Spatial Analysis Study on the Flood Impact of Walanae Cenranae River Area in Soppeng Regency South Sulawesi Province

By Sugiarto Sugiarto

Spatial Analysis Study on the Flood Impact of Walanae Cenranae River Area in Soppeng Regency South Sulawesi Province

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***Abstract*—Cabenge River is part of the WalanaeCenranae River area in Soppeng Regency. Annually, the area around the Cabenge River gets the most losses from floods, both in terms of facilities and infrastructures. This study aims to map the areas prone to flood and flood risk, based on the field that gets the most significant impact. This study uses a Geographic Information System (GIS) as a tool and ArcGis Software in determining the level of vulnerability and risk of flooding at the study site. This type of research is a combination of mapping (topographic results) and map analysis. The variables used are DEM (Digital Elevation Model) data and flood volume. The data processing technique used is the GIS-based inundation model approach using inundation height (H) based on a comparison between the volume of water (V) in inundated areas and the volume of water (Q) of flood sources. The results showed that Lilirilau District was in the high hazard class with an area of 100 km^2 and had the biggest impact, while in Liliriaja District, the area that was in a high hazard class was 34 km^2 and Ganra District was 21 km^2.**

Keywords*—*Flood; Map; Geographic Information System

I. Introduction

There are two main causes of flood, namely high rainfall intensity and low topographic conditions [1]. It is also caused by anthropogenic factors [2], for example, there is still the habit of throwing garbage into the river, people occupancy on the riverbanks, and the narrowing of the river due to buildings such as culverts or bridges.

Losses caused by floods are quite large [3], therefore, making maps to determine flood risk zones based on GIS (Geographic Information Systems) [4] - [6] is needed as a step in reducing risks caused by flood disasters [7]. Spatial analysis is a technique or process that involves some calculations and logical evaluations [8] carried out to find potential relationships or patterns that may exist between geographical elements contained in digital data with the boundaries of the study area in particular [9]. Spatial data analysis includes the overlay or overlapping process of topographic measurement data [10] and DEM data [11]. Whereas [12] said, in determining the level of flood vulnerability based on the results of data collection and analysis is by scoring and overlaying of three parameters namely: land use map, drainage channel density map, slope steepness map. Before overlaying, the weighing factors of each parameter are determined first [13]. Determination of the weighing factor is based on the magnitude of the parameter effect on flood vulnerability.

The Cabenge river is in the Walanae Cenranae River area which is located in Soppeng Regency. Floods occur each year due to this river whose inundation locations are spread across three districts including Liliriaja district, Lilirilau district and Ganra district. As it is known that these districts are traversed by the river Cabenge [14]. Soppeng is one of the regencies in South Sulawesi Province that is often flooded. The flood disaster that occurred in 2019 caused many losses and casualties, especially in the overflow area of the Cabenge river. This study aims to spatially analyze the level of hazard, vulnerability and risk of flooding in the Cabenge River area.

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II. Research Methodology

Flood hazard areas are identified through a GIS-based inundation model approach based on topographic data according to Figure 1, where DEM data and volume of flood sources are known [11]. This model uses an approximation algorithm to analyze inundation heights (H) based on a comparison between the amount of water (V) in inundated areas and the volume of water (Q) of flood sources [15]. The model development is conducted by developing an inundation approximation algorithm in the form of a process of distribution of runoff (height) between cells (pixels) in neighbouring DEM data. The algorithm is created using VBA (Visual Basic Application) macros to create scripts in a Microsoft Excel environment that is integrated with ArcGIS software.

The function of the approximation algorithm is to determine the area of inundation that is defined based on equation [16]:

$$F.H = Q - V = Q - {}_{i=1}^{m} H - E \quad (1)$$

Where the V value can be calculated using the equation:

$$V = {}_{i=1}^{m} A \times hi \quad (2)$$

Where Hi is the accumulation of heights between inundation height (hi) and DEM elevation (Ei) on the i pixel unit, hi = Hi - Ei; m is the number of pixel units inundated, and A is the area of pixel unit.

Figure 1. Research location

DEM data used are DEM integration between DEM SRTM 30 m and DEM resulting from high point interpolation [11] from various map sources, namely the Indonesian Earth Map scale 1: 50,000, the Basic Land Registration Scale 1: 1,000, and measurement of the cross-section of the Cabenge River elevation. The interpolation method used is a krigingsemivariogram with a pixel size output of 20 m through ArcGIS software [15], [17], [18].

The level of flood hazard is classified based on the water depth class. Water depth of <0.76 m is a low hazard class, water depth of 0.76-1.5 m is a moderate hazard class, and water depth of > 1.5 m is a high hazard class [19].

Vulnerability analysis is assessed based on the criteria of physical vulnerability, social vulnerability, and land exposures in hazard areas [7]. Physical vulnerability is assessed based on the number of buildings obtained from the digitization of building points on the 2019 WorldView-2 satellite imagery. The grouping of buildings is done using the Point Statistics method [20], then classified by the Natural Breaks classification method of 3 classes namely low class (< 17 building points; score 0.33), moderate (18–44 building points; score 0.67), and height (> 45 building points; score 1). Social vulnerability is assessed based on population density. Population density is calculated based on population (average population per unit/residential building point) per km^2 obtained from BPS Soppeng Regency data in 2019. The average population per unit/residential building point is 4 to 5 inhabitants. The population density was calculated by Point Density analysis [21], then classified by the Natural Breaks classification method of 3 classes, namely low class (<41 km^{-2} inhabitants; score 0.33), moderate (42-92 km^{-2} inhabitants; score 0.67), and height (> 92 km^{-2}; score 1).

The loss value for land exposures is based on the results of weighting using AHP method [22] namely settlements/housing valued at 0.18, business valued at 0.14, offices valued at 0.15, educational facilities valued at 0.14, health facilities valued at 0.14, rice fields valued at 0.11, mixed gardens valued at 0.08, and ponds valued at 0.08, and fishpond is worth 0.06 while the use of open space/field, shrubs, mangroves, and rivers is not taken into account.The level of flood hazard shows the level of

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threat in an area where there are community activities that can cause a loss impact.

Flood disaster risk is analyzed based on the product of the multiplication between hazard components (H) and vulnerability (V). According to [19], the multiplication index results need to be corrected to regain the original dimension. To make the correction, the equation is used:

$$R = \sqrt{H \times V} \quad (3)$$

The level of risk is assessed spatially to produce a risk map. The weight of each component is 0.5. Scores for each component class (hazard and vulnerability) are 0.33 (low), 0.67 (moderate), and 1 (high). The risk class is classified by the equal interval method into three classes, namely low, medium and high.

III. Results and Discussion

A. Analysis of Flood-prone Areas

Flood risk analysis with the process of combining hazard maps and vulnerability maps results in flood disaster risk maps at the study site. Qualitatively defining risk values (low, medium, high) provides a clear picture of how hazards and various components of vulnerability play a role in flood disasters.

Flood locations are spread across threedistricts including Liliriaja district, Lilirilau district and Ganra district. As it is known that this district is traversed by the Walanaeriver. In a complete view, the flood hazard class is presented in Figure 2 below:

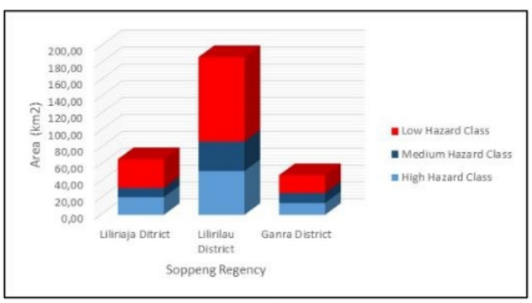

Figure 2. The area of each flood hazard class based on village administration map in Kab. Soppeng.

B. Flood Loss Impact Analysis

The level of flood hazard shows the level of threat in an area where there are community activities that can cause a loss impact. The impact of flood losses is presented in Table 1, and the area of the flood that affected by flood hazard class is presented in Figure 3.

Table 1. Impact of losses caused by flood

	Area (km^2)		
	Liliriaja	**Lilirilau**	**Ganra**
House	31,68	89,76	22,56
School	5,28	14,96	3,76
office	4,62	13,09	3,29
Irrigation	9,90	28,05	7,05
Garden	5,94	16,83	4,23
Road	7,26	20,57	5,17
Bridge	1,32	3,74	0,94

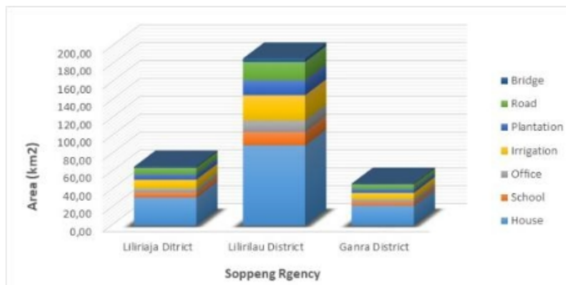

Figure 3. The area of each flood hazard class is based on infrastructureand facilities affected by the flood.

C. Map of the Flood Area

The flood area map is the result of a compilation of the earth map, satellite image map, DEM map and the measured topographic map. With reference to the highest flood events that have occurred from surveys and inventories, a flood event analysis is then conducted for the affected area and facilities and infrastructure, and then a flood area map is generated as shown in Figure 4 which considers data from Figures 5 and 6:

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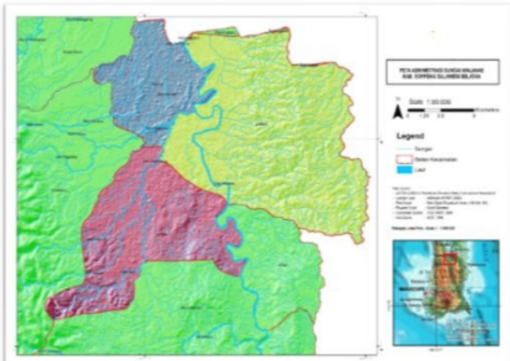

Figure 4. Administrative map for Cabengeriver, Soppeng regency

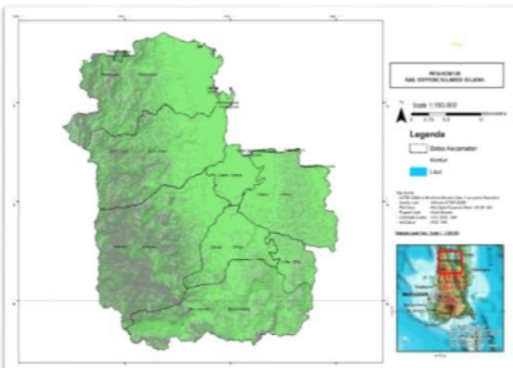

Figure 5. Contour map of Soppeng Regency

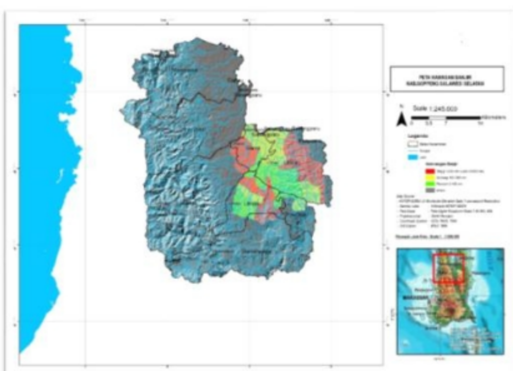

Figure 6. Map of the flooded area in Soppeng Regency

As can be seen in Figures 7 and 8, in the District of Ganra for high hazard class in Ganra Village (21 ha or 44.68%), moderate hazard class occurs in Lompulle Village (12 ha or 25.53%) and low hazard class occurs in Belo Village (14 ha or 44.68%).

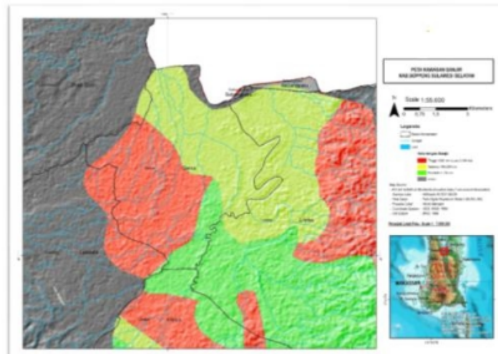

Figure 7. Map of the flooded area of Ganra District in Soppeng Regency

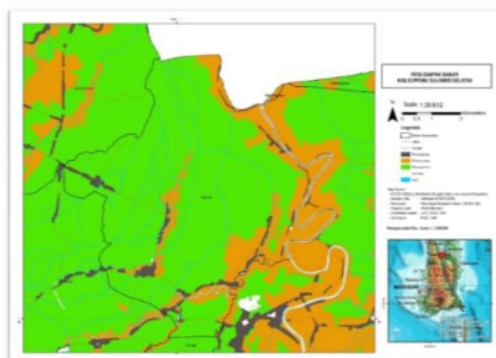

Figure 8. Flood impact map of Ganra District

As shown in Figures 9 and 10, for Liliriaja district, there are six affected villages, namely Rompegading, Galung, Jennae, Jampu, goods and Apanang. For Lilirilau district there are 12 affected villages, namely Cabenge, Kebo, Macanre, Pajalesang, Paroto, Baringeng, Tetewatu, Palangiseng, Abbanuangnge, Parenring, Ujung and Respect Villages, as presented in Figure 11 and 12. There are 3 affected villages in Ganra district, namely Lompulle, Belo, and Ganra villages, as shown in Figure 7 and 8.

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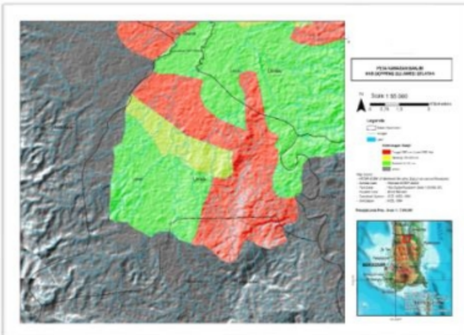

Figure 9. Map of the flooded area of Liliriaja district in Soppeng regency

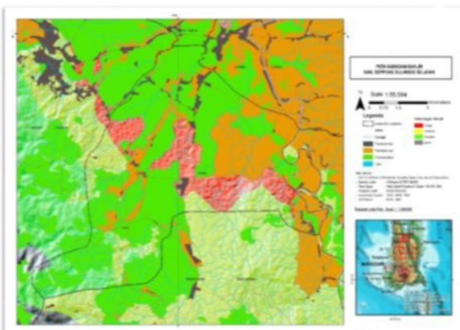

Figure 10. Flood impact map of Liliriaja district.

Administratively, the high hazard class dominates in Liliriaja district, namely in the Village of Jampu (87 ha or 24.24% of the total area of danger area), Barang (5 ha or 7.58%) and Apanang village (13 ha or 19.70%). Medium hazard class is in Galung village (11 ha or 16.67% of the total area of hazard area), low hazard class dominates in the area, namely in Rompegading and Jennae villages with an area of 12.12 ha and 13 ha respectively.

In Lilirilau district, the high hazard class is spread in Cabenge village (6 ha or 3.21%), Baringeng (21 ha or 11.23%), Abbanuangnge (29 ha or 15.51%), Parenring (21 ha or 11.23%), and Masing (19 ha or 10.16%), as shown in Figures 11 and 12. For moderate hazard classes in Kebo village (13 ha or 6.95%), Tetewatu (8 ha or 4.28%) and Palangiseng (14 ha or 7.49%). Low hazard class in Macanre village (4 ha or 2.14%), Pajalesang (12 ha or 6.42%) and Paroto (17 ha or 9.09%).

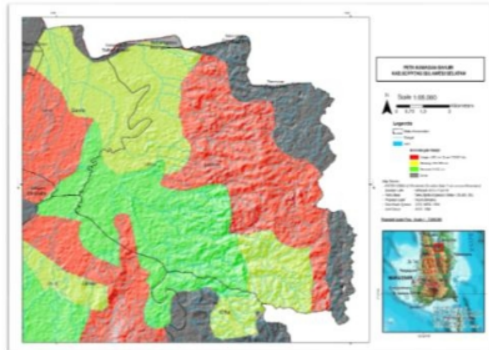

Figure 11. Map of the flooded area of LililrilauDistrict in Soppeng Regency

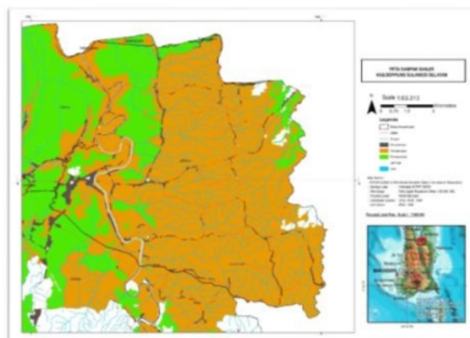

Figure 12. Flood impact map of Lilirilau District.

IV. Conclusion

From the results of the analysis and calculation, it can be concluded as follows:

1. The flood area map shows that the flood was in an area in the Cabenge river area and the largest flood event ever occurred between a depth of 0.3 - 2.5 m and an inundation area of 3,000 ha.

2. The level of flood hazard was assessed based on the results of inundation model simulation, and the water depth class showed that the high hazard class was mostly in the District of Lilirilau, namely 100 ha (53.48%), Liliriaja District at 34 ha (51.52%) while Ganra District was 21 ha (44.68 %) of the total area in the district.

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