Spatial analysis of flood-prone areas and flood discharge

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Abstract. The Wanggu watershed is a natural ecosystem that is very sensitive to changes in land use. Increased changes in land use and geomorphological conditions in the Wanggu watershed such as slope levels, altitude, soil texture, natural drainage density, rainfall factors and the influence of infrastructure development (road construction, housing) will affect the hydrological response of the watershed and become the cause of increased flood vulnerability in the region. The purpose of this study is to analyze the factors causing flood vulnerability and its impact on the city of Kendari and the Wanggu watershed and to determine the level and distribution of flood vulnerability in the Wanggu watershed area by utilizing geographic information system technology (GIS). This study uses Scoring, weighting, and Overlay methods on several parameters causing floodings such as rainfall, land use, slope, soil texture and height, drainage density, and infrastructure. The results showed that the causes of flooding in Wanggu watershed are rainfall, land-use change does not match the ability class because it is dominated by 40.1% flat slope, medium to rough soil texture 82.3%, altitude 29.0%, moderate drainage density 89.3% and run-off discharge 82.53 m³s⁻¹. The Wanggu watershed has four flood vulnerability classes, namely safe 27.7%, rather vulnerable 16.0%, vulnerable class 32.6%, and very vulnerable class 23.6%. The flood hazard class that dominates the Wanggu River Basin area is the Prone Class.

1. Introduction

Floods are natural disasters that occur unexpectedly, leaving adverse and detrimental impacts on humans, both physical and psychological, such as annual floods [1]. Flooding generally occurs in various watersheds in Indonesia due to land use activities that are not environmentally friendly. Increased changes in land use, settlement construction, and geomorphological conditions in Wanggu watershed such as slope levels, altitude, soil texture, drainage density, rainfall will affect the hydrological response of the watershed and be the cause of increased flood frequency in the region. Wanggu watershed plays a vital and strategic role in Southeast Sulawesi Province because, in the upstream, there is a protected forest and community cocoa plantations. In the middle area, there is the Haluoleo Field and irrigated rice fields, downstream of the watershed there is the city of Kendari, Kendari Bay, Jetty, harbor people's boat. Land use in the Wanggu watershed period 1992-2016 has led to land degradation that has affected the disruption of the hydrological function of the area. Wanggu watershed is included as one of the critical national priority watersheds in Southeast Sulawesi Province, which immediately requires treatment for its recovery [2].

Changes in land conditions from time to time make the threat of more significant flooding. This is caused by 1) the capacity of the river is getting smaller due to silting, 2) fluctuations in water discharge between the rainy season and the higher dry season, 3) conversion of forest land and natural buffer areas
to agricultural land, livestock, settlements by ignoring conservation technology has caused damage to the water catchment area (catchment area), and 4) development, regional infrastructure that is not environmentally friendly [3]. Water management is strongly influenced by the size of the forest in the watershed because of the function of forests as receivers, maintainers, and regulators water flow [4].

Floods are one of the most common and most harmful natural threats. Therefore, handling floods is always a priority. Flooding can be caused by the influence of 2 main factors, namely natural factors including rainfall, physiography of the river / geophysical area, or human influence factors include changes in land use, poor drainage, garbage disposal, etc. [5]. The study of the leading causes of flooding in an area is critical because the incidence of flooding between one region and another can be different.

The city of Kendari in the downstream area of the Wanggu watershed is one of the regions whose flood frequency has increased from year to year. A Geographic Information System (GIS) technology is needed to analyze the watershed conditions that have the potential to experience a flood by utilizing the ability to analyze spatial data. This is one step to help provide new information in the making of flood management policies and Wanggu watershed management in controlling floods in the city of Kendari. Large floods occurred in July 2013 and 2017 due to the overflow of Wanggu river water flow resulting in damage to public facilities and infrastructure, gardens, rice fields, and residential areas, especially in the downstream regions of the Wanggu watershed.

Increased changes in rainfall and land use in the Wanggu watershed have resulted in increased flood vulnerability in the Wanggu watershed and the city of Kendari, but the factors causing and spatial distribution of flood-prone areas in the Wanggu and Kendari watersheds have not been identified. Then it is necessary to study the factors causing the occurrence of floods and the level of flood vulnerability and mapping of the spatial distribution of flood-prone areas in the Wanggu watershed and Kendari city.

2. Method

2.1. Location and time
The research was carried out in Wanggu watershed, covering an area of 31,740.39 ha, which is administratively located in the districts of South Konawe, Konawe and the Kendari City of Southeast Sulawesi, geographically located at 30° 56' 54" - 40° 10' 24" South Latitude and 122° 22' 30" BT - 122° 35' 12" East Longitude from July 2017 to December 2017.

2.2. Materials and tools
Materials used in this research are: Wanggu River Basin Administration Map, River Map, Soil Type Map, Rainfall Map, Slope Slope Map, Land Use Map, Contour Map, and Wanggu River Basin Network Map. The tools used in this study are: 1) a set of computers consisting of hardware and software for entering data, processing data and outputting data, including hardware in the form of a notebook computer with 1 gigabyte of memory capacity, 1 gigabyte of ram and a printer for map printing and software, using ArcGIS 10.3 software, GoogleEarth Pro, and Microsoft Office Excel. Also, a set of survey tools, consisting of a Global Position System (GPS), a 50 m meter roll, a Digital Camera, and writing stationery.

2.3. Research methods
This study uses survey methods and data analysis using Geographic Information Systems (GIS) in mapping the level of flood hazard in the Wanggu watershed and Kendari city. Determination of maximum discharge (Q_{max}) using the Rational Method [4] and determination of the capacity of maximum river discharge capacity (Q_{max-S}) empirical equation method.

2.4. Data Sources and types
Sources of data used are primary data with direct observation in the field of the object under study, based on the map of land units obtained as many as 34 sample points for the ground check. Furthermore, at the sample point, the coordinates are taken using GPS on the observation plot to validate the flood hazard map data generated by matching the conditions directly in the field, and secondary data obtained from relevant agencies which are relevant data such as a) slope map/topography, soil type, land use and contour maps obtained from Sampara BPDAS, and b) annual rainfall data collected from the Sulawesi River Basin IV. Types of data in the study consist of quantitative data in the form of a) coordinate points and b) total rainfall data annual rainfall and monthly rainfall also qualitative data obtained from interviews, document analysis, FGDs, observations and images from photographs or video recordings.

2.5. Method of collecting data
Data collection techniques include recording and direct observation in the field of the factors causing floods, river cross-section measurements (width/height) and flow velocity, library studies conducted to obtain the theory and actual information that supports research and interview methods containing questions related to the history of flood events in the community who live around the location.

2.6. Research procedure

![Diagram of research procedure]

Figure 1. Stages of making flood-prone simulation maps.

2.7. Research variable
The research variables include rainfall, slope, soil texture, land use, altitude, drainage density, road construction, flood-prone levels, and spatial distribution of flood-prone areas with maximum flood risk ($Q_{max,s}$) respectively.

2.7.1. Rainfall includes rainfall data divided into five classes. The classification of rainfall classes can be seen in Table 1 as follows.
Table 1. Classification of Rainfall Classes.

| Annual Rainfall (mm) | Monthly Rainfall (mm) | Classification          | Score |
|----------------------|-----------------------|-------------------------|-------|
| > 3,000              | > 250                 | Really wet              | 9     |
| 2,501 – 3,000        | 200 – 250             | Wet                     | 7     |
| 2,001 – 2,500        | 150 – 200             | Moderate / moist        | 5     |
| 1,501 – 2,000        | 100 – 150             | Dry                     | 3     |
| < 1,500              | < 100                 | Very dry                | 1     |

2.7.2. Land Slope. The sloping grade, soil texture, and land-use class can be seen in Table 2 as follows.

Table 2. Slope grade, soil texture, and land-use class.

| Class slope (%) | Soil Texture Class | Land use class | Score |
|----------------|-------------------|----------------|-------|
| Flat 0–8       | Very smooth       | Sh, Tt, Ta (D & S) | 9     |
| Wavy 8–15      | Smooth            | PLK, P, Hm       | 7     |
| Hilly 15–25    | Is                | Sk, B, Al        | 5     |
| Mountains of 25 – 40 | Rough           | Plantation       | 3     |
| Steep mountainous> 40 | Very rough     | Forest           | 1     |

Information: Al = reed, B = shrub, Hm = mangrove forest, P = settlement, PLK = dry land agriculture, Sh = paddy field, Sk = bush, Tt = open land, T = pond, Ta = body of water (D = lake, S = river)

2.7.3. Place Height. The elevation class of the place and the drainage density class can be seen in Table 3 as follows.

Table 3. Classification of altitude and grade of drainage density.

| Place height class (m)* | Score | Drainage density class ** | Classification |
|-------------------------|-------|---------------------------|----------------|
| 0,0 – 12.5              | 9     | < 0.62                    | Rarely         |
| 12.6 – 25.0             | 7     | 0.62 – 1.44               | Rather rare    |
| 26.0 – 50.0             | 5     | 1.45 – 2.27               | Is             |
| 51.0 – 75.0             | 3     | 2.28 – 3.10               | Meeting        |
| 76.0 – 100.0            | 1     | > 3.10                    | Very tight     |
| >100                    | 0     |                           |                |

Note: * = Full Moon Source, 2008, ** = Source Linsley, 1999 and Paimin, 2010.

2.8. Data analysis

2.8.1. Spatial analysis. The spatial analysis used in this study is the classification/reclassification used for spatial data or attribute data into new spatial data using specific criteria, to facilitate the subsequent analysis process. Overlay, this process is an interaction or a combination of several maps. Overlay of some of these maps will produce new information. Dissolve, this analysis is used to generate views based on one of the attributes we choose.

2.8.2. Analysis of flood hazard rate. To determine the level of flood hazard done by adding up the product of the weight value (B) and score (S) in each parameter class [1] using the formula:

\[ \text{Total value} = B_c \times S_c + B_p \times S_p + B_t \times S_t + B_k \times S_k + B_l \times S_l \]  

Information :
B = Weight
c = Rainfall
k = Slope
l = Height of place
p = Land use
S = Score
t = Soil texture

Determination of the weight for each thematic map based on consideration, how likely flooding is affected by each geographical parameter, will be used in the GIS analysis. The weighting of flood parameters based on geographic parameters, such as rainfall weight 30, land use 20, slope 20, soil texture 20, and height 10 (Primayuda, 2006). Classification of the level of flood vulnerability at the study site is done by calculating the interval of flood hazard class by multiplying the weight with the value of each parameter:

\[ I = \frac{R}{n} \]  

(2)

Information:
I = interval width
R = Difference between maximum score and a minimum score
n = Number of flood hazard classes, namely (1) Very vulnerable, (2) vulnerable, (3) Rather vulnerable, and (4) Not vulnerable (Table 4).

\[ \text{Highest Scores} = 3 \times 30 + 7 \times 20 + 9 \times 20 + 9 \times 20 + 9 \times 10 \text{ is 680} \]
\[ \text{Lowest score} = 3 \times 30 + 3 \times 20 + 1 \times 20 + 1 \times 20 + 0 \times 10 \text{ is 190} \]
The class interval = 680 - 190: 4 is 122.5

| Class        | Total Value |
|--------------|-------------|
| Very vulnerable | 557,6 - 680 |
| Vulnerable    | 436 – 557,5 |
| Rather vulnerable | 312,6 – 435 |
| Safe          | 190 – 312,5 |

2.8.3. Measurement of maximum flood discharge data. The maximum flood discharge \( Q_{\text{max-s}} \) is determined using the formula:

\[ Q_{\text{max-s}} : V \times A \]

Information:
V = Average velocity of river flow in ms\(^{-1}\) of the Manning equation
A = River cross-sectional area in m\(^2\).

3. Results and discussion
The results of the analysis of several mapping parameters of flood vulnerable areas in the Wanggu watershed include rainfall, land use, slope, soil texture, altitude, and drainage density are described as follows:

3.1. Rainfall
The results of the monthly rainfall analysis in the Wanggu watershed show that there are three categories of rainfall classes namely: 1) very wet months on August, 2) wet and humid months in February, March, April, May, June, December and 3) dry months in January, September, October, and November in Figure 1.

Rainfall is a significant factor causing flooding in the watershed area. This supported by research [6] stating that hydrological modeling for identification of the flood-prone regions is influenced by rainfall in landforms, slope, soil type, and rock type, the factor which has the most role is rainfall. Furthermore, by [7–9] states rainfall is the most crucial factor determining the amount of run-off in a watershed area.

3.2. Land use

Land use in the Wanggu watershed is presented in table 5 and figure 2.

| Land Use          | Large (ha) | (%) |
|-------------------|------------|-----|
| The waters        | 14.26      | 0.04|
| Reeds             | 1,797.47   | 5.66|
| Thicket           | 2,145.76   | 6.76|
| Forest            | 10,891.19  | 34.31|
| Mangrove forest   | 45.87      | 0.14|
| Mixed Gardens     | 775.95     | 2.44|
| Meadow            | 535.39     | 1.69|
| Settlement        | 1,223.28   | 3.85|
| Dryland farming   | 333.34     | 1.05|
| Rice fields       | 1,746.64   | 5.50|
| Bush              | 1,368.72   | 4.31|
| Pond              | 219.05     | 0.69|
| Moor              | 10,643.41  | 33.53|
| **Total**         | **31,740.39** | **100**|

Source: BPDAS-HL Sampara (2016) and GIS analysis results.
Figure 2. Map of land use in the 2016 Wanggu watershed & the results of the GIS analysis.

Land use such as forests, agroforestry is an essential factor in influencing the level of flood vulnerability because forests can irrigate, store/hold, and control the flow of water from excessive rain, thus reducing the occurrence of flooding in the Wanggu watershed. Reduced forest area has caused an increase in run-off (C) coefficients, causing floods in the rainy season and drought in the dry season [4–6,10].

3.3. Slope

The slope in the Wanggu watershed consists of 4 classes each presented in Table 6. The slope affects the surface water flow velocity. The higher rainfall intensity and the slope make water faster to run off; on the contrary, making the watershed area flat, the smaller the run-off so that the flooding can be even more significant. The Wanggu watershed is dominated by slopes surging 1,606.89 ha (5.06%), hilly 6,518.93 ha, (20.53%) and steep mountains of 10,871.41 ha (34.25%) of the Wanggu watershed area. The topography is in the upstream and a little central part of the watershed. High rainfall intensity caused the run-off speed to be higher. Also, the shorter flow concentration-time and causes flood vulnerability in the middle region and more fabulous in the downstream area (outlet). This is as stated by [4,7,11] the higher the slope and rainfall make the higher of run-off speed, the shorter the flow concentration-time, causing flooding in the flat areas downstream of the watershed.

| Slope class | Slope (%) | Area (ha) | (%) |
|-------------|-----------|-----------|-----|
| Flat        | 0-8       | 12,743.14 | 40.14 |

Table 6. Slope area in the Wanggu watershed in 2017.
| Slope Class   | % Area | Total Area (ha) | Slope (%) |
|--------------|--------|-----------------|-----------|
| Wavy         | 8-15%  | 1,606.89        | 5.06      |
| Hilly        | 15-25% | 6,518.93        | 20.53     |
| Climbing Mountain | >40   | 10,871.41      | 34.25     |
| Total        |        | 31,740.39       | 100       |

Source: BPDAS-HL Sampara (2016) and GIS Analysis Results

A map of the slope class and slope area in the Wanggu watershed is shown in Figure 3.

**Figure 3.** Map of the slope class and slope area in the 2017 Wanggu watershed.

### 3.4. Soil texture

The results of soil texture analysis in the Wanggu watershed include three classes of soil texture, such as coarser sand, silt, and clay. The silt class was the most dominating texture of 17,142.85 ha (54%) areas, followed by the coarser sand texture class of 8,982.17 ha (28.29%) and clay class 5,615.36 ha (17.69%) of the total area of the watershed. More can be seen in Table 7 and Figure 4. Based on Table 7 shows that the soil in the Wanggu watershed according to the United States Soil Conservation Service (SCS) method, classified as a soil hydrology class A, B and C has a soil infiltration capacity classified as fast to very slow and the finer or smallest particles of soil, the slower infiltration capacity and the coarser particles of soil, the higher infiltration capacity [7,10].
Table 7. Soil texture in the Wanggu watershed.

| Soil Texture | Area (ha) | (%) |
|--------------|-----------|-----|
| Coarser      | 8,982.17  | 28.29 |
| Silt         | 17,142.85 | 54   |
| Clay         | 5,615.36  | 17.69 |
|              | 31,740.39 | 100  |

Source: BPDAS-HL Sampara (2016) and GIS analysis results

Figure 4. Map of soil texture in the Wanggu watershed in 2016.

3.5. Place height
The altitude classes in the Wanggu watershed are divided into six, namely, classes 0.0 m -12.5m, 12.6m-25m, 26m-50m, 51m-75m, 76m-100m, and > 100m (Table 8 and Figure 5).

Table 8. Data on altitude in the Wanggu watershed.

| Height (m) | Large (ha) | (%) |
|------------|------------|-----|
| 0.0 – 12.5 | 2,595.55   | 8.2 |
| 12.6 – 25.0 | 8,385.69   | 26.4 |
| 26.0 – 50.0 | 9,211.56   | 29.0 |
| 51.0 – 75.0 | 3,707.56   | 11.7 |
3.6. Drainage density

Based on the analysis of drainage density maps in the Wanggu watershed, ten sub-watersheds are obtained with a relatively equal density level and are divided into two classifications: medium density in sub-watersheds 1, 2, 3, 4, 5, 6, 8, 9, 10 and classification Meetings in sub-watershed 7 (Table 9 and Figure 6). The drainage density means that the volume and velocity of water that flows in a river body are classified as moderate to large. This condition is also influenced by the dominant coarser texture soil (28.29%), medium or silt soil 54.0%, and clay (17.69%) of the area of the watershed so that there is a great chance of flooding. Accordance with the opinion [10,12–14] that the higher of drainage density, made the flow of water faster so that the faster the flow is drained. Conversely, the lower the drainage density, the area always experiences inundation, and the drainage is poor.

Table 9. Classification of drainage densities in the Wanggu watershed.

| Flow Density (km/km²) | Sub-watershed | Density | Area (Km/Km²) | (%) |
|-----------------------|---------------|---------|---------------|-----|
| 76.0 – 100.0          | 2             | 2.11    | 28.98         | 9.13|
| > 100.0               | 3             | 2.19    | 22.37         | 7.05|
|                      | 4             | 2.24    | 29.51         | 9.30|
|                      | Medium        | 2.23    | 29.88         | 9.42|

Figure 5. Altitude in Wanggu watershed.

Source: BPDAS-HL Sampara (2016) and GIS analysis results.
3.7. Flood Hazard Levels in the Wanggu watershed in 2017

The results of the analysis show the level of flood vulnerability in the Wanggu watershed is divided into four classes, namely protected class, somewhat vulnerable, vulnerable, and very vulnerable class. Wanggu watershed is dominated by vulnerable classes 10,360.98 ha (32.6%). Then successively very vulnerable 7,496.14 ha (23.6%), safe 8,779.60 ha (27%), and the lowest is a somewhat vulnerable class 5,083.65 (16.0%) of the total watershed area (Table 11 and Figure 7). The high level of flood vulnerability in the Wanggu watershed area and Kendari city from somewhat vulnerable, vulnerable and very vulnerable is caused by the biophysical conditions of the region namely high rainfall (CH) > 150 - 330 mm per month (December, February, March, April, June, and August), land use is not in accordance with the capability of the land, especially mixed gardens, dry fields, dryland agriculture, and partial destruction of the forest area of 10,891.19 ha (34.31%), the dominant flat slope is 12,743.14 ha (40, 14%), erosion-sensitive soil type (dominant coarse-medium texture) of 26,125.02 ha (82.29%) of the watershed area, and moderate and dense drainage density. This is as stated by [5,7,11,15], states that the rainfall factor is high, land-use change is not appropriate; soil type is easily eroded, flat topography, and drainage density is not supportive. Kodoatie and Sjarief, 2008 subsequently add it; Maryono [15] that slums also cause floods along river banks/drainage, garbage disposal into rivers, and mistakes in land use planning.

| Classification | Total score | Area (ha) | (%) |
|----------------|-------------|-----------|-----|
| Safe           | 190.0 – 312.5 | 8799.60 | 27.7 |
| Tight| 2.37 | 34.04 | 10.73 |

Figure 6. River drainage map in the Wanggi watershed in 2017.
3.7.1. Analysis of flood discharge in the Wanggu watershed. The results of flood discharge analysis in the Wanggu watershed using the Rational Method are presented in Table 12. Table 12 shows that the maximum total discharge ($Q_{\text{max-L}}$) from various land uses in the Wanggu watershed is 69.28 m$^3$dt$^{-1}$. The most significant contribution of maximum discharge is the Dryland farm with the value of $Q_{\text{max-L}} = 28.60$ m$^3$dt$^{-1}$, and the smallest mixed farm is 1.86 m$^3$dt$^{-1}$.

Table 11. Surface run-off discharge on land use in the 2017 Wanggu watershed.

| Land use         | Constant | C  | I   (mm h$^{-1}$) | A   (ha) | $Q_{\text{max-L}}$ (m$^3$dt$^{-1}$) |
|------------------|----------|----|------------------|---------|-----------------------------------|
| Forest           | 0.278    | 0.19| 8.70            | 10,937.06 | 13.96                             |
| Mixed farm       | 0.278    | 0.25| 8.70            | 1,109.29  | 1.86                              |
| Shrubs           | 0.278    | 0.29| 8.70            | 5,847.40  | 11.39                             |
| Dry land farm    | 0.278    | 0.40| 8.70            | 10,643.41 | 28.60                             |
| Wet land farm    | 0.278    | 0.25| 8.70            | 1,979.95  | 3.33                              |
| Settlement       | 0.278    | 0.50| 8.70            | 1,223.28  | 4.11                              |
| Road             | 0.278    | 0.80| 8.70            | 1,215.06  | 6.53                              |
| **Total**        |          |     | **31,740.39**   | **69.78** |                                   |

Note: A = area of land use, C = surface runoff coefficient, h$^{-1}$ = per hour, I = daily maximum rainfall intensity, $Q_{\text{max-L}}$ = maximal surface runoff discharge.
3.7.2. Flood analysis in the 2017 Wanggu River Basin. Based on the analysis of total run-off surface run-off ($Q_{\text{max,1}}$) and Wanggu river flow crossing capacity ($Q_{\text{max,s}}$) for the first rainy day with a maximum daily rainfall of 8.70 mm hour$^{-1}$ resulting in a maximum discharge ($Q_{\text{max,1}}$) of 69.78 m$^3$dt$^{-1}$ and Wanggu river flow capacity ($Q_{\text{max,s}}$) is 71.28 m$^3$dt$^{-1}$. This shows that the first day has not occurred due to flooding due to $Q_{\text{max,1}} < Q_{\text{max,s}}$ is 1.5 m$^3$dt$^{-1}$. Furthermore, on days 2 and 3 with maximum rainfall intensity equal to day 1, the amount of flooding in the Wanggu watershed is $(2 \times 69.78 \text{ m}^3\text{dt}^{-1}) - 1.5 \text{ m}^3\text{dt}^{-1}$ is 137.98 m$^3$dt$^{-1}$. Floods on days 2 and 3 in the Wanggu watershed and Kendari City were caused by the water discharge on day one being fully saturated: soil profile (infiltration capacity = 0), detention storage, plant canopy (interception potential) and natural drainage channels, artificial settlements or the settlement has been filled with water, or the Wanggu watershed has been saturated with water and coincides with the maximum tides so that tidal floods occur for seven days.

4. Conclusions

The cause of flooding in the Wanggu watershed is high rainfall of 200 - 360 mm/month (March, April, August and December 2017), forest area 34.3% of the watershed area and a half has been damaged, hilly topography-steep mountainous 54.8%, soil type textured erosion texture moderate-rough with poor soil hydrological grade 82.3%, and moderate-large dominant drainage density 89.27% of Wanggu watershed area with moderate-large flood probability.

The level of flood vulnerability in the Wanggu watershed are four classes namely 1) Safe Class 8,799.60 ha (27.7%), 2) Rather vulnerable to 5083.65 ha (16.0%), 3) Vulnerable to 10,360.98 ha (32, 6%) and 4) Very vulnerable 7496.14 ha or (23.6%). Very vulnerable class area of 7,496.14 ha (23.6%) of the watershed area is located in 6 Districts of Kendari City Administration namely 1) Kadia District 95.98 ha, 2) Kambu 508.83 ha, 3) Mandonga 1.8 ha, 4) Poasia 34.22 ha, 5) Wua-Wua 96.98 ha and 6) Baruga District 1,620.41 ha, and 3 Districts in the area of South Konawe Regency, namely 1) Konda District 4,066.75 ha, 2) Ranomeeto 446.37 ha and 3) North Moramo District 350.72 ha.

The magnitude of flooding in the Wanggu watershed and the city of Kendari in 2017 on the 2nd and 3rd day of the maximum daily rainfall was 137.98 m$^3$dt$^{-1}$ and inundated the city of Kendari for seven days with three fatalities and failed rice harvesting of 1,492 ha and house washed away by flood seven houses.

Southeast Sulawesi Provincial Government PERDA is needed regarding 1) Utilization of land use in Wanggu river border and reforestation of damaged forests, 2) Standard operational procedures (SOP) for flood management and early warning of flood hazards in areas classified as very vulnerable and vulnerable flooding in the Wanggu watershed, and drainage will be immediately handled in areas classified as very vulnerable to and vulnerable to flooding in the Districts of Kadia, Kambu, Mandonga, Poasia, Wua-Wua, Baruga, Konda, Ranomeeto and Moramo North districts.

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