International Journal of Safety and Security Engineering
Vol. 15, No. 6, June, 2025, pp. 1197-1217
Journal homepage: http://iieta.org/journals/ijsse

Dynamics of Flood and Landslide Risk Governance Policy in Solok Regency, Indonesia

Zikri Alhadi[1*], Agid Rahman[1], Rahmadani Yusran[1], Yuliarti[1], Fitri Eriyanti[1], Yudi Antomi[2], Iip Permana[1]

[1] Department of Public Administration & Research Center for Policy, Governance, Development & Empowerment, Universitas Negeri Padang, West Sumatra 25132, Indonesia
[2] Department of Remote Sensing and Geographic Information System & Research Center for Rural and Urban Studies, Universitas Negeri Padang, West Sumatra 25132, Indonesia

Corresponding Author Email: zikrialhadi@fis.unp.ac.id

https://doi.org/10.18280/ijsse.150611

Received: 8 April 2025
Revised: 20 May 2025
Accepted: 15 June 2025
Available online: 30 June 2025

Keywords:
mitigation, policy, flood, landslide, disaster risk governance, Indonesia, SDGs

ABSTRACT

This research endeavors to elucidate the complexities associated with the policies aimed at mitigating flood and landslide disasters within the Lembah Gumanti region of Solok Regency. The investigation employs a qualitative methodology utilising descriptive techniques, meticulously observing, assessing, and analysing phenomena or issues with fidelity to the prevailing circumstances. The acquisition of data was facilitated through a combination of interviews, observational studies, and documentary analyses. According to the findings of this research, it can be articulated that the execution of flood and landslide disaster mitigation strategies in the Lembah Gumanti region has been undertaken by the Solok Government, bolstered by community engagement through a variety of initiatives. These mitigation strategies can be classified into the following categories: firstly, in terms of structural measures, disaster mitigation is achieved through the development of disaster-resistant infrastructure by the Solok Government; secondly, within the realm of non-structural mitigation, five principal variables emerge: a) The presence of a legal framework governing disaster mitigation; b) The existence of institutional mechanisms, notably the Solok Disaster Management Office, which operates as the command center for disaster management, coordinating with relevant organizational bodies; c) The implementation of an early warning system involving the placement of hazard signs and direct communication appeals through digital media; d) The Solok City Disaster Management Agency has carried out socialization, education, and training aimed at increasing community knowledge, awareness, and capacity, although it still faces many challenges to improve its achievements.

1. INTRODUCTION

Based on data from the Statistics Center, geographically, Nagari Air Dingin in Solok Regency, which is the locus of this research, has an area of 126.39 km², making it the second largest nagari in Lembah Gumanti District with a percentage of 27.6% of the total area of the district. The center of the Nagari government is 8 km from the capital of Alahan Panjang District, 38 km from the capital of Arosuka Regency, and 73 km from the capital of Padang Province. The administrative boundaries of Nagari Air Dingin are: to the east, it borders Nagari Salimpat and Hiliran Gumanti District, to the west, it borders Pesisir Selatan Regency, to the north, it borders Nagari Alahan Panjang, and to the south, it borders Pantai Cermin District. In terms of topography and climate conditions, Nagari Air Dingin has a varied topography between land, valleys, and hills. The highland area of Nagari Air Dingin is at an altitude of 1300-1500 meters above sea level with hilly and undulating topography.

Tropical climate with an average cold temperature of 14°C-20°C, rainfall in this area is high, reaching an average of 212 days per year. Hydrologically, the condition of the surface water system in Nagari Air Dingin comes from various water sources that flow through small rivers, which continue to flow throughout the year thanks to high rainfall. This area is included in the Batang Hari Jambi River Basin (DAS), which flows to the east, with major rivers such as the Sarasah I River and the Air Dingin River.

The Solok Regency is an area prone to disasters that occur at a high frequency almost every year. As one of the four Villages in Lembah Gumanti District, along with *Nagari* Alahan Panjang, Sungai Nanam, and Salimpat, *Nagari* Air Cool recorded various disaster events between 2020 and 2024, as shown in Table 1.

Table 1 shows that between 2020 and 2024, five disasters occurred in Lembah Gumanti, Solok Regency. Landslides were the most frequent disaster, with three incidents, followed by floods with two incidents, and strong winds with one incident. The impact of this disaster was significant, damaging residents' homes, agricultural land, and public facilities, as well as disrupting traffic access. Losses are estimated to reach up to 750 million rupiah, with several other losses yet to be

calculated. Natural and human factors influence the causes of floods and landslides. Geographically, this area is situated on a plateau with an altitude of 1300-1500 meters above sea level, characterised by hilly and undulating topography, and experiences a tropical climate with an average temperature of 14-20°C and an average annual rainfall of 212 days [1]. Research indicates that high rain, accompanied by increasing intensity and highland topography, collectively increases the risk of floods and landslides. During the rainy season, increased water flow increases the load on the slope, damages the soil structure, and reduces soil resistance, which triggers landslides from high to low places [2].

Table 1. Type, time, and impact of disasters, Lembah Gumanti District, Solok Regency (2020-2024)

No	Day/Date	Time of Event	Types of Disasters	Impact	Estimated Loss (IDR)
1	Saturday/April 18, 2020	21.00 WIB	Landslide	Damage to 3 community houses and disruption of access to the West Sumatra-Jambi National Highway	IDR. 55.000.000
2	Sunday/May 16, 2021	11.30 WIB	Landslides and Fallen Trees	The road access from Lubuk Selasih to Muara Labuh was cut off, affecting 153 people	The value of the loss is not estimated.
3	Saturday/January 8, 2022	17.00 WIB	Flood	Submerging of people's homes, places of worship, agricultural land, and other public facilities	IDR. 750.000.000
4	Thursday/June 30, 2022	10.00 WIB	Strong winds	The damage to several residents' houses due to strong winds ranged from minor to severe	The value of the loss is not estimated.
5	Wednesday/ April 03, 2024	17.30 WIB	Floods and Landslides	Landslide material blocked the road, cutting off access	The value of the loss is not estimated

Floods and landslides in the Lembah Gumanti Area resulted in significant losses, both material and human. These losses vary depending on the type, intensity, and frequency of disasters, as well as the community's vulnerability and capacity [3]. If not handled, this disaster can threaten people's lives. Therefore, disaster management efforts are needed. Disaster management is a public service that the regional government is required to organise by Law No. 24 of 2007 concerning Disaster Management. In this law it is explained that the government and regional governments are responsible for disaster management, which includes determining risky development policies, disaster prevention, emergency response, and rehabilitation. The main objective of disaster management is to protect the community from the threat of disaster.

In this study, the focus of disaster management will be directed at mitigation efforts. Disaster management has so far been more focused on handling the situation when a disaster occurs and the factors that cause it [4]. However, mitigation efforts as anticipatory steps to estimate the potential impact of specific threats have not been maximised [5]. The disaster management paradigm is now shifting to a preventive approach to reduce disaster risk [6-12].

Disaster mitigation encompasses the reduction of risk via the enhancement of public awareness, infrastructural development, and the fortification of capacities. Consequently, infrastructural enhancements, including ecological and residential advancements, alongside the elevation of community cognisance and capabilities about disaster threats and responses, must be executed comprehensively and sustainably to mitigate the ramifications of disasters (Law No. 24 of 2007).

The Government of Solok Regency has promulgated a Regent Regulation (Number 33 of 2020) about the Solok Regency Regional Disaster Management Plan for the period of 2020-2025, which comprehensively addresses disaster occurrences within the region. Within the framework of this regulation, the Solok Disaster Management Office has been designated as the principal technical institution responsible for implementation. Established under Regional Regulation Number 2 of 2010, the Solok Disaster Management Office is tasked with coordinating efforts among various related agencies, such as the Public Works Service, the Environmental Service, and additional institutions, while also engaging collaboratively with non-governmental organisations operating within the jurisdiction of Solok Regency. As a dedicated institution for disaster management, the Solok Disaster Management Office has undertaken numerous initiatives aimed at disaster mitigation, which include the dissemination of information and educational programs targeted at communities situated in disaster-prone areas. This undertaking is of paramount importance due to the community's limited comprehension of the underlying causes of disasters, such as land utilisation practices. Nevertheless, the Solok Disaster Management Office encounters considerable challenges resulting from fiscal constraints, which ultimately lead to a scarcity of socialization and educational endeavors. The enforcement of regulatory measures presents a significant impediment to the effective mitigation of flooding and landslides within the Lembah Gumanti Area of Solok Regency. It is suspected that mining activities, which exacerbate the potential for disasters, are predominantly unlicensed, with a subset constituting illegal mining operations.

Based on informants' statements, a dilemma exists in mining activities. Although it provides income for the region, mining also incurs costs for addressing environmental damage and disaster management. Problems also arise from the fact that ecological permit documents have not been reviewed, and the existence of illegal mines suggests that enforcement of environmental and land use regulations is often overlooked.

2. LITERATURE STUDY

In Law No. 21 of 2008 concerning Disaster Management, mitigation is carried out through (1) planning and implementing spatial planning based on disaster risk analysis; (2) regulating development, infrastructure, and building layout that follows technical standards set by authorised agencies/institutions; and (3) organising education, training, and counselling, both conventional and modern, by technical standards set by authorised agencies/institutions. Disaster mitigation is part of the pre-disaster stage in the disaster

management cycle. It focuses on long-term actions to mitigate the impact or risk of disasters [13], which the government and the community implement through both structural and non-structural approaches. Structural mitigation constitutes a concerted endeavor to reduce vulnerability to disasters by building infrastructure that is resistant to the impacts of disasters. This includes the construction of shelters, evacuation routes, and building engineering using technology designed to mitigate the effects of natural disasters as a step in reducing disaster risk. In addition to physical infrastructure development, effective non-structural mitigation strategies are also available. These strategies encompass various actions, including the establishment of government regulations, disaster education, and regional planning, which collectively can help reduce risk.

2.1 Relevant studies

Structural mitigation refers to "hard" measures that enhance the physical resilience of buildings against seismic events, such as retrofitting or using more robust materials. Non-structural mitigation involves strategies that do not alter the building's physical structure but improve safety and reduce risks, such as implementing building codes, conducting public awareness campaigns, and ensuring proper land-use planning. Both approaches are crucial for mitigating earthquake-induced damage and casualties, particularly in vulnerable urban areas like the Kathmandu Valley, where the quality of the building stock has a significant impact on overall seismic risk [14].

Structural mitigation refers to changes in the economic structure, such as shifts in sectoral composition and trade intensity, that can influence energy use and emissions. Non-structural mitigation involves policy measures and technologies that aim to reduce emissions without fundamentally altering the economic structure. The paper highlights that while climate policy has a minimal impact on the macro-sectoral level, it can induce significant changes within specific industries, particularly in the energy sector, suggesting a complex interplay between structural and non-structural approaches in achieving climate goals [15].

Structural mitigation refers to physical measures implemented to reduce the risk of disease transmission, such as building modifications or infrastructure improvements. Non-structural mitigation encompasses policy-driven actions, including public health guidelines, education, and behavioural interventions aimed at reducing transmission and managing health outcomes. The paper emphasises the importance of both types of mitigation in addressing the multifaceted impacts of COVID-19, advocating for a comprehensive approach that integrates community and clinical measures to manage public health emergencies effectively [16].

A combination of structural and non-structural measures is essential for effective risk management of natural hazards. Structural measures include physical infrastructure designed to protect against hazards, while non-structural measures involve policies, education, and community engagement aimed at reducing vulnerability and enhancing preparedness. The study emphasises that prioritising non-structural measures can improve awareness of residual risks and cases of overload, ultimately leading to better management of geohydrological hazards and gravitational mass movements in Alpine regions. This integrated approach is crucial for addressing the limitations of solely relying on structural solutions [17].

The paper primarily focuses on the seismic assessment of nonstructural elements (NEs), which are critical due to their vulnerability during seismic events. Structural mitigation involves reinforcing the building's framework to withstand seismic forces, while non-structural mitigation targets the protection and stabilisation of elements like architectural features and mechanical systems. The study emphasises the need for standardised testing protocols for NEs to enhance their resilience, thereby reducing overall seismic risk in facilities, particularly those deemed critical, such as hospitals and nuclear plants [18].

Structural mitigation refers to physical modifications to buildings, such as elevation and improved construction practices, designed to reduce damage from hurricanes. Non-structural mitigation involves strategies that do not alter the building's physical structure, focusing instead on planning, policies, and community preparedness to minimise socioeconomic impacts. The study emphasises the integration of both types of mitigation in a multiobjective optimisation framework to balance structural damages, home displacements, and economic losses, ultimately enhancing community resilience against hurricane threats [19].

Structural mitigation involves optimising the design and materials of building structures to enhance energy efficiency and reduce carbon emissions during construction and operation. This includes techniques such as structural optimisation and the use of sustainable materials. Non-structural mitigation focuses on improving construction processes through lean construction methods, which aim to minimise waste and enhance efficiency. Both approaches contribute to reducing energy consumption and emissions throughout the building's life cycle, particularly during the operational phase, while also addressing the embodied energy associated with construction [20].

Structural mitigation involves engineered infrastructures designed to withstand or reduce the impact of natural disasters, such as levees or seawalls. Non-structural mitigation focuses on strategies that do not include physical construction, such as land-use planning, ecosystem-based disaster risk reduction (Eco-DRR), and community awareness programs. The integration of both approaches, as highlighted in the review, enhances disaster resilience by utilising natural buffers alongside engineered solutions to manage risks associated with tsunamis and coastal flooding effectively [21].

The paper primarily focuses on seismic risk mitigation for unreinforced masonry buildings, emphasising structural retrofitting as a critical component. Structural mitigation involves strengthening the building's framework to withstand seismic forces, while non-structural mitigation includes measures such as securing fixtures and improving emergency preparedness. The effectiveness of these strategies is influenced by factors like financial options, design solutions, and compliance enforcement, which are essential for encouraging building owners to undertake necessary improvements. Understanding these aspects can enhance the overall resilience of communities in earthquake-prone areas [22].

The paper primarily focuses on adaptive mitigation strategies, which can be categorised as structural or non-structural. Structural mitigation involves implementing physical infrastructure changes, such as renewable energy systems or carbon capture technologies, to reduce emissions. Non-structural mitigation encompasses policy measures, regulations, and behavioral changes aimed at lowering emissions without physical alterations, such as carbon pricing

or awareness campaigns. Both approaches are essential for effective climate change mitigation, and the paper emphasises the importance of adaptive strategies that respond to observed climate conditions to optimise both economic and environmental outcomes [23].

Structural mitigation refers to physical modifications to buildings, such as elevating structures or installing flood barriers, aimed at reducing flood damage. Non-structural mitigation includes strategies that do not involve physical changes, such as land-use planning, flood insurance, and community awareness programs. The study emphasises the importance of both short-term (such as flood barriers) and long-term (such as building elevation) structural measures while also recognising the potential for non-structural approaches to enhance community resilience against flooding [24].

The research primarily focuses on asset management practices as a proactive tool for disaster risk reduction, encompassing both structural and non-structural mitigation strategies. Structural mitigation involves physical modifications to infrastructure to enhance its ability to withstand hazards, while non-structural mitigation encompasses policies, planning, and management practices that strengthen resilience. Effective asset prioritisation and whole-of-life considerations in asset management can improve decision-making and planning, ultimately reducing the impact of disasters in the MENA region. The study emphasises the need for appropriate asset management policies to support these mitigation strategies [25].

Structural mitigation involves physical modifications to urban drainage systems, such as decentralised designs that enhance resilience against failures like pipe clogging or pump failure. Non-structural mitigation encompasses strategies that do not involve physical changes, such as policy adjustments, maintenance practices, and community engagement, aimed at enhancing system performance and resilience. The paper emphasises the importance of integrating both approaches in the design of urban drainage networks, particularly in flat areas, to optimise performance while minimising costs and enhancing structural resilience [26].

The study primarily focuses on structural mitigation through project-level strategies, exemplified by disaster risk reservoir projects in South Korea, which are evaluated using cost-benefit analysis. Non-structural mitigation is implied in the first strategic implementation process (SIP-1), which enhances the predictability of financial losses from natural disasters using deep learning techniques. This dual approach enables a comprehensive evaluation of both structural and non-structural strategies for mitigating economic damages caused by natural disasters [27].

Mitigation strategies for structural and non-structural elements involve enhancing the resilience of buildings against natural disasters through risk-informed, performance-based approaches. Structural mitigation focuses on design methods that ensure safety and serviceability, such as modifying safety factors and adjusting load parameters based on risk assessments and evaluations. Non-structural mitigation encompasses measures such as retrofitting, utilising flexible materials, and implementing early warning systems to mitigate the impact of hazards. Both strategies aim to minimise the consequences of structural and non-structural failures, ensuring the built environment can withstand various natural risks effectively [28].

Structural mitigation refers to physical measures implemented to reduce risk, such as building reinforcements or infrastructure improvements. Non-structural mitigation involves policy changes, education, and planning strategies that aim to minimise risk without physical alterations, such as risk assessment protocols or community awareness programs. The paper emphasises the importance of both types in sustainable risk management, highlighting that a comprehensive approach combining structural and non-structural strategies can enhance the effectiveness of supply chain risk management in various scenarios, particularly in the case study presented in the food industry [29].

Structural mitigation involves techniques that enhance the building's ability to withstand seismic forces, such as retrofitting and strengthening methods that improve load-bearing capacity and stability. Non-structural mitigation focuses on protecting non-load-bearing elements, such as interior partitions, ceilings, and equipment, to prevent damage during an earthquake. The paper emphasises that effective retrofitting strategies should be integral and well-executed, addressing both structural and non-structural components to ensure overall building resilience against seismic events, as demonstrated by the performance of rehabilitated buildings during earthquakes [30].

The study primarily focuses on structural mitigation through seismic retrofitting techniques, aiming to enhance the resilience of strategic buildings. Structural mitigation involves strengthening the building's framework to withstand seismic forces, while non-structural mitigation includes measures such as securing contents, improving emergency response plans, and enhancing building systems. The research emphasises the importance of both types of mitigation in reducing seismic losses and ensuring rapid recovery, particularly for buildings with significant public and strategic roles during and after earthquakes [31].

The framework emphasises a comprehensive approach to earthquake risk by integrating both structural and non-structural mitigation strategies. Structural mitigation involves physical modifications to buildings and infrastructure to enhance their resilience against seismic events. In contrast, non-structural mitigation focuses on policies, community preparedness, and social interventions that reduce vulnerability. By harmonising these two aspects, the framework facilitates a more holistic understanding of risk and supports informed decision-making for future urban planning, considering both physical damage and social impacts [32].

The effectiveness of structural and non-structural rockfall protection measures in high-frequency rockfall areas was discussed, highlighting that structural measures typically involve physical barriers or nets to intercept falling rocks. In contrast, non-structural measures focus on land-use planning, vegetation management, and community awareness. An interim non-structural measure was proposed to address the self-evolution of rockfall, aiming to enhance mitigation efficiency and reduce maintenance costs. This approach emphasises the importance of adapting strategies to the changing terrain and rockfall dynamics in such regions [33].

2.2 Structural and non-structural mitigation case

Structural disaster mitigation in Timbulsloko Village involves the use of environmentally friendly coastal protection technology, specifically a Permeable Breakwater with a Hybrid Engineering structure, to protect against coastal erosion. Non-structural mitigation is achieved by analyzing

the Coastal Vulnerability Index (CVI) based on various parameters such as Coastal Typology and Sea Level Rise. This dual approach aims to enhance resilience against coastal disasters, particularly erosion, by combining physical barriers with vulnerability assessments [34].

Structural disaster mitigation involves physical measures to reduce disaster risks, such as building resilient infrastructure. In contrast, non-structural mitigation focuses on reducing non-physical risks through policies, community empowerment, institutional reinforcement, and awareness-raising activities. Effective non-structural mitigation relies on citizen participation to ensure alignment with planned strategies, enhancing community capacity to manage disaster risks sustainably. Both approaches are essential for comprehensive disaster management, particularly in areas prone to hazards like volcanic eruptions, as seen in Gung Pinto village [35].

The research identifies structural and non-structural disaster mitigation alternatives for flood management in Mandailing Natal, Indonesia. Structural options include river channel modification and earth-embankment dam construction, which aim to alter the landscape to manage floodwaters physically. Non-structural alternatives focus on strategies like rainwater harvesting (RWH), which emphasizes reducing runoff through sustainable practices. The study recommends RWH due to its significant runoff reduction capability (86.36%) and lower budget implications compared to the high costs associated with structural modifications [36].

Structural disaster mitigation involves physical constructions like levees and drainage systems to control flooding, while non-structural mitigation includes policies, land-use planning, and community education to reduce flood risks. The research paper emphasizes the importance of both approaches in managing flood disasters, highlighting that optimal flood control requires evaluating land suitability and social conditions. By integrating these strategies, flood prevention and control can be enhanced, addressing both technical and social aspects of flood-affected areas effectively [37].

The study identifies both structural and non-structural disaster mitigation measures in the Kutupalong Rohingya Camp. Structural measures include concrete retaining walls and geosandbag covers, which provide marginal protection against landslides. Non-structural measures suggested by the community include modifying slope inclinations, planting trees, and enhancing community awareness. The findings indicate that while structural measures are perceived as functional, there are significant concerns regarding their reliability and effectiveness, highlighting the need for a balanced approach to disaster risk reduction [38].

3. METHODS

This research examination centers on the strategies for disaster mitigation within the Lembah Gumanti Region, Solok Regency, employing a descriptive qualitative methodology. The selection of informants for this investigation was conducted utilising a purposive sampling technique. This methodological approach is anticipated to facilitate the identification of appropriate informants, thereby ensuring the credibility of the collected data. As delineated previously, the informants for this research comprised officials or functional representatives from the Solok Disaster Management Office, alongside various affiliated organisations engaged in disaster management, disaster specialists, community activists, local government representatives, and members of the Lembah Gumanti Area populace.

In order to acquire primary data for this investigation, the researchers identify individuals or informants deemed knowledgeable and reliable, serving as pivotal informants pertinent to the subject matter of the research. This selection process is predicated on the premise that the chosen informants possess accountability, hold authoritative positions, and actively engage in disaster mitigation efforts within the research locale. The following is a compilation of informants relevant to this research, which can be seen in Table 2:

Table 2. Research informants

No	Institutions	Role
1	Solok Disaster Management Office	local government institutions that are the leading sector in disaster management
2	Environmental Service	Local government agencies that are authorized to handle environmental damage, including that resulting from disasters.
3	Public Work Service	Local government institutions that are authorized to provide and manage infrastructure, including for disaster mitigation.
4	Disaster Expert	The experts who have knowledge and capacity in disaster mitigation
5	Village Government Institutions	Local government institutions at the village level that deal with community problems
6	Public	Communities living and working around the disaster location

In the present investigation, the categories of data utilized encompass both primary data and secondary data. In this research endeavor, data were amassed through a variety of methodologies specifically designed to elicit the requisite information, employing data collection techniques that comprised interviews, observations, and document analyses. In order to authenticate the data within this study, both source triangulation and method triangulation were implemented.

Qualitative research is inherently constrained by significant limitations regarding the generalizability of its findings. This is primarily because such research is typically conducted on a limited scale, employing restricted sample sizes and often utilizing purposive or snowball sampling methodologies, which precludes the extrapolation of results to a broader demographic. Moreover, qualitative methods are substantially reliant on the researcher's interpretation of the collected data, thus presenting notable challenges related to subjectivity and researcher bias. The interpretations generated may be susceptible to the researcher's personal background, values, or experiential context, consequently jeopardizing the validity of the resultant research outcomes.

4. RESULTS AND DISCUSSION

Floods and landslides are hydrometeorological disasters that occur due to disturbances in the hydrological cycle. These disturbances have an impact on climate stability and water availability, caused by irregular changes in seasonal patterns, the loss of hydrological function in river basins, and deforestation resulting from illegal logging for cultivation [39].

This causes soil erosion that leads to floods and landslides. Efforts to mitigate floods and landslides use principles and approaches that tend to be similar, although each disaster has its own characteristics. Both of these disasters necessitate a comprehensive and integrated approach that involves various stakeholders and considers social, economic, and environmental aspects. The high risk of floods and landslides in the Lembah Gumanti Area requires special attention from the Government through the relevant Regional Apparatus Organizations, through applicable laws and regulations. Mitigation efforts must be implemented to reduce disaster risks. Some strategies that have been implemented as mitigation efforts for these two disasters are as follows:

4.1 Preparation of legislation on disaster management plans

By Articles 35 and 36 of the Disaster Management Law (Law No. 24 of 2007), each jurisdiction must formulate a comprehensive disaster management plan. Government Regulation Number 21 of 2008 about the Execution of Disaster Management mandates that such a plan must be meticulously developed, grounded in thorough disaster risk assessment and mitigation strategies, and subsequently enacted through a variety of disaster management initiatives and programs. The Government of Solok Regency has manifested its dedication to disaster management initiatives by instituting Regent Regulation Number 33 of 2020, which pertains to the Solok Regency Regional Disaster Management Plan. This regulation holds particular importance, given the region's elevated vulnerability to disasters. The Solok Disaster Management Office is the institution responsible for disaster management within the Solok Regency area. This Office, as the institution responsible for disaster management in Solok Regency, plays a key role in the preparation of Solok Regent Regulation Number 33 of 2020, which concerns the regional disaster management plan. The preparation of this regulation involves various elements of government and society. The Solok Disaster Management Office formulates disaster management programs for all types of disasters at every stage, including mitigation. The preparation of the Solok Regency Regional Disaster Management Plan Policy Document is an effort by the regional government to ensure targeted disaster management. The regulation governs strategies, policy directions, and disaster management programs, serving as the basis for decision-making among related stakeholders. Furthermore, the importance of preparing rules related to the regional disaster management plan lies in the obligation of each region to provide a strong legal framework by its local government. This enables organised, coordinated, and sustainable disaster management efforts, promoting effective coordination among the public, private, and community sectors. Based on the documentation study conducted, the following are the strategies or programs planned as an effort to mitigate flood and landslide disasters in Solok Regency (Lembah Gumanti Area), which are stated in Regent Regulation Number 33 of 2020, which can be seen in Table 3:

Table 3. Planning of flood and landslide disaster prevention and mitigation policy program in Solok Regency

Types of Disasters	Policies	Priority Focus	Information
Flood	Prevention and Mitigation	1. Development of Disaster Resilience Infrastructure (periodic development of irrigation networks, development of technology for repairing water gates, and securing and preserving Water Resources through periodic river reclamation in flood-prone areas). 2. Establishing, supervising, and enforcing standards for Water Resources and Watershed management. 3. Development of Disaster Preparedness Culture and Community Resilience in the Face of Flooding Risk. 4. Development of Technical Capacity within the Government Apparatus for Disaster Management.	According to the findings of the research, the efficacy of the execution of policies and flood disaster mitigation initiatives that have been delineated has not universally attained optimal outcomes. First, various initiatives, such as infrastructure development, have commenced; however, they remain impeded by financial constraints. Second, the oversight and enforcement of regulatory frameworks have not been conducted effectively due to a deficiency in personnel and a lack of consistency in their execution. Third, the cultivation of a culture of community disaster preparedness has not progressed as anticipated. Fourth, the enhancement of the technical competencies of government officials has not been implemented effectively due to a scarcity of resources.
Landslide		1. Enforcement of Environmental Regulations Related to Land Use 2. Development of buffer zones or landslide impact dampers, increasing water catchment areas, and development of slope protection infrastructure in landslide-prone areas. 3. Development of innovative detection technology for landslide prevention 4. Building an early warning system for landslides down to the village level 5. Preparing community evacuation facilities and infrastructure. 6. Increasing the capacity and independence of communities in landslide-prone areas.	Based on the findings of the research, the efficacy of the execution of landslide disaster mitigation policies and programs that have been strategically formulated has not universally attained optimal outcomes. First, the implementation of regulatory measures has not been executed with the requisite consistency. Second, the development of buffer zones has not progressed effectively due to constraints in budgetary allocations and available resources. Third, there exist deficiencies in both capacity and technological advancements necessary for the establishment of an early warning system and innovations in disaster mitigation strategies. Fourth, there are significant limitations in both financial resources and budgetary provisions for the establishment of disaster mitigation facilities and infrastructure. Fifth, the development of community capacity and autonomy has not been adequately realized, as initiatives aimed at enhancing their capabilities remain insufficiently robust.

Table 3 elucidates that the disaster mitigation program addressing floods and landslides encompasses the development of infrastructure, the advancement of technological innovations, the augmentation of community capacities, and the enforcement of pertinent regulations. Drawing upon the data collected, it can be deduced that a critical disaster mitigation initiative executed by the Solok Government, via the Solok Disaster Management Office, is the formulation of the Regional Disaster Management Plan, as delineated in Regent Regulation Number 33 of 2020. This regulation establishes a robust legal framework designed to ensure a systematic, coordinated, and sustainable methodology for mitigating disaster risks and minimizing incurred losses. Conversely, there exists criticism concerning the execution of regulations, particularly those pertinent to disaster management.

Programs stipulated in regional disaster management regulations must be appropriately implemented by relevant parties within the regional government, within the limits of their authority. The problem is that the regional disaster management plan document, prepared in this manner, is often not thoroughly understood by the relevant parties and tends to be overlooked, not utilised as a reference, and not implemented. Therefore, although the Solok Government has attempted to formulate regulations on disaster management through Solok Regent Regulation Number 33 of 2020, its implementation is a challenge for related parties. This regulation must serve as the basis for stakeholders in developing disaster management policies and ensuring effective implementation to safeguard the community and mitigate disaster risks. The planned program must be implemented with complete understanding and commitment by all related stakeholders.

4.2 Mapping and placement of hazard warning signs at disaster-prone points

About the cartographic initiatives undertaken to delineate regions exhibiting a heightened susceptibility to inundations and landslides, the Solok Disaster Management Office, functioning as the authoritative body in disaster management, has executed comprehensive disaster risk mapping endeavors. These efforts aim to ascertain the specific locales within Solok Regency that are most susceptible to various disaster threats, which encompass both flooding and landslides. The mapping results, presented in the form of spatial data or maps, indicate areas with disaster hazards categorised as low, medium, or high vulnerability. The Lembah Gumanti Area is classified as an area with high vulnerability to floods and landslides, allowing government agencies to prioritise mitigation efforts in the area.

Figure 1, presented above, illustrates the Lembah Gumanti Region as a locale exhibiting a significant susceptibility to both flooding and landslides, delineated by red lines (indicating landslides) and yellow lines (indicating floods) against a black background. In the aftermath of the mapping initiatives, the Solok Disaster Management Office engaged in a collaborative effort with the Public Works Service of Solok Regency to strategically implement warning signage at identified vulnerable locations for the purpose of disaster mitigation. Within the Lembah Gumanti Region, warning signs have been strategically positioned in residential zones to alert inhabitants of potential flooding threats, as well as along the national thoroughfare to caution against the dangers posed by landslides. The overarching objective is to enhance public awareness, encourage vigilance, and cultivate preparedness for prospective disasters within the region.

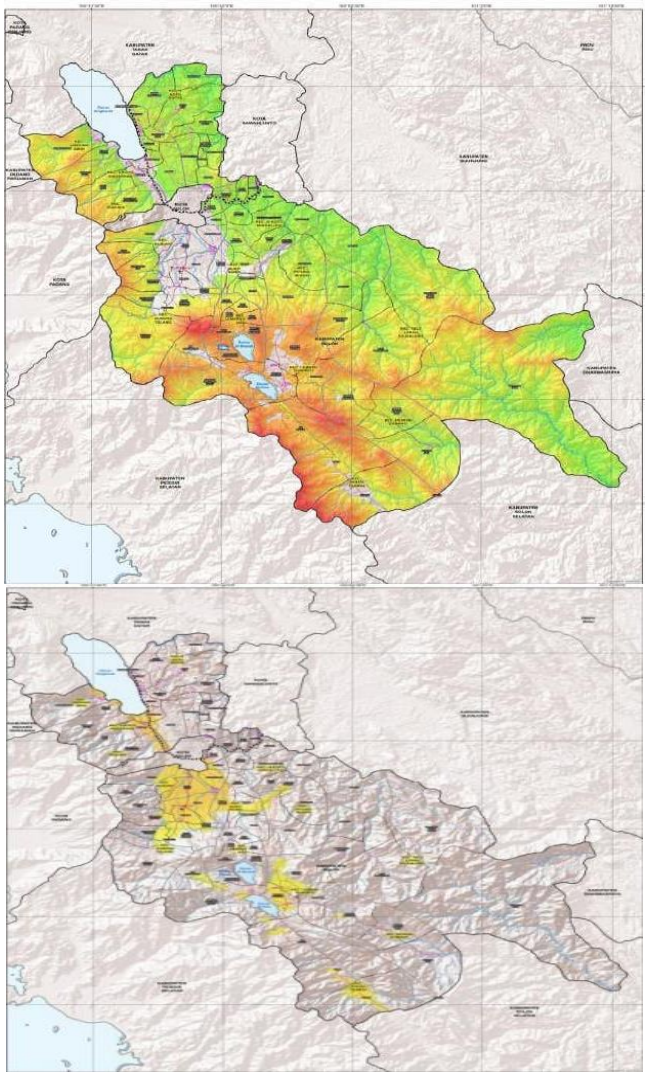

Figure 1. Map of landslide and flood disasters in Solok Regency

Figure 2. Warning signs or signs of flood and landslide disaster hazard in Lembah Gumanti District, Solok Regency

Figure 2, presented above, illustrates indicators or cautionary signals pertaining to flooding within residential communities as well as landslide occurrences along the national thoroughfare in the Lembah Gumanti Area. The researchers conducted interviews with local inhabitants who are both drivers and users of the national highway traversing

the Lembah Gumanti Area, which functions as the principal access route and is characterised by high traffic volume connecting Padang City with South Solok Regency or West Sumatra Province to Jambi Province, exhibiting significant susceptibility to landslides. The community articulated a favorable perspective concerning the implementation of disaster warning signs by the government as a crucial mitigation strategy. The presence of such warning signs has heightened community vigilance, particularly during periods of intense rainfall. Based on the aforementioned data collection, it can be concluded that the Solok Disaster Management Office has undertaken mapping initiatives to delineate disaster-prone zones within Solok Regency. The findings indicate that the Lembah Gumanti Area contains numerous points of vulnerability. The Solok Disaster Management Office, in collaboration with the Public Works Service, has systematically installed warning signs along the national highway to remind the public to exercise heightened caution. The process of identifying and designating high-risk zones is imperative for the formulation and execution of effective mitigation strategies.

4.3 Monitoring of disaster-prone locations and dissemination of disaster hazard information

Continuous monitoring initiatives must be undertaken in areas deemed vulnerable, as identified through comprehensive mapping assessments. The significance of these monitoring initiatives is underscored as a critical component of disaster mitigation strategies aimed at minimising disaster risks, particularly in regions such as the Lembah Gumanti Area. Relevant stakeholders must effectively communicate the data derived from such oversight to mitigate disaster risks. The Solok Disaster Management Office has engaged in monitoring activities, particularly during instances of heavy rainfall that pose dangers of flooding and landslides, collaborating with village officials and local community members to assess the conditions of slopes and waterways while providing pertinent information and advisories to the community regarding the on-ground situation. Furthermore, disaster monitoring and information dissemination efforts actively involve community members and stakeholders in regions susceptible to disasters.

The involvement of community members and village officials is vital in monitoring vulnerable areas, such as the Lembah Gumanti Area, especially considering the geographical distance between these locations and the Solok Disaster Management Office. Community members undertake the task of observing their immediate environment and reporting potential disaster indicators via online platforms such as WhatsApp Groups. The Solok Disaster Management Office then corroborates the received information, issues alert advisories, and disseminates relevant disaster-related information. Additionally, the Solok Disaster Management Office is poised to introduce the "Contact Person" initiative to enhance accessibility to disaster response services, including the reporting of disaster incidents within Solok Regency.

Then, the importance of the village apparatus in monitoring and disseminating disaster information significantly influences mitigation efforts. The Village apparatus monitors and provides disaster information, such as when heavy rain causes the river to overflow, the Village Head reports to the Solok Disaster Management Office, receives direction, and conveys an appeal to the community to be immediately conveyed (informed) to the local community directly or by utilising digital communication media. The Village community acknowledges that the WhatsApp Group serves as a digital communication medium for the community to stay informed about developments related to disaster events in the Lembah Gumanti Area, in addition to direct delivery. However, based on previous incidents, the local community assumes that the risk of landslides is challenging to avoid because it often occurs when people are resting, such as during sleep.

Based on the aforementioned data collection, one can deduce that the monitoring and dissemination of disaster-related information constitute vital components of disaster mitigation strategies. By closely observing areas susceptible to disasters when precursory signs manifest and issuing alerts to the community, it is possible to mitigate potential losses effectively. The Solok Solok Disaster Management Office, in collaboration with local governmental entities and active community participation in areas at risk of disasters, endeavors to monitor and disseminate disaster information through digital communication platforms, including WhatsApp Groups. For instance, upon the emergence of indicators such as extended periods of heavy rainfall and the onset of river overflow, the Solok Disaster Management Office will issue a community alert in at-risk areas to encourage vigilance and preparedness. This crucial information is communicated through messages posted on WhatsApp Groups and directly by the local village officials. Nevertheless, disasters such as landslides may occasionally transpire during times of rest, rendering the risk difficult to avert.

4.4 Strengthening cross-sector coordination through the disaster risk reduction forum

In the domain of disaster mitigation, the orchestration and collaboration among diverse sectors, notably among governmental entities, take on an essential role, as they are crucial to the development of a response that is both efficacious and resource-efficient [39]. The endeavors directed towards intersectoral coordination within the context of disaster risk management and mitigation in Solok have resulted in the creation of a Forum for Disaster Risk Reduction by the Solok Government, which aims to amalgamate a wide range of stakeholders in the regional disaster management efforts, thereby signifying a unified initiative. The governance of the Forum is entrusted to the Deputy Chairperson of the Solok Regency Regional People's Representative Council. The Forum's membership comprises a varied spectrum of relevant Regional Apparatus Organizations, including the Disaster Management Office, Environmental Service, Public Works Service, Social Service, Health Service, alongside military and law enforcement agencies, in addition to State and Regional Owned Enterprises such as Telkom, the Electricity Company, and the Clean Water Company, as well as volunteers and representatives from communities affected by disasters. The establishment of the Forum for Disaster Risk Reduction, as articulated in the Regent of Solok's Decree Number 360-115-2022, signifies a notable advancement in the disaster mitigation strategies enacted by the Solok Government.

This forum aspires to foster collaboration and synergistic partnerships with diverse stakeholders, thereby serving as a conduit for community engagement and promoting initiatives aimed at fortifying disaster management institutions. One of the significant outcomes of the Forum of Disaster Risk

Reduction encompasses the formulation of the Regional Action Plan for Disaster Risk Reduction. Furthermore, the Disaster Risk Reduction Forum, established within each jurisdiction, functions as a communication nexus that enables discourse on disasters and mitigation methodologies, which are subsequently articulated into policies that serve as a foundational reference for effective disaster risk reduction activities. To ensure the sustainability and evolution of the Disaster Risk Reduction Forum's role, this initiative must be institutionalised at the grassroots level, extending to the village tier, thereby facilitating efforts to enhance community capacity through awareness campaigns that underscore the significance of disaster risk reduction measures, including the advocacy of reforestation practices in response to the ramifications of deforestation. It can be inferred that the Disaster Risk Reduction Forum is instrumental in cultivating a disaster-resilient community, thereby mitigating losses or adverse effects stemming from calamities.

The Forum facilitates the enhancement of regional policies and strategic frameworks relevant to disaster risk mitigation, thus ensuring that the resulting policies are both thorough and precisely attuned to the distinct requirements of the locality. In the realm of capacity enhancement, this forum significantly contributes to the augmentation of institutional and human resource competencies in disaster management via training and capacity development initiatives. Most critically, through the establishment of a coordination platform, the Disaster Risk Reduction Forum embodies a collaborative endeavor to diminish disaster risk, thereby streamlining the coordination of disaster management efforts within Solok Regency, particularly concerning disaster occurrences in the Lembah Gumanti Area.

4.5 Socialisation, education, and training to increase community awareness and capacity

Enhancing community understanding, cognisance, and capacity concerning risks and disaster management strategies is imperative in the context of disaster mitigation initiatives [40-42]. Such initiatives may be executed through socialisation, educational endeavors, and training programs, as stipulated by Law Number 24 of 2007. The objective is to equip individuals and communities with the necessary tools to exhibit greater resilience and responsiveness to a variety of disaster scenarios, thereby mitigating their adverse effects [43-49]. The enhancement of community awareness and capacity is essential as a preventative measure in disaster mitigation [50-53]. Beyond fostering resilience, it also seeks to prepare communities for impending disasters, particularly through the augmentation of awareness regarding potential hazards within their residential environments [54-57]. Individuals who possess knowledge of the associated risks are statistically more inclined to engage in preventive actions. This initiative can be actualised through socialisation, educational programs, and training conducted by designated authorities as a preliminary measure to avert or diminish disaster-related risks [58-62].

Researchers assert that a fundamental comprehension of disasters is essential for community members, enabling them to undertake necessary actions in the event of a disaster, thereby mitigating feelings of fear or panic due to prior exposure to critical information pertaining to the disaster. The local government is instrumental in fostering community awareness and enhancing capabilities, as delineated by statutory requirements. About initiatives aimed at augmenting community knowledge and capacity as a strategy for disaster mitigation in the Lembah Gumanti Area, the Solok Government, through the Solok Disaster Management Office, has undertaken efforts to bolster the knowledge, awareness, and capacity of both officials and community members regarding disasters.

The Solok Disaster Management Office executes various mitigation programs, including Socialization, Communication, Information, and Education tailored for Disaster-Prone Areas, which are conducted annually in three cohorts. These programs are attended by officials and representatives from each village within Solok Regency, encompassing the Lembah Gumanti Area. Additionally, this institution has a regional capacity-building program for Prevention and Preparedness, the outcome of which is the establishment of Disaster Preparedness Groups in each village. Efforts to increase knowledge, awareness, and capacity are also carried out through other activities, such as counseling in schools (elementary to high school) within the Disaster Preparedness School program, as well as utilizing situations like coordination meetings with other agencies to provide an understanding of disasters. The Solok Disaster Management Office also uses digital media (Website, Mass Media, Facebook, and others) for the education and delivery of disaster information.

However, the effectiveness of socialisation, education, and training in increasing community knowledge, awareness, and capacity as disaster mitigation measures in the Lembah Gumanti Area is still considered low. Disaster socialisation and education activities in the Lembah Gumanti Area have been carried out through coordination between the Village Government and the Solok Disaster Management Office in recent years. However, the lack of community enthusiasm, which often manifests as indifference or apathy, poses a significant challenge in its own right. Therefore, the Lembah Gumanti Area and the Solok Disaster Management Office should collaborate to enhance education and foster community participation in the future. Some of the Lembah Gumanti Area community have participated in disaster socialisation and education to protect the environment and reduce disaster risks. However, the implementation of this socialisation, education, and training has not been evenly distributed, and some residents are still unaware of it. It can be concluded that the Solok Disaster Management Office is attempting to enhance community awareness, knowledge, and capacity in disaster management by collaborating with the Village Government. These mitigation steps are carried out through socialisation, education, and training activities, including the Disaster-Prone Areas program for officials and the community, the Increasing Regional Capacity for Disaster Prevention initiative, which involves the formation of Disaster Preparedness Groups, Disaster Preparedness Schools, seminars, disaster training, and education through social media. The materials delineated encompass methodologies about first aid, protocols for family evacuation, strategies for evacuation and rescue operations, as well as direct experiential simulations. The primary obstacle is the lack of community participation, particularly in the Lembah Gumanti Area, where people are unfamiliar with or uninvolved in these activities. The purpose of the socialisation, education, and training activities of the Solok Disaster Management Office is to increase public awareness of potential disaster threats, prepare the public for disasters, reduce the risk of damage, and ensure quick and effective

action during disasters. With active participation, it is hoped that the community will become more independent in managing disaster risks.

Sustainable rehabilitation and preservation initiatives concerning forest vegetation possess the capacity to mitigate environmental degradation and diminish disaster-related vulnerabilities [63-66]. Rehabilitation is primarily concerned with the restoration of forest ecosystems that have been adversely affected by anthropogenic activities through the reintroduction of diverse plant species aimed at reinstating the ecological functions of the forest. Conversely, forest conservation is directed towards safeguarding and sustaining the ecosystem functions that remain intact or have undergone rehabilitation [67-73], which encompasses the surveillance of unlawful logging activities via regulatory measures and enforcement of the law. Beyond governmental responsibilities, the active involvement of the community is deemed essential in the realm of environmental conservation [74-80], which includes the selection of appropriate plant species, the processes of planting, and ongoing maintenance to facilitate optimal growth and development. Academics assert that the involvement of local communities in the processes of forest vegetation rehabilitation and conservation not only improves the effectiveness of these conservation efforts but also strengthens the bond between humans and the natural world. This engagement guarantees the sustained vitality and appropriate functioning of forest ecosystems, consequently aiding in the mitigation of calamities [81-91] and safeguarding forests as an essential resource for future generations.

The deficient level of public cognizance regarding disaster mitigation from a socio-cultural standpoint can be attributed to a multitude of factors intricately linked to the prevailing values, beliefs, and social frameworks within society. A predominant factor is the presence of a fatalistic perspective, which is characterized by the conviction that disasters represent a divine predestination that is inescapable [92]. This conviction leads certain individuals to exhibit reluctance in engaging in mitigation efforts, as such actions are perceived to be in opposition to divine intent. Furthermore, deeply entrenched beliefs in local traditions and ritualistic practices frequently undermine the application of scientific methodologies. In various communities, disasters are construed as communications from forebears or as consequences of transgressions against customs, rather than being recognized as natural phenomena that are amenable to prediction and preparation [93].

A deficiency in education and literacy regarding disaster risks constitutes another significant element. Numerous individuals lack comprehension of the hazards and do not possess foundational knowledge concerning the mitigation measures that could be implemented [94]. This situation is exacerbated by a hierarchical social framework wherein individuals exhibit considerable reliance on traditional figures or informal leaders. Should these leaders fail to exemplify or endorse mitigation initiatives, the community is inclined toward passivity. In specific contexts, communities that have coexisted with the threat of disasters such as floods or volcanic eruptions for extended periods tend to normalize these risks as integral to daily existence, thereby diminishing the perceived necessity for specialized preparations or protective measures [95]. Additionally, a pervasive distrust of governmental bodies or external entities, potentially influenced by historical experiences of marginalization or prior failures in disaster management, further contributes to the community's hesitancy to engage in the mitigation programs presented [96]. Ultimately, the emotional attachment to one's residence, often revered as ancestral heritage, serves as a compelling rationale for individuals to resist relocation from regions classified as high-risk zones for disasters. Collectively, these factors underscore the imperative that disaster mitigation initiatives cannot solely rely on technical frameworks, but must be tailored to the socio-cultural dynamics of the community in order to achieve greater effectiveness and acceptance.

4.6 Strengthening infrastructure by building foundations, landslide retaining walls, and river safety structures

The enhancement and fortification of infrastructure, including embankments, drainage systems, terracing, and retaining walls, are instrumental in mitigating the risk of flooding and landslides. A particularly efficacious approach to landslide disaster mitigation is the intricate engineering technique, which entails the construction of rock structures, such as retaining walls, aimed at curtailing soil erosion in sloped regions, especially those adjacent to roadways [39]. The government of Solok Regency, via the Solok Disaster Management Office, in collaboration with the Solok Regency Public Works Service, has undertaken initiatives to erect landslide safety walls at various locations within slope areas susceptible to landslides along the Lembah Gumanti Area national highway in Lembah Gumanti District. In the year 2020, the Solok Disaster Management Office also initiated a river safety construction project within the Lembah Gumanti Area, aimed at flood prevention. The framework for disaster mitigation (prevention) endeavors concerning infrastructure development is executed by the Solok Disaster Management Office in partnership with the Solok Regency Public Works Service. For instance, in the process of constructing a landslide safety wall, the Solok Disaster Management Office offers recommendations regarding vulnerable locations that necessitate attention and action.

However, efforts to build infrastructure such as landslide safety walls on national roads are not the authority of the Regency/City Public Works Service, as in the construction of a landslide safety wall on the Lembah Gumanti Area road which is not part of the duties and functions of the Solok Regency Public Works Service, because the budget is not available. National roads are the responsibility of the central government, especially the Ministry of Public Works Service, Directorate General of Highways, through the West Sumatra National Road Management Agency. However, the Solok Regency Public Works Service is responsible for evaluating and coordinating with the West Sumatra National Road Management Agency regarding the preservation of national roads in the area.

Based on the documentation study conducted, it is evident that the handling of landslide disasters along the national road in the Lembah Gumanti Area, Solok Regency, has been carried out by the West Sumatra National Road Management Agency's Work Unit from the Public Works Ministry, which has been building landslide retaining walls since 2023. This construction is important because the road from Padang to Lubuk Selasih to Padang Aro is prone to landslides, including the Aia Dingin road section in the Lembah Gumanti District, which is located in a C mining area. Water erosion in the region has the potential to cause landslides and road collapses, thereby endangering the surrounding community and motorists.

Figure 3 shows a landslide protection wall constructed on a sloping area at several points along the national highway in the Lembah Gumanti Area, Solok Regency. The construction of landslide protection walls along the national road in Lembah Gumanti Area as one of the landslide disaster mitigation measures, the community views positively the government's efforts in building slope protection foundations at several points along the national highway in Lembah Gumanti Area, because this road is an important access to other areas, and with these efforts, the community feels safer when using it.

Figure 3. Land protection wall on the slope area on national crossroad, Solok Regency

Subsequently, as evidenced by the documentation analysis undertaken by the researcher, it is apparent that in the year 2021, the Government of Solok Regency, via the Solok Disaster Management Office, implemented the construction of a river safety infrastructure in the Lembah Gumanti Area, Solok Regency, to alleviate flood-related calamities (Refer to Figure 4). Consequently, it can be inferred that the Government of Solok Regency, through collaborative efforts between the Public Works Service and the Solok Disaster Management Office, is endeavoring to avert and diminish the hazards associated with floods and landslides in the Lembah Gumanti Area by bolstering infrastructure, which includes the establishment of landslide safety walls aimed at preserving slope stability (thus resisting landslides) at various locations along the national highway, in addition to a river normalisation initiative through the erection of safety structures along the Batang Kapalo Koto River.

Figure 4. Kapalo Koto River Normalization Project in Lembah Gumanti Area, Solok Regency
(Source: Suara Independent News, 2021)

The researcher posits that the construction of retaining walls and robust foundations is imperative for the stabilisation of slopes and the prevention of landslides, particularly in the context of unstable soil conditions exacerbated by substantial rainfall. Furthermore, the Solok Disaster Management Office has also instituted a program aimed at the establishment of river safety foundations to regulate river flow, thereby mitigating the risk of overflow, minimizing flooding potential, alleviating waterlogging, and averting soil disintegration that may precipitate landslides. Through this fortification of infrastructure, it is anticipated that both the frequency and impact of natural disasters may be significantly lessened. Conversely, the normalisation of rivers through the development of safety structures by the regional government of Solok Regency was initially perceived as a proactive measure to mitigate the risks of economic losses stemming from flooding and landslides. Nevertheless, as time has progressed, various challenges have surfaced in connection with this initiative, which will be elaborated upon in greater detail in the subsequent section addressing the constraints of disaster mitigation.

4.7 Inadequate quality and quantity of human resources among civil servants, and weak budget support

The implementation of disaster mitigation necessitates the availability of sufficient human resources, both in terms of caliber and quantity, to enhance the likelihood of attaining established objectives. Nonetheless, challenges about human resources frequently emerge as impediments that undermine the efficacy and efficiency of these initiatives—according to the data accrued, disaster mitigation endeavors in the Lembah Gumanti Area of Solok Regency faced hurdles concerning the quality and quantity of human resources accessible to the apparatus, in addition to financial constraints. This adversely influenced the efficacy and efficiency of the mitigation initiatives conducted by the Solok Disaster Management Office and the Environmental Service of Solok Regency.

Concerning the limitations on the quantity of human resources within various pertinent agencies, such as the Solok Disaster Management Office, encountered difficulties in disaster-related services (such as socialisation, disaster response, etc.), attributable to insufficient human resources. Solok Regency encompasses a vast area with significant disaster potential; however, the Solok Disaster Management Office is staffed by only 52 personnel, which includes 36 honorary workers, among whom are 21 functional officers from the Quick Reaction Team. In contrast, the Environmental Service of Solok Regency has faced challenges in overseeing disaster mitigation efforts within the region. With merely two supervisors, the Environmental Agency encounters difficulties in monitoring adherence to environmental management practices among the multitude of business entities operating in Solok Regency.

Then, regarding the quality of human resources, the researcher assessed that the Solok Disaster Management Office and the Environmental Agency experienced obstacles due to a lack of adequate personnel to carry out disaster mitigation tasks. With the potential for large-scale disasters and a vast area, including the Lembah Gumanti Area, which is far from the center of government, this lack of personnel can cause delays or failures in preventive measures. This includes supervision of mining activities by the Environmental Agency and monitoring or response to disaster events by the Solok Disaster Management Office. The quality of human resources is a problem in the Solok Disaster Management Office, which plays a crucial role in increasing community knowledge and capacity to deal with disasters. However, the lack of

competence among the apparatus and the majority of employees, who are often "structural people," hinders these efforts.

Ideally, the Solok Disaster Management Office necessitates personnel or officers possessing elevated levels of disaster competency and substantial experience. Furthermore, officers engaged in the functional rescue of disaster victims are expected to hold relevant certifications demonstrating their expertise; nevertheless, it is noteworthy that not all officers meet this criterion. This is crucial to avert malpractice that may exacerbate the disaster scenario. A considerable number of disaster mitigation officers exhibit a deficiency in practical experience, as certain employees within the Solok Disaster Management Office have transitioned from other organisations and lack the fundamental skills essential for effective disaster management. Although the competency of officers constitutes a significant impediment to the execution of disaster management functions (including mitigation), the Solok Disaster Management Office persists in its efforts to enhance the capacities of its personnel through an annual Technical Guidance program, which features distinguished speakers. Furthermore, the Solok Disaster Management Office implements daily instructional sessions each morning during attendance to enhance the caliber of internal human resources. Moreover, difficulties related to human resources and the challenge of insufficient financial backing for relevant institutions constitute significant impediments, resulting in less than optimal disaster mitigation efforts within Solok Regency. According to insights gleaned from the informants above, the Solok Disaster Management Office is reportedly assuming a less proactive role in disaster management within the region, despite the existence of 74 Nagari, characterised by high disaster potential. The Solok Disaster Management Office ought to adopt a proactive and comprehensive approach in the dissemination of knowledge and education regarding disaster prevention and response, accompanied by adequate budgetary provisions. However, in practice, the currently allocated budget is deemed insufficient, resulting in minimal engagement in disaster mitigation activities. Consequently, the populace of Solok Regency is reportedly still ill-prepared to confront potential disasters. Although the Solok Disaster Management Office retains the capacity to collaborate with relevant agencies in the realm of disaster management, fiscal constraints persist as a substantial hindrance, as the limited budget is also inadequate for other necessities, such as the remuneration of honorary officers and disaster mitigation initiatives, including the establishment of an early warning system.

In accordance with information derived from informants, the total budget allocated to the Solok Disaster Management Office for the fiscal year 2023 amounts to IDR 1.8 billion. The budgetary allocations encompass various mitigation initiatives, such as the Strengthening of Regional Capacity for Prevention and Preparedness (Formation of Disaster Preparedness Groups in Villages) program, which is financed by IDR 152,611,000, and the Socialization, Communication, Information, and Education program tailored for Disaster-Prone Districts and Cities (specific to each type of disaster) totaling IDR 308,510,200.

Furthermore, the Environmental Service of Solok Regency encounters significant financial limitations. The budget allocated to the Environmental Service is characterised as insufficient, thereby constraining the execution of its responsibilities, particularly in overseeing the environmental management of diverse activities and enterprises within the jurisdiction. In the year 2023, the Environmental Service was only able to manage ten prioritised activities or business units. With a more adequate financial allocation, the Environmental Service would be positioned to monitor a greater number of activities and businesses, consequently reducing the adverse environmental repercussions that may precipitate disasters. In summary, both the Solok Disaster Management Office and the Environmental Service of Solok Regency confront substantial obstacles in the realm of disaster management, especially in the area of mitigation, which includes a deficiency in personnel, constrained expertise, and insufficient funding. Addressing these challenges necessitates a multifaceted approach, concerted attention from governing bodies, and an augmented budget to enhance training, procure necessary equipment, and expand personnel, alongside improved and more transparent financial management to facilitate more effective disaster mitigation measures.

The researchers argue that the budget for disaster mitigation may be limited and insufficient to meet the needs of necessary programs, such as training and improving facilities and infrastructure. However, even though funds are available, their use is sometimes inefficient or off-target, resulting in waste and a lack of capacity building in disaster management.

4.8 Inadequate drainage system

Based on flood and landslide disaster data in the Lembah Gumanti Area, floods generally affect agricultural areas in low-lying areas near rivers, while landslides often occur along national highways. In addition to natural factors, such as prolonged high-intensity rain, non-natural factors, including human activities, also contribute to this disaster, primarily due to non-compliance by mining actors with adequate drainage systems. An audit by the Solok Regency Environmental Service revealed that this non-compliance resulted in water runoff onto the road, potentially causing landslides and road damage and endangering the safety of road users.

The Center for Volcanology and Geological Disaster Mitigation advocates for the establishment of a comprehensive drainage system on inclines to alleviate saturation and diminish the susceptibility to landslides [34]. According to observational findings, the national highway situated in the Lembah Gumanti Area of Solok Regency is deficient in sufficient drainage, leading to the overflow of water onto the roadway. Consequently, numerous sections of the road have experienced collapse, resulting in infrastructural damage. Refer to the observational results depicted in Figure 5 below:

Figure 5. Condition of water flowing to the road on the national crossroad in the Lembah Gumanti Area

One of the most efficacious strategies in alleviating flood-related calamities is to enhance the drainage system comprehensively, rather than incrementally, through concerted collective efforts. In this context, the government's role is paramount, with community members augmenting this initiative through self-directed participation [39]. A thorough analysis of the topography in the Lembah Gumanti Area reveals that the accumulation of water resulting from insufficient drainage channels will precipitate both floods and landslides. The issues of flooding and landslides, coupled with infrastructural degradation in the Lembah Gumanti Area, have emerged as significant public concerns, predominantly attributable to the lack of a robust drainage infrastructure. Additionally, mining operations, which include the transport of dug materials via vehicles and the resultant overflow of water onto thoroughfares, further exacerbate this predicament. In response, the Solok Government, in collaboration with the Solok Regency Public Works Service, is engaging with the West Sumatra Provincial Public Works Service and the Ministry of Public Works to address this pressing issue. Conversely, the West Sumatra Provincial Government has also conducted an assessment of the deteriorated condition of the national cross-country road in the Lembah Gumanti Area, finding that mining activities have led to uncontrolled excavation, culminating in the phenomenon of water slides. This gradually induces landslides and infrastructural damage.

To rectify this issue, the West Sumatra Provincial Government is faced with the decision of either rehabilitating the existing drainage infrastructure or reassessing mining operations within the vicinity, particularly concerning the responsibilities of pertinent stakeholders, specifically the damage inflicted upon the national roadway in the Lembah Gumanti Area and the complications arising from insufficient drainage systems. It may be concluded that the neglect of the drainage system constitutes the principal barrier to effectively mitigating flood and landslide disasters in the Lembah Gumanti Area of Solok Regency. The failure of governmental entities to repair or develop drainage systems, combined with a lack of resolve towards mining operators (who neglect to implement adequate drainage solutions), has the potential to escalate the risk of disasters, thereby intensifying this issue. By enhancing focus on the improvement of the drainage system, the government can mitigate the risks and repercussions associated with floods and landslides, ultimately fostering a more secure environment for the community.

In disaster mitigation, although some disaster impacts can be prevented, other consequences may still occur [97-101]. Therefore, it is essential to implement specific measures, in the form of targeted programs, to mitigate or minimise the impact of disasters. These measures are categorised into structural mitigation and non-structural mitigation [17, 39, 102]. Structural mitigation measures must be complemented by non-structural measures to build resilient physical infrastructure with various technologies [103-105].

4.9 Structural mitigation

Carter [97] delineated that structural mitigation encompasses the deployment of various human resources, including disaster management specialists and architects, alongside a meticulously formulated budget. This includes the planning, design, and oversight of the construction of edifices and infrastructure to ascertain compliance with suitable structural safety standards for disaster mitigation. Within the framework of this inquiry, the Solok Government, via the Solok Disaster Management Office, engaged in coordination with the Public Works Service and other pertinent institutions to address flood and landslide disasters in the Lembah Gumanti Area, Solok Regency. They erected disaster-resistant infrastructure, including retaining walls at multiple locations along the national highway and safety structures on the Batang Kapalo Koto River (river normalisation). Retaining walls play a crucial role in stabilising slopes and mitigating the occurrence of landslides. Concurrently, river safety structures are designed to regulate river flows and diminish the likelihood of flooding and waterlogging, which can precipitate landslides. The fortification of this infrastructure is anticipated to alleviate the impact and frequency of natural disasters significantly.

Carter [97] argued that the failure of unengineered structures contributes to the high death toll and economic losses associated with disasters. Important aspects of non-engineering structural mitigation include building strength assessment, monitoring business activities, and proper site planning [106]. This monitoring aims to ensure that buildings or business activities are not located in hazardous locations, such as steep slopes prone to landslides, floodplains prone to flash floods, or riverbanks that are easily eroded. In the context of this study, in the Lembah Gumanti Area of Solok Regency, people build settlements and engage in farming and mining without adequate structural engineering. First, the possibility of houses in landslide-prone zones on the edge of cliffs along the national highway should be questioned regarding their permits and compliance with spatial planning and safety measures against landslides. Second, agricultural and plantation activities often ignore the slope of the land, increasing the risk of danger to the community if landslides occur. Third, mining in the area damages the environment and fails to consider the land's vulnerability to disasters. Regarding mining, five companies with mining business permits, as per data from the Geoportal of the Ministry of Energy and Mineral Resources, operating in the Lembah Gumanti Area, increase the risk of flooding and landslides. Additionally, there are indications of illegal mining that hurt the environment. Large-scale forest clearing due to mining results in the loss of forest function and increases the likelihood of disasters [107-109].

The government must implement decisive measures to effectively confront environmental challenges that may culminate in catastrophic events stemming from mining operations. In the case of legally sanctioned mining endeavors, the government must conduct a meticulous assessment of the licensing documentation and, should it be deemed necessary, annul the permit. Concurrently, about illicit mining activities, law enforcement personnel need to enact measures through legal statutes. Consequently, local governmental entities necessitate focused attention and an assertive role in the enforcement of mining regulations. The efficacy of law enforcement is profoundly reliant on continual oversight and surveillance [110-114]. As such, it is anticipated that the government will guarantee the consistent execution of law enforcement as a non-engineering structural mitigation strategy.

4.10 Non-structural mitigation

Non-structural mitigation, as defined by the study [97], encompasses various efforts such as government regulation, disaster education, and regional planning, which serve as

alternatives to physical infrastructure development. Non-structural mitigation consists of five variables, namely:

4.11 Legal-policy framework

According to Carter [97], non-structural mitigation can be implemented by providing policies or legal frameworks that serve as the basis for implementing mitigation. Policies or regulations will enable actors, organisations, and other elements to collaborate in enforcing rules that have been established or serve as guidelines. In general, disaster management in Indonesia is regulated in Law Number 24 of 2007 and Government Regulation Number 21 of 2008, which includes disaster mitigation. Specifically, the Solok Government has prepared a Regional Disaster Management Plan, as outlined in Solok Regent Regulation Number 33 of 2020. This document includes disaster management strategies, policies, and programs, as well as responsible institutions. The preparation of the Regency Disaster Management Plans aims to ensure that disaster management is more focused and serves as the basis for informed decision-making among related stakeholders. In addition, this regulation is expected to provide a strong legal framework for disaster management in an organised and coordinated manner. The challenge is to ensure that the planned strategies and programs are implemented with complete understanding and commitment from all stakeholders.

4.12 Establishment of organizations or institutions responsible for disaster management affairs

The institutional determinants significantly influence disaster mitigation by enabling the development of a systematic and integrated mitigation framework [97]. Institutions establish a binding relational framework among members of society or organisations, regulating their interactions. Within institutions, there exist constraining and binding elements, such as norms, ethical codes, or both formal and informal regulations, which govern social conduct as individuals collaborate to realise shared objectives. In the context of disaster management within Solok Regency, Solok Regent Regulation Number 33 of 2020 delineates multiple institutions endowed with specific responsibilities and functions. The Solok Disaster Management Office acts as the principal coordinator, engaging in collaborative efforts with other pertinent agencies, including the Environmental Service, Public Works and Spatial Planning Service, Basarnas, Social Service, Health Service, and additional regional apparatus organisations within the Solok Government. Inter-agency governmental coordination across various sectors is of equal significance in the domain of disaster management.

The Solok Government has established a Disaster Risk Reduction Forum to enhance coordination among diverse stakeholders within Solok Regency. The forum is presided over by the Chairman of the Regional Representative Council of Solok Regency. It incorporates numerous relevant agencies, such as the Solok Disaster Management Office, Environmental Service, Public Works Service, Social Service, Health Service, and public enterprises, including Telkom, the State Electricity Company, and the Regional Clean Water Company. Scholars contend that the establishment of the Disaster Risk Reduction Forum promotes effective disaster coordination and mitigation, including within the Lembah Gumanti Area. The study [97] posits that robust institutions can significantly contribute to disaster mitigation through public awareness initiatives and training programs. Strengthening institutions is imperative to address the challenges encountered by entities such as the Solok Disaster Management Office and the Environmental Service of Solok Regency, including workforce limitations, insufficient expertise, and budgetary constraints. Navigating these challenges necessitates comprehensive strategies, encompassing heightened attention from authorities, augmented training activities and resources, increased personnel, and improved transparency in fund management, with the ultimate aim of fostering resilient institutions and achieving more effective disaster mitigation outcomes.

4.13 Early warning system

Early warning systems are important efforts to provide rapid information to the public about potential disasters from authorised institutions [115-117]. Based on the mitigation theory presented by the study [97], the effectiveness of disaster risk reduction is influenced by how easily the public can understand and access information from this system. An adequate warning system ensures that data is accessible and understandable to everyone. The quality of this system also depends on the resources and technology available, as well as the system's efficiency in reaching all required areas [60, 102, 118, 119].

Based on the findings of the research, the Solok Disaster Management Office has conducted a comprehensive mapping of areas susceptible to flooding and landslides within the Lembah Gumanti Region. As a proactive mitigation strategy, the Solok Disaster Management Office, in conjunction with the Public Works Service of Solok Regency, has implemented the installation of warning signage in residential zones identified as vulnerable to flooding, as well as along the national highway, to alert residents regarding potential landslides. This initiative is intended to enhance public awareness and preparedness concerning such disasters. Furthermore, the Solok Disaster Management Office engages in the continuous monitoring and dissemination of disaster-related information as an integral component of its early warning initiatives. The monitoring process is executed in partnership with the community to mitigate disaster risks effectively, and hazard information is communicated through digital channels as well as direct outreach by local village officials when indicators of a disaster emerge.

4.14 Socialisation, education, and training

The enhancement of community knowledge, awareness, and capacity concerning risks and disaster response methodologies is fundamental in the context of disaster mitigation initiatives. Such initiatives can be implemented through socialisation, education, and training, as stipulated by Law Number 24 of 2007. The objective is to equip individuals and communities with the necessary resilience and responsiveness to a diverse array of disasters, thereby attenuating their adverse impacts. This assertion underscores the significance of a foundational comprehension of catastrophe for the community. Armed with this understanding, community members can engage in appropriate actions during disaster occurrences, thereby mitigating feelings of fear and panic. Crucial information regarding disasters will empower the community to navigate the situation effectively.

Furthermore, the augmentation of community awareness and capacity as integral components of disaster mitigation is essential for fostering resilience and preparedness in confronting disasters, particularly concerning potential environmental risks. Empirical research indicates that the Solok Government, through the Solok Disaster Management Office, has undertaken various initiatives aimed at enhancing the knowledge, awareness, and capacity of both officials and the community about disaster management.

Such initiatives encompass the Dissemination, Communication, Information, and Education program for Disaster-Prone Areas, which is executed annually in three cohorts, in addition to the Regional Capacity Building program for Prevention and Preparedness, culminating in the establishment of Disaster Resilience Groups within each village. The Solok Disaster Management Office also facilitates counseling sessions in educational institutions designated as Disaster Preparedness Schools, capitalising on various opportunities such as coordination meetings and digital media for disaster education. The content delivered encompasses first-aid methodologies, family evacuation protocols, evacuation techniques, and live simulations. The aim of the socialisation, education, and training programs conducted by the Solok Government in collaboration with relevant stakeholders is to enhance community awareness regarding the imminent threats posed by disasters in their locality, thereby improving preparedness to confront such events, minimising potential damage resulting from disasters, and ensuring that community members can respond promptly and effectively when disasters arise. With robust community engagement, it is anticipated that individuals will become increasingly autonomous in managing disaster-related risks.

4.15 Public awareness

For the effectiveness of disaster mitigation, public awareness is critical. Based on the concept of mitigation [97], the community must understand the vulnerability of their area and the necessary mitigation steps. For the goal of mitigation, specifically reducing disaster risk, to be achieved, the community must be able to implement these steps independently. Based on the findings, the community in the Lembah Gumanti Area, Solok Regency, is generally aware of the risks of flooding and landslides in their area. However, there are still some actions that increase the risk of disaster. Some people who depend on the agricultural or plantation sector often utilise steep land, convert land functions, and leave critical land after use. Additionally, a small number of residents are involved in illegal mining that disregards environmental management principles, resulting in a negative impact on the environment. Although there is awareness of the potential for disasters, a clear understanding of the causes of increased risk remains lacking, and economic demands play a significant role. The local government is attempting to raise public awareness through socialisation, education, and training, aiming to disseminate knowledge about disaster vulnerability more evenly. According to Carter [97], disaster risk mitigation requires community participation in every government program attempted. Community participation reflects awareness and concern for the potential for disasters. In the context of this research, some local community members have shown concern for the environment by cultivating coffee for forest rehabilitation and supporting the local economy.

5. CONCLUSION

The execution of flood and landslide disaster mitigation initiatives within the Lembah Gumanti Area has been undertaken by the Solok Government, bolstered by community involvement through various endeavors. These mitigation strategies can be classified as follows: First, structural mitigation involves the implementation of disaster-resistant infrastructure by the Solok Government. This encompasses the establishment of foundations or retaining walls at multiple locations along the national highway in the Lembah Gumanti Area, in addition to the construction of safety structures for the Batang Kapalo Koto river in Jorong Koto, as part of the river normalisation program. Second, non-structural mitigation concentrates on addressing environmental issues arising from mining activities through oversight and enforcement of legal regulations. In this context, there exist five principal variables about non-structural mitigation. First, the legal framework comprises Law No. 24 of 2007 and Solok Regent Regulation No. 33 of 2020. Second, institutional frameworks are established, with the Solok Disaster Management Office functioning as the command center for disaster management, coordinating with relevant Regional Apparatus Organizations. Third, an early warning system may be instituted through the installation of hazard signage and direct appeals, along with the utilisation of digital communication platforms. Fourth, the Solok Disaster Management Office is tasked with the dissemination of knowledge, education, and training to enhance community awareness, understanding, and capacity regarding disaster preparedness. Fifth, community awareness remains insufficient, with a minimal segment of the population actively participating in environmental enhancement initiatives. Based on the aforementioned research findings, the researcher offers several recommendations. First, it is anticipated that the Solok Government will demonstrate a commitment to executing the flood and landslide disaster mitigation strategy delineated in Solok Regent Regulation Number 33 of 2020, which pertains to the Solok Regency Regional Disaster Management Plan. Second, the Solok Disaster Management Office is expected to augment the knowledge, awareness, and capacity of communities situated in disaster-prone areas, particularly within the Lembah Gumanti Area, through expanded outreach, educational programs, and disaster response training. Moreover, the Solok Disaster Management Office should advocate for the reinforcement of disaster prevention infrastructure via a cross-sectoral governmental coordination mechanism. Concurrently, the Solok Regency Environmental Service is expected to intensify its oversight of environmental management, particularly concerning mining activities in the Lembah Gumanti Area, which currently fall outside the full jurisdiction of the Solok Regency Environmental Service. The Environmental Service is also anticipated to promote public awareness through innovative initiatives focusing on environmental rehabilitation and disaster mitigation. Third, it is recommended that the Solok Government enhance the institutional capacity of agencies responsible for disaster management by increasing financial allocations, thereby facilitating the more effective execution of disaster mitigation programs. Fourth, the Regional Apparatus Organization of the West Sumatra Provincial Government and the Solok Government, which oversee mining activity permits in the Lembah Gumanti Area, are urged to temporarily suspend mining operations and conduct a thorough evaluation of

compliance with environmental management regulations. Should any infractions be identified, mining permits should be revoked. Fifth, about illegal mining activities, decisive action by law enforcement authorities is imperative. The successful implementation of all these measures necessitates unwavering commitment, consistency, and sustainability.

ACKNOWLEDGMENT

The Research Team appreciates and thanks the Research Center for Policy Governance Development and Empowerment, Universitas Negeri Padang, for conducting this research.

REFERENCES

[1] Yulmanita, Husnita, L., Meldawati. (2015). Socio-economic life of women sand miners in Air Dingin Village, Lembah Gumanti District, Solok Regency. UPGRISBA. Thesis.

[2] Rinaldo, A., Armi, I. (2022). Analysis of potential landslide-prone areas in Solok Regency, West Sumatra Province. Jurnal Geomatika dan Ilmu Alam, 1(2): 54-59.

[3] Yulianto, S., Apriyadi, R.K., Aprilyanto, A., Winugroho, T., Ponangsera, I.S., Wilopo, W. (2021). History of disasters and their management in Indonesia reviewed from a national security perspective. PENDIPA Journal of Science Education, 5(2): 180-187. https://doi.org/10.33369/pendipa.5.2.180-187

[4] Haeril, Mas'ud, Irfadat, T., Hendra. (2021). Implementation of disaster mitigation policies (physical and non-physical) in reducing disaster risk in Bima Regency. Journal of Governance and Local Politics (JGLP), 3(1): 1.

[5] Alhadi, Z., Riandini, O., Eriyanti, F., Yusran, R., Permana, I. (2024). Analysis of the effectiveness and efficiency of tsunami disaster contingency planning policies in the Province of West Sumatra, Indonesia. International Journal of Safety & Security Engineering, 14(4): 1087-1098. https://doi.org/10.18280/ijsse.140407

[6] Alhadi, Z., Riandini, O., Maani, K.D. (2023). Involvement and design of strengthening policy actors in tsunami disaster risk governance in Padang City. Jurnal Borneo Administrator, 19(3): 285-300. https://doi.org/10.24258/jba.v19i3.1164

[7] Ficara, F., Wheeler, M. (2023). A paradigm shift in disaster management: Incorporating a human rights-based approach to disaster risk reduction. Journal of Emergency Management (Weston, Mass.), 21(6): 557-576. https://doi.org/10.5055/jem.0748

[8] Silva, R.F.D., Siqueira, A.M.D., Silveira, L.T.C.D., Oliveira, A.B.D. (2023). Disaster risk reduction, the Sustainable Goals agenda and the principles of the SUS, in the context of the COVID-19 pandemic. Ciência & Saúde Coletiva, 28: 1777-1788. https://doi.org/10.1590/1413-81232023286.11272022en

[9] Bailey, E. (2022). Disaster risk reduction and management: Recalling the need for paradigm shift in definition. Journal of Geoscience and Environment Protection, 10(6): 86-105. https://doi.org/10.4236/gep.2022.106006

[10] Kim, S.Y., Kim, Y.K. (2022). A study on the standardization of disaster prevention projects to climate change response. Crisisonomy, 18(11): 19-33. https://doi.org/10.14251/crisisonomy.2022.18.11.19

[11] Graveline, M.H., Germain, D. (2022). Disaster risk resilience: Conceptual evolution, key issues, and opportunities. International Journal of Disaster Risk Science, 13(3): 330-341. https://doi.org/10.1007/s13753-022-00419-0

[12] Haque, M. (2022). Paradigm shift in disaster management: Bangladesh experience. In: Singh, A. (eds) International Handbook of Disaster Research. Springer, Singapore. https://doi.org/10.1007/978-981-16-8800-3_6-1

[13] Alhadi, Z., Sasmita, S., Yulfa, A., Fatimah, S., Syafrini, D., Maani, K.D., Riandini, O. (2023). The coping strategies patterns based on local wisdom and resilience capital in facing natural disaster risk in Nagari Mandeh, Indonesia. International Journal of Sustainable Development and Planning, 18(1): 315-325. https://doi.org/10.18280/ijsdp.180133

[14] Mesta, C., Kerschbaum, D., Cremen, G., Galasso, C. (2023). Quantifying the potential benefits of risk-mitigation strategies on present and future seismic losses in Kathmandu Valley, Nepal. Earthquake Spectra, 39(1): 377-401. https://doi.org/10.1177/87552930221134950

[15] Lefevre, J., Le Gallic, T., Fragkos, P., Mercure, J.F., Simsek, Y., Paroussos, L. (2022). Global socio-economic and climate change mitigation scenarios through the lens of structural change. Global Environmental Change, 74: 102510. https://doi.org/10.1016/j.gloenvcha.2022.102510

[16] Hakim, A.J., Victory, K.R., Summers, A., Jalloh, M.F., Richter, P., Bennett, S.D., Henao, O.L., Marston, B. (2023). Toward a continuum of measures to mitigate primary and secondary impacts of COVID-19 and other public health emergencies. Population Health Management, 26(2): 107-112. https://doi.org/10.1089/pop.2022.0263

[17] Hartmann, S., Pedoth, L., Dalla Torre, C., Schneiderbauer, S. (2021). Beyond the expected—Residual risk and cases of overload in the context of managing alpine natural hazards. International Journal of Disaster Risk Science, 12(2): 205-219. https://doi.org/10.1007/S13753-020-00325-3

[18] Zito, M., Nascimbene, R., Dubini, P., D'Angela, D., Magliulo, G. (2022). Experimental seismic assessment of nonstructural elements: Testing protocols and novel perspectives. Buildings, 12(11): 1871. https://doi.org/10.3390/buildings12111871

[19] Hughes, W., Zhang, W., Ding, Z. (2022). Multiobjective optimization for hurricane retrofit to improve coastal community structural and socioeconomic resilience. Natural Hazards Review, 23(4): 04022033. https://doi.org/10.1061/(asce)nh.1527-6996.0000590

[20] Tabrizikahou, A., Nowotarski, P. (2021). Mitigating the energy consumption and the carbon emission in the building structures by optimization of the construction processes. Energies, 14(11): 3287. https://doi.org/10.3390/EN14113287

[21] Dissanayaka, K.D.C.R., Tanaka, N., Vinodh, T.L.C. (2022). Integration of Eco-DRR and hybrid defense system on mitigation of natural disasters (Tsunami and Coastal Flooding): A review. Natural Hazards, 110(1): 1-28. https://doi.org/10.1007/S11069-021-04965-6

[22] Tong, Q., Filippova, O., Ingham, J. (2022). Effectiveness of unreinforced masonry seismic retrofit programmes: Review of policies in New Zealand and the United States. International Journal of Disaster Risk Reduction, 76: 103008. https://doi.org/10.1016/j.ijdrr.2022.103008
[23] Marangoni, G., Lamontagne, J.R., Quinn, J.D., Reed, P.M., Keller, K. (2021). Adaptive mitigation strategies hedge against extreme climate futures. Climatic Change, 166(3): 37. https://doi.org/10.1007/S10584-021-03132-X
[24] Gupta, H.S., Nofal, O.M., González, A.D., Nicholson, C.D., van de Lindt, J.W. (2022). Optimal selection of short-and long-term mitigation strategies for buildings within communities under flooding hazard. Sustainability, 14(16): 9812. https://doi.org/10.3390/su14169812
[25] Mastroianni, E., Lancaster, J., Korkmann, B., Opdyke, A., Beitelmal, W. (2021). Mitigating infrastructure disaster losses through asset management practices in the Middle East and North Africa region. International Journal of Disaster Risk Reduction, 53: 102011. https://doi.org/10.1016/J.IJDRR.2020.102011
[26] Bakhshipour, A.E., Hespen, J., Haghighi, A., Dittmer, U., Nowak, W. (2021). Integrating structural resilience in the design of urban drainage networks in flat areas using a simplified multi-objective optimization framework. Water, 13(3): 269. https://doi.org/10.3390/W13030269
[27] Kim, J.M., Yum, S.G., Park, H., Bae, J. (2022). Strategic framework for natural disaster risk mitigation using deep learning and cost-benefit analysis. Natural Hazards and Earth System Sciences, 22(6): 2131-2144. https://doi.org/10.5194/nhess-22-2131-2022
[28] de Almeida, N.M., Silva, M.J.F., Salvado, F., Rodrigues, H., Maletič, D. (2021). Risk-informed performance-based metrics for evaluating the structural safety and serviceability of constructed assets against natural disasters. Sustainability, 13(11): 5925. https://doi.org/10.3390/SU13115925
[29] Elmsalmi, M., Hachicha, W., Aljuaid, A.M. (2021). Modeling sustainable risks mitigation strategies using a morphological analysis-based approach: A real case study. Sustainability, 13(21): 12210. https://doi.org/10.3390/SU132112210
[30] Tena-Colunga, A., Godinez-Dominguez, E.A., Hernández-Ramírez, H. (2022). Seismic retrofit and strengthening of buildings. Observations from the 2017 Puebla-Morelos earthquake in Mexico City. Journal of Building Engineering, 47: 103916. https://doi.org/10.1016/j.jobe.2021.103916
[31] Vona, M., Flora, A., Carlucci, E., Foscolo, E. (2021). Seismic retrofitting resilience-based for strategic RC buildings. Buildings, 11(3): 111. https://doi.org/10.3390/BUILDINGS11030111
[32] Cremen, G., Galasso, C., McCloskey, J. (2022). A simulation-based framework for earthquake risk-informed and people-centered decision making on future urban planning. Earth's Future, 10(1): e2021EF002388. https://doi.org/10.1029/2021ef002388
[33] Jiang, N., Li, H.B., Zhou, J.W. (2021). Quantitative hazard analysis and mitigation measures of rockfall in a high-frequency rockfall region. Bulletin of Engineering Geology and the Environment, 80: 3439-3456. https://doi.org/10.1007/S10064-021-02137-1
[34] Sugianto, D.N., Widiaratih, R., Widada, S., Suripin, Handayani, E.P., Cahyaningtyas, P. (2022). Analysis of structural and non-structural disaster mitigation due to erosion in the Timbulsloko Village, Demak–Central Java. Journal of Ecological Engineering, 23(2): 246-254. https://doi.org/10.12911/22998993/144559
[35] Hutapea, D. (2022). Resources factors in the implementation of Sinabung eruption disaster mitigation in Gung Pinto Village, Karo Regency. In Second International Conference on Public Policy, Social Computing and Development (ICOPOSDEV 2021), pp. 412-420. https://doi.org/10.2991/assehr.k.220204.063
[36] Prastica, R.M.S., Adiluhung, M.T.P., Amarendra, N.P. (2023). Grey and green infrastructure alternatives for water-related disaster mitigation: The case of Mandailing Natal, North Sumatera, Indonesia. IOP Conference Series, 1165(1): 012030. https://doi.org/10.1088/1755-1315/1165/1/012030
[37] Sebastian, L. (2022). Flood control through structural and non-structural amplification approaches. Jurnal Teknik Sipil, 11(2): 75-79. https://doi.org/10.36546/tekniksipil.v11i2.519
[38] Kamal, A.S.M.M., Hossain, F., Ahmed, B., Rahman, M.Z., Sammonds, P. (2023). Assessing the effectiveness of landslide slope stability by analysing structural mitigation measures and community risk perception. Natural Hazards, 117(3): 2393–2418. https://doi.org/10.1007/s11069-023-05947-6
[39] Hermon. (2012). Hydrometeorological Disaster Mitigation. UNP Press.
[40] Marzuki, M., Vonnisa, M., Harmadi, H., Pujiastuti, D., Budiman, A., Puryanti, D., Oktamuliani, S., Taufiq, I., Yusfi, M., Rasyid, R., Astuti, A., Handani, S., Usna, S.R.A., Fitriyani, D., Elvaswer, E., Arif, M., Kahfi, M., Zulfa, M.A., Ramadhan, I., Hasanah, N., Irka, F.H. (2024). Education of disaster awareness through disaster readiness socialization as an effort to increase community knowledge around the Nobita Hill Tourism Area on disaster mitigation. Warta Pengabdian Andalas, 31: 353-361. https://doi.org/10.25077/jwa.31.2.353-361.2024
[41] Gouda, M., Yang, Y. (2023). Investigating the impact of a community disaster awareness training on subjective disaster preparedness: The case of Myanmar's Ayeyarwaddy region. Disasters, 47(4): 1047-1068. https://doi.org/10.1111/disa.12575
[42] Andreastuti, S.D., Paripurno, E.T., Subandriyo, S., Syahbana, D.K., Prayoga, A.S. (2023). Volcano disaster risk management during crisis: Implementation of risk communication in Indonesia. Journal of Applied Volcanology, 12(1): 3. https://doi.org/10.1186/s13617-023-00129-2
[43] Lu, Y., Wang, Y., Zhan, C. (2023). Building rural community disaster resilience in developing countries: Insights from a Chinese NGO's Safe Rural Community programme. Disasters, 47(4): 1090-1117. https://doi.org/10.1111/disa.12586
[44] Zhang, X., Luo, Y., Liu, Y., Han, Z., Wang, F. (2023). Resilience in urban, rural, and transitional communities: An empirical study in Guangdong, China. International Journal of Disaster Risk Reduction, 84: 103396. https://doi.org/10.1016/j.ijdrr.2022.103396
[45] Zander, K.K., Sibarani, R., Abunyewah, M., Erdiaw-Kwasie, M.O., Moss, S.A., Lassa, J., Garnett, S.T. (2024). Community resilience across Australia towards natural

hazards: An application of the Conjoint Community Resiliency Assessment Measurement. Disasters, 48(1): e12590. https://doi.org/10.1111/disa.12590
[46] Lin, J.Y., Chao, J.C., Lin, C.S. (2022). Evaluation of community resilience to debris-flow disasters: A case study of Nantou, Taiwan. International Journal of Disaster Risk Reduction, 81: 103258. https://doi.org/10.1016/j.ijdrr.2022.103258
[47] Hao, H., Wang, Y. (2023). Modeling dynamics of community resilience to extreme events with explainable deep learning. Natural Hazards Review, 24(2): 04023013. https://doi.org/10.1061/nhrefo.nheng-1696
[48] Polcarová, E., Pupíková, J. (2022). Analysis of socially vulnerable communities and factors affecting their safety and resilience in disaster risk reduction. Sustainability, 14(18): 11380. https://doi.org/10.3390/su141811380
[49] Gallego, R.I.F., Tejero, L.M.S. (2023). The Passivity-Responsiveness Continuum in the disaster preparedness and mitigation process: A synthesized theory. International Journal of Disaster Risk Reduction, 88: 103616. https://doi.org/10.1016/j.ijdrr.2023.103616
[50] Lin, B.C., Lee, C.H. (2023). Conducting an adaptive evaluation framework of importance and performance for community-based earthquake disaster management. Natural Hazards, 115(2): 1255-1274. https://doi.org/10.1007/s11069-022-05594-3
[51] Ali, S., George, A. (2022). Fostering disaster mitigation through community participation-case of Kochi residents following the Kerala floods of 2018 and 2019. Natural Hazards, 111(1): 389-410. https://doi.org/10.1007/S11069-021-05058-0
[52] Mutiarni, Y.S., Nakamura, H., Bhattacharya, Y. (2022). The resilient community: Strengthening people-centered disaster risk reduction in the Merapi Volcano Community, Java, Indonesia. Sustainability, 14(4): 2215. https://doi.org/10.3390/su14042215
[53] Kong, T.M., de Villiers, A.C., Ntloana, M.B., Pollard, S., Vogel, C. (2020). Implementing capacity development for disaster risk reduction as a social learning system. International Journal of Disaster Risk Reduction, 50: 101740. https://doi.org/10.1016/J.IJDRR.2020.101740
[54] Zeballos-Velarde, C., Butron-Revilla, C., Manchego-Huaquipaco, G., Yory, C. (2023). The role of ancestral practices as social capital to enhance community disaster resilience. The case of the Colca Valley, Peru. International Journal of Disaster Risk Reduction, 92: 103737. https://doi.org/10.1016/j.ijdrr.2023.103737
[55] Sim, T., Han, Z., Guo, C., Lau, J., Yu, J., Su, G. (2021). Disaster preparedness, perceived community resilience, and place of rural villages in northwest China. Natural Hazards, 108: 907-923. https://doi.org/10.1007/S11069-021-04712-X
[56] Kusumastuti, R.D., Nurmala, N., Arviansyah, A., Wibowo, S.S. (2022). Indicators of community preparedness for fast-onset disasters: A systematic literature review and case study. Natural Hazards, 110(1): 787-821. https://doi.org/10.1007/S11069-021-04970-9
[57] Ryan, B., Johnston, K.A., Taylor, M., McAndrew, R. (2020). Community engagement for disaster preparedness: A systematic literature review. International Journal of Disaster Risk Reduction, 49: 101655. https://doi.org/10.1016/J.IJDRR.2020.101655
[58] Trejo-Rangel, M.A., Marchezini, V., Rodriguez, D.A., dos Santos, D.M., Gabos, M., de Paula, A.L., Santos, E., do Amaral, F.S. (2023). Incorporating social innovations in the elaboration of disaster risk mitigation policies. International Journal of Disaster Risk Reduction, 84: 103450. https://doi.org/10.1016/j.ijdrr.2022.103450
[59] Coates, R. (2021). Educational hazards? The politics of disaster risk education in Rio de Janeiro. Disasters, 45(1): 86-106. https://doi.org/10.1111/DISA.12399
[60] Haque, A., Fatema, K. (2022). Disaster risk reduction for whom? The gap between centrally planned Disaster Management Program and people's risk perception and adaptation. International Journal of Disaster Risk Reduction, 82: 103229. https://doi.org/10.1016/j.ijdrr.2022.103229
[61] Cai, J., Hu, S., Que, T., Li, H., Xing, H., Li, H. (2023). Influences of social environment and psychological cognition on individuals' behavioral intentions to reduce disaster risk in geological hazard-prone areas: An application of social cognitive theory. International Journal of Disaster Risk Reduction, 86: 103546. https://doi.org/10.1016/j.ijdrr.2023.103546
[62] Kitagawa, K. (2021). Disaster risk reduction activities as learning. Natural Hazards, 105(3): 3099-3118. https://doi.org/10.1007/S11069-020-04443-5
[63] Turner, M.D., Carney, T., Lawler, L., Reynolds, J., Kelly, L., Teague, M.S., Brottem, L. (2021). Environmental rehabilitation and the vulnerability of the poor: The case of the Great Green Wall. Land Use Policy, 111: 105750. https://doi.org/10.1016/J.LANDUSEPOL.2021.105750
[64] Wu, X., Lü, Y., Zhang, J., Lu, N., Jiang, W., Fu, B. (2023). Adapting ecosystem restoration for sustainable development in a changing world. The Innovation, 4(1): 100375. https://doi.org/10.1016/j.xinn.2023.100375
[65] Chazdon, R.L. (2019). Towards more effective integration of tropical forest restoration and conservation. Biotropica, 51(4): 463-472. https://doi.org/10.1111/BTP.12678
[66] Nolan, R.H., Drew, D.M., O'Grady, A.P., Pinkard, E.A., Paul, K., Roxburgh, S.H., Mitchell, P.J., Bruce, J., Battaglia, M., Ramp, D. (2018). Safeguarding reforestation efforts against changes in climate and disturbance regimes. Forest Ecology and Management, 424: 458-467. https://doi.org/10.1016/J.FORECO.2018.05.025
[67] Willig, M.R., Presley, S.J., Klingbeil, B.T., Kosman, E., Zhang, T., Scheiner, S.M. (2023). Protecting biodiversity via conservation networks: Taxonomic, functional, and phylogenetic considerations. Biological Conservation, 278: 109876. https://doi.org/10.1016/j.biocon.2022.109876
[68] Cazorla, B.P., Cabello, J., Peñas, J., Garcillán, P.P., Reyes, A., Alcaraz-Segura, D. (2021). Incorporating ecosystem functional diversity into geographic conservation priorities using remotely sensed ecosystem functional types. Ecosystems, 24(3): 548-564. https://doi.org/10.1007/S10021-020-00533-4
[69] Pavoine, S., Ricotta, C. (2023). Identifying functionally distinctive and threatened species. Biological Conservation, 284: 110170. https://doi.org/10.1016/j.biocon.2023.110170
[70] Leuzinger, S., Rewald, B. (2021). The who or the how? Species vs. ecosystem function priorities in conservation ecology. Frontiers in Plant Science, 12: 758413. https://doi.org/10.3389/FPLS.2021.758413
[71] Han, Q., Zhang, J., Shi, X., Zhou, D., Ding, Y., Peng, S.

(2022). Ecological function-oriented vegetation protection and restoration strategies in China's Loess Plateau. Journal of Environmental Management, 323: 116290. https://doi.org/10.1016/j.jenvman.2022.116290
[72] Li, Z., Lu, Y., Wang, Y., Liu, J. (2022). The Spatio-temporal evolution of the soil conservation function of ecosystems in the north–south transition zone in China: A case study of the Qinling-Daba Mountains. Sustainability, 14(10): 5829. https://doi.org/10.3390/su14105829
[73] Liu, F., Feng, C., Zhou, Y., Zhang, L., Du, J., Huang, W., Luo, J., Wang, W. (2022). Effectiveness of functional zones in National Nature Reserves for the protection of forest ecosystems in China. Journal of Environmental Management, 308: 114593. https://doi.org/10.1016/j.jenvman.2022.114593
[74] Vignieri, V. (2023). Active community for climate change: A Dynamic Performance Governance analysis of a biodiversity preservation program. Sustainability Accounting, Management and Policy Journal, 14(6): 1150-1182. https://doi.org/10.1108/sampj-04-2022-0167
[75] Andrade, R., van Riper, C.J., Goodson, D., Johnson, D.N., Stewart, W. (2022). Learning pathways for engagement: Understanding drivers of pro-environmental behavior in the context of protected area management. Journal of Environmental Management, 323: 116204. https://doi.org/10.1016/j.jenvman.2022.116204
[76] Wu, T., Jia, W., Wang, Q. (2023). Deviation between willingness and actual behavior regarding community participation in protected areas: A case study in Shengjin lake national nature reserve in China. Frontiers in Environmental Science, 11: 1062147. https://doi.org/10.3389/fenvs.2023.1062147
[77] Day, G., Fuller, R.A., Nichols, C., Dean, A.J. (2022). Characteristics of immersive citizen science experiences that drive conservation engagement. People and Nature, 4(4): 983-995. https://doi.org/10.1002/pan3.10332
[78] Sattayapanich, T., Janmaimool, P., Chontanawat, J. (2022). Factors affecting community participation in environmental corporate social responsibility projects: Evidence from mangrove forest management project. Journal of Open Innovation: Technology, Market, and Complexity, 8(4): 209. https://doi.org/10.3390/joitmc8040209
[79] Fidler, R.Y., Ahmadia, G.N., Cox, C., Glew, L., et al. (2022). Participation, not penalties: Community involvement and equitable governance contribute to more effective multiuse protected areas. Science Advances, 8(18): eabl8929. https://doi.org/10.1126/sciadv.abl8929
[80] Baker-Médard, M., Gantt, C., White, E.R. (2021). Classed conservation: Socio-economic drivers of participation in marine resource management. Environmental Science & Policy, 124: 156-162. https://doi.org/10.1016/J.ENVSCI.2021.06.007
[81] Mihardja, E.J., Alisjahbana, S., Agustini, P.M., Sari, D. A.P., Pardede, T.S. (2023). Forest wellness tourism destination branding for supporting disaster mitigation: A case of Batur UNESCO Global Geopark, Bali. International Journal of Geoheritage and Parks, 11(1): 169-181. https://doi.org/10.1016/j.ijgeop.2023.01.003
[82] Haq, S.M., Waheed, M., Khoja, A.A., Amjad, M.S., Bussmann, R.W., Ali, K., Jones, D.A. (2023). Measuring forest health at stand level: A multi-indicator evaluation for use in adaptive management and policy. Ecological Indicators, 150: 110225. https://doi.org/10.1016/j.ecolind.2023.110225
[83] Thom, D., Taylor, A.R., Seidl, R., Thuiller, W., Wang, J., Robideau, M., Keeton, W.S. (2021). Forest structure, not climate, is the primary driver of functional diversity in northeastern North America. Science of the Total Environment, 762: 143070. https://doi.org/10.1016/J.SCITOTENV.2020.143070
[84] Aquilué, N., Messier, C., Martins, K.T., Dumais-Lalonde, V., Mina, M. (2021). A simple-to-use management approach to boost adaptive capacity of forests to global uncertainty. Forest Ecology and Management, 481: 118692. https://doi.org/10.1016/J.FORECO.2020.118692
[85] Hu, Y., Xiang, W., Schäfer, K.V., Lei, P., et al. (2022). Photosynthetic and hydraulic traits influence forest resistance and resilience to drought stress across different biomes. Science of the Total Environment, 828: 154517. https://doi.org/10.1016/j.scitotenv.2022.154517
[86] Filipe, J.C., Rymer, P.D., Byrne, M., Hardy, G., Mazanec, R., Ahrens, C.W. (2022). Signatures of natural selection in a foundation tree along Mediterranean climatic gradients. Molecular Ecology, 31(6): 1735-1752. https://doi.org/10.1111/mec.16351
[87] Odppes, G.F., Bulle, C., Ugaya, C.M.L. (2021). Wood forest resource consumption impact assessment based on a scarcity index accounting for wood functionality and substitutability (WoodSI). The International Journal of Life Cycle Assessment, 26: 1045-1061. https://doi.org/10.1007/S11367-021-01880-7
[88] Alananbeh, K.M., Othman, Y.A., Tahat, M.M., Al-Dakil, H., Yahya, A.A., Ayasrah, B., Al-Share, T., Alkhatatbeh, S., Al-Zoubi, R., Alnaanah, M., Malkawy, S., Alananbeh, M.B. (2023). Forest health assessment in four Jordanian reserves located in semi-arid environments. Forests, 14(5): 918. https://doi.org/10.3390/f14050918
[89] Morcillo, L., Turrion, D., Soliveres, S., Chirino, E., Vallejo, V.R., Vilagrosa, A. (2022). Moderate pine cover maximizes 10-year survival and growth in late-successional species of contrasting functional strategies. Forest Ecology and Management, 509: 120098. https://doi.org/10.1016/j.foreco.2022.120098
[90] Jõks, M., Helm, A., Kasari-Toussaint, L., Kook, E., Lutter, R., Noreika, N., Oja, E., Öpik, M., Randlane, T., Reier, Ü., Riibak, K., Saag, A., Tullus, H., Tullus, T., Pärtel, M. (2023). A simulation model of functional habitat connectivity demonstrates the importance of species establishment in older forests. Ecological Modelling, 481: 110361. https://doi.org/10.1016/j.ecolmodel.2023.110361
[91] Santos, E.A., Haro-Carrión, X., Oshun, J. (2022). Age-specific and species-specific tree response to seasonal drought in tropical dry forests. Science of the Total Environment, 850: 157908. https://doi.org/10.1016/j.scitotenv.2022.157908
[92] Prasad, K.N. (2020). Disaster management – Planning and mitigation. International Journal of Advance Research, Ideas and Innovations in Technology, 6(4): 284-288.
[93] Fakhriati, F., Nasri, D., Mu'jizah, M.J., Supriatin, Y.M., Supriadi, A., Musfeptial, M., Kustini, K. (2023). Making peace with disaster: A study of earthquake disaster

communication through manuscripts and oral traditions. Progress in Disaster Science, 18: 100287. https://doi.org/10.1016/j.pdisas.2023.100287
[94] Sarvothaman, H. (2022). Disasters and hazards: Risk reduction, mitigation and management. Journal of Geosciences Research, 7(2): 10-21. https://doi.org/10.56153/g19088-022-0002-r
[95] Jackson, G. (2021). Perceptions of disaster temporalities in two Indigenous societies from the Southwest Pacific. International Journal of Disaster Risk Reduction, 57: 102221. https://doi.org/10.1016/J.IJDRR.2021.102221
[96] Fornale, E., Armiero, M., Odasso, L. (2023). Trust in disaster resilience. Disaster Prevention and Management, 32(2): 253-267. https://doi.org/10.1108/dpm-04-2022-0082
[97] Carter, W.N. (2008). Disaster Management: A Disaster Manager's Handbook Asian Development Bank.
[98] Rabonza, M.L., Lin, Y.C., Lallemant, D. (2022). Learning from success, not catastrophe: Using counterfactual analysis to highlight successful disaster risk reduction interventions. Frontiers in Earth Science, 10: 847196. https://doi.org/10.3389/feart.2022.847196
[99] Sapountzaki, K. (2022). Risk mitigation, vulnerability management, and resilience under disasters. Sustainability, 14(6): 3589. https://doi.org/10.3390/su14063589
[100] Canon-Barriga, C., Bogardi, J., Tischbein, B. (2023). Prioritizing neighborhoods for intervention to mitigate urban small disasters triggered by rainfall. Urban Water Journal, 20(10): 1672-1681. https://doi.org/10.1080/1573062x.2022.2026981
[101] Baldwin, K., Effland, A. (2022). Integrating prevention into the risk management policy toolkit: A strategy for improving resilience to extreme events. Applied Economic Perspectives and Policy, 44(3): 1222-1240. https://doi.org/10.1002/aepp.13303
[102] Akola, J., Chakwizira, J., Ingwani, E., Bikam, P. (2022). An AHP-TOWS analysis of options for promoting disaster risk reduction infrastructure in informal settlements of Greater Giyani Local Municipality, South Africa. Sustainability, 15(1): 267. https://doi.org/10.3390/su15010267
[103] Mehvar, S., Wijnberg, K., Borsje, B., Kerle, N., Schraagen, J.M., Vinke-de Kruijf, J., Geurs, K., Hartmann, A., Hogeboom, R., Hulscher, S. (2021). Towards resilient vital infrastructure systems–Challenges, opportunities, and future research agenda. Natural Hazards and Earth System Sciences, 21(5): 1383-1407. https://doi.org/10.5194/NHESS-21-1383-2021
[104] Singh, P., Amekudzi-Kennedy, A., Ashuri, B., Chester, M., Labi, S., Wall, T.A. (2023). Developing adaptive resilience in infrastructure systems: An approach to quantify long-term benefits. Sustainable and Resilient Infrastructure, 8(sup1): 26-47. https://doi.org/10.1080/23789689.2022.2126631
[105] Trejo, D., Gardoni, P. (2023). Special issue on adaptive pathways for resilient infrastructure: An introduction. Sustainable and Resilient Infrastructure, 8(sup1): 1-2. https://doi.org/10.1080/23789689.2022.2139564
[106] Dusenberry, D.O. (2022). New SEI/ASCE disproportionate collapse mitigation standard. Journal of Structural Engineering, 148(4): 04022014. https://doi.org/10.1061/(asce)st.1943-541x.0003305
[107] Mishra, A., Swamy, S.L., Thakur, T.K., Kumar, A., Pandey, M. (2022). Impact of coal mining on land use changes, deforestation, biomass, and C losses in Central India: Implications for offsetting CO_2 emissions. Land Degradation & Development, 33(18): 3731-3747. https://doi.org/10.1002/ldr.4419
[108] Wang, X., Liu, W., Zhang, H., Lu, F. (2022). Spatiotemporal differentiation characteristics of land ecological quality and its obstacle factors in the typical compound area of mine agriculture urban. Sustainability, 14(16): 10427. https://doi.org/10.3390/su141610427
[109] Pandey, M., Mishra, A., Swamy, S.L., Thakur, T.K., Pandey, V.C. (2022). Impact of coal mining on land use dynamics and soil quality: Assessment of land degradation vulnerability through conjunctive use of analytical hierarchy process and geospatial techniques. Land Degradation & Development, 33(16): 3310-3324. https://doi.org/10.1002/ldr.4390
[110] Pan, J., Du, L., Wu, H., Liu, X. (2024). Does environmental law enforcement supervision improve corporate carbon reduction performance? Evidence from environmental protection interview. Energy Economics, 132: 107441. https://doi.org/10.1016/j.eneco.2024.107441
[111] Gonzaga, C.A.C., Roquette, J.G., Angeoletto, F., Silgueiro, V.D.F., Macedo, L.O.B., Valdiones, A.P., da Silva, N.M. (2024). The Public Prosecutor's Office's experience using Global Forest Watch to monitor and deter deforestation in the Cerrado. Environmental Conservation, 51(3): 236-241. https://doi.org/10.1017/s0376892924000110
[112] Banikhalid, A., Rahbeh, M. (2024). The role of the law in prompting environmental stewardship for farms located near phosphate mines. Sustainability, 16(3): 1140. https://doi.org/10.3390/su16031140
[113] Lan, M., Zhang, G., Yan, W., Qi, F., Qin, L. (2024). Greening through courts: Environmental law enforcement and corporate green innovation. Economic Analysis and Policy, 83: 223-242. https://doi.org/10.1016/j.eap.2024.06.016
[114] Liao, Z., Chen, J., Weng, C., Zhu, C. (2023). The effects of external supervision on firm-level environmental innovation in China: Are they substantive or strategic?. Economic Analysis and Policy, 80: 267-277. https://doi.org/10.1016/j.eap.2023.08.016
[115] de Moraes, O.L.L. (2023). Proposing a metric to evaluate early warning system applicable to hydrometeorological disasters in Brazil. International Journal of Disaster Risk Reduction, 87: 103579. https://doi.org/10.1016/j.ijdrr.2023.103579
[116] Moises, D.J., Kunguma, O. (2023). Improving flood early warning systems in Kabbe, Namibia: A situational analysis approach. International Journal of Disaster Risk Reduction, 93: 103765. https://doi.org/10.1016/j.ijdrr.2023.103765
[117] Sadiq, A.A., Dougherty, R.B., Tyler, J., Entress, R. (2023). Public alert and warning system literature review in the USA: Identifying research gaps and lessons for practice. Natural Hazards, 117(2): 1711-1744. https://doi.org/10.1007/s11069-023-05926-x
[118] Mashiyi, S., Weesakul, S., Vojinovic, Z., Torres, A.S., Babel, M.S., Ditthabumrung, S., Ruangpan, L. (2023). Designing and evaluating robust nature-based solutions

for hydro-meteorological risk reduction. International Journal of Disaster Risk Reduction, 93: 103787. https://doi.org/10.1016/j.ijdrr.2023.103787

[119] Okuda, K., Kawasaki, A. (2022). Effects of disaster risk reduction on socio-economic development and poverty reduction. International Journal of Disaster Risk Reduction, 80: 103241. https://doi.org/10.1016/j.ijdrr.2022.103241