A vulnerability assessment for water availability related to the impacts of climate change in Banyuasin Valley, South Sumatra, Indonesia

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Abstract. Banyuasin Valley region is located in lowland areas that is potentially subjected to hazard of flooding and submergence. The indication of reduction hazard in water availability is in the period of 2010 with decreasing value of Total Run Off at - 500 mm/year and in the period 2030 is the lowest decline of the region Banyuasin with a value of -100 mm/year. Tanjung Api-api port, built in this area, is feared to be vulnerable to the availability of clean water due to the impact of climate change. The vulnerability components consist of exposure, sensitivity, and adaptive capacity. The formula means vulnerability to a certain hazard is strengthened by its exposure and its sensitivity and decreased by its adaptive capacity. The results of this study showed that water availability in the baseline condition is in low vulnerability (47.91%) whereas, at the projection condition, vulnerability is in the category of moderate vulnerability (81.28%).

1. Introduction
Global climate change is an issue that is increasingly influencing the development of policy at national and regional levels. It is not an exaggeration, as some studies suggest that the history of climate change impacts could be fatal to the survival of a nation. Some of the historical studies of the extinction of the Maya civilization in Central America around the year 950 AD concluded that the prolonged drought has affected people who are vulnerable to climate change [1]. The phenomenon of climate change has now become a necessity that needs to be anticipated and mitigated by all the parties in view of 83% from total emissions [2]. One of the causes of the phenomenon of climate change, Indonesia is generated from the change in land use and forestry [3]. Referring to the law No. 32 of 2009, the protection plan and environmental management requires a strategic environmental assessment on article 16 of the need for assessment of vulnerability and adaptive capacity to climate change. Based on the report of the IPCC, climate change impacts on coastal areas/river have the highest risk such as tropical storms, floods and rising sea levels [4]. In general, the changes of rainfall patterns and freshwater runoff are potential to cause some significant changes in the physical environment, among others, changes in the hydrological cycle, the effect on the availability of water in coastal areas and changes in water circulation [5]. Measurement of water availability effect on the coast is not easy to conduct and very necessary because of the availability of clean water in the coastal areas that has become a social and environmental issue disrupted by the tidal conditions. As the impacts of climate change, it needs to protect the public from the potential dangers posed by rising surface seawater, flooding, changes in rainfall, and other negative impacts [6]. Unless adaptive measures are not taken immediately, an analysis predicts that Indonesia could experience freshwater scarcity, declining crop yields, as well as
the loss or destruction of habitat and ecosystem in coastal areas. As one approaches that the measurement can be done is with a vulnerability assessment [7]. Research on the vulnerability assessment, in general, has been widely performed, especially the vulnerability of social communities, such as the Social Vulnerability Index developed by [8].

South Sumatra Province is one of the areas in Indonesia who suffered exposure to climate change triggered by global warming. At 91.774.99 km², approximately 30% of the province area, which is low lying areas, are exposed to climate change. The exposure also occurs through the medium of the atmosphere and ocean (Bangka Strait), which is based on the study of the scientific basis of climate and sea level rise. The scientific basis of oceanographic studies concludes the rise in sea level to approximately 13.5 ± 6.15 cm at year 2030 relative to current conditions (scenario of greenhouse gas emissions are moderate - SRESa1b) [9]. The results report also mentions that the general conditions of water availability in the forecast period are relatively unchanged and actually increased when compared to the baseline period of 1970-2000. However, it could be the indication of hazard reduction in water availability in some areas, such as in the period of 2010 Musi Rawas and Lubuk Lingga with decreasing value of Total Run Off at - 500 mm / year and in the period 2030 which is the lowest decline of the region Musi Rawas and Musi Banyu Asin with a value of -100 mm / year. A region port of Tanjung Api-api as an area of strategic potential for the port area of the ocean and various supporting facilities, is expected to develop various sectors of development in the Province of South Sumatra, and in turn it could attract and generate growth in various sectors of development and will influence and impact significantly to Banyuasin. The results of these studies in micro can be illustrated by a map that can be predicted by region and area that has a low start up the vulnerability of the highest rate of climate change.

At the macro level study, Banyuasin Valley region located in lowland areas is potentially subjected to the danger of flooding and submergence [10]. This macro scale hazard assessment needs to be studied further in micro scale, to provide more detailed information concerning vulnerabilities in Banyuasin Valley region to climate change.

2. Research Method
This research is a field survey analysis. The parameters or indicators of vulnerability are employed to analyze the vulnerability of Banyuasin Valley and its surrounding areas. The parameter of vulnerability is exposure (water needs, land use) and, sensitivity (population density/population, water resources), as well as the adaptive capacity (welfare of the population). The degree of vulnerability is determined based on an index of vulnerability resulting from the parameters/indicators that are owned by the elements that have the potential risk to the impacts of climate change [11].

Surveying the measurement/mark ing has already done to see changes in land use in Banyuasin Valley region based on the maps of land cover/land use existing and the condition of land cover Banyuasin Valley region. GPS (Global Positioning System) is used to perform measurements, and determine the location of spatial and elevation measurements. Meanwhile, the questionnaire is administered in residential areas/housing in Banyuasin Valley Region. The survey activities include discussions and interviews with local people guided to fill the questionnaire. The data collected from the interview are arranged to identify the conditions that exist in the field. The collection of secondary data that aims to obtain the data of the number of the population, the population growth rate, topography, administration maps, land use maps and land use planning is collected from the Detail Spatial Plan Area Support Tanjung Api–api and the supporting data related to this research.

2.1. Research Location
The research location is located in Banyuasin Valley with limits on the north bordered by Bangka Strait, Sebalik canal at the South, the West by the Banyuasin River and East by the Telang River. The location was selected because the region will build the ocean port of Tanjung Api-api and will be used as a special economic zone in South Sumatra Province.
2.2. The Framework of Vulnerability Assessment.

Vulnerability in this study is obtained from the preparation of the component parameters/indicators of vulnerability composed of topographic maps, population density, land use, water requirements, and welfare of the population. It will then be overlaid to get a map of vulnerability in the existing conditions (baseline) and the projection condition in year 2030.

The components of vulnerability consist of exposure (E), sensitivity (S), and adaptive capacity (AC). The function initially is a multiplication between E with S factors and divided by AC factor as in the following formula:

\[ V = \frac{(E \times S)}{AC} \]  

Where

- \( V \) = vulnerability
- \( E \) = exposure
- \( S \) = sensitivity
- \( AC \) = adaptive capacity

The formula of vulnerability to specific hazards is strengthened by exposure and sensitivity and decreased its adaptive capacity. In this assessment, the function of \( V \) is a pseudo multiplication, because, in practice, the vulnerability is obtained from the addition of the exposure component to the sensitivity component and reducing adaptive capacity component. Vulnerability index has a value of 0-1, with the highest index value is indicated as the highest vulnerability. The Index itself is a combination of proxies scores indicators of vulnerability. Proxie scoring on each parameter is different, that takes into account how much influence these parameters are. The greater the influence of parameters, the greater the value is and otherwise.

The level of vulnerability is classified into five classes of vulnerabilities including very low vulnerability, low vulnerability, moderate vulnerability, high vulnerability, and very high vulnerability. The parameters of vulnerability analysis will determine the accuracy of the resulting level of vulnerability of the region and the adaptation strategies to be formulated later. It can be seen from the level of vulnerability in each level such as macro, meso and micro level.

The framework of vulnerability assessment can be seen below.
Vulnerability in this study is obtained from the preparation of the component indicators of vulnerability composed of topographic maps, population density, land use, water requirements, and welfare of the population that will be an overlay to get a map of vulnerability in the baseline condition and the projection condition. Administratively based on the Detail Spatial Plan of Banyuasin Valley, this region consists of three districts including the District of Banyuasin II, Muara Telang, and Tanjung Lago, with an unevenly distributed population. The topography of Banyuasin Valley Region is a lowland swamp elevation. Based on the current condition of land cover, most of the area is covered by rice fields and swamps and forests. A vulnerability assessment on these activities is done with qualitative and quantitative analysis based on the weighting of indicators that influence the susceptibility of water availability at the area of research, in which the level of vulnerability weights is determined by the pairwise comparison method is used to get a vulnerability map. The modeling results were processed using GIS based program that will be used in data processing to obtain a vulnerability map.

Weighting is based on the land use element of the ability of the land use to deal with the hazard of climate change. In this case, it is the hazard of flooding and water storage capacity that influences the reduction in water availability. Satellite imagery from the map results obtained from the Regional Development Planning Agency Banyuasin, known that the existing land use on location Banyuasin Valley is grouped on the secondary mangrove forests, plantations, settlements, dry land agriculture mixed shrubs, fields, shrub swamps and water bodies. In the projection conditions, parameters of land

Figure 2. Framework of vulnerability assessment
use change into 8 kinds of spatial planning, namely the industry, the logistics center/warehouse, urban, residential and campus, central park, recreational water, swamp forest, and river border. Granting land use parameter weights based on the vulnerability reduction in water availability are grouped in residential areas and vital infrastructure, agricultural areas, aquatic ecosystems, and non-agricultural forest areas then are ranked and given weight.

The level of water needs are classified into three categories including low, medium, and high in every district. The calculation of water demand in the region is the sum of the domestic and non-domestic water needs. Its weighting parameter is based on the population density of each district. Classification weighting is based on population density, low, medium and high density. Population density index is distributed into the region in accordance with the land use map of Banyuasin Valley Region. In the analysis of vulnerability to the condition of the projection using the data, the average percentage of population growth per year is calculated based on the capacity of a regional population of Banyuasin Valley. Water resources are one of the indicators of vulnerability that are classified based on the source of water that is used such as rainwater, wells, water river/lake, bottled water, local water installations, and make the determination to obtain the rank of the parameter weights. The population welfare as a vulnerability in terms of the economics of the population is obtained from the survey and interviews in the field to the baseline condition. It is then classified based on the percentage of the prosperous and underprivileged population. For the projection conditions, the population welfare is assumed by the industrial area. Meanwhile, the level of welfare is expected to increase that it can contribute to reducing vulnerability.

2.3. Data and Material

The data included in this study is based on the spatial data for each of the necessary data. The results of studies are based on spatial or in the form of a map. Nevertheless, the qualitative data are also available when it is still involved in the study. For it, a variety of secondary data collection has been done to obtain the complete data.

The data and tools used in the analysis are shown in Table 1 and Table 2

| No | Data properties                | Data type  | Sources                       |
|----|--------------------------------|------------|-------------------------------|
| 1  | Water quality                  | Primary    | PDAM Tirta Musi Lab.         |
| 2  | Number of inhabitants          | Primary    | Field                         |
| 3  | Condition of the house         | Primary    | Field                         |
| 4  | Water consumption              | Primary    | Field                         |
| 5  | Income per capita              | Primary    | Field                         |
| 6  | Existing land use map          | Primary    | Field                         |
| 7  | Land use plan map              | Secondary  | BAPPEDA                       |
| 8  | Rain data                      | Secondary  | BMG                           |
| 9  | Map of Digital Elevation Model (DEM) SRTM | Secondary | http://srtm.csi.cgiar.org |
| 10 | Map Region Banyuasin Valley    | Secondary  | BAPPEDA Banyuasin            |

| No | Name of tools                  | Number of uses                     |
|----|--------------------------------|------------------------------------|
| 1  | Stationery 2 pieces            | Writing to recording data          |
| 2  | Computer (RAM 2 GB) 1 unit     | Performing general modeling        |
| 3  | Printer 1 unit                 | Displaying form of report          |
| 4  | ILWIS 3.6 Program, ArcGIS, Global Mapper 16 | Performing modeling and data processing |
| 5  | GPS Tracker                    | Tracking research location         |
| 6  | Laptop and Printer 1 pieces   | Assisting to preparing reports     |
3. Result and Discussion
The vulnerability assessment in Banyuasin Valley and its surrounding areas are classified as a vulnerability assessment of local level where global climate change is translated into local events in response to geography and local environmental, economic and social factors. It results from the interaction between the many socio-ecological factors and processes such as income level, and individual habits. Vulnerability and adaptive capacity are also manifested locally. The vulnerability of water shortages consists of three indicators, where each indicator represents a different component of vulnerabilities. People’s water needs and land use are considered as exposure component indicators, whereas water resources and people density belong to sensitivity component indicators. Meanwhile, the welfare of the population is considered as adaptive capacity component indicators. Physically, the land use of natural areas that changes into an area of man-made, which is often found in urban areas, will reduce the capacity of the surface water infiltration into the soil. Changes in land use will also be accompanied by an increase in water demand, and the risk of flooding as well as the degradation of areas as a result of erosion, resulting in increased sedimentation of rivers.

The comparison components of vulnerability can be seen in Table 3.

| Component                  | Indicator             | Ratio |
|----------------------------|-----------------------|-------|
| Exposure (E)               | People’s water needs  | 0,50  |
|                            | Land use              |       |
| Sensitivity (S)            | Water resources       | 0,32  |
|                            | People density        |       |
| Adaptive Capacity (AC)     | Population welfare    | 0,18  |

Based on the indicators above, the vulnerability map drawn up will be overlaid so that the resulting vulnerability level map of Banyuasin Valley region were analyzed at baseline and projections conditions. The results of the vulnerability map can be seen in Figure 3.

![Figure 3. Vulnerability map at (a) Baseline Condition and (b) Projection Condition](image)

| District    | Vulnerability area (Ha) Baseline condition (left) and Projection condition (right) |
|-------------|----------------------------------------------------------------------------------|
|             | Very low | Low | Moderate | High | Very high |
| Banyuasin II| 33.5     | 0   | 13156    | 5258.5 | 19372.5 | 1215.5 | 0   | 559.25 |
| Muara Telang| 0        | 0   | 10       | 2002.5 | 681.5  | 0     | 955.75 | 2447.5 | 2802.5 | 0     |
| Tanjung Lago| 0        | 0   | 0        | 3.75   | 3184.5 | 2198  | 0     | 1167.25 | 184.75 |
According to Table 4, at baseline condition, Banyuasin Valley and its surrounding areas consist of a very low vulnerability level of 33.5 ha, low 13 166 ha, moderate 5943.75 ha, high 4369.25 ha, very high 3969.75 ha. The high and very high vulnerability that has the most extensive area lies in the sub-district of Tanjung Lago and Muara Telang. Meanwhile, viewed from the projection condition, Banyuasin Valley and its surrounding areas consist of a low level of vulnerability of 2002.5 ha, moderate 22 557 ha, high 2447.5 ha, very high 744 ha. The high and very high vulnerability that has the most extensive area lies in Muara Telang, and Banyuasin II. In general, susceptibility to water availability in the baseline condition is in the category of low vulnerability, which is mostly located on Banyuasin II. There are still a lot of industries and settlements built so that water demand yet too much and people in the region still mostly rely on rainwater reservoirs for clean water and river water for the daily usage. On projection condition, the greatest degree of vulnerability is moderate vulnerability, which is administratively located in Banyuasin II and Tanjung Lago district. According to spatial planning port of Tanjung Api – Api, in this area settlements and the various industries will be built so that it will require much water that needs to be anticipated from now on, as well as in Muara Telang. Thus, these regions are considered as a high vulnerability.

Both conditions above indicate that the level of vulnerability in the region of Banyuasin Valley and its surrounding likely tends to decline in the extent of the area of the baseline condition to projections, especially at the level of vulnerability that is very low, low, high and very high, while an increase in the extent of which is significant at the level of vulnerability. This indicates that the potential for an increased risk of water availability is in the medium category.

4. Conclusion
From the analysis of the study, it can be summarized that the results of total vulnerability at the site showed that the highest level of vulnerability at baseline condition is low vulnerability whereas the projected conditions level of vulnerability occurring is a moderate vulnerability.

Physically, the land use of natural areas changes into an area of man made, which is often found in urban areas, will reduce the capacity of the surface water infiltration into the soil. Changes in land use will also be accompanied by an increase in water demand and the risk of flooding, as well as the degradation of areas due to erosion, resulting in increased sedimentation of rivers.

The main concept is built without putting pressure on the surrounding environment and green open space requires at least 30%. Therefore, the existing land use and prediction of future changes should be considered carefully. The increase of the development in urban areas is expected to result in the increasing welfare of urban living. Short term adaptation strategy is to increase the water storage capacity by creating a retention pond, or reservoir, and expansion of rainwater, increasing the efficiency of water use by recycling and rainwater harvesting in areas that do not have groundwater. As for the long-term adaptation strategy are the development of artificial water catchment area in the protected Telang forest, the development of surface water resources by supplying water from the local water company, the desalination of seawater if necessary, the control of the population, and the supervision of the spatial planning.

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