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GIS-based Flood Susceptibility Mapping in Central Sulawesi

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Abstract. Central Sulawesi is the largest province on the Sulawesi island with a dominant sloping topographic condition. It has a variety of soil types, flow density, land use, and rainfall that makes this region vulnerable to flooding. Flooding is a hydrometeorological disaster that will adversely affect aspects of human life such as social and economic activities in an area because it can cause environmental damage, casualties, and disrupt economic activity. Because of its enormous impact, the purpose of this research study is to find out areas in the province of Central Sulawesi that are susceptible to flooding. The method used in this research study is scoring the classification of flood hazard parameters such as slope level, elevation, soil type, rainfall, land use, and low density which then overlay all the parameters. The results are obtained that the province of Central Sulawesi has three categories of areas susceptible to flooding with a low category 6630.3 km^2, moderate 46081.9 km^2, and high category 7104.7 km^2. Based on the results and discussion, it can be concluded that Central Sulawesi province has a moderate dominant level of vulnerability.

Keywords: Flood Susceptibility, Central Sulawesi, Mapping, Scoring.

1. Introduction

Flooding is a type of hydrometeorology disaster that occurs due to water volume that drastically increases to exceed the capacity of a channel or water flow (Adi, 2013; Harini *et al.*, 2017). In general, the impact of flood disasters is categorized between direct and indirect impacts. The impact experienced is also different depending on the population in the region of flooding events such as in urban areas and rural areas. The direct impacts caused by floods that hit an area are the destruction of people's homes, loss of property swept away by the flow of water, injuries and even the loss of lives. Meanwhile, the indirect impacts caused by floods are decreasing community income due to stalled work and also the emergence of disease sources due to decreased sanitation quality (Rosyidie, 2013).

After knowing the consequences caused by floods, the factors leading to floods in an area are also explained. There are several important factors causing floods, including the inadequacy of watershed retention, misplaced planning in determining river flow, river siltation, spatial planning, and the most important factor of course is the intensity of extreme rainfall (Maryono & Prajarto, 2005). The occurrence of flooding is also supported by the management system of water resources that is not good in especially urban areas. It makes so that the ability of drainage and flood control to be not smooth on the surface runoff so that flooding occurs (Nugroho, 2002). Flood susceptibility is a condition where an area is subject to flood, based on meteorological factors such as extreme rainfall intensity and regional arrangement factors on river basin characteristics including slope, soil types, land use, and elevation (Arifin & Kasim, 2012; Indawati, 2015).

Central Sulawesi Province with a wide enough area has never been spared from the devastating flood. Some areas in Central

Sulawesi Province also have geographical conditions with flat and gentle reliefs so that it is very possible for floods to occur, especially when extreme conditions occur in the form of high rainfall intensity. In early December 2019 there was a flash flood that hit Sigi Regency, resulting in considerable casualties and material losses (CNN, 2019). According to media reports Liputan 6, the flood disaster that hit Buol was caused by extreme weather and thus severed the connecting bridge between Central Sulawesi and Gorontalo. Therefore, by looking at the quite high risk of flood disaster in Central Sulawesi Province, a map of flood susceptibility areas (Marfai, 2004) need to be provided. Furthermore, an analysis of which areas in Central Sulawesi Province are vulnerable to potential flooding events are also needed. They are so that stakeholders, in this case the government and related institutions, can issue policies to anticipate the potential for flooding especially in areas that are considered vulnerable.

2. Research Method

The research location is in the province of Central Sulawesi which is the largest province on Sulawesi Island. In Figure 1, it shows that there are 116 rain gauge from Indonesian Agency for Meteorology, Climatology and Geophysics (BMKG) spread across 13 all districts/cities in Central Sulawesi. In this research, rainfall data was obtained from the rain gauge. This study uses several data processing applications consisting of ArcMap 10.2.2 Software, Libre Office, and Microsoft Excel. The data used in this study can be seen in Table 1.

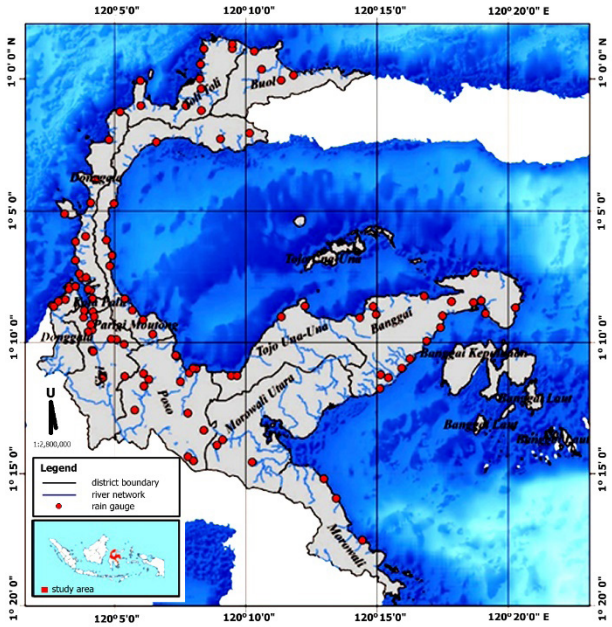

Figure 1. The study area and rain gauge (red points) in Central Sulawesi.

Table 1. Datasets of study.

No	Data	Year	Source
1	Slope	2020	Aster Digital Elevation Model (DEM)
2	Elevation	2020	Aster Digital Elevation Model (DEM)
3	Soil Type	2020	Harmonized World Soil Database (HWSD)
4	Rainfall	1981-2020	BMKG
5	Land Use	2020	*Kementrian Lingkungan Hidup dan Kehutanan* (KLHK)
6	Flood Events	2012-2018	*Badan Nasional Penanggulangan Bencana* (BNPB)
7	Indonesia Shapefile	2020	*Badan Informasi Geospasial* (BIG)

Flood susceptibility in this study uses six parameters that will be overlaid to determine the flood hazard area in Central Sulawesi (Table 2). Each parameter has classes based on predetermined categories and then each parameter will then be bought weight based on its contribution to the occurrence of flooding. The slope is divided into five classes consisting of flat, sloping, slightly steep, steep, and very steep. The possibility of flooding decreases with increasing slope of an area (Rahmati *et al*., 2016), therefore flat areas will be more vulnerable to flooding. Furthermore, the parameter that influences the occurrence of a flood is the elevation. The elevation is a measure of the height of the location to sea level. Elevation has an important role in determining flood susceptibility in an area, areas that have low and flat elevation are very vulnerable to flooding (Haghizadeh *et al*., 2017). Soil type has an important role in determining flood susceptibility areas. Soil type influences the drainage process because each type of soil has different infiltration (Mojaddadi *et al*., 2017). The greater the soil infiltration, the smaller the level of flood hazard. In determining the flood hazard in an area, the rainfall factor is very important because the high intensity of rainfall will have the potential for flooding (Mukherjee & Singh, 2019). Rainfall data was obtained from 116 rain stations scattered in Central Sulawesi Province. Changes in land cover will affect the infiltration process. Areas that are not planted with vegetation will be more vulnerable to flooding compared to areas with a lot of vegetation because the infiltration rate of areas with a lot of vegetation is faster. Land that is heavily planted with vegetation will also slow the rate of runoff to reach the river so that the possibility of flooding is smaller (Zope *et al*., 2017). Drainage density is an index that shows the number of tributaries in a watershed, expressed in a comparison between the length of a river and the total area of a watershed. The higher the density indicates the better the drainage system (Matondang *et al*., 2013) (Table 7).

Table 2. The parameter used to define the flood susceptibility.

No	Parameter	Characteristic	Category/Description	Score	Weight
1	Slope (%)	0 – 8	Flat	5	20
		8 – 15	Sloping	4	
		15 – 25	Slightly Steep	3	
		25 – 45	Steep	2	
		>45	Very Steep	1	
2	Elevation (m)	< 10	very low altitude	5	10
		10 – 50	low altitude	4	
		50 – 100	moderate altitude	3	
		100 – 200	high altitude	2	
		>200	very high altitude	1	
3	Soil Type	Alluvial, Planosol, Hidromorf	no infiltration	5	20
		Latosol	very low infiltration rate	4	
		Timberland, Mediterranean	low ilfiltration rate	3	
		Andosol, Lateritic, Grumosol, Podzol	moderate infiltration rate	2	
		Regosol, Lithosol, Organosol, Renzina	high infiltration rate	1	

No	Parameter	Characteristic	Category/Description	Score	Weight
4	Rainfall (mm/year)	>2500	Very wet	5	15
		2000 – 2500	Wet	4	
		1500 – 2000	Wet enough	3	
		1000 – 1500	Dry	2	
		<1000	Very dry	1	
5	Landuse	Residential	Very high suceptibility to flooding	5	15
		Rice fields/Agriculture Land	high suceptibility to flooding	4	
		Field/Farm	moderate suceptibility to flooding	3	
		Shrubs	low suceptibility to flooding	2	
		Forest	very low suceptibility to flooding	1	
6	Drainage Density (km/km^2)	<0.62	very low density	5	10
		0.62 – 1.44	low density	4	
		1.45 – 2.27	moderate density	3	
		2.28 – 3.1	high density	2	
		>3.1	very high density	1	

Source: Haryani *et al*., (2012) with modification; Darmawan & Suprayogi, (2017) with modification; Solahuddin, (2014); Matondang *et al*., (2013) with modification.

Furthermore, each parameter is given a weight, weighting for each thematic map is based on consideration of how much influence each parameter is used in the process of flooding (Darmawan & Suprayogi, 2017). The assignment of values for each class of parameters is the same, from one to five, while the weights depend on how much influence these parameters have in the process of flooding (Matondang *et al*., 2013).

Especially for rainfall data, the average annual rainfall is calculated with the formula given in Equation 1. Whereas CH is average annual rainfall, N expresses the number of years, n is the number of days in year t, and is the total daily rainfall. After the average annual rainfall is obtained, interpolation is done using the Inverse Distance Weightage (IDW) method to obtain the spatial pattern of rainfall in Central Sulawesi Province. The IDW formulas are given as Equation 2 and 3. Where means the unknown rainfall data (mm); means the known rainfall data from rain gauge (mm); N means the amount of rain gauge; means the weighting of each rain gauge; means the distance from each rain gauge to the unknown site; means the power, and is also a control parameter.

$$\bar{X}\ CH = \frac{1}{N}\sum_{t=1}^{N}\sum_{i=1}^{n} X_i \quad (1)$$

$$\hat{R}_p = \sum_{i=1}^{N} w_i R_i \quad (2)$$

$$w_i = \frac{d_i^{-\alpha}}{\sum_{i=1}^{N} d_i^{-\alpha}} \quad (3)$$

The scoring method for each parameter class is based on predetermined criteria. After scoring is carried out, weighting method is used because each parameter has a different role to determine the vulnerability in an area. Susceptibility score is obtained from the multiplication of the parameter value to the weight value. Based on the cumulative score

obtained, potential flood susceptibility areas are divided into three classes as shown in Table 3.

Table 3. Flood susceptibility classification.

No	Flood Susceptibility	Score
1	Low	<210
2	Moderate	210-330
3	High	>330

Source: Darmawan & Suprayogi, (2017), with modification.

3. Results and Discussion

3.1 Flood Susceptibility Analysis

The slope map of Central Sulawesi province is shown in Figure 2a. It can be seen that the map is dominated by the sloping category with an area of 28267.83 km^2, followed by a flat category with an area of 20294.56 km^2 (Table 4). The slope of the flat slope to the slope will affect the puddle in the event of extreme rain and the flat to the sloping area is also commonly found in daily activities of residents in an area (Handoyo *et al.*, 2016; Riyanto *et al.*, 2019). Areas with very steep categories have the smallest area of 26.63 km^2. Steep slopes are rarely flooded but there are landslides because it will accelerate soil movement (Mala *et al.*, 2017). In Figure 2a, the flat to the sloping category is found near the shoreline and the steep category is found in mountainous areas. The area between Poso and Morowali has a dominant sloping category that needs to be analyzed further to determine the susceptibility in the area.

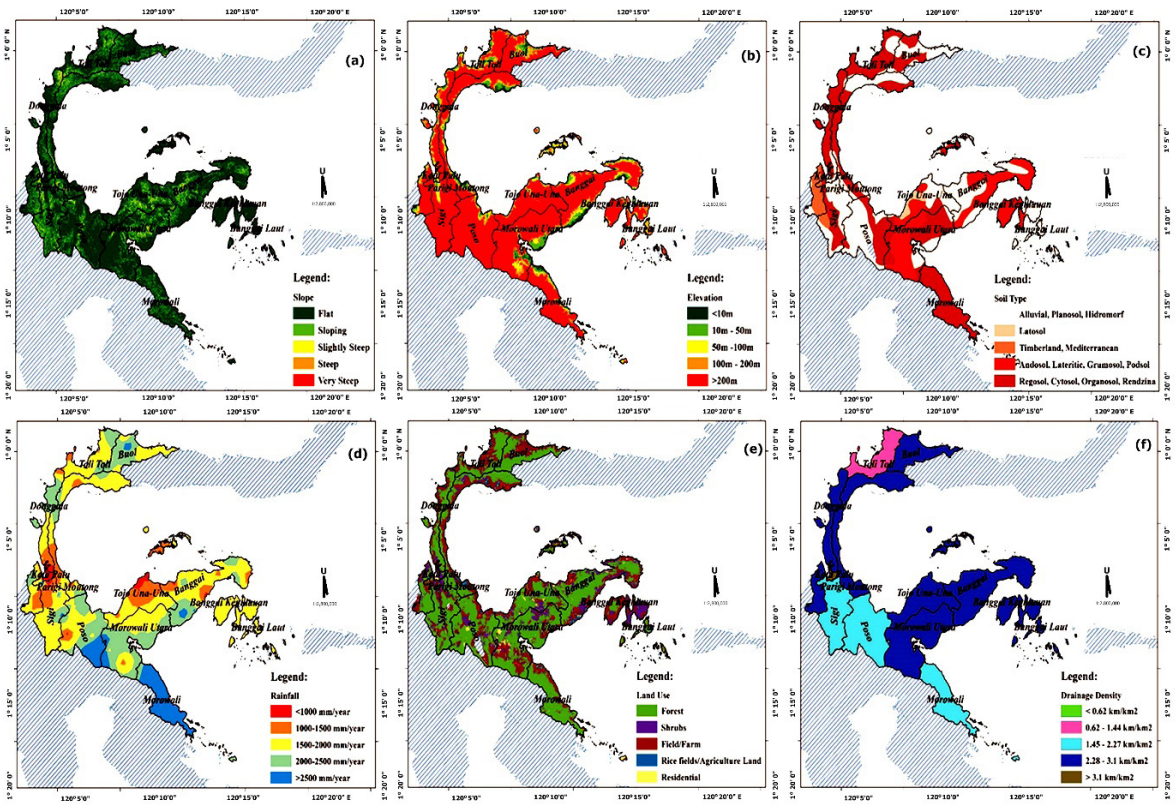

Figure 2. Flood susceptibility parameter map. (a) slope map, (b) elevation map, (c) soil types map, (d) land use map, (e) drainage density map, and (f) rainfall map.

Table 4. Slope area.

No	Category	Area (km^2)
1	Flat	20294.56
2	Sloping	28267.83

No	Category	Area (km²)
3	Slightly Steep	9999.01
4	Steep	488.58
5	Very Steep	26.63

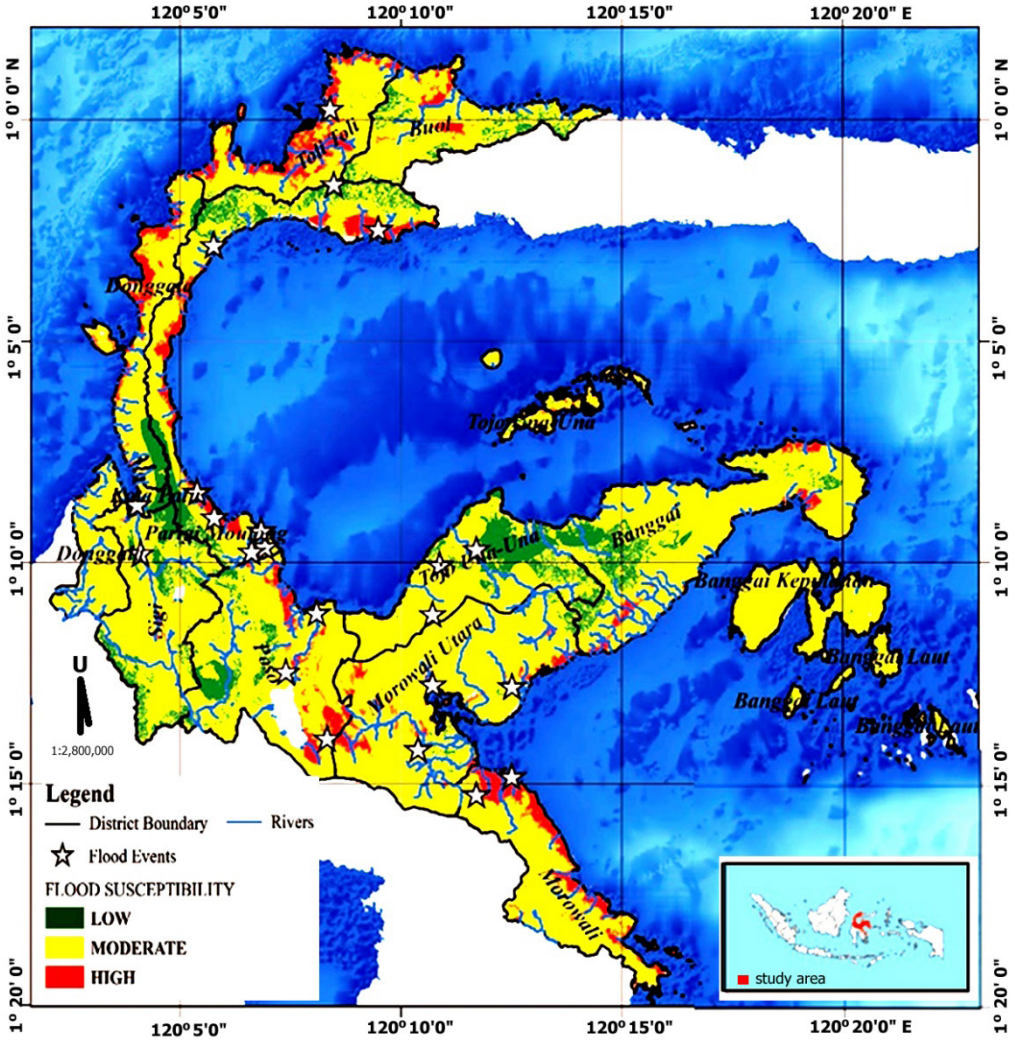

Figure 3. Flood Susceptibility map in Central Sulawesi.

In Figure 2b it shows that all coastal areas in Central Sulawesi have elevations of less than 10 meters above sea level. In the middle of Central Sulawesi, the height is increasing because the area is hilly or mountainous. Central Sulawesi in general has a height above 200 meters, meaning that the Central Sulawesi region has mountainous topography. An area with a height of fewer than 10 meters consisting of the Palu city and all the coastline in each regency of Central Sulawesi will have the potential to cause flooding due to the nature of the water that flows from high to low places (Arief *et al.*, 2019).

In Figure 2c, Poso has the most Alluvial, Planosol, and Hidromorf soils among other districts in Central Sulawesi. This soil types have the potential for flooding because they are difficult to absorb water (Rahmati *et al.*, 2016). Most of the Banggai, Sigi, Tojo Una-Una, and Buol areas must also be on the alert because there are Alluvial, Planosol, and Hidromorf soil types. The Morowali and Donggala areas have regosol, cytosol, organosol, and rendzina

soils which are types of soil that are very easy to absorb water so that water will not easily stagnate.

Rainfall is one of the factors in the occurrence of floods in each region. The amount of rainfall that is more than average is usually a trigger for flooding (Shafapour Tehrany *et al*., 2017). In Figure 2d we can see the Morowali area and part of Poso which have a very wet category of rainfall of more than 2500 mm/ year. Areas with very wet rainfall categories should be wary of because they can cause flooding. Palu City and parts of Tojo Una-Una have a very dry rainfall intensity so that they can reduce the risk of flooding in the area.

Central Sulawesi is still abundant in forests and shrubs. Farm, rice fields, and residential are dominant especially in coastal areas (Figure 2e). The highest score is found in areas with residential types where residential areas generally have waterproof surfaces which can cause an increase in rainwater runoff (Al-Zahrani *et al*., 2017). Residential land, rice fields, and fields need special attention because the number of people in the area is higher than the type of forest land and shrubs. Based on Figure 2f, Palu has the largest river density value that is greater than 3.1 km/km^2 meaning that Palu has less potential for flooding. The smallest density value is found in the Toli-Toli area, so this district has the potential to cause flooding. According to research (Utama *et al*., 2016), rivers with densities of more than 2.74 km/km^2 generally often experience drought. Rivers with densities of 0.73 - 2.74 km/km^{2}generally have good drainage or rarely experience flooding. While rivers with densities less than 0.73 km/ km^2 generally have poor drainage or frequent flooding.

The weighted overlay results in Figure 3 show that the level of flood hazard in the Central Sulawesi Province is predominantly in the quite moderate category, but the area with the high category is found more in Toli-Toli Regency. Moderate categories occur in almost every district and city. The districts of Morowali, Poso, North Morowali, Donggala, Toli-Toli, and Buol are predominantly in the moderate category of flood susceptibility levels. Areas with a low category are in Palu City, Tojo Una-Una Regency, and Parigi Moutong Regency.

Table 5. Flood susceptibility area of each city/regency.

City/Regency	Area (km^2)			
	Low (%)	Moderate (%)	High (%)	Total
Banggai	1307.18 (15.59)	6641.45 (79.19)	437.94 (5.22)	8386.57
Banggai Kepulauan	9.90 (0.42)	2348.95 (99.44)	3.35 (0.14)	2362.20
Banggai Laut	18.88 (3.52)	517.59 (96.48)	0.00 (0)	536.47
Buol	581.26 (15.12)	2944.71 (76.61)	317.74 (8.27)	3843.71
Donggala	368.55 (7.48)	3851.50 (78.21)	704.28 (14.30)	4924.34
Morowali	0.00 (0)	3237.45 (74.15)	1128.82 (25.85)	4366.27
Morowali Utara	153.56 (1.83)	8032.36 (95.78)	725.94 (8.66)	8911.86
Parigi Moutong	1302.15 (22.33)	3448.75 (59.14)	1080.58 (18.53)	5831.48
Poso	789.70 (11.35)	5372.98 (77.22)	795.76 (11.44)	6958.44
Sigi	1086.47 (20.70)	4097.25 (78.08)	63.79 (1.22)	5247.51
Tojo Una-Una	1314.38 (23.94)	4110.63 (74.88)	64.81 (1.18)	5489.82
Toli Toli	43.46 (1.21)	2236.88 (62.50)	1298.50 (36.28)	3578.83
Palu	129.19 (34.05)	241.37 (62.62)	8.81 (2.32)	379.37
Total	7104.7 (11.88%)	46081.9 (77.04%)	6630.3 (11.08)	59816.9 (100%)

Flood susceptibility in Central Sulawesi is divided into three criteria, namely areas that are not vulnerable, are quite vulnerable, and are not vulnerable. Central Sulawesi Province has an area of low category level that is 7104.7 km^2. The moderate category has an area of 46081.9 km^2. While the area which has a high category level is 6630.3 km^2 (Table 5). The majority of Central Sulawesi regions are in the moderate categories so that residents and governments in Central Sulawesi need to be considerate about this. It can be seen in Table 5 that Morowali, Parigi Moutong, and Toli-Toli districts have a high percentage of high category, so there is the need for mitigation of flooding in this area. Palu City is the safest area for the flood because it has the highest low percentage category.

3.2 Discussion

Flood disasters in Central Sulawesi are affected by a variety of parameters. At each flood event in Central Sulawesi (Figure 3) the scores of each parameter vary resulting in varying hazard values. Flood events in Sulawesi on the map of vulnerability generally occur around the river, so the area around the river needs to be aware of. Flood events usually occur downstream, due to gravity which causes the flow of water to move from high elevation to lower elevation. However, flooding will be more severe if the ground level elevation is lower than the sea/river water level elevation so that the water cannot flow according to gravity so that the area becomes prone to flooding caused by rain or sea/river overflow (Tawil *et al*., 2019). The occurrence of floods in Central Sulawesi located in the coastal areas such as in Donggala and Parigi Moutong districts needs to be aware of especially with the existence of tidal floods caused by rising sea levels by storms. The height of the land in the sloping coastal area will affect the formation of tidal inundation. In addition, many residents are found in the coastal areas so there is the need for good urban/spatial planning to minimize the risk of the amount of damage and casualties (Handoyo *et al*., 2016). Floods in Central Sulawesi not only occur in coastal areas but also occur in areas that have elevations of more than 200 meters, for example, such as flood events in Poso and Morowali districts. Flooding events in this region are not so much affected by elevation but slope shape. In Figure 2a and Figure 2b it can be seen that Poso and Morowali districts have flat slopes with elevations of more than 200 meters.

Floods in areas that have low annual rainfall such as in Palu City and Tojo Una-Una Regency can be caused by high rainfall intensity or in areas that have higher elevations so that flash floods occur (Adi, 2013). The intensity of high rainfall upstream can cause flash floods in the downstream. The occurrence of floods in the Palu area can be caused by rapid land cover changes so that if there is a high rainfall intensity it will cause flooding because the land cover infiltration ability has decreased (Akhbar, 2019).

4. Conclusion

Based on the results of the analysis of this study, it can be concluded that the flood-prone locations in Central Sulawesi Province which includes 13 cities/districts are categorized as high flood susceptibility areas covering 7104.7 km^2, 46081.9 km^2 for the moderate category, and 6630.3 km^2 for the low category. Based on the total area of vulnerability categories in Central Sulawesi, it can be concluded that the area of Central Sulawesi is quite vulnerable to flooding so that there is a need for the local government attention to adapt and mitigate flooding. The location of floods in Central Sulawesi is mostly found at 0-8% slope. This is because the flat area will be easier to collect rainwater which causes flooding.

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References

Adi, S. (2013). Karakterisasi bencana banjir bandang di Indonesia. *Jurnal Sains Dan Teknologi Indonesia*, *15*(1).

Akhbar, R. K. (2019). Analisis Spasial Rawan Banjir Terhadap Dampak Lingkungan Kabupaten Sigi Provinsi Sulawesi Tengah. *Jurnal Warta Rimba*, *7*(4), 172–180.

Al-Zahrani, M., Al-Areeq, A., & Sharif, H. O. (2017). Estimating urban flooding potential near the outlet of an arid catchment in Saudi Arabia. *Geomatics, Natural Hazards and Risk*, *8*(2), 672–688.

Arief, S. M., Siburian, R. H., & Wahyudi, W. (2019). Tingkat Kerentanan Banjir Kota Sorong Papua Barat. *Median: Jurnal Ilmu Ilmu Eksakta*, *11*(2), 23–27.

Arifin, Y. I., & Kasim, M. (2012). Penentuan Zonasi Daerah Tingkat Kerawanan Banjir di Kota Gorontalo Propinsi Gorontalo untuk Mitigasi Bencana. *Sainstek*, *6*(06).

CNN. (2019). Banjir bandang kembali terjang sigi dua orang tewas, https://www.cnnindonesia.com/nasional/20191212203208-20-456511/banjir-bandang-kembali-terjang-sigi-dua-orang-tewas (21 March 2020).

Darmawan, K., & Suprayogi, A. (2017). Analisis Tingkat Kerawanan Banjir Di Kabupaten Sampang Menggunakan Metode Overlay Dengan Scoring Berbasis Sistem Informasi Geografis. *Jurnal Geodesi Undip*, *6*(1), 31–40.

Haghizadeh, A., Siahkamari, S., Haghiabi, A. H., & Rahmati, O. (2017). Forecasting flood-prone areas using Shannon's entropy model. *Journal of Earth System Science*, *126*(3), 39.

Handoyo, G., Suryoputro, A. A. D., & Subardjo, P. (2016). Genangan banjir rob di Kecamatan Semarang Utara. *Jurnal Kelautan Tropis*, *19*(1), 55–59.

Harini, R., Susilo, B., Sarastika, T., Supriyati, S., Satriagasa, M. C., & Ariani, R. D. (2017). The Survival Strategy of Households Affected by Tidal Floods: The Cases of Two Villages in the Pekalongan Coastal Area. *Forum Geografi*, *31*(1), 163–175.

Haryani, N. S., Zubaidah, A., Dirgahayu, D., Yulianto, H. F., & Pasaribu, J. (2012). Model Bahaya Banjir Menggunakan Data Penginderaan Jauh Di Kabupaten Sampang (Flood Hazard Model Using Remote Sensing Data In Sampang District). *Jurnal Penginderaan Jauh Dan Pengolahan Data Citra Digital*, *9*(1).

Indawati, L. (2015). *Analisis Tingkat Kerawanan Banjir Dan Persepsi Masyarakat Terhadap Upaya Pengurangan Dampak Banjir Di Kecamatan Baureno Kabupaten Bojonegoro (Implementasinya sebagai sumber belajar siswa kelas 7 SMPN 2 Baureno, pada Topik: Keadaan alam dan aktifitas pendu*. UNS (Sebelas Maret University).

Mala, B. K. S., Moniaga, I. L., & Karongkong, H. H. (2017). Perubahan Tutupan Lahan Terhadap Potensi Bahaya Longsor Dengan Pendekatan Sistem Informasi Geografis Di Kolonodale Kabupaten Morowali Utara. *Spasial*, *4*(3), 155–166.

Marfai, M. A. (2004). Flood Modelling of Banjir Kanal Barat (Integration of Hydrology Model and GIS). *Forum Geografi*, *17*(1).

Maryono, A., & Prajarto, N. (2005). *Menangani banjir, kekeringan, dan lingkungan*. Gadjah Mada University Press.

Matondang, J. P., Kahar, S., & Sasmito, B. (2013). Analisis Zonasi Daerah Rentan Banjir Dengan Pemanfaatan Sistem Informasi Geografis (Studi Kasus: Kota Kendal dan Sekitarnya). *Jurnal Geodesi Undip*, *2*(2).

Mojaddadi, H., Pradhan, B., Nampak, H., Ahmad, N., & Ghazali, A. H. B. (2017). Ensemble machine-learning-based geospatial approach for flood risk assessment using multi-sensor remote-sensing data and GIS. *Geomatics, Natural Hazards and Risk*, *8*(2), 1080–1102.

Mukherjee, F., & Singh, D. (2019). Detecting flood prone areas in Harris County: A GIS based analysis. *GeoJournal*, 1–17.

Nugroho, S. P. (2002). Evaluasi Dan Analisis Curah Hujan Sebagai Faktor Penyebab Bencana Banjir Jakarta. *Jurnal Sains & Teknologi Modifikasi Cuaca*, *3*(2), 91–97.

Rahmati, O., Pourghasemi, H. R., & Zeinivand, H. (2016). Flood susceptibility mapping using frequency ratio and weights-of-evidence models in the Golastan Province, Iran. *Geocarto International*, *31*(1), 42–70.

Riyanto, D., Wulandari, C., Darmawan, A., & Setiawan, A. (2019). Analisis Spasial Sebaran Kopi Codot menggunakan Sistem Informasi Geografis. *Paper Dipresentasikan Dalam Smeinar Nasional Biologi 4 Tahun 2019 Di Bandung Tanggal 25 April 2019*.

Rosyidie, A. (2013). Banjir: fakta dan dampaknya, serta pengaruh dari perubahan guna lahan. *Journal of Regional and City Planning*, *24*(3), 241–249.

Shafapour Tehrany, M., Shabani, F., Neamah Jebur, M., Hong, H., Chen, W., & Xie, X. (2017). GIS-based spatial prediction of flood prone areas using standalone frequency ratio, logistic regression, weight of evidence and their ensemble techniques. *Geomatics, Natural Hazards and Risk*, *8*(2), 1538–1561.

Solahuddin, M. (2014). SIG Untuk Memetakan Daerah Banjir Dengan Metode Skoring Dan Pembobotan (Studi Kasus Kabupaten Jepara). *Jepara: Udinus*.

Tawil, S., Sukiyah, E., Rosana, M. F., & Muslim, D. (2019). Peran Karakteristik Morfometri Daerah Aliran Sungai Buol Terhadap Banjir Di Wilayah Bukal, Tiloan, Momunu Dan Biau, Provinsi Sulawesi Tengah. *Bulletin of Scientific Contribution: Geology*, *17*(2), 143–152.

Utama, A. G., Wijaya, A. P., & Sukmono, A. (2016). Kajian Kerapatan Sungai Dan Indeks Penutupan Lahan Sungai Menggunakan Penginderaan Jauh (Studi Kasus: DAS Juana). *Jurnal Geodesi Undip*, *5*(1), 285–293.

Zope, P. E., Eldho, T. I., & Jothiprakash, V. (2017). Hydrological impacts of land use–land cover change and detention basins on urban flood hazard: a case study of Poisar River basin, Mumbai, India. *Natural Hazards*, *87*(3), 1267–1283.