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Investigation of Flash Flood Threats Using Spatial Data in Lawe Sigala-gala District, Southeast Aceh District, Aceh

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Abstract

Flash floods are floods with very large water discharge that comes suddenly. In 2017, Lawe Sigala-gala District, including areas affected by flash flood in Central Aceh District, needs to be done by researching maps of potentially flood-prone areas. The study was conducted using DESKTOP ArcGIS software with a scoring method and weighting of parameters. The threat parameters are 6 parameters and the score given to each parameter has an interval of 5 with a low, rather low, medium, rather high, and high class. Based on the calculation results, the study location consisted of 3 flash flood threat classes namely low class covering Lawe Deski sub-watershed, medium class covering Lawe Tua Makmur sub-watershed, Suka Jaya sub-watershed, Lawe Rakat sub-watershed and Tanoh Alas sub-watershed, and high class covering Bukit Sub-watershed Independent. The threat of flash flood in this sub-district is influenced by land use. This is due to the uneven distribution of the population that is a settlement in this sub-district.

Keywords: Flash Floods; Threats; Vulnerabilities; Risks; Geographic Information Systems

1. Introduction

Flash floods occur due to the high intensity of rainfall resulting in floods (Ruin et.al.,2008). In Act No. 24 of 2007 BNPB (National Disaster Management Agency) the notion of flash flood is a flood that comes suddenly with a very large water discharge caused by the damming of the river flow in the river channel.

Previously, flash flood had occurred in several sub-districts, namely Semadam Subdistrict in 2007 as many as 5 villages were severely damaged and 1 person died, Bukit Tusam District in 2009 as many as 4 deceased villages, Lauser District in 2012, which is precisely Liang Pangi Village, killed 11 people and Districts Ketambe in 2012 was 3 affected villages (POS SAR Kutacane).With the occurrence of flash flood events, it is necessary to map the potential areas of flash flood threats so as to minimize the consequences of flash flood disasters in Southeast Aceh Regency (Azmeri, 2016).

In 2017, there was a flash flood in Southeast Aceh Regency, precisely on April 11 2017 caused by heavy rainfall in the last four days in the area and the location of extreme villages on the edge of steep mountain hills and also side by side with children tributary (Cochard, 2017). As a result of the flash floods, 14 villages in two sub-districts in Southeast Aceh District were severely damaged, namely 12 villages in Lawe Sigala-Gala District, and 2 villages in Semadam District. The people affected by the disaster were 2476 people or 648 families.In the history of flash floods that have occurred in Southeast Aceh Regency, the biggest flash flood is in the District of Lawe Sigala-gala which is detrimental to the local community. In addition, because of its extreme location in the hills and adjacent to the watershed, the area is prone to flash flood disasters (Gore & Fischer, 2014).

This research aims to determine the area threatened by flash flood in Lawe Sigala-gala District through mapping, Subsquently, this research determine areas that are vulnerable to flash flood in Lawe Sigala-gala District by mapping as well.

2. *Area descriptions, methods and material studied*

The description area includes research data, scoring, weighting, Mapping of Flash floods Threat Areas, Interpretation. This research method uses descriptive data analysis by interpreting data that has been processed.

This research area studied covers one district namely Lawe Sigala-gala District, Southeast Aceh Regency. Administratively, the area of the study is 71.72 km2 or 2% percent of the total area of Southeast Aceh. The number of villages in this district is 34 villages which are divided into 4 population settlements. The number of villages affected were 12 villages including Batu Dua Ratus Village, Lawe Kesumpat Village, Bukit Merdeka Village, Lawe Tua Makmur Village, Lawe Tua Persatuan Village, Lawe Tua Gabungan Village, Lawe Sigala II Village, Kayu Mbelin Village, West Lawe Sigala Village, Lawe Sigala Barat Jaya Village, Kute Tengah Village, and Lawe Loning Village. Lawe Sigala-gala District has administrative boundaries as follows.

a. North side is directly bordered to North Sumatra Province.
b. East side is directly bordered to North Sumatra Province.
c. The South is bordered by the district of Babul Makmur, Southeast Aceh Regency.
d. The West is bordered by the District of Babul Rahman, Southeast Aceh Regency.

Geographically, the western part of the Lawe Sigala-gala district is the Alas River sub-watershed which stretches along the Southeast Aceh Regency. In addition, the western part of the district is downstream from the small river with upstream in the Bandahara mountain range.

Data

Data needed to obtain zoning Risk of flash floods shown in Table 1.

Table 1. Data needed to determine areas of threat, vulnerable and at risk of flash floods.

No	Data	Source
1.	Administrative boundary data for 2013	Agriculture and Plantation Service District Southeast Aceh
2.	2000 SRTM DEM data	USGS, earthexplorer.usgs.gov
	Recording Landsat 8 imagery dated	USGS, earthexplorer.usgs.gov

3.	June 29, 2015	
4.	Rainfall data	Station watchers look cool
5.	River network data	Agriculture and Plantation Service District Southeast Aceh
6.	Land type data	Agriculture and Plantation Service District Southeast Aceh
7.	Population data	BAPPEDA Kab. Southeast Aceh and Google Earth

Scoring

The data that has been obtained will be several maps including administrative maps, surface elevation class maps, rainfall maps, and river network maps (Craig & Elwood (1998). Then an data analysis is carried out by giving scores to each map classification.

Weighting

Weighting is giving the weighting to the database of each parameter which influences flood compliance (Chen, et.al., 2010). The weighting value is carried out qualitatively which can be reviewed based on the condition of the region. So the writer gives weight to each parameter as follows.

Table 2. Weighting of flash floods threat areas based on flood threat area parameters.

No	**Parameter**	**Weight (100%)**
1.	Average maximum daily rain (mm / day)	25
2.	Form of watershed	10
3.	River density	15
4.	The slope of the watershed	5
5.	Type of soil	5
6.	Land use	40

Source: Paimin, et al (2012)

The generation of weighting data for flash floods threat areas is carried out in the ArcGIS software on the table 2 by utilizing the Field Calculator by entering the following equation.

$$\text{Threat} = \frac{(H \times 25) + (BD \times 10) + (KS \times 15) + (KD \times 5) + (JT \times 5) + (PL \times 40)}{100} c$$

Where,

H = maximum average daily rainfall score
BD = watershed form score
KS = river density score
KD = watershed slope score
JT = soil type score

PL = land use score

Furthermore, according to Paimin, et al (2012), scoring is done by using the following equation.

Score Score Interval = (Highest Value - Lowest Value) / Score Interval

Mapping of Flash floods Threat Areas

After weighting the locations that are suspected of being flood threat areas, then the location of the flash floods threat area will be identified based on the village. The identification data is then combined with administrative data to obtain a map of the area of flash floods threat in Lawe Sigala-gala District.

3. Results and Discussion

Average Maximum Daily Rain

Rainfall data for the location of this study came from the rain observation post of Gayo Lues Regency. This is because the Southeast Aceh District does not have complete data, besides that the Gayo Lues district is also the upstream of the Lawe Alas River, which makes it very influential on the arrival of floods due to high rainfall upstream. The period of maximum daily rainfall data obtained is starting from 1998 to 2002. The final result of the maximum daily rainfall average in Gayo Lues Regency is 113 mm / day, the rainfall data can be seen in Table 3.

Table 3. List of daily maximum rainfall obtained from daily rainfall data based on the Rain Observers Station data in Gayo Lues Regency in the period 1998 - 2002.

	Year					Average Maximum Rainfall
Month	**1998**	**1999**	**2000**	**2001**	**2002**	
Jan	121	39	16	12	18	
Feb	125	41	5	15	6	
Mar	62	31	20	74	30	
Apr	102	37	17	52	37	
May	35	50	15	79	78	
Jun	48	37	16	72	33	
Jul	38	60	20	45	50	
Agt	155	101	26	63	40	
Sep	80	35	10	79	152	
Oct	61	135	15	96	151	
Nov	116	42	29	57	90	
Dec	82	94	12	90	54	
Average	155	135	29	96	152	113

River density

River network data is obtained from river network maps in the Indonesian Central Statistics Agency in Southeast Aceh Regency. From these data it can be seen the branching of rivers which flow to the Alas River through the Lawe Sigala-gala District. The calculation is done by calculating the percentage between the lengths of the river through the sub-watershed with the area of the sub-watershed. So that the percentage value can be classified based on the river density class that has been developed by Paimin, et al (2010).

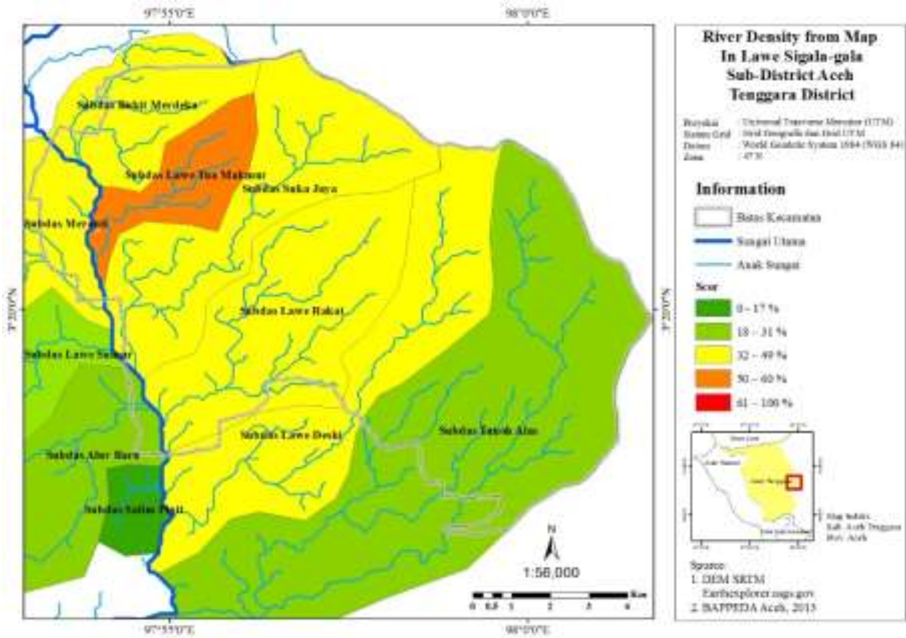

Figure 1. River density map based on sub-watershed in Lawe Sigala-gala District.

Shape of Sub Watershed

Determining the form of the sub-watershed class follows the recommendations written by Paimin, et al (2010), which are based on the number of branches in one tributary. Class division also follows the form of the sub-wathershed. The highest class is for rounded sub-watershed, this is because the rounded form has the most number of branches and covers the widest area. The lowest class with a value of 1 is aimed at the oblong sub-watershed form, this is due to the oblong sub-watershed form having fewer branches with a small area coverage. The division of the sub-watershed form class area has been explained in the Watershed Form Map below:

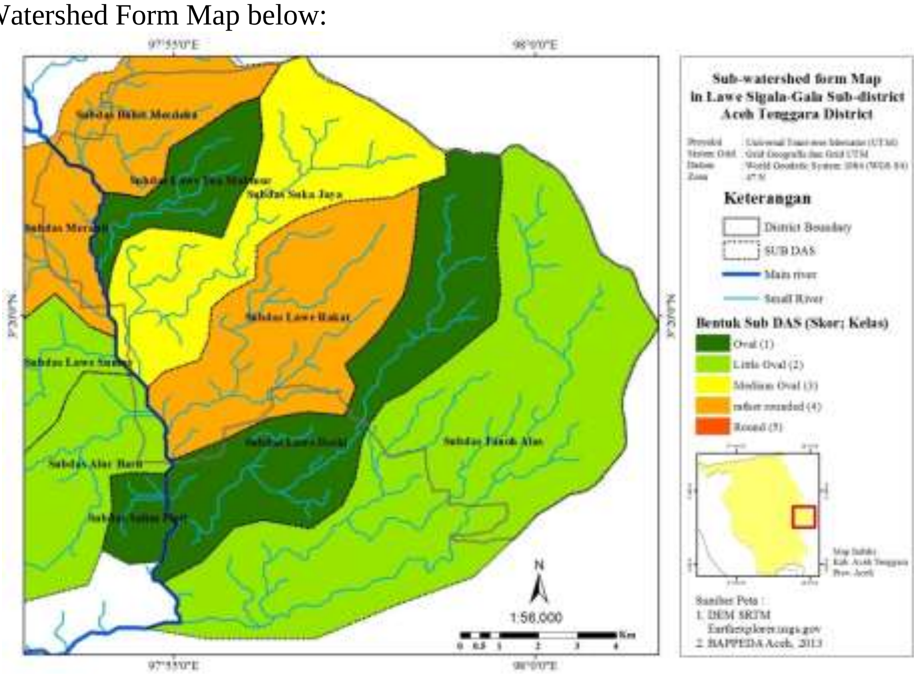

Figure 2. Shape of sub-watershed map of sub-regional forms

Slope of the Watershed

The sub-watershed slope in Lawe Sigala-gala sub-district varies greatly, this is shown by the color contour obtained in the watershed slope map image. In general, steep and thick areas have very high class and are in mountainous areas. It can be seen directly on the map image above in figure 3, the area that has a very high grade value is located in the mountain area right on Mount Bendahara. The mountains are upstream of the tributaries in Lawe Sigala-gala District. Approaching the lower reaches of the tributaries, the slope of the sub-watershed is almost close to medium. But on the sidelines between high-class locations, there is also a low grade slope. This is estimated to be flat and occupied by the people.

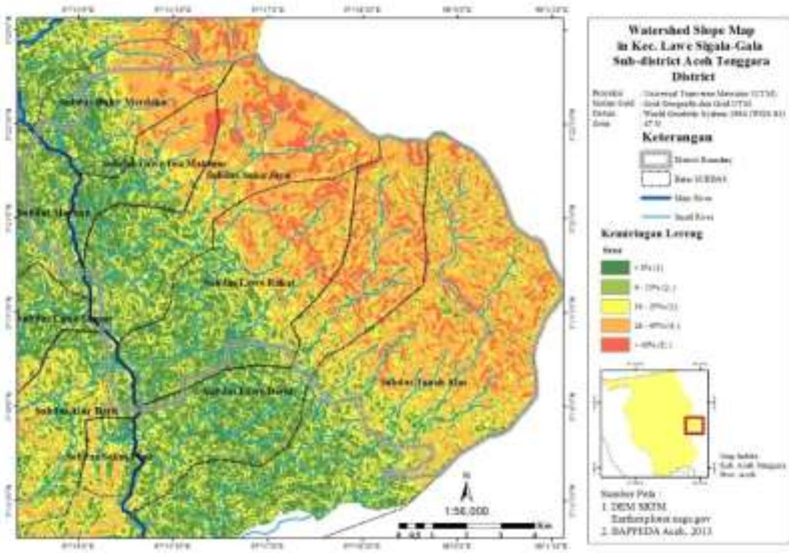

Figure 3. Land slope map in Lawe Sigala-gala District.

Type of soil

In general, the type of soil in this area is alluvial land carried by the main river yak River Lawe Alas. Alluvial soil is very easily carried away by water, this is because alluvial soils are soft. So that when flash floods occur, alluvial soil will be easily carried away by the flood.

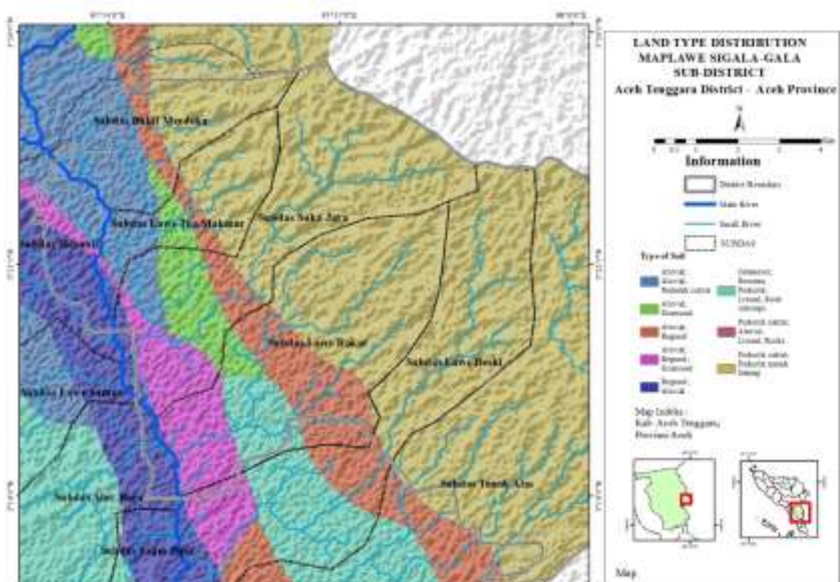

Figure 4. Map of soil types in Lawe Sigala-gala district.

Land Use

Land use or land cover is natural land but has been managed by humans. Errors in land use management can lead to greater risk of flash floods. For example the existence of community settlements that are very close to the river will increase the risk of flash floods compared to settlements that are not on the edge of the river. In addition, settlements located on steep slopes such as in the Lawe Sigala-gala District can also increase the risk of flash floods. This is because the sudden rate of water will get faster on steep or high slopes. The figure below will show the current distribution of land cover in Lawe Sigala-gala District.

The land use map shows that land for rice fields and forests dominate in this area. Almost all of the area covered by rice fields with settlements is only around the main road indicated by red following the main road. Furthermore, for forest areas, no settlement was found. So that for Lawe Sigala-gala District it can be included in the flash floods risk category towards high if seen from the distribution of land cover.

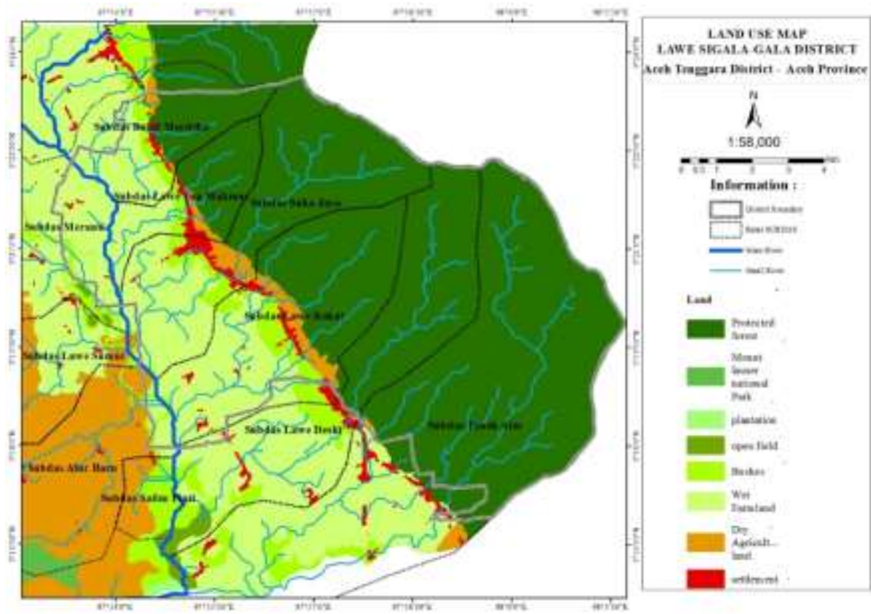

Figure 5. Map of land use in Lawe Sigala-gala District.

The threat score for flash floods in Lawe Sigala-gala District is based on the parameters of flash floods threats that have been triggered by Paimin, 2010. Scores or classifications are divided into 5 magnitudes expressed in low, rather low, medium, rather high, and high. Where the low category indicates not vulnerable and the high category shows that it is very vulnerable to the components seen. Furthermore, each parameter that has been given a category will be weighted based on consideration of the research location environment.

The highest parameter weight is the parameter for rainfall which reaches 25% of the total. Then followed by the parameters of the shape of the watershed, the density of the river, the slope of the watershed, the type of land, and land use in the sub-district.

The results of the calculation of flash floods threats are then given a score based on the assumption of threats in a sub-watershed. The highest threat of flash floods is 4.6 units, while for the lowest flash floods threat value is 1 unit projected into the flash floods threat map below in figure 6:

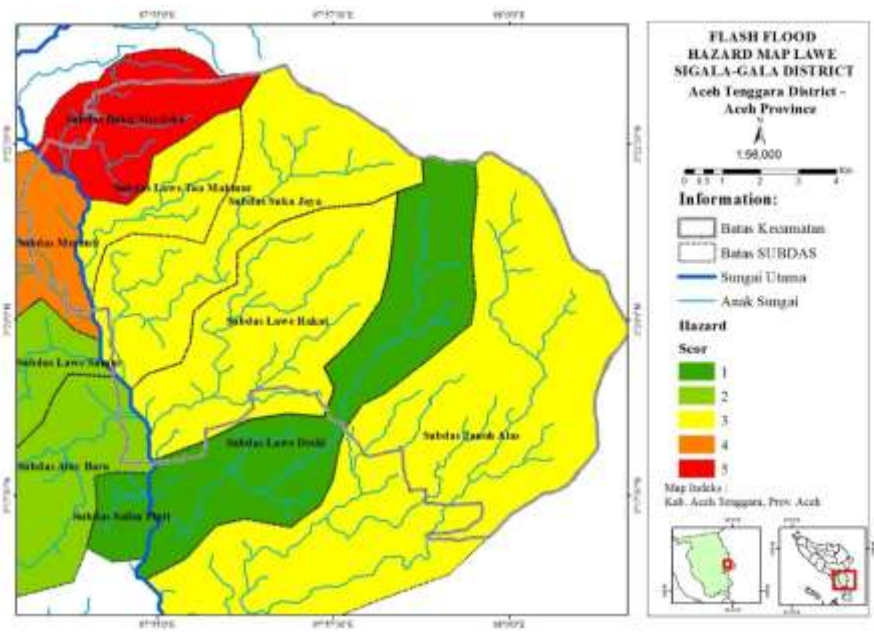

Figure 6. Map of the threat of flash floods in Lawe Sigala-gala District

Lawe Sigala-gala Subdistrict is located in a flash floods area with moderate scores such as the Lawe Tua Makmur sub-watershed, Suka Jaya sub-watershed, and Lawe Rakat sub-watershed. There is one Sub-watershed that has the highest score namely Bukit Merdeka Sub-District. This is strongly influenced by the threat factors of flash floods which become a threat parameter. Except for scattered rainfall factors with the same value in each sub-watershed. Furthermore, the upper reaches of the rivers in the Lawe Sigala-gala District are generally located in the Treasurer Mountains which flow directly to the Alas River.

Bukit Merdeka sub-watershed has the highest threat score. The influencing factor is moderate river density, most of the watershed area is in areas with slopes above 25%, soil types (alluvial, brown podsolic and grumusol), and land use in forests, settlements and plantations. Sub-watersheds which have scores are being influenced by various threat factors, including the form of watersheds, river density in moderate scores, slope of watersheds, soil types (mainly Alluvial constituents), and land use dominated by rice fields and plantations.

Conclusion

The Lawe Sigala-gala District consists of 6 Sub-watersheds, consisting of 3 flash floods threat classes namely low class (score 1) which includes Lawe Deski District, medium class (score 3) which includes Lawe Tua Makmur Sub-watershed, Suka Jaya sub-watershed, Lawe Rakat sub-watershed and Tanoh Alas sub-watershed, and high class (score 5) which includes Bukit Merdeka sub-watershed. Furthermore, in this research there are no district caried by score 2 and score 4.

Flash flood events that can come suddenly such as Kejadi in 2017 are very important for disaster management activities and flood disaster mitigation measures must be improved. Structural mitigation in the form of embankments and flood control buildings in the river that have the potential for flash floods needs to be done, while non-structural mitigation in the form of planning and spatial planning needs to be adjusted to disaster risk needs to be done so that disaster risk can be reduced.

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