

Landslide disaster mitigation in Sawahlunto City

Tirza Haqia Purnama¹, Roni Ekha Putera^{1*}, and Hendri Koeswara¹

¹Faculty of Social and Political Sciences, Universitas Andalas, Padang 25175, Indonesia

Abstract. The research aims to analyze the implementation of landslide disaster mitigation in Sawahlunto. Motivated by the high risk of landslides in Sawahlunto. Efforts are needed to reduce the risk of landslides by implementing the theory used of W.N. Carter's theory of non-structural and structural disaster mitigation. The method used is descriptive qualitative, with data collection techniques using interviews, documentation, and observation. This is concluded that the implementation of landslide disaster mitigation in Sawahlunto has been running, but the implementation has not been optimal. Several things, non-structural, cause this: In the legal framework, a lack of understanding of policies that contain appropriate mitigation as well as the role of each agency or institution; the disaster risk reduction forum (FPRB) has been formed at the level, but at the village level only has a disaster preparedness group (KSB); the lack of implementation of disaster mitigation measures by the community. Structural disaster mitigation activities are still inadequate, as seen from the unavailability of vertical evacuation buildings. Efforts that can be made to support the implementation of landslide disaster mitigation in Sawahlunto include reviewing mitigation policy documents, increasing the capacity of FPRB, and collaborating with various parties to support the implementation of disaster mitigation.

1 Introduction

Indonesia is ranked as the second most disaster-prone country in the world due to various geological, geographical, and climatic factors [1]. It is located in the Pacific Ring of Fire, an area of high seismic and volcanic activity due to the meeting of several large plates, including the Indo-Australian, Eurasian, and Pacific plates [2, 3]. In addition to natural factors, human

activities such as deforestation and unplanned development also reduce the soil's water absorption capacity and cause erosion, increasing the risk of natural disasters. Global climate change also affects weather patterns in Indonesia, with extreme weather events such as tropical storms and extreme rainfall becoming more frequent and intense [4]. Therefore, containment and prevention efforts are essential to mitigate its impacts.



Fig 1. Map of the distribution of natural disasters in Indonesia

* Corresponding author : roniekhaputera@soc.unand.ac.id

Figure 1 shows Indonesia's high vulnerability to disasters. In addition, the islands of Sumatra, Java, Kalimantan, and Sulawesi, shown in red, are at the highest risk. Disasters are natural or non-natural disasters that cannot be predicted and cause casualties, environmental damage,

and property losses [5, 6]. In addition, it is difficult to predict when exactly the disaster will occur.

The following data describes the impact and damage that occurred in Indonesia due to disasters in the period from January 2021 to May 2024, namely:

Table 1. Impact and damage from natural disasters in 2021 – 2024

Year	Impact of natural disasters		Natural disaster damage		Total cases
	Died	Evacuate	Damaged house	Damaged facilities	
2021	728	7,630,692	158,658	4,445	5,402
2022	858	6,144,534	95,403	1,983	3,544
2023	275	8,491,288	47,214	1,291	5,400
2024	239	3,526,054	37,287	706	783

From Table 1, the impact of various disasters in Indonesia from 2021 to 2024 is very concerning, causing losses and damage to different aspects such as houses and multiple facilities such as education, worship, and health. In addition, many casualties and people are displaced due to disasters. Based on this data, damage due to disasters is increasing yearly, and the total number of disasters continues to grow until May alone. In 2024, it has reached 783 disaster cases.

West Sumatra is a province located on the west coast of the island of Sumatra. It is one of Indonesia's regions

that is very prone to natural disasters [7]. This vulnerability is due to West Sumatra's location on the Pacific Ring of Fire, which has high tectonic activity [8]. The topography of West Sumatra, which consists of hills and mountains, makes this area vulnerable to landslides, especially during the rainy season [7,9]. Heavy rainfall can cause soil erosion and increase the risk of landslides, destroying infrastructure, settlements, and agricultural land. The following table shows the disaster potential for each regency/city in West Sumatra.

Table 2. Distribution of disaster potential in West Sumatra

Location	Disaster					
	Earthquake	Tsunami	Flood	Fire mountain	Landslides	Fire
Padang	Potential	Potential	Potential		Potential	Potential
Pariaman	Potential	Potential	Potential		Potential	Potential
Bukittinggi	Potential			Potential	Potential	Potential
Padang Panjang	Potential			Potential	Potential	Potential
Payakumbuh			Potential	Potential		Potential
Sawahlunto					Potential	Potential
Solok	Potential		Potential			Potential
Padang Pariaman	Potential	Potential	Potential	Potential	Potential	Potential
Agam	Potential	Potential	Potential	Potential	Potential	Potential
West Pasaman	Potential	Potential	Potential	Potential	Potential	Potential
Pasaman	Potential		Potential	Potential	Potential	Potential
Limapuluh Kota	Potential		Potential	Potential	Potential	Potential
Tanah Datar	Potential		Potential	Potential	Potential	Potential
Solok	Potential		Potential	Potential	Potential	Potential
South Solok	Potential		Potential	Potential	Potential	Potential
South Coastal	Potential	Potential	Potential		Potential	Potential
Sijunjung			Potential		Potential	Potential
Dharmasraya			Potential		Potential	Potential
Mentawai	Potential	Potential			Potential	Potential

It can be seen in Table 2 that each region in West Sumatra province has more than one potential disaster. One is Sawahlunto, which has the potential for landslides and fires. Sawahlunto is an area that is vulnerable to

natural and non-natural disasters [10] This is evidenced by the disasters that always occur in West Sumatra, as shown in Table 3 below.

Table 3. Landslide disaster in West Sumatra regency/city in 2017

District/City	Landslide
Lima Puluh Kota	8
Agam	15
Dharmasraya	1
Mentawai	1
Padang Pariaman	3
Pasaman	8
West Pasaman	9
Pesisir Selatan	7
Sijunjung	12
Solok	8
Solok Selatan	2
Tanah Datar	9
Bukittinggi	3
Padang	12
Padang Panjang	2
Pariaman	0
Payakumbuh	2
Sawahlunto	27
Solok	0
Total	139

Table 3 shows that Sawahlunto is the most frequent area for landslides; as of 2017, there have been 27. Sawahlunto has hilly contours and land slope conditions from 45° to 75°; this can potentially cause landslides in Sawahlunto if hit by continuous rain. Landslide-prone areas in Sawahlunto include all villages in the Silungkang sub-district, all towns in the Fresh Valley sub-district, all villages in the Barangin sub-district except Kolok Mudik and Kolok Nan Tuo, and several areas in the Talawi sub-district except Salak Village, Talawi Mudik, Talawi Hilir and Rantih. This is also evidenced by the number of landslides in Sawahlunto from 2018 to 2019, as shown in Table 4 below.

Table 4. Number of landslide in Sawahlunto

Year	Landslides
2018	123
2019	136

From Table 4, it can be seen that the most disastrous events in Sawahlunto were landslides; as many as 259 landslide events occurred from 2018 to 2019 due to the city's hilly topography with undulating contours. Sawahlunto is also prone to recent floods and landslides, which caused considerable losses, as in the news in Fig. 2.

Figure 2 shows that Sawahlunto recently experienced floods and landslides, which resulted in losses totaling 6 billion rupiah. Dedi Ardana, acting head of the Regional Disaster Management Agency (BPBD) of Sawahlunto, said the total loss was calculated from the agriculture, fisheries, houses/settlements, schools, roads, and irrigation sectors.

**Fig 2.** News of flood and landslide losses in Sawahlunto

Disaster management, which includes prevention/mitigation, preparedness, emergency response, rehabilitation, and reconstruction after a disaster occurs, is needed to avoid and reduce the impact of disaster risk [11]. To minimize the impact of disasters, prevention must be carried out at the pre-disaster stage through mitigation efforts. According to Law No. 24/2007, disaster mitigation is a series of efforts to reduce disaster risk through physical development and increasing awareness and ability to deal with disaster threats [12]

Several relevant previous studies can be used as references in this research. First, Haeril's research entitled "The Strategy of the Regional Disaster Management Agency (BPBD) in Natural Disaster Risk Reduction in Bima Regency." [13]. This research discusses the various strategies implemented by BPBD Bima District in reducing the risk of natural disasters, including preventive measures, preparedness, and emergency response. Haeril examines the effectiveness of BPBD programs and how they involve the community in mitigation efforts.

Second, a research entitled "Landslide Disaster Risk Reduction Strategy in Bogor Regency, West Java Province." [14]. This research explores the strategies implemented by BPBD Bogor Regency in reducing landslide risk, including the development of landslide retaining infrastructure, community education, and early warning systems. Nindy highlighted the importance of collaboration between the government, local communities, and non-governmental organizations in disaster management. The shortcoming of this research is the lack of long-term evaluation of the effectiveness of the strategies implemented, so the impact of the measures cannot be thoroughly measured.

Furthermore, research by Chintya entitled "Flood Disaster Management Strategy by the Regional Disaster Management Agency (BPBD) of Solok, West Sumatra." [15]. This study examines BPBD Solok's strategy in dealing with flood disasters, including river flow management, embankment construction, and the provision of evacuation facilities. We also discussed how the BPBD coordinated with related agencies and the community in a flood emergency. This research provides a comprehensive overview of the multi-faceted approach to flood management in urban areas.

Therefore, new research is needed to assess landslide mitigation in Sawahlunto. Understanding the strategies implemented and evaluating their effectiveness is expected to provide recommendations to improve preparedness and response to future landslides. Through this study, it is hoped to make a meaningful contribution to developing disaster mitigation policies and practices at the local level and support government and community efforts to create a safer and more resilient environment. This research provides a comprehensive overview of Sawahlunto in landslide mitigation and offers insights that can be applied to other areas with similar vulnerabilities.

2 Research method

This research uses a qualitative approach with a description method and is coupled with a literature study. This method aims to solve problems by describing the issues that occur factually, systematically, and accurately related to the properties, facts, and relationships between the phenomena to be investigated. The theory used to analyze this research problem is the theory of disaster mitigation by W.N. Carter, which will explore non-structural and structural disaster mitigation in Sawahlunto's landslide mitigation. In the nonstructural mitigation variable, there are six indicators, namely, legal framework, institutional establishment, raising public awareness, conducting training and education, providing incentives, and an early warning system.

3 Results and discussion

This research aims to analyze landslide mitigation efforts in Sawahlunto using W.N. Carter's Disaster Mitigation Theory, which includes structural and non-structural mitigation. Data was collected through field observation and review of related documents. The following are the main findings of this research:

3.1 Structural mitigation

3.1.1 Construction and repair of waterways

This effort aims to improve the capacity and efficiency of the drainage system in Sawahlunto. A good drainage system is essential to drain surface water quickly, especially during the rainy season, to prevent inundation that could potentially trigger landslides. Standing water not only damages infrastructure but also increases the risk of soil erosion, which can weaken slopes and trigger landslides.

To achieve this goal, the first step was to conduct a thorough survey and analysis to determine critical points vulnerable to waterlogging. This includes mapping areas that frequently experience drainage problems and identifying the leading causes of waterlogging, such as blocked or damaged drains. A comprehensive analysis will help design appropriate solutions, be it through repairing existing drains or constructing new, more effective drains.

Implementing the survey and analyzing the results involved various concrete actions. Improving existing waterways was made by widening or deepening the channels to increase capacity. In addition, new waterways were constructed to direct water flow more efficiently and reduce the risk of inundation. Regular cleaning of drains is also an essential part of this implementation to ensure the drains remain optimally functional and not clogged with sedimentation or trash. Through this approach, it is hoped that the drainage problem in Sawahlunto can be adequately addressed to minimize the risk of landslides due to waterlogging.

3.1.2 Making gutters in the roof of a house

This effort aims to rainwater from rooftops directly to drains or pools to pool water infiltration into the soil around the foundation's foundation. Water infiltration can lead to increased soil moisture and pore water pressure, weakening the foundation structure and increasing the risk of landslides, especially in vulnerable areas.

The implementation of this goal involves several concrete steps. First, communities are encouraged to install gutters on the roofs of their houses. These gutters collect rainwater and channel it directly into drains or rivers, reducing the risk of infiltration. Socialization and education on the importance of gutter installation were conducted through public campaigns, brochures, and social media to ensure that all residents understood its benefits.

In addition, local governments or related institutions can provide technical and material assistance to needy residents. Technical assistance can include consultations on the design and installation of effective gutters, while material assistance includes the provision of affordable gutters or subsidies for underprivileged families. This approach ensures that all levels of society can participate in the mitigation efforts so that overall landslide risk can be significantly reduced in Sawahlunto.

3.1.3 Channeling household waste water to riol/sewer

This effort aims to reduce wastewater infiltration into the soil, which can lead to increased pore water pressure and potential landslides. Household wastewater infiltrating into the soil can harm the environment and contribute to soil instability around residential areas. This increase in pore water pressure due to infiltration can weaken the soil structure and increase the risk of landslides, especially in areas with slopes.

The implementation of this objective requires a comprehensive approach. First, community outreach is conducted on the importance of proper household wastewater management. This includes information on the dangers of wastewater infiltration and ways to safely manage household waste, such as using proper septic systems or channeling waste directly into designated sewers. This educational campaign can be conducted through seminars, workshops, and brochure distribution in residential neighborhoods.

In addition to counseling, enforcement of regulations on wastewater management is also critical. Local governments should issue and implement rules governing the discharge of household wastewater, including regular inspections to ensure residents' compliance with the regulations. Sanctions or fines can be imposed for those who violate them to ensure compliance and awareness of the importance of proper waste management. In combination with education and law enforcement, this approach is expected to reduce wastewater infiltration into the ground, thereby reducing the risk of landslides and creating a safer environment in Sawahlunto.

3.1.4 Routine cleaning of sedimentation and trash in waterways

These efforts aim to prevent blockage of waterways that can cause flooding and accelerate the flow of water that can erode slopes. Blockage of waterways often results from sedimentation and accumulation of garbage, which not only blocks the flow of water but also increases the risk of flooding. This flooding, in turn, can accelerate soil erosion and result in landslides, especially in areas with steep slopes.

To achieve this goal, implementation included organizing gotong royong activities and scheduling regular cleaning of waterways, especially during the rainy season. Gotong royong involves active participation from the community in clearing waterways of garbage and sediments that block the flow of water. This activity clears the waterways and raises residents' awareness of the importance of keeping the environment clean.

Scheduling regular cleaning is also an essential part of this implementation. Local governments and relevant agencies should establish a regular cleaning schedule and ensure that it is carried out consistently, especially during the rainy season when water volumes increase. In addition, education on the negative impacts of blocked drains and the importance of community participation in cleaning activities should be continuously socialized. With a combination of gotong royong and regular cleaning, it is expected that waterways in Sawahlunto can function adequately, reduce the risk of flooding, and prevent soil erosion that can trigger landslides.

The results of BPBD's evaluation of flood and landslide disasters that have occurred in recent years show that the above measures need to be optimized and implemented thoughtfully. Proper preventive measures can reduce disaster risks and impacts. Acting Mayor of Sawahlunto Fauzan Hasan reminded the importance of going the extra mile in anticipating disaster risks rather than just coping when disasters occur. The commitment of all regional apparatus and the community is significant for the success of this mitigation effort. The circular letter for follow-up and accelerated implementation of BPBD recommendations is an essential first step in improving disaster preparedness and mitigation in Sawahlunto.

3.2 Non-structural mitigation

Place the figure as close as possible after the point where it is first referenced in the text. If there are many figures and tables, it might be necessary to place some before their text citation.

3.2.1 Optimizing the role of disaster preparedness groups in village

This effort aims to improve community preparedness by forming and training disaster preparedness groups that can respond quickly in the event of a disaster. Establishing disaster preparedness groups in each village and kelurahan aims to ensure that local units are ready to provide first aid and coordinate immediate evacuation in the event of a disaster. The training covers basic knowledge of different types of disasters, first aid skills, and safe and efficient evacuation procedures. Disaster simulations are conducted regularly to ensure that all members of the disaster preparedness group can apply their knowledge and skills in emergencies. In addition, disaster preparedness groups are equipped with essential equipment such as first aid kits, communication tools, and simple rescue equipment to support their operations.

The implementation of this program does not stop at training and simulation. The local government also conducts regular evaluations to assess the effectiveness and readiness of the disaster preparedness group. This evaluation includes an assessment of the team's response during simulations, the condition and completeness of equipment, and coordination between team members and related agencies. Based on the evaluation results, follow-up is carried out to correct deficiencies and increase the team's capacity. This may include additional training, equipment repair or replacement, and improvement of standard operating procedures (SOPs) for disaster management. With this comprehensive approach, disaster preparedness groups in Sawahlunto are expected to function optimally in minimizing disaster impacts and saving more lives.

3.2.2 Legal framework

The Sawahlunto Government is aware of the potential landslide hazard in its area. Therefore, it has taken proactive measures by establishing land use and development regulations in landslide-prone areas. These regulations aim to minimize the risk of landslides by controlling human activities that can aggravate the condition, such as development on steep slopes or deforestation.

3.2.3 Institutional establishment

Establishing a Regional Disaster Management Agency (BPBD) in Sawahlunto is essential in disaster mitigation efforts. BPBD is responsible for coordinating and implementing mitigation efforts, including risk monitoring, emergency management, and post-disaster rehabilitation. With the existence of BPBD, disaster

management is expected to be done more structurally and effectively. BPBD also has a role in disaster-related data collection, risk analysis, and the preparation of comprehensive disaster management plans.

BPBDs also serve as communication and coordination centers between various government agencies, communities, and non-government organizations involved in disaster mitigation. This function is essential to ensure that information regarding disaster threats can be disseminated immediately and preventive actions can be taken quickly. In addition, BPBDs play a role in increasing community awareness and preparedness for disasters through various education and training programs. Collaboration between BPBD and multiple parties can improve Sawahlunto's resilience to disasters.

3.2.4 Raising public awareness

Public awareness is critical in landslide mitigation. Sawahlunto has conducted public education and outreach campaigns on landslide hazards and preventive measures. The campaign includes various activities that aim to deliver information effectively and evenly to all levels of society. One method used was social media, which has a wide and fast reach. In addition, brochure distribution and seminars were also conducted to provide more in-depth and direct information to the community.

Social media, brochures, and seminars were educational tools to reach the broader community. The campaign aims to increase people's understanding of landslide risks and teach them how to protect themselves and their families. Through continuous education, the community is expected to be more aware of the early signs of landslides and know what actions to take during an emergency. Thus, the level of community preparedness can increase to minimize potential losses and casualties due to landslides. This effort shows a commitment to building a more resilient and disaster-prepared community.

4 Conclusion

In the context of Sawahlunto, the synergy between structural and non-structural measures has shown positive results in landslide mitigation. The construction of dams, retaining walls, improved drainage systems, and the application of modern technology for soil monitoring have helped significantly reduce landslide risk. On the other hand, non-structural efforts such as the implementation of legal frameworks, establishment of strong institutions, education and training, provision of incentives, and development of early warning systems have increased community awareness and preparedness in facing disasters.

However, challenges remain, particularly in funding, infrastructure maintenance, and increasing community awareness and participation on an ongoing basis. Limited funding may hamper efforts to maintain and repair the infrastructure that has been built. At the same time, community awareness and participation still need to be

improved, requiring more effective education and communication strategies.

This study concludes that a holistic and adaptive mitigation approach is needed to reduce the impact of landslides effectively. Integration between structural and non-structural solutions should be continuously strengthened, considering local conditions and potential risks. Continuous regional capacity-building efforts, such as regular training and community education, and increased cooperation between the government, community, and private sector are crucial to achieving sustainable disaster mitigation.

Firstly, the increased funding by local government needs to seek additional sources of financing. Whether from the central government, international donors, or the private sector, to ensure the sustainability of disaster mitigation infrastructure maintenance and repair.

Infrastructure maintenance needs a regular program to ensure that dams, retaining walls, and drainage systems remain in good condition and effectively prevent landslides. Education and training programs need to be improved by involving more communities and using more interactive and engaging methods. Information technology and social media can be effective tools in disseminating information and raising awareness. They increase community participation, and the government needs to encourage active community participation in disaster mitigation efforts through more attractive incentives and rewards for citizens who contribute significantly.

Multisectoral cooperation: increased collaboration between the government, communities, and the private sector needs to be increased in disaster mitigation efforts. This partnership can cover various aspects, such as funding, training, and technology provision. Early warning systems need to be continuously developed and refined, ensuring that the information provided is accurate, timely, and easily accessible to all levels of society, and research and innovation further in disaster mitigation techniques should continue to be encouraged to find more effective and efficient solutions to the growing landslide risk.

The research funder is Universitas Andalas with grand number Nomor: 249/UN16.19/PT.01.03/PSS/2024.

References

1. E. Suharini, D. Liesnoor S., and E. Kurniawan, *Univers. J. Geosci.* **2**, 195 (2014)
2. A. T. Fathani, R. E. Putera, A. Asrinaldi, T. R. Valentina, D. Hariyati, D. Holidin, and A. Agustiyara, *E3S Web Conf.* **464**, 05002 (2023)
3. P. Febri Wialdi, R. E. Putera, Kusdarini, R. Ariany, T. R. Valentina, and R. Dermawan, *E3S Web Conf.* **331**, 04001 (2021)
4. I. T. N. H. Ullum, A. Fitria, and W. Widodo, *JSN J. Sains Nat.* **2**, 40 (2024)
5. I. Setyawan, S. A. Sajidah, A. Sabila, A. P. Wijayanti, and K. S. Dewi, *Proc. Int. Conf. Psychol. Stud.* **4**, 423 (2023)

6. R. E. Putera, H. Nurasa, and Y. S. Sugandi, *Bisnis Birokrasi J.* **23**, (2018)
7. T. U. Vemileza Putri, I. K. Dewi, and L. Marlinda, *Sci. Phys. Educ. J.* **5**, 47 (2022)
8. M. Fuady, R. Munadi, and M. A. K. Fuady, *IOP Conf. Ser. Mater. Sci. Eng.* **1087**, 012011 (2021)
9. T. Ahmad, Roni Ekha Putera, and Hendri Koeswara, *J. Soc. Policy Issues* 45 (2024)
10. S. N. Fadhilah, R. E. Putera, D. Aromatica, and E. Hasyimi, *Sawala J. Adm. Negara* **10**, 196 (2022)
11. R. Fajria, R. E. Putera, and R. Ariany, *E3S Web Conf.* **464**, 10001 (2023)
12. N. Laframboise and B. Loko, *IMF Work. Pap.* **12**, 1 (2012)
13. H. Haeril, T. Irfadat, and M. Mas'ud, *J. Stud. Ilmu Pemerintah.* **3**, 1 (2022)
14. N. Pratiwi, *IPDN* (n.d.)
15. Chyntia Aulia and Geovani Meiwanda, *J. Res. Dev. Public Policy* **1**, 35 (2022)