ISSN No:-2456-2165 https://doi.org/10.5281/zenodo.14591142

Study of Slope Gravity on Flood Vulnerability Level in Gorontalo City

Dr. Ir. Arqam Laya, MT
Department of Civil Engineering
Gorontalo State University, Indonesia

Abstract:- The purpose of this research was to know the condition of vulnerability of Gorontalo City to flood inundation, based on land slope through a hydro geomorphology study approach. The sampling method by dividing the research area size 250 x 250 m2 (based on the grid). Land unit approach was used in the analysis technique. The results of this study concluded that the area of Gorontalo City, (1) slope of 3507.84 Ha or 52.6% of the total area with very flat class-details (class L1, L2, L3 and L4), (2) Class Flat to very sloping class this slope of the region 0-7%; (3) Very flat-sloped class or of this 52.6%, potential to floods of 965.8 Ha (27.5%) of the plain area or 14.4% of Gorontalo City (4) Class is quite steep (Class L5> 8%) area of 2782.18 ha in the form of hills / mountains

Keywords:- *Slope, Flood Vulnerability, Gorontalo City*.

I. INTRODUCTION

Gorontalo City is a lowland, with a slope gradient of approximately 0.–7%, therefore this area is very vulnerable to flooding. Viewed from the toponymy aspect, many villages or sub-districts indicate that the area is often inundated. Sub-district toponyms related to inundation include Heledulaa (large shrimp), Biawao (monitor lizard), Padebuolo (where sea waves break). In addition to being based on toponymy when viewed from residential buildings, the height of the building foundation ranges from 1–1.5 meters from the ground surface (Figure 1).

(1.a) (1.b) (1.c) (1.d)

Fig 1: Visualization of Residential Building Adaptation Against Floods
Source: 2008 Observation Results

Description: (1.a). Post-flood house foundation (1948); (1.b) House foundation before 1900; (1.c) Traditional house foundation; (1.d) Height of house foundation after 1970 flood.

II. LITERATURE REVIEW

Slope is a morphometric part of geomorphology that provides a description of the characteristics of the earth's appearance. Slope provides information on the conditions of the earth's surface relief, processes that affect relief, so that it can provide firm conclusions.

nomenclature of geomorphological units in detail. The slope assessment measure that is the basis for the unit is*United States Soil Management System*(USSSM) or Universal Soil Loss Equation (USLE) or the slope gradient measurement proposed by Zuidam (1983). KSlope gradient and slope length are variables in measuring the calculation of erosion levels, slope stability and regional planning. The agreed slope gradient measurements for assessing a landform are presented in Table 1.

Table 1: Slope Gradient Size

Slope Gradient (%)	Information	USSSM Classification (%)	USLE Classification (%)
0–2	Flat – Almost flat	0–2	0–2
3–7	Very gentle slope	2–6	2–7

ISSN No:-2456-2165 https://doi.org/10.5281/zenodo.14591142

8–13	Gentle slope	6–13	7–12
14–20	The slope is rather steep	13–25	12–18
21–55	Steep slope	25–55	18–24
56–140	The slope is very steep	> 55	>24

Source: Zuidam (1983)

The grade for the slope gradient is divided into 5 (five) classes starting from the classification of very steep water to flat. Based on this classification, the slope conditions of the earth's surface relief use the modified Van Zuidam (1983) approach, as shown in Table 2.

Table 2: Slope Gradient Values

No	Class	Slope Gradient	Classification	Score
1	L5	> 8%	Very Flat	1
2	L4	6–7%	Flat	2
3	L3	4–5%	Very flat	3
4	L2	2–3%	Sloping	4
5	L1	0–1%	Quite Steep	5

Source: Modification of Van Zuidam (1983)

III. RESEARCH METHODS

Slope data is done by processing the RBI Base Map of Gorontalo sheet and Bilungala sheet, then a field survey is conducted. This survey is carried out at predetermined points to be matched with the processed data of the base map.

The land unit approach is used to conduct flood hydrogeomorphology studies. Land is defined as a physical environment consisting of landforms, soil, water, and vegetation covering the land and the influence of land use (Arsyad, 1989). Hydrogeomorphological land units are mapping units that combine landform characteristics, soil types, slope gradients, land use, rainfall, infiltration and drainage conditions. Land unit characteristics are arranged based on the classification ofeach variable.

The slope gradient classification consists of five classes, namely class L1 (very flat relief 0-1%), class L2 (flat relief 2-3%), class L3 (very gentle relief 4-5%), class L4 (gentle relief 6-7%) and class L5 (quite steep relief more than 8%). The slope classification related to the analysis of hydrogeomorphological mapping units is only 4 classes (L1, L2, L3, L4).

The results of the hydrogeomorphological mapping unit are validated with the height of the inundation at the location of the flood event which produces the level of flood hazard. The level of flood hazard consists of five classes, namely areas without hazard (f0), light hazard (f1), moderate hazard (f2), moderately severe hazard (f3) and severe hazard (f4). The results of this validation are then overlaid with a land use map to produce a level of flood hazard vulnerability. The classification of land use is divided into four classes based on vegetation cover, namely: highway areas (national, provincial, district), shopping areas, residential areas, rice fields and mixed fields. The results of this overlay are in the form of land units to produce a zoning map of the level of flood vulnerability in Gorontalo City.

Land units are used to analyze flood vulnerability zoning in Gorontalo City. So the hydrogeomorphological mapping unit is based on the grid method in order to represent a number of land units (720 units). This land unit is the result of overlapping infiltration maps, rainfall maps, drainage condition maps, slope maps, soil type maps, landform maps and land use maps and inundation height maps. The grid approach is intended to divide Gorontalo City into boxes measuring 250 mx 250 m. The distance of 250 m is taken into account by considering the geomorphological conditions of Gorontalo City in terms of landform, soil type, and slope gradient aspects which are almost homogeneous.

IV. DISCUSSION

According to the available data, the slope data uses the RBI Map Limboto sheet and Tapa sheet scale 1: 50,000 in 2007 published by BAKORSURTANAL. The slope gradient in the research area consists of five classes as shown in Table 3 and Figure 2. The slope gradient of 2–3% (class L2 with flat relief) is the largest at 1684.94 Ha (25.25%), followed by slope 0–1% (class L1 with very flat relief) covering an area of 1296.29 Ha (19.43%), followed by slope 4–5 (class L3 with very gentle relief) covering an area of 734.90 Ha (11.01%), then slope 6–7 (class L4 with gentle relief) covering an area of 174.71 Ha (2.62%). The total area of these four classes is 58.31% which is an area that has the potential to be hit by flooding. Meanwhile, slopes of more than 8% covering an area of 2782.17 Ha or 41.69% are slopes that are rarely or have no potential to be hit by flooding.

Table 3: Slope Gradient of Gorontalo City

No.	Slope Gradient		Characteristics	Wide (Ha)	Wide (%)
	Class	Slope			
1	L1	0–1	Very Flat	1,296.29	19.43
2	L2	2–3	Flat	1,684.94	25.25
3	L3	4–5	Very Flat	734.90	11.01
4	L4	6–7	Sloping	174.71	2.62
5	L5	>8	Quite Steep	2,782.17	41.69

Source: Analysis of Slope Map of Gorontalo City

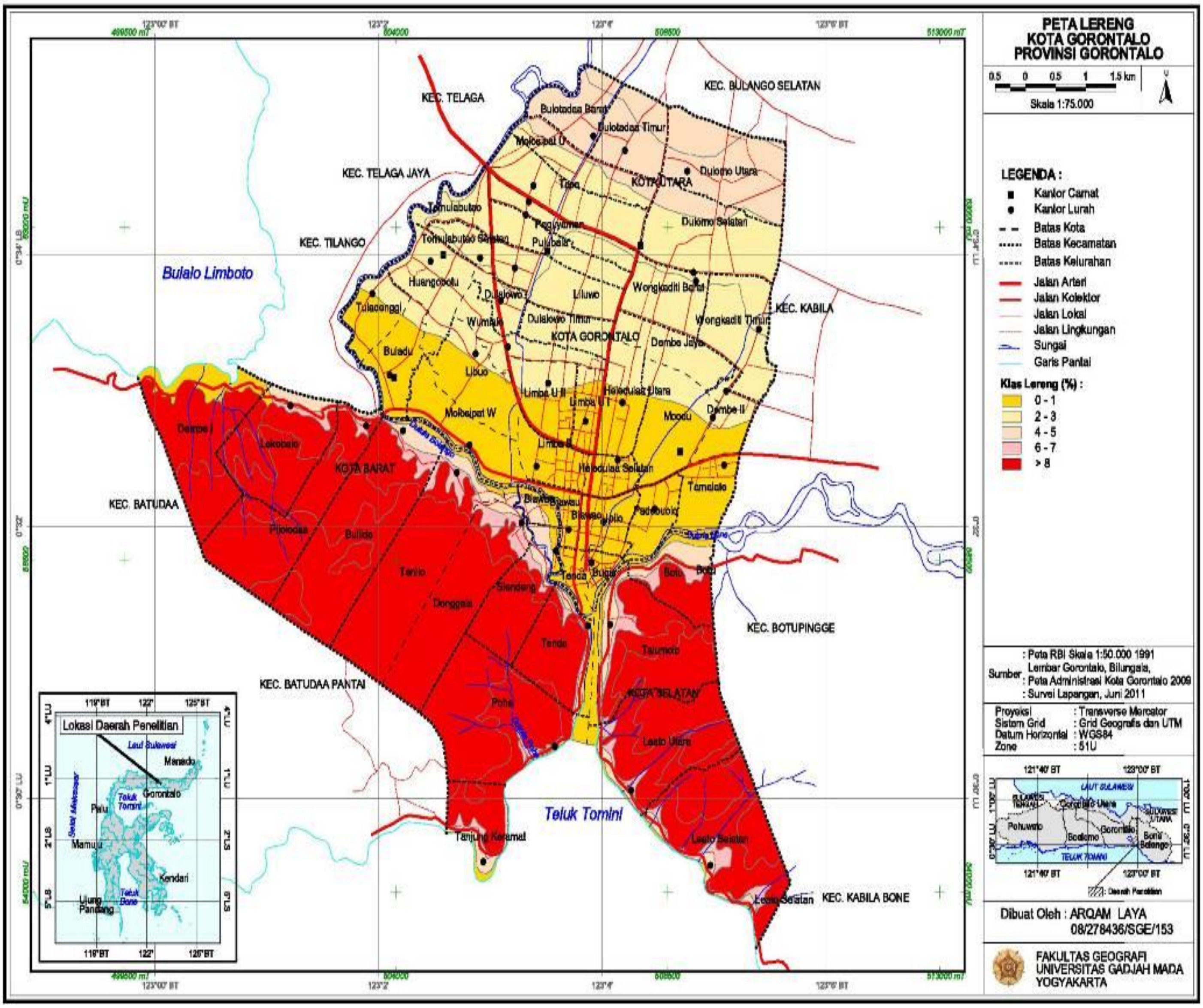

Fig 2: Gorontalo City Slope Map 2010

The spatial pattern of the slope for the entire Kota Tengah District has a flat relief (class L2). Dungingi District has a flat to very flat relief (class L2 and L1). Kota Utara District has a moderate to very flat relief (class L3, L2 and L1). Meanwhile, the other 3 districts, namely Kota Barat, Kota Selatan and Kota Timur, have quite steep to very flat relief. The three districts also have a slope of more than 40% because some of their areas are hilly and mountainous areas.

Statistical data analysis for slope gradient according to the results of cross-tabulation analysis has a very significant relationship with the level of flood vulnerability. The statement of a very significant relationship is in accordance with the Chi-Square test on the Pearson Chi-Square reading, Likelihood Ratio, and linear by linear reading. The results of the chi-square test reading on Asymp. Sig. (2-sided) of 0% is less than 1%. This means accepting HA and rejecting H0 with a confidence level of 81.3% (Appendix IX-5). Other cross-tabulation analysis based on the directional measures test shows the same reading results, according to approx.sig of 0% less than 1%.

ISSN No:-2456-2165 https://doi.org/10.5281/zenodo.14591142

The classification of the less vulnerable vulnerability level has a relationship with the slope of 28.3%. The number of evaluated grids is 13 consisting of class L3 as many as 6 grids, and class L4 as many as 6 grids and L5 as many as 1 grid. The classification of moderately vulnerable is 41.3% with 19 evaluated grids consisting of L2 as many as 1 grid, L4 as many as 12 grids and L5 as many as 4 grids. The classification of the vulnerable vulnerability level is related to the slope of 19.6%. The number of evaluated grids is 9 grids, consisting of class L3 as many as 1 grid, and class L5 as many as 8 grids. The classification of moderately vulnerable is 10.9% with 5 evaluated grids, consisting of L2 as many as 1 grid and L5 as many as 4 grids. The relationship between the slope class and the vulnerability level category is as presented in Figure 3.

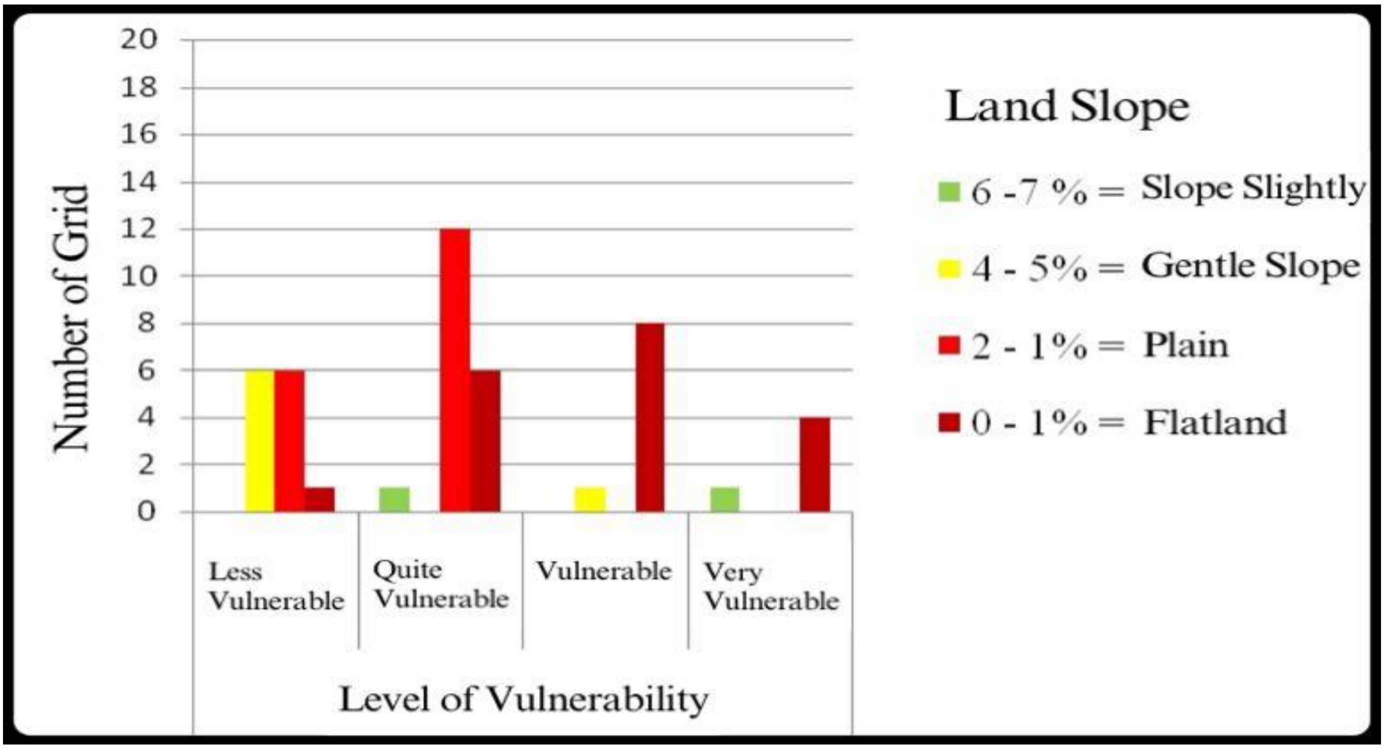

Fig 3: Relationship between Vulnerability Level Classification and Slope Gradient
Source: Cross Tabulation Analysis

The relationship between the classification of vulnerability levels and slope gradients as in Figure 3 shows that in the classification of vulnerability levels with a fairly vulnerable class, it is connected by 2 slope gradient classes, namely the very gentle class (6-7%) and the gentle class (4-5%). The classification of vulnerability levels with a fairly vulnerable class when examined, the level of vulnerability is more connected by the flat L4 class with a slope of 2-3%. The vulnerable and very classifications have very low slopes with a slope of 0-1%.

The results of statistical analysis also show that the slope with L4 qualification of 4.3% and the rest of 95.7%, has almost flat relief, even indicated the area with flat slope (0-2%) is twice as large as gentle slope (2-7%). Thus, the speed of surface flow towards the sea or river will be slow because the maximum slope is 2%. As a result, when it rains, if the speed of surface flow is less than the speed of flow in the river, then the surface flow is unlikely to be channeled into the river and the impact will be inundation. Floods that occurred other than May 22, 2010, namely rain in other places caused the volume of the river in the downstream to increase, as a result the river flow turned back into residential areas located near the Bolango River and Bone River such as Heledulaa Selatan, Ipilo, Bugis, Biawu, Biawao, Limba B, and Siendeng Villages. Especially for Biawao, Biawu and Ipolo Sub-districts, where these three sub-districts are the centers of economy, business, services and government, then the flood disaster greatly disrupts the economic activities of business and government. If the water level has reached 50 cm, this condition is not only disruptive but material losses are certain to occur. The impact of these material losses, for example, the cessation of business transactions, submerged goods, hampered public administration services by the government, damage to stored administrative files, damaged roads, damage to agricultural products such as rice and corn plants and disruption to public health.

The spatial distribution of slope gradients for each class in each type of land use such as residential areas, shopping areas, rice field areas, highways and mixed farming areas is shown in Table4 map analysis results and not based on grid.

ISSN No:-2456-2165 https://doi.org/10.5281/zenodo.14591142

Table 4: Slope Gradient Classes and Their Relation to Land Use

K_PL	L1 (Ha)	L2 (Ha)	L3 (Ha)	L4 (Ha)	L5 (Ha)	Total (Ha)
Jl	70,515	77,847	36,425	9,246	3,960	197,993
Pk	157,479	517,888	168,108	7,575	13,479	864,529
Pm	482,809	354,977	199,371	61,813	39,091	1,138,061
Pt	138,251	111,382				249,633
Sw	306,194	611,511	270,184			1,187,889
Sb	22,786		25,575	41,411	1,984,233	2,074,005
Tg	15,767		30,372	54,659	741,417	842,215
TA	102,505	11,346	4,882			118,733
Grand Total	1,296,306	1,684,951	734,917	174,704	2,782,180	6,673,058
	19.43%	25.25%	11.01%	2.62%	41.69%	100%

Source: Results of Land Use Map Analysis 2010

Description: L1 to L5 are slope classes, Jl = Road, KC = Mixed Field (Pk = Plantation, Tg = Field/Ground, Sb = Shrubs), Pm = Settlement, Sw = Rice Field, and Pt = Shops. TA = Water Body

Based on Table 4 it is shownthat the slope according to the analysis of the class qualification map is quite steep (class L5 = > 8%) covering an area of 2782.18 Ha or 41.69% of the total administrative area of Gorontalo City. Class L5 with a slope gradient above 8% is generally spread in the southern and eastern parts, in the form of hills and mountains. The use of land on this slope is dominated by bushes, settlements, fields/fields, offices and roads. The construction of road facilities, offices by the provincial government, has its own negative impacts. These negative impacts are in the form of large amounts of soil and sand sediment carried by water flow during the rainy season, disturbed vegetation, shallowing of rivers and landslides at several points.

Land use for dry fields/fields on hillsides or mountains increases the criticality of the slope, the land becomes bare, water absorption capacity decreases, erosion occurs. Map analysis shows that around 741.42 Ha and 13.48 Ha of land area are used for farming and plantation activities. The land area for plantations and farmers could become critical land if not cultivated anymore. The use of land in this hilly area, in addition to fields, settlements, offices, roads and bushes, is also used for mining mountain soil/sand. C excavation mining is used for the purpose of building physical facilities in the form of landfills, building foundations, selected embankments on roads and lime industry activities. This mining activity further increases the criticality of the slope, because there is erosion of the ditch at the mining location. The impact of this slope criticality, the river located at the foot of the hill becomes shallow, changes in the river cross-section, changes in the slope/slope of the river, changes in the speed of river flow and the elevation of the flood water level. Another impact is that surface water in the hill/mountainous area quickly enters the river, so that the volume of river water increases. The condition of the river during the rainy season, quickly fills up, because the distance of the river from the hills/mountains is relatively close, the slope conditions are steep and the area coverage is wide. The consequence of this condition, surface flow originating from the plains is hampered from entering the river. The spatial distribution of the hilly and mountainous areas includes 3 sub-districts, namely East City, South City and West City. East City Sub-district is spread across Botu, Talumolo, North Leato and South Leato Villages, while South City Sub-district is spread across Tanjung Keramat, Pohe, Tenda, Siendeng, Donggala Villages and West City Sub-district is spread across Tenilo, Buladu, Buliide, Pilolodaa, Lekobalo and Dembe Villages.

The results of the map analysis contained in Table 4 of the slope land units show that land use for class L2 (2–3%) is the largest at1,684.95Ha or 25.25% of the total area of Gorontalo City. The flow velocity is calculated based on the force of gravity (9.81 m2/second), so the maximum velocity is 0.29 m/second in 1 meter length. Furthermore, Class L1 (0–1%) covers an area of 1296.30 Ha or 19.43%. The maximum flow velocity for a slope of 1% multiplied by the force of gravity is 0.098 m/second per meter length. Other slope classes with quite large flow velocities are L3 (4–5%) and slope class L4 (6–7%) covering an area of 909.62 Ha or 13.63% of the total area of Gorontalo City.

Analysis of the relationship between flood hazard potential and slope gradient based on the distribution of frequency values as shown in Figure 4.

ISSN No:-2456-2165 https://doi.org/10.5281/zenodo.14591142

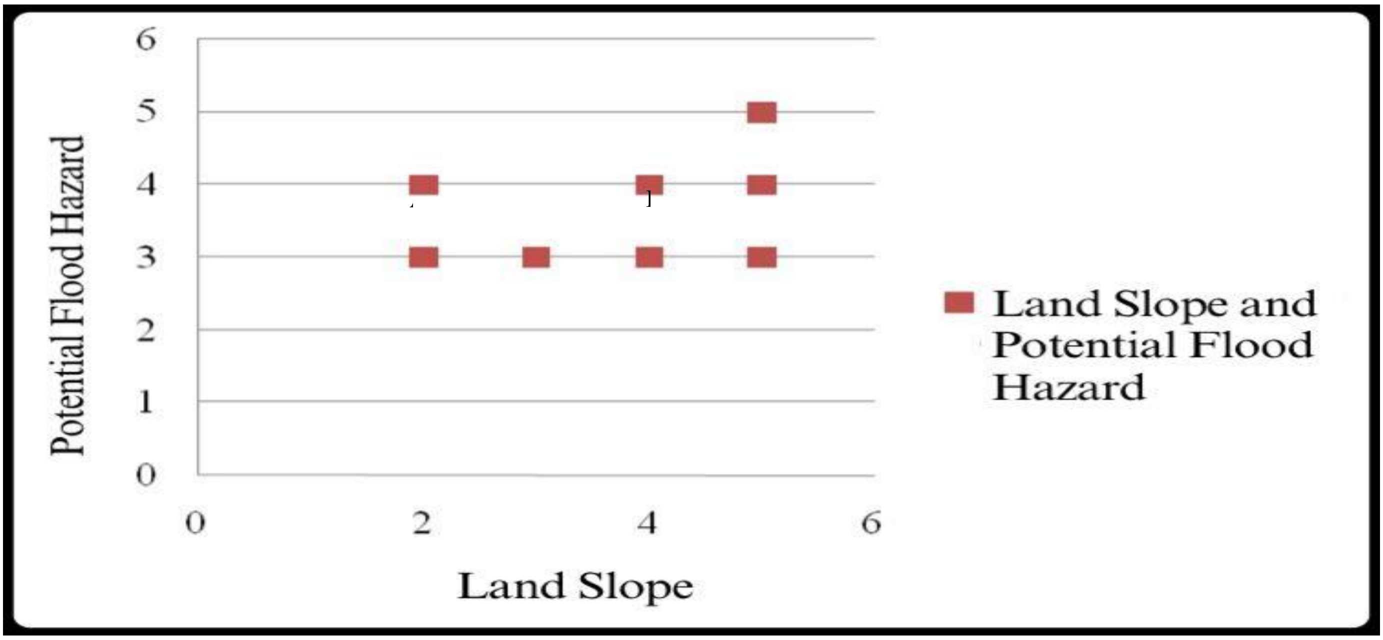

Fig 4: Frequency Distribution of Potential Flood Hazards and Slope Gradient
Source: Results of Frequency Value Distribution Analysis

Figure 4 is a scatter diagram of the relationship between flood hazard potential and slope gradient. This correlation consists of 46 grids represented by seven points, namely point A, point B, point C, point D, point E, point F, point G, and point H. Point A is the correlation value between flood hazard potential of moderate hazard classification and very gentle slope class (class L4). Point A represents one grid, namely grid D5. Point B is the correlation value between flood hazard potential of moderate hazard classification and gentle slope class (class L3). Point B represents seven grids, namely grid G1, H1, I1, J1, I2, J2, and G7. Point C is the correlation value between flood hazard potential of moderate hazard classification and Flat slope class (class L2). Point C represents 12 (twelve) grids, namely grid H2, G3, H3, I3, F4, G4, H4, I4, J4, I5, J5 and K5. Point D is the correlation value between flood hazard potential of moderate hazard classification and very gentle slope class (class L1). Point D represents four grids, namely grid G5, H5, F6 and J6. Point E is the correlation value between the potential flood hazard classification of moderately severe hazard and the slope of the very gentle class (class L4). Point E represents one grid, namely grid C5. Point F is the correlation value between the potential flood hazard classification of moderately severe hazard and the slope of the flat class (class L2). Point G represents six grids, namely grids F2, K2, E3, F3, E4 and K4. Point G is the correlation value between the potential flood hazard classification of moderately severe hazard and the slope of the very flat class (class L1). Point G represents ten grids, namely grids G2, J3, K3, E5, F5, G6, H6, I6, I7 and J7. Point H is the correlation value between the potential flood hazard classification of severe hazard and the slope of the very flat class (class L1). Point H represents five grids, namely grids D4, A5, B5, H7 and H8.

Based on the cross tabulation method in the test*Chi Square Test*and directional measures, cross as shown in Table 5.

Table 5: Relationship between Flood Hazard Potential and Slope Gradient according to the Chi-Square Test and Directional Measures

Chi-Square Tests						
			Value	**df**	**Asymp. Sig. (2-sided)**	
Pearson Chi-Square			18.434a	6	.005	
Likelihood Ratio			22.925	6	.001	
Linear-by-Linear Association			11,548	1	.001	
N of Valid Cases			46			
a. 8 cells (66.7%) have expected count less than 5. The minimum expected count is .22.						
Directional Measures						
			Value	**Asymp. Std. Error**	**Approx. Tb**	**Approx. Sig.**
Ordinal by Ordinal	Somers' d	Symmetric	.434	.111	3,689	.000
		Potential Dependent Flood Hazards	.408	.112	3,689	.000
		K. Dependent Slope	.463	.114	3,689	.000

Source: Cross Tabulation Analysis Results

ISSN No:-2456-2165 https://doi.org/10.5281/zenodo.14591142

Based on Table5. Results of cross-tabulation analysis, there is an equal or independent relationship between the potential for flood hazard and slope gradient, indicated by the large correlation value. 18,434where the expected value is 66.7%. Table 5 also shows that the slope value is very significant to the potential for flood hazard according to Pearson Chi-Square and Likelihood Ratio where the Asymp. Sig. (2-sided) value is 0.5% and 0.1% and 0.1% is less than 5%. So Pearson Chi-Square and Likelihood Ratio and*linear-by-linear association*accept hypothesis H1 and reject hypothesis H0. This means that the potential for flood hazard in Gorontalo City is very significantly related to slope gradient. The slope gradient map in Figure 4 shows that topographically Gorontalo City has a good slope gradient.

Table5 shows that the relationship between the potential for flood hazard and slope gradient has a very real relationship, as emphasized by the value*directional measures*of 43.4%, that there is an equal or free relationship between the potential for flood hazard and slope gradient. This equal relationship is marked by a significance approximation probability value of 0% less than the table value of 1%. This means that in a straight line, the slope gradient is very significantly related to the potential for flood hazard in Gorontalo City. The directional measures test shows that a decrease in slope gradient or an increase in its value is related to an increase in the classification of potential flood hazard. The increase in potential flood hazard occurs because the slope gradient value of 46.3% is more than 40.8% compared to the potential flood hazard value. The potential flood hazard value of 40.8% according to ordinal by ordinal (*Somers' d*), the probability of approximation of significance is 0% or less than the table value of 1%.

Cross tabulation analysis when compared with the reading method based on the Table5 will obtain a slope value of 81.7%. The result of this percentage is obtained from the total slope value divided by the very high classification value of 5 and multiplied by the number of grids of 46 units or 188/(5*46). This means that the potential for flooding in the plains of Gorontalo City is related to the slope, especially the very flat classification of 81.7% and the remaining 18.3% by classifications other than the very flat classification. This analysis is once again valid when viewed from the relationship between slope and flood hazard potential linearly (straight line). When viewed from the hydrogeomorphological aspect, the relationship between slope and hazard potential is 23% and the remaining 77% by other hydrogeomorphological factors.

V. CONCLUSION

➢ *The Conclusions that can be Drawn from this Research are:*

- The slope gradient factor covers an area of 3507.84 Ha or 52.6% of the total area with details of flat–very gentle classes (classes L1, L2, L3 and L4),
- This flat to very gentle class has a slope of 0–7%;
- The flat-very flat class or 52.6% of this, has the potential for flooding of an area of965.8 Ha or27.5% of the plain area and/or 14.4% of the area of Gorontalo City
- The class is quite steep (class L5 >8%) covering an area of2,782.18 Ha in the form of hilly/mountainous areas

REFERENCES

[1]. Arsyad, S., 2006, Soil and Water Conservation, IPB Press, Bogor

[2]. Public Works Department, 1987, Standard Method for Calculating Flood Discharge, Public Works Department, LPMB Foundation, Bandung

[3]. Department of Public Works, 2004, Hydrology and Hydrometry Report, Department of Public Works / Kimpraswil, Gorontalo Province

[4]. Ghozali, H. Imam, 2011, Multivariate Analysis Application with IBM SPSS 19 Program, Diponegoro University Publishing Agency, Semarang.

[5]. Purba, MP, 2009,The Amount of Surface Flow (Runoff) on Various Types of Slopes Under Eucalyptus spp. Stands. (Case study in HPHTI PT. Toba Pulp Lestari, Tbk. Aek Nauli Sector, Thesis, Department of Forestry, Faculty of Agriculture, North Sumatra, Medan.

[6]. Sebastian, L., 2008, Flood Prevention and Mitigation Approach, Journal of Civil Engineering Dynamics, Volume 8, Number 2, July 2008 : 162 – 169.

[7]. USDA, 1968, Soil Interpretation for Recreation, Soil Memorandum 69, SCS-USDA, Washington.

[8]. Zuidam, RAV, and Cancelado, 1979, Terrain Analysis and Classification Using Aerial Photography, ITC, Enshede, (The Netherlands)

[9]. Zuidam, RAV, 1983, Guide to Geomorphologic Aerial Photograph Interpretation and Mapping, Section of Geology and Geomorphology, ITC, Enshede, (The Netherlands).

[10]. Zuidam RAV and Voskuil, 1982, Example for Geomorphological Maping in Central Java, ITC Journal, 3 : 293 – 297