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ANALYSIS OF THE LEVEL OF VULNERABILITY TO LANDSLIDE DISASTER IN PAMIJAHAN DISTRICT OF BOGOR REGENCY

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Abstract: The Pamijahan District area is a plain that is quite vulnerable to landslides. The morphology is hilly and has a slope that varies from gentle (8–15%) to steep (> 40%). In addition, landslides can be very risky due to social, economic, physical, and environmental conditions. The purpose of this study was to determine the level of vulnerability to landslides and the distribution of vulnerability to landslides in Pamijahan District. In this study, the methodology and techniques used are quantitative descriptive with scoring or grading data analysis techniques. Based on the analytical calculations carried out, there are two categories of landslide vulnerability levels, namely high vulnerability and moderate vulnerability. The high vulnerability category covers an area of 2,605 ha covering 6 villages namely Ciasihan Village, Cibitung Kulon Village, Gunung Sari Village, Gunung Picung Village, Gunung Menyan Village, and Gunung Bunder Satu Village. The moderate vulnerability category covers an area of 3,959 ha covering 4 villages namely Cibunian Village, Ciasihan Village, Purwabakti Village, and Pasarean Village.

INTRODUCTION

West Java Province is a land area that is divided into hilly areas in the middle which are between 100 and 1,500 meters above sea level, a fairly large plain area in the north which is between 0 and 10 meters above sea level, and mountainous in the south which is more than 1,500 meters above sea level. The area of West Java covers a total area of about 35,377.76 km^2 (Dody Herlando, 2019).

According to the Center for Volcanology and Geological Hazard Mitigation (PVMBG), Bogor Regency is one of 21 places in West Java Province that are prone to landslides. Pamijahan District is one of the sub-districts in Bogor Regency which is located at the foot of Mount Salak Bogor and is one of 16 sub-districts that are prone to landslides in Bogor Regency (Rahayu, 2016). With the morphological characteristics of the hilly land, it has a slope that varies from gentle slope (8-15%) to steep (> 40%). The condition of the land makes Pamijahan sub-district the potential for landslides to occur (Ulfah Rahayu et al., 2019).

One of the main causes of landslides in Pamijahan District, which has a total area of 10,624.28 ha, is the type of soil, namely clay and lithosol soils with clay and sandy textures. In addition, the condition of the slopes which are quite high and steep from the hills to the mountains is another determining factor in the occurrence of landslides. Moreover, the climate-type

conditions are moderate with an average rainfall of 363.116 mm/year. Land use conditions are plantations, rice fields and settlements. The area condition makes the Pamijahan sub-district an area prone to landslides which has the potential to cause loss of property and take lives (Ulfah Rahayu et al., 2019). It can be seen in (Figure 1), shows a map of the level of vulnerability to landslides in Pamijahan sub-district.

Figure 1. Map of Landslide Vulnerability in Pamijahan District, Bogor Regency
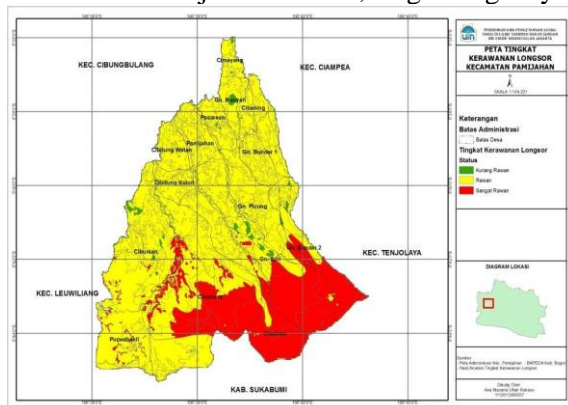
Source:Ulfah Rahayu et al., (2019)

According to the Bogor Regency Regional Disaster Management Agency (BPBD) information, 17 landslides have occurred in Pamijahan District, Bogor Regency. The last incident occurred on June 22, 2022, in Cibunian Village, Pamijahan District. The results of a rapid investigation by BPBD Bogor Regency have suspected that the landslide occurred due to heavy rain. The existence of residents' houses around the incident site and the unexpected landslide disaster caused damage to residents' houses and many casualties (bpbd.bogorkab.go.id).

The existence of landslides and the negative impacts they cause indicate that the vulnerability of the area to landslides is

still high (Fitri, 2016). Therefore, knowing the level of vulnerability is very important because it affects the impact or risk when a disaster occurs and factors that affect high risk arise, one of which is when the hazard is in a vulnerable state (Aryan, 2015). The level of vulnerability can be assessed in terms of physical (infrastructure), social (human), economic, and environmental as stated in the Regulation of the Head of the National Disaster Management Agency Number 02 of 2012.

The characteristics of landslide disasters such as those that occur suddenly and repeatedly can pose a serious threat in the form of high risk (Harnani, 2020). Therefore, it is important to analyze how much the level of vulnerability of an area affects the level of landslide risk. This research was conducted to provide information on the level of landslide vulnerability and an overview of the distribution of landslide vulnerability levels (Nugroho & Nugroho, 2020).

Based on the physical condition of the area, there is a potential for landslides to recur. The potential for landslide disasters may be repeated and there are elements at risk in landslide-prone areas such as social, physical, economic, and environmental conditions. This has the potential to generate a high level of risk when another landslide occurs (Dyah Susanti et al., 2017). Therefore, it is necessary to deal with disasters through disaster mitigation, one of that is non-structural through mapping the level of vulnerability to landslides which has a function as identifying areas with vulnerable groups or the highest losses which can be prioritized recommendations before a landslide disaster occurs (Nugraha et al., 2022).

Based on this background and the problem, this study has 2 (two) research objectives, namely as follows; (1) To determine the level of vulnerability to landslides in Pamijahan District; and (2) To find out the distribution of landslide vulnerability levels in Pamijahan District

LITERATURE REVIEW

Vulnerability is a condition that describes the condition of a community with its characteristics, assets, or property conditions that make it vulnerable to the impact of threats or hazards (UNISDR inDahlia, 2021)

Because a disaster only occurs when a "threat" appears in a "vulnerable" condition, it is important to understand the level of vulnerability as one of the components that affect the impact of a disaster (Rorong et al., 2019). The level of vulnerability can be seen in terms of physical (infrastructure), social (human), economic and, environmental, as stated in the Regulation of the Head of the National Disaster Management Agency Number 02 of 2012.

According to the 2013 Indonesian Disaster Risk Index (IRBI) (Muzani, 2021), a disaster is an event or series of events that threatens and disrupts people's lives and livelihoods, resulting in human casualties, environmental damage, loss of property, and psychological impacts. Disasters can come from natural or non-natural sources, as well as the human element. Vulnerability is one of the things related to disasters, especially related to the magnitude of disaster risk.

A landslide is the movement of slope-forming material, such as rock, sand, or a mixture of other materials moving down or

away from the slope. In addition, a landslide also known as ground motion, is a geological phenomenon caused by the movement of various types of rock or soil masses, such as the fall of large boulders or lumps of soil (Yuniarta et al., 2015). It can be defined that a landslide disaster is described as a movement of soil or rock that forms a slope which results in loss of life and property.

RESEARCH METHODS

The research location is in Pamijahan District, ten villages as research samples with certain characteristics, including landslides that have occurred and are prone to landslides, consisting of Ciasihan Village, Pasarean Village, Purwabakti Village, Gunung Sari Village, Cibunian Village, Ciasmara Village, Gunung Village. Menyan, Gunung Bunder I Village, Gunung Picung Village, Cibitung Kulon Village. It can be seen in (Figure 2) the administrative boundary map of Pamijahan sub-district, Bogor Regency.

Figure 2. Administrative Boundary Map in Pamijahan District, Bogor Regency
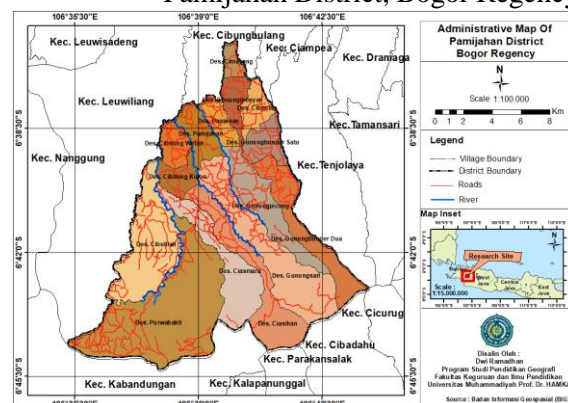
This research is a type of quantitative descriptive research, namely research that reveals a problem or event with a numerical explanation (Heryana, 2020).

This study aims to map the level of landslide vulnerability in Pamijahan District, including the distribution of areas with landslide vulnerability levels. Data collection methods are field surveys and document review, while the data analysis technique used in this study is scoring or grading, after that, a landslide vulnerability score is given to each indicator according to the characteristics in the field.

The vulnerability map is the result of overlapping all vulnerability indicators. Meanwhile, in determining the level of vulnerability of landslides, based on the total score of all indicators. The value of each indicator is multiplied by its weight to determine its weighted score, which is then summed to determine the overall vulnerability of the indicator. Thus, resulting in total vulnerability. Furthermore, the total vulnerability score is divided into three classes **(low, medium, and high)** based on arithmetic categorization to assess the level of vulnerability to landslides (Haribulan et al., 2019).

Based on the social, economic, physical, and environmental conditions, the landslide vulnerability class is determined using a scoring analysis. Population density indicators include the number of children under the age of 5, the number of elderly people, the number of pregnant women, the area of productive land, the density of settlements, public/critical facilities, agricultural land, infrastructure, forest area, shrubs, etc. Here are some examples of score analysis used. Because it is only used to speed up analysis in estimating the degree of landslide susceptibility, weights, and scores do not have absolute values (Tuwonaung et al., 2019).

The primary data collection methods used in this study are observation and documentation. There are two types of data in this study: primary and secondary. To collect secondary data for this research, namely a review of BPBD documents, journals, BPS, and sub-district or village monographs in the research area.

The initial stage of analyzing the level of landslide vulnerability is by giving a value according to the class level of landslide vulnerability on each variable indicator before calculating the score (Scoring). Each level of landslide vulnerability is given a value for each vulnerability class as shown in table 1 below:

Table 1. Landslide Vulnerability Rate

Class	Mark
Low	1
Moderate	2
High	3

Source: (BNPB, 2012)

After determining the vulnerability value, then, determine the total landslide vulnerability by entering the index values (social vulnerability, economic vulnerability, physical vulnerability, and environmental vulnerability) using the following formula:

Kerentanan tanah longsor = $(0,4 \times social\ vulnerability\ index) + (0,25 \times economic\ vulnerability\ index) + (0.25 \times physical\ vulnerability\ index) + (0.1 \times environmental\ vulnerability\ index)$

Source: (BNPB, 2012)

To distinguish one landslide vulnerability class from another, then the value of the landslide vulnerability class interval is determined. The following equation is used to generate the interval class:

$$Class\ Interval = \frac{Max\ score - Min\ score}{3}$$

The categories of social, economic, physical, and environmental vulnerability are used to analyze the level of landslide vulnerability referring to BNPB Regulation 2012 and previous research related to landslide vulnerability. So, the landslide vulnerability parameters are obtained as shown in (table 2), and the research flow thinking framework can be seen in (figure 3):

Table 2. Landslide Vulnerability Parameters

Component vulnerability	Vulnerability Parameters	Weight (%)	Class			Score
Social	Density Resident	60	<500 soul /km ^{2}	500-1000 soul /km ^{2}	>1000 soul /km ^{2}	
	Number of Pregnant Women	40	<20%	20-40%	>40%	
	Amount Poverty					
	Number of Disabled People					
	Amount Group Age Prone to					
Economic	Land Productive	60	>30%	30%-50%	>50%	
	GRDP	40	<100 million	100-300 million	>300 million	Class / Class Max Value
Physical	Density Settlement	40	>40%	40%-60%	>60%	
	Facility General / Critical	30	RS available	Available Health Center / Pustu	No Available	
	Accessibility	30	Arterial Road available	Available Health Center / Pustu	No Available	
Environment	Forest protect	40	<20ha	20-50ha	>50ha	
	Forest Natural	40	<25ha	25-75ha	>75ha	
	Forest Conservation	10	<10ha	10-30ha	>30ha	
	Bush	10	<10ha	10-30ha	>30ha	

Source: Modification based on Perka BNPB 2012; Amalia 2015; Arifin 2010; Muawanah 2016 in (Mantika et al., 2020).

**Figure 3.** Systematic Chart of Thinking Framework
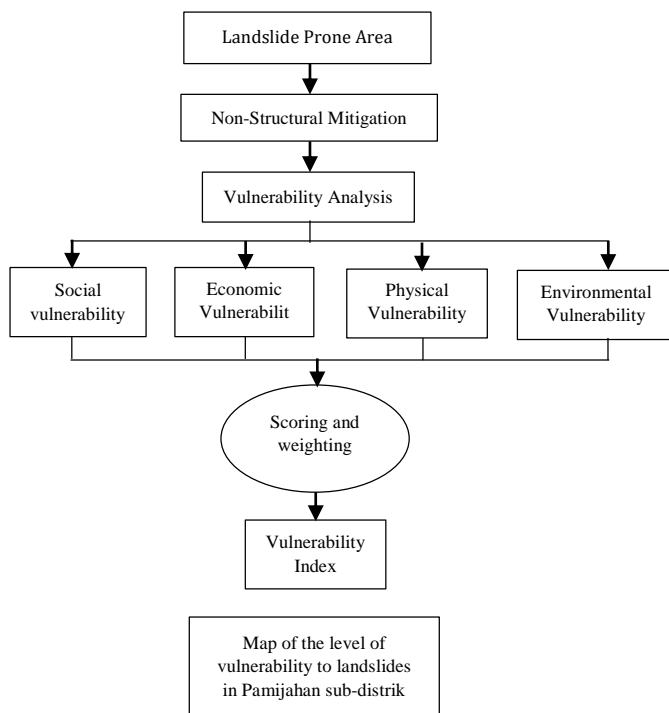
RESULTS AND DISCUSSION

1. Parameter Analysis of Social Vulnerability

The results of the analysis of social vulnerability parameters consisting of 5 (five) indicators consisting of population density, number of pregnant women, number of poor people, number of people with disabilities, and number of people of vulnerable age (toddlers and the elderly) in landslide-prone areas in Pamijahan District. It can be known that areas with low, moderate, and high levels of social vulnerability to landslides. Areas with a high level of social vulnerability are Ciasihan Village, Ciasmara Village, Cibitung Kulon Village, Gunung Bunder 1 Village, Gunung Menyan Village, Gunung Picung Village, and Gunung Sari Village with a total area of 3,377 ha or (41.8%) of the area Pamijahan District. The high level

of social vulnerability is affected by the uneven distribution of the population (centralized) in areas prone to landslides and also the high number of vulnerable groups. Regions with moderate levels of social vulnerability include Cibunian Village and Pasarean Village with an area of 1,525 ha (18.9%) of the total area of Pamijahan District. Regions with moderate levels of vulnerability are affected by the uneven distribution of the population, there are quite a lot of vulnerable groups of people and there are still quite a lot of poor people. Meanwhile, the area with the lowest level of social vulnerability is in Purwabakti Village with a total area of 1,662 ha or (20.6%) of Pamijahan District. The population is spread evenly, the number of poor people is small, and the small number of disabled people is one of the factors for the low level of social vulnerability in the region. This condition is strengthened by (Xiao et al., 2022), stating the conditions and characteristics of each individual in dealing with landslides is one of the variables that affect social vulnerability in landslide-prone areas. The level of social vulnerability to landslides in Pamijahan District is illustrated in figure 4.

Figure 4. Map of Social Vulnerability to Landslides in Pamijahan District, Bogor Regency
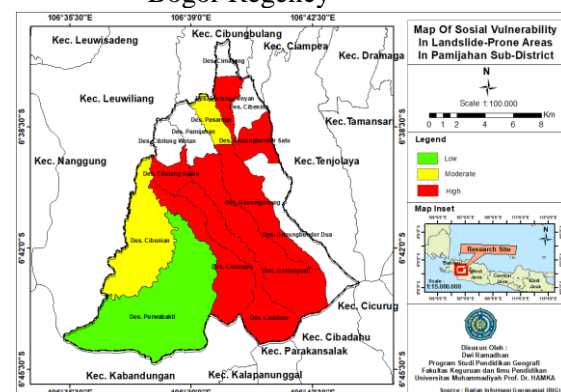
## 2. Parameter Analysis of Economic Vulnerability

From the results of the analysis of economic vulnerability parameters consisting of 2 indicators, namely Productive Land and Gross Regional Domestic Product (GRDP) in landslide-prone areas in Pamijahan District, it can be identified areas with moderate and high levels of economic vulnerability. The area of Ciasmara Village, Gunung Picung Village, and Gunung Sari Village with an area of 1,786 ha or 22.1% of the total area of Pamijahan District, is an area with a high level of vulnerability.

The extent of productive land and the high Gross Domestic Product (GRDP) have an impact on the high level of economic vulnerability, so, when a landslide occurs there is a risk of considerable economic loss in the area because many crops are damaged or crop failures. And areas with moderate levels of vulnerability are Ciasihan Village, Cibitung Kulon Village, Cibunian Village, Gunung Bunder 1 Village, Gunung Menyan Village, Pasarean Village, and Purwabakti Village with a total area of 4,582 ha or (56.7%) of Pamijahan District.

The small area of productive land and the low Gross Domestic Product (GRDP) have an impact on the low level of economic vulnerability, so, there is little economic loss in the area if a landslide occurs.

This condition is strengthened in (Fitri, 2020) the amount of productive land and regional income has an impact on the high level of economic vulnerability when a landslide occurs. The economic vulnerability map of Pamijahan District to landslides can be seen in figure 5.

Figure 5. Map of Economic Vulnerability to Landslides in Pamijahan District, Bogor Regency
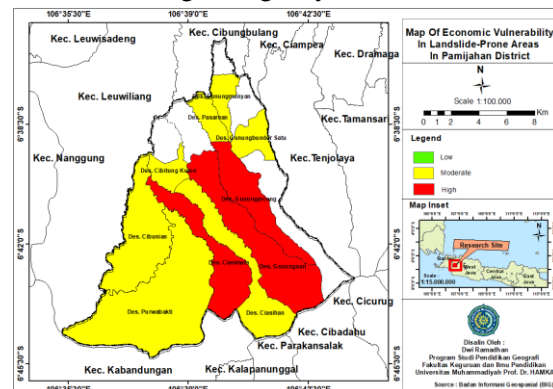
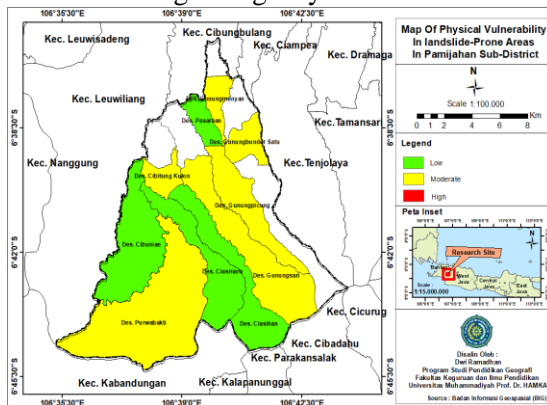## 3. Analysis of Physical Vulnerability Parameters

From the results of the analysis of physical vulnerability parameters consist of 3 indicators, namely: Residential Density, Public/Critical Facilities, and Accessibility in landslide-prone areas in Pamijahan District. It can be known that areas with a level of physical vulnerability to landslides are low dan moderate. Areas with a low level of vulnerability are Ciasihan Village, Ciasmara Village, Cibunian Village, and Pasarean Village with a total area of 2,873 ha or (35.5%) of the total area of Pamijahan District.

The low level of physical vulnerability is influenced by the low number of public facilities/critical facilities, accessibility in the form of public roads, and residential density. When a landslide disaster occurs, there is a low risk of public/critical facilities, accessibility, or settlements. And areas with moderate levels of vulnerability are Cibitung Kulon Village, Gunung Bunder 1 Village, Gunung Menyan Village, Gunung Picung Village, Gunung Sari Village, and Purwabakti Village, with an area of 3,691 ha or (45.7%) of the total area of the Pamijahan District.

Areas with a moderate level of vulnerability are affected by a large number of public/critical facilities, accessibility, and settlements so that when a landslide occurs it will have enough impact on public/critical facilities, accessibility, and settlements to cause material losses.

This condition is reinforced in (Photopoulou & Pitilakis, 2017) states that various buildings are considered to be glued to the soil foundation structure, a foundation is considered flexible so that it is possible to be affected by changes when there is movement of the ground (slide). In figure 6 shows a map of the level of physical vulnerability to landslides in Pamijahan District.

Figure 6. Map of Physical Vulnerability to Landslides in Pamijahan District, Bogor Regency

4. Analysis of Environmental Vulnerability Parameters

Based on the analysis results, there are 4 indicators of environmental vulnerability, namely protected forest, natural forest, conservation forest, and shrubs in landslide-prone areas in Pamijahan District.

It can be seen that landslide-prone areas in Pamijahan District are divided into two categories of environmental vulnerability, namely low vulnerability and moderate vulnerability.

Areas with a low level of environmental vulnerability are Ciasihan Village, Ciasmara Village, Cibitung Kulon Village, Gunung Bunder 1 Village, Gunung Menyan Village, Gunung Picung Village, Gunung Sari Village, Pasarean Village, and Purwabakti Village with a total area of 5,316 ha or (65 .8%) of the total area of Pamijahan District.

The low level of environmental vulnerability is influenced by the low area of protected forests, natural forests, conservation forests, and shrubs. So, the risk of environmental damage is low when a landslide disaster occurs. In the area of Cibunian Village with an area of 1,248 ha or 15.4% of the total area of Pamijahan District, it is an area with a moderate level of environmental vulnerability.

Areas with a moderate level of vulnerability are affected by an area of protected forests, natural forests, conservation forests, and scrubland which is quite large so that it is quite a risk to the environment when a landslide disaster occurs.

This condition is reinforced by (Bhattacharya et al., 2013) stating that in landslide-prone areas, large forest areas can have an impact on how vulnerable ecosystems are to landslides and cause damage to forest land. The level of environmental vulnerability to landslides in Pamijahan District is depicted on the map in figure 7.

Figure 7. Map of Environmental Vulnerability to Landslides in Pamijahan District, Bogor Regency
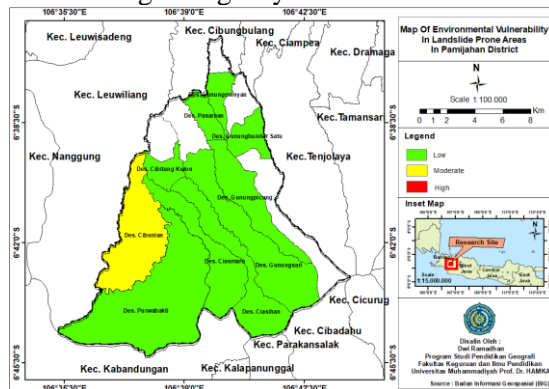
Figure 8. Map of Vulnerabilities in landslide-prone areas in Pamijahan District, Bogor Regency
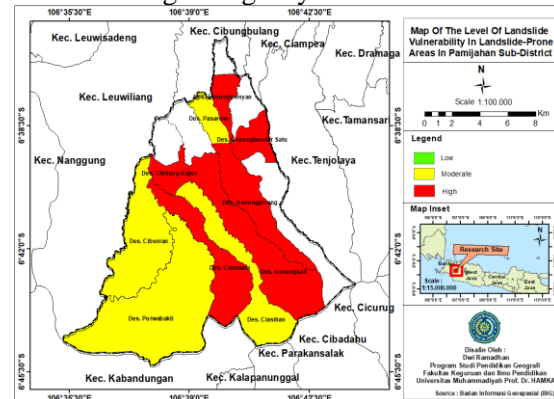
5. Analysis of Landslide Vulnerability

Based on the results of an analysis of the level of landslide vulnerability in 10 villages which are landslide-prone areas in Pamijahan District, Bogor Regency, it is influenced by several factors, including social vulnerability, economic vulnerability, physical vulnerability, and environmental vulnerability.

After calculating the level of landslide vulnerability analysis by using a scoring or grading technique, it is known that there are two classes of vulnerability levels in landslide-prone areas in Pamijahan District, namely medium class and high class. So, it can be classified for differences in the level of vulnerability to landslides in each region which is depicted on a map of the level of vulnerability to landslides. It can be seen the difference in the level of vulnerability and the distribution of vulnerability levels in 10 villages in Pamijahan District which are included in landslide-prone areas. In figure 7 shows a map of the level of vulnerability in landslide-prone areas in Pamijahan District.

It is known that the area of moderate landslide vulnerability in landslide-prone areas in Pamijahan District is 3,959 ha with a percentage of 49% of the area of Pamijahan District, the area with a high level of vulnerability is 2,605 ha with a percentage of 32.2% of the area of Pamijahan District.

The moderate vulnerability level includes 4 (four) villages, namely: Cibunian Village, Ciasihan Village, Purwabakti Village, and Pasarean Village. Areas with a high level of vulnerability include 6 (six) villages, namely: Ciasihan Village, Cibitung Kulon Village, Gunung Sari Village, Gunung Picung Village, Gunung Menyan Village, and Gunung Bunder Satu Village.

Based on the distribution of landslide vulnerability areas in Pamijahan District, most of them are located on the slopes of Mount Salak Endah. The area is the center of economic development in Pamijahan District and is densely populated, with a large area of productive land. So that, when a landslide disaster occurs it can have a significant impact.

CONCLUSION

From the results of the calculations that have been carried out in the form of research data analysis and discussion, it can be concluded that: (1) Areas with a (moderate) level of vulnerability in landslide-prone areas in Pamijahan District, which are 3,959 hectares or 49% of the total area of Pamijahan District. For areas with a (high) class vulnerability area of 2,605 ha or 32.2% of the area Pamijahan District; and (2) In landslide-prone areas in Pamijahan District, the distribution of landslide vulnerability levels is divided into two classes, namely the medium class and the high class. Regions with a moderate level of vulnerability include 6 (six) villages; Ciasihan Village, Cibitung Kulon Village, Gunung Sari Village, Gunung Picung Village, Gunung Menyan Village, and Gunung Bunder Satu Village, with an area of 3,959 ha. In addition, the area with a high level of vulnerability is 2,605 ha which includes 4 (four) villages, including Cibunian Village, Ciasihan Village, Purwabakti Village, and Pasarean Village.

THANK-YOU NOTE

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