Resilience Of Flood Disasters In The Wanggu Watershed, Kendari City

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Abstract. Floods are disasters that often hit cities in Indonesia. Even in certain cities, flooding is a recurring disaster. Kendari City is a service and trade city in Southeast Sulawesi Province which has a vulnerability to repeated flood disasters in urban areas including 10 Districts, which are still included in the Wanggu River Basin. This urban area experiences the phenomenon of urbanization, namely population growth and high land use change and land ownership transfer. The development of residential areas as a consequence of population growth, is also a cumulative factor triggering the flood disaster in the Wanggu River Basin. This study aims to determine the development of the expansion of flood areas in the Wanggu watershed in a time series (period 2007 - 2017) and how they impact the development of Kendari City. This research will also investigate the impact of land use change and the impact of urban population growth on the expansion of flood disasters. The method used is the collection of qualitative and quantitative data, observation, and verification in the field, to map analysis using High Resolution Satellite Imagery to determine changes in land use in the Wanggu watershed area. The expected outcome of this research is the mapping of areas that are vulnerable to the risk of flooding, especially in urban areas to the resilience strategy chosen as one of the city's resilience efforts against disasters.

Keywords: Disaster, Flood, Resilience, Land, Urban.

1. Introduction
Kendari City is located in a flood plain area, both on the edge of a river or on the edge of a beach that are prone to flooding. As a developing city, the conversion of land into developed land has occurred on a massive scale for infrastructure developments such as construction of roads, bridges, hospitals, housing, hotels, and shops. Landfill swamps cause a reduction in the area of retention that is very important in the hydrological process and ecosystem order. These conditions are the factors that cause flooding (Gandri, 2018). In addition, the high conversion of land into developed land makes the area waterproof so that its infiltration capacity is small. This is supported by research conducted by (Alwi, Sinukaban, Solahuddin, & Pawitan., 2011) which explains that the expansion of the Kendari City region is accelerating the speed of uncontrolled spatial expansion and rapid depletion of forest areas.

Viewed from the perspective of the Wanggu River Basin, which passes through 3 cities and regencies including Kendari City, Konawe Regency, and South Konawe Regency, the Wanggu watershed that passes through the Kendari urban area experiences a fairly high population growth. The economic activities of the people in the Wanggu watershed are also very diverse and continue to experience shifts in line with the development of the region. If we see the development of high land use...
conversion and land ownership transfer in this area, in addition with the development of residential areas as a consequence of population growth, it becomes the cumulative factor triggering flood disasters in the Wanggu River Basin.

This study aims to determine the development of the expansion of flood areas in the Wanggu watershed in a time series (period 2007 - 2017) and how they impact on the development of Kendari City. This research will also investigate the impact of land use change and the impact of urban population growth on the expansion of flood disasters. The method used is the collection of qualitative and quantitative data, observation, and verification in the field, to map analysis using High Resolution Satellite Imagery to determine changes in land use in the Wanggu watershed area. The expected outcome of this research is the mapping of areas that are vulnerable to the risk of flooding, especially in urban areas to the resilience strategy chosen as one of the city's resilience efforts against disasters.

2. Literature Review
(Catanese & Snyder, 1992) mentions factors that can affect the development of the city which can be physical or non-physical factors. The physical factors are in the form of location and geographical factors, while non-physical factors are in the form of population development factors and urban activity factors. Changes in land use are the main causes of flooding compared to others. For example, if a forest that is in a watershed is converted into a settlement, then the peak flow of the river will increase between 6 to 20 times. Figures 6 and 20 depend on the type of forest and type of settlement (Kodoatie & Sjarief, 2008). Flood disasters in several countries in the world can also be driven by population migration due to economic pressure, as a result, land use control is reduced especially in catchments and watersheds (Penning-Rowsell, 2003). Whereas (Yuksel, Kanka, Ucuncu, & I, 2013) suggested that human factors are the most important in causing disasters as a result of land use mistakes, deforestation, urbanization, and settlements.

(Stoica & Iancu, 2011) suggested that in order to estimate flood vulnerability in an area there must be a value of losses incurred. To determine the value of vulnerability, the potential losses need to be evaluated based on certain parameters. Geographic Information System (GIS) is a tool widely used by researchers to map the spatial distribution of flood risk and vulnerability to flooding. GIS facilitates spatial data input, storage, management, analysis, integration, and output that can help decision making and strategic planning for effective risk management. GIS can be utilized to improve mitigation, evacuation, and emergency response systems (Karmakar, Simonovic, Peck, & Black, 2010).

3. Methodology
The approach in this study uses a quantitative rationalistic deductive method. There are several variables that will be analyzed in this study, to reduce answers to the research questions set. These variables is related to the development of urban areas and their impact on the environment.

| No | Variable | Data Source | Analysis Methods |
|----|----------|-------------|------------------|
| 1  | Land Use | Kendari Earth Surface Map (RBI) | Regional Spatial Analysis |
| 2  | Topography, Slope and Regional Morphology | Kendari Earth Surface Map (RBI), Morphological Map | Regional Spatial Analysis |
| 3  | Disaster Hazard | Map of flood prone areas | Regional Spatial Analysis |
| 4  | Climate | Climatic conditions, rainfall, air temperature, barometric pressure | Literature Review, Regional Spatial Analysis |

Table 1. Research Variables, Data Sources and Analysis Methods
According to (Sugiyono, 2009), descriptive statistics are statistics used to analyze data by describing data that has been collected as it is without the intention to make generally accepted or generalized conclusions. (Handayani, 2005), state that the main characteristic of Geographic Information Systems is the ability to analyze systems such as statistical analysis and overlays called spatial analysis, which, unlike other information systems, is by adding the 'space' or geography dimensions.

4. Result And Discussion

4.1. Critical Land Problems in the Wanggu River Basin
The land in the Wanggu watershed is divided into uncritical, critical, potentially critical, and very critical. The indicators in compiling degraded land consider the changes in land use that have been declining over the years and the level of community demand for land, especially forest clearance. The problem of degradation of land into critical land is also affecting the decline in the function of the Watershed. This is indicated by the emergence of the following problems:

- Increased water discharge fluctuations where in the dry seasons the water discharge is very low, but in the rainy seasons the water discharge is very high so that it often causes flooding in the middle and downstream.
- Critical land also increases the content of sedimentation, mud, rubbish, and waste content in the river water flow which is getting higher so that the water quality becomes very poor, which causes siltation problems in the Kendari bay.
- The increase in the number and activity of residents in the Wanggu watershed area both in the upstream and in the middle parts has also triggered the conversion of land from forest areas to agricultural land and residential land, to increase the industry and settlements on the edge (border) of the river.

Table 2. Hydrometeorological Disasters Data in the Kendari City in period 1999 – 2016

| No | Disaster Type      | Number of Events | Number of Deaths | Number of Injured | Evacuate | Broken House | Broken Facility | Damaged Land (Ha) |
|----|--------------------|------------------|------------------|------------------|----------|--------------|----------------|------------------|
| 1  | Flood             | 19               | 3                | 126              | 17,345   | 22           | 40             | 2,334            |
| 2  | Flood and Landslide | 2               | 1                | -                | 2,679    | 6,797        | 1              | -                |
| 3  | Landslide         | 14               | 3                | -                | 148      | 48           | -              | -                |
| 4  | Tornado           | 9                | -                | 2                | -        | 30           | -              | -                |
|    | TOTAL             | 44               | 7                | 128              | 20,172   | 6,897        | 41             | 2,334            |

Source: Processed from BNPB Data, 2016
4.2. Population Increasing in the Wanggu River Basin Area

Based on the study findings, the settlement areas in the upstream area of the Wanggu watershed have found that the existing tenure patterns are quite diverse. At least 3 important land tenure patterns are found combined with the accompanying land use patterns (farming) as follows:

- Land controlled by local residents, this land is managed by the residents themselves with a farming business that is generally in the form of horticultural crops, and is managed by themselves by paying farm laborers from the local population;
- Land owned by people outside the village, cultivated by local residents with the status as tenants. The harvest is fully owned by the cultivators and the residents get monthly wages in return for having been instrumental in protecting and maintaining the land;
- Land owned by people outside the village that the local people cultivate with the harvest which belongs to the farmers but they do not receive salary compensation.

Table 3. Population Increasing in Kendari City 2013-2017

| No | Districts | 2013   | 2014   | 2015   | 2016   | 2017   |
|----|-----------|--------|--------|--------|--------|--------|
| 1  | Mandonga  | 39.177 | 41.891 | 43.338 | 44.819 | 46.235 |
| 2  | Baruga    | 20.982 | 22.437 | 23.213 | 24.004 | 24.762 |
| 3  | Puuwatu   | 30.061 | 32.143 | 33.254 | 34.390 | 35.478 |
| 4  | Kadia     | 42.515 | 45.460 | 47.031 | 48.638 | 50.175 |
| 5  | Wua-wua   | 26.441 | 28.272 | 29.249 | 30.249 | 31.205 |
| 6  | Poasia    | 27.058 | 28.932 | 29.932 | 30.955 | 31.933 |
| 7  | Abeli     | 24.307 | 25.991 | 26.890 | 27.809 | 17.527 |
| 8  | Kambu     | 29.395 | 31.433 | 32.519 | 33.630 | 34.693 |
| 9  | Nambo*)   | -      | -      | -      | -      | 11.161 |
| 10 | Kendari   | 27.686 | 29.605 | 30.627 | 31.674 | 32.675 |
| 11 | Kendari Barat | 46.505 | 49.725 | 51.443 | 53.203 | 54.884 |
|    | **TOTAL** | **314.127** | **335.889** | **347.496** | **359.371** | **370.728** |

*) = New Expantion District

Source: Kendari City in Figures, 2013-2017. Central Bureau of Statistics, Kendari City
4.3. **Slope Characteristics in Wanggu Watershed**

The total area of the Wanggu watershed in 2015 is approximately 45,234 Ha which is divided into the upper reaches of the Wanggu watershed covering an area of 16,476 Ha which is a dense forested mountainous area with elevations between 25 m to 100 m above sea level with a slope that varies quite steep (more than 40%). The middle part of the Wanggu watershed covers an area of 21,864 Ha which is a bumpy and hilly area with elevation variations between 25 m to 100 m above sea level. In terms of slope the center of the Wanggu watershed is dominated by an area with a slope of 8-15%. The downstream part of the Wanggu watershed, which empties into Kendari Bay, Kendari City, has a slope characteristic of 0-8%, the remaining 25-45%, with the distribution condition being dominated by flat slopes. The area of the flat area in the downstream reaches 6,893 Ha.

The upstream part of the Wanggu watershed covers 5 sub-districts in Konawe Selatan District, namely Wolasi, Konda, Ranomeeto, and North Moramo Districts. In the central and downstream areas include 10 sub-districts in Kendari City, namely: Kambu, Baruga, Poasia, Abeli, Kadia, Wua-wua, Puuwatu, Mandonga, Kendari, and West Kendari Districts. While the Konawe Regency which is covered by the Wanggu watershed is the Lalonggasu Meeto and Soropia District. Based on the coverage area of the Wanggu watershed, the management planning and implementation and evaluation of activities in the Wanggu watershed are the responsibility of the provincial government by involving the participation of the government and the community in South Konawe, Konawe, and Kendari City.

Table 4. Land Slope Distribution in the Wanggu River Basin, 2016

| No | City / Regency   | Land Size according to Slope Class | Total |
|----|-----------------|------------------------------------|-------|
|    |                 | 0-8%  | 8-15%  | 15-25% | >40%  |
| 1  | Konawe          | -     | -      | -      | 889.78|
| 2  | Konawe Selatan  | 2,735.49 | 8,238.39 | 3,357.10 | 11,300.16 | 25,631.14 |
| 3  | Kota Kendari    | 4,157.53 | 3,223.61 | 7,045.71 | 4,286.81 | 18,713.66 |
|    | Total           | 6,893.02 | 11,462.00 | 10,402.81 | 16,476.75 | 45,234.58 |

*Source: Processed from Data on City Planning and Housing Agency, 2016*
4.4. Rainfall Characteristics in the Wanggu River Basin
From the analysis of heavy rainfall, it was found that for downstream areas of Wanggu, an average of 2 heavy rainfall events occurred in January and only 0.2 events occurred in June. The average intensity of heavy rainfall varies between 2 mm/hour to 4 mm/hour with an incidence time of 1 to 3 hours. For the Wanggu Hulu region, it was found that daily rainfall of more than 25 mm and 2-day rain exceeding 50 mm could be classified as heavy rain, which could produce flooding in the downstream area. The nature of heavy rain can be considered the same for the upstream, middle, and downstream areas of the Wanggu River Basin. And the results of frequency analysis for daily maximum rainfall data for the rainfall station at Haluoleo Airport produce a daily maximum rainfall value for a 5-year return period of 36 mm; 10-yearly of 79 mm; 25-yearly of 122 mm; 50-yearly of 221 mm; and 100 annuals of 123 mm.

4.5. Analysis of Flood Threats and Risks
The parameters used in this analysis are: rainfall, land slope, and land cover. Rainfall analyzed is dasarian (10-day) rainfall. High-intensity rain will not necessarily cause flooding if it only occurs in a short period of time (less than one day). But if it rains continuously for several consecutive days (even if it rains only have low or moderate intensity), then flooding will most likely occur. The close relationship between the level of infiltration and the slope of the land makes this parameter one of the main determinants of flooding. Land surface elevation data used in this analysis is sourced from the SRTM (Shuttle Radar Topography Mission). This data is processed spatially to produce a distribution of land slope. The level of land slope and rainfall is then grouped into groups and converted into scores.
Table 5 dan 6. Scoring for Dasarian Rainfall And the slope of the land

| Parameter               | Classification | Scores | Parameter | Classification | Scores |
|-------------------------|----------------|--------|-----------|----------------|--------|
| Rainfall (Dasarian)     | < 50 mm        | 1      | Slope     | 0 - 8 %        | 5      |
|                         | 50 - 100 mm    | 2      |           | 8 - 15 %       | 4      |
|                         | 100 - 200 mm   | 3      |           | 15 - 25 %      | 3      |
|                         | 200 - 300 mm   | 4      |           | 25 - 40 %      | 2      |
|                         | > 300 mm       | 5      |           | > 40 %         | 1      |

Source: Processing of Personal Data, 2019

The results of mapping of flood threats in the landscape of Konawe Selatan Regency and Kendari City show that the danger of high floods is concentrated on the coast of Kendari City. This threat is mainly in urban areas (areas with a greater proportion of pavement land cover and less green land cover). Flood risk is the opportunity for inundation to occur in an area, the magnitude of flood risk can be seen from the frequency of occurrence, extent, and height of inundation. In general, Kendari City is not included in a very high risk area for flooding, although threats and vulnerabilities are quite high in several places. However, quite a number of areas have high and medium risks, especially in the western part of Kendari City. Kendari city itself is categorized as a medium-risk area. In these areas, priority needs flood prevention.

4.6. Flood Vulnerability Analysis

Factors influencing exposure to flooding are population density and land use. Factors affecting sensitivity are poverty and the spread of critical land, while the factor that influences adaptive capacity is the level of education. To measure the exposure index, normalization of population density and land use is carried out; then multiplied by the weight. These two indicators are then added up. The overlapping process of indicators of exposure, sensitivity, and adaptive capacity is carried out in the Geographic Information System (GIS) to determine the vulnerability index of a village or resident.

Table 7. Scoring for Vulnerability Analysis

| Factors       | Indicators      | Numbers | Scores | Weight | Values | Total | Vulnerability Scores | Vulnerability Index   |
|---------------|-----------------|---------|--------|--------|--------|-------|----------------------|-----------------------|
| Exposure      | Population Density | P       | (1 s/d 5) | 0,30   | V      | V + W = K           | K X S / CA            | Normalization of Vulnerability Score : 1 s/d 5 |
|               | Land Used       | Q       | (1 s/d 5) | 0,30   | W      |                    |                       |                       |
| Sensitivity   | Poverty         | R       | (1 s/d 5) | 0,20   | X      | X + Y = S           |                       |                       |
|               | Critical Land   | S       | (1 s/d 5) | 0,10   | Y      |                    |                       |                       |
| Adaptive Capacity | Level of education | T       | (1 s/d 5) | 0,10   | Z      | CA                 |                       |                       |
Based on the overlay results of the area parameters that have the potential for inundation and flooding, it is known that almost all the southern coastal areas of Kendari City have the potential to experience inundation. In general, Kendari City has a low vulnerability at this time. However, in some areas such as in Wua-wua Sub-district, Barug, and around Kambu vulnerability to flooding is high to moderate. Likewise, several subdistricts in Mandonga have high vulnerabilities.

5. Conclusion
The results of mapping of flood threats in the landscape of Konawe Selatan Regency and Kendari City show that the danger of high floods is concentrated on the coast of Kendari City. This threat is mainly in urban areas (areas with a greater proportion of pavement land cover and less green land cover). This
is related to the intensification of rain and land conversion, which are predicted to be quite fast in this area. In general, in South Kendari City, there are no areas at very high risk of flooding, although threats and vulnerabilities are quite high in several places. Kota Kendiri itself is categorized as a medium-risk area. In these areas, flood prevention is a priority. However, in some area, such as in Wua-wua Subdistrict, Baruga, and around Kambu, there is a high to moderate vulnerability to flooding. Likewise, several villages in Mandonga Subdistrict have high vulnerabilities.

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