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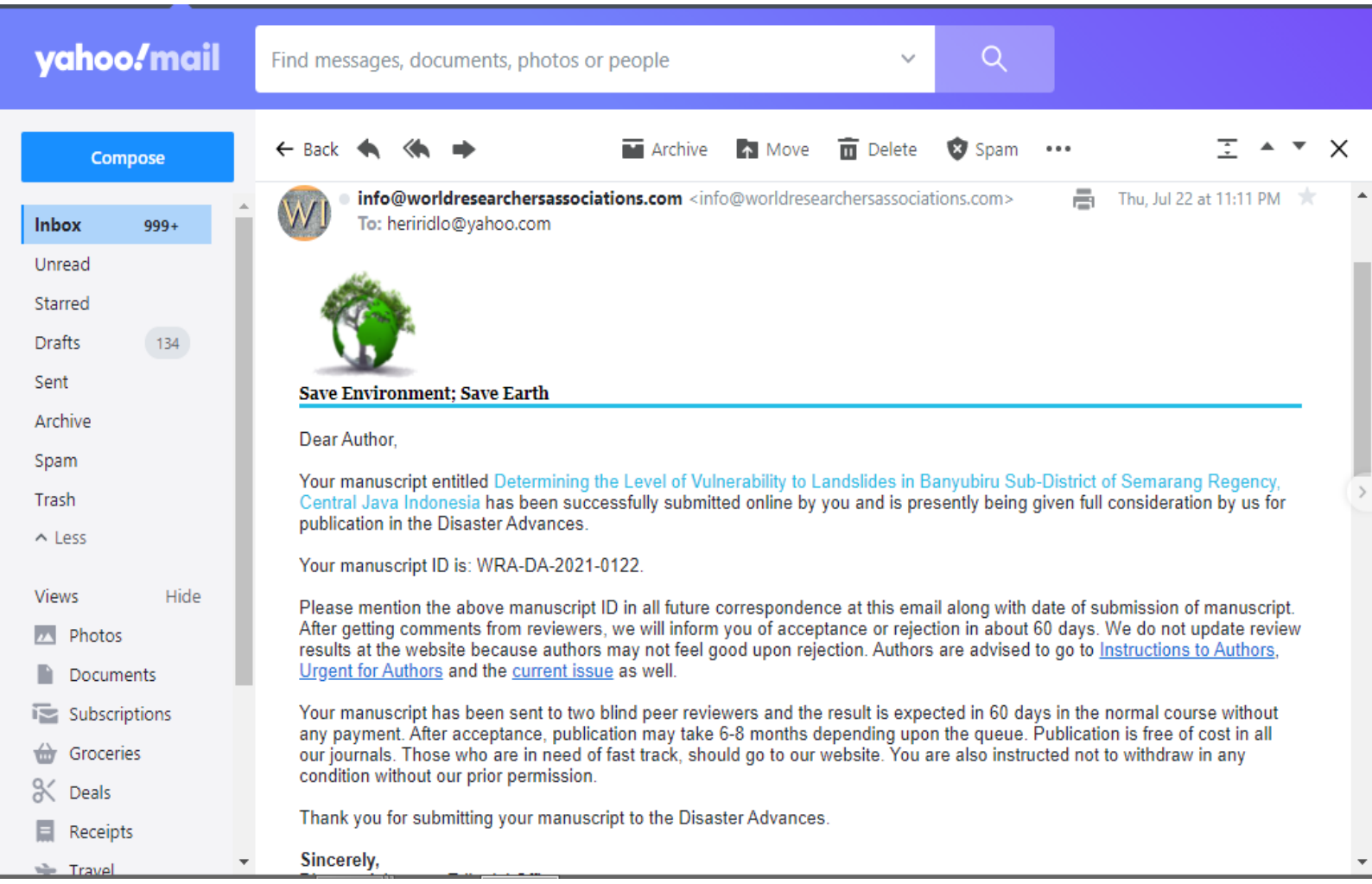
Determining the Level of Vulnerability to Landslides in Banyubiru Sub-District of Semarang Regency, Central Java, Indonesia



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Prof. Dr. Shankar Garg
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Determining the Level of Vulnerability to Landslides in Banyubiru Sub-District of Semarang Regency, Central Java Indonesia.

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Abstract

Based on historical record, Semarang Regency in Central Java, Indonesia frequently experiences landslides. Therefore, this study was conducted in Banyubiru Sub District, Semarang Regency, Central Java. The purpose of this study is to determine the variation of field vulnerability to lanslides in the Sub District, also establish the efforts that must be made to reduce vulnerability in order to decrease losses during the occurance of landslides. Vulnerability include physical, social, economic, and environmental variables. Each region has varying levels, types and characteristics of vulnerability. So as to be refined, the original three classes of the vulnerability index criteria were modified into five criteria, i.e. very low vulnerability index criterion (1.00-<1.40), low vulnerability index (1.40-<1.80), moderate vulnerability index (1.80<2.20), high vulnerability index (2.20-<2.40) and very high vulnerability index (2,40- < = 3,0). The results show that the vulnerability level of landslide is devided into 2 parts according to vulnerability indicators in Perka BNPB No.2/2012. Banyubiru sub-district has a moderate and high level of vulnerability. The average of vulnerability rate belong to the moderate category with an index value of 2,17. The lowest rate is owned by Rowoboni Village, while Sepakung village has the highest vulnerability.

Key words*: landslide vulnerability, Banyubiru Sub District, Semarang Regency.*

Introduction

Historically, Banyubiru sub-district of Semarang Regency is an area that is prone to disasters, one of which is landslides. Its topography shows that the sub-district consists of lowlands and low to high hilly-lands as part of Telomoyo Volcano. Landslides frequently occur, from relatively low hills to high hills, with a dip slope of 15- 45 %. The presence of andesite breccia rocks along with wide-ranging of slopes from tilting to steep and the presence of clay soil texture supports the occurrence of landslides.

Landslide, particularly, as the available data shows that its occurrence in Semarang Regency has a high frequency. There were 20 incidents in 2016 in the Regency, 34 times in 2017, and in 2018 it occurred 65 times[3]. This shows an inclination, from 29 cases in 2016 to 65 in 2018. Based on the data, it is known that landslides are the most common disasters in Semarang Regency. Landslides that occurred in Semarang Regency included the avalanche disaster that occurred in Banyubiru sub-district, smashing down 3 houses, meanwhile, most of the houses in the settlements were heavily damaged and could no longer be used[4].

The increase in disaster events is generally followed by an increase in losses[2]. Likewise, the increase in landslide disasters is always followed by increased losses in the form of casualties and property[11, 16]. For this reason, further studies on landslide susceptibility are needed to reduce the risk of avalanches.

Regulation of the Head of the National Agency for Disaster Management No. 02 of 2012 concerning General Guidelines for Disaster Risk Assessment[13] explains that disaster management in an area is a mandate from Law Number 24 of 2007 on Disaster Management[20]. The Disaster Management Plan is a

manifestation of the government's efforts related to the formulation of activity programs and the priority focus of disaster management. The existence of various disaster potentials, the high affinity level of disaster, and the low level of population capacity is relatively, have urged a necessity for an integrated plan to reduce vulnerability to landslides[21].

Threats or hazards, vulnerability and capacity are the three components determining a disaster risk. Disaster threats are geological, biological, climatological, geographical, social, cultural, political, economic and technological conditions or characteristics in an area for a certain period of time which decrease the ability to prevent, dampen, achieve readiness, and reduce the ability to respond to the adverse effects of certain hazards. Vulnerability can be defined as a condition of a community or society leading to or causing an inability to deal with the threat of disaster. Avalanche vulnerability assessment is an approach to show a potential negative impact that may occur due to landslides. The negative impacts that arise are calculated based on the level of threat, vulnerability and community capacity. Potential negative impacts can be seen from the potential number of people exposed, property losses, and environmental damage[7, 10, 14].

Whereas the ability of the region and the community to take action on reducing the level of threat and the level of losses due to disasters is showing the capacity of the community. Disaster risk is the potential loss caused by disasters in an area and in a certain period of time i.e. fatality, injury, illness, life threat, insecurity, evacuation, damage or lost of property, and social activity disruption[13].

We must strive to reduce the vulnerability of the region to landslides disaster, in order to minimize the disaster risk of landslides. Vulnerability is a condition determined by physical, social, economic, and environmental factors or physical processes resulting in codensed ability of an area to face hazards[8]. The efforts to decrease vulnerability are to analyze actions that can be taken by an area for reducing vulnerability to landslides based on physical, social, economic, and environtmental factors of that area, so that the cost of losses and the number of casualties due to landslides can be minimized or avoided, thus, the ability to deal with landslide is increased[22].

The objectives of this study are (1) determining the level of the vulnerability of the terrain towards landslides in Banyubiru sub-district, Semarang Regency, (2) determining the effort that must be made to reduce vulnerability, so as to decrease the level of disaster risk if landslides happen in Banyubiru sub-district, Semarang Regency.

Material and Methods

Banyubiru sub-district, Semarang in the province of Central Java becomes the research object due to this area experience to landslides almost every year, from small landslide without property losses to the one resulting lost of both property and human life. The research design on the vulnerability of the field to landslides is a field study (observational), analyzed with quantitative descriptive, namely by making a description of the conditions in the field systematically, factually, and accurately regarding to the facts, characteristics, and by examining the relationship between phenomena investigated[12].
The variables studied in this research are (1) Social vulnerability includes indicators (a) Number of vulnerable population aged under five, (b) Number of exposed population (population density), (c) Total female population, (d) Number of elderly vulnerable population, (e) Number of people with disabilities, and (f) trained personnel; (2) Physical vulnerability variables, including indicators of the condition of public and special facilities, housing conditions; (3) Environmental vulnerability includes indicators of green open space, mixed gardens, shrubs, productive/limited production forest, and water catchment, (4) Economic vulnerability includes indicators of productive lands, income, ownership of capital goods, and assets with economic value; (5) Variables regarding the efforts that must be made to reduce the vulnerability of the area to landslides. Data were collected using interview, documentation techniques and surveys/field condition checks.

The unit of data analysis in the study of field vulnerability research to landslides is administratively analyzed in the village level. Meanwhile, the data analysis about the efforts that must be made to reduce area vulnerability against landslides is carried out using AHP or Analysis Hierarchy Process[15]. The level of field vulnerability to landslides analysis is based on the resilience index analysis, consisting of a loss index and exposed population index which includes an analysis indexes of the social, physical, economic, and environmental vulnerabilities. The field vulnerability level towards landslides can be calculated after the four indicators of vulnerabilities (social, economic, physical, environmental) have been determined. They can be calculated using the following formula:

The parameters of social security are population density, the percentage of females, the percentage of the poor population, the percentage of people with disabilities, and the percentage of elderly people. The formula to calculate social vulnerability is as follows:

SV = (0.6*PD) +(0.1*FP)+(0.1*PPP)+ (0.1*DPP)+ (0.1*EPP)

Where SV =Social Vulnerability, PD=Population Density, FP= Female Percentage, PPP=Poor population percentage, DPP= Disable people percentase, EPP=Elderly people persentage

The parameter and weight used to determine the level of social vulnerability is shown in Table 1, as follows.

Table 1. Parameters and weights for determining the level of social vulnerability

Parameter	Weight (%)	Class		
		Low (Score 1)	Moderate (Score 2)	High (Score 3)
Population Density	60	<5 people/ha	5-10 people/ha	>10 people/ha
Females Persentage (10%)	40	<20%	20-40%	>40%
The Poor Persentage (10%)				
The Disabled Persentage (10%)				
The Elderly Persentage (10%)				

Source: Perka BNPB 2012 with modification[13]

Economic vulnerability consists of productive land value, asset vulnerability value, and the Gross Regional Domestic Product (GRDP) of the village sector. The formula for calculating economic vulnerability is as follows.

EV = (0.4*PLV) + (0.4*AVV) + (0.2*GRDPv)

Where EV = Economic Vulnerability, PLV =Produktive land Value, AVV= Asset Vulnerability Value, and GRDPv= Gross Regional Domestic Product Value.

The parameter and weight used to determine the level of economic vulnerability is shown in Table 2, as follows.

Table 2. Parameter and weight to determine the level of economic vulnerability

Parameter	Weight (%)	Class		
		Low (score 1)	Moderate (score 2)	High (score 3)
Productive Land	40	<50 M	50-200 M	>200 M
Asset Vulnerability	40	<50 M	50-200 M	>200 M
GRPD	20	<100 M	100-300 M	>300 M

Source: Perka BNPB 2012 with modification[13]

The formulation for calculating GRDP in the village sector and the conversion from productive land area into the rupiah value is depicted from the disaster risk assessment methodology used by BNPB, that is:The Formula of rupiah value of productive land

$$RLPi = \frac{\text{PLPtot} - \text{i}}{\text{LLPtot} - \text{i}} \; x \; LLPdesa - i$$

.

Where:

RLPi = the rupiah value of productive land for the–i^{th} land use class at the village level

PLPtot-i = the total rupiah value of productive land based on the value of rupiah sector -i in the level of Regency/City

LLPtot-I = the-i^{th} total area of productive land at district/city level

LLPdesa-i = the-i^{th} area of productive land at village level

Village Sector PDRB/GRDP Score

$$RPPdesa\text{-}i = \frac{\text{RPPKK}}{LKK} \; x \; LDi$$

Where :

RPPdesa-i = the rupiah value of the –i^{th} village GRDP sector

RPPKK = the rupiah value of GRDP sector at Regency/City level

LKK = the area width of Regency/City

LDi = the –i^{th} of village width

The parameter of physical vulnerability numbers of houses, public facilities, and critical facilities. The formulation to calculate the physical vulnerability is in the following:

PV = (0.4*HV) + (0.3 PFV) + (0.3 CFV)

Where PV = Physical Vulnerability, HV=House Value, PFV= Public Facility Value, and CFV = Critical Facility Value.

The parameter and weight used to determine the level of physical vulnerability is shown in Table 3, as follows:

Table 3. Parameter and weight to determine the level of physical vulnerability

Parameter	Weight (%)	Class		
		Low (score 1)	Moderate (score 2)	High (score 3)
House	40	<400 M	400-800 M	>800 M
Public Facility	30	<500 M	500 jt-1 B	>1 B
Critical Facility	30	<500 M	500 jt-1 B	>1 B

Source: Perka BNPB 2012 with modification[13]

The indicators of environmental vulnerability are the areas of the protected forest, natural forest area, mangrove forest and shrubs. However, this research does not calculate the areas of protected forest and natural forest because they are not found in the location of research, the same thing happens to the absence of mangrove forest in the landslide area. Therefore, the calculation is only for shrubs and mixed gardens as the indicators. Classification of environmental vulnerability parameters based on

the modification from several experts and the experienced researchers stated that a high environmental vulnerability class is an area having a narrow area of shrubs and mixed gardens, while the wider the area of shrubs and mixed gardens are, the lower environmental vulnerability against landslides will be. This applies only for calculation of landslide vulnerability in this study. As for the formulation for calculating environmental vulnerability is as the following:

EnV = (0.4*SV) + (0.6*MGV)

Where EnV = Environmental Vulnerability, SV= Shrubs Value, and MGV= Mix Garden Value

The parameter and weight used to determine the level of environmental vulnerability is shown in Table 4.

Table 4. Parameter and weight to determine the level of environmental vulnerability.

Parameter	Weight (%)	Class		
		Low (score 1)	Moderate (score 2)	High (score 3)
Mixed Gardens	60	> 50 ha	20-50 ha	< 20 ha
Shrubs	40	> 75 ha	25-75 ha	< 25 ha

Source: Perka BNPB 2012 with modification[13]

The data on landslide susceptibility in the form of population data can be obtained by secondary data (population data collected by BPS Semarang Regency/BPS Central Java Province), such data are the number of population, vulnerable ages (toddlers and elderly), female population, and people with disabilities. Beside completing the data, interviews with the community or community leaders were carried out during the collection of data in the field.

After knowing and calculating the social, economic, physical, and environmental vulnerabilities, thus, the vulnerability to landslides can be determined. The calculation refers to BNPB 2012 as follows[13]:

VL = (0.4*SVV)+ (0.25*EVV) + (0.25*PVV) + (0.1*EVV)

Where VL = Vulnerability to Landslide, SVV =Social Vulnerability Value, EVV= Economic Vulnerability Value, PVV = Physical Vulnerability Value, and EVV = Environmental Vulnerability Value

After the vulnerability to landslide is calculated, the results are then consulted with Table 5. about the criteria of index value towards landslide vulnerability, which was made referring to the BNPB (2012) with modifications. The purpose of modifications are making the class criteria smoother, and appropriate with other landslide risk variables. The original value made by BNPB were three classes (low, moderate, high), is the modified into five (very low, low, moderate, high, and very high), so that they become as follows.

Table 5. Criteria Determination of Index Values to Landslides Vulnerability

No.	Interval of Index Value	Class Criteria
1	1,00- <1,40	Very Low
2	1,40-<1,80	Low
3	1,80-<2,20	Moderate
4	2,20-<2,60	High
5	2,60-<=3,00	Very High

Source: BNPB, 2012 with modification[13]

Result And Discussion

Banyubiru sub-district is one of the sub-districts in Semarang Regency, the Province of Central Java which has the potential for landslides to occur. The administrative area of each village in Banyubiru sub-district can be seen in Table 6.

Table 6. The administrative area of each village in Banyubiru sub-district (ha)

No.	Name of Village	Area (Ha)	Area (%)
1	Kebumen	404,99	8,0
2	Rowoboni	406,88	8,0
3	Gedong	418,32	8,2
4	Tegaron	632,17	12,4
5	Banyubiru	480,00	9,4
6	Kebondowo	542,27	10,6
7	Kemambang	363,23	7,1
8	Ngrapah	303,21	6,0
9	Sepakung	975,96	19,2
10	Wirogomo	565,35	11,1
	Total Area	5092,37	100,0

Source: BPS, Banyubiru Sub-District Semarang Regency in numbers, year 2019[20]

The administrative boundary of the Banyubiru sub-district in the north are Rawa Pening and Ambarawa sub-district; in the east are Tuntang and Getasan sub-districts; in the south are Getasan sub-district and Magelang Regency: in the West side there is Getasan sub-district. Part of Banyubiru sub-district territory is located Telomoyo hills, namely Wirogomo Village, Kemambang Village, Sepakung and Gedong villages. For the other 6 villages some are in the plains and most of them are on the hills, such as Kebumen Village, Tegaron, Kebondowo, Rowoboni, Ngrapah, and Banyubiru. Spatially, the administrative area of Banyubiru sub-district can be seen in Figure 1 . About Administrative Map of Banyubiru sub-District

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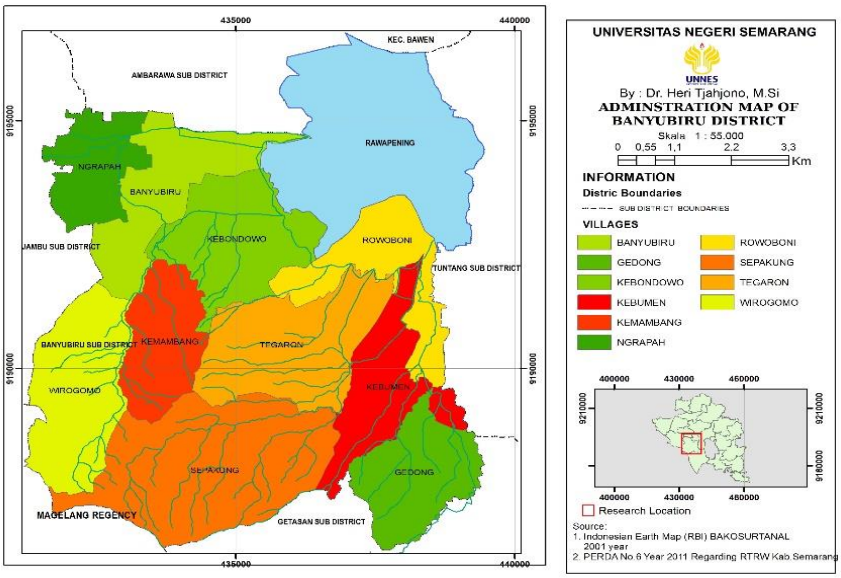


Figure 1 . About Administrative Map of Banyubiru sub-District[19]

The topographic conditions are quite varied, the widest dip slope is found in an even area, with a slope of 0-8%, which is 1601.93 Ha or 31.5% of the total area of Banyubiru District. Areas with a gentle slope, i.e. a slope of 8-< 15% has the smallest area (464.87 Ha) or 9.1% of the total area of Banyubiru sub-District. While the steep slope has a large area with a percentage of 28.2%, or an area of 1435.41 hectares

The research area has a fairly high rainfall. The maximum rainfall of 2500-3000 mm/year spread over Banyubiru sub-district with an area of 2553.50 Ha, and the minimum rainfall is between 1500-2000 mm/year, spreading over the Banyubiru area with an area of 1 519.13 hectares. According to Schmidt Ferguson, the research area has the same climate type, that is type C (slightly wet) with a Q value (comparison between the average dry month and wet month) which is not much different.

The assessment of the level of landslide vulnerability in Banyubiru sub-District, Semarang Regency, was examined using primary data (with field surveys) and secondary data collected by BPS (Central Statistics Agency) Semarang Regency[5] . This research uses four indicators, including the values of physical vulnerability, social vulnerability, environmental vulnerability, and economic vulnerability. Each indicator has its own weight in accordance with the provisions in Perka BNPB No. 2/2012, which has been developed according to research requirements and the availability of data in the field[13].

The determination of the vulnerability index criteria which were originally three classes to be more refined was modified into five criteria classes, namely very low vulnerability index (1.00-<1.40), low vulnerability index (1.40-<1.80), moderate vulnerability index (1.80-<2.20), high vulnerability index (2.20-<2.40) and very high vulnerability index (2.40- < =3.0). The provision of vulnerability index criteria is carried out after the 4 vulnerability indicators are calculated into a vulnerability index.

Based on Table 6, about the value of the vulnerability index to landslides, it can be explained that in Banyubiru sub-district, Semarang Regency has the vulnerability level of medium and high criteria. There are four villages having a “high criteria” of vulnerability level, those villages are Sepakung, Wiragama, Gedong, and Kebumen. Whereas the villages having vulnerability level of “moderate criteria” are Banyubiru, Kebondowo, Kemambang, Ngrapah, Rowoboni, and Tegaron. The village owns the highest vulnerability level is Sepakung, with the vulnerability index value of 2,36. The average vulnerability level is in the moderate criteria with an index value of 2,17. The lowest vulnerability is owned by Rowoboni Village (1.82), while the highest vulnerability is owned by Sepakung Village (2.36). The highest score of physical vulnerability in Banyubiru District, Semarang Regency, belongs to Gedong Village (3) and Kebumen Village (3). The highest score of social vulnerability is for Sepakung Village (2.70). As for environmental vulnerability, it

has two varied scores: 1.7 and 1.8. The highest environmental vulnerability value (1.8) is owned by Sepakung Village, Tegaron, Banyubiru, Rowoboni, Kebondowo, and Ngrapah Village. While the score 1.7 belongs to Kebumen Village, Wirogomo, Gedong, and Kemambang Village. As for the economic vulnerability, each village has the same vulnerability value (2). The calculation results of the vulnerability index can be seen in Table 6 below.

Table 6. Index Value of Vulnerability to Landslide in Banyubiru sub-District, Semarang Regency

No.	Village Names	PV	SV	EnV	EV	VIV	Criteria of Vunerability Level
1	Wirogomo	2,7	2,2	1,7	2,00	2,23	High
2	Kemambang	2,7	1,6	1,7	2,00	1,99	Moderate
3	Sepakung	2.4	2,7	1,8	2,00	2,36	High
4	Kebumen	3	2,2	1,7	2,00	2,30	High
5	Gedong	3	2,2	1,7	2,00	2,30	High
6	Rowoboni	2	1,6	1,8	2,00	1,82	Moderate
7	Tegaron	2,7	2,1	1,8	2,00	2,20	Moderate
8	Kebondowo	2,7	2,1	1,8	2,00	2,20	Moderate
9	Banyubiru	2,7	2,1	1,8	2,00	2,20	Moderate
10	Ngrapah	2,4	2,1	1,8	2,00	2,12	Moderate
	Average	2,63	2,09	1,76	2,00	2,17	Moderate

Source: Result of Research Data Analysis1[19]

Where :

PV = Physical vulnerability value/score

SV = Social vulnerability value

EnV = Environmental vulnerability value

EV = Economic vulnerability value

VIV = Vulnerability Index value

The result of vulnerability index calculation is shown in Figure 2.

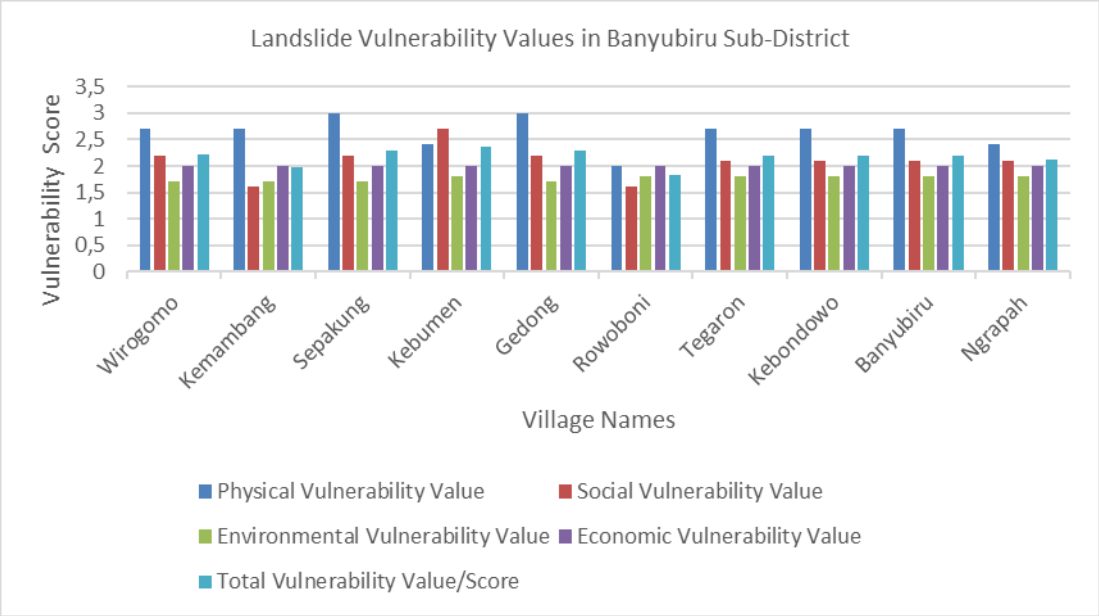
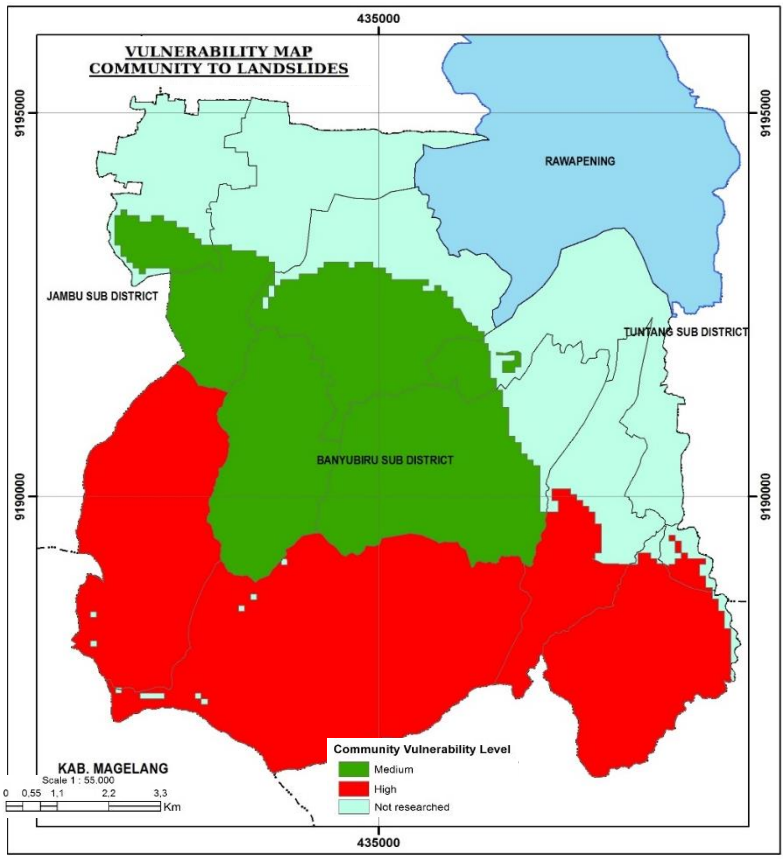


Figure 2. The value of community vulnerability index to landslides per-village in Banyubiru Sub-District, Semarang Regency. Source: Result Research Data Analysis[19]

Spatially, the level of community vulnerability to landslides in each village in Banyubiru sub-District, Semarang Regency is presented in Figure 3, that is the map on level of community vulnerability to landslides in Banyubiru sub-District, Semarang Regency.



Pigure 3. Map of level variation in landslide vulnerability in Banyubiru sub-District[19]

Based on the results of the analysis of research data using AHP and scoring, conducted on 65 respondents from the community, government officials and community organizations, it is concluded that several efforts must be made by the community and government to reduce vulnerability to landslides so that disaster risk can be minimized as much as possible, such efforts are; (1) the government needs to make laws that regulate or limit the use of areas or lands having landslides potential; (2) Do not build houses on steep slopes to avoid people from landslide disasters; (3) The community needs to construct a strong building foundation but with light building top, to reduce the risk of landslides; (4) Form a community organization in which purpose is safeguarding vulnerable people (the elderly, pregnant women, people with disabilities) of landslide hazards; (5) create a diversity of community assets and resources in landslide-prone areas; (6) Mapping or visual information about the level of landslide threat is required as an input to the government and the community to avoid development/construction from disasters; (7) Community, supported by the government, need to arrange new public facilities in landslide-prone areas; (8) Relocate houses prone to landslides to safer areas; (9) establish observation posts in landslide-prone areas, (10) organize special officers/officals to manage landslide disaster, taken from the village apparatus or youth organization; (11) conduct evacuation and first aid training on landslide disaster for vulnerable community groups; (12) The community has already chosen and determined the location used as a shelter in the event of a disaster; (13) Create a landslide border or adjust the distance between houses (minimally 15 meters) with the edge of the ever-slided cliff or having landslide potential; (14) Train yourself and family members on things to do in the event of a landslide; (15) set up a bag of disaster preparedness, containing necessities, such as food, drinking water, vital medicines box; (16) It is necessary to form an early warning team, consisting of the local government, communities, organizations and volunteers to anticipate landslide that may occur.

Social, physical, economic, and environmental conditions in an area are assessed to determine the level of community vulnerability to landslides. The differences in social, physical, economic, and environmental conditions in an area will result in different vulnerability values. This will be different from conditions in rural areas where the population is sparse, with inadequate facilities, and the area is mostly agricultural land and mixed gardens. Such conditions if found in landslide-prone areas will result in different levels of vulnerability of the area to landslides.

The level of landslide vulnerability in Banyubiru sub-District varies among the villages. The distribution of vulnerability level of the area in the Banyubiru sub-district, Semarang Regency towards landslides is depicted on a map. It is hoped that through this map a person will be able to figure out and use the information about the vulnerability of an area, and quickly see the vulnerability of an area to landslide. According to Sumaryono, et al[17] landslide vulnerability maps and landslide inventory databases can be used for landslide prevention and mitigation, and planning future land use [1, 9]. The existence of good land use planning will be able to reduce physical, social, environmental and economic vulnerabilities. In order to reduce the level of vulnerability it will be more effective if the community is willing to comply with land use regulations, and the government is willing to enforce the rules on land use according to the predetermined spatial plan[6]. So far, some people have violated land use regulations that are not in accordance with the spatial designation which results to the increase of landslides vulnerability.

Social vulnerability is determined by several indicators, such as social conditions, i.e. population density and number of vulnerable population. Vulnerable population includes (a) elderly population, (b) disabled population, (c) female population, (d) population under five, and (e) poor or underprivileged population. High social vulnerability can occur if there are a large numbers of vulnerable residents occupying or living in an area prone to landslides. Conversely, if there are only few or no vulnerable population in an area prone to landslides, the social vulnerability to landslides will be lower/smaller.

Physical vulnerability in an area is determined by several indicators. They are: (a) public facilities consisting of educational facilities, religious facilities, markets, and office buildings, (b) the density of houses or the number of houses, and (c) critical facilities consisting of hospitals, clinics, and health centers. If there are many houses, public facilities, and critical facilities in the areas prone to landslides, it will cause the area to have high physical

vulnerability. On the other hand, if there are only a few houses, few public facilities, or few critical facilities in a landslide-prone area, it will cause the area to have low physical vulnerability.

The more luxurious or the higher the value or the price of the facility, the higher the physical vulnerability of the area will be.

Economic Vulnerability in an area is determined by some indicators, such as: (a) productive land, including agricultural land, and plantation land, (b) valuable assets consisting of livestock, vehicle, and shop assets or kiosk, (c) GRDP of the village sector which is calculated based on the Regency GRDP, the area of the Regency, and the area of the village. The size or the narrow area of productive land and valuable assets in landslide-prone areas will affect the high or low economic vulnerability. Economic vulnerability will be higher if (a) there are bigger area or more productive lands available in landslide-prone areas, (b) the price of valuable assets are higher in landslide-prone areas; (c) the village area is wider, so that the value of GRDP of the village sector is also higher. On the other hand, if the productive lands, valuable assets, and the area of the village is relatively small or narrow, the economic vulnerability of the area will be low.

Environmental vulnerability in an area is determined by several indicators. Such conditions that become indicators are (a) the amount of mixed gardens (more or less), (b) the wide area or narrowness of the forest, and (c) the wide area or narrowness of shrubs. Environmental vulnerability will be low if the area of mixed gardens, forest and shrubs in the areas prone to landslides is narrow or small. On the other hand, the environmental vulnerability in landslide-prone areas will be higher if the area is narrower or the mixed garden, forest and shrubs are unavailable in that area.

The high value of the vulnerability index to landslides occurs because of the influence of several sub-variables with high vulnerability values. Sepakung village has the highest vulnerability index value to landslides (2.36) due to the influence of high social vulnerability value (2.7), also high physical vulnerability value (2.4). Gedong Village is likewise, because of the influence of high physical vulnerability value (3) and a quite high social vulnerability score (2.2), it has a high vulnerability index value to landslides (2.30).

Kebumen village also has a high vulnerability index value (2.30) because it is influenced by the presence of a high value of physical vulnerability (3) and a fairly high social vulnerability (2.2). Thus, it can be emphasized that a high value of vulnerability index to landslides occurs when several sub-variables of vulnerability have high vulnerability values.

With the purpose of reducing landslide vulnerability as described in the research results before, the community and government must be made some efforts. If it is carried out seriously even at times of no disaster (pre-disaster), it will be able to reduce disaster risk as small as possible. However, in reality many people are unable to carry out the efforts planned and made by the community to reduce landslides vulnerability for various reasons, including (1) due to the limited economic conditions their economic ability is also low in economics, (2) due to the limited land owned, meaning that people only have land located in a potential landslide area, so that they will continue to build in there, (3) the community are accustomed to responding to disasters when a it occurs, they still do not understand some important things to do during pre-disaster. This is related to the results of research[18], (4) there have not been strict rules and sanctions from the government regarding the use of disaster-prone areas by local residents, (5) there has not been proper organization whom properly coordinated to handle disasters at the village level.

Conclusion

Based on the results of this study, it can be concluded that: **(1)** Banyubiru sub-District of Semarang Regency has two criteria of landslide vulnerability levels, i.e. *moderate* and *high*. There are four villages with *high criteria* of level of landslide vulnerability, Sepakung Village, Wiragama, Gedong and Kebumen Village. Those with *moderate criteria* are Banyubiru village, Kebondowo, Kemambang, Ngrapah, Rowoboni, and Tegaron village. The village with the highest vulnerability is Sepakung with vulnerability index value of 2.36. The average vulnerability level is in the *moderate* criteria with an index value of 2.17. Rowoboni Village has the lowest vulnerability (1.82). The existence of different social, physical, economic and environmental conditions from one region to another can cause the regional vulnerability index values to landslides to vary. **(2)** There are many

efforts that must be made by the community and the government to reduce vulnerability to landslide disasters in order to minimalize the risk of loss during landslide, including: (a) The government needs to make a draft of regulation to control land use that has the potential for landslides; (b) Communities are advised not to build houses on steep slopes; (c) Communities need to establish organizations that can protect vulnerable communities (elderly, pregnant women, people with disabilities) from landslide hazards; (d) The community must create a diversity of community assets and resources in landslide-prone areas; (e) It is necessary to map visual information about the threat level of landslides; (f) conducting training on landslide disaster evacuation and first aid for vulnerable community groups; (g) Creating a landslide border or adjusting the distance between houses or buildings (minimally 15 meters) from the cliff edge that is prone to landslides: (h) Train yourself and family members on what to do during the occurence of landslide; and (i) setting up a disaster preparedness bag containing necessities, and vital medicines.

The recommendations given based on the results of the research are (1) the community must be alert, careful, and aware that they live in an area that has moderate vulnerability and high vulnerability to landslides; (2) To reduce the area's vulnerability to landslides, the community together with the government and private institutions must carry out efforts that can reduce the level of regional vulnerability to landslides, such as the community being asked not to build buildings/houses in areas that have a high level of vulnerability; the government should make rules that regulate or limit or prohibit land use in areas that have medium and high vulnerability to landslides.

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Determining the Level of Vulnerability to Landslides in Banyubiru Sub-District of Semarang Regency, Central Java, Indonesia

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Abstract
Based on historical record, Semarang Regency in Central Java, Indonesia frequently experiences landslides. Therefore, this study was conducted in Banyubiru Sub District, Semarang Regency, Central Java. The purpose of this study is to determine the variation of field vulnerability to lanslides in the Sub District and also to establish the efforts that must be made to reduce vulnerability in order to decrease losses during the occurance of landslides. Vulnerability includes physical, social, economic, and environmental variables. Each region has varying levels, types and characteristics of vulnerability. So as to be refined, the original three classes of the vulnerability index criteria were modified into five criteria i.e. very low vulnerability index criterion (1.00-<1.40), low vulnerability index (1.40-<1.80), moderate vulnerability index (1.80<2.20), high vulnerability index (2.20-<2.40) and very high vulnerability index (2,40- < = 3,0).

The results show that the vulnerability level of landslide is divided into 2 parts according to vulnerability indicators in Perka BNPB No.2/2012. Banyubiru sub-district has a moderate and high level of vulnerability. The average of vulnerability rate belongs to the moderate category with an index value of 2,17. The lowest rate is owned by Rowoboni Village while Sepakung village has the highest vulnerability.

Keywords*:* Landslide vulnerability, Banyubiru Sub District, Semarang Regency.

Introduction

Historically, Banyubiru sub-district of Semarang Regency is an area that is prone to disasters, one of which is landslides. Its topography shows that the sub-district consists of lowlands and low to high hilly-lands as part of Telomoyo Volcano. Landslides frequently occur from relatively low hills to high hills with a dip slope of 15-45 %. The presence of andesite breccia rocks along with wide-ranging of slopes from tilting to steep and the presence of clay soil texture supports the occurrence of landslides.

Landslide, particularly, as the available data shows that its occurrence in Semarang Regency has a high frequency. There were 20 incidents in 2016 in the Regency, 34 times in 2017, and in 2018 it occurred 65 times[3]. This shows an inclination from 29 cases in 2016 to 65 in 2018. Based on the data, it is known that landslides are the most common disasters in Semarang Regency. Landslides that occurred in Semarang Regency included the avalanche disaster that occurred in Banyubiru sub-district, smashing down 3 houses. Meanwhile, most of the houses in the settlements were heavily damaged and could no longer be used[4].

The increase in disaster events is generally followed by an increase in losses[2]. Likewise, the increase in landslide disasters is always followed by increased losses in the form of casualties and property[11,16]. For this reason, further studies on landslide susceptibility are needed to reduce the risk of avalanches.

Regulation of the Head of the National Agency for Disaster Management No. 02 of 2012 concerning General Guidelines for Disaster Risk Assessment[13] explains that disaster management in an area is a mandate from Law Number 24 of 2007 on Disaster Management[20]. The Disaster Management Plan is a manifestation of the government's efforts related to the formulation of activity programs and the priority focus of disaster management. The existence of various disaster potentials, the high affinity level of disaster, and the low level of population capacity have urged a necessity for an integrated plan to reduce vulnerability to landslides[21].

Threats or hazards, vulnerability and capacity are the three components determining a disaster risk. Disaster threats are geological, biological, climatological, geographical, social, cultural, political, economic and technological conditions or characteristics in an area for a certain period of time which decrease the ability to prevent, dampen, achieve readiness, and reduce the ability to respond to the adverse effects of certain hazards. Vulnerability can be defined as a condition of a community or society leading to or causing an inability to deal with the threat of disaster. Avalanche vulnerability assessment is an approach to show a potential negative impact that may occur due to landslides. The negative impacts that arise are calculated based on the level of threat, vulnerability and community capacity. Potential negative impacts can be seen from the potential number of people exposed, property losses, and environmental damage[7,10,14].

The ability of the region and the community to take action on reducing the level of threat and the level of losses due to

disasters is showing the capacity of the community. Disaster risk is the potential loss caused by disasters in an area and in a certain period of time i.e. fatality, injury, illness, life threat, insecurity, evacuation, damage or losts of property, and social activity disruption[13].

We must strive to reduce the vulnerability of the region to landslides disaster in order to minimize the disaster risk of landslides. Vulnerability is a condition determined by physical, social, economic, and environmental factors or physical processes resulting in ability of an area to face hazards[8]. The efforts to decrease vulnerability are to analyze actions that can be taken by an area for reducing vulnerability to landslides based on physical, social, economic, and environtmental factors of that area, so that the cost of losses and the number of casualties due to landslides can be minimized or avoided. Thus, the ability to deal with landslide is increased[22].

The objectives of this study are (1) determining the level of the vulnerability of the terrain towards landslides in Banyubiru sub-district, Semarang Regency and (2) determining the effort that must be made to reduce vulnerability so as to decrease the level of disaster risk if landslides happen in Banyubiru sub-district, Semarang Regency.

Material and Methods

Banyubiru sub-district, Semarang in the province of Central Java becomes the research object due to landslides almost every year, from small landslide without property losses to the one resulting in loss of both property and human life. The research design on the vulnerability of the field to landslides is a field study (observational) analyzed with quantitative descriptive, namely by making a description of the conditions in the field systematically, factually, and accurately regarding the facts, characteristics, and by examining the relationship between phenomena investigated[12].

The variables studied in this research are: (1) Social vulnerability includes indicators (a) Number of vulnerable population aged under five, (b) Number of exposed population (population density), (c) Total female population, (d) Number of elderly vulnerable population, (e) Number of people with disabilities and (f) trained personnel; (2) Physical vulnerability variables including indicators of the condition of public and special facilities, housing conditions; (3) Environmental vulnerability includes indicators of green open space, mixed gardens, shrubs, productive/limited production forest, and water catchment, (4) Economic vulnerability includes indicators of productive lands, income, ownership of capital goods, and assets with economic value; (5) Variables regarding the efforts that must be made to reduce the vulnerability of the area to landslides. Data were collected using interview, documentation techniques and surveys/field condition checks.

The unit of data analysis in the study of field vulnerability research to landslides is administratively analyzed in the village level. Meanwhile, the data analysis about the efforts that must be made to reduce area vulnerability against landslides is carried out using AHP or Analysis Hierarchy Process[15]. The level of field vulnerability to landslides analysis is based on the resilience index analysis consisting of a loss index and exposed population index which includes an analysis index of the social, physical, economic, and environmental vulnerabilities. The field vulnerability level towards landslides can be calculated after the four indicators of vulnerabilities (social, economic, physical, environmental) have been determined.

The parameters of social security are population density, the percentage of females, the percentage of the poor population, the percentage of people with disabilities, and the percentage of elderly people. The formula to calculate social vulnerability is as follows:

SV = (0.6*PD) + (0.1*FP) + (0.1*PPP) + (0.1*DPP) + (0.1*EPP)

where SV = Social Vulnerability, PD = Population Density, FP = Female percentage, PPP=Poor population percentage, DPP = Disable people percentage and EPP = Elderly people percentage.

The parameter and weight used to determine the level of social vulnerability are shown in table 1.

Table 1
Parameters and weights for determining the level of social vulnerability

Parameter	Weight (%)	Class		
		Low (Score 1)	Moderate (Score 2)	High (Score 3)
Population Density	**60**	**<5 people/ha**	**5-10 people/ha**	**>10 people/ha**
Females Percentage (10%)	40	<20%	20-40%	>40%
The Poor Percentage (10%)				
The Disabled Percentage (10%)				
The Elderly Percentage (10%)				

Source: Perka BNPB 2012 with modification[13]

Economic vulnerability consists of productive land value, asset vulnerability value, and the Gross Regional Domestic Product (GRDP) of the village sector. The formula for calculating economic vulnerability is as follows:

EV = (0.4*PLV) + (0.4*AVV) + (0.2*GRDPv)

where EV = Economic Vulnerability, PLV = Produktive land Value, AVV = Asset Vulnerability Value and GRDPv = Gross Regional Domestic Product Value.

The parameter and weight used to determine the level of economic vulnerability are shown in table 2.

The formulation for calculating GRDP in the village sector and the conversion from productive land area into the rupiah value are depicted from the disaster risk assessment methodology used by BNPB, that is, The Formula of rupiah value of productive land:

$$RLPi = \frac{\text{PLPtot} - \text{i}}{\text{LLPtot} - \text{i}} \; x \; LLPdesa - i$$

where RLPi = the rupiah value of productive land for the–i^{th} land use class at the village level, PLPtot-i = the total rupiah value of productive land based on the value of rupiah sector -i in the level of Regency/City, LLPtot-I = the-i^{th} total area of productive land at district/city level and LLPdesa-i = the-i^{th} area of productive land at village level.

Village Sector PDRB/GRDP Score is:

$$RPPdesa\text{-}i = \frac{\text{RPPKK}}{LKK} \; x \; LDi$$

where RPPdesa-i = the rupiah value of the –i^{th} village GRDP sector, RPPKK = the rupiah value of GRDP sector at Regency/City level, LKK = the area width of Regency/City and LDi = the –i^{th} of village width.

The formulation to calculate the physical vulnerability is as follows:

PV = (0.4*HV) + (0.3 PFV) + (0.3 CFV)

where PV = Physical Vulnerability, HV=House Value, PFV= Public Facility Value, and CFV = Critical Facility Value.

The parameter and weight used to determine the level of physical vulnerability are shown in table 3.

The indicators of environmental vulnerability are the areas of the protected forest, natural forest area, mangrove forest and shrubs. However, this research does not calculate the areas of protected forest and natural forest because they are not found in the location of research, the same thing happens to the absence of mangrove forest in the landslide area. Therefore, the calculation is only for shrubs and mixed gardens as the indicators. Classification of environmental vulnerability parameters based on the modification from several experts and the experienced researchers stated that a high environmental vulnerability class is an area having a narrow area of shrubs and mixed gardens while the wider is the area of shrubs and mixed gardens, the lower environmental vulnerability will be against landslides. This applies only for calculation of landslide vulnerability in this study. The formulation for calculating environmental vulnerability is as follows:

EnV = (0.4*SV) + (0.6*MGV)

where EnV = Environmental Vulnerability, SV= Shrubs Value, and MGV= Mix Garden Value.

Table 2
Parameter and weight to determine the level of economic vulnerability

Parameter	Weight (%)	Class		
		Low (score 1)	Moderate (score 2)	High (score 3)
Productive Land	40	<50 M	50-200 M	>200 M
Asset Vulnerability	40	<50 M	50-200 M	>200 M
GRPD	20	<100 M	100-300 M	>300 M

Source: Perka BNPB 2012 with modification[13]

Table 3
Parameter and weight to determine the level of physical vulnerability

Parameter	Weight (%)	Class		
		Low (score 1)	Moderate (score 2)	High (score 3)
House	40	<400 M	400-800 M	>800 M
Public Facility	30	<500 M	500 jt-1 B	>1 B
Critical Facility	30	<500 M	500 jt-1 B	>1 B

Source: Perka BNPB 2012 with modification[13]

The parameter and weight used to determine the level of environmental vulnerability are shown in table 4.

The data on landslide susceptibility in the form of population data can be obtained by secondary data (population data collected by BPS Semarang Regency/BPS Central Java Province). Such data are the number of population, vulnerable ages (toddlers and elderly), female population, and people with disabilities. Beside completing the data, interviews with the community or community leaders were carried out during the collection of data in the field.

After knowing and calculating the social, economic, physical, and environmental vulnerabilities, the vulnerability to landslides can be determined. The calculation refers to BNPB 2012 as follows[13]:

VL = (0.4*SVV) + (0.25*EVV) + (0.25*PVV) + (0.1*EVV)

where VL = Vulnerability to Landslide, SVV =Social Vulnerability Value, EVV= Economic Vulnerability Value, PVV = Physical Vulnerability Value, and EVV = Environmental Vulnerability Value.

After the vulnerability to landslide is calculated, the results are then consulted with table 5 about the criteria of index value towards landslide vulnerability, which was made referring to the BNPB (2012) with modifications. The purpose of modifications is making the class criteria smoother, and appropriate with other landslide risk variables.

The original value made by BNPB in three classes (low, moderate, high) is modified into five (very low, low, moderate, high, and very high).

Results and Discussion

Banyubiru sub-district is one of the sub-districts in Semarang Regency, the Province of Central Java which has the potential for landslides to occur. The administrative area of each village in Banyubiru sub-district can be seen in table 6.

Table 4
Parameter and weight to determine the level of environmental vulnerability.

Parameter	Weight (%)	Class		
		Low (score 1)	Moderate (score 2)	High (score 3)
Mixed Gardens	60	> 50 ha	20-50 ha	< 20 ha
Shrubs	40	> 75 ha	25-75 ha	< 25 ha

Source: Perka BNPB 2012 with modification[13]

Table 5
Criteria Determination of Index Values to Landslides Vulnerability

S.N.	Interval of Index Value	Class Criteria
1	1,00- <1,40	Very Low
2	1,40-<1,80	Low
3	1,80-<2,20	Moderate
4	2,20-<2,60	High
5	2,60-<=3,00	Very High

Source: BNPB, 2012 with modification[13]

Table 6
The administrative area of each village in Banyubiru sub-district (ha)

S.N.	Name of Village	Area (Ha)	Area (%)
1	Kebumen	404,99	8,0
2	Rowoboni	406,88	8,0
3	Gedong	418,32	8,2
4	Tegaron	632,17	12,4
5	Banyubiru	480,00	9,4
6	Kebondowo	542,27	10,6
7	Kemambang	363,23	7,1
8	Ngrapah	303,21	6,0
9	Sepakung	975,96	19,2
10	Wirogomo	565,35	11,1
	Total Area	5092,37	100,0

Source: BPS, Banyubiru Sub-District Semarang Regency in numbers, year 2019[20]

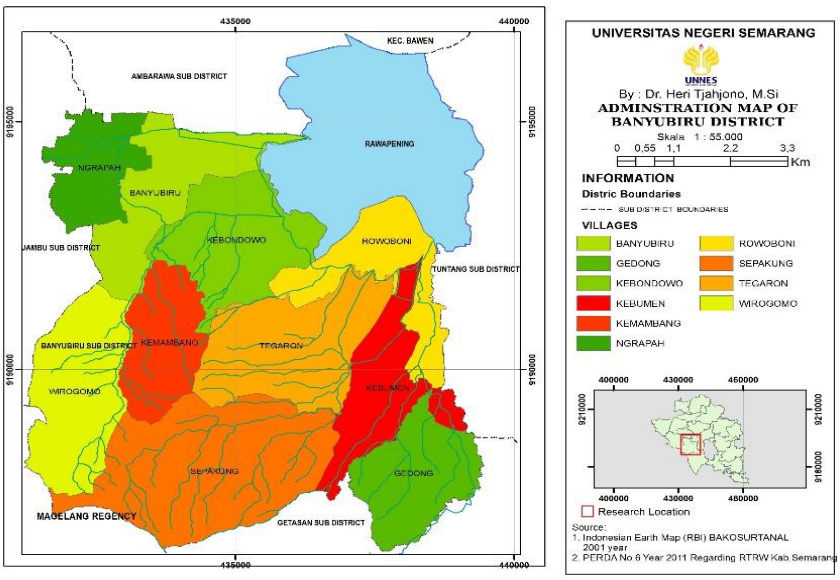

Figure 1: About Administrative Map of Banyubiru sub-District[19]

The administrative boundaries of the Banyubiru sub-district in the north are Rawa Pening and Ambarawa sub-district; in the east are Tuntang and Getasan sub-districts; in the south are Getasan sub-district and Magelang Regency: in the West side there is Getasan sub-district. Part of Banyubiru sub-district territory is located in Telomoyo hills, namely Wirogomo Village, Kemambang Village, Sepakung and Gedong villages. For the other 6 villages, some are in the plains and most of them are on the hills, such as Kebumen Village, Tegaron, Kebondowo, Rowoboni, Ngrapah, and Banyubiru. Spatially, the administrative area of Banyubiru sub-district can be seen in figure 1.

The topographic conditions are quite varied, the widest dip slope is found in an even area with a slope of 0-8% which is 1601.93 Ha or 31.5% of the total area of Banyubiru District. Areas with a gentle slope i.e. a slope of 8-< 15% have the smallest area (464.87 Ha) or 9.1% of the total area of Banyubiru sub-District while the steep slope has a large area with a percentage of 28.2%, or an area of 1435.41 hectares

The research area has a fairly high rainfall. The maximum rainfall of 2500-3000 mm/year spreads over Banyubiru sub-district with an area of 2553.50 Ha, and the minimum rainfall is between 1500-2000 mm/year spreading over the Banyubiru area with an area of 1 519.13 hectares. According to Schmidt Ferguson, the research area has the same climate type, that is type C (slightly wet) with a Q value (comparison between the average dry month and wet month) which is not much different.

The assessment of the level of landslide vulnerability in Banyubiru sub-District, Semarang Regency, was examined using primary data (with field surveys) and secondary data collected by BPS (Central Statistics Agency), Semarang Regency[5]. This research uses four indicators including the values of physical vulnerability, social vulnerability, environmental vulnerability, and economic vulnerability. Each indicator has its own weight in accordance with the provisions in Perka BNPB No. 2/2012, which has been developed according to research requirements and the availability of data in the field[13].

The determination of the vulnerability index criteria which were originally three classes was modified into five criteria classes namely very low vulnerability index (1.00-<1.40), low vulnerability index (1.40-<1.80), moderate vulnerability index (1.80-<2.20), high vulnerability index (2.20-<2.40) and very high vulnerability index (2.40- < =3.0). The provision of vulnerability index criteria is carried out after the 4 vulnerability indicators are calculated into a vulnerability index.

Based on table 6, about the value of the vulnerability index to landslides, it can be explained that in Banyubiru sub-district, Semarang Regency has the vulnerability level of medium and high criteria. There are four villages having a "high criteria" of vulnerability level, those villages are Sepakung, Wiragama, Gedong, and Kebumen whereas the villages having vulnerability level of "moderate criteria" are Banyubiru, Kebondowo, Kemambang, Ngrapah, Rowoboni, and Tegaron. The village owns the highest vulnerability level is Sepakung with the vulnerability index value of 2,36. The average vulnerability level is in the moderate criteria with an index value of 2,17. The lowest vulnerability is owned by Rowoboni Village (1.82) while the highest vulnerability is owned by Sepakung Village (2.36). The highest score of physical vulnerability in Banyubiru District, Semarang Regency, belongs to Gedong Village (3) and Kebumen Village (3).

The highest score of social vulnerability is for Sepakung Village (2.70). As for environmental vulnerability, it has two varied scores: 1.7 and 1.8. The highest environmental vulnerability value (1.8) is owned by Sepakung Village, Tegaron, Banyubiru, Rowoboni, Kebondowo, and Ngrapah

Village while the score 1.7 belongs to Kebumen Village, Wirogomo, Gedong, and Kemambang Village. For the economic vulnerability, each village has the same vulnerability value (2). The calculation results of the vulnerability index can be seen in table 6.

Spatially, the level of community vulnerability to landslides in each village in Banyubiru sub-District, Semarang Regency is presented in figure 3, that is the map on level of community vulnerability to landslides in Banyubiru sub-District, Semarang Regency.

Table 6
Index Value of Vulnerability to Landslide in Banyubiru sub-District, Semarang Regency

S.N.	Village Names	PV	SV	EnV	EV	VIV	Criteria of Vunerability Level
1	Wirogomo	2,7	2,2	1,7	2,00	2,23	High
2	Kemambang	2,7	1,6	1,7	2,00	1,99	Moderate
3	Sepakung	2.4	2,7	1,8	2,00	2,36	High
4	Kebumen	3	2,2	1,7	2,00	2,30	High
5	Gedong	3	2,2	1,7	2,00	2,30	High
6	Rowoboni	2	1,6	1,8	2,00	1,82	Moderate
7	Tegaron	2,7	2,1	1,8	2,00	2,20	Moderate
8	Kebondowo	2,7	2,1	1,8	2,00	2,20	Moderate
9	Banyubiru	2,7	2,1	1,8	2,00	2,20	Moderate
10	Ngrapah	2,4	2,1	1,8	2,00	2,12	Moderate
	Average	2,63	2,09	1,76	2,00	2,17	Moderate

Source: Result of Research Data Analysis1[19]
where PV = Physical vulnerability value/score; SV = Social vulnerability value; EnV = Environmental vulnerability value; EV = Economic vulnerability value; VIV = Vulnerability Index value. The result of vulnerability index calculation is shown in figure 2.

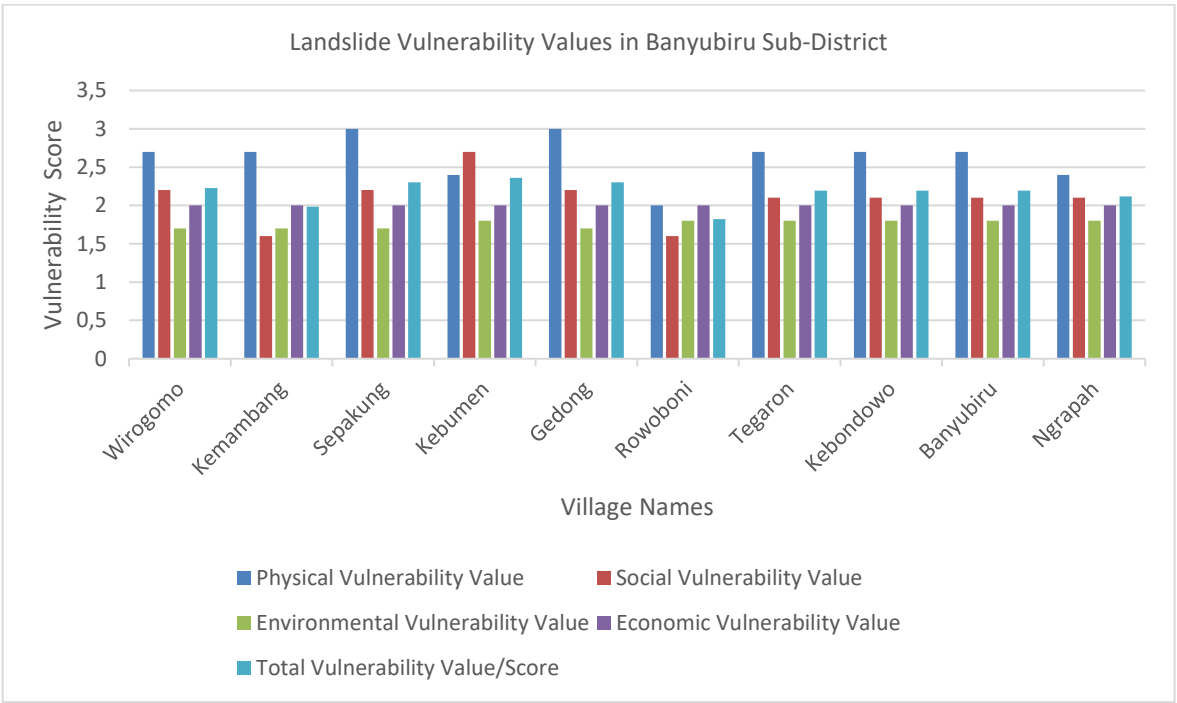

Figure 2: The value of community vulnerability index to landslides per-village in Banyubiru Sub-District, Semarang Regency. Source: Result Research Data Analysis[19]

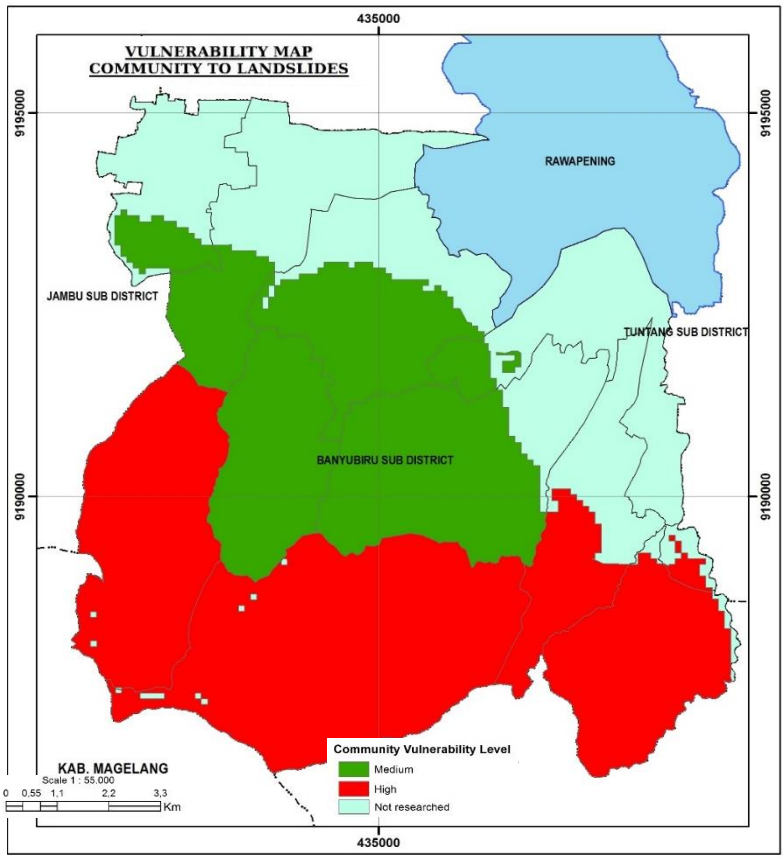

Figure 3: Map of level variation in landslide vulnerability in Banyubiru sub-District[19]

Based on the results of the analysis of research data using AHP and scoring conducted on 65 respondents from the community, Government officials and community organizations, it is concluded that several efforts must be made by the community and Government to reduce vulnerability to landslides so that disaster risk can be minimized as much as possible. Such efforts are:

(1) The Government needs to make laws that regulate or limit the use of areas or lands having landslides potential;
(2) Do not build houses on steep slopes to avoid people from landslide disasters;
(3) The community needs to construct a strong building foundation but with light building top, to reduce the risk of landslides;
(4) Form a community organization in which purpose is safeguarding vulnerable people (the elderly, pregnant women, people with disabilities) of landslide hazards;
(5) Create a diversity of community assets and resources in landslide-prone areas;
(6) Mapping or visual information about the level of landslide threat is required as an input to the Government and the community to avoid development/construction from disasters;
(7) Community, supported by the government, need to arrange new public facilities in landslide-prone areas;
(8) Relocate houses prone to landslides to safer areas;
(9) Establish observation posts in landslide-prone areas,
(10) Organize special officers/officals to manage landslide disaster taken from the village apparatus or youth organization;
(11) Conduct evacuation and first aid training on landslide disaster for vulnerable community groups;
(12) The community has already chosen and determined the location used as a shelter in the event of a disaster;
(13) Create a landslide border or adjust the distance between houses (minimally 15 meters) with the edge of the ever-slided cliff or having landslide potential;
(14) Train yourself and family members on things to do in the event of a landslide;
(15) Set up a bag of disaster preparedness, containing necessities, such as food, drinking water, vital medicines box;
(16) It is necessary to form an early warning team consisting of the local Government, communities, organizations and volunteers to anticipate landslide that may occur.

Social, physical, economic, and environmental conditions in an area are assessed to determine the level of community vulnerability to landslides. The differences in social, physical, economic, and environmental conditions in an area will result in different vulnerability values. This will be different from conditions in rural areas where the population is sparse with inadequate facilities, and the area is mostly agricultural land and mixed gardens. Such conditions if found in landslide-prone areas will result in different levels of vulnerability of the area to landslides.

The level of landslide vulnerability in Banyubiru sub-District varies among the villages. The distribution of vulnerability level of the area in the Banyubiru sub-district, Semarang Regency towards landslides is depicted on a map. It is hoped that through this map, a person will be able to figure out and use the information about the vulnerability of an area, and quickly see the vulnerability of an area to landslide.

According to Sumaryono et al[17], landslide vulnerability maps and landslide inventory databases can be used for landslide prevention and mitigation, and planning future land use [1, 9]. The existence of good land use planning will be able to reduce physical, social, environmental and economic vulnerabilities. In order to reduce the level of vulnerability it will be more effective if the community is willing to comply with land use regulations and the Government is willing to enforce the rules on land use according to the predetermined spatial plan[6]. So far, some people have violated land use regulations that are not in accordance with the spatial designation which results to the increase of landslides vulnerability.

Social vulnerability is determined by several indicators such as social conditions i.e. population density and number of vulnerable population. Vulnerable population includes (a) elderly population, (b) disabled population, (c) female population, (d) population under five, and (e) poor or underprivileged population. High social vulnerability can occur if there are a large numbers of vulnerable residents occupying or living in an area prone to landslides. Conversely, if there are only few or no vulnerable population in an area prone to landslides, the social vulnerability to landslides will be lower/smaller.

Physical vulnerability in an area is determined by several indicators. They are: (a) public facilities consisting of educational facilities, religious facilities, markets, and office buildings, (b) the density of houses or the number of houses, and (c) critical facilities consisting of hospitals, clinics, and health centers. If there are many houses, public facilities, and critical facilities in the areas prone to landslides, they will cause the area to have high physical vulnerability. On the other hand, if there are only a few houses, few public facilities, or few critical facilities in a landslide-prone area, it will cause the area to have low physical vulnerability.

The more luxurious or the higher is the value or the price of the facility, the higher will be the physical vulnerability of the area.

Economic vulnerability in an area is determined by some indicators such as: (a) productive land including agricultural land, and plantation land, (b) valuable assets consisting of livestock, vehicle, and shop assets or kiosk, (c) GRDP of the village sector which is calculated based on the Regency GRDP, the area of the Regency, and the area of the village. The size or the narrow area of productive land and valuable assets in landslide-prone areas will affect the high or low economic vulnerability.

Economic vulnerability will be higher if (a) there are bigger area or more productive lands available in landslide-prone areas, (b) the price of valuable assets is higher in landslide-prone areas; (c) the village area is wider so that the value of GRDP of the village sector is also higher. On the other hand, if the productive lands, valuable assets and the area of the village are relatively small or narrow, the economic vulnerability of the area will be low.

Environmental vulnerability in an area is determined by several indicators. Such conditions that become indicators are (a) the amount of mixed gardens (more or less), (b) the wide area or narrowness of the forest, and (c) the wide area or narrowness of shrubs. Environmental vulnerability will be low if the area of mixed gardens, forest and shrubs in the areas prone to landslides is narrow or small. On the other hand, the environmental vulnerability in landslide-prone areas will be higher, if the area is narrower or the mixed garden, forest and shrubs are unavailable in that area.

The high value of the vulnerability index to landslides occurs because of the influence of several sub-variables with high vulnerability values. Sepakung village has the highest vulnerability index value to landslides (2.36) due to the influence of high social vulnerability value (2.7), also high physical vulnerability value (2.4). Gedong Village is likewise because of the influence of high physical vulnerability value (3) and a quite high social vulnerability score (2.2), it has a high vulnerability index value to landslides (2.30).

Kebumen village also has a high vulnerability index value (2.30) because it is influenced by the presence of a high value of physical vulnerability (3) and a fairly high social vulnerability (2.2). Thus, it can be emphasized that a high value of vulnerability index to landslides occurs when several sub-variables of vulnerability have high vulnerability values.

With the purpose of reducing landslide vulnerability as described in the research results before, the community and Government must make some efforts. If it is carried out seriously even at times of no disaster (pre-disaster), it will be able to reduce disaster risk. However, in reality, many people are unable to carry out the efforts planned and made by the community to reduce landslides vulnerability for various reasons (1) due to the limited economic conditions (2) due to the limited land owned, meaning that people only have land located in a potential landslide area, so that they will continue to build in there, (3) the community is accustomed to responding to disasters when it occurs, (4) there have not been strict rules and sanctions from the Government regarding the use of disaster-prone areas by local residents and (5) there has been no proper organization to handle disasters at the village level.

Conclusion

Based on the results of this study, it can be concluded that (1) Banyubiru sub-District of Semarang Regency has two criteria of landslide vulnerability levels i.e. moderate and high. There are four villages with high criteria of level of landslide vulnerability: Sepakung Village, Wiragama, Gedong and Kebumen Villages. Those with moderate criteria are Banyubiru village, Kebondowo, Kemambang, Ngrapah, Rowoboni and Tegaron villages. The village with the highest vulnerability is Sepakung with vulnerability index value of 2.36. The average vulnerability level is in the moderate criteria with an index value of 2.17. Rowoboni Village has the lowest vulnerability (1.82). The existence of different social, physical, economic and environmental conditions from one region to another can cause the regional vulnerability index values to landslides to vary.

(2) There are many efforts that must be made by the community and the government to reduce vulnerability to landslide disasters in order to minimalize the risk of loss during landslide including: (a) The Government needs to make a draft of regulation to control land use that has the potential for landslides; (b) Communities are advised not to build houses on steep slopes; (c) Communities need to establish organizations that can protect vulnerable communities (elderly, pregnant women, people with disabilities) from landslide hazards; (d) The community must create a diversity of community assets and resources in landslide-prone areas; (e) It is necessary to map visual information about the threat level of landslides; (f) Conducting training on landslide disaster evacuation and first aid for vulnerable community groups; (g) Creating a landslide border or adjusting the distance between houses or buildings (minimally 15 meters) from the cliff edge that is prone to landslides: (h) Train yourself and family members on what to do during the occurence of landslide and (i) Setting up a disaster preparedness bag containing necessities, and vital medicines.

The recommendations given based on the results of the research are (1) The community must be alert, careful, and aware that they live in an area that has moderate vulnerability and high vulnerability to landslides; (2) To reduce the area's vulnerability to landslides, the community together with the Government and private institutions must carry out efforts that can reduce the level of regional vulnerability to landslides such as the community being asked not to build buildings/houses in areas that have a high level of vulnerability; the Government should make rules that regulate or limit or prohibit land use in areas that have medium and high vulnerability to landslides.

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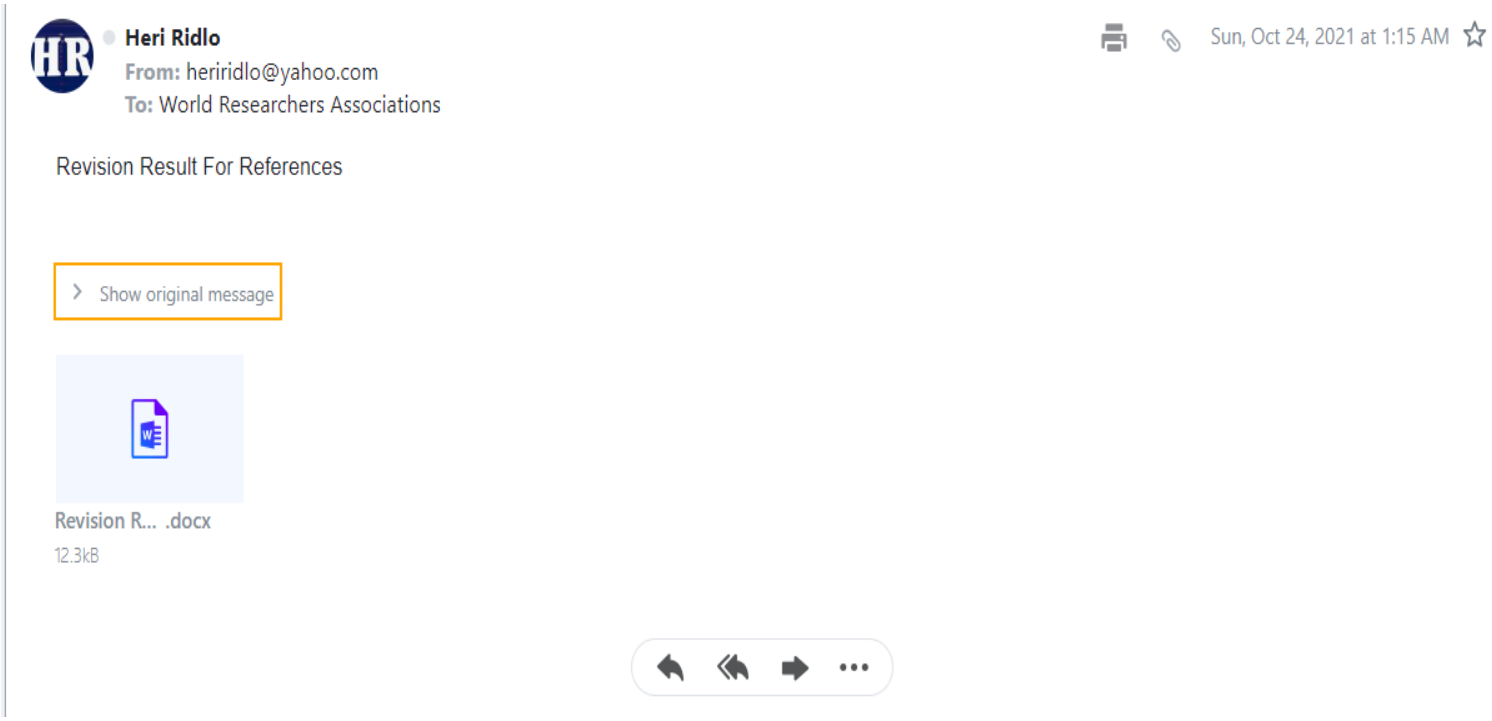

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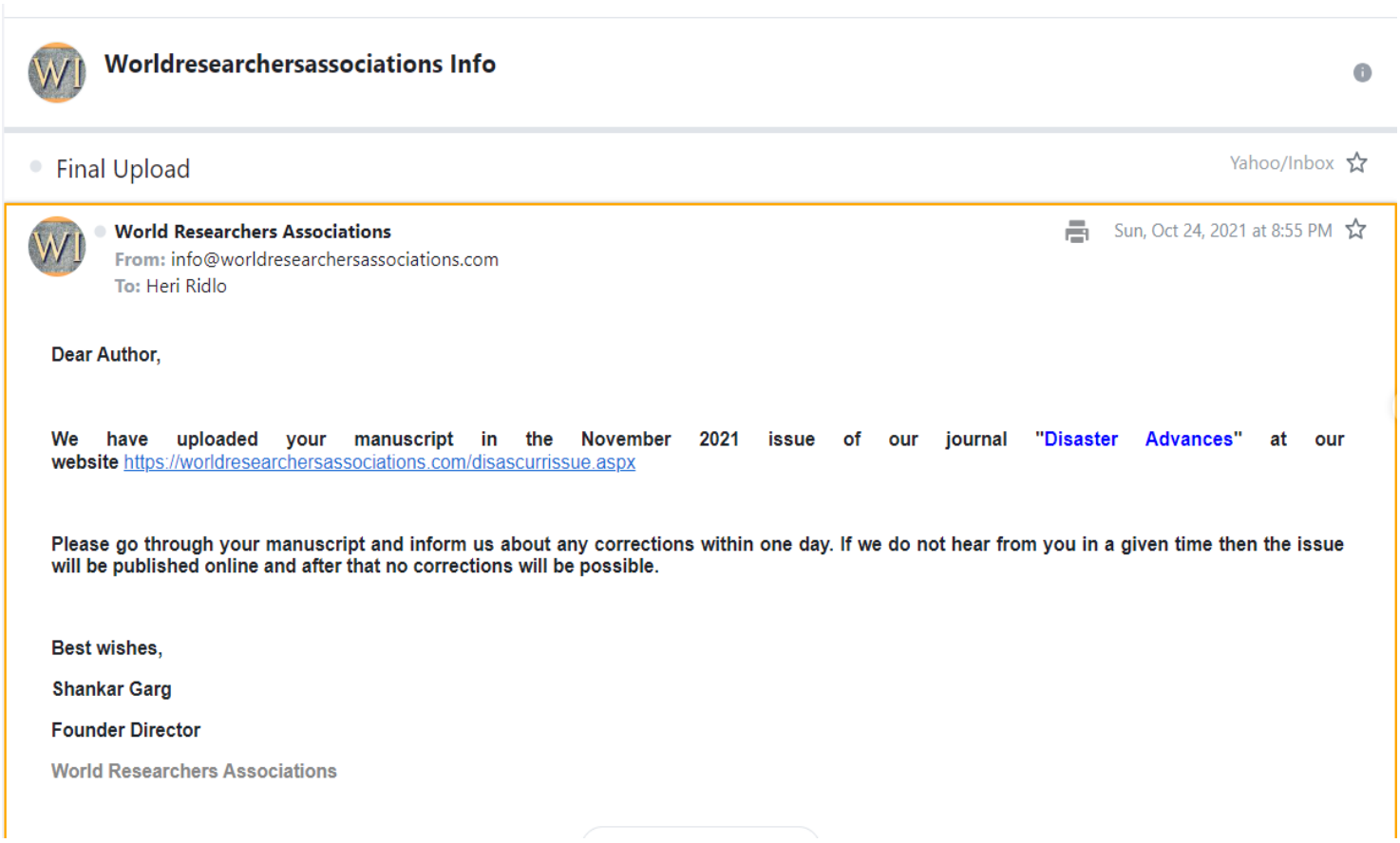

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