Gis Application to Determine the Settlement Environment of Landslide Prone in Ngaliyan District, Semarang City

Heri Tjahjono
{heriridlo@yahoo.com}

Universitas Negeri Semarang, Indonesia

Abstract. The population in Semarang City is increasing in number. The limited area of settlements has caused many settlements to be established in unfavorable locations, which are located in landslide prone areas. The purpose of this study is (1) Determine the distribution of settlement environments prone to landslides with the help of GIS (Geographic Information System) technology in the Ngaliyan District of Semarang City, (2) Analyze community efforts in tackling settlements that are prone to landslides.The variables studied were: (a) terrain physical including: slope, soil texture, density (number) incision, land use, rock weathering depth, steep walls, soil solum, soil permeability, vegetation density, rock weathering, structure rock lining, rock strength, groundwater depth, concentration of springs / seepage, and rainfall; (b) Land use for settlements. Data was collected through field surveys. Data analysis with scoring, and overlaying with GIS technology. The total score is used to determine the distribution of landslide prone areas. Landslide hazard maps are then overlay with residential land use maps with the ArcGIS program, so that maps of residential areas prone to landslides can be obtained.

Keywords: Settlements Prone to Landslides, Ngaliyan District

1. Introduction

Landslide disaster in Central Java in 2011-2015 have the highest frequency compared to other disaster, that 568 incidents [1]. Specifically for landslide, the existing data shows that the occurence of landslide in the Semarang City has a high frequency. In 2012, there were 39 occurrences of landslide in Semarang City, in 2013 there were 44 times and in 2014 there were 123 times [2]. The Occurrence of landslide in Semarang City showed a tendency to increase.

Ngaliyan subdistrict is one of the subdistrict that Semarang City Government is wary of as an area threatened by landslides. Ngaliyan subdistrict has quite a lot of landslides during 2012 happened 5 times, in 2013 it happened 12 times, in 2014 it happened 18 times, in 2016 it happened once, in 2017 happened 3 times and in 2018 it happened once. Landslides occur in several villages, including Tambak Aji Village, Purwoyoso, Kalipancur, Gondoriyo, Wonosari, Bamban Kerep and Ngaliyan Village [3].

Disaster impact vary, if the community is not ready, disasters often cause cummunity panic and cause suffering and sadness prolonged, such as wounds, deaths, economic pressures due to loss of business/work and wealth, loss of family members and damage to infrastructure, and environment. The fact that has happened so far is the loss of preperty and casualties, which means that the attention and concern of the community for disasters needs to be [4].

Humans or communities in the context of disasters, are objects as well as subjects of the disaster itself. The community not only faces the threat before the disaster, but also has to bear

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the risk of losing lives and property due the disaster, even they still have to face a situation where they have to make a recovery both physically and mentally after disaster. Therefore, there needs to be an effort to be able improve the capability or capacity of the community in the faces of disasters [5].

The development of settlements needs to be directed in an integrated manner so that the synergy of productivity and natural sustainability can be established. The selection of the right location for settlements has strategic and important meaning in spatial aspects [6]. This can determine the durability of the building, the economic value and the impact of the settlement on the environment.

The population of Indonesia from year to year is always increasing. This condition will bring consequences to the increasing need for living space in the form of residential land. The limited land for settlements has caused many buildings and facilities to be erected in locations that are not profitable and can even endanger the safety of the occupants, because it is located in an avalanche danger area.

In each area development plan for the residential area or for other uses regional information is needed. Considering the above information from time to time can change rapidly then a system is needed that can store, edit, analyze information quickly too, that is Geographic Information Systems (GIS).

In line with rapid population growth and rapid development, of course, it will be followed by the use of natural resources that exceeds its carrying capacity and increasing land needs, even occupying an unstable area, so that it is feared that the human environment will be drastically degraded. Land degradation especially the physical environment will trigger natural disasters. Concerns about the increasing number of casualties and property losses in the occur of a natural disaster, especially due to catastrophic landslides have invited a thought of researchers to try to reduce and prevent, or at least identify, map landslide-prone areas that can be used to mitigate landslides.

The upper Semarang region, which is partly in the form of hills with steep sloping slopes, is an area that is currently a residential development area. One of them is Ngaliyan subdistrict, Semarang City. The existence of slope instability driven by human activities that do not pay attention to the balance of the environment, such as cutting cliffs for roads, making residential complexes on steep slopes, will further support the occurrence of landslides that can cause many losses.

The purpose of this research is (a) to determine the distribution of landslide-prone residential environments with the help of GIS technology, (b) to analyze efforts made by the community in tackling landslides prone to landslides in the Ngaliyan subdistrict of Semarang City.

2. Research Method

The objects researched were physical conditions and land use for settlements. The research population was in the form of physical conditions and land use for settlements in the Ngaliyan subdistrict of Semarang City. The research sample was taken using a purposive sampling technique (considering the possibility of an avalanche). The number of samples is 15 sample points.

Variables in this study include; 1) the field physical characteristics variable against the threat of landslides, consisting of: (a) geomorphology conditions (slope), (b) soil texture, (c) rock weathering rates, (d) rainfall, (e) History of incidents / year, (f) rock coating structure, (g)

slope / seepage water management, (h) vegetation density, (i) excavation / slope cutting, and (j) object position / risk position; 2) Variable efforts made by the community in tackling landslide-prone environments.

Primary data is collected by survey in the field. The data analysis techniques used are (1) qualitative description; used to describe the research area in general; (2) scoring analysis, carried out by summing the value or score for each field physical parameter variable in the settlement environment. The sum of the variable values is used as the basis for determining the level of threat of avalanche disaster. After scoring analysis, followed by (3) map overlay analysis, with the help of ArcGIS 10.3 tool, to obtain (a) avalanche threat level maps, and (b) avalanche disaster-prone neighborhood maps, obtained from the overlay between land use maps for settlements with landslide hazard level maps.

Hazards Level Analysis is completed by scoring to the physical characteristic of field that becomes indicator of hazards. The lowest score = 1 means very low hazards. Score 2 means low hazards, Score = 3 means the hazards is medium, Score = 4 means high hazards, and the highest score = 5 means a very high hazards. The higher the score, means the higher the contribution of these variables to the hazards of landslides. Parameters and Scoring in the hazards Index is shown in Table 1.

Table 1. Parameters and Scoring in the hazards Index

Parameter	Score					Weight (%)
	1	2	3	4	5	
Slope of the slope	0-2 %	>2-15 %	>15-25 %	>25-45 %	>45 %	20
Soil Texture	Sand	Clay sand Dusty sand	Sandy clay clay,Dusty clay Dust	Clay Sandy clay Clay clay	Sandy sand Clay Dust Clay	10
Rock weathering level	Mild weathering	Medium weathering	Advanced weathering	Weathering is very advanced	Perfect weathering	10
Rainfall	<1500 mm/year	1500 - <2000 mm/year	2000 - <2500 mm/year	2500 - <3000 mm/year	>3000 mm/year	10
History of genesis/year	0	1	2 s.d 3	4	>4	10
Stone Coating Structure	Horizontal, on flat terrain (0-3%)	Oblique, on flat to choppy terrain (3-8%)	Tilt on Wavy terrain (8-14%)	Lean with soft-hard coating on corrugated / wavy terrain (8-20%)	Sloping with soft hard coating on bumpy-hilly terrain (> 20%)	10
Slope water/ seepage	There is no water springs	There is 1 spring	There is 2 spring	There is 3 spring	seepage belt	5
Vegetation density	Very tight (75%-100%)	Tight (50 % - < 75 %)	Medium (25 % - <50 %)	Rarely (15 % - < 25%)	Very rarely (< 15 %)	5

Extracting / cutting slopes	There is no	a little 1	Is being/ Medium 2 s.d 3	Many 4 s.d 5	Very much >5	10
Position of the object is at risk of threats	Very far (>100 m)	far (100->50 m)	medium (50 - > 20 m)	Close/ near (20->5 m)	Very close (< 5 m)	10
Total						100

Source: [7]–[11].

In detail the steps taken to analyze the level of threats to landslide disasters are as follows:
1. Determine the lowest number of index values.

The lowest number of index values is determined by multiplying the lowest score (1) with the weight of each physical parameter divided by 100 so as to find the index value. Than, the index value for each physical parameter is summed so that the lowest threat index value is found. Likewise for the highest number of index values, calculated by multiplying the highest score (5) with the weight of each physical parameter divided by 100. Further, these steps can be seen in Table 2, and Table 3.

Table 2. lowest threat index value (score 1)

Physic Parameter Number	Lowest Score	Weight	Index Value
1	1	20	0,2
2	1	10	0,1
3	1	10	0,1
4	1	10	0,1
5	1	10	0,1
6	1	10	0,1
7	1	5	0,05
8	1	5	0,05
9	1	10	0,1
10	1	10	0,1
Total			**1**

(Source:Research Analyze, 2017)

The lowest number of threat index values = 1

2. Determine the highest number of index values

Table 3. The Highest Threat Index Value (score 5)

Physic Parameter Number	Highest Score	Weight	Indexs Value
1	5	20	1
2	5	10	0,5
3	5	10	0,5
4	5	10	0,5

5	5	10	0,5
6	5	10	0,5
7	5	5	0,25
8	5	5	0,25
9	5	10	0,5
10	5	10	0,5
Total			**5**

(Source:Research Analyze, 2017)

The highest number of threat index values = 5

3. Calculating the range of index values
   = the highest number of index values - the lowest number of index values
   = 5 - 1 = 4
4. Determine the criteria used.
   In this research using 5 threat criteria (very low, low, medium, high, very high).
5. Determine the interval of index values, namely the range of index values divided by the threat criteria used.
   = 4/5 = 0.8.
6. Make the threat criteria class table with the threat index value interval class, as in Table. 4

Tabel 4. Criteria for determining landslides disaster levels

No	Class Threat	Interval Value of Threat Index
1	Very Low	1 - < 1,8
2	Low	1,8 – <2,6
3	Medium	2,6 - <3,4
4	Height	3,4 - < 4,2
5	Very High	4,2 - 5

(Source:Research Analyze, 2017)

3. Result and Discussion

The area of Ngaliyan Subdistrict based on the Regional Spatial Plan in 2011 was 4,490.73 hectares. Ngaliyan Subdistrict has administrative boundaries as follows: (a) The north is bordered by Tugu Subdistrict and Semarang Barat Subdistrict, (b) East side borders Gajah Mungkur and Gunungpati Subdistricts, (c) South borders with Mijen Subdistrict and Gunungpati Subdistrict, and in the West are bordered by Mijen Subdistrict and Kendal Regency. Ngaliyan Subdistrict consists of 10 urban villages, namely Bambankerep Subdistric, Beringin, Gondoriyo, Kalipancur, Ngaliyan, Podorejo, Purwoyoso, Tambakaji, Wates, and Wonosari Subdistric.

Assessment of landslide threats / hazards in Ngaliyan Subdistrict, Semarang City, is compiled using several physical indicators that contribute to the threat / danger of landslides. Physical indicators related to the threat of landslides referred to are slope, soil texture, rock type (geological conditions), rainfall, history of landslide occurs, rock structure, slope water / seepage, vegetation density, excavation / slope cutting, position or the location of the object risks the threat of landslides.

The unit of analysis used is the terrain unit, which is composed of maps of landforms, types of constituent rocks, family of land and slope classes. The four maps are stacked

(overlayed) to produce a terrain unit map. After analyzing using the geographic information system tool (ArcGIS.release 1.4), results were obtained in the form of variations in the level of danger / threat of landslides in the city of Semarang.

The threat of landslides area based on the area of the terrain in Ngaliyan Subistrict is 4,011.4 ha (89.3% of the total administrative area of the Ngaliyan Subdistrict). The widest threat area of the largest landslide is owned by the Podorejo village with an area of 731.0 ha (consisting of 4 terrain units). The smallest threat area is owned by Purwoyoso Village with an area of 186.3 ha (consisting of 4 terrain units). Based on the avalanche threat class, Ngaliyan Subdistrict is dominated by low category threats, with an area of 2.009,1 ha (44.7% of the total administrative area of Ngaliyan Subdistrict). From this area there are 19 terrain units (from 57 terrain units in Ngaliyan Subistrict). Furthermore, data on the number of terrain units and the extent of landslide threats in Ngaliyan Subdistrict are detailed in Table 5.

Table 5. Data on the Number of Terrain Units and The Extent of Landslide Threat in Ngaliyan Subdistrict

No.	Village	Low Threat Class			Medium Threat Class			High Threat Class			Large Totals
		Terrain Unit	Large (Ha)	% Large	Terrain Unit	Large (Ha)	% Large	Terrain Unit	Large (Ha)	% Large	
1	Bambankerep	2	19,5	1	4	278,9	14	4	1,4	9,8	299,7
2	Beringin	3	99,1	4,9	6	199,6	10	0	0	0	298,7
3	Gondoriyo	1	134,1	6,7	1	383,4	19,3	0	0	0	517,5
4	Kalipancur	2	35,7	1,8	7	153,6	7,7	0	0	0	189,3
5	Ngaliyan	2	146,7	7,3	5	402,5	20,2	1	12,5	90,2	561,7
6	Podorejo	3	458,1	22,8	1	272,9	13,7	0	0	0	731
7	Purwoyoso	1	109,4	5,4	3	76,8	3,9	0	0	0	186,3
8	Tambakaji	1	246,4	12,3	2	168,8	8,5	0	0	0	415,2
9	Wates	3	375,1	18,7	2	14,1	0,7	0	0	0	389,2
10	Wonosari	1	385	19,2	2	37,7	1,9	0	0	0	422,7
	Total	19	2.009,1	100	33	1.988,3	100	5	13,9	100	4.011,4
	Terrian Unit Total										57
	Large %		44,7			44,3			0,3		89,3

Source: Research Results (2017-2018)

Podorejo Village has the widest threat area in the low category with an area of 458.1 ha (7.3% of the total area that has a low category threat in Ngaliyan Subdistrict, which consists of 2 terrain units). Ngaliyan Village has the widest threat category in the broadest area with an area of 402.5 ha (20.2% of the area that has a moderate threat in Ngaliyan Subdistrict, which consists of 5 terrain units). Ngaliyan Village has a threat area of the widest high category with an area of 12.5 ha (90.2% of the total area which has a high category threat in Ngaliyan District, which consists of 1 terrain unit). Besides Ngaliyan Village, Bambankerep Village also has a high category threat area with an area 1,4 Ha. Furthermore, the distribution of the threat level in Ngaliyan District is presented in Figure 1.

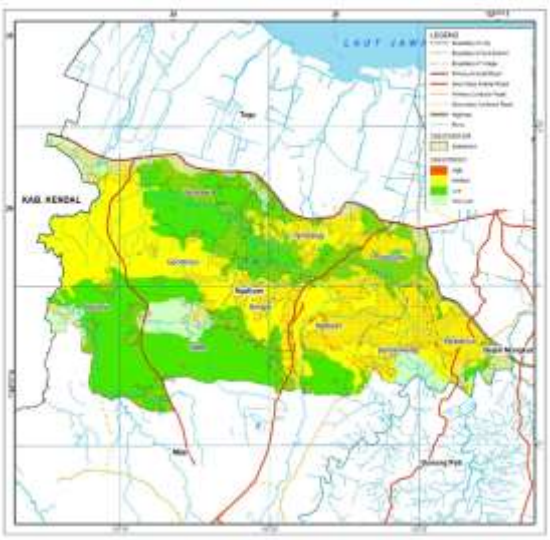

Fig. 1. Map of the distribution of threat levels for landslides in Ngaliyan District

Furtheremore, the broad percentage of threats of each Village in Ngaliyan Subdistrict is presented in Figure 2

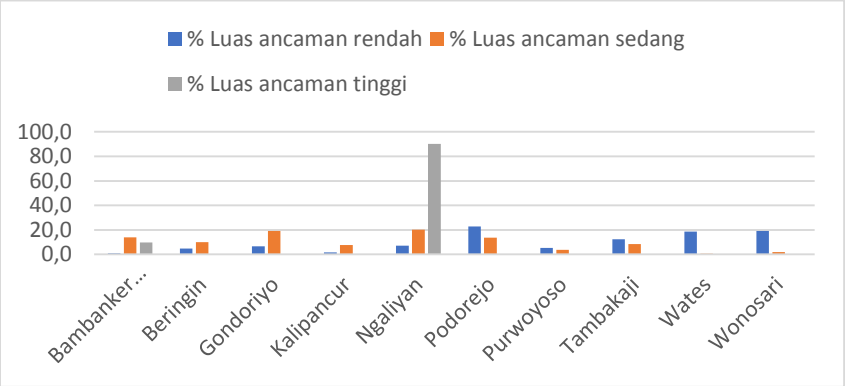

Fig. 2. Threats Large Percentage Graph on each Village in Ngaliyan Sudistrict
(Source: Research Results 2017-2018)

After the threat map for the landslide disaster is determined, the next step is to map the land use for settlements. The map of land use for settlements in this study was made by referring to the existing land use map. Furthermore, existing land use maps are upgraded with High Resolution Satellite Imagery (CSRT) so that new land use maps are obtained. Based on the analysis of high resolution satellite imagery, the Ngaliyan Subdistrict area has many variations in land use. The variations in land use in Ngaliyan District are presented in Table 5.

Table 6. Land Use Data in Ngaliyan District

No	Type of Land Use	Large area (Ha)	Large area (%)
1	Mixed Gardens	916,11	20,40
2	Empty land	131,66	2,93
3	Field	2,79	0,06
4	Plantation	1.019,03	22,69
5	Settlements and other buildings	1.828,25	40,71
6	Rice Fields	63,85	1,42
7	Shrubs	99,07	2,21
8	Moor	429,98	9,57
	Total	4.490,73	100

Source: Analysis of Hight Resolution Sattelite Imagery, Semarang City,(2016).

Table 6 shows that land use in Ngaliyan subdistrict is grouped into eight, namely mixed gardens, vacant land, fields, plantations, settlements and other buildings, rice fields, shrubs, and moor. The most extensive land use is settlements and other buildings with an area of 1,828, 25 ha or 40.71% of the total area of Ngaliyan Subdistrict. This area shows that Ngaliyan Subdistrict is one of the sub-districts in Semarang City which is a concentration of settlements, so it requires serious attention.

For the distribution of new land uses can be seen in Figure 3. About the map of land use in Ngaliyan Subdistrict.

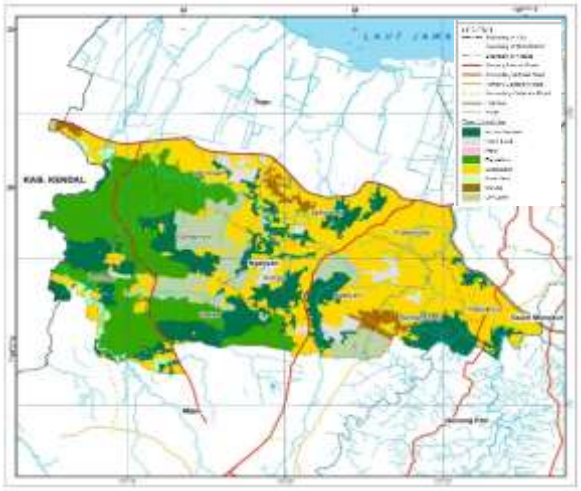

Fig. 3. Map of land use in Ngaliyan District

After the land use map in Ngalian Subdistrict is determined, the next stage of the land use map in Ngalian Subdistrict is overlaid with an avalanche hazard map, using the help of the GIS tool. The results of the overlay of the two maps resulted in new information in the form of residential areas that have the threat of landslides with various levels, from residential areas that have the threat of low, medium and high landslides, as well as areas that are safe from disasters. Furthermore, maps of residential areas that have low, medium and high landslide hazards are presented in Figure 4.

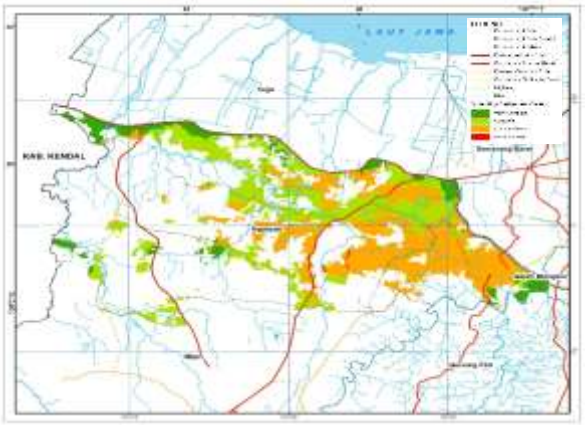

Fig. 4. Distribution map of settlements with avalanche threat level.

Data on residential areas that have the threat of landslide disasters in Ngaliyan subdistrict are presented in Table 6.

Table 7. Extent of residential areas that are threatened by landslides low, medium and high in Ngaliyan Subdistrict

Landslides Threat Level	Type of Land Use	Information	Large area (Ha)
There is no threat	Settlement	Settlements without the threat of landslides	218.48
Low	Settlement	Low threat settlements	736.85
Medium	Settlement	Medium threat settlements	869.65
High	Settlement	High threat settlements	3.26
Total			1828,25

Source: Research Results 2017-2018.

Based on Table 6, it can be explained that the area of settlements in Ngaliyan Subdistrict which have the threat of landslide disaster with the medium criteria are the most extensive residential areas and buildings with an area of 869.65 Ha. Whereas the residential areas in Ngaliyan Subdistrict which have the threat of landslides with high criteria are the smallest (narrow) residential areas with an area of 3.26 Ha.

Settlement areas in Ngaliyan Subdistrict that do not have the threat of landslide disaster are the most suitable areas for settlement and settlement future development, because this region has no inhibiting factors, and from the point of view of environmental carrying capacity has the highest environmental carrying capacity. Settlement areas that have the threat of landslides with low criteria are suitable areas for settlements, because this area has the threat of a small avalanche. For residential areas that have the threat of landslide disaster with moderate criteria, it is an area that begins to be less suitable for settlements, because it has a reduced carrying capacity of the environment. Whereas residential areas that have the threat of landslides with high criteria are areas that are not suitable for settlements, because at any time there can be catastrophic landslides that result in loss of property, as well as human lives.

The results of observations and interviews with residents who occupy settlements prone to landslides about efforts to prevent landslides from occurring, can be explained by several efforts to prevent landslides in residential areas, including:

1. Making mud / swales to prevent landslides from occurring on land the slant around the settlement.
2. Arrange waterways so that water does not enter the land in residential areas or built-up areas that are sloping and prone to landslides.
3. Reducing development with heavy construction in residential areas, because the presence of heavy construction can increase the weight of the soil, so that it will easily erode.
4. Communities are prohibited from digging/cutting slopes around residential areas or built areas.
5. The community is recommended not to make water ponds in sloping residential areas, because the presence of a pool of water can accelerate the saturation of the land and increase the heavy burden of the land so that it will easily erode.
6. The community needs to check cracks in the soil and the flow of water on the slopes which becomes increasingly cloudy as an initial sign or symptom of an avalanche disaster; (g) Increasing the strengthening of the physical structure of houses in landslide-prone areas.
7. Do not build houses on steep slopes to avoid landslides.
8. There is a need for people (village officials) or community organizations (youth organizations) that specifically handle landslide disaster management.
9. Hold socialization on landslide disaster education in areas prone to landslides.
10. Hold training on landslide and first aid disaster evacuation in each vulnerable community group.
11. Avoid hoarding on slopes and cutting at the foot of the slope.
12. Drying puddles (ponds, puddles, etc.) at the top of the slope.
13. Greening deforested areas with certain plants (lamtorogung, sanakeling, etc .
14. Controlling surface water on slopes so that erosion does not occur causing deeper flow.
15. Preventing the erosion of rivers around the built up area which will.
16. Closing / flattening the indentation area that allows inundation.
17. Use of fastening buildings (poles, retaining walls, etc.).
18. Arrangement of land / land use according to directions in conservation.
19. No to cut trees in slope areas to prevent landslides.
20. Planting hard-rooted perennials (such as mahogany, teak, sono keling, and others) in landslide prone areas.

The government needs to make landslide hazard maps, in sub-districts / kelurahan or areas that have potential landslides.

4. Conclusion

Based on the results of the research and discussion it can be concluded that:

1. Residential areas that have landslide threats with low criteria covering an area of 736.85 ha, are suitable areas for settlements, because this area has the threat of a small avalanche. Whereas the residential areas that have the threat of landslide disaster with high criteria covering an area of 3.26 are areas that are not suitable for settlements, because at any time there can be catastrophic landslides that result in loss of property, as well as human lives.
2. Several efforts to prevent landslides in residential areas, including:

a. Making mud / swales to prevent landslides from occurring on land the slant around the settlement.
b. Arrange waterways so that water does not enter the land in residential areas or built-up areas that are sloping and prone to landslides.
c. Reducing development with heavy construction in residential areas, because the presence of heavy construction can increase the weight of the soil, so that it will easily erode.
d. Communities are prohibited from digging/cutting slopes around residential areas or built areas.
e. The community is recommended not to make water ponds in sloping residential areas, because the presence of a pool of water can accelerate the saturation of the land and increase the heavy burden of the land so that it will easily erode.
f. The community needs to check cracks in the soil and the flow of water on the slopes which becomes increasingly cloudy as an initial sign or symptom of an avalanche disaster.
g. Increasing the strengthening of the physical structure of houses in landslide-prone areas.

Do not build houses on steep slopes to avoid landslides.

4.1 Recomendation

People/communities in residential areas that have the threat of landslides with high criteria are advised (1) to always be aware of the occurrence of landslides, which can occur at any time, especially in the rainy season. The community must cooperate with the government and the private sector in an effort to reduce losses due to landslides. (2) to always try both individually or in groups to prevent landslides.

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