

Analysis of Flood Hazard Level in Widas Sub Watershed of Nganjuk Regency Using Geographic Information System

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Article Information	ABSTRACT
Article History Received : December 17, 2024 Revised : December 27, 2024 Published : January 06, 2025	Widas Subwatershed in Nganjuk Regency is a tributary of the Brantas Subwatershed that often experiences flooding during the rainy season. The data on flooding is still in the form of numbers and tables so it needs to be mapped. The presentation of data in the form of a map is needed so that readers can analyse its distribution and help in mitigation planning against flood disasters. The purpose of this research is to analyse the level of flood hazard in the Widas Subwatershed of Nganjuk Regency and present it in the form of a map. The method used was scoring of 6 flood parameters, namely slope, land elevation, soil type, rainfall, land use, and river density, then weighting with the Analytic Hierarchy Process (AHP) method. The result of this research is that Widas Sub Watershed of Nganjuk Regency is dominated by flood hazard area of 33,375.95 Ha while the flood hazard area is 3,415.55 Ha. Flood hazard areas are found in 28 villages in Gondang, Loceret, Nganjuk, Pare, Sukomoro, and Tanjunganom sub-districts. The flood-prone areas are caused by 4 main factors: low land elevation, Alluvial soil type, residential land use, and the density of the river is very sparse.
Keywords: <i>Flood; Geographic Information System; Widas Sub Watershed Nganjuk Regency;</i>	

INTRODUCTION

Widas Subwatershed is a tributary of the Brantas Watershed which is administratively located in Nganjuk Regency and has an area of 1538 km². The problem that often occurs in the area is flooding during the rainy season (Valiant, 2017). This is because the water flow into the Widas Sub-watershed cannot be fully channeled into the Brantas Watershed because the permitted water flow from Widas to Brantas is only about 270 m³/s (Erlina, 2018).

Flooding occurred on 15 April 2021 in 5 villages of Lengkong sub-district after overflowing water from the Widas sub-watershed. Water inundated houses and roads in 5 villages, namely Dowo Village, Kedungmlaten Village, Lengkong Village, Jegreg Village and Balongasem Village. The flood was estimated to be as high as 20-30 cm in the Lengkong sub-district office area and as high as 40 cm to the west of the Lengkong gas station (Nugroho, 16 April 2021).

The presentation of data regarding flooding in the Widas Sub-watershed of Nganjuk Regency is still in the form of numbers and tables so that it needs to be mapped so that its distribution can be analysed. In addition, the presentation of data in the form of maps is very helpful in decision-making and mitigation planning for flood problems. Converting data from numbers and tables to map form can be done using Geographic Information Systems (GIS) (Aryanto & Mandenni, 2020).

The literature review shows that in GIS there are many tools such as Q-GIS, ArcView, ArcGIS and GRASS GIS, but the most commonly used is ArcGIS software, which is currently the latest version 10.8 (Tallo & Nahak, 2023). The components of GIS are hardware, software, brainware, spatial data, and methods. The scope of GIS is data input, editing, data management, analysis, visualisation, and data types. There are 2 types of data in GIS, namely spatial data consisting of raster and vector, then tabular data that describes the characteristics of an object in spatial data (Jasman, Ridwan, & Guntara, 2021).

Flood factors have 6 main parameters, namely slope, land elevation, soil type, rainfall, land use and river density (Siburian, Siregar, & Berlianti, 2024). Regional rainfall can be found by 3 methods, namely the arithmetic method, Thiessen polygon, and Isohyet (Sanusi & Side, 2016). The arithmetic method is used if the review area has an area of 250 - 50,000 Ha with 2 or 3 rain stations, the Thiessen polygon method is used if the review area has an area of 120,000 - 500,000 Ha with more than 3 rain stations that are unevenly located and the rainfall is not too influenced by topographic conditions, the Isohyet method is used if the review area has an area of >500,000 Ha (Dwirani, 2019).

In analysing the level of flood hazard, weighting is needed which can be done in many ways, one of which is the Analytic Hierarchy Process (AHP). The purpose of AHP is to capture the perception of people or experts rationally on a problem by applying a procedure that has a scale of preference for various sets of alternatives (Cantik, Fadilah, Putri, & Agustia, 2024). AHP is carried out by comparing one parameter with another parameter using pairwise comparisons to determine how important its influence on the goal is. The result of AHP is the relative weight between one parameter and another (Kurniawan & Roestam, 2021). The assignment of comparison values is free according to experts so there is a chance of inconsistency in the research. Inconsistencies can be avoided by calculating the Consistency Index (CI) and Consistency Ratio (CR) values, if the CI and CR values are less than 10% then the inconsistency is still acceptable or considered rational (Kurniawan & Roestam, 2021).

The purpose of this study is to present data on flooding in the Widas Subwatershed of Nganjuk Regency so that its distribution can be analysed. The specific objectives of this research are: 1. to analyse the level of flood hazard in Widas Sub Watershed of Nganjuk Regency; 2. to map the distribution of flood hazard in Widas Sub Watershed of Nganjuk Regency. This research is expected to provide information on the level of flood hazard and its distribution map that is useful in calculations when conducting sustainable regional planning and development.

RESEARCH METHODS

This research is a type of quantitative descriptive research, which is research that is carried out transparently from the beginning to the end of the research, in this research there is also survey research in analysing the level of flood hazard (Syahrizal & Jailani, 2023). The location of this research is in the Widas Subwatershed which is administratively located in Nganjuk Regency.

Data collection in this study used secondary data obtained through agencies related to the research, namely: 1. administrative map of Widas Sub Watershed of Nganjuk Regency with boundaries per village from InaGeoportal; 2. slope and land elevation data from Digital Elevation Model (DEM); 3. soil type data from Geospatial Information Agency; 4. rainfall data for 2014 - 2023 from the Public Works and Public Housing Office (PUPR) of Nganjuk Regency; 5. land use and river flow data from the Ministry of Environment and Forestry (KLHK). Field checks were conducted for land use data because it has the potential to change in a short period of time.

The first data analysis was to score the data on slope, land elevation, soil type, rainfall, land use, and river density. Scoring of slope data was taken from the terminology according to the Directorate General of Reforestation and Land Rehabilitation (2022). Scoring of land elevation data was taken from terminology according to Rahmanizah, dkk., (2023). Scoring of soil type data is adjusted based on infiltration taken from the terminology according to Muzaki, dkk., (2022). Rainfall data scoring was taken from the terminology according to Rahmanizah, dkk., (2023).

Regional rainfall was calculated using the Thiessen polygon method because the area has several rainfall stations that are unevenly distributed and the rainfall is not too influenced by topographic conditions (Dwirani, 2019). Land use data scoring was taken from the terminology according to Rahmanizah, dkk., (2023). Scoring of river density data is taken from terminology according to Fauzi (2022).

The second data analysis was to find the weighting using the AHP technique. Input from AHP was taken from experts at the Nganjuk Regency PUPR Office. The tool used is Microsoft Excel. The results obtained from AHP are used to determine the weight of each flood parameter on the level of flood hazard.

Overlaying the six flood parameters was conducted after the first and second data analyses were completed. The overlay was conducted using the Union feature in Arcgis 10.8 so that the classification of the flood hazard level could be found. The classification of flood hazard levels is sought using the flood hazard index formula obtained from AHP. The flow chart of this research is as follows.

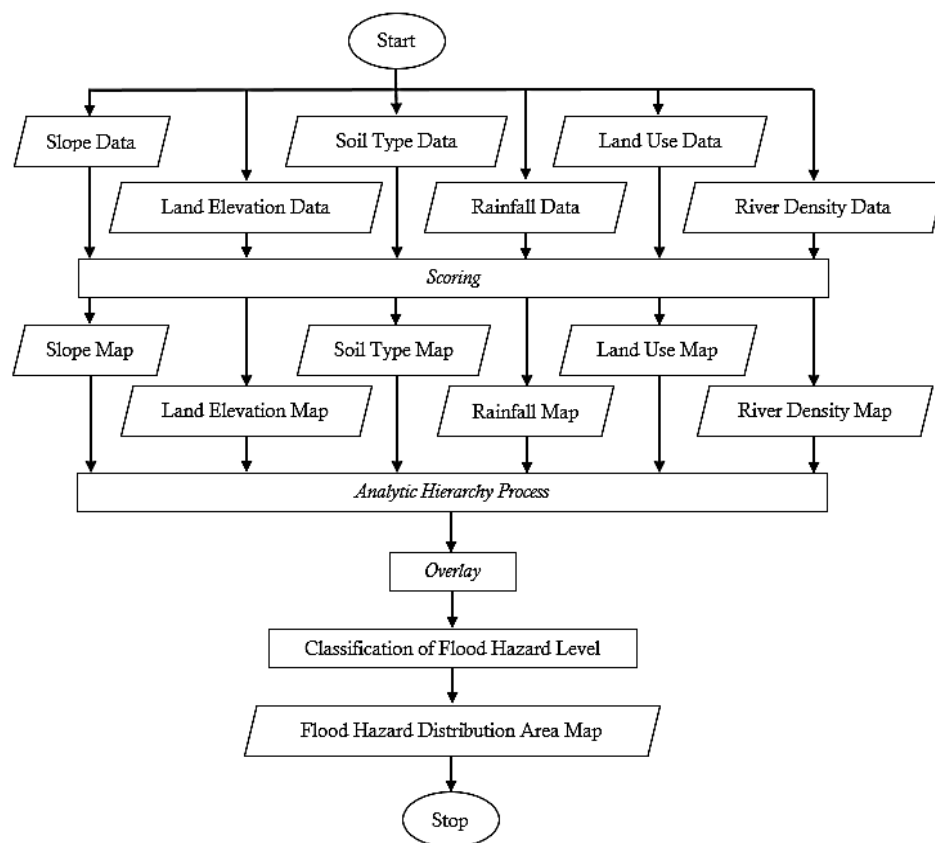


Figure 1. Flowchart

RESULTS AND DISCUSSION

Flood Hazard Level Analysis

Slope data was obtained from Digital Elevation Model (DEM) raster data which was then compared to vertical distance and land height with ArcGIS 10.8 to find the percentage of slope. The slope in Widas Sub Watershed of Nganjuk Regency is dominated by a flat slope of 62.2%. This is influenced by light rainfall because light rainfall causes the slope to be not steep (Aisah & Gofar, 2022). Sedimentation results from the weathering of limestone during the formation of Grumosol soil also causes the slope to be flat (Mangkunegara & Firdamayanti, 2021). This research is in accordance with research conducted by Maulana (2023) which shows that slope is the number 3 influencing factor on the level of flood hazard.

Table 1. Flood Parameter Scoring

Slope (%)	Description	Score
0 – 8	Flat	5
>8 – 15	Ramps	4
>15 – 25	Slightly steep	3
>25 – 45	Steep	2
>45	Very steep	1
Land Elevation (M)	Description	Score
10 – 50	Low	4
50 – 100	Slightly low	3
100 – 200	High	2
>200	Very high	1
Soil Type	Infiltration	Score
Alluvial	Not sensitive	5
Latosol	Slightly sensitive	4
Grumosol	Sensitive	2
Andosol	Sensitive	2
Regosol	Highly sensitive	1
Rainfall (Mm/Day)	Description	Score
21 – 50	Medium	3
5 – 20	Light	2
Land Use		Score
Sattlement		5
Rice fields/ Ponds		4
Field/ moor/ garden		3
Shrubs		2
Forest		1
River Density (Km/Km ²)	Description	Score
<1,434	Very tight	5
1,4345-2,87	Tight	4
2,88-4,305	Slightly tight	3

Land elevation data was obtained from Digital Elevation Model (DEM) raster data which was then processed with ArcGIS 10.8. Land elevation in Widas Subwatershed of Nganjuk Regency is dominated by very high land elevation of 42.58%. This is because the area is included in the Wilis mountain range which is the dudusan of volcanoes in East Java (Kurniawan B. T., 2019). This study is in accordance with research conducted by Maulana, dkk., (2023) which shows that land elevation is the parameter that has the weakest influence on the level of flood hazard.

Soil type data was obtained from the Geospatial Information Agency (BIG) processed with ArcGIS 10.8. Widas Sub Watershed of Nganjuk Regency has 5 different soil types namely Alluvial, Latosol, Grumosol, Andosol, and Regosol with dominated by Grumosol soil type of 44.83%. This is influenced by light rainfall that occurs over thousands to poluhan thousands of years. The area which is a mountain also causes a lot of volcanic tuff which eventually forms the Grumosol soil type (Mangkunegara & Firdamayanti, 2021). This research is in accordance with research conducted by Rahmanizah, dkk., (2023) which shows that soil type is the number 4 influential parameter on the level of flood hazard.

Rainfall data was obtained from the Nganjuk Regency Public Works and Public Housing Office (PUPR) processed with ArcGIS 10.8. The data used is rainfall data at 23 rainfall stations in 2014 - 2023. The method used in calculating regional rainfall is polygon Thiessen because the area has several rain stations that are unevenly distributed and the rainfall is not too influenced by topographic conditions. The formula of Thiessen polygon is as follows (Sanusi & Side, 2016).

$$R = W_1 R_1 + W_2 R_2 + \dots + W_n R_n \quad (1)$$

Description: R = regional rainfall (mm/day)
 R_1, R_2, R_n = average rainfall at each observation point (mm/day)
 W_1, W_2, W_n = $\frac{\text{polygon area}_1}{\text{study area}}, \frac{\text{polygon area}_2}{\text{study area}}, \frac{\text{polygon area}_n}{\text{study area}}$

The result of the calculation of regional rainfall in Widas Sub Watershed of Nganjuk Regency using the Thiessen polygon method is 19.98 mm/day which is included in the light class. This is influenced by high land altitude, the higher an area, the lower the rainfall will be because the air temperature is colder (Molle & Larasati, 2020). The calculation of the region's rainfall is as in the following table.

Table 2. Calculation of Regional Rainfall with *Polygon Thiessen*

Rain Station Name	Average Rainfall (Mm/Day)	Area (Ha)	W	R
Kedung maron	18,09	11,373	0,0002	0,004
Rejoso	18,72	42,834	0,0009	0,016
Nganjuk	19,96	4564,682	0,0931	1,858
Tunglur	22,53	3522,645	0,0719	1,619
Jatirejo	16,71	1841,515	0,0376	0,628
Berbek	16,17	2281,624	0,0465	0,753
Palu ombo	19,68	2431,135	0,0496	0,976
Sawahan	21,69	6965,122	0,1421	3,082
Klodan	22,91	6966,086	0,1421	3,256
Kedung rejo (Bandungan)	18,57	93,361	0,0019	0,035
Kedung rejo (Baron)	20,37	320,259	0,0065	0,133
Warujayeng	17,86	37,972	0,0008	0,014
Sumber soko	16,92	4789,360	0,0977	1,653
Pace	19,33	667,422	0,0136	0,263
Mililir	18,15	992,374	0,0202	0,367
Ngudikan	22,68	604,719	0,0123	0,280
Ngrambek	20,10	1811,577	0,0370	0,743
Glatik	19,89	825,626	0,0168	0,335
Kedung soko	20,48	1808,155	0,0369	0,755
Patihan	16,98	1287,688	0,0263	0,446
Badong	19,06	2321,376	0,0474	0,903
Banaran	17,46	2375,126	0,0485	0,846
Genjeng	20,13	2455,612	0,0501	1,008
			R =	19,98

Land use data was obtained from InaGeoportal in 2024 which was processed with ArcGIS 10.8. Land use in the Widas Subwatershed of Nganjuk Regency is dominated by rice fields/ponds covering an area of 48.54%. This is influenced by light rainfall. Stable and light rainfall greatly supports farmers in growing their crops (Ruminta & Nurmala, 2018). The flat slope also affects because areas with slopes $>15^\circ$ will more easily damage plants (Dengen, Nurcahyo, & Kusrini, 2019). Grumosol and Andosol soil types also influence because these soil types are suitable for use in agriculture (Prasetyowati & Sunaryo, 2018). Very high land altitude also affects because very high land altitude is good for crops (Arvi, Syakur, & Karim, 2019). This research is in accordance with research conducted by Maulana (2023) which shows that land use is the most influential parameter after rainfall on the level of flood hazard.

River density data obtained from the Ministry of Environment and Forestry (KLHK) processed with Arcgis 10.8. The calculation of river density uses the formula from Matondang (2013) as follows.

$$Dd = \sum Ln/A \quad (2)$$

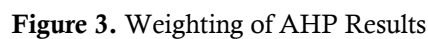
Description: Dd = river density (km/km²)

The density of rivers in the Widas Sub-watershed of Nganjuk Regency is dominated by a tenuous river density of 61.33%. This is influenced by the flat slope because the flat slope causes the river flow pattern to be more regular so that the river density is tenuous (Tarigan, 2022). This research is in accordance with research conducted by Rahmanizah, dkk., (2023) which shows that river density is the parameter that has the number 5 influence on the level of flood hazard.



1. Respondent name = Imam Hanafi
Position/Division = Functional Irrigation Engineering Nganjuk District Public Works and Public Housing Office
CI value = 0,112 > 0,1 (Inconsistency)
CR value = 0,09 < 0,1 (Rational)

- Of the three respondents, only one respondent whose CI and CR values did not exceed the maximum limit was considered rational, namely Mr Triyono Purwanto. The weighting of all flood parameters obtained from the AHP results as shown in the following Figure.


$$\text{Flood hazard index} = (18,77 \times \text{score slope}) + (9,64 \times \text{score KL}) + (12,36 \times \text{score JT}) + (27,41 \times \text{score CH}) + (20,87 \times \text{score PL}) + (10,94 \times \text{score KS}) \quad (3)$$

Flood Hazard Distribution Mapping

Table 3. Level of Flood Vulnerability

Widas Subwatershed of Nganjuk Regency is dominated by flood hazard area of 33,375.95 Ha and very flood hazard area of 3,415.55 Ha in 28 villages. The details of the 28 villages are as follows.

- Gondang sub-district : Nglinggo Village, and Sumberjo Village
- Loceret sub-district : Nglaban village, and Putukrejo village
- Nganjuk sub-district : Bogo Village, Ganung Kidul Village, Kauman Village,

- Mangundikaran Village, Payaman village, and Werungotok village
- Pace sub-district : Gemenggeng village, Kepanjen village, Kauman village, Pacewetan village, and Plosoharjo Village
- Tanjunganom sub-district : Getas village, Kedungombo village, Malangsari village, and Sonobekel village
- Sukomoro Sub-district : Blitaran village, Bungur village, Kapas village, Kedungsoko village, Nglundo village, Ngrami village, Pehsurut village, Sukomoro village, and Sumengko village

All of these high flood hazard areas are caused by low land elevation, Alluvial soil type, residential land use, and very dense river. These factors are the ones that most influence the flood hazard areas compared to other parameters.

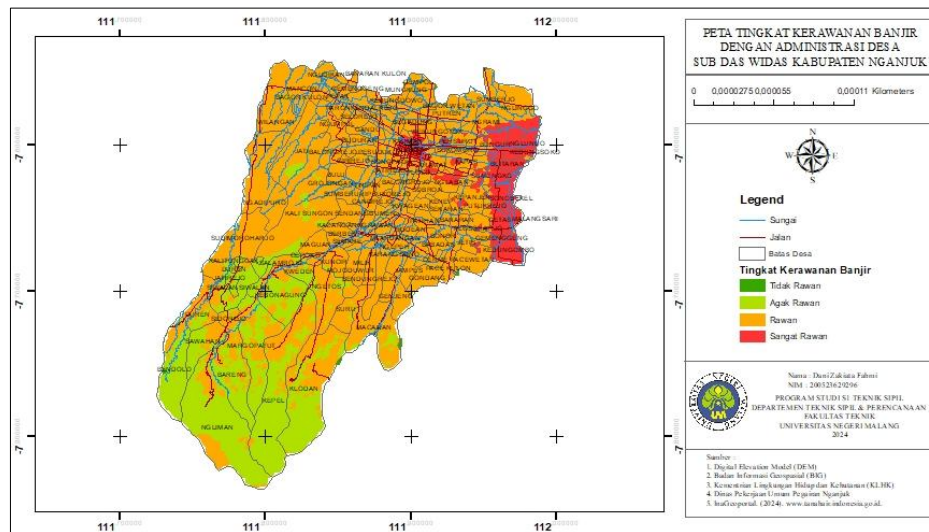


Figure 4. Flood vulnerability map

CONCLUSION

Conclusion

Widas Sub Watershed of Nganjuk Regency has a very flood hazard area of 3,366.14 Ha or 7.06%, a flood hazard area of 32,990.69 Ha or 69.19%, a moderate flood hazard area of 11,261.55 Ha or 23.63%, and a no flood hazard area of 62.02 Ha or 0.13%.

The distribution of flood hazard levels in the Widas Subwatershed of Nganjuk Regency as shown in Figure 4. Highly flood-prone areas are found in 28 villages in Gondang, Loceret, Nganjuk, Pare, Sukomoro, and Tanjunganom Subdistricts with the most dominating area being Sukomoro Subdistrict with an area of 1,459 Ha. All of these highly flood-prone areas are caused by 4 main factors: low land elevation, Alluvial soil type, residential land use, and very sparse river density.

The results of this study are expected to help the community in mitigating against flood hazards as well as assisting local governments in calculations when conducting sustainable regional planning and development.

Suggestions

In accordance with the above conclusions, the suggestions given are that this research can be continued by analysing evacuation routes when flooding occurs in the Widas Subwatershed of Nganjuk Regency.

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