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LANDSLIDE DISASTER MITIGATION BASED ON DISASTER RISK LEVEL IN GRESIK, EAST JAVA

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ABSTRACT

Landslides are a natural disaster with a serious threat in Indonesia, especially in areas with vulnerable geographic conditions. Gresik Regency, East Java, is one such area that is prone to landslides. This research aims to identify mitigation measures that are appropriate to the level of landslide risk in Gresik Regency. The research method used is a descriptive approach by collecting secondary data from various reports and available data. The research results show that the proposed solution is to install an internet-based landslide Early Warning System (EWS) in locations that are prone to ground movement and landslides. This EWS is based on standard disaster risk assessment parameters, such as slope slope, slope direction, rock type, etc., which are adapted to regional conditions in Gresik Regency. Installation of this internet-based EWS has several innovative values, including providing added value for the organization and stakeholders, innovation in technology, can be replicated, can be applied sustainably, is in line with organizational values, and provides benefits to the organization. Short, medium and long-term activity stages are outlined to achieve successful implementation, including installing EWS, developing the latest formats and applications, as well as monitoring and outreach. The installation of an internet-based landslide EWS in Gresik Regency is an innovative step that has great potential to increase preparedness and reduce the impact of landslides. This EWS is in line with the values of BPBD Gresik Regency and can be replicated by other agencies. Successful implementation depends on short, medium and long term planning steps, as well as ongoing efforts in system development and outreach to the community. It is hoped that this research can contribute to reducing the impact of landslides in Gresik Regency and similar areas in the future.

Keywords: *Disaster, Gresik, landslide, mitigation.*

ABSTRAK

Tanah longsor merupakan bencana alam dengan ancaman yang serius di Indonesia, terutama di wilayah-wilayah dengan kondisi geografis yang rentan. Kabupaten Gresik, Jawa Timur, adalah salah satu wilayah yang rawan terhadap tanah longsor. Penelitian ini bertujuan untuk mengidentifikasi langkah mitigasi yang sesuai dengan tingkat risiko bencana longsor di Kabupaten Gresik. Metode penelitian yang digunakan adalah pendekatan deskriptif dengan mengumpulkan data sekunder dari berbagai laporan dan data yang tersedia. Hasil penelitian menunjukkan bahwa solusi yang diusulkan adalah melaksanakan pemasangan *Early Warning System* (EWS) tanah longsor berbasis internet pada lokasi yang rawan terjadi pergerakan tanah dan kejadian tanah longsor. EWS ini didasarkan pada parameter-parameter standar pengkajian risiko bencana, seperti kemiringan lereng, arah lereng, tipe batuan, dan lain-lain, yang disesuaikan dengan kondisi daerah di Kabupaten Gresik. Pemasangan EWS berbasis internet ini memiliki beberapa nilai inovatif, termasuk memberi nilai tambah bagi organisasi dan *stakeholder*, inovasi dalam teknologi, dapat direplikasi, dapat diterapkan secara berkelanjutan, selaras dengan nilai organisasi, dan memberikan manfaat bagi organisasi. Tahapan kegiatan jangka pendek, menengah, dan panjang diuraikan untuk mencapai kesuksesan implementasi ini, termasuk melaksanakan pemasangan EWS, mengembangkan format-format dan aplikasi terbaru, serta melakukan monitoring dan sosialisasi. Pemasangan EWS tanah longsor berbasis internet di Kabupaten Gresik merupakan langkah inovatif yang memiliki potensi besar untuk meningkatkan kesiapsiagaan dan mengurangi dampak bencana tanah longsor. EWS ini sejalan dengan nilai-nilai BPBD Kabupaten Gresik dan dapat direplikasi oleh instansi lain. Keberhasilan implementasi bergantung pada perencanaan langkah-langkah jangka pendek, menengah, dan panjang, serta upaya berkelanjutan dalam pengembangan sistem dan sosialisasi kepada masyarakat. Penelitian ini diharapkan dapat berkontribusi dalam

mengurangi dampak bencana tanah longsor di Kabupaten Gresik serta wilayah-wilayah sejenis di masa depan.

Kata kunci: Bencana, Gresik, tanah longsor, mitigasi.

INTRODUCTION

Natural disasters are phenomena that can occur at any time and place, posing hazards or risks to human life as they can result in property damage and loss of life (Sholikah et al., 2021). The geographical and demographic conditions of Indonesia make the country susceptible to both natural and non-natural disasters (Yulianto et al., 2021). As an archipelago located along the equator between the continents of Asia and Australia, Indonesia lies at the convergence of three major tectonic plates: the Eurasian, Pacific, and Australian plates. The collision of these plates has led to the formation of a volcanic belt. This volcanic belt has caused several regions in Indonesia to consist of mountain ranges and hilly areas with slopes ranging from gentle to steep. These conditions contribute to Indonesia's potential for landslide disasters (Sholikah et al., 2021).

Landslides are geological natural disasters that can result in significant losses, both in terms of human casualties and material damage. These include sedimentation, disruption of transportation access, damage to agricultural land and residential areas, irrigation channels, as well as physical infrastructure (Sholikah et al., 2021). According to data compiled by the Badan Nasional Penanggulangan Bencana (BNPB) in 2020, the recap of landslide occurrences and casualties in Indonesia from 2009 to 2018 recorded 4,336 landslide incidents, resulting in 1,761 deaths, 1,556 injuries, and 232,678 people affected or displaced. Additionally, 12,834 houses were severely damaged, 4,718 houses sustained moderate damage, and 16,754 houses suffered minor damage (Sudiana, 2020).

Based on data collected by the BNPB Indonesia in 2022, there were 3,544 natural disaster events recorded across Indonesia. Among these, 1,531 were flood events, 1,068 extreme weather incidents, 634 landslides, 252 forest and land fires, 28 earthquakes, 26 tidal waves and coastal erosion, 4 droughts, and 1 volcanic eruption. These disasters resulted in various forms of damage, including loss of life and infrastructure destruction. Every year, several regions in Indonesia frequently experience landslides, which are among the most common types of natural disasters in the country (BNPB, 2022).

The East Java Province is surrounded by active volcanoes, seas, and experiences high rainfall intensity, making it prone to natural disasters. One of the most frequent disasters during the rainy season is landslides. Gresik Regency is one of the areas in East Java with considerable landslide potential, primarily due to its geographical characteristics, which include limestone mountains, onyx mountains, and hills. The 2017 disaster risk assessment by the Badan Penanggulangan Bencana Daerah (BPBD) of East Java Province identified three sub-districts in Gresik Regency as part of the 50 sub-districts with high landslide risk, underscoring the need for serious mitigation and preparedness measures in facing this potential disaster (Puspita et al., 2024).

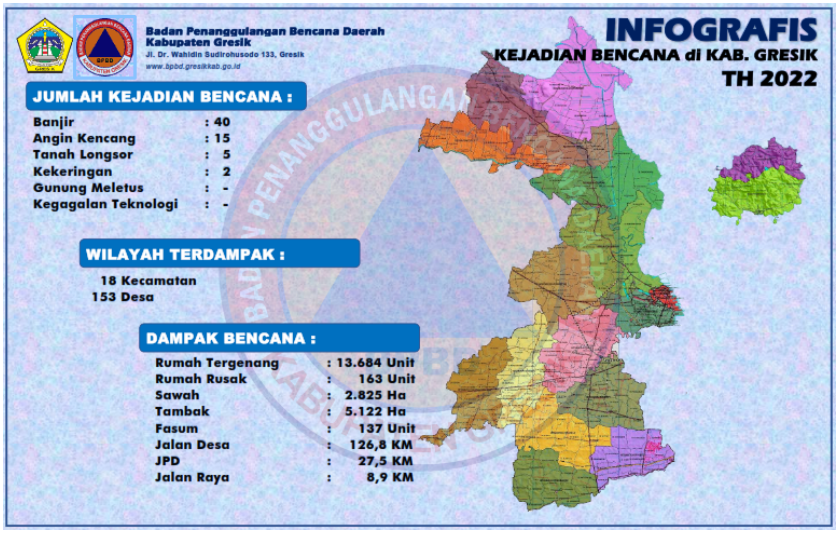

Figure 1. Disaster Event Infographic of Gresik Regency (2022).

Based on data from the Badan Penanggulangan Bencana Daerah (BPBD) of Gresik Regency in 2022, Gresik Regency experienced 62 natural disaster events, including 40 flood incidents, 15 strong wind events, 5 landslides, and 2 droughts, affecting 18 sub-districts and 153 villages. Three sub-districts in Gresik Regency were impacted by landslides, namely Sangkapura, Tambak, and Gresik sub-districts (BPBD Gresik, 2022).

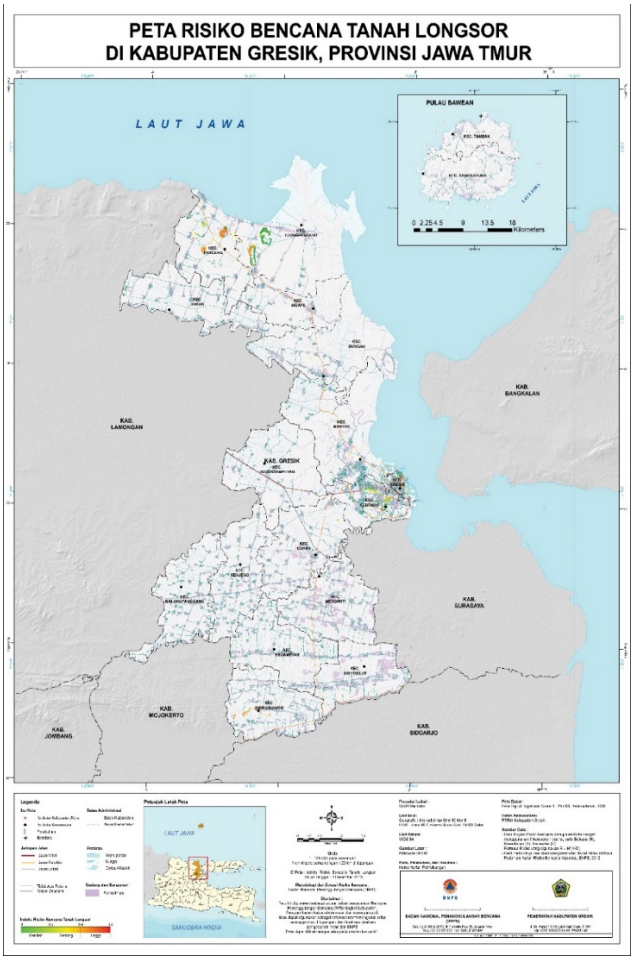

Figure 2. Landslide Disaster Risk Map of Gresik Regency

The map above indicates that there are several areas in Gresik Regency with a landslide disaster risk index, both at moderate and high levels. Landslides occur due to the interaction between controlling and triggering factors. Controlling factors are related to the inherent conditions of materials susceptible to landslides, including geological aspects, slope gradient, rock type (lithology), the presence of faults, and fractures within the rock formations. On the other hand, triggering factors are conditions that initiate the movement of these materials, which can include the intensity of rainfall, erosion processes, earthquakes, and human activities that affect slope stability. Landslide movements involve the materials that form the slope, which can consist of rocks, eroded materials, soil, or a combination of these materials, moving downward or outward along the slope. The process starts as rainwater infiltrates the soil, adding to its weight. If this water encounters an impermeable layer that acts as a sliding plane, the soil becomes slippery, causing the overlying weathered soil layer to shift downslope, which can trigger a landslide (Lustono et al., 2024).

Gresik Regency, located in a region characterized by limestone and onyx hills, such as those found on Bawean Island, as well as hilly terrains, continues to face serious threats from natural disasters. According to a disaster risk assessment by the BPBD of East Java Province, three sub-districts in Gresik Regency are included in the list of 50 sub-districts with high landslide potential. These areas are highly vulnerable to landslides, whether caused by natural factors or human activities. Landslides triggered by natural factors frequently occur in regions such as Sangkapura Sub-district and Tambak Sub-district, located on Bawean Island, with a moderate to high level of landslide hazard. On the other hand, landslides induced by human activities, particularly limestone mountain mining and C-excavation activities, present a serious problem in Gresik Regency. Limestone mining is primarily concentrated in Panceng and Ujungpangkah Sub-districts, while C-excavation mining is found in Kebomas, Kedamean, and Wringinanom Sub-districts. These areas exhibit a high level of landslide hazard (BPBD Gresik, 2022).

Several measures have been implemented to mitigate the impact of landslides as preventive steps, such as installing early warning systems and conducting evacuations to save landslide victims. Disaster mitigation refers to a series of actions aimed at reducing disaster risks by enhancing capacity and reducing threats and vulnerabilities, both through infrastructure development and education to raise awareness and preparedness for disasters. Landslide mitigation efforts can be approached through both structural and non-structural means. Structural approaches involve the construction of physical infrastructure, such as building embankments or retaining walls in areas with steep slopes. Meanwhile, non-structural approaches focus more on the use of technology to predict and anticipate disaster risks, as well as education and training to enhance public knowledge and preparedness. Landslide disaster risk is influenced by the physical vulnerability of the area as well as social, economic, and environmental factors. Therefore, disaster mitigation must consider the existing level of risk and involve both physical and non-physical actions. Additionally, mitigation efforts should include preventive measures, disaster management during the event, and post-disaster recovery activities (Zulfa et al., 2022).

Based on the results of disaster risk assessments, mitigation efforts, and hazard mapping in Gresik Regency, there is a significant need for modern and advanced technologies to reduce disaster risks. An early warning system (EWS) based on the internet is essential for providing timely data and information about areas prone to landslides. This EWS will serve as a tool to enhance public awareness and prevent potential damage to property and loss of life. The implementation of EWS technology can aid disaster mitigation efforts by identifying locations at risk and evaluating issues related to landslide impacts. The rapid advancement of technology

supports the principles of accurate and timely information, enabling communities to act appropriately and reduce disaster risks effectively (Salisa, 2021).

Table 1. Landslide Incidents on Bawean Island

Event	Year	Location	Impact
Landslide	2013	Daun Village and Sungairujing Village, Sangkapura District	4 houses affected, Bawean Ring Road (JLB) with a width of 20m and length of 3m, depth of 45m
Landslide	November 2021	Telukjatidawang Village, Tambak District	TPT Landslide
Landslide	December 2022	Gunung Teguh Village and Sungairujing Village, Sangkapura District	Bridge collapsed
Landslide	February 2023	Gunung Teguh Village and Sungairujing Village, Sangkapura District	Material obstructing the main road
Landslide	March 2023	Tanjungori Village, Tambak District and Sungairujing Village, Sangkapura District	SDN 357 affected by landslide debris

Based on an analysis of landslide disaster data occurring on Bawean Island from 2013 to 2023, and field studies conducted at several locations affected by landslides and flooding, the following areas have been identified as suitable for the installation of Early Warning Systems (EWS): Sungairujing Village, Dekatagung Village, and Daun Village in Sangkapura District, as well as Telukjatidawang Village and Tanjungori Village in Tambak District. These locations were selected due to the significant number of houses and infrastructure at risk, the presence of residential areas directly below landslide-prone hills, and the existence of public bathing facilities, which considerably increase the risk of casualties during landslide events.

In response to this situation, this study aims to identify appropriate mitigation measures corresponding to the landslide risk levels in Gresik Regency, East Java. These measures are expected to help reduce the potential impact of future disasters.

METHOD

Place and time of research

This study focuses on mitigation efforts for landslide disasters in Gresik Regency, East Java. The choice of the research location is based on the similarity of the area's characteristics, specifically areas situated in highland regions within mountainous zones.

Method

This research is a descriptive study using a qualitative approach, designed to identify suitable mitigation strategies for landslide risk levels in Gresik Regency. The population of this study comprises all areas affected by or potentially at risk of landslides in Gresik Regency. The sample selected includes villages identified with high landslide risk, namely Sungairujing Village, Dekatagung Village, and Daun Village in Sangkapura District, as well as Telukjatidawang Village and Tanjungori Village in Tambak District. The data sources used in this study are secondary data, consisting of reports on land movement and landslide incidents

in Gresik Regency. Data were collected through the analysis of landslide data from 2013 to 2023, as well as field surveys of several disaster-affected locations.

RESULTS AND DISCUSSION

The proposed solution for addressing the identified issue involves implementing an internet-based Early Warning System (EWS) for landslides at locations prone to soil movement and landslide occurrences. The hazard assessment for landslides is based on standard disaster risk assessment parameters and other guidelines provided by national ministries or agencies. These parameters include slope gradient (above 15%), slope direction, slope length, rock type, distance from fault lines or active faults, soil type (soil texture), rainfall, and slope stability. By calculating these parameters according to the conditions in Gresik Regency and surveying affected areas, the aim is to enhance public and organizational awareness and preparedness for potential landslides, as well as to reduce the potential number of affected victims. This internet-based landslide EWS introduces several innovative features, including:

1. Adding Value for Organizations and Stakeholders: Implementing an internet-based early warning system, such as an Early Warning System (EWS), in landslide-prone areas can enhance local community knowledge of information technology, support a cultural shift towards advanced IT understanding, and help reduce the number of affected victims. This indicates the success of the BPBD and the Gresik Regency Government in their disaster prevention and management efforts.
2. Technological Innovation: Although early warning systems (EWS) for landslides have been installed in various locations, the newly implemented internet-based version in Dekatagung Village, Sangkapura District, offers more modern and responsive advantages. This system uses the internet to deliver alerts directly to mobile devices, monitors at the BPBD Gresik Regency Control Center, as well as through telemetry messaging systems and sirens. This innovation is expected to significantly contribute to reducing landslide casualties.
3. Replicability: This innovation is designed to be easily adaptable by other parties, allowing the same method to provide similar benefits to various agencies or organizations.
4. Sustainability: Effective innovation should be sustainable, not limited to a single event. This early warning system is not only confined to current technology but also aimed at ongoing development and enhancement in monitoring areas at risk of landslides with increasingly advanced technology.
5. Alignment with Organizational Values: The implementation of this innovation is consistent with the values upheld by the BPBD, which are reflected in its vision to create rapid, precise, and efficient disaster management. The implementation of this system supports this vision by contributing to the physical and mental well-being of the community through enhanced access to education, health, and social services.
6. Organizational Benefits: The success of this innovation can be explained based on the expected achievements over three distinct time frames (short-term, medium-term, and long-term), including:
    a. Short-Term Phase: Installation of internet-based landslide Early Warning Systems (EWS) at designated locations with landslide risks, implementation of EWS procurement SOPs, and formation of a technical implementation team.
    b. Medium-Term Phase: Development of updated formats and applications for the installed landslide EWS to enhance their sophistication and provide broader benefits, as well as improving the performance of the Quick Reaction Team (TRC) in conducting disaster assessments at landslide-prone areas.

c. Long-Term Phase: Installation of landslide EWS at all locations that have experienced landslides and those indicated as vulnerable to landslides based on risk assessments, improving public satisfaction with the BPBD of Gresik Regency, and conducting monitoring, socialization, and application development.

This is consistent with the research conducted by (Sudiana, 2020), in Kampung Jatiradio, Kabupaten Bandung Barat, which examined landslide disaster risk and mitigation efforts. These efforts included the formation of a disaster preparedness team known as the Kelompok Siaga Bencana (KSB) Desa Cililin, the creation of an evacuation operational guide (including landslide vulnerability maps, evacuation route plans, and installation of evacuation direction signs), monitoring early warning systems, and conducting evacuation drills (such as installing a pilot project for landslide early warning systems and performing community readiness drills for landslide hazards). Additionally, the study highlighted the establishment of a commitment between local authorities and the community for the operation and maintenance of early warning systems through a cooperation agreement between BPPT and BPBD Kabupaten Bandung Barat.

Similarly, (Siswanto et al., 2023) demonstrated that in Desa Kedungosono, Kecamatan Bulu, Sukoharjo, an early warning system (EWS) for landslides has been developed as a mitigation measure to increase community awareness of landslide risks and to reduce the impact of such disasters on residents in the landslide-prone area. Furthermore, Putra & Rohana (2022) developed a landslide early warning system utilizing various sensors connected in real-time to a web server, which effectively detects and transmits information and data on soil movement.

CONCLUSION

The implementation of an Internet-based Early Warning System (EWS) for landslides in Gresik Regency represents an innovative step with significant potential to enhance preparedness and mitigate the impact of landslide disasters. By leveraging information technology and standardized parameters to assess disaster risk, this initiative is expected to add value to organizations and stakeholders, contributing substantially to risk mitigation efforts. This innovation not only provides a responsive and modern technological solution but can also be replicated by other agencies or organizations. Additionally, the deployment of this EWS aligns with the values upheld by the Gresik Regency Disaster Management Agency (BPBD), aiming to achieve rapid, accurate, and efficient disaster response.

To ensure successful implementation, well-formulated short-term, medium-term, and long-term measures have been established. However, for long-term success, continuous efforts are required in the development and enhancement of the EWS, as well as broader outreach to the community to raise awareness and encourage participation in disaster mitigation. Based on the findings of this study, several recommendations can be made.

First, it is crucial to conduct routine evaluations of the EWS performance, including updates to the technology and software used, and to monitor environmental changes that may affect disaster risk. Second, there is a need to enhance public outreach and training on the importance of safety and preparedness for landslide disasters and responsiveness to early warnings. Third, cross-sectoral and inter-agency cooperation should be strengthened in the implementation and development of the EWS, expanding collaboration to research institutions, universities, and non-governmental organizations. Fourth, monitoring and evaluating the social, economic, and environmental impacts of the EWS implementation is essential, with ongoing adjustments and improvements based on these evaluations. By taking these steps, it is

hoped that the Internet-based landslide EWS in Gresik Regency can serve as a successful example of disaster risk reduction, providing lasting benefits to the community and the surrounding environment.

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