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Community Technical Support for Rebuilding After Cianjur Landslides Due to Earthquake 2022

Lolom Evalita Hutabarat[1*], Pinondang Simanjuntak[1], Efendy Tambunan[1], Candra Christian Purnomo [1]

[1]Department of Civil Engineering, Universitas Kristen Indonesia (UKI)
[lolom.hutabarat@uki.ac.id]*

ABSTRACT
The occurrence of earthquake disasters in Indonesia, attributed to its location within the Ring of Fire, consistently leads to human and material losses for the residents residing in the impacted areas. The seismic event on November 21, 2022, at Cianjur, resulted from tectonic activity along the Cugenang Cianjur fault and subsequent landslides near Sarampad Village, the horseshoe-shaped region. The seismic activity associated with an earthquake can induce landslides, amplifying their destructive potential and posing a severe threat to slopes already susceptible to instability. Still, landslides can occur for various reasons depending on the local soil and weather. Subsequently, a data collection process was undertaken to allocate governmental aid to the community to reconstruct their residences. The Cugenang fault area is characterized by its topographical features, including mountain slopes, hillsides, and river cliffs or valleys. Specifically, areas with slopes over 40% are classified as zone A. The identification of landslide-prone locations is conducted following established protocols such as Landslide Management Planning Procedures SNI 03-1962-1990, Field Engineering Geological Mapping Procedures SNI 03-2849-1992, and Procedures for Making Slope Maps SNI 03-3977-1995. If necessary, community mitigation actions can be implemented after identifying landslide danger or regions at risk. In the event of a landslide, communities employ several methods, including preparation, engineering, acceptance, and monitoring and warning systems. Planning control reduces risk; an engineering solution strategy reduces landslide probability or impact. Acceptance strategy accepts or unavoidable, and monitoring and warning system strategy reduces risk by evacuating before failure.

Keywords — community mitigation, Cugenang fault, landslide-prone locations

1. Introduction

An earthquake is, in its most basic sense, a vibration or shaking of the Earth's surface generated by the release of energy in the piles of the Earth's crust. An earthquake occurs when the tectonic plates beneath the Earth's surface move or slide against each other. This movement or sliding generates tension that is eventually released as an earthquake. Cianjur region, as Indonesian Province West Java, is located in a zone of high seismic activity because it is close to the junction of three major tectonic plates: the Eurasian Plate, the Indo-Australian Plate, and the Indian Ocean Plate [1]–[9]. As a result, this region is in a zone of high seismic activity. The collision of tectonic plates leads to the formation of an extensive subduction zone to the west of Sumatra Island, next to the south of Java Island towards Bali and the Nusa Tenggara Islands, and to the north of the Maluku Islands and northern Papua. An additional outcome resulting from the collision event was the creation of many geological features, including troughs in oceans, folds, ridges, and faults in island arcs, the distribution of volcanic activity, and the generation of seismic events [10]. The complicated interactions between these plates release the probability that earthquakes may occur in Cianjur regions. The Cianjur region is intersected by the Cimandiri Fault in the Rajamandala segment, which features a left-lateral strike-slip fault mechanism, according to the book Sources and Dangers of Indonesian Earthquakes in 2017 [4]. The Cimandiri Fault runs from Pelabuhan Ratu Bay in Sukabumi to Padalarang in West Bandung Regency, covering approximately 100 km and divided into three segments: the Cimandiri segment (upward fault mechanism), the Nyalindung-Cibeber segment (upward fault mechanism), and the Rajamandala [7], [9]. The Cimandiri Fault zone had several notable earthquakes, such as earthquake events with magnitudes of M5.5 in 1982, M5.4 in 2000, as in September 2009, a magnitude M7.3 earthquake struck the Cikangkareng region of Cianjur, Indonesia, causing the ground to shift [11], [12].

Additionally, historical records indicate the occurrence of an earthquake in 1900 inside this fault zone, which was measured to have an intensity level of VII on the Modified Mercalli Intensity (MMI) scale [9]. The magnitude of 5.6 earthquakes lasted 10-15 seconds on November 21, 2022, at 13.21 WIB. The earthquake's epicenter was located on land approximately 10 kilometers southwest of Cianjur Regency in West Java Province. The earthquake had a depth of 11 kilometers [3].

In general, landslides follow earthquakes [11], [13]–[15], as in Cianjur and the adjacent areas after the earthquakes. The weathered soil commonly encountered in Indonesia is primarily attributed to volcanic eruptions. The soil makeup of this particular sample is primarily clay, with a minor presence of sand, and is characterized by its fertility. The presence of weathered soil on impermeable rock formations located on hills or ridges characterized by moderate to steep slopes might lead to landslides during periods of heavy rainfall in the rainy season. Landslides are more likely to occur in hilly areas lacking robust and deeply established perennial vegetation.

However, earthquakes can cause landslides if the location has weak geological characteristics or if the earthquake is strong enough. Landslides occur when layers of soil or rock on steep slopes cannot sustain the stress due to earthquakes or other factors, resulting in rapid ground movements that potentially harm buildings, infrastructure, and the surrounding environment. The magnitude of the retention force is often influenced by the rock's strength and the soil's density. The driving force is subject to various factors, including the slope angle, the presence of water, applied load, and the specific gravity of the rock soil.

Nonetheless, it is essential to note that earthquakes do not invariably result in landslides. In the event of an earthquake impacting an area characterized by geologically unstable conditions and a sufficiently high magnitude, landslides can transpire promptly after the seismic event. The seismic activity associated with an earthquake can induce landslides, amplifying their destructive potential and posing a severe threat to slopes already susceptible to instability. Still, landslides can occur for various reasons depending on the local soil and weather. Therefore, more investigation and analysis are required to ascertain whether earthquakes play a role in landslides. Several landslide events in Indonesia can be seen in Table 1.

Table 1. Landslide Disasters in Indonesia

Year	Location	Influenced factor
2014	Pasuruan	earthquake
2014	Banjarnegara	high rainfall
2016	Garut	earthquake
2018	Flores	high rainfall
2018	Lombok	earthquake
2018	Palu	earthquake
2019	Sukabumi	earthquake
2021	Menado	earthquake
2021	Mamuju	earthquake

Source: [16]

2. Targets and Output

Disaster mitigation is a strategic planning endeavor to minimize the adverse consequences of disasters on human populations. Disaster mitigation is a crucial component of disaster management, encompassing various activities. These activities can be categorized into three main phases: pre-disaster, disaster emergency, and post-planning. The pre-disaster phase involves preventive measures, alleviation efforts, preparedness initiatives, and early warning systems. The disaster emergency phase encompasses emergency response, search and rescue operations, emergency assistance provision, and support for displaced individuals. Lastly, the post-planning phase involves site selection, rehabilitation, and reconstruction. The user refers to the Indonesian Law No. 24 of 2007.

The Technical Assistance Team of the FT UKI Civil Engineering Study Program will offer guidance and technical support to the community in constructing earthquake-resistant buildings. The focus of extension and technical support initiatives is dedicated to matters about geotechnical concerns. The scope of this study encompasses geological mapping, explicitly focusing on active fault zones that pose a significant risk of earthquakes. It is crucial to relocate these fault zones during the reconstruction phase, as seen in Figure 1. in addition to the points above. It is crucial to consider understanding microzones susceptible to landslides, building a simple earthquake-resistant house capable of withstanding seismic vibrations, and implementing earthquake disaster mitigation measures by creating practical knowledge modules on procedures and management in this context.

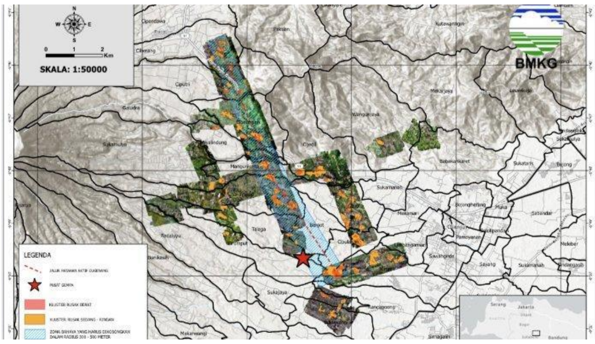

Figure 1. Earthquake-prone locations in 9 villages that need relocation (Source: BMKG)

3. Method

The proposed approach for providing technical support to the community impacted by the Cianjur earthquake that occurred on November 21, 2022, in terms of reconstruction efforts and proactive risk mitigation measures is outlined as follows:

a. Compiling information data on active fault zones exhibiting elevated seismic hazard levels aims to produce a concise reference resource.
b. Develop information data of concise micro-level data on areas susceptible to landslide occurrences.
c. Compile information on a foundation and building structure designed to withstand seismic disasters.
d. Compile information on developing earthquake disaster mitigation aimed at earthquake disaster response communities.
e. Compile information on developing pragmatic knowledge about procedures and management for mitigating seismic disasters.

4. Discussion

The Community Service Program (PKM) Civil Studies Program Faculty of Indonesian Christian University focuses on providing technical support information to communities devastated by the Cianjur earthquake on

November 21, 2022. The program aims to aid rehabilitation efforts and mitigate future hazards associated with such natural disasters. The activity above is scheduled during the academic year 2022/2023.

4.1. Active Fault Zones

Disaster-prone areas in the Cianjur and Sukabumi regions were mapped using data on active faults, basin features, bedrock thickness, subduction processes, and other relevant geological factors. These maps show where disasters are most likely to happen every 500 years. The worst ground shifts and building damage happen in places prone to earthquakes. Because the earthquake was not very strong, the longitudinal fault event did not break through the Earth's surface. It did, however, cause many aftershocks of lower strength along a 12 km long and 8 km wide area that went from Warungkondang to Karang Tengah. It was seen that the Rupture Area had the most severe building damage.

Compared to the 7.4 M earthquake in Palu on September 28, 2018, which the Palu Koro Fault caused, the one on the Cugenang Cianjur Fault was not as strong and classified as a shallow tectonic earthquake [3]. However, BNPB data shows that buildings in the area were damaged in a reasonably wide area, with levels of damage ranging from light to heavy. It is crucial for people who are at disaster sites to know about building standards that make buildings less likely to collapse during earthquakes. This situation is especially true given that Indonesia has had many earthquakes in different parts over the past ten years. Understanding this is important for figuring out how much damage earthquakes do to homes [17]–[23].

Table 2. Active Fault Location in Java

Fault Name	Fault Location	Fault Direction
Mandiri	The distance from Padalarang to Ratu Harbor.	Shear faults have vertical and diagonal displacement with West-East and Northeast-West orientations spanning over 100 kilometers.
Lembang	Starting from Mount Manglayang and ending at Cisarua, North Bandung.	It extends 22 kilometers and rises west to east, following the Cimandiri fault.
Baribis	Earrings with an elongated pendant found in the Majalengka region	extends and ascends, spanning a distance of 100 kilometers.
Semarang	This line runs parallel to Kaligarang or the Kaligarang Fault from north to south.	From north to south, start at Gajah Mungkur and end at Mount Swakul, spanning 34 kilometers.
Opak	The route from Wonosari to Yogyakarta	Plateau with Yogyakarta plains and Merapi deposits that are up to 30 to 40 km away from each other
Kendeng	A plateau containing the Yogyakarta plains and Merapi deposits	A few fissures connect a section of the Semarang fault and Beribis spanning 300 kilometers.
Cugenang	A new fault runs through nine towns, eight of which are in the Cugenang District area of Cianjur.	From Nagrak village to Ciherang village, go north 347°E and slope 82.8° to the right. It will lead to the East Sea.

Source: [12]

4.2. Landslides Zones

The Technical Assistance Team of the FT UKI Civil Engineering Study Program was engaged in disseminating specific information to the local community (Figure 2) regarding the occurrence of landslides in the Sarampad village area, which has been designated as the red zone (Figure 3) after the 2022 Cianjur earthquake. This red zone has subsequently been transferred to Sirnagalih village, Cilaku.

Figure 2. Relocated Community from Red Zone After Cianjur Earthquake 2022

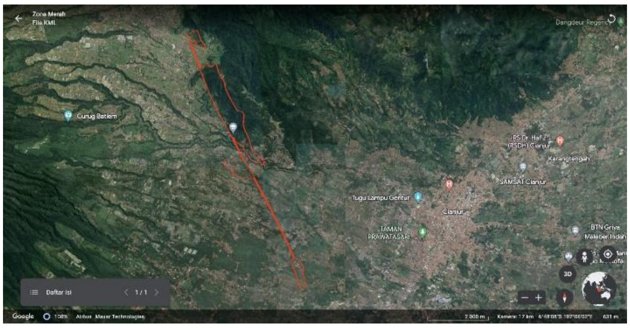

Figure 3. Red Zone After Cianjur Earthquake 2022 (Source: Google Earth)

Based on the analysis of geological mapping and the findings of seismic disaster mitigation measures, it can be concluded that this place is deemed a secure location with less risk of landslides.

4.3. Foundation and Structure for Earthquake Resistance

The guidelines for constructing a basic residential structure that can effectively endure seismic activities and soil movements, whenever feasible, adhere to the technical specifications outlined in Table 3.

Table 3. Build a simple earthquake-resistant house

Component of Structure	**Technical Specification**
Foundation	1. Depth of base more than 60 cm. 2. Width of the base more than 60 cm 3. The column reinforcement is at least 30 cm deep in the base.
Sloofs	1. Size 15×20cm. 2. At least 4–10 mm of horizontal reinforcement. 3. Begel ∅8–15 cm and ∅6–12.5 cm.
Columns	1. Size 15×15cm. 2. longitudinal reinforcement min 4∅–10mm. 3. Begel ∅8–15 cm and ∅6–12.5 cm. 4. wall anchors installed
Joints	The reinforcement joint between the beam and columns at the building corners (pass connection).
Walls	The wall space includes columns, sloofs, and a maximum ring beam area of 12 m^2.
Beams	1. Size 12×15cm. 2. longitudinal reinforcement min 4∅–10mm. 3. Begel ∅8–15 cm and ∅6–12.5 cm.
Roof Truss	1. inclined concrete block size 12×15cm. 2. longitudinal reinforcement min 4∅–10mm. 3. Begel ∅8–15 cm and ∅6–12.5 cm. 4. Curtain and roof mount anchor. 5. Wind-bonding stiffeners exist.
Roof Frames	1. Wood size 6×12cm. 2. Each joint has Begel plates. 3. Wind-bonding stiffeners exist. 4. Curtain and roof mount anchor.

Source: [24]

4.4. Landslide Disaster Mitigation Procedure

The identification of landslide-prone locations is conducted following established protocols such as Landslide Management Planning Procedures [25], Field Engineering Geological Mapping Procedures [26], and Procedures for Making Slope Slope Maps [27].

In theory, landslides occur when the slope driving force exceeds the restraining force. Rock strength and soil density affect the general resisting force, whereas slope angle, water, load, and specific gravity of soil and rock affect the driving force. Identifying and inventorying natural physical qualities that cause landslides determines landslide-prone locations. Generally, 14 elements can trigger landslides, as seen in Table 4.**Table 4.** Factors Triggered Landslides

Parameter	Description
Rainfall	high annual rainfall (2500+ mm)
Slope	The slope conditions range from 15% to 70%.
Soil layer	characteristics of the soil, slopes with a dense soil cover (greater than 2 meters)
Lithology	Rock structures consist of regions characterized by discontinuities or fractures.
Vegetation	Types of plants that cover the ground (such as plant type, canopy shape, and nature rooting)
Vibration	Strong vibrations (heavy machinery, factory tools, cars) and ground movement are observed.
Groundwater level	Lowering of lake and dam water levels
Incremental Stress	An added burden is the construction of buildings and the operation of vehicles.
Erosion	Erosion of the soil occurs.
Embankment	There is a presence of stacked material on cliffs.
Sliding path	Unaddressed historical indicators of landslides that were not promptly remediated.
Discontinuity plate	The fault structure traverses the region.
Deforestation	Destruction of forests
Waste Disposal	Location for dumping garbage

Source: [28]

Areas susceptible to landslides are categorized into zones according to their characteristics and natural physical conditions. This zoning aims to establish distinct variations in depth, spatial structure, spatial patterns, and the permissible, conditionally permissible, or prohibited types and intensities of activities within each zone. "zone" refers to a specific area or region defined by certain characteristics.

Landslide potential refers to a specific geographic region with a heightened susceptibility to landslides. This susceptibility is primarily influenced by the terrain and geological characteristics of the area, which are highly susceptible to external disturbances. These disturbances can arise from various sources, including both natural phenomena and human activities, and serve as triggering factors for ground movement, ultimately leading to an increased likelihood of landslides. Hydrogeomorphology can be classified into three distinct zone types in Table 5.

Table 5. Landslides Potential Zone

Classification	Description
Zone A	The areas of concern for potential landslides include mountain slopes, hillsides, and river banks characterized by slopes above 40% and elevations over 2000 meters above sea level.

Zone B	The regions under consideration for potential landslide occurrences include mountain foot areas, foothills, foothills hills, foothills, and river cliffs. These locations exhibit diverse slopes ranging from 21% to 40% and are situated at elevations between 500 and 2000 meters above sea level.
Zone C	This potential area was prone to landslides in several topographical regions, including highland, lowland, plain, river cliffs, and river valleys. The slopes in these regions range from 0% to 20%, and the altitude spans from 0 to 500 meters above sea level.

Source: [28]

The Cugenang fault area is characterized by its topographical features, including mountain slopes, hillsides, and river cliffs or valleys. Specifically, areas with slopes over 40% are classified as zone A, as shown in Table 6.

Table 6. Landslides in Sarampad Village Cugenang Area

Causative Factors	Description
Conditions in Nature	Over 40% of mountain slopes are convex. Mountains have overburdened soil over 2 meters deep, loose and water-permeable (e.g., residual soils), above hard, impermeable rock (e.g., andesite breccia, tuff, marl, and clay stone). At the foot of the slope lies a river made of residual soil, vernacular soil, or sedimentary rock from river deposits over 2 meters deep. The Cugenang fault runs along slopes with discontinuities or cracks. Water seepage or springs occur on slopes, especially when impermeable rock meets porous soil. Natural vegetation consists of fibrous-rooted bushes, shrubs, and grass.
The forms of ground movement	The slides manifest as rock slides, soil slides, or material rockfalls, exhibiting slip surfaces that are straight, curved, or irregular. These slides are often accompanied by a mix of multiple types of ground movement, and their displacement rate is relatively rapid after an earthquake.
Human Activities	The excavation and cutting of slopes are sometimes conducted without considering the underlying soil or rock layers and without incorporating slope stability studies. This oversight is particularly concerning in road building and other heavy-load construction activities. The drainage system is insufficient. A reservoir is located at the base of the incline, serving as a water source for the nearby military barracks (Figure 4).

Figure 4. Location of the Cianjur horseshoe, West Java (source: Google Earth)

4.5. Earthquake Disaster Management

Prioritizing the identification and preparation of Cianjur's landslide-prone regions is essential for disaster management (Hutabarat et al., 2021). Before providing technical support information to communities, a team meeting with the Cianjur district's Housing, Settlement, and Land Service (PKPP) was conducted (Figures 5 & 6).


Figure 5. Discussion at PKPP Cianjur Regency

Earthquake **Figure 6.** Mapping of Disaster Zone after Cianjur

If necessary, community mitigation actions can be implemented after identifying landslide danger or regions at risk. In the event of a landslide, communities employ several methods, including preparation, engineering, acceptance, and monitoring and warning systems. Planning control reduces risk; engineering solution strategy reduces landslide probability or impact. Acceptance strategy accepts or unavoidable, and monitoring and warning system strategy reduces risk by evacuating before failure. Assessed hazards can be compared to acceptance criteria to determine necessary landslide mitigation measures.

5. Conclusion

Disaster mitigation is a strategic planning endeavor to minimize the adverse consequences of disasters on human populations. Disaster mitigation is a crucial component of disaster management, encompassing various activities. The Community Service Program (PKM) Civil Studies Program Faculty of Indonesian Christian University focuses on providing technical support to communities devastated by the Cianjur earthquake on November 21, 2022. The program aims to aid rehabilitation efforts and mitigate future hazards associated with such natural disasters. The Cugenang fault area is characterized by its topographical features, including mountain slopes, hillsides, and river cliffs or valleys. Specifically, areas with slopes over 40% are classified as zone A. Community mitigation actions can be implemented if necessary after identifying landslide danger or regions at risk. In the event of a landslide, communities employ several methods, including preparation, engineering, acceptance, and monitoring and warning systems. Planning control reduces risk, an engineering solution strategy reduces landslide probability or impact, an acceptance strategy accepts or is unavoidable, and a monitoring and warning system strategy reduces risk by evacuating before failure.

6. Acknowledgments

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