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Analysis of Landslide Vulnerability Rate Using Geographic Information Systems in Ciniru Subdistrict, Kuningan District

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Abstract: The purpose of this study is to determine the level of landslide vulnerability in Ciniru Subdistrict, Kuningan District. This research is expected to contribute to disaster mitigation programs and minimize the risk of disasters due to landslides. The method used in this research is the descriptive method. The population in this study is the entire area of the Ciniru subdistrict, which is used as the object of research. The data collection technique is collecting secondary data needed in accordance with the parameters of landslide vulnerability according to Perka BNPB No. 12 of 2012. Data analysis techniques utilize geographic information systems with the help of the ArcGIS 10.3 application in processing secondary data into required base maps. The result of this study shows that the level of landslide vulnerability in Ciniru subdistrict is in the low and medium categories. The medium category covers eight villages: Cipedes Village, Pinara Village, Gunungmanik Village, Cijemit Village, Ciniru Village, Longkewang Village, Rambatan Village, and Mungkaldatar Village, with Cipedes Village as the village that has the highest landslide susceptibility value. The low category includes Pamupukan Village. Villages that are vulnerable to landslides are affected by the values of physical vulnerability, economic vulnerability, and environmental vulnerability, which are included in various categories with the value of social vulnerability, which is included in the low category. Pamupukan village has the lowest vulnerability value for each parameter. The values of physical vulnerability and economic vulnerability of Pamupukan village are included in the medium category, while the values of social vulnerability and environmental vulnerability are included in the low category.

Keywords: vulnerability, landslides, GIS.

基于地理信息系统的库宁南区奇尼鲁街道滑坡易损性分析

摘要：这项研究的目的是确定库宁南区奇尼鲁分区的滑坡脆弱性水平。预计这项研究将有助于减灾计划，并将滑坡造成的灾害风险降至最低。本研究中使用的方法是描述性方法。本研究的人口是奇尼鲁街道的整个区域，被用作研究对象。根据佩尔卡国家银行 2012 年第 12 号，数据收集技术正在根据滑坡易损性参数收集所需的辅助数据。数据分析技术借助弧地理信息系统 10.3 应用程序利用地理信息系统将辅助数据处理为所需的底图。这项研究的结果表明，奇尼鲁街道的滑坡易损程度处于中低类别。中等类别包括八个村庄：西皮德斯村，皮纳拉村，古农曼尼克村，西耶米特村，奇尼鲁村，龙科王村，兰巴丹村和 Mungkaldatar 村，其中西皮德斯村是滑坡敏感性最高的村庄。低级类别包括棉花堡村。易受山体滑坡影响的村庄受到物理脆弱性，经济脆弱性和环境脆弱性的价值的影响，这些价值包括在各个类别中，而社会脆弱性的价值则包含在低类别中。棉花堡村庄的每个参数的脆弱性值最低。棉花堡村的物理脆弱性和经济脆弱性的值包括在中等类别中，而社会脆弱性和环境脆弱性的值包括在低类别中。

关键词：脆弱性，滑坡，地理信息系统。

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1. Introduction

Geologis Indonesia is located at the confluence of three large plates: the Indo-Australian plate, Eurasian plate, and Pacific plate. The plates collide with each other, making Indonesia very vulnerable to disasters [2]. Astronomically, Indonesia is located at coordinates 94^{O} EL-141^{O} EL and 6^{O}SL-11^{O} SL, which causes Indonesia to lie on the equator. It is a country that is illuminated by the sun throughout the year [3]. Its location is at latitude 0^{O} or tropical so that it has two seasons, namely the rainy season and summer in one year [4]. The two seasons' intensity in each region and archipelago varies, depending on the region's location to the longitude position. The more westward to the longitude, the greater the intensity of rainfall. The high rainfall caused various natural disasters [4].

Kuningan Regency is one of the districts located in the southern part of Java Island and is located at the foot of Mount Ciremai. The topographical condition of the Kuningan regency is very varied, starting from the plains to the hills. However, most of the area is hilly and mountainous, with the highest peak, Mount Ciremai. Morphologically, Kuningan Regency is divided into two parts, namely the Plains Morphology Unit and the Hill Morphology Unit. The Morphology Unit of the Hill area is divided into three, namely the Sloping Hill Morphology Sub-Unit, the Moderate Hill Morphology Sub-Unit, and the Ramped Hill Morphology Sub-Unit. The geographical and climate conditions of the Kuningan Regency, as such, cause frequent disasters.

Based on the data from BNPB [11] and BPS [12], landslides are disasters that often occur in the Kuningan regency compared to other disasters. Every year, the number of landslides continues to grow. In 2015 there were 90 incidents. In 2016 there was a significant increase in the number of landslides, which increased to 131 incidents, while in 2017, the number of incidents increased slightly, namely 137 times. This data proves that landslides need to be considered because there is an increase every year. One of the sub-districts that frequently experience landslides is Ciniru District. Areas that often (each year) experience landslides in the Ciniru Subdistrict are Pinara Village and Gunungmanik Village.

The occurrence of landslides often in the Ciniru Subdistrict is due to the geographical conditions in the Ciniru Subdistrict region, which are in the Rough Hills Morphological Subsidence area having a varied slope with a range between 5% -60%. The shape of the landscape forms a rough *berubifatan* so that Ciniru Subdistrict has a bumpy landform. Ciniru Subdistrict is geomorphologically divided into two parts, namely Synclinal Geomorphology Unit and Alluvial Geomorphology Unit. Most of its territory is in the Sinklinal Geomorphology Unit area, a hilly area with steep enough and very steep slopes. Rainfall in Ciniru District is in the range of 2000-2500 mm / year.

Land use in the Ciniru Subdistrict is mostly dominated by productive land in the form of rice fields and non-productive land in the form of natural forests and protected forests. Some villages located in synclinal geomorphology areas such as Gunungmanik Village and Pinara Village residents' houses are usually built on slopes to increase the land burden, triggering landslides.

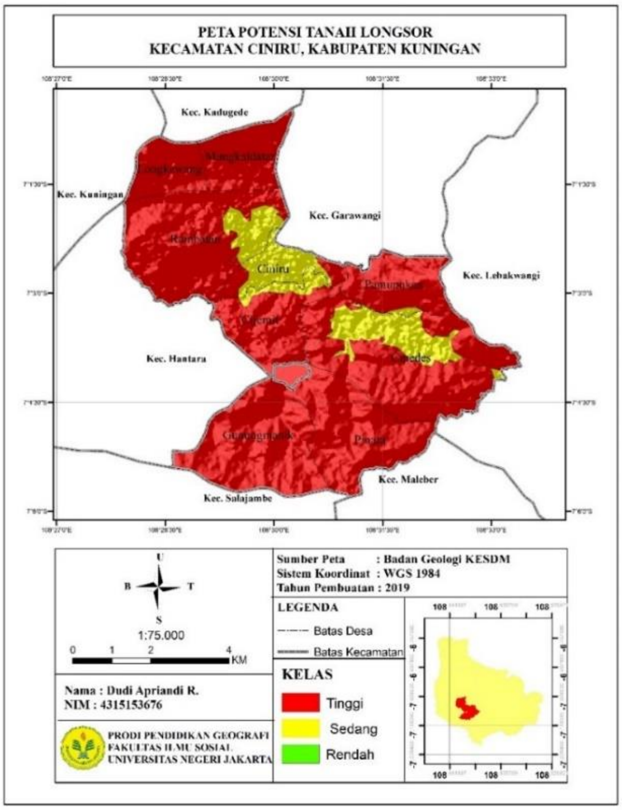

Fig. 1 Landslide potential map of Ciniru District [1]

Ciniru sub-district is a sub-district that has the potential for landslides in the medium and high category. Almost all areas in Ciniru Subdistrict are in the category of high landslide disaster potential. In contrast, the medium category only covers a portion of the area in three villages: Rambatan Village, Ciniru Village, Cipedes Village, and a small portion in Pamupukan Village. According to the Central Statistics Agency (BPS) of Kuningan District in 2018 [12], Ciniru Subdistrict has 18,245 people spread across nine villages. The villages with a high population are Cipedes Village, Rambatan Village, and Cijemit Village, while the village with the lowest population is Longkewang Village. Villages with high population numbers are in high to medium landslide potential areas, and villages with the lowest population numbers are in high landslide potential areas.

Looking at the landslide potential map and each village's population in Ciniru District, it can be assumed that the average population lives in a high landslide potential. With this problem, researchers are interested in researching the vulnerability of landslides in the Ciniru Subdistrict.

1.1. Landslide

A landslide is a form of mass movement of soil, rock, and rock/soil collapse that occurs instantly moving towards the lower slope controlled by the force of gravity and glides over a waterproof, impermeable layer (sliding plane) [5]. Landslide is a mass transfer of soil/rock in an oblique direction from its original position. It is separated from a steady mass due to gravity's influence on the rotational and translational movements [6].

Geologically, a landslide is a geological event in which land movements occur, such as falling rocks or large lumps [7]. Avalanche (slide) is one type of mass movement, namely, the movement of slope-forming material caused by the occurrence of shear collapse along with one or more landslide fields [8]. Landslides are often a factor for substantial losses both in the form of money and lives. The severity of landslides has worsened with increasing urban development and land-use changes [9]. Landslides can be classified into various types, based on the speed of movement, the presence and absence of slip fields, the shape of the slip plane, and the type of mass that moves. If the movement is fast, there is a slip plane, and the mass that moves is a rock called a rockslide. If that moves is the soil, it is called a soil slide. At the same time, a landslide with a slow movement in the form of a flow is a rush flow. Another type of landslide that moves very slowly is the creep's motion.

1.2. Landslide Type

According to the Ministry of Energy and Mineral Resources [10], Landslides can be classified into six types:

1. *Translation* - the movement of soil and rock masses in the plane of a flat or sloping wavy shape.
2. *Rotation avalanche* - the moving mass of soil and rock in a slipped concave field.
3. *Block Movement* - the displacement of rocks that move in the plane of a flat slip. This avalanche is also called the translational block avalanche.
4. *Rock collapse* occurs when large amounts of rock or other material moves downward by free fall. Generally, it occurs on steep slopes to hang, especially in coastal areas. Large rocks that fall can cause severe damage.
5. *Landpan* - a type of slow-moving landslide. The type of soil is coarse and fine grain. This type of landslide is almost unrecognizable. After a long time, this type of landslide avalanche can cause telephone poles, trees, or houses to tilt downward.
6. *Flow:* this type of landslide occurs when a moving mass of land is pushed by water. Flow velocity depends on the slope, the volume and pressure of the water, and material type. Its movements occur along the valley and can reach hundreds of meters away.

1.3. Vulnerability

Vulnerability is a condition of a community or community that leads to or causes the inability to face the threat of disaster [11]. Vulnerability is a set of conditions resulting from circumstances (physical, social, economic, and environmental factors) that adversely affect disaster prevention and management efforts [13], [21].

According to the International strategy for disaster reduction (ISDR) in Diposaptono [4], Vulnerability is conditions determined by physical, social, economic, and environmental factors or processes that increase a community's vulnerability to disaster. A vulnerability assessment is an essential aspect of a mitigation plan where this mitigation effort needs to be targeted at the location and components of its community activities [14].

The vulnerability level needs to be known as a factor that influences a disaster's occurrence because a new disaster will occur if the hazard occurs in a vulnerable condition. That the level of vulnerability can be viewed from physical vulnerability (Infrastructure), social population, and economy [15]. This research's scope can be included in a part of the disaster mitigation program launched by BNPB of the Republic of Indonesia [11]. So, it is hoped that the results can help related parties regarding disaster prevention and management in Ciniru Subdistrict. This study is different from previous studies where this study used the four parameters of Vulnerability set by BNPB in 2012 [11]. According to BNPB [11] in Perka BNPB No. 2 of 2012 concerning General Guidelines for Disaster Risk Assessment, to analyze the level of vulnerability of an area from the provincial and village levels using four parameters. These parameters are:

1.3.1. Social Vulnerability

Social vulnerability illustrates the condition of the level of social fragility in dealing with danger. This social parameter is divided into two, namely, population density and vulnerable groups. Settlement density is the number of inhabitants per unit of a residential area, usually expressed as the number of inhabitants per km2 [5].

Social vulnerability is related to demography, population structure in an area. The number of vulnerable community groups such as infants, toddlers, pregnant women, nursing mothers, disabled people, elderly is a social vulnerability variable from the demographic aspects [16].

1.3.2. Economic Vulnerability

Economic vulnerability describes a condition of the level of economic fragility in dealing with the threat of danger. Economic parameters are divided into two, namely land use (cultivation area) and GRDP per sector.

The economic vulnerability affects the choice of people/society in responding to the threat of danger. Economic limitations lead to the fulfillment of safety standards that are not correctly fulfilled in the context of the choice of residence, buildings, provision of facilities and infrastructure for preparedness and decision making when disasters occur [16].

The lower the socioeconomic, the higher the vulnerability in dealing with disasters. When affected by a disaster, people with strong economies can help themselves, for example, by evacuating in lodging or other places [17]. In developing countries, it is always challenging to deal with disasters due to high-cost factors in handling natural disasters [18].

1.3.3. Physical Vulnerability

Physical vulnerability (infrastructure) describes a physical condition (infrastructure) vulnerable to certain hazard factors. This condition of vulnerability can be seen from various indicators. The indicators used are houses and facilities. This facility is divided into critical facilities including hospitals, health centers, posyandu, and private property and public facilities, which include schools, mosques, prayer rooms, village halls, sub-district offices, markets, and other buildings that are owned by the government or private [15].

1.3.4. Ecological/Environmental Vulnerability

Environmental vulnerability describes the condition of land cover in an area and is prone to hazard factors. Land cover in the form of forest plants will reduce erosion. However, vegetation does not always help in the slope's stability as there is a disturbance in the stability of the slope caused by the weight of the vegetation. The strength of the wind that hits the vegetation becomes an additional power in the slope's stability. Besides, plant roots can be detrimental because they can penetrate the soil and widen pores in the soil [9].

Indicators in ecological parameters are land use in protected forest areas, including protected forests, natural forests, mangrove/mangrove forests, swamps, and shrubs. This forest type has very dense vegetation so that the erosion process can be reduced, and the level of water saturation can be retained by vegetation in the area [20]. Good soil cover vegetation such as thick grass or dense jungle will eliminate the influence of rain and topography on landslides [19].

2. Method

This study's research method is a descriptive method that aims to provide a more in-depth picture of the level of landslide vulnerability in the Ciniru District. This study's research subject is the Ciniru Subdistrict region with its unit of analysis, namely in each village so that the sub-district and village governments act as supporting data.

Data collection techniques in this study are interview techniques. This study uses primary and secondary data. This study's primary data are looking for information to the district and village governments about the level of landslide vulnerability as support. This study's secondary data were obtained from several agencies, especially the village government and the Kuningan District Statistics Agency. This secondary data is useful to obtain the level of landslide vulnerability, including population density, vulnerable groups, number of houses, number of critical facilities, number of public facilities, productive land area, non-productive land area, and Village Original Income. Data analysis techniques in this study used the help of Geographic Information Systems. This geographic information system aims to map the level of landslide vulnerability in the Ciniru Subdistrict.

The secondary data obtained is used as a reference to become a base map. The base map is weighted according to the parameters of landslide vulnerability according to Perka BNPB No. 12 [11], which is then merged to obtain a landslide vulnerability map.

The minimum and maximum scores in this study are based on scores issued by BNPB [11]. So, the minimum score gained in this study is 0.33, and the maximum score is 1. While X is the class interval, the formula used is:

$$X = \text{Class interval} = \frac{Smaks - Smin}{3} = \frac{1-0{,}33}{3} = \frac{0{,}67}{3} = 0{,}22$$

So, the classification of landslide vulnerability in this study are:

Table 1 Classification of landslide vulnerability rates (Processing by the researchers, 2019)

Total Score	Vulnerability Classification	Class
0,33 – 0,55	Low vulnerability	1
0,56 – 0,77	Medium vulnerability	2
0,78 – 1	High vulnerability	3

After calculating each vulnerability's parameters (social, economic, physical, and environmental) for each village, then mapped from each parameter, landslide vulnerability classification and overlaid using ArcGIS 10.3. In order to obtain a landslide vulnerability map for Ciniru District. Landslide vulnerability maps are then described to understand landslide vulnerability in each village better.

3. Result

3.1. Social Vulnerability

The level of social vulnerability in the Ciniru Subdistrict was in the low category in each village with 4865 ha. This social vulnerability is based on overlay results from population density and vulnerable groups (ratio of age groups, people with disabilities, sex ratio, and low-income families ratio.

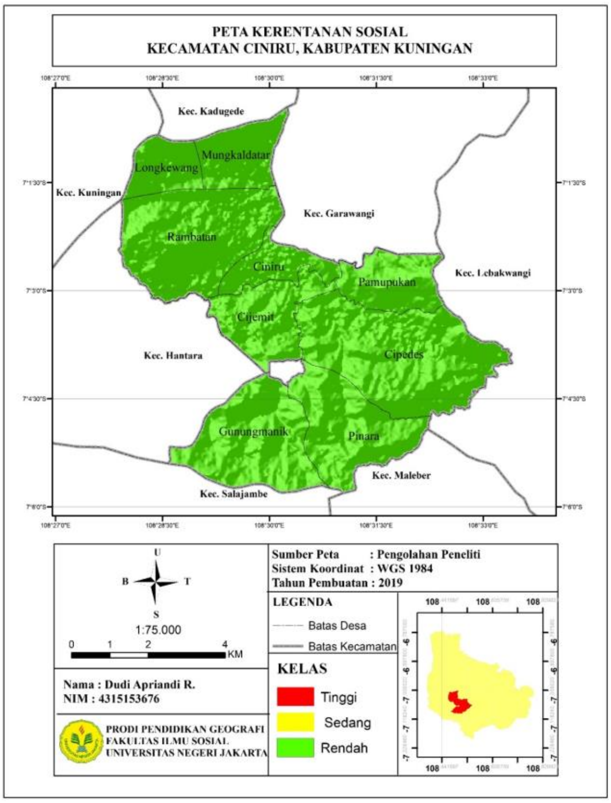

Fig. 2 Social vulnerability map (Processing by the researchers, 2019)

In each village, social vulnerability is influenced by vulnerable age groups and poor groups with weighting results of medium and high classes. The addition of the population density value and the vulnerable groups show the number of social vulnerability values below 0.55. In Ciniru Subdistrict, social vulnerability is in a low category, with Cijemit Village and Mungkaldatar Village as villages having the highest vulnerability value. In contrast, Rambatan Village, Pamupukan Village, and Pinara Village have the lowest values of 0.46. Other villages have varied values.

3.2. Economic Vulnerability

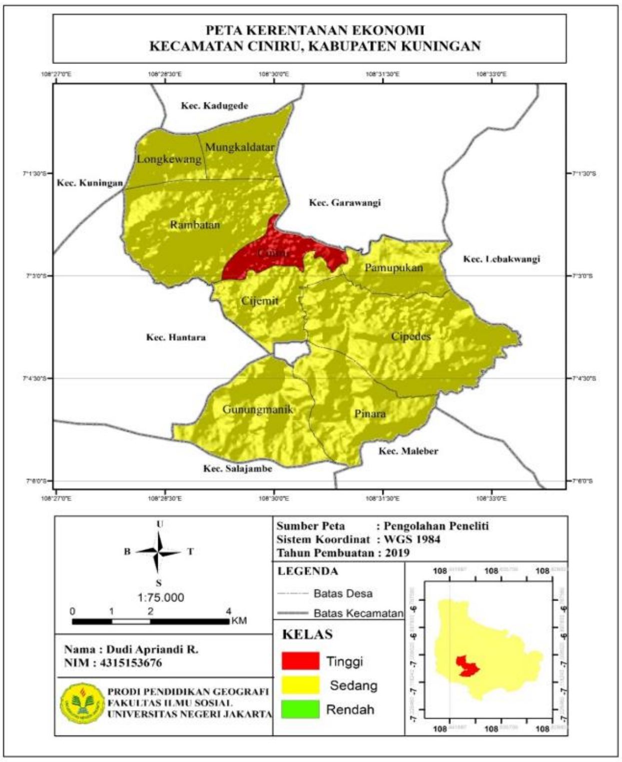

Fig. 3 Economic vulnerability (Processing by the researchers, 2019)

The level of economic vulnerability in the Ciniru sub-district is high and very high class. The very high class is in Ciniru Village with an area of 2.94 km2 or 294 ha, while in the high class it covers eight villages, namely Mungkaldatar Village, Longkewang Village, Rambatan Village, Pamupukan Village, Cijemit Village, Cipedes Village, Pinedes Village, and Gunungmanik Village with a total of area of 45.32 km2 or 4523 ha.

Ciniru village has an economic vulnerability in the high category because it has the value of weighting productive land in the high category and PAD in the medium category. The value of economic vulnerability in Ciniru Village is 0.86. Mungkaldatar Village, Longkewang Village, RambatanVillage, Pamupukan Village, Cijemit Village, Cipedes Village, Pinara Village, and Gunungmanik Village are in the medium category, which is affected by productive land. At the same time, the eight PAD villages are low. The economic vulnerability value of the eight villages is 0.73.

3.3. Physical Vulnerability

The level of physical vulnerability in Ciniru Subdistrict is in the middle and high classes. The medium class area of 2529 km2 or 2,529 ha covers five villages: Mungkaldatar Village, Longkewang Village, Pamupukan Village, Pinara Village, and Gunungmanik Village, while the high-class area of 22.97 km2 or 2297 ha includes four villages: Rambatan Village, Desa Ciniru, Cijemit Village, and Cipedes Village.

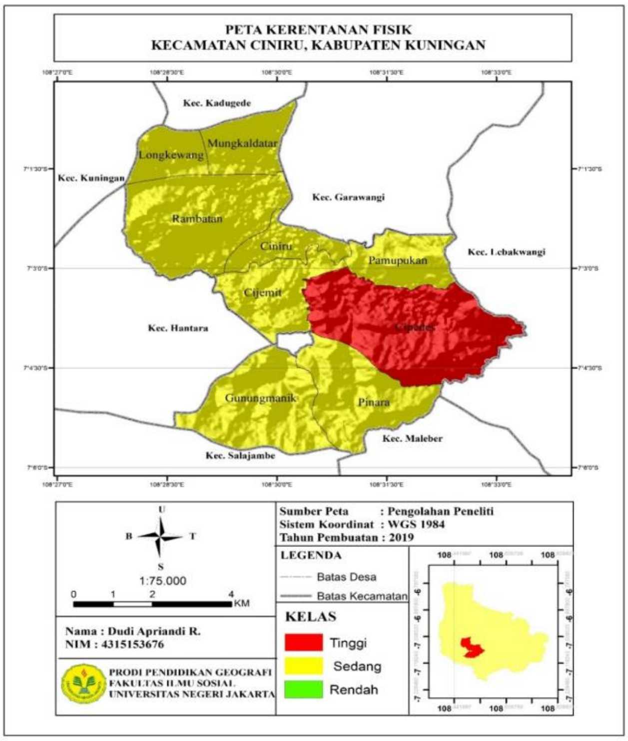

Fig. 4 Physical vulnerability map (Processing by the researchers, 2019)

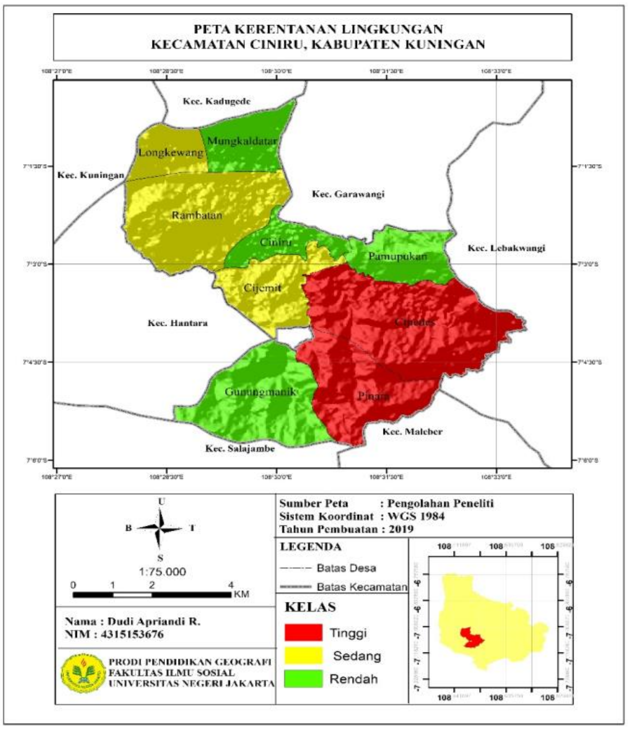

Fig. 5 Environmental vulnerability map (Processing by the researchers, 2019)

The high-class physical vulnerability in the Village Cipedes is 0.79. Factors influencing the weighting value of Cipedes Village are that houses and public facilities are in the high category. The most common facilities in the village of Cipedes are prayer rooms and school buildings at the PAUD to SMP levels and several meeting halls scattered in each hamlet.

The other eight villages are in physical vulnerability in the medium category. These villages have varying physical vulnerability values but are more influenced by public facilities' value and the value of houses.

3.4. Environmental Vulnerability

The level of environmental vulnerability in the Ciniru Subdistrict is in the low to high category. The low category includes Mungkaldatar Village, Ciniru Village, Pamupukan Village, and Gunungmanik Village; the medium category - Longkewang Village, Rambatan Village, and Cijemit Village; the high category - Cipedes Village and Pinara Village.

The value of environmental vulnerability in villages in the low category is 0.16 in Ciniru Village, 0.26 in Pamupukan Village, 0.4 in Mungkaldatar Village, and 0.53 in Gunungmanik Village. This is because it has the value of protected forests, natural forests, and shrubs in the low and medium categories. Besides, there is one indicator that is not owned by the village in the low category.

In the medium category, the value in Longkewang Village was 0.66, in Rambatan Village - 0.70, in Cijemit Village - 0.69, and in Gunungmanik Village - 0.53. The influencing factors are protection forest and natural forest in the high to moderate category and shrubs in Cijemit Village in the low category.

The high category with a value of 0.80 includes Pinara Village and Gunungmanik Village. Both of these villages have a high value of protected and natural forests. Both villages have no bush value.

3.5. Landslide Vulnerability

The vulnerability of landslides in the Ciniru sub-district is in the medium category, including eight villages, namely Mungkalatar Village, Lonkewang Village, Rambatan Village, Ciniru Village, Cijemit Village, Cipedes Village, Pinara Village, and Gunungmanik Village while in the low category, namely Pamupukan Village. Factors affecting the vulnerability of landslides in Ciniru Subdistrict are physical factors such as houses, places of worship, school buildings, and government buildings and economic factors in the form of productive land.

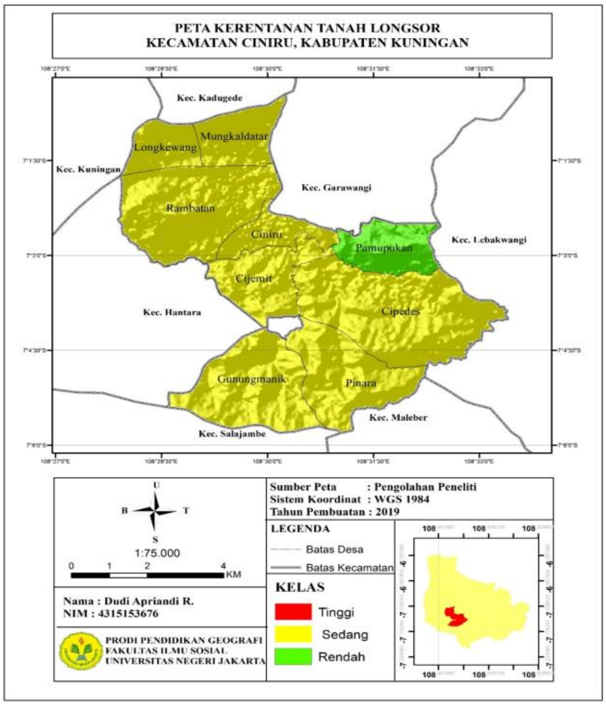

Fig. 6 Landslide vulnerability map (Processing by the researchers, 2019)

The village that had the highest total landslide value was Cipedes Village with a 0.66 figure. Factors that influence the high value of landslide vulnerability in the Village of Cipedes are social factors of 0.202, physical factors of 0.199, economic factors of 0.183, and environmental factors of 0.08.

The village which has the lowest total landslide value is Pamupukan Village, with a number of 0.54. Factors influencing the low vulnerability value of landslides in Pamupukan Village are environmental and physical factors. Environmental vulnerability in Pamupukan Village is at a low class because it only has protected forest and natural forest area with a value of the protected forest and natural forest of 0.132 and the lowest social factor with a physical vulnerability value of 0.46.

4. Conclusion

From the description of the research results and their descriptions, it can be concluded that the four parameters mentioned in Perka BNPB No. 12 [11], which can be used to determine the vulnerability of landslides in an area. With this parameter, disaster mitigation programs or activities in an area can be carried out correctly as expected. From this study's results, Landslide vulnerability in Ciniru Subdistrict is in the low and medium category. The low category includes Pamupukan Village. The medium category covers eight villages, namely Mungkaldatar Village, Longkewang Village, Rambat Village, Ciniru Village, Cijemit Village, Cipedes Village, Pinara Village, and Gunungmanik Village. The risk of landslides in Ciniru Subdistrict is in the medium category. It means landslides' potential in this area, but still in the level of being minimized with a disaster mitigation program that has been prepared.

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