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Assessment of a Coastal Community's Readiness, Response, and Recovery to 2020 Taal Eruption: The Case of Lemery, Batangas

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Abstract

The Taal Volcanic Eruption in January 2020 posed significant social and economic challenges to the coastal municipality of Lemery, Batangas. This disaster emphasizes the need for targeted management strategies, particularly in coastal communities vulnerable to volcanic eruptions. This study aims to provide a comprehensive baseline for improving future volcanic disaster management by applying a systems thinking approach and integrating disaster readiness into land use planning and zoning to address interconnected risks and minimize vulnerabilities. The study used primary data from key informant interviews, supplemented by secondary data from government reports and academic literature. Using a phenomenological design, thematic analysis was used to generate themes on readiness, response, and recovery mechanisms of coastal communities and the factors affecting them. The findings identified the critical gaps in the municipality's disaster preparedness, response, and recovery mechanisms. Significant findings were (1) total lack of preparedness, (2) individualized response efforts shaped by socioeconomic conditions, and (3) recovery processes that faced barriers from the COVID-19 pandemic, ineffective coordination, and poor resource mobilization. These challenges emphasize the need for a multi-sectoral and cross-boundary approach to disaster risk reduction. Developing an inclusive and context-sensitive disaster management framework can enhance the resilience of coastal communities, thus ensuring better outcomes for future volcanic hazards.

Keywords— coastal communities, disaster readiness, disaster recovery, disaster response, volcanic eruptions

1 Introduction

The Philippines is one of the most disaster-prone countries globally due to its geographical and topographical characteristics. As an archipelagic nation, with over 7,640 islands surrounded by the South China Sea and the Pacific Ocean, the Philippines faces frequent extreme weather events, including heavy rains and flooding [1]. It is also situated within the Pacific Ring of Fire, a region known for high seismic and volcanic activity [2]. With over 300 volcanoes, 24 of which are active, volcanic eruptions in the Philippines have been particularly devastating. For instance, the 1991 eruption of Mount Pinatubo, located on the tripoint of Zambales, Tarlac, and Pampanga, displaced hundreds of thousands and caused thousands of deaths, while the eruption of Mount Mayon in 2018 led to mass evacuations and widespread damage [3, 4]. Moreover, the Taal volcano eruption in 2020 led to the evacuation of the nearby communities, human casualties, and damage to properties amounting to USD 46,081,380 in Batangas province alone [5]. These events illustrate the profound impacts of volcanic hazards on communities, with over 1,825 recorded deaths from volcanic activity in the country over the past two decades [6]. To address these challenges, the Philippines has enacted policies to strengthen disaster management mechanisms of preparedness, response, recovery, and mitigation. A notable example is the Philippine Disaster Risk Reduction and Management Act of 2010 or RA 10121, which established a holistic, comprehensive, and proactive framework for disaster risk reduction in the country. This legislation seeks to minimize the socioeconomic and environmental impacts of disasters by emphasizing a multi-sectoral approach and fostering the active participation of all stakeholders in managing and mitigating disaster risk [7].

According to the National Adaptation Plan of the Philippines [8], 55.47% of all municipalities, 48.72% of all the cities, and 81.01% of all the provinces in the Philippines are situated along coastlines. Coastal communities rely heavily on the nearby water bodies for food, livelihood, and culture. However, this proximity exposes them to heightened risks from natural hazards, including sea level rise, storm surges, and coastal erosion. Despite this, research on volcanic hazards, specifically in coastal contexts, remains limited in the Philippines, with most disaster studies focusing on typhoons due to their frequent occurrence and significant impacts [9]. With climate change contributing to stronger tropical cyclones, contemporary typhoons "have the potential to kill many more people than the largest terrorist attack" [10]. Volcanic eruptions, though less frequent, have equally devastating social and economic consequences, including infrastructure destruction, displacement, long-term livelihood disruptions, and casualties. However, the unpredictable eruptive power and the often long intervals of quiet dormancy of volcanoes make it challenging to forecast and study them [11, 12]. The two factors combined contribute to the gap in knowledge that hinders the complete comprehension of the unique challenges faced by communities in proximity to active volcanoes. This gap highlights the need for further studies and increased attention to contribute to developing more effective disaster risk reduction strategies.

Recent literature on disaster risk reduction and management (DRRM) has highlighted the value of systems thinking as a framework for understanding disasters as complex, interconnected phenomena. Disasters are increasingly recognized as "wicked problems" characterized by volatility, uncertainty, complexity, and ambiguity (VUCA), requiring holistic and adaptive approaches [13]. Systems thinking emphasizes the interrelationship, feedback loops, and systemic interaction, enabling a more comprehensive understanding of how various factors contribute to disaster risk and recovery outcomes [14]. This perspective moves beyond linear cause-effect relationships and instead focuses on dynamic systems, making it highly applicable to the multifaceted challenges of disasters. Existing literature made significant progress in integrating systems thinking into disaster risk reduction and management across various hazards, including floods, cyclones, and urban vulnerabilities. Rehman et al. [14] and Muntanga & Lunga [15] effectively highlight the utility of tools like Causal Loop Diagrams (CLD) and non-linear frameworks to map interdependencies and address systemic vulnerabilities. Similarly, Uddin et al. [16] emphasized the importance of systems

thinking in community resilience, particularly for critical infrastructure systems.

However, these studies predominantly focus on hazards like floods and cyclones, which are frequent and well-documented, leaving volcanic hazards notably unexplored. Moreover, the intersection of systems thinking and volcanic hazards in coastal contexts is almost absent from current research. Despite the unique vulnerabilities and exposure to overlapping hazards, no studies have explicitly applied systems thinking to analyze and address the compound risks of volcanic eruptions in these settings. The glaring gap in the available literature and the catastrophic impacts of past volcanic eruptions emphasize the urgent need for targeted disaster management strategies in the Philippines. These eruptions caused widespread destruction, displacement, and long-term socioeconomic consequences for affected communities. In response, this study focuses on the coastal communities of Lemery, Batangas, which were severely affected during the 2020 Taal eruption, to analyze their preparedness, response, and recovery mechanisms. The research focuses on five of the 14 impacted coastal barangays— Anak-Dagat, Maligaya, Sambal Ibaba, Wawa Ibaba, and Wawa Ilaya— to provide a comprehensive baseline for improving future volcanic disaster management. Guided by the principles of human ecology, particularly systems thinking, which balances community development with environmental integrity, this assessment highlights the critical need to integrate disaster readiness into planning and zoning to minimize risks. The findings offer practical insights into reducing population and infrastructure exposure to volcanic hazards while contributing to achieving Sustainable Development Goal 11, advocating for resilient and sustainable cities and communities. With the continued activity of Taal and other active volcanoes like Kanlaon, this research is a timely response to the increasing threat of volcanic disasters in the country.

2 Methodology

2.1 Site Selection

The phreatic eruption of Taal Volcano on January 12, 2020, is one of the most recent significant volcanic activities in the Philippines. This event generated ground tremors, ashfalls, and pyroclastic materials, affecting over 400,000 individuals across various areas in South Luzon [17]. Among the 12 municipalities in Batangas severely impacted by the eruption was Lemery, a first-class coastal municipality within a 14-kilometer radius of Taal Volcano (see Figure 1). Due to its proximity, all residents of Lemery were placed on high alert and evacuated to safety during the crisis.

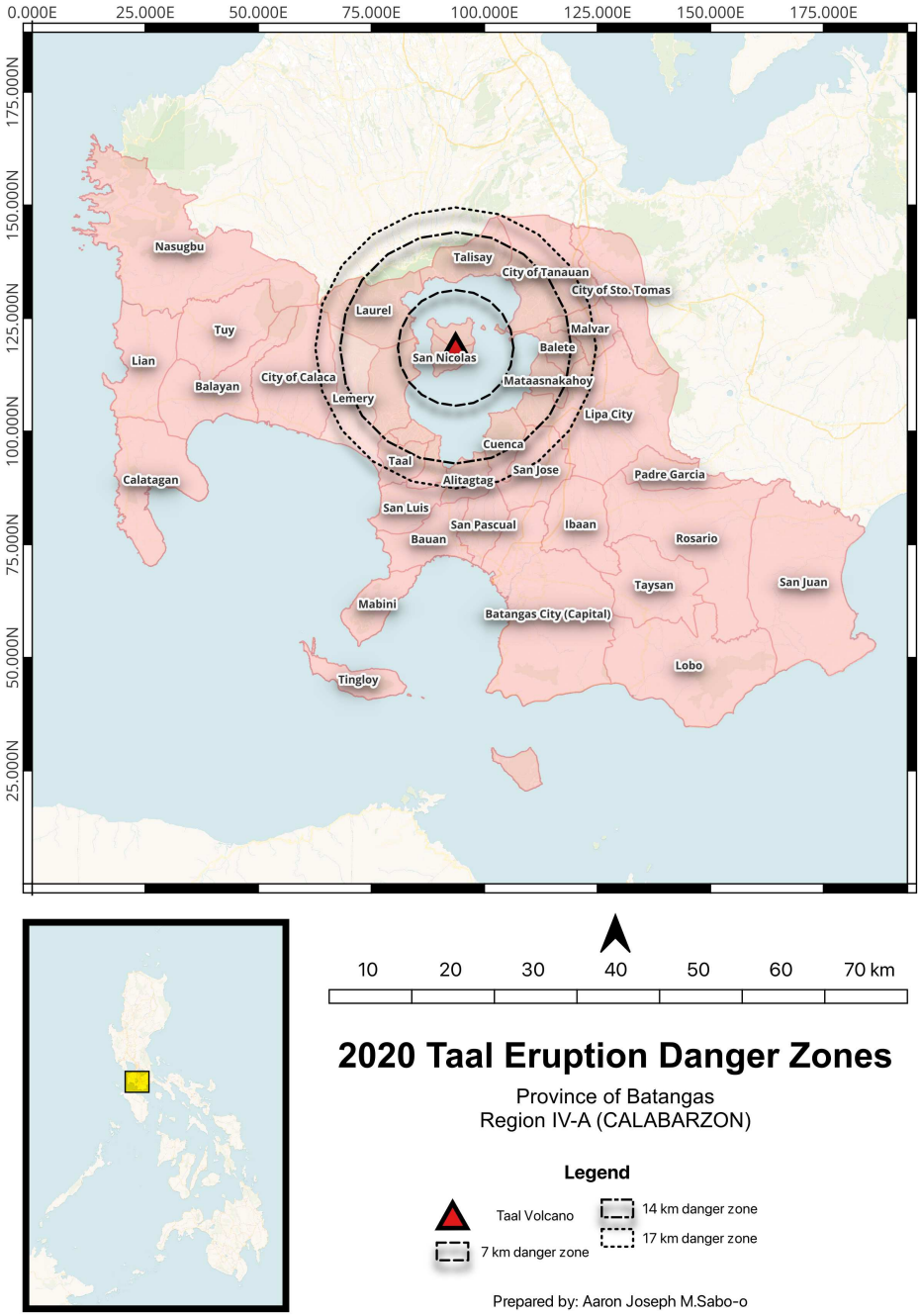

Figure 1.
2020 Taal Eruption Danger Zones. Republished from Sabo-o [18] under CC-BY-4.0

Lemery is located in the province of Batangas and covers a land area of 10,155 hectares. Geologically, the municipality is composed of solidified pyroclastic flows, lahar deposits, ashfall layers, lava deposits, and collapsed volcanic craters, evidencing its historical connection to past volcanic activities [17]. It is a part of the 1st Congressional District of Batangas, situated in the northwestern part of the province. It is bounded by the Municipality of Calaca (North), Municipality of Agoncillo (East), Municipality of Taal (South), and Balayan Bay (West) [19]. According to the 2020 Population Census, Lemery has a population of 93,000 distributed across its 46 barangays.

Preliminary research and consultations with the Municipal Disaster Risk Response and Management Office identified 14 barangays bordering Balayan Bay at heightened risk during volcanic eruptions. The municipality's Comprehensive Land Use Plan (CLUP) highlights that these barangays are vulnerable to base surges and volcanic tsunamis, adding further risk to their coastal locations [19]. Although all 14 coastal barangays were affected by the 2020 Taal Eruption, this study focused on five barangays (see Figure 2) based on the following criteria included (1) proximity to water, (2) primary livelihoods centered around fishing, and (3) high population density and urbanized settings. After the selection, the identified barangays were: (1) Brgy. Anak-Dagat, (2) Brgy. Wawa Ibaba, (3) Brgy. Sambal Ibaba, (4) Brgy. Wawa Ilaya, and (5) Brgy. Maligaya.

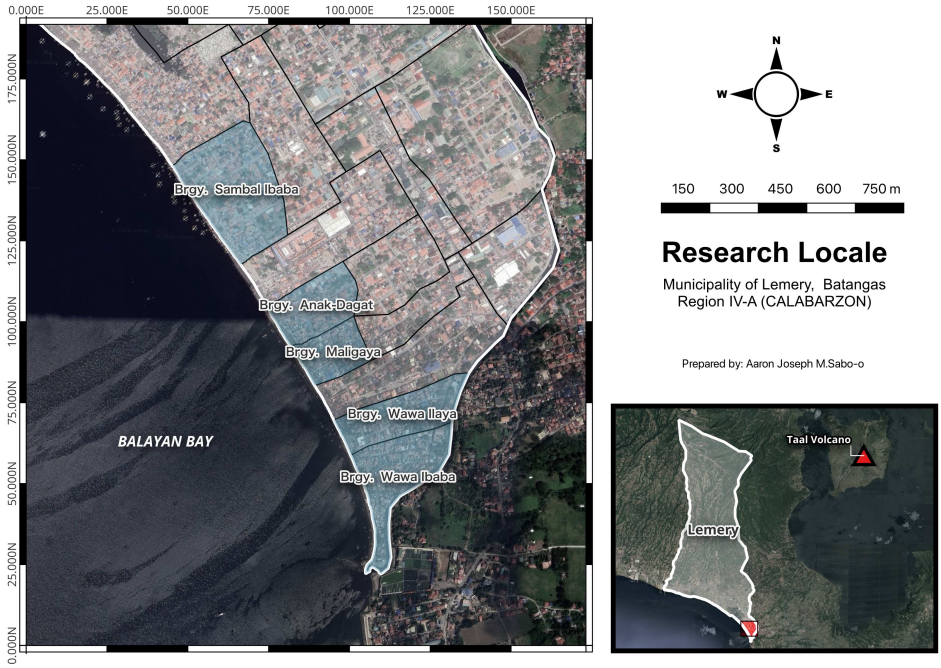

Figure 2.
Research Locale Map. Republished from Sabo-o [18] under CC-BY-4.0

2.2 Research Design

This study employed a phenomenological study design to explore the experiences of the coastal residents of Lemery, Batangas during the 2020 Taal Eruption. Phenomenology is a research method that seeks to understand how individuals perceive and interpret their experiences concerning specific events [20]. By focusing on the subjective perceptions and interpretations of the participants, this qualitative approach enables researchers to capture the complexities of their experiences, especially in the aftermath of environmental crises.

The design was aligned with incorporating experiential knowledge into disaster management planning to address the unique socio-economic and cultural dynamics of underserved commu-

nities [21]. From the perspective of affected communities, understanding Indigenous knowledge and wisdom on environmental protection, social justice, and economic growth is critical to building resilience and sustainability through disaster risk reduction efforts [22]. The methodological framework of the study is illustrated in Figure 3.

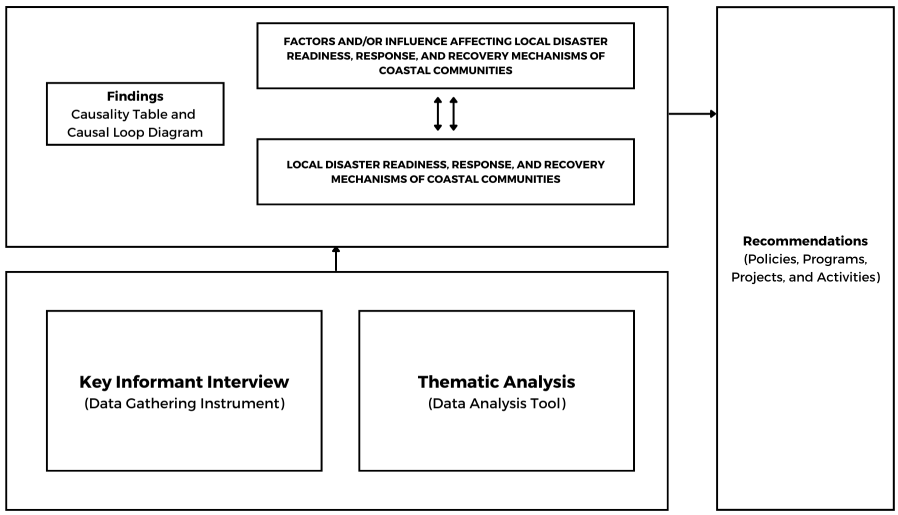

Figure 3.
The Research Methodology of the Study. Republished from Sabo-o [18] under CC-BY-4.0

2.3 Data Collection

This study's sample size determination was based on a non-randomized quota sampling method to ensure equal representation from each of the five coastal communities. Four key informants were selected from each community based on predefined criteria, resulting in 20 participants. The key informants satisfied the following criteria: (1) they experienced the 2020 Taal Eruption firsthand, (2) living in one of the five coastal communities determined as a research locale–Brgy. Anak-Dagat, Brgy. Wawa Ibaba, Brgy. Sambal Ibaba, Brgy. Wawa Ilaya, and Brgy. Maligaya–at the time of the eruption, and (3) they returned and settled in their respective communities after the eruption. This ensured a diverse and representative sample that captured the unique perspectives of affected individuals across all communities.

The key informants were interviewed using a semi-structured interview guide reviewed and approved by the Municipal Disaster Risk Reduction and Management Office. The questions include demographic information, preparations done, responses made, and recovery mechanisms they did during the 2020 Taal eruption. A separate segment asking for possible recommendations was also included.

The study faced limitations, as with any research reliant on retrospective accounts. The research relied on the narratives and self-reported responses of the coastal community members about a disaster that occurred four years prior. This reliance introduces potential biases and memory recall errors, which may be further compounded by the close succession of the volcanic eruption and the COVID-19 pandemic.

2.4 Data Analysis

The data from the key informant interviews were analyzed using thematic analysis. This method simplified raw data from the in-depth interviews into categorized themes and subthemes [23]. This identified patterns that helped analyze the coastal communities' readiness, response, and recovery

mechanisms and the factors that affected them.

The generated themes and connections were illustrated using a causal loop diagram (CLD), a key tool in systems thinking [24]. The CLDs provided a dynamic visualization of how interrelated variables interact within a system, highlighting feedback loops and causal relationships. This systems-thinking approach offered a holistic perspective on the complex interactions influencing disaster management practices in coastal communities. The CLDs were accompanied by a causality table (see Table 1) detailing each diagram link. The table included the following variables:

Table 1. Variables of the Causality Table. Adopted from Sabo-o [18] under CC-BY-4.0

Variable	Definition
Link Number	Identifies the specific causal connection
Trend	Indicates whether the relationship is reinforcing or balancing. Reinforcing (blue arrows) signify positive feedback, where one variable amplifies another. Balancing trends (red arrows) denote negative feedback, where one variable weakens the effect of another.
V_1 (Variable One) and V_2 (Variable Two)	Represents the two variables involved in each causal relationship.
Identified Subtheme	Categorizes the link within the broader thematic framework.

2.5 Ethical Considerations

Ethical considerations were carefully observed throughout the study. First, participation was entirely voluntary, allowing participants to participate freely or opt-out at any research stage. Second, informed consent was obtained from all participants, providing them with complete details about the study's purpose, objectives, potential benefits, and any risks involved. Third, confidentiality was maintained by ensuring that participants' identities were not essential to the study. Participants were not allowed to disclose their names; only general demographic details such as age, livelihood, and barangay were recorded. Fourth, participants were informed of their right to access a summary of the study's findings, its main conclusions, and a final approved copy of the study upon request. Lastly, measures were taken to ensure that the study avoided plagiarism and any form of research misconduct.

3 Results and Discussion

3.1 Disaster Readiness

The 2020 eruption of Taal Volcano exposed a stark reality: no community, regardless of its proximity to the hazards, was adequately prepared to face the disaster. Table 2 summarizes the factors that illustrate the interconnected challenges that hindered the preparedness of the Lemery, Batangas coastal communities.

Table 2. Causality Table of the factors affecting disaster readiness in coastal communities. Adopted from Sabo-o [18] under CC-BY-4.0

Link	Trend	V1	V2	Sub-Theme
L1	Reinforcing	Lack of access to information and resources	No Preparations (None)	Lack of technological access and usage affected disaster preparedness
L2	Balancing	Income and Livelihood	Lack of access to information and communication devices	Intensive livelihoods prevented time for technological usage and DRRM attendance
L3	Reinforcing	Lack of DRRM training, drills, and seminars	No Preparations (None)	Lack of capacity-building initiatives to prepare for volcanic eruptions
L4	Reinforcing	Weak attendance and participation	No Preparations (None)	Weak population attendance, participation, and representation in DRRM initiatives for volcanic eruptions
L5	Reinforcing	Weak population attendance and participation in DRRM initiatives	Lack of incentives	Lack of incentive to encourage attendance and participation in DRRM initiatives

Limited access to information and resources was widely cited as a significant barrier to the preparedness of the coastal communities of Lemery, Batangas, with 70% of the key informants expressing their agreement. Coastal communities, often because of geographic isolation, experience challenges in receiving timely and accurate disaster information [25]. A participant shared:

> "The information we received was insufficient. Because, you know, some people here don't use cell phones. So sometimes, internet updates, it's lacking" (KI06).

The lack of early warning systems and poor internet connectivity hampered the ability of the residents to receive warnings and updates during the volcanic eruption. These findings also align with Tablate [26] emphasizing that effective communication bridges first responders, support networks, and family members with disaster-affected communities and individuals. The absence of technological infrastructure and information exacerbates vulnerability by limiting the community's capacity to respond to disasters effectively [27].

Moreover, income and livelihood patterns, particularly intensive livelihoods, also hindered community engagement in disaster preparedness measures for coastal communities. A balancing trend emerges when livelihood activities like fishing require significant time commitments, leaving little room for technological usage and attending disaster preparedness activities [28]. The responses of the population expressed affirmation of having conflicting priorities.

> "We are not really into social media. We are focused on making a living. The barangay updates are fine. If there's a problem, the barangay is always attentive or there's someone assigned to it and that's enough." (KI08)

> "I haven't attended any. I can't say because, you know, making a living, but if I have the time, maybe." (KI08)

In the coastal communities of Lemery, where the livelihoods do require significant hours of the day, there was reluctance or inability to divert attention towards DRRM efforts as individuals are focused on securing their daily sustenance, leaving and relying all the preparations to their LGUs.

The absence of targeted capacity-building initiatives, including DRRM training, drills, and seminars, was a crucial factor that limited the preparedness of the coastal communities. According to

Hoffmann and Muttarak, disaster preparedness can be significantly enhanced through continuous education that equips communities with the necessary skills and knowledge [29]. However, in many cases, training initiatives focus on more frequent hazards like typhoons, earthquakes, and fire, neglecting less common but equally devastating threats like volcanic eruptions [30]. One community member noted,

> "Before the volcano erupted, we didn't have anything prepared for that because the issues we tackled before were for typhoons, earthquakes, and fires. Those were the things we were trained for, things we are used to happening in a barangay and community. But regarding a volcanic eruption, it seems like we were caught off guard." (KI07)

Without these targeted training opportunities, community member remain uninformed about how to act during volcanic eruptions, reducing their ability to respond effectively. The reinforcing trend observed underscores how the lack of comprehensive, hazard-specific training leads to a continuation of unpreparedness, perpetuating vulnerability.

In connection, weak attendance and participation in DRRM activities are recurring issues in disaster preparedness. Literature often identifies apathy, lack of trust in government initiatives, or competing priorities as key reasons for weak participation [31, 32]. However, in the case of Lemery's coastal communities, the factors that contributed to this trend were the selective participation process and the availability of individuals to attend this initiative. One key informant noted,

> "It's selective. Not everyone can be accommodated. Also, the availability of people." (KI04)

This highlights the limited reach of DRRM programs, where only specific individuals, often local leaders or barangay officials, are prioritized for training or participation. Another informant emphasized the necessity of their participation due to their roles in the barangay:

> Yeah, because it's necessary. Because we serve the barangay. We need to be the number 1 present.(KI03)

Selective participation limits the broader community's engagement, as those outside the priority groups often miss critical training and resources, reducing overall preparedness [33]. Moreover, the lack of inclusive approaches reinforce a cycle of unpreparedness, leaving vulnerable groups such as women, the elderly, and persons with disabilities with minimal disaster readiness [34].

Incentives are powerful motivators for community engagement in disaster preparedness initiatives. Without incentives, participation in DRRM efforts tends to be low, as community members view them as non-essential and burdensome [35]. Incentives, whether financial, social, or logistical, can encourage community members to prioritize DRRM involvement. The lack of such incentives in the coastal communities of Lemery, paired with the intensive livelihood of the population, contributed to the weak attendance observed. The reinforcing nature of this relationship suggests that addressing the lack of incentives could break the cycle of unpreparedness and foster a more proactive approach to disaster management.

The causal loop diagram below illustrates the causality of the mentioned preparation measures and the factors that influenced or affected them (Figure 4).

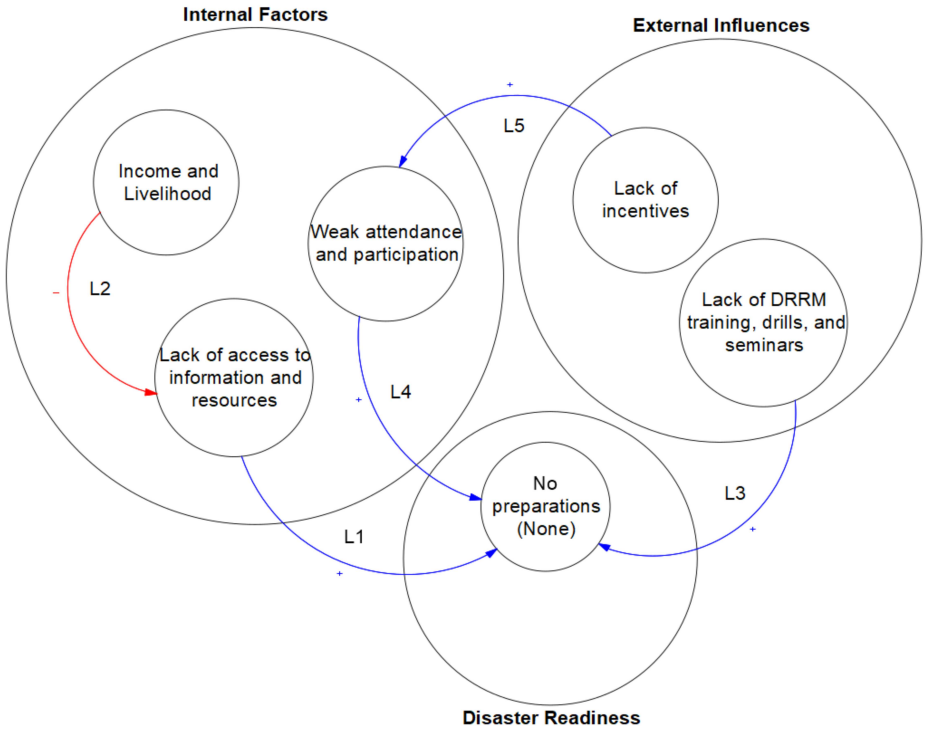

Figure 4.
Causal loop diagram of the factors affecting disaster readiness in coastal communities. Republished from Sabo-o [18] under CC-BY-4.0

3.2 Disaster Response

The findings revealed that socioeconomic characteristics, including income, resource access, and social networks, primarily influenced the responses of the coastal communities in Lemery. These factors shaped decisions on evacuation, cooperation, and access to aid, resulting in varied response behaviors. Table 3 summarizes the assessment, highlighting how these socioeconomic disparities impacted disaster response behaviors.

Table 3. Causality Table of the factors affecting disaster response in coastal communities. Adopted from Sabo-o [18] under CC-BY-4.0

Link	Trend	V1	V2	Sub-Theme
L1	Balancing	Lack of access to evacuation vehicles	Voluntary evacuation	The lack of private evacuation vehicles strained available public evacuation
L2	Reinforcing	Government provisions (vehicles, emergency supplies, etc.)	Voluntary evacuation	The provision of emergency vehicles assisted the population in the evacuation
L3	Reinforcing	Water and electricity supply shutoff	Forced Evacuation	Cutting off water and energy lines to force people into evacuation
L4	Balancing	Assisting nearby municipalities	Lack of access to evacuation vehicles	Assisting in emergency responses of nearby municipalities led to delays in hometown's emergency responses
L5	Balancing	Substandard condition of public infrastructures	Voluntary Evacuation	Substandard condition of public infrastructures slowed down evacuation efforts
L6	Reinforcing	Cooperation of the population	Voluntary Evacuation	The willingness of the population to evacuate affected the smoothness of evacuation efforts. Eventually led to a forced evacuation.
L7			Forced Evacuation	
L8	Reinforcing	Lack of credible information and advisories	Visits to the community (Authorized and unauthorized)	Lack of credible sources of information promoted legal and illegal visits to the community
L9	Reinforcing	Low budget allotment to DRRM	Disproportionate supply to population ratio	Limited basic necessities received by the evacuees due to the lack of supply
L10	Balancing	Communication and coordination (among LGUs and support groups)		Donations and support from other government units added to the available supply for the population
L11	Reinforcing	Vulnerabilities of the population	Cooperation of the population	Prioritization of individuals with vulnerabilities in health, income, and age
L12	Balancing	Constant volcanic activities (ashfall, earthquakes, etc.)	Voluntary Evacuation	Volcanic activities and debris slowing down the evacuation process

Despite their varying capacities, the gravity of the situation during the 2020 Taal Eruption ultimately necessitated evacuation. One critical factor that influenced the evacuation of the coastal residents was the lack of access to evacuation vehicles, creating significant challenges for voluntary evacuation. Coastal and rural communities often lack sufficient transport infrastructure resulting in delays and difficulties in moving [36]. While the voluntary nature of evacuation relies heavily on individual decisions, the absence of reliable transportation adds a balancing effect as it prevents smooth evacuation processes despite residents' willingness. Participants shared their sentiments about this lack of access.

> It was like "everyone for themselves" because it happened suddenly, especially for those without vehicles. We didn't have a rescue team at first, but later, some came from the municipality to help us." (KI19)

Some families with access to private vehicles, reached safer locations before the impact of the eruption. Meanwhile, individuals without access to transportation were assisted by deploying available vehicles, such as trucks and ambulances. The provision of government-supplied vehicles and emergency resources played a reinforcing role in encouraging voluntary evacuation. According to Chen et al. [37], when government support is effectively mobilized, it addresses logistical challenges and builds trust in disaster efforts. An interviewed barangay police stated:

> "For those without the means, we went to their barangay, gathered all our available vehicles like trucks, ambulances; we used everything." (KI01)

The evacuees sought refuge in neighboring municipalities including Nasugbu, Balayan, San Luis, Bauan, and the nearby cities of Calaca and Batangas. According to the experiences the coastal community members shared, individuals who evacuated using municipal vehicles were transported to a location relatively closer to Lemery. In contrast, those who used private vehicles traveled to more distant areas. This strategy was implemented to ensure that community vehicles could quickly return to Lemery and assist in transporting additional evacuees to safety.

However, despite the danger from the eruption, some coastal residents still resisted evacuation. Many residents were reluctant to leave their homes for various psychological and socio-economic reasons. As noted by Cox & Perry [38], people resist evacuation because of strong emotional connections to their homes, with the idea of leaving their personal belongings behind triggering feelings of loss and insecurity. Furthermore, concerns about the safety of property and livelihood deter people from abandoning their homes [39]. The municipality of Lemery responded by cutting off essential utilities such as water and electricity. One informant recalled:

> "They turned off all the lights, electricity, and water here to force the people to leave. It was really mandatory." (KI02)

Additionally, assisting the nearby municipalities further strained Lemery's capacity to respond to local needs. A participant described the situation as follows:

> "When the volcano erupted, around noon, Lemery was not yet affected. Our initial response was to help Agoncillo and evacuate the people there. When we were affected here, it was past 5:00 PM. That's when we started the evacuation. We even catered to people from Agoncillo because we brought them here. Eventually, we also sent them away as we are also affected." (KI01)

While inter-municipal cooperation is crucial, it can strain resources and divert attention from immediate local priorities, mainly when simultaneous emergencies occur [40]. This delayed local

evacuation highlights the challenges faced when municipalities assist in neighboring areas at the expense of their readiness.

The poor condition of public infrastructure also played a critical role in Lemery's evacuation process. This challenge is particularly pronounced in low-income areas, where investments in disaster-resilient infrastructure are often inadequate [41, 42]. Substandard infrastructure, such as poorly maintained and narrow roads and bridges, slowed down the evacuation process in the municipality. Participants shared their experiences being stuck in traffic while evacuating:

> "Due to the traffic, getting out was tough. It became difficult for us here when it erupted because the earth was quaking and our roads were cracked." (KI16)

In hindsight, the population's willingness and cooperation significantly impacted the evacuation efforts' effectiveness. Lemery's community cooperation was guided by prioritized groups, such as the elderly, pregnant women, children, and people with disabilities. This ensured that the most vulnerable members of the community were evacuated first. One key informant explained:

> "Our priority was the elderly, vulnerable individuals, and those without vehicles. So, the youth, elderly, those without vehicles, and pregnant women." (KI01)

This prioritization is crucial for managing evacuation effectively, as it addresses the needs of groups that face additional challenges during evacuation [43]. This willingness to prioritize vulnerable individuals ensured evacuation efforts were smoother and more coordinated.

Like their preparations, the coastal populations also expressed that the lack of credible information and advisories affected their responses. Days after the eruption, the municipality of Lemery was put under lockdown, with only authorized visits for brief hours of the day allowed. The lack of credible information sources led to rumors regarding the lifting of the municipality's lockdown and incidences of theft, resulting in the population's attempts to access their households illegally. This reinforcing trend highlights transparent and timely communication's critical role in mitigating mass panic and security risks [44].

The inadequate budget allocation for DRRM became apparent during the case of the 2020 Taal Eruption in Lemery. The limited financial resources affected the relief supplies, resulting in a disproportionate supply-to-population ratio, leaving many evacuees underserved. Leaders assigned to proportion the rations stated their experiences:

> "Of course, the goods, we need to manage them. It's not really that much that's given to us. We need to ration it accordingly. It won't be enough because of the sheer number of evacuees. We just try to stretch the supplies, but it's not enough." (KI02)

These narratives align with Hamza et al., who emphasized that insufficient funding for disaster management efforts perpetuates vulnerabilities, especially in resource-constrained municipalities [45]. Fortunately, communicating and coordinating with other LGUs and support groups balanced the supply and demand. The contribution from other LGUs and groups, in the form of in-kind donations and logistical support, alleviated the resource shortage. This highlights the importance of efficient inter-agency coordination in disaster management efforts to enhance resource mobilization, as promoted by Menya and K'Akumu [46].

The causal loop diagram below illustrates the causality of the mentioned response mechanism and the factors that influenced or affected them (Figure 5).

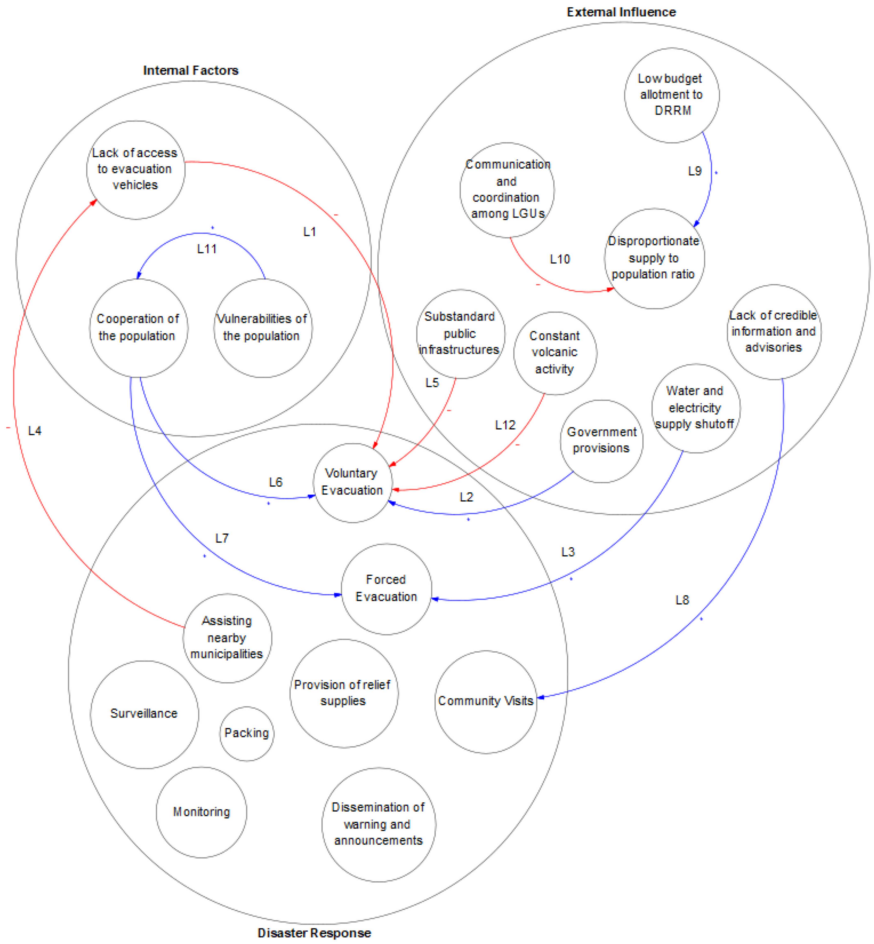

Figure 5.
Causal loop diagram of the factors affecting disaster response in coastal communities. Republished from Sabo-o [18] under CC-BY-4.0

3.3 Disaster Recovery

The ability of the coastal community of Lemery to recover from the eruption was deeply influenced by their access to resources and support systems. The situation became even more complex when compounded by an additional stressor, the COVID-19 pandemic. Despite these challenges, the LGU and support groups implemented various recovery mechanisms to assist in the restoration of the coastal communities. The causality table below summarizes the factors that influenced and affected these recovery mechanisms (Table 4).

Table 4. Causality Table of the factors affecting disaster recovery in coastal communities. Adopted from Sabo-o [18] under CC-BY-4.0

Link	Trend	V1	V2	Sub-Theme
L1	Balancing	Unjust criteria in aid distribution	Provision of financial, resource, and material aid	Unequal amount of financial and material aid received due to unjust criteria
L2	Reinforcing	Provision of financial, resource, and material aid	Cleaning and restoration of houses and infrastructures	Ease of restoration of damaged houses and infrastructures due to financial and resource aids
L3	Reinforcing	Presence of support groups (NGOs)	Provision of financial, resource, and material aid	Additional financial and material aid from support groups to help in recovery
L4	Balancing	Corruption	Provision of financial, resource, and material aid	Relief funds were not able to reach the intended beneficiaries due to corruption
L5	Balancing	Disruptions in income and livelihood	Cleaning and restoration of houses and infrastructures	Disruptions of income and local livelihood affected the ability to restore damaged houses and infrastructures
L6	Balancing	Lack or insufficient financial aid		Lack or insufficient financial aid received affected the ability to restore damaged houses and infrastructures
L7	Balancing	COVID-19 Pandemic		Unfinished post-eruption damage assessments due to the rise of COVID-19 pandemic
L8	Reinforcing		Disruptions in income and livelihood	The COVID-19 pandemic worsened the disruptions in the population's income and livelihood post-eruption
L9	Reinforcing	LGU-mandated recovery programs	Provision of financial, resource, and material aid	LGU provided financial, resource, and material supplies to the population to aid in their recovery
L10	Balancing		Disruptions in income and livelihood	LGU providing alternative work for the affected population (cash-for-work)

Reports from key informants indicated that the criteria for disseminating relief aid were unjust. This led to an imbalance of financial and material support received by the disaster-affected individuals. Due to resource constraints, the LGU was forced to prioritize providing to "heavily affected" members, judged through the damages in their homes. Meanwhile, those who were not able to report the damages and/or required assistance in other forms were overlooked. A key informant narrates:

> "We didn't receive anything. Maybe others received, those who said their houses were severely damaged. But we didn't report because we were told by the LGU that they would only provide for severely damaged houses. That's the only thing they needed to address." (KI07)

Kathleen Geale [47] highlighted that disaster relief should be equitable, ensuring aid reaches those most need it. When aid is distributed based on biased or inequitable criteria, specific segments of the population, particularly the most vulnerable, may not receive their fair share of assistance. However, financially constrained municipalities are often unable to do so, allocating the available resources to those who they deem “really need it” [48].

The result of the provision of financial and material aid played a critical role in facilitating the restoration of the damaged houses and infrastructure in Lemery. Recovery efforts proceed more smoothly when sufficient resources are available [49]. Rouhanizadeh et al. [50] stated that timely financial support accelerates rebuilding and reduces long-term socioeconomic disruption. This aligns with the LGU’s effort to provide immediate support for its constituents.

Lemery also partnered with non-governmental organizations (NGOs) and other support groups during recovery. A key informant expressed their experience receiving aid from the support group:

> "Usually, from private companies, they give basic needs. Some also gave financial aid. Like the church, like in CALASAC, they provided roofing sheets and materials to repair houses." (KI01)

The presence of these support groups complemented Lemery’s efforts by providing additional resources. According to Seddiky et al. [51], NGOs bring expertise and flexibility that government programs often lack. This allows for more tailored and rapid responses to disasters. This external support was crucial in the recovery process of the coastal communities in Lemery as the LGU’s resources were stretched thin or delayed.

The significant delay in the distribution of financial aid led the coastal population to speculate about potential corruption. Corruption during the disaster recovery phase leads to a significant loss of resources intended for relief efforts, resulting in a balancing effect that undermines recovery. Relief funds may be diverted or mismanaged, preventing the aid from reaching the intended beneficiaries. A key informant narrates:

> "The assistance that the Governor was supposed to give for repairs wasn’t given to us. That was our only hope, but it wasn’t given." (KI03)

Corruption delays recovery and fosters mistrust in authorities and relief organizations [52]. However, corruption has been identified as a common barrier to effective disaster management efforts, particularly in regions where governance structures are weak [53].

Aside from the lack of financial aid, livelihood disruptions significantly affected the ability of households to restore damaged homes on their own. As local economies took time to recover, many individuals struggled to rebuild, further delaying recovery. An informant expressed:

> "It really affected our lives, primarily our livelihood. Our vendors, immediately have no customers. Most here sell fish in the market, but when they arrive there, there are no stalls immediately; the roofs are damaged. We were stuck at home, and couldn’t find work immediately." (KI07)

This balancing effect highlights the interconnectedness of economic stability and the ability to recover from disasters. According to Colburn et al. [54], losing income sources compounds vulnerabilities and recovery, especially in communities that rely on agriculture, fishing, or small businesses.

In response to the growing concerns about the lack of immediate income sources, the LGU of Lemery initiated mandated recovery programs in the form of alternative work opportunities. These cash-for-work and food-for-work programs included planting and cleaning debris and ashfall in exchange for financial relief. A key informant described the program as follows:

> "Yes. We had a cash-for-work project with Agriculture. They will plant, and then they will be paid. The names of the volunteers were given by the Barangay Captain, they were referred. They can also clear up debris and ash and they will get paid." (KI02)

However, the COVID-19 pandemic further exacerbated the challenges faced by the coastal communities in the aftermath of the Taal eruption. As health protocols took precedence, post-eruption damage assessments were delayed, preventing timely interventions and hindering recovery planning.

> "But many properties were really damaged due to fissures. Because the extent of our recovery wasn't thoroughly measured, COVID erupted. We couldn't thoroughly assess the actual damages and recovery." (KI01)

This balancing trend effect demonstrates how the pandemic disrupted normal recovery processes and diverted attention away from the immediate needs of the disaster-affected population. According to Martinez-Villegas et al. [55], the pandemic added a layer of complexity to the recovery, as health concerns restricted movement, meetings, and resource mobilization. Additionally, the pandemic also compounded the disruption to income and livelihood, worsening the economic strain of the coastal communities of Lemery. The ongoing financial crisis and the pandemic further delayed recovery efforts as many households struggled to secure basic income. A key informant shared their experience:

> "It's like we didn't achieve recovery because, following the volcanic eruption, COVID happened. It's like no one recovered because of the quarantine. We couldn't even leave the house." (KI06)

The causal loop diagram below illustrates the causality of the mentioned recovery mechanisms and the factors that influenced or affected them (Figure 6).

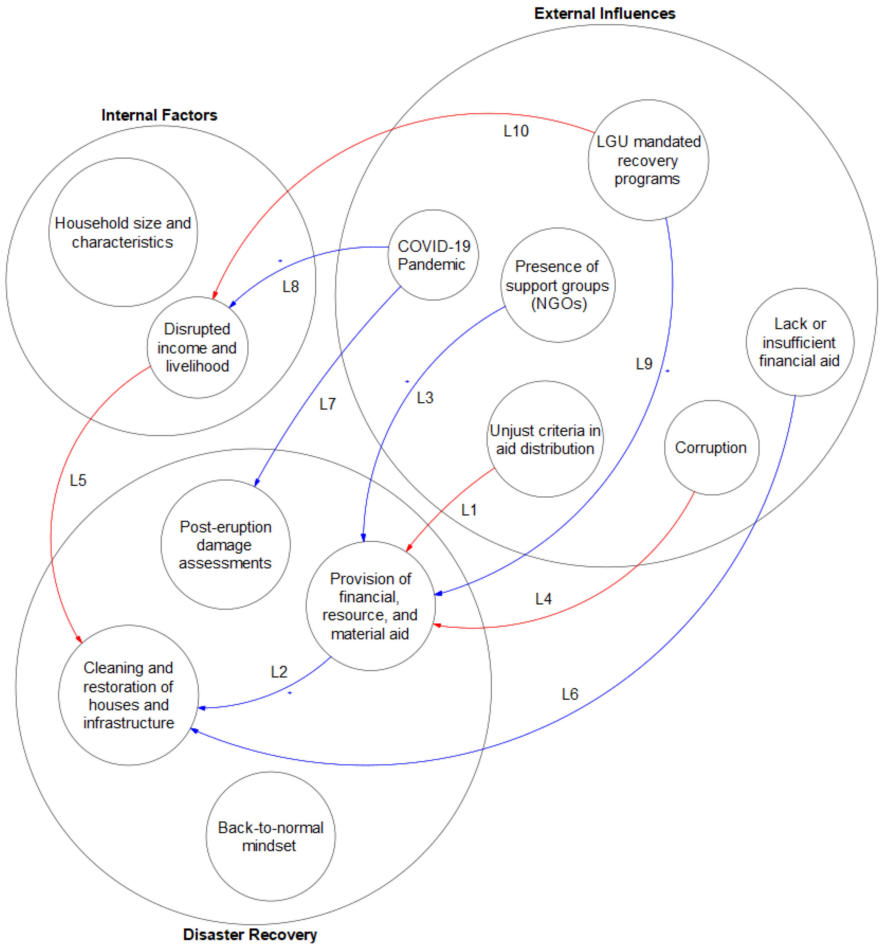

Figure 6.
Causal loop diagram of the factors affecting disaster recovery in coastal communities. Republished from Sabo-o [18] under CC-BY-4.0

4 Conclusion and Recommendation

The study reveals several critical factors for enhancing disaster management in coastal communities vulnerable to volcanic eruptions. A key finding from the study in Lemery, Batangas, was the lack of preparedness for the 2020 Taal Eruption, caused by the combination of the unpredictable nature of the disaster and the lack of local capacity-building initiatives. This resulted in their responses being spontaneous reactions determined by their socio-economic characteristics. Using systems thinking, these fragmented responses were understood as parts of a larger, interconnected system, where vulnerabilities in the area, such as infrastructure deficit, cascade to exacerbate other challenges, such as transportation difficulties, population vulnerabilities, and logistical issues. In the recovery phase, systems thinking provided an overview of the interdependent challenges that needed to be addressed. Financial constraints, health conditions, knowledge gaps, and disruptions to daily activities, compounded by the COVID-19 pandemic, significantly hindered recovery efforts. The Lemery, Batangas coastal communities emphasize the importance of a comprehensive disaster and risk reduction and management plan. Other key actions include improving post-disaster assessments, ensuring sufficient emergency supply, increasing budget allocations, and investing in necessary DRRM tools and infrastructure.

In alignment with Sustainable Development Goal (SDG) 11, this study advocates for building

inclusive, safe, resilient, and sustainable communities by integrating systems thinking into DRRM policies and practices. By doing so, coastal communities can mitigate the impacts of volcanic eruptions, reduce socio-economic disparities in DRRM initiatives and ensure adaptive, long-term solutions that enhance the overall well-being of the populations. The findings provide recommendations to improve the disaster management efforts of coastal communities in Lemery, Batangas, in anticipation of future volcanic eruptions:

1. **Long-term Relocation Studies:** Conduct in-depth studies on the feasibility and acceptability of long-term relocation for coastal residents, considering their attachment to homes and livelihoods.
2. **Multi-Sectoral Collaboration:** Encourage active participation and engagement from all sectors to ensure a unified and efficient response when disasters arise. A smoother response requires a more efficient system with established clear communication channels and protocols for information sharing at all levels (from national to barangay) during volcanic crises.
3. **Resource Allocation and Budget Planning:** Advocate for increased budget allocations dedicated to disaster management efforts, including the provision of emergency supplies, equipment, and infrastructure development. Investing in technologies that can capitalize on the context of coastal communities, such as early warning systems and transport boats, can help improve overall resilience.
4. **Capacity Building.** Invest in capacity-building programs for community members, local leaders, and responders to enhance their skills exclusive to the context of volcanic eruptions.
5. **Cross-Boundary Coordination.** Developing protocols for cross-boundary coordination and information-sharing mechanisms between neighboring municipalities and national agencies can contribute to a more efficient response.
6. **Incorporate Local Practices.** Incorporating local knowledge, such as traditional evacuation routes and community-based coping strategies, ensures planning efforts are locally relevant. Community consultations can help update land use and zoning plans based on new information or changing environmental conditions.
7. **Develop Integrated, Multi-Hazard Plans.** Systems thinking highlights the interconnectedness of hazards. Facing multiple risks such as volcanic eruptions, tsunamis, storm surges, and pandemic, plans must be flexible and adaptable to evolving circumstances. Adopting multi-hazard plans that recognize how these risks interact and compound ensures comprehensive disaster preparedness.

This article is the full version of the research paper presented at the 2024 DCERP Research Day, CHE-UPLB [56, 57] and the International Conference on Human Settlements Planning and Development (ICHSPD) 2024, SM Aura, BGC, Manila [58].

Statements and Declarations

Acknowledgment

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Conflict of Interest

The authors declare no conflicts of interest.

Ethical Considerations

This study was conducted following the Declaration of Helsinki. Free, prior, and informed consent (FPIC) was sought from the participants, which included explaining the purpose of the study, their voluntary participation, and how the data collected would be used.

Data Availability

The data presented in this study are available upon request from the authors.

Author Contributions

A.J.M.S.: conceptualization, methodology, formal analysis, investigation, writing—original draft preparation, visualization. **A.G.L.dM.**: conceptualization, methodology, writing—original draft preparation, supervision. **K.S.A.C.B**: conceptualization, validation, writing—review, and editing. **C.B.A.**: conceptualization, validation, writing—review and editing.

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