumatera poses Very High Vulnerable to WSS. Whereas, the areas which pose High Vulnerable of WSS are almost half of Java-Bali Region, small parts of northern, western, and southern Sumatera, southern of Sulawesi, and Nusa Tenggara Barat.

3.3. Risk on Water Supply Shortage

Figure 3 presents the risk map on WSS and shows that the Java-Bali region, several parts of Sumatera, Nusa Tenggara and Sulawesi would experience very high risk on WSS.

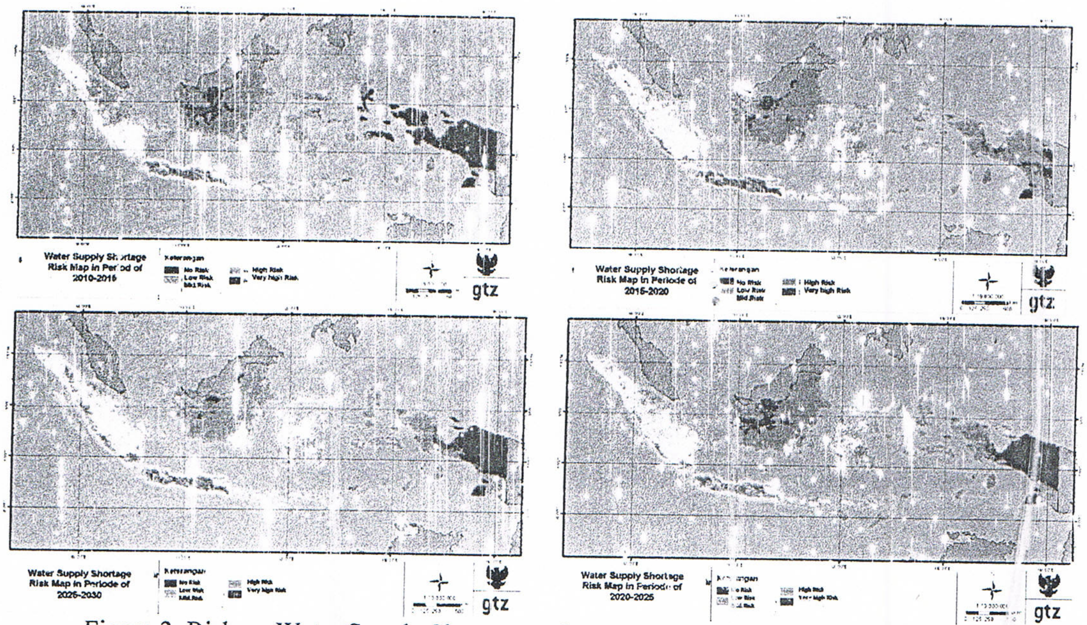

Figure 3. Risk on Water Supply Shortage, using SRA2, for the period of 2010-2015, 2015-2020, 2020-2025, and 2025-2030

As seen in Figure 3, the risk on WSS is classified into five levels as follows:

1. **Very high risk** would be occurring in small areas of the Java-Bali region, particularly in Northern and Southern West Java, Central and Southern Central Java and East Java, as well as in the capital of North Sumatera, West Sumatera, Bengkulu and Lampung (Sumatera). Other areas which could experience very high risk include: Bali, Nusa Tenggara and South Sulawesi;
2. **High risk** would be experienced by many parts of Java-Bali region; a small area in Northern, Western, and Southern Sumatera region, and South Sulawesi (Sulawesi);
3. **Moderate risk** could take place in the rest of Java Island region, particularly in central region of West Java, in around 70% of Sumatera region, except in its central to eastern areas;
4. **Low risk** could happen in around 80% of Kalimantan, and in a small part of Maluku and Papua;
5. **Very low risk** stretches in large part of Maluku and Papua region.

3.4. Discussion on the Results of Risk Analysis

From the risk maps presented above, it can be seen that the highest risk on water supply shortage could take place in Java-Bali region. GIS analysis illustrates that Java-Bali in general has a high to very high risk level to WSS. The risk profile in the Java region can be categorized as follow:

(1) Jakarta, Bogor, Bandung and their's surrounding areas; Yogyakarta, Semarang, and Solo (Central Java); and Surabaya and its surrounding area (East Java) have high to very high risk on water supply shortage.
(2) Based on water quality analysis, it is known that northern coast of Jakarta and Semarang possess high to very high risk of seawater intrusion.

In terms of its vulnerability to WSS, the Java-Bali region is characterized by highly dense population, dominated by built up areas, highest water demand due to population growth and concentrated industrial activities, and relatively low water quality. From, the hazards perspective, all parameters of climate change i.e. increases temperature, precipitation change, sea level rise and extreme events contribute to water supply shortage risk. However, at least until the next 20 years, we will not be able to control the climate change as mitigation actions will need longer time to produce the result if they are done. Therefore, the hope to adapt to climate change impacts to water supply shortage is laid on reducing vulnerability. In the context of Java-Bali, it means there is an urgent need to manage and distribute population growth and industries, to efficiently use the water, to control water pollution, to construct more water infrastructures and to save the use of ground water resources.

4. CONCLUSION

The risk assessment framework applied is able to identify the regions which could experience high to very high risk of water shortage capacity caused by climate change. This study found that the risk level of Java-Bali to WSS is the highest among all regions in Indonesia. This will exacerbate the current water balance of Java-Bali which is already in deficit condition. On the other hand, Papua and Maluku are considered to have low risk to WSS. As discussed above, we will not be able to immediately stop global climate change. If concerted efforts by global communities to mitigate climate change succeed, it will still need a long time to stabilize global warming. At least for the next 20 years, we should be well prepared in adapting to water supply shortage. It means that we can not immediately change the magnitude of hazards. What we can do is to adapt to climate change through reducing vulnerability. In the context of vulnerability to WSS, especially in Java-Bali, we should apply population management, forest rehabilitation and minimizing land conversion to become built up areas, public education in water saving, increase water storage capacity by constructing more water infrastructures, increase the capacity of ground water supply by extensification and intensification of ground water exploration.

Water shortage supply for irrigation, for an example, could reduce the production of rice which in turn could undermine the national food security. It shows that risk of WSS has cross-cutting issues nature. Climate change provides more pressure on the need to revitalize water catchment areas, especially which are considered in critical states. To be able to formulate more précised adaptation action, it is recommended that this study is followed up with more detailed study especially for regions which are considered as high to very high risk of water supply shortage.

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