Strategies to enhance community capacity on reducing landslides risk at Ngargoyoso District, Karanganyar Regency

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Abstract. Ngargoyoso District, Karanganyar Regency Central Java Indonesia is categorized as vulnerable area for landslides. This area is characterized with high slope and its soil has texture and structure which easy to slide and erosion. The purpose of this study was to formulate a strategy to increase the community capacity on reducing regional and morphological risks of development in accordance with area functions, landslide susceptibility and soil erosion hazard level. The data used in this study was primary data, obtained through interviews with farmers and agricultural extension workers. Respondents were purposively selected with certain criteria. Qualitative descriptive approach and SWOT analysis were employed for data analysis. Strategies formulated were: 1) community needed to increase knowledge to understand environmental risks; 2) community motivation needed to create sustainable environment; 3) importance of environmentally friendly tourism management. The expected implementation of the current result is that community need to depend on the sustainable agricultural sector for their livelihood. Communities can reduce the risk of landslides that can harm their live in material and non-material aspect.

1. Introduction

Ngargoyoso district, Karanganyar regency is an area located on the western slope of Mount Lawu, that it has land characteristics which is potential to be developed as productive agricultural area. The soil is dominated by the deep solum characteristics, the availability of water throughout the year, and the weather supports for the agricultural area. The existing obstacles that it has high slope and the character of the texture and structure are easily to slide and erosion, that regionally and morphologically development carried out should consider the function of the area, vulnerability to landslides, and the danger level of soil erosion.

Based on the results of research conducted by [1], it was known that Ngargoyoso district was an area that had a high vulnerability in Karanganyar regency. Besides Ngargoyoso district, there were five other sub-districts, these were Jatiyoso, Matesih, Tawangmangu, Karangpandan, and Jenawi. The moderate vulnerability level included Jumapolo district and Kerjo district. The low vulnerability level included nine sub-districts including Jatipuro, Jumantono, Karanganyar, Tasikmadu, Jaten, Colomadu, Gondangrejo, Kebakkramat, and Mojogedang. Landslide risk classification in the study area included high risk, medium risk, and low risk. The high risk was found in Matesih District and Karangpan District. The risk was moderate in Jatiyoso, Jenawi, Ngargoyoso, Tawangmangu, Jumapolo, Jaten,
Karanganyar, Colomadu, and Kebakkramat sub-districts. While the low risk was spread in the districts of Kerjo, Gondangrejo, Jatipuro, Jumantono, Mojogedang, and Tasikmadu.

![Figure 1. Landslide susceptibility level in Karanganyar Regency](Image)

Source: Regional Disaster Management Agency (BPBD) Karanganyar Regency

**Figure 1.** Landslide susceptibility level in Karanganyar Regency

Based on Figure 1, it was known that several sub-districts which had a high and moderate level of susceptibility were on the slopes of Mount Lawu. Characteristics of areas that have high susceptibility as stated by [1]. By the characteristics of area that is inclined to landslide, the risk of people living in the area is also included in the high category. Landslides can occur if there is soil movement or rock mass movement on a slope due to effect of gravity. The movement of rock or soil mass occurs because of a disturbance in the balance of the shear strength and shear stress that run on a slope. The imbalance force is caused by a force from outside the slope which causes the magnitude of the sliding force on a slope to be greater than the resisting force. According to [2], some factors which increased the susceptibility of landslide are geological conditions, rainy conditions, land use conditions, human activities and earthquakes.

2. **Literature review**

The GIS analysis approach is widely used to measure the susceptibility level of landslide, especially for the physical approach. The technique is to overlay the factors that are suspected to affect the susceptibility level of landslide. The variables used include rainfall, soil type, geology, and slope as done by [3–5]. Besides GIS analysis techniques, descriptive statistic and variable weighting can also be used. This technique was carried out by [6], they produced recommendations that the community needed to pay attention to the area susceptibility level and activity related to flood and tidal waves in Tanjung Mas Village, Semarang. The form of adaptation carried out by the community could not be distinguished from social strata, income level or livelihood. The adaptation strategies carried out included: in non-
fishing settlement areas, 60% of the community elevated buildings and floors of the houses, 28% repaired and elevated roads, 7% cultivated mangroves, and 5% built embankments. Earlier report [7] use the same method with [6]. The technique used was also descriptive statistics and weighting, the difference was the use of data from satellite imagery. The results of his study was in the level of susceptibility in the study area. In the end, the conclusion of the study showed that this descriptive and weighting technique could produce conclusions about the gradation of landslide susceptibility levels in the local.

Strategies to reduce the risk of landslides can also use a SWOT approach as previous study [8] have done. Some regions have limited infrastructure for mitigation, therefore local wisdom assets can be optimized. For example in Purworejo District, the Regional Disaster Management Agency which has not had landslide contingency plan document as a reference for action. Inadequate quality and quantity of human resources such as low in knowledge and community apathy attitude towards landslide mitigation attempt in Purworejo. Effective strategies carried out by BPBD Purworejo Regency included improving landslide mitigation by utilizing existing local wisdom, increasing collaboration with other parties in the preparation of contingency documents, improving human resource to deal with high public enthusiasm, and utilizing facilities and infrastructure to increase public knowledge.

The approach of social susceptibility level was also developed by [9–11]. If depend on the Spatial Multi Criteria Evaluation (SMCE) to measure the level of susceptibility to landslides [9], the research of [10,11] used weighting for several social variables. The results of research by [9] showed that the level of social vulnerability could be distinguished from the level of social vulnerability was a social indicator. It contained five parameters, these were population density, sex ratio, ratio of people with disabilities, total population according to the lastest completed education and age group ratio or dependency ratio. Meanwhile, the research by [11] used the variables of population density, elderly population and toddlers, female population and community understanding of disasters for social vulnerability. Meanwhile, economic vulnerability was measured by the percentage of the population's poverty level and institutional vulnerability was measured by the existence of disaster management institutions and disaster risk reduction forums.

Previously [12] took different approach than before. The usual approach was GIS and descriptive for the level of physical vulnerability as well as weighting analysis and SWOT analysis for adaptation strategy. The climate change scenario approach associated with the risk of landslide was an option for the research conducted by [12]. They concluded that climate change would have an impact on changing the factors that affected landslides which would then affect the risk of landslides.

3. Method

This research relied on primary data and secondary data. Primary data relied on focus group discussions and secondary data came from the Regional Disaster Management Agency. The Focus Group Discussion by 32 participants consisted of several community groups, included farmer groups, government groups, instructor groups, and non-farmer community groups. The selection of FGD participants was by purposive sampling by considering the representation of community elements. The study area was in Berjo Village, Ngargoyoso District, Karanganyar Regency.

The analysis method used in this research was quantitative descriptive analysis which was formulated into a SWOT analysis. SWOT analysis technique with a qualitative approach, which consisted of strengths, weaknesses, opportunities and threats. SWOT analysis aimed to maximize strengths and opportunities, but able to minimize weaknesses and threats. According to Rangkuti (2006) in [13], SWOT analysis is a systematic identification of strategic factors to formulate strategies. Strategy is a very important tool to achieve goals (Porter: 1985 in [14]). Meanwhile, according to Rangkuti (2006) in [13] strategy is a comprehensive master plan that explains how to achieve all the goals that have been set previously.
4. Data analysis and discussions
This section was divided into two discussion groups. The first group was related to the description of the level of landslide susceptibility and the level of community vulnerability and the second group used a SWOT analysis to determine the strategy.

4.1. Descriptive analysis
Karanganyar has a mountainous area located on Mount Lawu. Mountain areas on some sides have steep slopes. The type of rock in it is volcanic sedimentary rock. As in several previous literature studies, the triggering factor for landslides in Karanganyar Regency was high rainfall happened quite frequently. When the rainy season comes, the risk of landslides is also higher.

In general, according to [15] the potential for medium to high landslides in Karanganyar Regency was located in the north eastern part (Districts of Jenawi, Kerjo, and Ngargoyoso) and in the eastern part of the south (Sub-districts Tawangmangu, Atiyoso, Karangpandan, Matesih, Jatiyoso, Jatipuro and Jumapol). The areas that had medium potential are also found in the Districts of Kebakkramat, Mojogedang, Gondangrejo and Jumapol.

The high landslide susceptibility zone has a high tendency for landslides to occur. Landslides happened frequently in this area, while previous landslides and new soil movements were still actively moving due to effect of high rainfall and strong riverbed erosion. The high morphology was formed by steep hills with a slope of 50-70% (27-36°) to almost upright dominated this area. Covering vegetation was lack generally. In detail, from the analysis of satellite imagery in Karanganyar Regency, it was seen that the vulnerable areas in the medium vulnerability and high vulnerability reaching to 80% of the district's area.

Medium to high potential for landslides in Karanganyar Regency was located in the eastern part of the north (Districts of Jenawi, Kerjo, and Ngargoyoso) and in the eastern part of the south (Sub-districts of Tawangmangu, Atiyoso, Karangpandan, Matesih, Jatiyoso. Based on field observations, it was known that Berjo Village had a quite dense occupancy rate. However, areas for residential and agriculture could still be clearly distinguished. This meant that if landslides occured in agricultural areas, it would not certainly affect the risk of landslides in residential areas. Residential areas was in the small slopes compared to agricultural areas which had larger slopes. If it was viewed from the level of the slope, the agricultural area was more risky.

![Figure 2. Slope and water system](image_url)
Figure 2 illustrated the condition of agricultural area in Berjo Village, Ngargoyoso District. Based on the level of the slope and the flow of water created by farmers, it increased the risk of landslides. Figure 3 showed the water way created by the farmers by cutting the slope. This drain made the slopes below the drain became more risky. Rain and running water would absorb in and created a landslide. The risk of this agricultural area was proven by the frequency of landslides. When it was viewed from the frequency of landslides in agricultural areas, it was higher than in residential areas. Most of farmers will experience loss if the agricultural area have landslide. The main livelihood of most of the people in the area are farmer. Farmers in Berjo Village used the land for horticultural crops, seasonal farm in the form of various vegetables, including carrots, onions, chilies, tomatoes, cucumbers, cassava, flowers and so on. Morphologically to the north Berjo village was a quite steep hill with a wide variety of vegetable crops, while to the south the morphology was downward to the river valley from the Grojogan Sewu waterfall. Landslides occured normally in the season of high intensity rainfall in the area, that rocks would have a high water saturation that the rock will have high water saturation so that the claystone in the one of its constituent rock layers expanded that it functioned as a landslide slip area. When this was confirmed to the FGD participants, on average they already knew information about the types of rocks around them.

The type of landslide was the creep type, especially found the claystone layer in rock layer (Figure 4). The movement of the landslide occurred slowly, and rather quickly when the water saturation in the rock pores was already highy saturated due to the high rainfall in the area.

Figure 3. Waterway made by farmers

Figure 4. Some facts of creeping in Berjo Village

The adaptation strategy carried out in Berjo Village include physical/structural strategy such as gabions, concrete, drainage and so on. The construction of concrete and gabions for preventing landslides has been carried out with funds from various parties such as the Regional Government, independent PNPM, non-governmental organizations and so on. Non-structural adaptation strategy carried out were socialization, counseling, preparedness, rehearsals, and so on. Local governments,
LSM and university have carried out various non-structural activities to avoid disaster risks that might occur in the area. Active counselings need to be carried out in areas that are vulnerable to landslides about the threats of landslide, the indications of landslides, procedures to handle it, its anticipation and mitigation. People who live under the cliff should be aware, especially when it rains. If the rainfall is high and it lasts for a long time, people must evacuate themselves to a safe place, because the avalanche material can move along with the rainwater at any time.

Farmers need to gain to the local knowledge that has been acquired so far. Farmers are advised not to dig or cut slopes on steep areas or slopes. Excavation will cause the strength to withstand the load of the soil on it to be reduced, so that it will accelerate the formation of landslides. Digging will cause the strength to withstand the load of the soil on it to be reduced, so that it will form landslide faster. Digging that form holes will cause puddles when it rains, that it will cause rock saturation underneath which trigger landslides. Cutting slopes will cause steep slopes, and this will trigger erosion and landslides. Immediate handling of area that is still critical, especially on steep-extremely steep slopes with a tuff lithology type with hard, strong and deep rooted plants. Most areas with steep slopes are planted with seasonal crops which are the main livelihood of the people of the area.

Figure 5. A. Utilization of plastic mulch only to reduce erosion and B. Terraces to reduce landslide risk.

Figure 5 showed the activities of farmers in Berjo Village, most of which have made terraces to reduce the risk of landslides (Figure 5B). A small number have used plastic mulch to reduce the risk of erosion (Figure 5A). In areas where landslides have occurred, attention should be given more to the area above to make reforestation with strong root plants. This is very useful in reducing the landslide load that occurs underneath. Repair of damaged facilities and immediately relocate damaged homes by the disaster to a safe location. For choosing relocation areas that are safe from the threat of landslides, it needs coordination between the Karanganyar Regency Government, the community with suggestion and advice from experts. Trees/annual plants with dense canopies can be planted in areas where there is high risk of landslides caused by soil mechanic factors (soil texture, soil consistency, soil permeability, soil depth).

Annual plants can also conduct water around the roots and seep it into deeper layers and release it slowly. The choice of this plants should be considered especially for it is easy to adapt the local environment, growing fast and the roots are tight and deep. Examples: rosewood, bamboo, mahogany, calliandra, lamtoro, acacia, petai, jengkol, melinjo, jackfruit, chocolate, coffee, longan.

4.2. SWOT analysis
Based on the results of the identification of strengths, weaknesses, opportunities, and challenges in Berjo Village, Ngargoyoso District, Karanganyar Regency, it can be arranged in Table 1. The result strategy is expected to be used to increase community capacity to reduce landslide risk. This is the following SWOT analysis.
Table 1. SWOT analysis

| Internals: | Weakness |
|------------|----------|
| **Strengths** | **Weakness** |
| 1. Community had an open attitude towards new knowledge | 1. The level of formal education of farmers was mostly middle down |
| 2. Some people have utilized information technology | 2. Knowledge of landslide hazard was still limited (rain characteristic, land, rock types, etc.) |
| 3. The people in Berjo Village had togetherness in facing risks. | 3. Limited sources of income from the agricultural sector |
| 4. The community already had local knowledge and wisdom to reduce the risk of landslides. | 4. Population ratio of productive and non-productive age. |

**External:**

**Opportunity:**

1. There are many collaboration opportunities for regional development to become safer areas from landslides.
2. Community motivation to reduce high risk.
3. Berjo Village has a tourism attraction that can be managed in an environmentally friendly way

- The community has an open attitude to accept higher education to be together develop safer area
- Community motivation is increased through spread of information
- Tourism object are developed with local wisdom.

- Need to increase the level of knowledge regarding to land characteristics, rock types, climate, and slope
- People's motivation to learn can be used to increase income
- Enabling residents to participate in economic activities

**Threat:**

1. Sleep slopes
2. Climate change is harder to predict
3. Limited land causes the demand for land for housing to increase
4. The more diverse livelihoods of the community

- Climate change can be reduced with the knowledge in the community
- Limited land for housing can be overcomed by providing an explanation to the community
- The togetherness attitude can be used to make BUMDES for the improvement of the village economy.
- It is necessary to increase up-to-date knowledge about climate change and its effect on landslides.
- It is necessary to increase understanding of landslide risk
- It is necessary for mass socialization. The more diverse the livelihoods, the more heterogeneous of spreading information

5. Policy conclusions and implications

Based on observations in the research area, there are several conclusions that can be drawn:

- Land use in Berjo Village, Ngargoyoso District, Karanganyar Regency was generally dominated by seasonal gardens and settlements on steep topography that it affected on erosion and landslides. Steep slopes were found on agricultural land, while land for settlement had lower steep. Based on the available evidence, it was concluded that the landslide was a creeping type, especially when claystone layer were found in rock layer. Some farmers already knew the characteristics of rocks in their area. They also had understood that their area was vunerable to landslides so that land utilizati has been managed well. Several observation points were found that there were cutting slopes which are suspected to be mining activities. The conclusions of SWOT analysis were: Community and farmers were aware of the risks and they were willing to work together to reduce risks; tourism object development was based on local wisdom and it did not increase the risk of landslides; supervision of dangerous mining activities. The implication that can be taken is that the community and government need to adopt sustainable land use based on environmental risks. The policies taken are expected to support, for example, the use of residential land not on high-risk area. Policies for the preparation of regional planning, evaluation of spatial planning, disaster mitigation, early warning systems and the preparedness of the agency and the community for the possibility of landslides. Utilization of agricultural area for crops that can reduce the risk of landslides. Farmers can plant shrubs and grass under annual crops in areas where there are landslide triggers which is caused by soil mechanics factors (soil texture, soil consistency, soil permeability, soil depth). Bush and grass are planted under these annuals will later serve as media for interception of rain for the second layer after trees, binding soil mass in shallower layer, producing leaf
fall, twigs and branches that can protect the soil surface from direct raindrops hit, draining water around the roots and releasing it slowly. The government can help to repair surface drainage system on slopes that have indication of soil cracks. The drainage system is made by making a drainage (SPA) which is reinforced with a drop structure of stone.

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