Volcano Eruption Disaster Mitigation Strategy based on Local Wisdom in the Archipelago Region of North Sulawesi

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Abstract
This research examines strategies for mitigating volcanic eruption disasters based on local wisdom in archipelagic regions, with a specific focus on Mount Ruang in North Sulawesi, Indonesia. Situated on the Pacific Ring of Fire, Indonesia is home to over 130 active volcanoes and experiences frequent eruptions that significantly affect both the environment and local communities. The research employs a SWOT analysis to assess the strengths, weaknesses, opportunities and threats associated with disaster mitigation efforts.The findings indicate that traditional knowledge within communities and social cohesion can enhance preparedness for volcanic events.

However, challenges such as inadequate infrastructure and insufficient educational resources need to be addressed. Utilizing the Analytical Hierarchy Process (AHP), the research formulates prioritized strategies that include: (1) Education and training based on local wisdom, (2) Community based early warning systems, (3) Evacuation simulations and community drills, (4) Development of disaster prone area maps and (5) Strengthening social networks and community ties. This research underscores the critical role of integrating local wisdom into disaster mitigation strategies to safeguard communities from the adverse effects of volcanic eruptions.

Keywords: Local Wisdom, Natural Disaster, Mitigation, Archipelago, Volcano Eruption.

Introduction

Volcanic eruptions in archipelagic regions, especially in Indonesia, are a natural phenomenon having a significant impact on the environment, society and economy. Indonesia is located on the Pacific Ring of Fire, which makes it one of the countries with the highest volcanic activity in the world. With more than 130 active volcanoes, volcanic eruptions are often accompanied by various risks including volcanic tsunamis which can cause huge losses[10]. Mount Ruang is a genuine illustration of the effects of a volcanic eruption. The history of this mountain's eruptions is lengthy and hazardous. Ruang Island, which is a part of the Sitaro Islands Regency in North Sulawesi, is home to Mount Ruang. This mountain, which rises around 725 meters above sea level, is located in the Pacific Ring of Fire, a region with a high level of volcanic and seismic activity. These geological characteristics make Mount Ruang a volcano that needs attention.

At the meeting point of the tectonic plates from Japan to Southeast Asia, the Pacific "Ring of Fire" is where Mount Ruang is situated. Because of the region's active geotectonic interactions, seismic and volcanic activity are frequent. Mount Ruang's volcanic history records several significant eruptions during the past few decades. The first eruption of Mount Ruang was recorded in 1603. Although there are not many accurate records about the type and intensity of the eruption at this time, it marked the beginning of this volcano's volcanic activity. Mount Ruang erupted again in 1808, 1810, 1840, 1870, 1871 and 1874. The intervals between eruptions, which ranged from one to thirty years, show that this volcano was still active in the nineteenth century. Throughout the 20th century, Mount Ruang kept erupting.

As evidenced by eruption records from 1904, 1905, 1914 and 1915, the volcano's volcanic activity never completely stopped. Also documented in historical documents are eruptions in 1946 and 1949. Despite the fact that Mount Ruang is still erupting, it had a lengthy hiatus of almost fifty years before erupting once more on September 25, 2002. Hot clouds that accompanied this eruption damaged nearby villages and caused damage to the ground, necessitating the evacuation of local populations. Around 21:45 WITA on April 16, 2024, Mount Ruang erupted once more. In the first eruption, the volcanic ash column rose to a height of roughly 2 kilometers and in the second eruption, it rose to a height of 2.5 kilometers. The frequency of Deep Volcanic Earthquakes (VTA) increased following the tectonic earthquakes that occurred on April 9 and 14, 2024, according to PVMBG.

The VTA frequency increased significantly between April 10 and April 15, rising from 4 times on April 10 to 42 times on April 15 at 18:00 WITA. An explosive eruption took place on April 16, 2024, with the eruption column rising 2,000 meters from the top. 198 VTA episodes occurred between 0:00 and 12:00 WITA, whereas 493 VTA events and multiple other tectonic earthquakes occurred between 12:00 and 24:00 WITA. The eruption recurred on April 17, 2024, with a column height of 2,500 meters with booming and rumbling noises. The eruption, which reached a height of 3,000 meters

from the peak, happened multiple times that day, including 05:05 WITA and 20:15 WITA.

Beginning at 16:00 WITA on April 16, 2024, the Center for Volcanology and Geological Disaster Mitigation raised the volcano warning level from level II (be alert) to level III (alert). Additionally, authorities encouraged locals to stay inside the risk radius suggested by the PVMBG and established a four-kilometer exclusion zone surrounding the active crater. The Gunung Ruang Volcano Disaster Prone Area was home to the majority of the evacuated residents, specifically Pumpente Village (332 people) and Laimpatehi Village (506 people). In the afternoon, independent evacuation started, with a focus on children, the elderly and those who were ill.

Approximately 12,000 residents of the Mount Ruang area, particularly in Tagulandang District, were evacuated to safer locations if we consider the social and humanitarian effects. Basarnas and KRI ships were used in the evacuation process to get to the nearby tiny islands. To protect citizens and make catastrophe management easier, the local Government extended the emergency response status until May 14, 2024. The possibility of an eruption prompted the closure or relocation of a number of establishments including hospitals and monasteries. From an environmental standpoint, air pollution from volcanic ash and other materials can be harmful to both human and animal health.

In addition, the dispersed volcanic material is polluting the area surrounding Mount Ruang. In certain places, red lava pouring after an eruption can improve soil fertility but in other places, changes in soil composition might harm fertility. Volcanic debris falling into the ocean have the potential to pollute seawater and harm coral reefs and other marine habitats in marine ecosystems. Fish and other marine species may be disturbed by this. Economically, volcanic ash activity has caused hundreds of aircraft in the Gorontalo and North Sulawesi regions to be temporarily delayed. As well, agricultural operations may have a long-term impact on productivity, which could have lower wages for those employed in the industry[22].

Particularly in Indonesia with its diverse cultural diversity, a region's customs and traditions are typically referred to as local knowledge. This local knowledge has been transmitted from one generation to the next as part of a custom and culture[3]. The concept of "local wisdom" in the context of mitigating volcanic disasters refers to a blend of social integrity, environmental preservation and community norms and cultural traditions[8,11,18]. This research focuses on how local knowledge, particularly in the North Sulawesi archipelagic region, might be used as a method to lessen the effects of volcanic eruption disasters.

Material and Methods

This volcanic eruption tragedy in the Archipelago Region is an example of a natural disaster that can occur anywhere and at any time. To lessen the effects of the disaster, appropriate mitigation strategies are necessary. Utilizing the SWOT and AHP analysis methodologies, the volcanic eruption disaster in the archipelago region specifically, the one that takes place on Ruang Mount, one of the archipelagos in North Sulawesi is lessened.

SWOT analysis is a tool used to establish successful policy plans for disaster risk mitigation. It takes into account both external (opportunities and threats) and internal (strengths and weaknesses). FGD exercises with a few social and disaster experts are used to carry out the AHP process in order to identify strategic priorities, once the strategic direction from the SWOT analysis process has been developed[12,15,25,27]. Figure 1 shows the flow of the research.

Results and Discussion

Identification SWOT Factors: Interviews with organizations directly involved in volcanic eruption disasters in the archipelago and direct field observations were used to gather SWOT factors. In this instance, the strategy is developed in collaboration with the BPBD and local leaders. The strengths of the community include: (1) a wealth of traditional knowledge about volcanic behavior patterns and how to survive in a disaster-prone area including traditional land management techniques and efficient evacuation procedures; (2) a high level of social solidarity where social ties among members of the community can improve communication and coordination in emergency situations and (3) environmentally friendly sustainable agricultural practices that can lessen the impact of eruptions on agricultural land.

Weakness factors include: (1) a lack of shelter and evacuation infrastructure, which hinders the community's ability to respond quickly to disasters (2) a lack of disaster risk management education and training, which leaves the community confused when an eruption occurs and (3) a reliance on natural resources that has a major impact on the local economy when volcanic eruptions occur. Opportunities factors include: (1) the development of early warning technology, which is expected to help the community better prepare for volcanic eruptions (2) collaboration between the Government and non-governmental organizations that can strengthen community mitigation capacity in various programs like training and counseling and (3) raising public awareness through educational programs that can raise public awareness and readiness in disaster mitigation.

Threats factors consist of: (1) Climate change which can affect volcanic activity patterns and increase the frequency and intensity of disasters (2) Rapid levels of urbanization result in population growth and urbanization in disaster-prone areas, thereby increasing society's disaster vulnerability and (3) Geological uncertainty, in this case unpredictable volcanic activity will appear at any time which can result in large losses if there is no effective mitigation system.

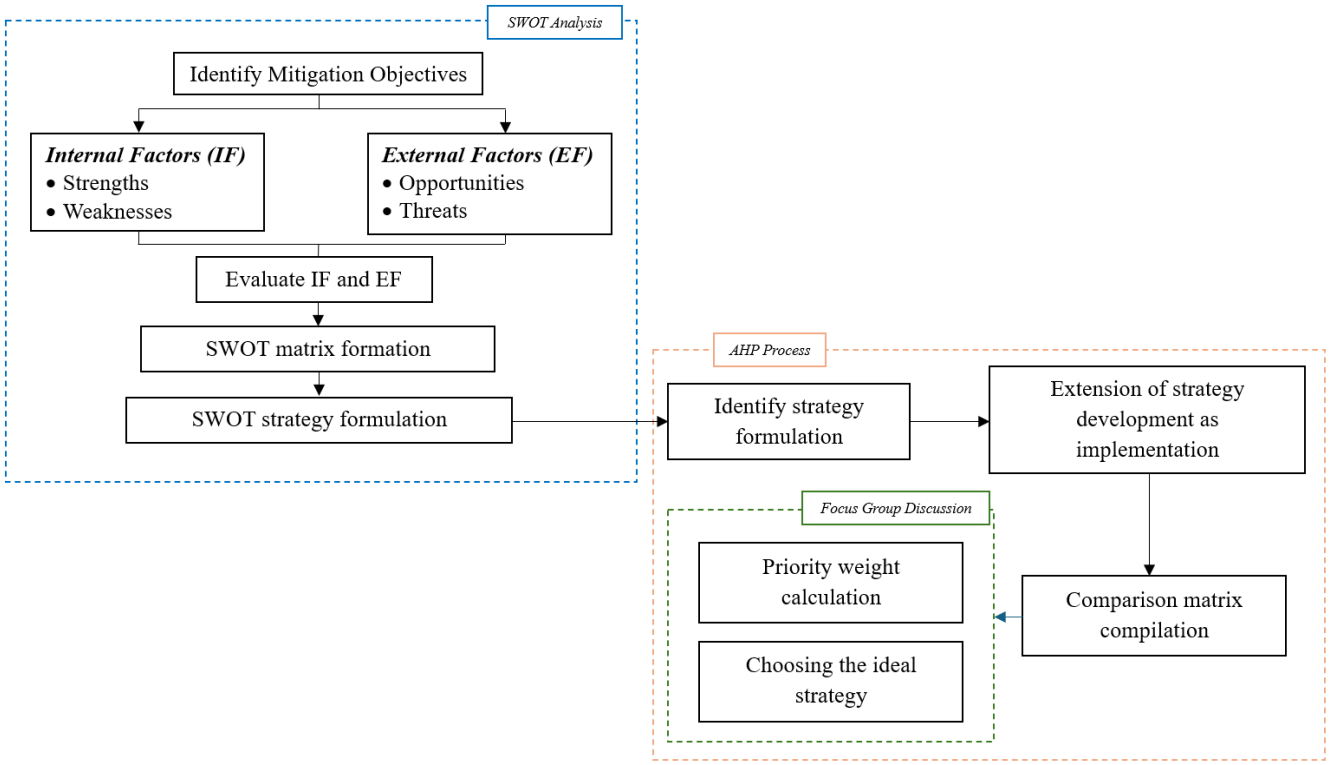

Figure 1: Research Methodology

Table 1
Designing Volcano Eruption Disaster Mitigation Plans in the North Sulawesi Islands Region Using SWOT Analysis

Strength Factors	Weaknesses Factors	Opportunities Factors	Threats Factors
1. Conventional wisdom 2. High social solidarity 3. Sustainable agricultural practices	1. Inedaquate facilities 2. Inedaquate catastrophe education 3. The reliance of communities on natural resources	1. Establishment of Early Warning System 2. Cooperation between NGOs and Government 3. Raising disaster awareness among the general populace	1. Climate change 2. High level of urbanization 3. Geological uncertainty

The description of the SWOT factors that have been identified is then simplified in the form of a SWOT matrix table which is presented in table 1.

Table 1 illustrates how a comprehensive strategy that takes into account a number of variables that affect community readiness and reaction is necessary to mitigate volcanic eruption disasters in archipelagic settings. SWOT analysis demonstrates how to use strengths like social cohesion and traditional knowledge to boost community resilience. However, in order for communities to properly respond to disasters, flaws like inadequate infrastructure and a lack of risk management education must be fixed. Mitigation capability can be strengthened by opportunities for early warning technology development and increased government-NGOs collaboration.

However, planning for mitigation must give careful consideration to the risks posed by geological uncertainty, growing urbanization and climate change. Mitigation measures based on local knowledge can be developed to improve community readiness for volcanic eruptions by leveraging current strengths and opportunities, as well as overcoming weaknesses and threats[5]. In addition to safeguarding people and property, this will aid in the social and economic rehabilitation that follows a disaster.

SWOT Strategy Formulation: Following the identification of the components derived from direct observation and interviews based on their attributes, the strategy to be developed is created in a SWOT matrix, which will subsequently yield a number of strategies such as:

(1) The SO (Strength – Opportunities) method, which is found on local wisdom, uses strength to take advantage of opportunities in an effort to lessen the effects of volcanic eruption disasters (2) The goal of the WO (Weaknesses – chances) strategy is to strengthen weaknesses by taking use of outside chances (3) To counter threats, the ST (Strength – Threats) strategy is built on strengths and advantages (4) The WT (Weaknesses – Threats) strategy is a defensive tactic that seeks to minimize weaknesses and prevent threats[1].

Tabel 2
SWOT Strategy Formulation

Internal Factors External Factors	Strength (S)	Weaknesses (W)
Opportunities (O)	Building a community-based early warning system with the use of traditional knowledge	Involve disaster management organizations in community training on disaster risk management.
Threats (T)	Developing efficient emergency communications networks in the face of climate change concerns by leveraging social embeddedness	While raising public knowledge of the dangers, improve evacuation facilities.

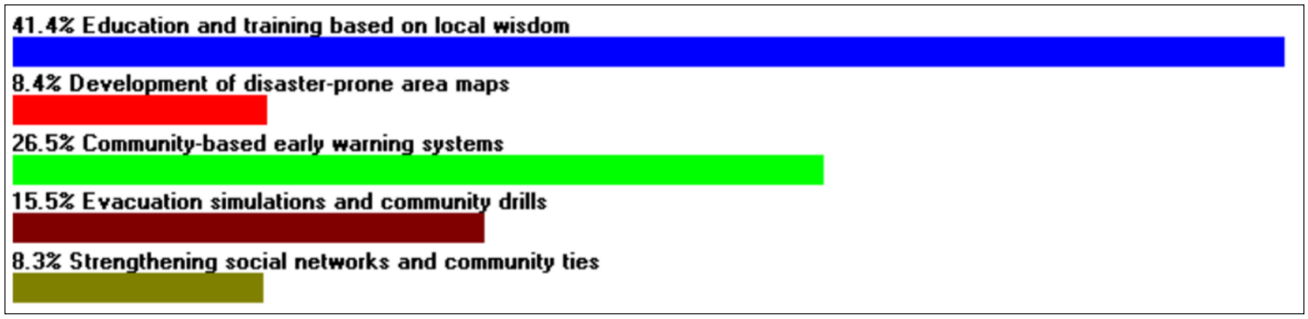

Figure 2: Priority Weight Calculation

Table 2 describes the SWOT strategy formulation that was produced. Community empowerment via the use of traditional knowledge, risk management training, bolstering emergency communication networks and enhancing evacuation infrastructure is the main objective of the volcanic eruption disaster mitigation plan as suggested in table 2. Through training disaster management institutions and incorporating local knowledge into the early warning system, communities can become more resilient and prepared for disaster risks. Having strong social links makes it possible to establish efficient networks of communication, which is crucial in emergency situations. Furthermore, improved evacuation infrastructure will guarantee public safety and accessibility in the event of an eruption.

AHP Process: An advanced step of SWOT analysis, the Analytical Hierarchy technique (AHP) seeks to identify the best course of action based on priorities. To better plan and prepare the strategic priorities for dealing with volcanic eruption disasters in the North Sulawesi archipelagic region based on local wisdom, a number of experts with expertise in disaster management and social sciences provide a weighting assessment during this process[6,14,17,23]. Four specialists with scientific expertise in geography, social sciences and sociology comprise the team participating in the focus group discussion.

Alternative Strategy As Implementation: The researchers developed a concrete strategy based on the SWOT analysis results of the strategy formulation. This strategy can be readily modified to determine future volcanic eruption disaster mitigation policies in the North Sulawesi archipelagic region. Among the outcomes of the developed strategy are the following: (1) Education and training based on local wisdom; (2) Development of disaster prone area maps; (3) Community based early warning systems; (4) Evacuation simulations and community drills; (5) Strengthening social networks and community ties. Based on local knowledge in the archipelagic region of North Sulawesi, the weight of these five methods will then be determined by calculating the outcomes of expert assessments to determine which approach is the primary step in attempts to minimize volcanic eruption disasters.

Priority Weight Calculation: Calculation of the weight of each alternative strategy proposed is carried out by comparing one strategy with another strategy to see the tendency of the value to be obtained. The reason the researchers used various experts in the fields of geography, social sciences and sociology, was that the weighting assessments carried out were in line with strategies that lead to local wisdom for efforts to mitigate volcanic eruption disasters in the archipelagic region of North Sulawesi. The weighting calculation process is carried out using cross tabulations carried out in the expert choice application. The priority weight calculation results obtained can be seen in figure 2.

Figure 2 shows that education and training based on local wisdom received the highest score from various SWOT factors with a score of 41.4%.

Then, the second priority is the community based early warning system with a score of 26.5%. The third priority with a score of 15.5% is evacuation simulations and community drills. The fourth and fifth priorities with scores of 8.4% and 8.3% are the development of disaster prone area maps and strengthening social networks and community ties.

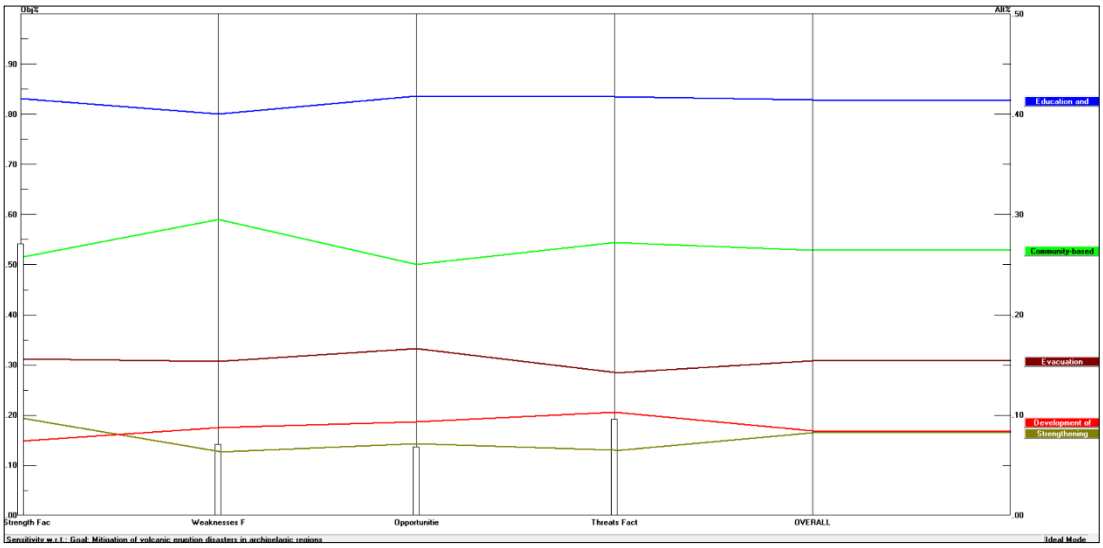

Figure 3: Sensitive Graph of Priority Weighted

Ideal Strategy: The weighting results assessed by experts are then sorted so that we can find out the priority strategies based on the order that can be taken in efforts to mitigate volcanic eruption disasters in the archipelagic region of North Sulawesi. The graph in figure 3 shows the order of priority strategies from highest to lowest based on expert assessments.

According to the previously developed SWOT elements, the priority determined by a weighted evaluation from highest to lowest is explained in figure 3. When implementing it in the field, the following steps must be taken in order to achieve successful mitigation efforts: (1) Education and training based on local wisdom; (2) Community based early warning systems; (3) Evacuation simulations and community drills; (4) Development of disaster prone area maps and (5) Strengthening social networks and community ties.

Discussion

Based on the analysis and concrete strategies that have been described previously, the priority order from highest to lowest in the volcanic eruption disaster mitigation strategy in the archipelagic region of North Sulawesi is education and training based on local wisdom, community-based early warning systems, evacuation simulations and community drills, development of disaster prone area maps and strengthening social networks and community ties.

First, education and training based on local wisdom are the main strategies because people who have the knowledge and skills in dealing with disasters, can offer responsive preventive effort. Through measurable and regular training activities coupled with adopting local wisdom such as Mapalus culture, we can form a community that is ready and responsive to emergency disaster situations[3,20]. Second, community-based early warning system allows the community to receive the latest information about potential eruptions, so that armed with the knowledge and skills obtained through the first strategy, the community can take preventive action quickly (during a disaster). Of course, these strategies must be accompanied by good technology accompanied by operators who understand how the equipment works[9,13,19].

Third, evacuation simulations and community drills can assist the community in preventing volcanic eruption disasters by following established protocols that are conducted on a regular basis. These exercises can boost self-confidence and lessen anxiety in the event of a disaster.[2,7,19]. Fourth, development of disaster prone area maps by involving local community participation in evacuation planning and determining locations that are safe from disasters in order to increase community awareness about the risks, they will face[24]. Fifth, strengthening social networks and community ties to increase solidarity when disasters occur. This strengthening can take the form of forming volunteer groups who are trained for the evacuation process, distribution of aid and providing psychological support to victims of volcanic eruptions[4,21,26].

By adhering to this priority sequence, it is intended that the archipelagic region of North Sulawesi will be able to mitigate volcanic eruption disasters more successfully, with local knowledge serving as the primary force in addressing the threat of disaster.

Conclusion

Local wisdom must be the primary basis for mitigating the catastrophic effects of volcanic eruptions in the North Sulawesi archipelago, according to this study. Effective mitigation measures have been developed by leveraging community strengths including social solidarity and traditional knowledge, through SWOT and AHP analysis. While infrastructure and education have shortcomings that require improvement, mitigation capability can be strengthened through partnerships with other institutions and possibilities to create early warning technology.

Included in the suggested tactics are education and training based on local wisdom, community based early warning systems, evacuation simulations and community drills, development of disaster-prone area maps, strengthening social networks and community ties. Implementing this plan will therefore aid in the economic and social recovery that follows disaster in addition to safeguarding people and property.

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