Jurnal Sains dan Teknologi
Volume 12 Number 2, Tahun 2023, pp. 553-561
P-ISSN: 2303-3142 E-ISSN: 2548-8570
Open Access: https://doi.org/10.23887/jstundiksha.v12i2.52737

Flood Susceptibility Index Analysis using Overlay Method and GIS-based

Viviana Irmawati[1*], Ongko Cahyono[2], Mujiyo[3], Siti Maroah[4], Nanda Mei Istiqomah[5], Muhammad Rizky Romadhon[6]

[1,2,3,4,5,6] Departement of Soil Science, Universitas Sebelas Maret, Surakarta, Indonesia

ARTICLE INFO

Article history:
Received October 02, 2022
Revised October 11, 2022
Accepted June 13, 2023
Available online July 25, 2023

Kata Kunci:
Lahan Terdegradasi, Curah Hujan, Kesehatan Fisik Tanah

Keywords:
Degraded Land, Rainfall, Soil Physical Health

ABSTRAK

Curah hujan yang tinggi menyebabkan meluapnya sungai Wiroko sehingga menyebabkan banjir di Nguntoronadi. Penelitian ini bertujuan untuk menganalisis potensi banjir, memberikan evaluasi dan rekomendasi terhadap wilayah yang memiliki kerentanan banjir tinggi. Jenis penelitian yang digunakan adalah deskriptif kuantitatif dengan menggunakan metode overlay penilaian karakteristik lahan yang mempengaruhi kondisi lingkungan. Karakteristik lahan adalah curah hujan, ketinggian tempat, kemiringan lereng, jenis tanah dan penggunaan lahan. Karakteristik lahan dioverlay menggunakan aplikasi ArcGIS untuk menentukan peta indeks kerentanan banjir, dan data dianalisis menggunakan metode deskriptif. Hasilnya ditemukan tiga kategori indeks kerentanan banjir: rendah, sedang, dan tinggi. Hasil studi menunjukkan total wilayah rawan banjir adalah 6.566,52 ha, dimana 33,79% mempunyai kerentanan banjir tinggi. Potensi kerentanan banjir yang tinggi terdapat pada dataran rendah, curah hujan tinggi dan penggunaan lahan terbuka. Daerah yang mempunyai kerentanan banjir tinggi dapat dilakukan dengan memperbaiki aliran sungai, drainase dan pembuatan terasering pada persawahan. Kerentanan banjir yang tinggi disebabkan oleh curah hujan, dataran rendah dan rendahnya vegetasi serta tingginya populasi manusia.

ABSTRACT

High rainfall caused the overflow of the Wiroko river, causing flooding in Nguntoronadi. This study aims to analyze flood potential, provide evaluation and recommendations on areas that have high flood suscetibility. Type of research is quantitative descriptive by using the overlay method of scoring land characteristics that affect environmental conditions. Land characteristics are rainfall, altitude, slope, soil type and land use. The characteristics of the land are overlayed using the ArcGIS application to determine a map of flood susceptibility index, and the data were analyzed using descriptive methods. The result found three categories of flood susceptibility indexes: low, medium, and high. The study revealed a total area flood susceptibility of 6566.52 ha, with 33.79% having high flood susceptibility. The potential for high flood vulnerability is found in lowland, high rainfall and open land use. Areas which has a high flood susceptibility by improving river flow, drainage and terraces in rice fields. The high flood susceptibiity caused by rainfall, lowland and low vegetation as well as high human populations.

1. INTRODUCTION

Wonogiri Regency has an area of 182,236.02 hectares with hilly contours and is dominated by karst rocks. Karst in Wonogiri has several types of fracturing, namely closed fracturing and open fracturing. Closed fracturing has a low water absorption power while open fracturing has a high water absorption capacity due to the formation of holes that function to escape surface water into groundwater (Milanovic, 2002; Sun et al., 2018). Nguntoronadi District is one of the locations that have environmental conditions dominated by karst rocks and has a altitude of approximately 600 masl of 6660.24 hectares, 13% or 888.99 hectares of area are used as settlements (Azis et al., 2021; Tarkono et al., 2021). The environmental conditions of Nguntoronadi with slope contours, it should have a low potential for flood susceptibility index. However, in 2017, 2020 and 2021 several villages in Nguntoronadi always experienced floods caused by the runoff of the Wiroko river, resulting in the submergence of a number of residents' houses and the interruption of access to the highway. Flood disasters can be caused by low soil contours, high rainfall and close to river flows (Choubin et al., 2019; Vojtek & Vojteková, 2019). Flood disasters can cause damage to housing and infrastructure which can lead to a decline in the economy of an area for the improvement of

*Corresponding author.
E-mail addresses: vivianairmawati05@student.uns.ac.id (Viviana Irmawati)

housing and infrastructure. Flood disasters can also cause high mortality rates caused by landslides in areas that have steep slopes (Bubeck et al., 2017; Khosravi et al., 2016).

The high number of floods caused by extreme weather changes and human activity. Flooding is a disaster that harms many parties, both in terms of economic, social, environment and health (Hirabayashi et al., 2013; Sofia et al., 2017; Yu et al., 2022). From the above problems, it attracted the attention of researchers to map the potential for flooding in Nguntoronadi because of the lack of information about the potential floods in Nguntoronadi. Nguntoronadi is one of the districts included in Keduang Sub-Watershed. Keduang Sub-Watershed is the largest sub-watershed in Wonogiri and also has a high sedimentation rate. High sedimentation rates can cause downstream areas to easily experience flooding during the rainy season due to the low capacity of rivers and reservoirs (Kastolani & Mainaki, 2018; Liu et al., 2021).

Mapping flood potential in Nguntoronadi using spatial analysis with the ArcGis 10 application which aims to determine the flood vulnerability index in the study area. This mapping uses data from thematic maps of rainfall, altitude, slope, soil type and land use which is then carried out by overlaying or arranging several parameters that are factors of potential flood susceptibility (Choubin et al., 2019; Samanta et al., 2018; Tehrany et al., 2015). The mapping of the Nguntoronadi area aims to analyze a high flood susceptibility index in order to increase public awareness, to evaluated the causes of floods and provide information to the community, so that the community is able to prepare and mitigate flood disasters.

2. METHOD

This type of research is descriptive quantative research by collected secondary data in the Nguntoronadi area. Descriptive quantitative research aims to describe the characteristics of flood susceptibility index (Romadhon & Aziz, 2022). According to previous research on mapping flood susceptibility index has several stages, consisting of: a) initial survey, conducted to obtain preliminary studies on the research area, especially the environmental conditions of the research area, b) data collection is carried out by looking for information both through the internet and agencies that hold authority over the data needed in research, c) overlay, the collected parameters are then carried out the overlay method with the aim of obtaining a unit of land map which is then calculated score and weighting, d) scoring and weighting, the results of the overlay are then scoring and weighting to find the total score of potential flood susceptibility and d) intervals, intervals are given to make it easier to classify from low, medium and high flood potentials (Tarkono et al., 2021).

This study used secondary data in the form of thematic maps of rainfall, elevation, slope, soil type and land use. Rainfall is a major factor that can cause flooding in various areas. The high rainfall in an area can increase the flood susceptibility index, so that in scoring in areas that have high rainfall, a high score will be given. Scoring on precipitation is presented in Table 1.

Table 1. Rainfall scoring of Flood Susceptibility Parameters

Map Parameters	Classification	Category	Score
Rainfall (mm/year)	>2500 mm	Very Wet	9
	2001 – 2500 mm	Wet	7
	1501 – 2000 mm	Medium	5
	1000 – 1500 mm	Dry	3
	<1000 mm	Very Dry	1

Elevation is one of the factors that can affect the flooded area. Areas that have a low altitude can increase the potential for high flooding because water flows from high places to low places. Thus, the higher the research area, the lower the score given. The height score of the place is presented in Table 2.

Table 2. Elevation scoring of Flood Susceptibility Parameters

Map Parameters	Classification	Category	Score
Elevation	0 – 150 masl	Low	7
	151 – 250 masl	Medium	5
	251 – 350 masl	High	3
	351 – 600 masl	Very High	1

The slope is the same as the height of the place, where the lower the level of slope, the higher the flood susceptibility index. Areas that have a slope of 0 - 8% have a higher flood susceptibility index so that

the highest score is given, while on slopes >45% has the lowest score. The slope score of the slope is presented in Table 3.

Table 3. Slope Scoring of Flood Susceptibility Parameters

Map Parameters	Classification	Category	Score
Slope	0 – 8%	Flat	9
	8 – 15%	Sloping	7
	15 – 25%	Rather steep	5
	25 – 40%	Steep	3
	>40%	Very steep	1

Soil types is a factor that can cause flooding because different soil types can cause pores in different soils, thus affecting the infiltration rate. Soil types that have a high clay content such as vertisol have a high score compared to sand soils such as entisol. The soil type score is presented in Table 4.

Table 4. Soil Types Scoring of Flood Susceptibility Parameters

Map Parameters	Classification	Category	Score
Soil Types	Vertisol, Oxisol	No Infiltration	9
	Alfisol, Ultisol, Molisol	Very Low	7
	Inceptisol	Low	5
	Entisol, Histosol	Medium	3
	Spodosol, Andisol	High	1

Land use can affect the rate of water infiltration so that it can affect the potential for flood insecurity. Areas that have land use with many trees have a greater infiltration rate compared to areas that have land use as settlements. Areas dominated by open land, water bodies and ponds have a high flood susceptibility index with a score of 9 (Kusumo & Nursari, 2016). The land use score is presented in Table 5.

Table 5. Land use Scoring of Flood Susceptibility Parameters

Map Parameters	Classification	Category	Score
Land Use	Open Ground, Water Bodies, Ponds	Very High	9
	Settlements, Paddy Fields	High	7
	Plantations, Moor	Medium	5
	Mixed Garden, Shrubs	Low	3
	Forest	Very Low	1

Secondary data that are parameters of flood susceptibility index are obtained from the internet and from relevant agencies. Data sources and how to obtain are presented in Table 6.

Table 6. Secondary Data Sources of Flood Susceptibility Research

No.	Map Parameters	Data Sources	Analysis
1	Rainfall (mm/year)	BBWS Bengawan Solo	Excel to Table -> Thiessen polygon -> Classification -> Scoring
2	Elevation	Digital Elevation National Model	3D Analysis : Classification -> Scoring
3	Slope	Digital Elevation National Model	3D Analys : Slope -> Classification -> Scoring
4	Soil Types		Geoprocessing Clip Kec. Nguntoronadi -> Classification -> Scoring
5	Land Use	Indonesia-geospasial.com	Geoprocessing Clip Kec. Nguntoronadi -> Classification -> Scoring
6	Nguntoronadi District	Indonesia-geospasial.com	Geoprocessing Clip Kec. Nguntoronadi

The collected secondary data is processed using the Arcgis 10.8 application with the overlay method. The overlay method is an analysis that uses an overlay technique or stacks several mapping parameters that affect susceptibility by using scoring or weighting techniques after the classification of each

map is known (Adlyansah et al., 2019). Scoring was carried out by referring to the research and adjustment of field conditions using five map parameters that is rainfall, altitude, slope, soil type and land use.

The analysis method used in this study is scoring on each parameter, weighting and then an overlay method to obtain a classification of potential flood susceptibility. Overlay is done by stacking rainfall data, soil type, slope slope, altitude of place and land use to obtain information from the merger of several thematic maps. Each parameter has an influence on the potential for flood insecurity so that weighting is carried out from parameters that have a very large influence to parameters that have a low influence on potential flood susceptibility (Aziza et al., 2021; Romadhon & Aziz, 2022). Land use parameters have a high level of weighting because the more open a land will result in high water runoff. Parameter weighting is presented in Table 7.

Tabel 7. Parameters Weighting of Flood Susceptibility Index

No.	Map Parameters	Weight (%)
1	Rainfall (mm/year)	15
2	Elevation (masl)	20
3	Slope	10
4	Soil Types	10
5	Land Use	25

The flood susceptibility score that has been obtained is then grouped by calculating the interval. This interval calculation aims to facilitate and divide into several classifications of flood susceptibility index. The classification of flood susceptibility index is useful for knowing areas that have low to high levels so that in map processing different colors are obtained according to classification. From the interval calculations that have been carried out, this research obtains three classifications of flood-prone areas as in Table 8.

Table 8. Classification of Flood Susceptibility Index

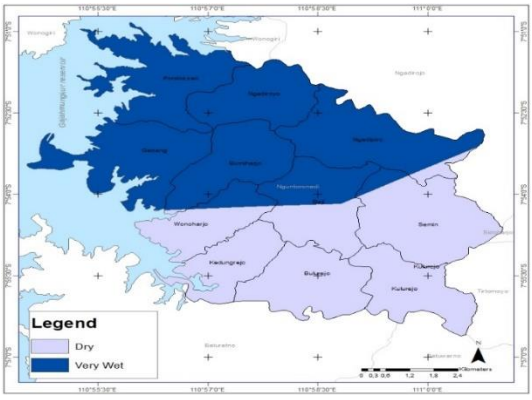
No.	Class Interval	Class Description
1	240 – 365	Low Vulnerable
2	370 – 495	Moderate Vulnerable
3	500 – 620	High Vulnerable

3. RESULT AND DISCUSSION

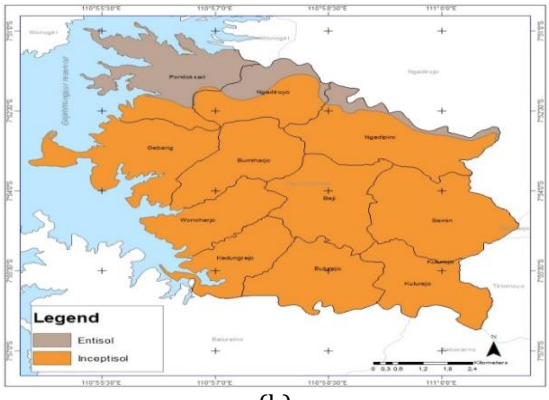
Result

Mapping Parameters of Flood Susceptibility Index

The results of the study were obtained from mapping each parameter, namely rainfall, altitude, slope, soil type and land use. This mapping aims to obtain information about parameters that are one of the factors of flood susceptibility index. Some of the mapping results of each parameter are presented in Figure 1.



(a)



(b)

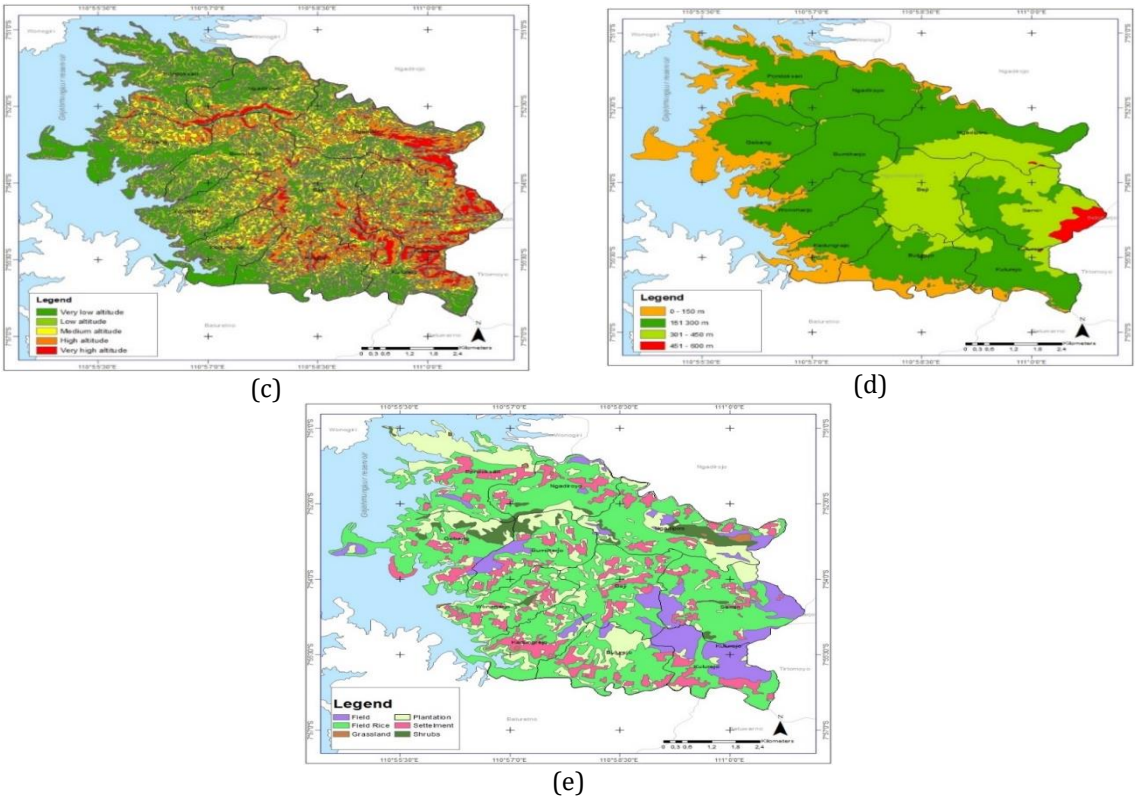


Figure 1. a. Rainfall Map, b. Soil Type Map, c. Slope Map, d. Altitude Map and d. Land Use Map

The results of this study found that the annual rainfall had the highest of 2832 mm/year in the northern and the lowest of 1368 mm/year in the southern of Nguntoronadi (Figure 1a). The soil type in this study has two types of soil, namely entisol and inceptisol (Figure 1b), but Nguntoronadi is dominated by inceptisol which has 87,5% while entisol is only 12.5% of the area of Nguntoronadi. Inceptisol soil types with high clay content can inhibit the infiltration rate, thus affecting flood susceptibility in the Nguntoronadi area. Nguntoronadi has five classifications of slopes, namely flat, sloping, rather steep, steep and very steep (Figure 1c). The steeper slope of a place, the stronger the water flow will be, so that in areas with low slopes the level of flood susceptibility is higher. Strengthened in the study areas that have a slope of 0-8% have a higher flood susceptibility score compared to areas with a slope of >45%. A result of this study shows that a flat with an altitude of <300 masl has a high flood potential compared to areas that have an altitude of >500 masl. In this study, the area that has a flat slope classification of 1552.88 ha, sloping with an area of 1637.83 ha, rather steep with an area of 1731.93 ha, steep with an area of 1251.28 ha and very steep has an area of 425.40 ha. The Nguntoronadi District, which is dominated by flat slopes, is found in the north, west and south, while areas with very steep are found in the middle areas to the east with an altitude of more than 300 masl. The height of the place in this study was divided into four classifications, namely 0-150 masl, 151- 300 masl, 301- 450 masl and 451 - 600 masl (Figure 1d). The height of a place with a low classification of <300 masl has a high level of flood susceptibility supported by areas close to rivers. The results of the land use classification in Nguntoronadi obtained six land uses, namely pastures, plantations/gardens, settlements and places of activity, paddy fields, shrubs and moorings or fields (Figure 1e). The widest land use is paddy fields with an area of 6579.63 hectares, plantations/gardens with an area of 5553.15 hectares, moorings of 2841.66 hectares, shrubs of 889.74 hectares, settlements and places of activity of 888.99 hectares and 103.36 hectares of grasslands. Land use is very important to assess the flood susceptibility index because land use is related to water absorption power. Land use dominated by settlements and places of activity has a high flood susceptibility index. Land use in Nguntoronadi is dominated by paddy fields, the use of paddy fields is very vulnerable to flooding, especially in lowland areas because in paddy fields there is less vegetation and in general paddy fields are processed by flooding so that this reduces water absorption during the rainy season.

Flood Susceptibility Index

Mapping of flood susceptibility index using the overlay method from the parameters above which aims to obtain information about the potential class of flood susceptibility in Nguntoronasi. The potential

for low flood susceptibility is found in the middle to the southeast of the Nguntoronadi District which has a dry annual rainfall of 1500 mm/year is show in Figure 2.

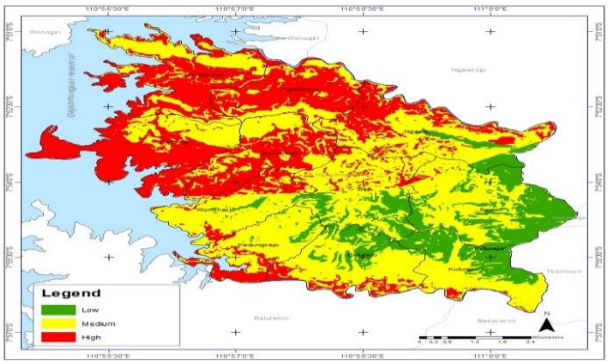


Figure 2. Flood Susceptibility Map

Base on Figure 2 show the results of the map overlay show that the Nguntoronadi area has a potential flood susceptibility of 6566.52 ha which is divided into three levels, namely low, medium and high levels. Areas with high flood susceptibility potential have an area of 2219.12 ha / 33.79% of the total area located near the Northern and Southern river flows. The level of flood susceptibility with a moderate classification has an area of 3355.14 ha / 51.09% of the entire Nguntoronadi area. Areas with moderate flooding have sloping to steep slopes, with altitudes ranging from 300 - 450 masl. The potential level of low flood vulnrtability has an area of 992.26 ha / 15.11% of the area of Nguntoronadi. Land use in areas that have low flood susceptibility potential is paddy fields, settlements / and places of activity as well as plantations/gardens dominated by inceptisol soil types. Classification of Nguntoronadi flood susceptibility is show in Table 9.

Table 9. Classification of Nguntoronadi flood susceptibility

Flood Susceptibility	Area (ha)	Percentage (%)
Low Vulnerable	992.26 ha	15.11 %
Moderate Vulnerable	3355.14 ha	51.09 %
High Vulnerable	2219.12 ha	33.79 %

Discussion

Flood Parameter Assessment

The potential flood susceptibility in this study used rainfall data, soil type, land use, altitude and slope. The first factor that affects is rainfall, rainfall of more than 2500 mm/year has a high-class classification, this can cause some areas of Nguntoronadi to occur flooding. Flooding in Nguntoronadi can be affected by a lack of water infiltration and shallow river conditions and poor management (Sholihah et al., 2020; Suprayogo et al., 2020). According to previous study showed in months that have high rain intensity, namely December, January and February, the average flooding increased by 7.26% (Tabari, 2020). Very high rainfall is influenced by extreme weather changes so it can increase the potential for flooding of an area, supported by conditions of flat areas and soils that have a small water absorption capacity (Sofia et al., 2017; Tarkono et al., 2021).

The type of soil that has low water absorption is that it has a high clay content. In this study, soil types are dominated by inceptisol, the characteristics of a developing soil having a depth of 40-50 cm from the surface of mineral soil. Some areas with inceptisol soils have a high level of flood susceptibility, this can be influenced by the type of material that forms inceptisol soils derived from mineral clay so that water absorption is less than optimal (Dalimunthe et al., 2019; Haghizadeh et al., 2017; Suprayogo et al., 2020). Study in the previous study state soils with clay content and soil management have an infiltration rate of 1.6 cm/hour while soils dominated by sand have an infiltration rate of 8.53 cm/hour, this is influenced by soil dominated by sand has macro pores so that water easily escapes (Dagadu & Nimbalkar, 2012). Java island has several types of soil that also have different infiltration rates. The infiltration rate is influenced by soil physical properties such as texture, structure, organic matter and type of land use (Prakasa et al., 2021; Basri et al., 2022). Other study showed, the entisol soil type has a low water retention ability due to the sandy texture and is a soil that has a shallow depth (Hutauruk et al., 2020).

In addition to soil type, land use can affect the rate of infiltration, land that has diverse vegetation has a higher infiltration rate than land without vegetation or land used as settlements explained that water

infiltration is influenced by the amount of vegetation in land use such as forest has the greatest infiltration compared to other land uses, this is because the roots that penetrate the soil can form pores so that the soil becomes loose and makes it easier for water to enter the soil (Dalimunthe et al., 2019; Sofia et al., 2017; Zaharia et al., 2017). Research conducted by previous study explained that land use in the form of grasslands has a relatively low flood susceptibility index, this is because the grassroots can suppress water rates (Romadhon & Aziz, 2022). Other researchs massive land conversion causes changes in soil properties that are unable to absorb water runoff, this can lead to a decrease in water infiltration power that is normally able to store more than 300 m^3 ha^{-1} (Cazorzi et al., 2012; Rachmat & Pamungkas, 2014).

The next factors are the slope and elevation, the slopes and the elevation are one of the factors that can influence the high potential for flooding (Choudhury et al., 2022; Dung et al., 2020). The flat slope and the low height of the place can increase the potential for high flooding. In the study show areas with a slope of 0 - 8% with a flat category have a higher level of flooding compared to areas that have rather steep contours, this is because rainwater moves from high places to lower places (Hutauruk et al., 2020). In other research explained that, the flood that hit the city of Padang was caused by the altitude and the slope 0 – 50 masl which has a high level of flood susceptibility (Ikhvan & Mera, 2021).

Flood Susceptibility Index

The results of this study overlay obtained three classifications of flood susceptibility index, namely high potential, medium potential and low potential. The potential for high-level flooding is caused by flat slopes, low altitudes and high rainfall (Choudhury et al., 2022; Romadhon & Aziz, 2022). In the northern, the average annual rainfall reaches >2,500 mm / year . Land use in high flood potentials is dominated by paddy fields. Paddy fields have a high flood potential due to low land cover, paddy fields are also dominated by high clay content, resulting in a low infiltration rate due to conventional processing (Khosravi et al., 2016; Rachmat & Pamungkas, 2014). The western of Nguntoronadi has a high level of flood susceptibility because it is caused by being close to the water source, namely the Gajah Mungkur Reservoir. Research by previous study showed that the distance from water sources such as rivers, reservoirs, dams and others greatly affects the flood susceptibility index, the location distance of 0-250 m is stated to have very high flood susceptibility, the safest distance is more than 975 m from the water source (Adlyansah et al., 2019).

In this study, the potential for moderate-level flood susceptibility is in the middle of the Nguntoronadi area with an altitude of 350 - 450 masl, previous study declared a safe zone from flooding, namely with an altitude of >350 masl (Adlyansah et al., 2019). Land use in areas of medium potential is dominated by plantations. The plantation has a high water suction power, in the study explained that plantations have diverse vegetation, this can reduce the potential for flooding because the infiltration rate in the plantation area is relatively high (Dalimunthe et al., 2019). The other one showed, massive land conversion from plantations to densely populated areas can result in soil damage due to soil hardening and inhibit the rate of infiltration so as to increase the potential for flooding (Rachmat & Pamungkas, 2014).

Areas that have a very steep slope with an altitude of >450 masl in the study have a low flood susceptibility index. In areas with low potential of flood susceptibility, it has the use of paddy fields, settlements and places of activity and plantations. According to the research state areas with an altitude of >200 masl have a lower level of flood susceptibility compared to areas with a height of <10 masl such as in Palu City which is on the coast (Hutauruk et al., 2020). Areas that have a very high level in this study >450 masl will have a lower potential for flooding compared to areas that have an altitude of <150 masl because the movement of water always follows gravity from high areas to lower areas (Arief et al., 2019; Hutauruk et al., 2020).

The area has high potential flood susceptibility with low altitude and dominated paddy field could be recommendation to prevent flooded. The area with high potential of flood susceptibility could be water management with drainages, terraces in the paddy field, seattlement areas and improving hydrological networks to increase water capacity. Previous studies showed, to prevent high potential flooding by improving the drainage system and terraces, it also manages dams, deepens and expands shallow rivers (Hutauruk et al., 2020; Khosravi et al., 2016). Additionally, the land use could be changes with plantation or reforestation in near water sources because the plantation can be prevent flooded (Aziza et al., 2021; Khosravi et al., 2016).

4. CONCLUSION

The conclusion of the results of this study in the Nguntoronadi area has three classification flood susceptibility indexes, namely low, medium and high levels. Factors who have potensial high flood susceptibility in the Nguntoronadi area are caused by factors of high rainfall. The higher the rainfall will cause a high potential for flooding. The second factor is that areas that have lowlands, where the lower the

elevation maka will increase the high potential for flood susceptibility. The third factor is the use, the lower the vegetation of a land, feeding can increase the high potential for flood susceptibility due to low water infiltration. In addition, areas that have a high level of population density have a high potential for flood susceptibility index.

5. REFERENCES

Adlyansah, A. L., Husain, R. L., & Pachri, H. (2019). Analysis of Flood Hazard Zones Using Overlay Method with Figused-Based Scoring Based on Geographic Information Systems: Case Study in Parepare City South Sulawesi Province. *IOP Conference Series: Earth and Environmental Science*, *280*(1). https://doi.org/10.1088/1755-1315/280/1/012003.

Arief, S. M., Siburian, R. H. ., & Wahyudi. (2019). Tingkat Kerentanan Banjir Kota Sorong Papua Barat. *Median*, *11*(2), 23–27. https://doi.org/Doi http://doi.org/md.v11i2.456.

Azis, A. A. A., Mujiyo, & Cahyono, O. (2021). Mapping of soil degradation potential in Nguntoronadi District Wonogiri Regency. *IOP Conference Series: Earth and Environmental Science*, *905*(1). https://doi.org/10.1088/1755-1315/905/1/012085.

Aziza, S. N., Somantri, L., & Setiawan, I. (2021). Analisis pemetaan tingkat rawan banjir di Kecamatan Bontang Barat Kota Bontang berbasis sistem informasi geografis. *Jurnal Pendidikan Geografis Undiksha*, *9*(2), 109–120. https://doi.org/10.23887/jjpg.v9i2.35173.

Basri, H., Syakur, S., Azmeri, A., & Fatimah, E. (2022). Floods and their problems: Land uses and soil types perspectives. *IOP Conference Series: Earth and Environmental Science*, *951*(1). https://doi.org/10.1088/1755-1315/951/1/012111.

Bubeck, P., Otto, A., & Weichselgartner, J. (2017). Societal Impacts of Flood Hazards. *Oxford Research Encyclopedia of Natural Hazard Science*, *June*. https://doi.org/10.1093/acrefore/9780199389407.013.281.

Cazorzi, F., Fontana, G. D., Luca, A. De, Sofia, G., & Tarolli, P. (2012). Drainage network detection and assessment of network storage capacity in agrarian landscape. *Hydrological Processes*. https://doi.org/10.1002/hyp.9224 Drainage.

Choubin, B., Moradi, E., Golshan, M., Adamowski, J., Sajedi-Hosseini, F., & Mosavi, A. (2019). An ensemble prediction of flood susceptibility using multivariate discriminant analysis, classification and regression trees, and support vector machines. *Science of the Total Environment*, *651*, 2087–2096. https://doi.org/10.1016/j.scitotenv.2018.10.064.

Choudhury, S., Basak, A., Biswas, S., & Das, J. (2022). *Flash Flood Susceptibility Mapping Using GIS-Based AHP Method*. *April*, 119–142. https://doi.org/10.1007/978-3-030-94544-2_8.

Dagadu, J. S., & Nimbalkar, P. . (2012). Infiltration studies of different soil under different soil conditions and comparison of infiltration models with field data. *International Journal of Advanced Engineering Technology*, *3*(2), 154–157. https://www.researchgate.net/profile/Satyawan-Jagdale/publication/337858258.

Dalimunthe, M. ., Suyarto, R., & Diara, I. . (2019). Analisis Bentuklahan untuk Menentukan Zona Resapan Air di Lereng Selatan Kawasan Bedugul. *Jurnal Agroekoteknologi Tropika*, *8*(2), 171–181. https://ojs.unud.ac.id/index.php/JAT/article/download/51195/30327.

Dung, N. B., Minh, D. T., Ahmad, A., & Long, N. Q. (2020). The role of relative slope length in flood hazard mapping using ahp and gis (Case study: Lam river basin, Vietnam). *Geography, Environment, Sustainability*, *13*(2), 115–123. https://doi.org/10.24057/2071-9388-2020-48.

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). https://doi.org/10.1007/s12040-017-0819-x.

Hirabayashi, Y., Mahendran, R., Koirala, S., Konoshima, L., Yamazaki, D., Watanabe, S., Kim, H., & Kanae, S. (2013). Global flood risk under climate change. *Nature Climate Change*, *3*(9), 816–821. https://doi.org/10.1038/nclimate1911.

Hutauruk, R. C., Alfiandy, S., Nainggolan, H. A., & Raharjo, M. H. F. Y. (2020). GIS-based Flood Susceptibility Mapping Using Overlay Method in Central Sulawesi. *Forum Geografi*, *34*(2). https://doi.org/10.23917/forgeo.v34i2.10667.

Ikhvan, A., & Mera, M. (2021). Case Study: Significant factors in hazard and vulnerability assessments in flood mitigation in Padang City. *IOP Conference Series: Earth and Environmental Science*, *708*(1). https://doi.org/10.1088/1755-1315/708/1/012026.

Kastolani, W., & Mainaki, R. (2018). Does Educational Disaster Mitigation Need To Be Introduced In School? *SHS Web of Conferences*, *42*, 00063. https://doi.org/10.1051/shsconf/20184200063.

Khosravi, K., Nohani, E., Maroufinia, E., & Pourghasemi, H. R. (2016). A GIS-based flood susceptibility

assessment and its mapping in Iran: a comparison between frequency ratio and weights-of-evidence bivariate statistical models with multi-criteria decision-making technique. *Natural Hazards*, *83*(2), 947–987. https://doi.org/10.1007/s11069-016-2357-2.

Kusumo, P., & Nursari, E. (2016). Zonasi Tingkat Kerawanan Banjir dengan Sistem Informasi Geografis pada DAS Cidurian Kab. Serang, Banten. *STRING (Satuan Tulisan Riset Dan Inovasi Teknologi)*, *1*(1), 29–38. https://doi.org/10.30998/string.v1i1.966.

Liu, H., Yi, Y., & Jin, Z. (2021). Sensitivity Analysis of Flash Flood Hazard on Sediment Load Characteristics. *Frontiers in Earth Science*, *9*(September), 1–10. https://doi.org/10.3389/feart.2021.683453.

Milanovic, P. (2002). The environmental impacts of human activities and engineering constructions in karst regions. *Episodes*, *25*(1), 13–21. https://doi.org/10.18814/epiiugs/2002/v25i1/002.

Prakasa, R. M. A., Manfarizah, & Basri, H. (2021). Kajian Laju Infiltrasi pada Berbagai Penggunaan Lahan dan Jenis Tanah di Kecamatan Blang Jeurango (Study of Infiltration Rate On Various Land Use and Soil Types in Blang Jeurango District) Program Studi Ilmu Tanah , Fakultas Pertanian , Universitas Syia. *Jurnal Ilmiah Mahasiswa Pertanian*, *6*(3), 254–262. http://jim.usk.ac.id/JFP/article/view/17655.

Rachmat, A. R., & Pamungkas, A. (2014). Faktor-Faktor Kerentanan yang Berpengaruh terhadap Bencana Banjir di Kecamatan Manggala Kota Makassar. *Jurnal Teknik ITS*, *3*(2), C178–C183. https://doi.org/10.12962/j23373539.v3i2.7263.

Romadhon, M. R., & Aziz, A. (2022). Determination of Flood Susceptibility Index Using Overlay-Scoring Data Method based on Geographic Information System (GIS) in Semarang City, Central Java, Indonesia. *AgriHealth: Journal of Agri-Food, Nutrition and Public Health*, *3*(2), 104. https://doi.org/10.20961/agrihealth.v3i2.60451.

Samanta, S., Pal, D. K., & Palsamanta, B. (2018). Flood susceptibility analysis through remote sensing, GIS and frequency ratio model. *Applied Water Science*, *8*(2). https://doi.org/10.1007/s13201-018-0710-1

Sholihah, Q., Kuncoro, W., Wahyuni, S., Puni Suwandi, S., & Dwi Feditasari, E. (2020). The analysis of the causes of flood disasters and their impacts in the perspective of environmental law. *IOP Conference Series: Earth and Environmental Science*, *437*(1). https://doi.org/10.1088/1755-1315/437/1/012056.

Sofia, G., Roder, G., Dalla Fontana, G., & Tarolli, P. (2017). Flood dynamics in urbanised landscapes: 100 years of climate and humans' interaction. *Scientific Reports*, *7*(December 2016), 1–12. https://doi.org/10.1038/srep40527.

Sun, S., Li, L., Wang, J., Shi, S., Song, S., Fang, Z., Ba, X., & Jin, H. (2018). Karst development mechanism and characteristics based on comprehensive exploration along Jinan Metro, China. *Sustainability (Switzerland)*, *10*(10), 1–21. https://doi.org/10.3390/su10103383.

Suprayogo, D., van Noordwijk, M., Hairiah, K., Meilasari, N., Rabbani, A. L., Ishaq, R. M., & Widianto, W. (2020). Infiltration-friendly agroforestry land uses on volcanic slopes in the Rejoso Watershed, East Java, Indonesia. *Land*, *9*(8). https://doi.org/10.3390/LAND9080240.

Tabari, H. (2020). Climate change impact on flood and extreme precipitation increases with water availability. *Scientific Reports*, *10*(1). https://doi.org/10.1038/s41598-020-70816-2.

Tarkono, Humam, A., Baladin, D. S. P., Hermastuti, G. A., Rahmayani, I., Mahyunis, R. V., & Sayuti, S. F. (2021). Pemetaan Daerah Potensi Rawan Banjir Dengan Sistem Informasi Geografi Metode Weighted Overlay Di Kelurahan Keteguhan. In *Buguh: Jurnal Pengabdian Kepada Masyarakat* (Vol. 1, Issue 3). https://doi.org/10.23960/buguh.v1n3.138.

Tehrany, M. S., Pradhan, B., & Jebur, M. N. (2015). Flood susceptibility analysis and its verification using a novel ensemble support vector machine and frequency ratio method. *Stochastic Environmental Research and Risk Assessment*, *29*(4), 1149–1165. https://doi.org/10.1007/s00477-015-1021-9.

Vojtek, M., & Vojteková, J. (2019). Flood susceptibility mapping on a national scale in Slovakia using the analytical hierarchy process. *Water (Switzerland)*, *11*(2). https://doi.org/10.3390/w11020364.

Yu, Q., Wang, Y., & Li, N. (2022). Extreme Flood Disasters: Comprehensive Impact and Assessment. *Water (Switzerland)*, *14*(8), 1–14. https://doi.org/10.3390/w14081211.

Zaharia, L., Costache, R., Prăvălie, R., & Ioana-Toroimac, G. (2017). Mapping flood and flooding potential indices: a methodological approach to identifying areas susceptible to flood and flooding risk. Case study: the Prahova catchment (Romania). *Frontiers of Earth Science*, *11*(2), 229–247. https://doi.org/10.1007/s11707-017-0636-1.