ARTICLE

Visualizing the cascading impacts of multi-hazards in three selected barangays in the Quinali A Watershed, Albay, Philippines

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ABSTRACT

The Philippines exists at the crossroads of climate-induced hazards and disasters – it ranked fourth in the 2021 Global Climate Risk Index and first in the 2023 World Risk Index. Representative of this is the Province of Albay, where many human, geological, meteorological, and most recently—biological hazards—are present and seen to cascade and compound. Understanding these multi-hazards is imperative in adaptation and risk management, with community knowledge, experience, and sound data at the core of the scientific inquiry. This study investigates the cases of three barangays (Buga in Libon, Pandan in Ligao City, and Quirangay in Camalig) from Quinali A Watershed in Albay to capture the exposure dynamics to various hazards such as floodings, landslides, and volcanic eruptions, among others. Focus group discussions (FGDs) were conducted with key barangay officials and community members to assess their vulnerability to identified hazard events following the participatory assessment from the Local Government Unit (LGU) Local Climate Change Action Plan (LCCAP) Guidebook.

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KEYWORDS

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These were complemented with key informant interviews and secondary data. Utilizing a multi-hazard-impact relationship framework, a qualitative visualization of cascading and compounding impacts was done from the lived experiences of the community. Results revealed that the barangays' strong adaptive capacity (in terms of wealth, technology, infrastructure, social capital, information, and institutions) has contributed to reducing their vulnerability to frequent hazards, such as typhoons, floods, landslides, and even COVID-19. However, the cascading impacts have shown that a single-hazard approach was not enough in assessing the barangays' vulnerability and designing effective adaptation strategies to promote resilience. The complex nature of hazards calls for compounding and cascading impact analyses to support Albay's zero-casualty vision. This approach that may also benefit other high-risk regions through the use of impact chain diagrams tailored to their context.

INTRODUCTION

The geographic location of the Philippines has placed it on the path of various climate-induced hazards and disasters—most recently by Category 5 Typhoon Rolly, with the international name Goni, in 2020. It affected the Bicol Region with winds reaching 225 km/h, which made it the strongest typhoon to make landfall that year (Inquirer.net, 2020). It left at least seven dead in the country (Inquirer.net, 2020). Recently, the Mayon Volcano showed signs of unrest magmatic activity, and the volcano warning was raised to Alert Level 3. Communities and residents near the volcano were ordered to evacuate to safe areas. Consequently, the country ranked first in the 2020 World Risk Index, and fourth in the 2021 Global Climate Risk Index. Albay stood as a testament to this ranking, where geological, meteorological, and public health emergencies, such as the COVID-19 pandemic, are known to occur. This multitude of hazards is the perfect recipe for disaster occurrences and has far-reaching consequences and impacts not just on the physical but also on human systems (Cutter, 2018; Lawrence et al., 2020) such as deaths, health issues, damages to property and infrastructure, and degradation of the environment (Sendai Framework Terminology on Disaster Risk Reduction, 2017).

Agreements, frameworks, and conventions at several levels have been published to ensure that the global community can adequately respond to these challenges. The Hyogo Framework for Action was a groundbreaking agreement on disaster risk reduction (DRR) to enhance the resilience of communities across the globe. Adopted in 2005, it outlined a list of deliverables for the parties to accomplish by 2015. Despite the successes under the Hyogo Framework, hazards and disasters continued to devastate communities and effective anticipation, planning, and DRR remained crucial over the ensuing decade (Sendai Framework, 2015). Sensing a push for urgency amidst uncertainty, the parties have adopted the Sendai Framework for Disaster Risk Reduction 2015-2030 (Sendai Framework) called for "multi-hazard, multi-sectoral, inclusive, and accessible" approaches in disaster risk management (Sendai Framework, 2015). The renewed framework has set out four priorities in the coming decade centering on the enhancement of resilience of communities through better understanding of disasters, improved risk governance, efficient allocation of investments, and better preparations and response. Parallel to these are the adoption of similar treaties among countries with similar goals, such as the United Nations Framework Convention on Climate Change and the 2030 Agenda for Sustainable Development.

In the Philippines, landmark legislation has been passed and enforced to support these international agreements. The 1991 Local Government Code has given the local government units the mandate and power to respond to disaster events. Three decades later, a national and local structure was also institutionalized through the passage of the Disaster Risk Reduction and Management Act of 2010. This law mandated the creation of Disaster Risk Reduction and Management Offices (DRRMO) at all LGU levels and DRRM Councils at the regional and national levels, together with their corresponding plans and frameworks. Also, adopting the Climate Change Act of 2009 has brought to the fore the crucial role climate change plays in the DRR arena. Adaptation challenges to climate change are expected to worsen the impacts of hazards. Among these challenges are inadequate response to the long-term impacts and risks, mismatch investment in adaptation and mitigation, exacerbation of existing inequalities, and persistence of vicious cycles of poverty and discrimination (UNDRR, 2020).

Multi-Hazards and Cascading Impacts

The Sendai Framework explicitly called for multi-hazard approaches to DRR. Multi-hazard approaches are the consideration of more than one hazard at a specific place and their possible simultaneous (compound) and cumulative (cascade) occurrences (Gill and Malamud, 2014, as cited by De Angeli et al., 2022). However, traditional methods of individual hazard assessments at any given time remain widespread. These methods are inadequate for describing and properly assessing the risks and impacts associated with multi-hazard events (AghaKouchak et al., 2020; Lawrence et al., 2020), which better reflects the complexities of hazards. Often, a combination of several hazards, along with cascading impacts, may expound on the initial effects causing greater and widespread impacts (AghaKouchak et al., 2020; Lawrence et al., 2020; Schauwecker et al., 2019; Pescaroli & Alexander, 2018; Cutter, 2018) across multiple scales (Cash et al., 2006) and would require a breakthrough in disaster management and governance (Galaz et al., 2011; Pescaroli and Alexander, 2018; Lawrence et al., 2020; De Angeli et al., 2022) that combines a participatory, inclusive, whole-of-society, ridge-to-reef approach, and a complete shift from single to multiple hazard and impact assessment. In addition, the multi-hazard events and cascading impacts have gained renewed interest due to three factors (Cutter, 2018): the humanitarian impacts such scenarios can produce, the annual nature of occurrence, and the drive to establish a single definition of multi-hazard events and cascading impacts through multidisciplinary perspectives. However, studies on multi-hazard events and cascading impacts remain scarce (de Brito, 2021), especially at local levels. In addition, it is rarely considered in planning and development strategies (Mignan et al., 2016). Therefore, defining multi-hazard relationships, such as compounding and cascading hazards, is the initial step in the right direction for transformative and effective disaster response and mitigation efforts, as a consideration of multi-hazards without a proper definition of different multi-hazard relationships can cause further "redundancy and confusion" (Pescarolli & Alexander, 2018).

Cascading multi-hazard relationship is important as it generally deals with the effects of these hazards on the socio-economic sector, whose impacts will be felt directly by local communities. A thorough understanding of each step of a cascading multi-hazard is crucial, as failure to do so can result in dire consequences and situations (Mignan et al., 2016). At its core, a cascading multi-hazard relationship is characterized by its sequential nature—where one event (Event A) triggers another (Event B), and so on—forming what is known as a process chain (Schauwecker et al., 2019). Each successive event tends to be more disruptive than the last, escalating the overall impact rather than stabilizing it (Barquet et al., 2023). Additionally, compounding multi-hazards may produce subsequent disasters, resulting in cascading hazards (de Brito, 2021). However, recent developments on the concept have found that there is a need to move from "toppling dominoes" that use a single cascading chain of hazards and impacts towards multiple, non-linear (Galaz et al., 2011), cascading chains—one hazard triggering a multitude of other hazard that will cascade through physical and human systems (Cutter, 2018). In addition, they also stated that cascading multi-hazards have complex causalities and have recombination potential as they interact with various other factors in a system dynamic (Lawrence et al., 2020). Cascading multi-hazards are closely associated with the concept of NaTech Disasters (Cutter, 2018; Pescaroli & Alexander, 2018) in which a natural hazard can trigger technological disasters, particularly in factories and in the failure of critical infrastructures (Schauwecker et al., 2019) and found different applications as well in urban and DRR (Lawrence et al., 2020).

Impacts, on the other hand, are defined as the totality of effects, both positive or negative, by a single or multi-hazard including social, economic, or environmental impacts (UNISDR, 2021 as cited by De Angeli et al., 2022). Cascading impacts involve a primary trigger (usually a hazard) that causes successive events (Pescaroli & Alexander, 2015, as cited by Barquet et al., 2023). Cascading impacts and disasters are the unpredicted secondary and tertiary effects that cause greater and disastrous impacts eclipsing the effects of the initial event (Lawrence et al., 2020; Cutter, 2018; Pescaroli & Alexander, 2018). Regarding time frame, impacts may be continually occurring or abrupt, depending on the trigger (Lawrence et al., 2020). With many lives at stake, cascading impacts deserve crucial attention in an increasingly interconnected world.

Cascading impacts share a common baseline: they primarily focus on their effects on communities, or the human systems involved in disaster risk reduction (DRR). These impacts tend to follow pathways along vulnerability in the communities that have accumulated across time and scale (Cutter, 2018; Pescaroli & Alexander, 2018; Schauwecker et al., 2019; Habacon, 2022).

This paper is an exploratory investigation of the cascading impacts of multi-hazards in selected barangays in the Quinali A Watershed in Albay using qualitative and participatory methods. Through this, a deeper understanding of various hazards' cascading impacts and effects can be achieved. Effectively combining community knowledge, lived experience, and reliable data is essential for transformative and effective adaptation and risk reduction—directly supporting the priorities of the Sendai Framework (2015). Given the limited research on multi-hazards and cascading impacts at the community level in the Philippines, this paper aims to produce local case studies. The lack of case studies that are reflective of local contexts can result in ineffective DRR (Schauwecker et al., 2019).

The APN-Funded Capacity-Building Project

This paper is part of a wider capacity-building project in Albay funded by the Asia-Pacific Network for Global Change Research entitled "Resilience-building and future-proofing Strategies in a Multi-stressed Scenario in the Province of Albay, Philippines" implemented by the UPLB-INREM in partnership with the UP Resilience Institute from October 2021 to March 2024. The project has four main goals, and this paper forms part of the output of the third objective: the conduct of both participatory and probabilistic climate change risk scenario assessment.

Study Site

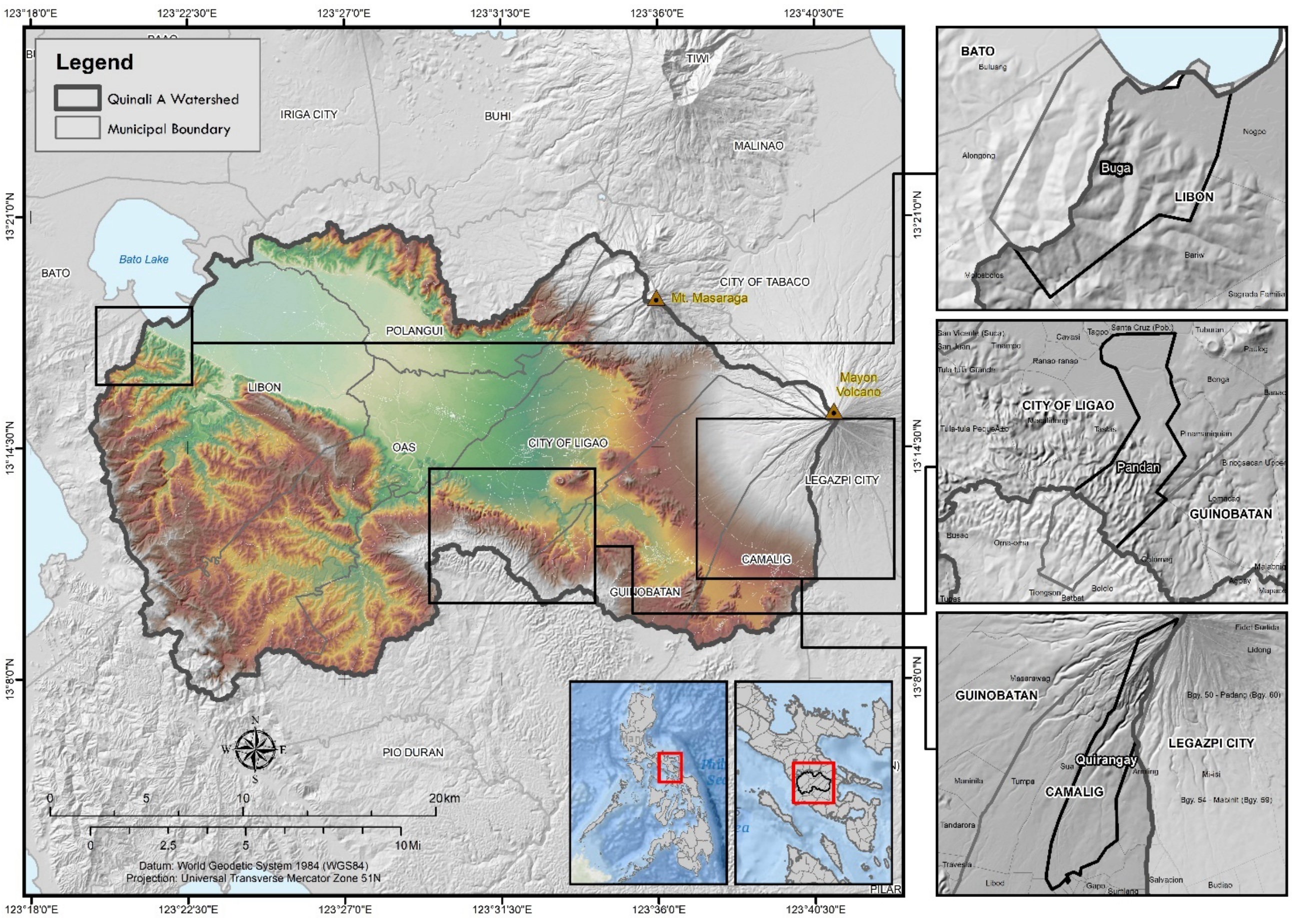

Figure 1: Location of Barangays Buga, Pandan, and Quirangay in the Quinali A Watershed in Albay.

The study site of the paper is the Quinali A Watershed in Albay (Figure 1). Considered one of the major sub-basins of the Bicol River Basin, it provides various ecosystem services (i.e. provisioning, regulating, and cultural services) to the inhabitants of the six LGUs within its boundaries, namely Camalig, Guinobatan, Ligao City, Oas, Libon, and Polangui (Quinali "A" Watershed, n.d.) with an estimated population of around 420,000 people within the watershed as of 2020.

Specifically, this paper focuses on the case of three barangays in the Quinali A Watershed namely: Barangay Quirangay in Camalig, Barangay Pandan in Ligao City, and Barangay Buga in Libon. These three barangays were chosen due to three factors: 1) their location within the watershed (one along the downstream, one at the midstream, and the last one in the upstream area); 2) the variety of hazards present; and 3) their 2020 population from the Philippines Statistics Authority (PSA). The differing locations of the barangays ensure that the experiences and context would come from various parts of the watershed.

Barangay Quirangay is an upstream barangay located on the slopes of Mt. Mayon and has a population of 3,553.37. About 12% are 14 years old and below, and 4.26% are 65 years old and above. The median age of the barangay is 22 years old (PhilAtlas, n.d.). Considered a rural barangay by the PSA, it has an area of 918 ha located around two kilometers from the Camalig town proper and 167.2 meters above sea level. Barangay Pandan (midstream) in Ligao City at the midstream has 5,090 residents and is the only urban barangay among the three barangays. About 34.60% of the population are 14 years old and below, while 5.11% are 65 years old and above. The area is about 3.5 kilometers from the Ligao City center (PhilAtlas, n.d.). It has an area of 874.4 hectares and is 47.3 meters above sea level. Barangay Buga in the downstream has a rural population of 3,734, 36.02% of which are 14 years old and below, and 4.67% are 65 years old and above. It is located along the shores of Lake Bato, and has an average elevation of 13.7 meters.

METHODOLOGY

Pescaroli and Alexander (2018), among other authors, have provided a clear situation on the current discourses and dominant messaging in multi-hazard relationships. They also devised a multi-hazard framework that claims to be a non-exhaustive review but is comprehensive. Sperstad et al. (2020) also devised a framework for multi-hazards and cascading impacts on power systems vulnerability in the Nordic countries. Spersted et al. (2020) linked multi-hazards, vulnerability, and impacts. A modified version of the power systems' vulnerability and the multi-hazard framework of Pescaroli and Alexander (2018) was adopted for this paper.The specific method used in the investigation of the cascading impacts in the study site was patterned after the systems map of Lawrence et al. (2020), the branching tree structure of Schauwecker et al. (2019), the climate impact chains of Zebich et al. (2021), and the Book 4 of the LGU LCCAP Guidebook (DILG LGU Academy, 2017) -all of which utilized a version of cascading impact chains that have proven applications in vulnerability and risk assessments (Zebisch et al., 2021; Lückerath et al., 2023; Estoque et al., 2022) and in building up climate change evidence bases (Regional Resource Center for Asia and the Pacific, 2021).

Cascading Impact Framework

Building on the works of Pescaroli and Alexander (2018) on multi-hazards, Cutter (2018) on cascading impacts, and De Angeli et al. (2021), Sperstad et al. (2020), Barquet et al. (2023) in both multi-hazards and cascading impacts, a conceptual framework was created that connects multi-hazards, vulnerability, and cascading impacts.

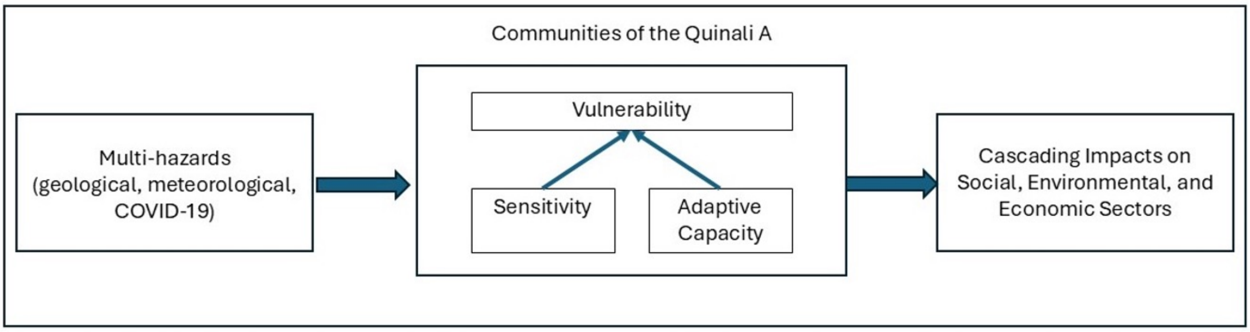

Figure 2: The conceptual framework used in the study, modified from the power systems vulnerability of Sperstad et al. (2020).

The framework is divided into three parts: (1) the multi-hazard trigger event, (2) the vulnerability of the communities in Quinali A composed of sensitivity and adaptive capacity, and (3) the resulting cascading impact on the communities.

The power system vulnerability framework of Sperstad et al. (2020) describes the vulnerabilities of power systems to threats and the resulting cascading impacts. They defined vulnerability as the "internal characteristics" of the system and as the "expression of the problems that a system faces." We argue that their definition can also be applied to the analysis of the vulnerability of communities. Ciurean et al. (2013) argued that vulnerability is the state of the system before the onset of hazard events – the internal characteristic mentioned by Sperstad et al. (2020). Wisner et al. (2013) expanded the definition to include not just the state of the system but also the current situation of a group of people that may influence their ability to cope with and anticipate natural hazards. Ciurean et al. (2013) further argued that this definition puts forth the importance of the assessment of human systems in discussions of vulnerability, including the factors that make them sensitive and their ability to cope and adapt. Wisner et al. (2013) reinforced this notion by arguing that disasters are not just a function of the physical side of natural hazards but also the characteristics of the human systems, which they called the social causation of disaster. Further, vulnerability has a time dimension in that it can also include assessments and analysis of future impacts, not just necessarily the immediate impacts at the time of the hazard events (Wisner et al., 2013). Therefore, the analysis of cascading impacts can be argued as being inextricably linked to hazard and vulnerability. This paper, therefore, attempts to see how the modified framework operates on the ground due to the possible widespread effects on human systems of cascading impacts and its importance in anticipatory and preventive DRRM measures. Analytical tools on cascading impacts used in this paper were patterned after existing methods on cascading impact diagrams and vulnerability assessment tools that are used in formulating LCCAP in the Philippines.

Cascading Impact Diagrams

To visualize the cascading impacts of a multi-hazard scenario in the selected barangays, a cascading impact or impact chain diagram was created to show the abovementioned impact pathways that may be unknown at the time of the trigger event. (Schauwecker et al., 2019). Impact chain diagrams are described by the Regional Resource Center for Asia and the Pacific (RRC.AP) (2021) as a backbone upon which the "stories" of how climate change is felt in their communities and their impacts on human systems. The cascading impact diagrams connect the hazards to an interconnected web of impacts on the social, environmental, and economic sectors. Various versions of cascading impact diagrams exist in the literature, such as the systems maps of Lawrence et al. (2020), the event-based pathways of Schauwecker et al. (2019), the climate impact chains of Zebisch et al. (2021), and the impact chains described in the Philippine LCCAP Guidebook (2017). The systems map created by Lawrence et al. (2020) for their respondents in Wellington, Hamilton, and Christchurch in New Zealand is a simplified version of impact chain diagrams. This map shows how the subcomponents of "water, urban and infrastructure, and financial services" are interconnected across a wide network and how a trigger can cause a cascade at any part of the system with a potential emergence of a vicious cycle where communities may have a hard time ending. The impact chain diagram of Zebich et al. (2021) claims to be a method of operationalizing and visualizing vulnerability through its three parts: exposure, vulnerability, and adaptive capacity. They consider it the backbone of vulnerability assessment by encapsulating climate vulnerability within a systems approach.

Schauwecker et al.'s (2019)'s event-based pathway scheme was used to analyze the cascading impacts of extreme precipitation events in three sites: freezing rain in Slovenia, convective event in Switzerland, and snow in Spain. The authors claim that the method has great visualizing power for cascading impacts to people with little to no background in DRR – thereby reducing its complexity for the communities. The pathway scheme has the following benefits: it fills in the blind spots of models on cascades, identifies intricate interdependencies in a system and critical infrastructures, and serves as documentation of complex events and becomes the basis of future best practices. The cascading impact diagrams in the DILG LCCAP Guidebook (2017) portray a similar method whereby primary, secondary, and tertiary impacts are identified from a single trigger. Ultimately, the cascading impact diagrams of the DILG LCCAP Guidebook (2017) were chosen as the simplified version of the systems map, event-based pathway, and climate impact chain, which presents the cascading impacts in a form that can be easily understood by communities (Schauwecker et al., 2019). It also allows for upscaling and possible integration into the Local Climate Change Action Plans of their respective municipal LGUs, making its immediate use and utilization crucial for effective and transformative adaptation and DRR as it can funnel much-needed resources.

While all methods above considered the multiplicity of impacts from a single trigger, its glaring shortcoming is that it only takes into account a single event that can trigger the impacts. As stated above, multi-hazard assessments reflect the realities on the ground. While these singular assessments may form an accurate impact pathway of the identified event, which in this case are hazards, its interaction with the impacts of other triggers is not brought into the light. Thus, this paper adopted a modified version of these to incorporate a multi-hazard trigger in an impact chain diagram.

Data-Gathering methods

Various methods and approaches have been used to determine cascades in case studies. Quantitative methods have been developed to analyze cascading impacts of different hazards, such as the work of de Brito (2021) on the compound and cascading impacts of drought. She believes that this approach, which used data mining tools and network inferences, among others, was a novel attempt at identifying impact patterns that may have been buried underneath piles of data. It also can contribute to the further development of impact-based forecasting systems by predicting possible cascading impacts of drought occurrences.

Despite this perceived advantage of quantitative approaches, authors prefer the use of qualitative methods in approaching the concept of cascading impacts due to the following reasons: quantitative methods are arbitrary and demand a huge amount of data by nature (AghaKouchak et al., 2020; Schauwecker et al., 2019; Robielos et al., 2020); and some cascading impacts may be understated due to data unavailability (AghaKouchak et al., 2020; Schauwecker et al., 2019) warranting the use of qualitative data (Pescaroli & Alexander, 2018). Qualitative methods have shown great promise in analyzing "complex process behaviors" typical of cascading impacts with its ability to unpack community members' lived experiences, which quantitative data may not express adequately. (Schauwecker et al., 2019). Mignan et al. (2016) used reasoned imagination to identify cascades that have happened and those that have yet to occur but are reasonable enough for a possibility to happen in the future. The authors emphasize that the latter point is the main strength of this method, as cascading impacts that rarely occur may be brought to the attention of policymakers. Thus, a participatory and inclusive approach creating impact chain diagrams is highly encouraged (Zebisch et al., 2021).

To produce qualitative data, participatory methods were also used to engage directly with local stakeholders – akin to the approach of Lawrence et al. (2020) to similarly learn about the local experiences and contexts of cascading impacts. These methods have been used by various climate change adaptation and resilience projects in different locations of the Philippines (Pulhin et al., 2021; Pulhin et al., 2022), such as in the Province of Aurora and the Saug and Baroro Watersheds in the Provinces of Davao del Norte/Compostela Valley and La Union, respectively. The collaborative and enabling environment created by the participatory approach allowed different stakeholders to come together and develop solutions for their mutual benefit (Pulhin et al., 2021). In the participatory adaptation process flow that Pulhin et al. (2021) devised, they found that the provision of ample recognition of the part played by communities in the adaptation process, as well as in the interest of the conservation of their livelihood, increases their willingness to participate and to become effective stewards of the environment and the watershed.

Figure 3: The three-step approach used to produce multi-hazard impact chain diagrams for the three study sites.

Using qualitative and participatory approaches, the project team conducted three focus group discussions (FGD), one in each of the three study sites from 2022 to 2023. It was attended by barangay (village) officials of the Sangguniang Barangay (Village Council) and community leaders, numbering around 10 participants on average (Table 1). These FGDs have elicited lively discussions and exchanges of information and experiences. For Brgy. Quirangay, the FGD was held in their barangay hall; for Brgy. Pandan the venue is the Ligao City Hall (where they were grouped with neighboring Barangays Layon and Tuburan); and for Barangay Buga, the event was held in the covered court of Barangay Burabod. The FGDs were divided into four parts: 1) community experience of hazard events, 2) participatory vulnerability assessment, 3) impact chain analysis, and 4) adaptation measures planning. This paper discusses the results of Parts 2 and 3. In addition to FGDs, key informant interviews were also conducted with key officials of the municipal LGUs to gain additional insights into the experiences of the chosen barangays. The multi-hazard impact chain diagrams of cascading impacts was developed using a three-step approach combining community and expert knowledge. Figure 3 shows a summary of the process.

Table 1: Scale descriptions for Threat Level, Adaptive Capacity, and Relative Vulnerability (DILG LCCAP Guidebook, 2017).

Scale	Threat Level	Adaptive Capacity	Relative Vulnerability
5	High	High	High (4-5)
4	Medium High	Medium High	Medium High (2.1-3.9)
3	Medium	Medium	Medium (1.5-2)
2	Medium Low	Medium Low	Medium Low (1.1-1.49)
1	Low	Low	Low (<1)

Table 2: Focus Group Discussions conducted on the project site from 2022 to 2023.

Site	Date	Venue	Participants
Brgy. Quirangay, Camalig	February 22, 2023	Quirangay Barangay Hall	Barangay Officials, Barangay Health Workers, Community Members
Brgy. Pandan, Ligao City	June 14, 2022	Ligao City Hall	Barangay Officials, Barangay Health Workers, Community Members
Brgy. Buga, Libon	November 24, 2022	Burabod Barangay Hall	Barangay Officials, Barangay Tanods (Security), Barangay Health Workers

Reflecting on the conceptual framework in Figure 2, the paper explored the vulnerability of the communities through a participatory assessment. The study was conducted with the local stakeholders to identify possible linkages with the cascading impact diagrams. The formula used for computing the relative vulnerability of the barangays is "Vulnerability = Threat level / Adaptive capacity," taken from Book 4 of the LGU LCCAP Guidebook (DILG Academy, 2017). An assessment was produced for each hazard and sector depending on the context of the specific barangay. A Likert scale of 1 to 5 was adopted for both Threat Level and Adaptive Capacity, and the participants assessed themselves based on their experiences. As for the former, it comprises six factors: Wealth, Information, Institution, Social Capital, Infrastructure, and Technology. It must be noted that while the scales for both Threat Level and Adaptive Capacity have the same descriptions, the desired scores were the opposite. This formula and scoring matrix were also adopted by Raza et al. (2020) in their proposed science-policy framework in Quezon City. The description of the scale can be found in Table 2, together with the interpretation of the vulnerability scores. During the FGDs, the participants were provided with handouts with the scoring matrixes and corresponding interpretations and factors. The communities' threat level and adaptive capacity scores were determined through a consensus-building approach, with sustained discussions among the stakeholders.

For the impact chain analysis, the local stakeholders were asked to identify the hazards known to occur within their locality and were encouraged to narrate their experiences of the identified hazards. Once listed down, the next step was to create and discuss single-hazard cascading impact diagrams for the environment, social, and economic sectors. Finally, using thematic analysis and expert-based evaluation, the researchers combined the impact-chain diagrams for each hazard and sector to form one diagram for each barangay. The single diagram would be the final output of the process.

RESULTS AND DISCUSSION

Barangay Quirangay, Municipality of Camalig

Barangay Quirangay in Camalig has identified two sets of hazards present in their jurisdiction: hazards associated with Mt. Mayon eruption (geological) and those from typhoon-associated hazards (meteorological)—a direct consequence of its location at the southwestern slopes of the volcano. Their major experience of the eruption of Mt. Mayon was in 2018 and was raised to Alert Level 4, which means hazardous eruption may be possible within days and the danger zone may be extended to 8 kilometers (Phivolcs, 2018). The eruption in 2014 was up to Alert Level 3 (High level of volcanic unrest) and around 60-65 families living inside the permanent danger zone were regularly evacuated. The barangay and multi-purpose halls are in the 6-8km extended danger zone and must likewise be vacated during volcanic unrest.

Barangay Quirangay and other Mt. Mayon-unit barangays,were heavily affected by eruptions and their combined effects with other hazards exacerbated their vulnerabilities. The destruction caused by Typhoon Reming (a landmark disaster event across various communities in the watershed) and the lahar deposits by earlier eruptions by Mt. Mayon caused severe impacts (Scott, 2010; Orense and Ikeda, 2007). These authors described how wide swaths of rice fields, houses, and roads have been buried in debris, leaving around 1,100 people dead in the Bicol Region. Waterways were also filled to the banks and the flowing lahar was forced to re-route causing additional damage (Orense and Ikeda, 2007).

Vulnerability Assessment

Table 3: Vulnerability Assessment for Barangay Quirangay, Camalig (across all sectors).

Hazard	Threat Level	Adaptive Capacity	Vulnerability
Geological	4	3.5	1.14
Meteorological	4	3.67	1.09

For their threat level assessment, a self-assessment score of 4 (High) for both geologic (volcanic unrest) and meteorological (typhoon-associated hazards) was obtained because of the amount of area and people affected by these events. They shared that the heavy rainfall caused by typhoons affects 50-60% of their crops along the slopes and gullies of Mt. Mayon. The same volcanic activity would severely affect the crops and burn under a blanket of ash. In addition to the restrictions imposed by the municipal and provincial governments on the 6-km permanent danger zone prohibiting access to their farm lots – a significant effect on their primarily agricultural livelihood of crops such as sitaw (*Vigna unguiculata* ssp. *sesquipedalis*), apay (*Colocasia esculenta*), labanos (*Raphanus sativus*), ampalaya (*Momordica charantia*), and sayote (*Sechium edule*) as the upper slopes of Mt. Mayon are conducive for vegetable plantation due to its cooler climate. The moderate adaptive capacity of Barangay Quirangay was due to its low scores in wealth (3), technology (2), and infrastructure (3). The barangay has limited funds for DRRM activities and equipment and depends on the Municipal DRRMO for assistance. They have no vehicles and only have flashlights and whistles as equipment for the barangay security force. The barangay and multi-purpose halls are the only structures they can use, and the lack of water services remains a challenge. Very few NGOs also aid during troubled times - and only two were identified: Simon of Cyrene, which provides psychosocial training and support for person with disabilities (PWD) concerns, and Sunwest Care Foundation. Conversely, they have very high (5) scores for institutions and information. The Barangay Disaster Risk Reduction and Management Committee was given a commendation by the Camalig MDRRMO for their "moderate/progressive functionality" as a testament to their institutional commitment to DRRM. They also strive to go house-to-house to disseminate relevant and timely information.

Considering their high threat level and moderate adaptive capacity, Barangay Quirangay has a medium-low vulnerability score for both geological (1.14) and meteorological (1.09) hazards (Table 3).

Cascading Impact Diagram

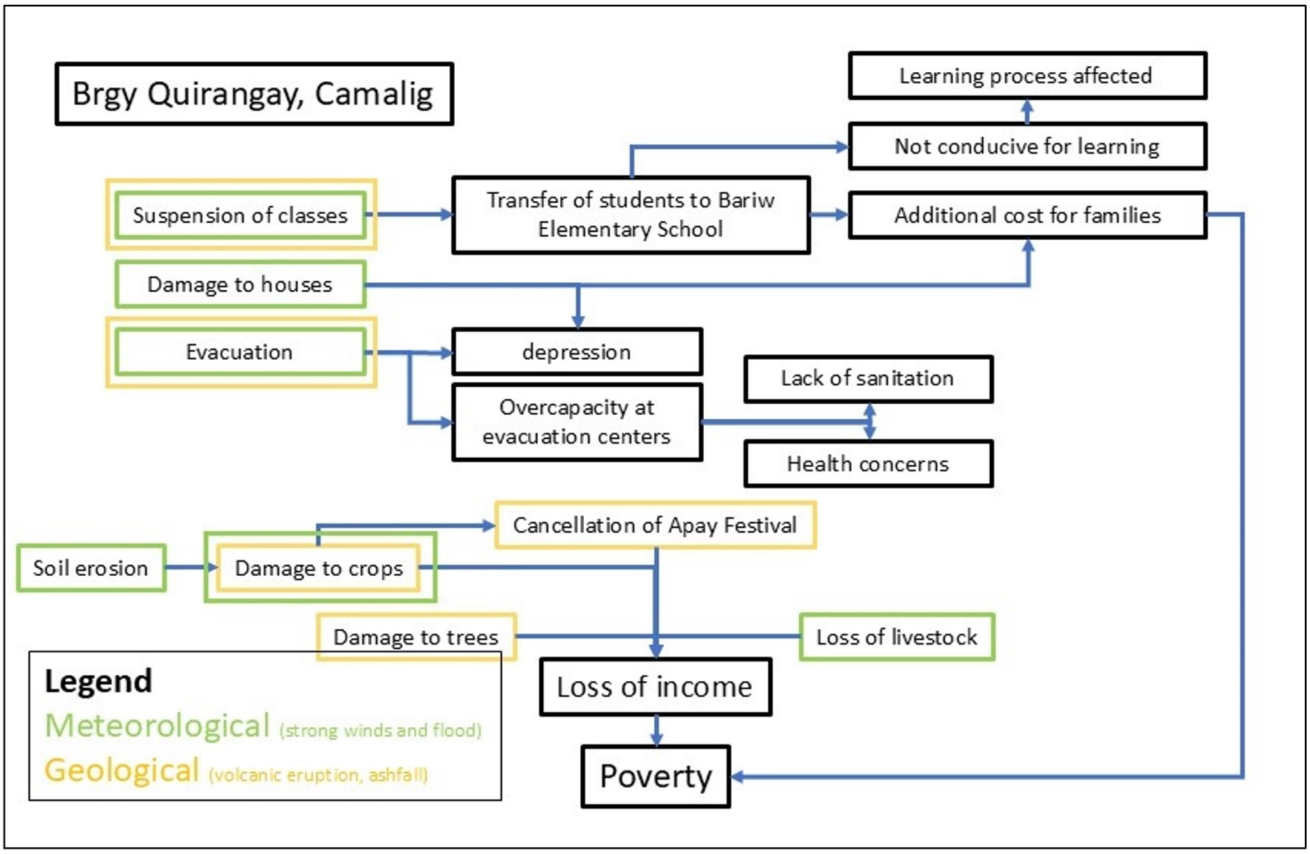

Figure 4: Cascading Impact Diagram for Barangay Quirangay, Camalig.

The participants shared that the Mt. Mayon eruption severely affected their livelihood, being a primarily agricultural barangay, causing damage to their livestock and crops. The negative consequences on their income may further lead to poverty and recovery may take years. Also, the damage to the *apay* (taro) crops would lead to the cancellation of their annual Apay Festival, an alternative income source for the community. Quarrying operations, in part, cause the loss of tree cover in the upper slopes, leading to increased soil erosion due to floodwater. The eroded soils would be deposited in their downstream vegetable plantations, rendering their fields untenable which eventually lead to losses in livelihood, and ultimately, poverty.

The process of evacuation varies depending on the imminent hazard. The main evacuation site for typhoons is the Camalig North Central School, and the site will receive decampment orders within 24-48 hours once the situation is clear. However, the evacuation encampment for volcanic unrest can take three to six months at Bariw Elementary and National High School. As part of the Camalig Contingency Plan, classes in make-shift tents are set up on the school grounds to ensure continuity of learning, but residents question the conduciveness of this arrangement. A participant shared how the municipal/city government has been very supportive in aiding the barangays. A change in the environment and poor sanitation (due to insufficient comfort rooms) have become health concerns in the evacuation centers. In this situation, lack of supplies and medicines due to limited budget becomes apparent. Despite this, some participants resisted relocation based on previous experiences where they were unable to find livelihood in their new homes, causing their eventual abandonment. For both hazards, damage to properties causes psychosocial health problems such as stress, anxiety, and even depression.

Barangay Pandan, Ligao City

The hazards identified by respondents in this area were meteorological (typhoon and flood) and COVID-19. Typhoons are atmospheric phenomenon often described as an "organized system of clouds" with low-level circulation and formed when warm tropical waters are present (National Ocean Service, 2024). The World Health Organization (n.d.) also considers typhoons a weather phenomenon. However, typhoons are considered the source of various typhoon-associated hazards such as strong winds, storm surges, flooding, and tornadoes (National Oceanic and Atmospheric Administration (2023). These associated hazards are the reason why typhoons are considered a hazard despite being an atmospheric phenomenon. In this case, the paper treats "Typhoon" as strong winds as typhoons are also considered an "extreme wind event" by the International Group for Wind-related Disaster Risk Reduction (2013) in Japan. Likewise, Typhoon Reming is the most destructive typhoon they have experienced, which also brought massive flooding in their barangay, and a similar experience with the passage of Typhoon Rolly in 2020. These events were exacerbated by their location between the Kitanglad and Cabilugan rivers and near an unnamed lake that overflows during similar events. These water bodies, despite the threat they possess, are an important source of irrigation. The barangay also has an isolation facility where residents from Manila are isolated.

Vulnerability Assessment

Table 4: Vulnerability Scores for Barangay Pandan, Ligao City.

Hazard	Threat Level	Adaptive Capacity (Economic Sector)	Vulnerability
Strong Winds	3	4.33	0.69
Flood	4	3.67	1.09
COVID	2	2.83	0.71
Hazard	**Threat Level**	**Adaptive Capacity (People Sector)**	**Vulnerability**
Strong Winds	3	3.33	0.90
Flood	4	5	0.80
COVID	2	4.17	0.48
Hazard	**Threat Level**	**Adaptive Capacity (Environment Sector)**	**Vulnerability**
Strong Winds	3	3.5	0.86
Flood	4	-	-
COVID	2	4	0.50

In Barangays Quirangay and Buga, their vulnerability assessment covered all three sectors (social, economic, and environment), citing similarities among them. For Barangay Pandan, they shared that the vulnerabilities among these sectors vary and warrant separate assessments. Table 4 summarizes their relative vulnerability assessments.

For threat level self-assessment, they were most sensitive to floods with a score of four (4 – medium-high) compared to strong winds (3 – medium) and COVID-19 (2 – medium-low). This reflects their location along major waterways, and the floodwaters can be chest-deep. Similar scores were given across sectors. Their adaptive capacity scores per sector varied greatly – reflecting the different levels of hazard responses. They scored lowest for the wealth factor for the economic sector, an ironic result, and the highest were in the institution and information factors. In the social sector, the infrastructure factor was the lowest, and information was also the highest. For the environment sector, all the factors got the same score of four (4 – medium-high) except for the infrastructure factor, which got a score of 1. The community provided no adaptive capacity score for the environment sector. These scores reflect the diverse strengths and weaknesses of the sectors to adapt to the hazards properly.

Given the moderate scores of their self-assessed threat level and adaptive capacity scores, the communities in Barangay Pandan have a vulnerability score of low (less than 1), except for the economic sector during flooding events, which has a score within the medium-low range.

Cascading Impact Diagram

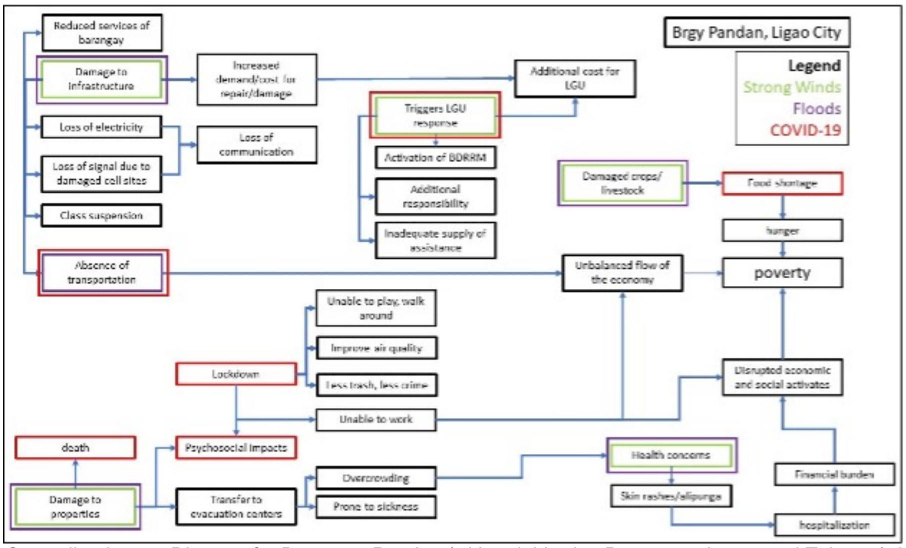

Figure 5: Cascading Impact Diagram for Barangay Pandan (with neighboring Barangays Layon and Tuburan), Ligao City.

The impact chain diagram in Barangay Pandan showed a diverse set of impacts that can be triggered from a single hazard and can be exacerbated when occurring in a multi-event scenario. For strong winds, the primary impacts are health concerns and damage to properties, infrastructure, crops, and livestock. Floods have similar primary impacts with strong winds, with the absence of public transportation (due to the inaccessibility of flooded roads). Unique primary impacts of COVID-19 are deaths, psychosocial impacts, food shortage, and lockdowns—showing that more than the virus itself, the policies and restrictions in response to the pandemic have a profound impact on the communities of Barangay Pandan. These primary impacts would eventually cascade across the diagram, most ending in poverty—reflecting the poor wealth factor in their adaptive capacity assessment score.

Barangay Buga, Municipality of Libon

The hazards in Barangay Buga in Libon were categorized into three: Meteorological (typhoon-associated hazards), Geological (eruption-related hazards), and Biological (COVID-19), with the first category being the most significant of the three. Unlike the two previous barangays, their location relatively far from Mt. Mayon made eruption-related hazards less significant than other hazards. According to the FGD participants, ashfall only affects the barangay when the westward wind carries the ash in their general direction. They said that it was the main eruption-related hazard they experienced. Located on the downstream portion of the Quinali A Watershed, their adjacent position to Lake Bato meant that they were sandwiched by two sources of floodwater. The local stakeholders shared that their barangay, together with Barangays Nogpo and Sta. Cruz, is usually the last to receive evacuation decampment orders from the Municipal DRRMO since their community is still flooded with the backflow of water from Lake Bato. In addition, the lake's capacity to hold water has been compromised over the years due to siltation, which could be a contributing cause for the backflow of water. As for COVID-19, the virus itself is of great concern, but the restrictions and responses to it were also found to be a significant stressor due to its negative impacts on the community.

Vulnerability Assessment

Table 5: Vulnerability Assessment for Barangay Buga, Libon (across all sectors).

Hazard	Threat Level	Adaptive Capacity	Vulnerability
Meteorological	5	4	1.25
Geological	5	2.83	1.78
COVID-19	5	3.5	1.43

For meteorological hazards, the FGD participants gave a score of five (5) for threat level since a significant portion of their community was affected due to the previously mentioned proximity to the lake and other waterways and the narrow drainage canals clogged by debris. Although ashfall was of little concern, they gave a threat level of five (5) for this hazard because of its effect on their crops (where the majority of their income comes from), if it does occur. A similar score was given to COVID-19.

For adaptive capacity assessment, the element with the lowest scores is related to wealth and technology—especially for geological hazards, where they gave their community a score of one (1) due to the limited budget earmarked for mitigation and response to it. The available technological tools in the barangay were a radio, one computer set, and a printer. This implies that they might have difficulty in complying with tight report deadlines. As for COVID-19, they allocated funds for relief and assistance due to a re-alignment in their annual budget. A score of five (5) was given for all hazards for information since a system was already in place in their barangay. A similar score was also given for social capital due to the swift response of the Municipal DRRMO to provide assistance, as well as a number of NGOs.

Both the meteorological and COVID-19 hazards got relative vulnerability scores within the medium-low range (1.25 and 1.43, respectively). The score for the geological hazard was in the medium range at 1.78, which can be attributed to their low adaptive capacity score (2.83 / 5.00), where much of their resources were devoted to DRRM efforts in the previous two hazards.

Cascading Impact Diagram

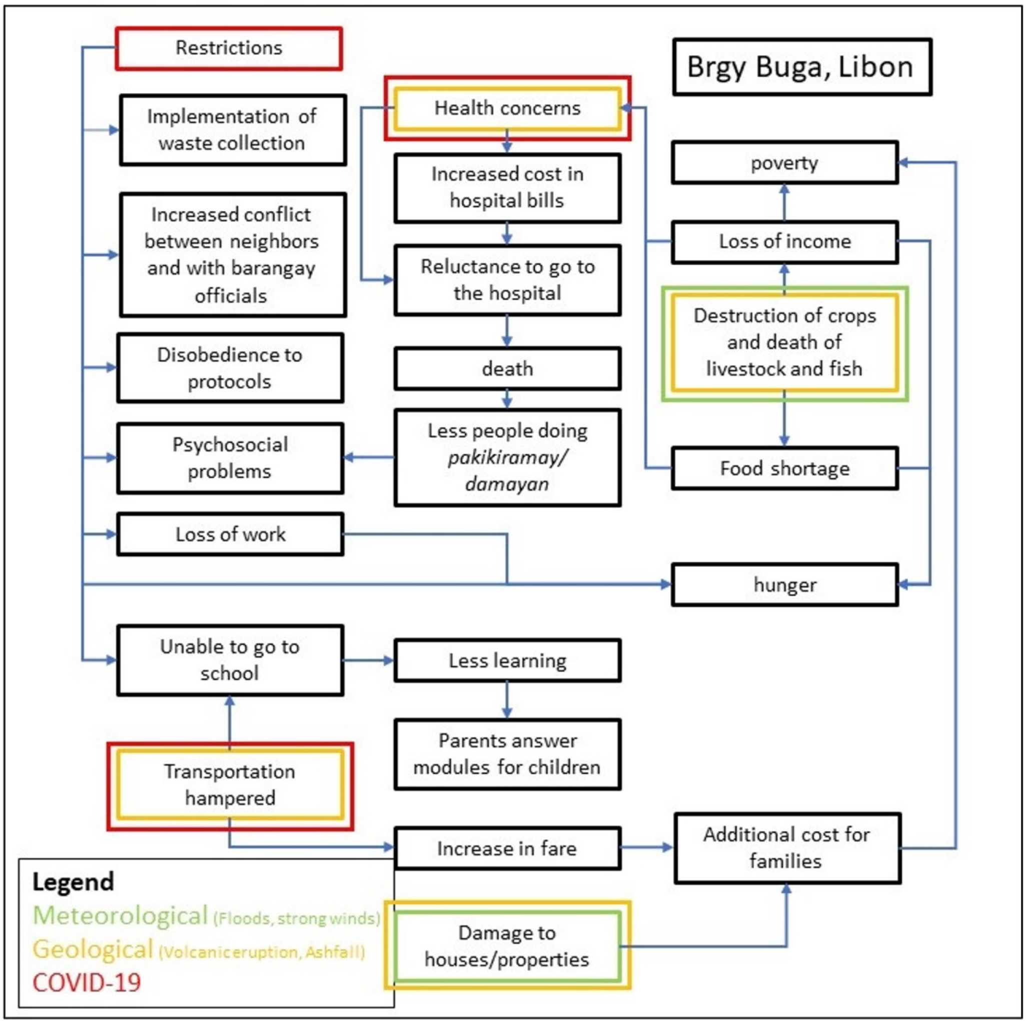

Figure 6: Cascading Impact Diagram for Barangay Buga, Municipality of Libon.

Meteorological and geological hazards can wipe out agricultural and aquatic products, leading to food shortages and dependency on canned goods and government assistance. This devastation would lead to tightened spending in the community dependent on these agricultural products. The food shortage may eventually lead to health problems such as a lack of nutrition, and hunger. Together with damaged houses, additional financial burdens for families would eventually plunge the community into poverty.

Ash from Mt. Mayon eruptions puts children and elderly people at risk from allergies and asthma and contaminates drinking water sources. COVID-19 has put restrictions and policies in place to prevent its spread. Concerns related to restrictions include the cost associated with hospitalization, fear of being cremated immediately after death, and the altered practice of mourning for the dead who were afflicted by the virus. Such gloomy days of grief resulted in psychosocial problems where the comfort provided by a sense of community was absent.

Due to strict mobility protocols, the COVID-19 response also scaled back the implementation of the barangay's waste collection system. Conflicts and disagreements on the implementation of the restrictions also took place. A handful of community members refused to follow health protocols such as physical distancing, use of face masks, and quarantine measures. They complained that strict rules drove them towards hunger with meager assistance. As an effect of the restrictions, some employees were laid off from work, further adding to the collective stress of the time. Restrictions on physical classes affected how students learn, caused by the transition to modular learning. Limitations in mobility have resulted in higher fare prices; thus, some opted to walk instead.

Discussion

The vulnerability assessment and cascading impact diagrams used in the three case studies fulfilled the paper's objective of analyzing cascading impacts in a multi-hazard scenario. The diagrams, created through participatory approaches, illustrated how multi-hazard events can generate cascading effects that follow similar paths, often converging on a common final or near-final impact. This characteristic of cascading impacts—and the vulnerabilities it exacerbates—has important anticipatory implications (Cutter, 2018; Pescaroli & Alexander, 2018; Schauwecker et al., 2019; Habacon, 2022). Such insights can inform future adaptation strategies aimed at reducing risks to affected communities and may offer broader applicability when replicated in other regions across the country.

While the analysis of cascading impacts in this paper revolved around the cases of three barangays, cascading impacts are known to respect no boundaries, and their impacts cut across space and scale (Schauwecker et al., 2019). The recognition of cross-scale dynamics is crucial for effective mitigation and response. These cross-scale challenges can be solved through proper institutional interplay, effective co-management schemes, and the maintenance of strong boundary organizations (Cash et al., 2006). Despite this, analysis focusing on lower spatial and jurisdictional scales has profound benefits in bringing to the fore impacts that may have been diluted up the scales. Additionally, various geographic scales are not discrete systems but are rather interconnected (Department of Geography Pennsylvania State University, n.d.)

Among the three barangays, common themes in their vulnerability assessment are: 1) the lack of funds and budget allocation (wealth factor); 2) the crucial role of critical infrastructure; and 3) the importance of social infrastructure to respond to these hazards, which increases their vulnerabilities.

Barangay Buga has no allotted budget for geologic hazards due to its considerable distance from Mt. Mayon However, its ashfall has had a significant historical effect on their agricultural livelihoods based on the cascading impact diagram. This insufficient funding, in turn, creates its own cascading impact in the form of technological, infrastructural, and informational gaps in these barangays—since they cannot procure the necessary items for effective DRRM. Most of these funds are generated at the municipal/city and provincial level through tax and non-tax sources or the internal revenue allotment (Resuello, 2020). The same study found that provinces and municipalities mostly depend on the internal revenue allotment (IRA) and that disaster incidents significantly negatively impact overall local revenue—which was confirmed through interviews with LGUs where real property taxes dip succeeding a disastrous event. Budgetary limits have been a concern as early as the late 1970s when the supposed construction of *sabo* infrastructure was deferred to 1984 in the wake of another Mt. Mayon eruption (Scott, 2010). Sabo structures are built to control debris flow and have been found to be useful in effectively routing lahar flows on volcanic slopes (Purwantoro et al., 2020; Kunitomo, 2003). Therefore, efficient revenue generation of LGUs is desired to improve these barangay's technological and infrastructural DRRM support and to spare the people from using their own resources during disasters (Resuello, 2020; Habacon, 2022). Despite the insufficient funds they are facing, the barangay and municipal/city institutions have found ways to alleviate the cascading impacts of a multi-hazard as Albay is known for its robust DRRM Network headed by the Albay Public Safety and Emergency Management Office (APSEMO) and supported by the Local DRRM Officers through the Local Association of DRRMOs in Albay (LADA).

The role of critical infrastructure has been highlighted in literature, as it prevents further exacerbation of cascading impacts. The three diagrams above identified the following critical infrastructure: hospitals and health centers, transportation networks, government and institutional buildings, evacuation centers, schools, food storage areas, and flood control structures. Hospitals and health centers have found a particularly crucial role during the COVID-19 pandemic and were subjected to further stress during the simultaneous occurrence of other hazards. Schools and evacuation centers are also burdened, as the former also doubles as the latter. Powerlines and communication links represent a critical infrastructure that hampers a significant portion of disaster response. This focus on critical structure has permeated into the mindset of the communities as most of the adaptation measures they have suggested are physical structures such as flood control dikes and other *sabo* infrastructure (Scott, 2010), construction of more evacuation centers, post-harvest facilities, vehicles, and isolation facilities, among others. However, physical adaptation measures respond and/or aim to adapt communities to the physical aspects of hazards.

The literature, and the impact chain diagrams findings have proven that these hazards have cascading impacts on human systems where critical social infrastructure should be in place effectively mitigate and respond to such cascading impacts. Among the social infrastructures recommended by the communities were instilling proper waste segregation, information dissemination, and strengthening the education sector in the field of DRRM. In addition, LGUs should also focus on rapid information dissemination and information consolidation. This ensures that swift and decisive actions can be implemented during a multi-hazard event to prevent cascading impacts of hazards and ensure more effective response from the government institutions (Galaz et al., 2011).

CONCLUSION AND RECOMMENDATIONS

This paper has initially assessed the cascading impacts of a multi-hazard scenario of three selected barangays in the Quinali A Watershed. This visualization of cascading impacts using qualitative and participatory approaches has proven anticipatory value that would allow local government units to anticipate possible impacts on human systems resulting from initial triggers. With the multitude of hazards and cascading impacts identified, it was no surprise that Albay was described as a "Disaster Paradise" by one local stakeholder.

From the cascading impact diagrams, common trigger points have been identified that typically lead to cascading impacts: destruction of houses or properties (relating to infrastructure), loss of crops or livestock (pertaining to livelihood), and effects on children's education (class suspension, use of modules, less learning). The third impact has implications for securing a brighter future for the next generation, as education is often seen as a ticket to better opportunities in life, whereas the first two involve apparent loss and damage. The psycho-social effects of hazards are a common impact in the three barangays but are usually less addressed in terms of CCA and DRRM planning in the Philippines. Although this impact was diagrammatically represented as a "cul-de-sac," disaster mental health may have effects beyond the duration of the hazards. These four trigger points warrant swift and immediate attention from local government units and national government agencies through 1) Provide adequate resources up to the barangay level to address the possible cascading impacts of hazards; 2) Create an enabling environment for the establishment of people's organizations and non-government organizations; 3) Capacitate the same organizations and barangay officials to become partners in DRRM as frontline responders; 4) Conduct a robust information and dissemination campaign on DRRM focused on multi-hazards and cascading impacts on communities; and 5) Addressing the root causes of vulnerabilities by decreasing their sensitivities and increasing their adaptive capacities to ensure the prevention of the cascading impacts of multi-hazards.

The paper also represents an early attempt to explore multi-hazards and cascading impacts at the community level. The methods used in this study are replicable in other areas where multiple hazards are known to occur. Since the paper demonstrated the use of qualitative methods to create cascading impact diagrams, further studies may opt to use quantitative methods to create quantitative impact diagrams.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

CONTRIBUTIONS OF INDIVIDUAL AUTHORS

SINGSON, KVR: Paper outline, Draft manuscript, Data-gathering, Data processing and analysis
PULHIN, JM: Project Leader, Manuscript edits, Data-gathering
VILLAMAYOR, MT: Draft manuscript, Manuscript edits, data-gathering, Data processing and analysis
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