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The Geographic Information System Based on Mapping and Landslide Early Warning System for Disaster Mitigation in Kalongan Climate Village

Zahra Yulia Putri[1], Slamet Isworo[2], Salsa bella Anjani[3], Sri Hapsari Wahyuningtyas[4], Afifah Nur Najiyah[5], Aprelia Dwi Hapsari[6], Hugi Cerlyawati[7], Ika Pantiawati[8]

[1]412202100177@mhs.dinus.ac.id
[2]slametisworo@dsn.dinus.ac.id
[3]412202000168@mhs.dinus.ac.id
[4]412202100175@mhs.dinus.ac.id
[5]412202200211@mhs.dinus.ac.id
[6]412202000158@mhs.dinus.ac.id
[7]hugi.cerlyawati@dsn.dinus.ac.id
[8]ikapantia13@mhs.dinus.ac.id

Abstract

Landslides are a serious threat to many communities in rural areas, including the Climate Village in Kalongan Village. This activity aims to mitigate the risk of landslides in Kalongan Village by combining scientific knowledge, mapping of vulnerable areas, technology and active community participation. This research uses the Geographic Information System (GIS) method for mapping landslide potential and applies the Landslide Early Warning System (LEWS) method to help mitigate landslides. Questionnaires were used to measure the community's knowledge about landslides and their level of preparedness for landslides Mapping using Geographic Information System (GIS) identified landslide-prone areas in Climate Village of Kalongan Village. Landslide geological hazards are scattered in a small part of the village, with a hazard area of about 8.2 ha, while areas safe from landslide hazards cover 854.8 ha of the total Kalongan Village area The implementation of the Landslide Early Warning System (LEWS) Method aims to provide early warning to the community in relation to potential landslide hazards, with a special device that detects ground movement and provides signals in case of hazardous movement. In addition, a questionnaire was conducted to assess the community's knowledge about landslides and their level o preparedness to face potential disasters. The results of the questionnaire showed that the majority of the community had a good understanding of the impacts caused by landslides, especially with respect to the damage they can cause, as wel as the potential for death. This level of understanding is considered important in improving preparedness and risk mitigation against landslides.

Correspondence Address:
Universitas Dian Nuswantoro
E-mail:
412202100177@mhs.dinus.ac.id

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Introduction

Landslide is a significant threat to the safety and well – being of people residing in mountainous areas (Science, 2021). Landslide is a natural disaster that frequently occurs in sloped areas and has the potential to cause significant losses to human lives and properties (Government of Indonesia, 2017). Landslides result in not only material losses but sometimes also human casualties. Continuous ground movements necessitate disaster management efforts, involving planned and organized activities aimed at minimizing or eliminating the dangers or losses from disaster consequences, as well as avoiding potential disaster risks, to reduce, minimize, or ideally eliminate the resulting impacts (Sutikno, 2001).

Kalongan Village is located in the East Ungaran Subdistrict, Semarang Regency, Central Java. Kalongan Village covers an area of 8.68 KM^2 (22.85% of the total subdistrict area in East Ungaran). The topography in Kalongan Village falls under topographic classes of 8 - 15% and 25 – 45%. The 8 – 15% class is categorized as gentle slopes, while the 25 – 45% class is steep. The 8 – 15% slope class encompasses an area of 800 ha, constituting 97.70% of the total area, whereas the 25 – 45% slope class covers 63 ha, accounting for 7.30%. This indicates that the slope class in Kalongan Village is predominantly classified as gentle slopes within the 8 – 15% category. However, a small portion of Dampu Hamlet has slopes in the 25 – 45% category, located at the border between Dampu Hamlet and Susukan Subdistrict. Areas with slopes of 8-15% are suitable for development as residential, business, and office areas due to good drainage conditions. This area is where many human settlements are found. The slope levels categorized as hilly areas due to the gentle and very steep slopes.

The Climate Village in Kalongan Village is one of the areas vulnerable to landslides. This study aims to understand the community's knowledge of landslides and mitigate the risk by applying a landslide disaster mitigation approach based on Geographic Information System (GIS) and Landslide Early Warning System (LEWS) method in Kampung Iklim Kalongan (Jeon and Kang, 2020) (Mukhlisin et al., 2010). Geographic Information System (GIS) is used for mapping landslide potential by applying the Landslide Early Warning System (LEWS) method to assist in landslide disaster mitigation (Abdurrohim and Firman, 2018). LEWS is also used to provide early warnings to the community in landslide cases (Summary, 2015).

Public awareness is crucial in facing potential disasters, whether natural or non-natural, to minimize their occurrence. This includes landslides. Therefore, the importance of community knowledge in managing land in landslide-prone areas in Kalongan Village cannot be overstated. The role of the community is highly necessary in reducing disaster risks, where community knowledge is beneficial in managing land in landslide – prone areas.

Methods

a. Mapping with Geographic Information System (GIS)

Mapping is conducted by collecting spatial data through field surveys. Subsequently, data analysis is performed using ARCGIS software to identify and create maps of landslide-prone areas in Kalongan Village.

b. Landslide Early Warning System (LEWS) Method

Development of landslide prediction models based on risk factors such as rainfall, slope steepness, and revegetation, and the implementation of an early warning system to inform the community about potential landslide hazards.

c. Landslide Knowledge Questionnaire to the Community

Distribution of questionnaires to develop a questionnaire covering aspects of the community's knowledge of landslides. Additionally, distributing the questionnaire to the community of Kampung Iklim and analyzing the questionnaire data to understand the level of knowledge and awareness of the community regarding landslide risks.

Results and Discussion

This research is located in Kalongan Village, located in East Ungaran Subdistrict, Semarang Regency, which has recently gained recognition for opening tourist spots in the area. According to surveys conducted, Kalongan Village has excellent potential in terms of agricultural productivity, with extensive land suitable for agriculture that appears to be fertile.

Figure 1 Location of Kalongan Village
Source: primary data, 2023

According to surveys, Kalongan Village has excellent potential in terms of agricultural productivity, with extensive land suitable for agriculture that appears to be fertile. Some areas of Kalongan Village have hilly contours and are supported by high rainfall in the area, resulting in several areas in Kalongan Village being classified as disaster-prone areas, especially for landslides.

Figure 2 Landslide Events
Source: primary data, 2023

Mapping with Geographic Information System (GIS)

The results of mapping using ARCGIS identified landslide-prone areas in Kampung Iklim. Kalongan Village has a geological landslide hazard area that does not spread throughout the village. The geological landslide hazard in Kalongan Village covers an area of 8.2 ha, while the areas not prone to geological landslide hazards cover 854.8 ha, with a total area of Kalongan being 863 ha. The percentage of areas experiencing geological landslide hazards is 0.95%, and the percentage of areas not experiencing geological landslide hazards is 99.05%. Thus, geological landslide hazards occur in a small portion of Kalongan Village.

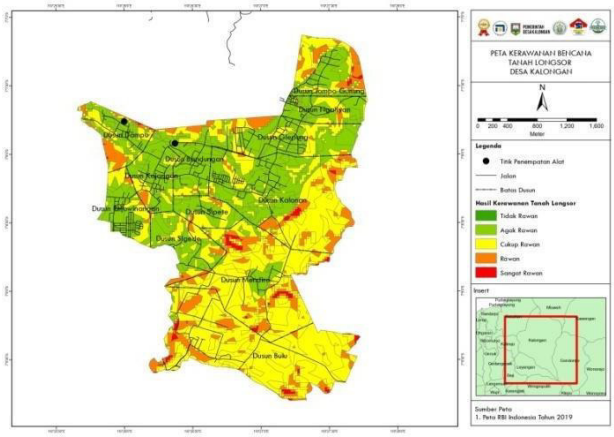

Figure 3 Mapping of Landslides in Kalongan Village

Source: primary data, 2023

Based on Figure 3, there are five categories of risk levels: not at risk, slightly at risk, moderately at risk, and highly at risk. In the slightly at-risk category, there are hamlets such as Dampu, Bandungan, Kalongan, Rejowinangan, Lompo Gunung, Ngaliyan, Glepung, Kalonan, Sipete, and Sigede. Meanwhile, the moderately at-risk category includes the hamlets of Bulu and Mendiro. These categories are determined based on indicators such as rainfall, slope/soil steepness, and soil type. Different colors in each hamlet indicate different soil slope steepness in each area.

Landslide Early Warning System (LEWS) Method

The Landslide Early Warning System method provides early warning recommendations to the residents of Kalongan Village. The LEWS landslide detection device is specifically designed to detect ground movements and provide early warnings about landslides. The LEWS landslide detection sensors are installed at landslide-prone points, and any slight movements will be detected. Therefore, the community can be informed early about potential landslide dangers, and especially loss of life can be minimized.

Figure 4 Installation of LEWS Equipment
Source: primary data, 2023

In Figure 4, the formation of the LEWS (Landslide Early Warning System) Disaster Mitigation tool, which has been installed at points where landslides usually occur, is shown. It is then connected to a smartphone that will be fully monitored by the village authorities. If there is ground movement, the sensor will provide a signal and emit a siren/sound. Additionally, the planting of hardy plants is carried out with the hope that in the long run, when the plants grow large and fertile, the plant roots can support the soil and prevent landslides.

Landslide Knowledge Questionnaire to the Community

Based on the results of the questionnaire aimed at evaluating the community's understanding of landslides and their readiness to face the possibility of disasters, Diagram 1 provides a detailed breakdown. The community's knowledge of landslides is at 85.7% for the response that soil shifting is caused by water absorption, while 14.3% believe that excessive water absorption is the cause. This data reflects the community's understanding of the root causes of landslides, which, in turn, can help reduce the risk of landslides.

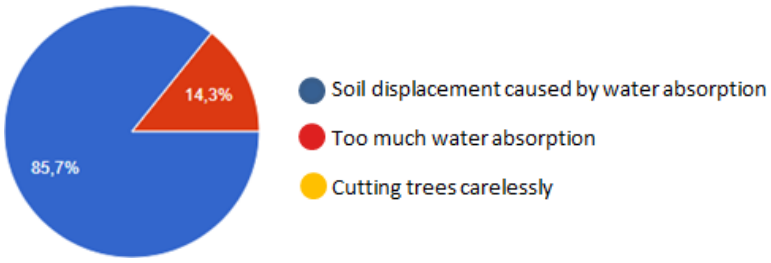

Diagram 1 Results of the Landslide Causes Questionnaire
Source: primary data, 2023

In Diagram 2, the types of rainfall that can trigger landslides are explained. It is concluded that heavy rainfall can increase the risk of landslides. Landslides occur due to sudden movement and steepness of the soil, rocks, or other landslide materials on slopes or mountainsides. Heavy rainfall increases moisture in the soil, thus altering slope stability. This pressure can weaken the soil structure, potentially leading to landslides. The questionnaire results show that the majority of the community understands the impact of landslides triggered by rainfall. They acknowledge that heavy rainfall can trigger landslides, so it is important to pay attention to and take preventive measures to reduce the risk of landslides. Prevention measures include improving drainage systems, appropriate land use planning, slope reinforcement, and the use of landslide detection equipment.

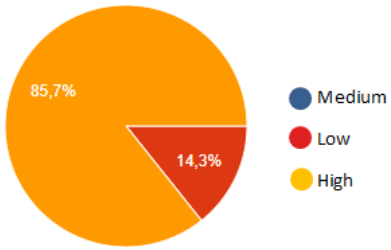

Diagram 2 Results of the Rainfall Causes Landslides Questionnaire
Source: primary data, 2023

Overall, the questionnaire results in Diagram 3 illustrate the significant impact of landslides on the economic conditions of the surrounding community. Loss of livelihoods and additional financial burdens due to home renovations are the two aspects that most affect their comfort and economic stability in the affected area. Some of the community (28.6%) states that landslides make them uncomfortable staying in the area. This may be related to concerns about safety, uncertainty, and insecurity due to the potential for landslides in the future. Most respondents (42.9%) express that landslides impact their livelihoods. Landslides can damage infrastructure, fields, or workplaces, disrupting the livelihoods of the population. This loss of livelihood can affect their overall economic conditions. Some of the community (28.6%) also indicate that landslides force them to spend more on home renovations. The damage caused by landslides requires additional investment to repair or renovate homes, affecting household financial situations.

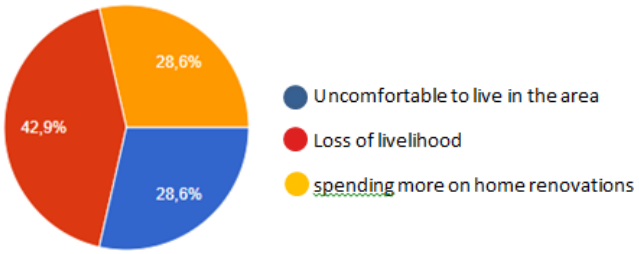

Diagram 3 Economic Impact of Landslide Disasters on the Community
Source: primary data, 2023

Diagram 4 of this questionnaire reflects the mitigation actions taken by the community before landslides occur. Emphasis on awareness and response to warnings and landslide mitigation instructions is crucial in minimizing the risk and impact of this disaster on the community. Furthermore, further education is needed to enhance the community's understanding and preparedness for potential landslide hazards. A small percentage of respondents (14.3%) state that they are cautious about heavy rainfall as a mitigation measure before landslides occur. This reflects their awareness of weather factors that can trigger landslides. The majority of respondents (42.9%) state that they are relaxed when there is a landslide threat. This attitude may reflect a lack of understanding of the risks and dangers associated with landslides or a lack of preparedness in facing potential hazards. Most respondents (42.9%) indicate that they would take action in line with landslide warning instructions. This indicates that the community tends to respond to warnings and mitigation guidelines provided by relevant authorities or experts to reduce landslide risks.

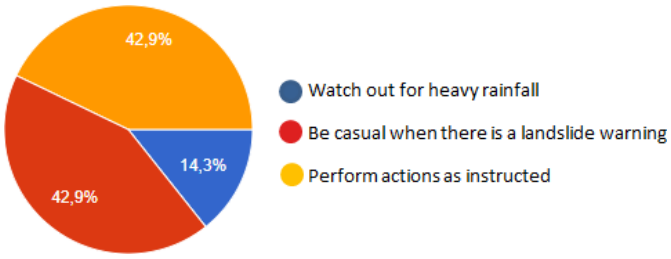

Diagram 4 Mitigation Actions Before Landslides
Source: primary data, 2023

Diagram 5 reflects the factors that can influence the risk of landslides according to respondents' perceptions. By recognizing and understanding the roles of factors such as land degradation, the community, and the government, steps can be taken to reduce the risk and vulnerability to landslides. This includes adopting sustainable practices in land management and development that consider local environmental conditions. The majority of respondents (42.9%) identify land degradation as a factor that can influence the risk of landslides. Land degradation can occur due to activities such as deforestation, unsustainable farming, or construction that disrupts the natural structure of the soil. This can reduce soil resilience and stability, increasing the risk of landslides.

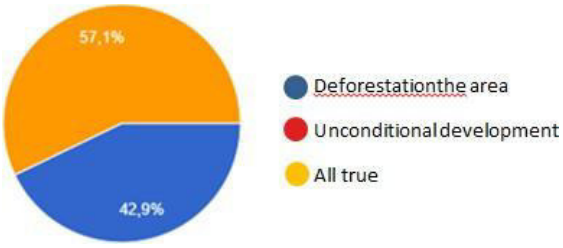

Diagram 5 Landslide Risk
Source: primary data, 2023

Diagram 6 visualizes the results of the questionnaire that asked respondents about their knowledge regarding the impact of landslides. The results show that it causes damage of 28.6%. Meanwhile, the majority of respondents, 71.4%, understand well that landslides can cause damage and even lead to death. This graph highlights the level of understanding of the community regarding the impacts of landslides, providing an overview of how well they comprehend the potential dangers and risks associated with landslides. This understanding is crucial to enhance preparedness and risk mitigation for landslides.

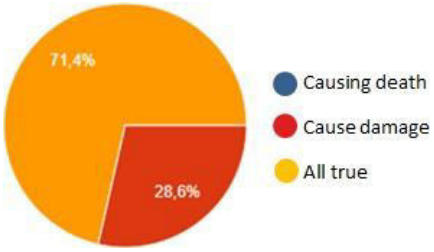

Diagram 6 Negative Impacts of Landslide Disasters
Source: primary data, 2023

in stressful conditions are more likely to occur in the group with good thesis consultation frequency (55.3%), and the p value is 0.496. Then, stress conditions were found more in respondents in the good knowledge group (52.2%) with p value of 0.205. The respondent's mindset shows that respondents in stressful conditions are more found in respondents with a negative mindset (61.0%), and the p value is 0.010. Respondents with stressful conditions were found more in the low supportive peer social support group (57.5%) and p value 0.070. The social support of the thesis supervisor showed that respondents who were under stressful conditions were more likely to be found in the social support group of the thesis supervisors who were low supportive (59.8%), and the p value 0.023.

Based on the bivariate analysis (chi-square test), it is known that several stress risk factors are associated with the respondent's stress level, namely gender, mindset, and social support for the thesis supervisor. While the stress risk factor variables that were not related to the respondent's stress level were

the year of admission, knowledge, thesis guidance method, frequency of thesis consultation, and peer social support. It is also known that there is no correlation between stress levels and the incidence of insomnia (as measured by sleep quality) in respondents.

Conclusion

Mapping based on Geographic Information Systems and the implementation of the Landslide Early Warning System can aid in mitigating landslide risks in the Climate Village of Kalongan. Evaluating public knowledge through questionnaires is a crucial step to increase awareness and preparedness of the community towards landslide threats. These steps are expected to contribute positively to the effort of reducing landslide disaster risks in this area. Overall, landslide risk mitigation efforts in Kalongan Village integrate scientific knowledge, mapping of vulnerable areas, technology, and active community participation. These measures are vital to creating a safer environment and improving the quality of life for the people in landslide – prone areas.

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