Health Risk Assessment of Residents in Disaster-Prone Areas in the Province of Bukidnon

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Abstract

The increasing incidence of calamity calls for the development of modeling and prediction indicators to assess the impact of disaster on health. The study evaluated the health risk of residents through the development and validation of the DRR mathematical model for health in disaster-prone areas in the Province of Bukidnon. The model measured the extent of the hazard, exposure, vulnerabilities, adaptive capacity, and disaster risk reduction of residents affected by the disaster. This study focused on five disaster-prone barangays in Bukidnon. Using the mixed-method design, results revealed that themes and derived meanings from literature created qualitative risk estimation and disaster risk reduction model for health. The DRR parameter was found to be consistent with the observations conducted in various barangays in Bukidnon. The application of DRR model revealed that Barangay Batangan has the highest risk reduction despite having the highest magnitude of risk among the five barangays.

Keywords: Disaster, hazard, vulnerability, exposure, capacity, disaster risk reduction

Introduction

An increasing interest in combating disasters is prioritized globally. In the past two decades, an average of more than 200 million people has been affected every year by disasters (ISDR, 2007). The growing vulnerabilities related to changing demographic, technological and socio-economic conditions, unplanned urbanization, development within high-risk zones, environmental degradation, climate change, and the impact of epidemics point to a future where disasters could increasingly threaten the world’s population and its development. This threat seems to be real in the local setting, especially in Bukidnon Province, where the incident of disaster is evident. With that in mind, it is needed to have an in-depth understanding of disaster to grasp further the reduction of risk and its effects as a whole in the local setting.

Various studies have a collective meaning of disaster and have contextualized it according to its application and incidence. WHO (2007) defined disaster as a serious disruption of the functioning of a community, causing widespread losses that exceed the ability to cope using its resources. The Delhi Central Board of Secondary Education (2006) identified three essential combinations for a calamity to occur: hazard, vulnerability, and insufficient capacity to reduce the probable chances of risk. Conversely, UNISDR (2019) averred that calamity could be reduced by decreasing exposure to hazards, lessening vulnerability of people and property, wise management of land and the environment, and improving preparedness and early warning for adverse events. Also, Aitsi-Selmi, Egawa, Sasaki, Wannous, and Murray (2015) observed that the progress in disaster risk reduction (DRR) is often not the hazard that determines a disaster, but the vulnerability, exposure, and
ability of the population to anticipate, respond to, and recover from its effects.

In detail, the main components that consequently relate to the discussion of disaster are risk, hazard, exposure, vulnerability, capacity, and disaster risk reduction. Predominantly, the risk is the probability of harmful consequences or expected losses resulting from interactions between natural or human-induced hazards and vulnerability (WHO, 2007), while hazard is mathematically expressed as the probability of occurrence of a threatening event (NEDA, 2008). Similarly, Mainstreaming Disaster Risk Reduction in Subnational Development and Land Use/Physical Planning (2008) stated that vulnerability is mathematically measured as the proportion of damage expected from exposure to hazards and expressed on a scale of 0 to 100 percent damage. On the other hand, capacity is the resources, means, and strengths which exist in communities to enable them to cope with, prevent, mitigate, or quickly recover from a disaster (Delhi Central Board of Secondary Education, 2006). UNISDR (2019) further added the definition of disaster risk reduction as a concept and practice of reducing disaster risks through systematic efforts to analyze and reduce the causal factors of disasters. Harmonizing above stated ideas they are expressed as:

\[
(1) \text{Disaster (IFRC)} = \frac{(\text{Vulnerability} + \text{Hazard})}{\text{Capacity}}
\]

The abovementioned literature is evident in the International Federation of Red Cross (2019) definition, stating that disaster is the combination of hazard and vulnerability over the inability to reduce the potential negative consequences of risk. However, there are several ways by which disaster (1) can be computed by complementing various literature cited.

The computation of disaster and DRR for this study focuses on risk, hazard, vulnerability, and adaptive capacity vis-à-vis its effects on health. This goal is consistent with the UNISDR (2007) call for the development of a system of indicators of disaster risk and vulnerability that will enable decision-makers to assess the impact of disasters. Further, UNISDR (2007) encourages the improvement of scientific and technical methods and capacities for risk assessment, monitoring, and early warning through research, hazard modeling, and prediction. These observations see the need for a development of DRR-related modeling and prediction for health.

In light of this reality, the Mainstreaming Disaster Risk Reduction in Subnational Development and Land Use/Physical Planning in the Philippines (2008) made a mathematical tool to identify areas of high risks and indicate how a disaster affects the economy as a whole. Yet, the computation is limited to fatalities, the cost of property loss or damage, usually under a direct cost category. This calculation does not cover the indirect costs in the risk estimation and assessment like nondelivery of vital health services and other activities. Up to the present, there is still limited to no computation that looks into the effects of the disaster on one's health.

Moreover, the traditional focus of the healthcare sector has been on the response to disaster emergencies. The challenge is to widen the focus of disaster risk management for health from that of response and recovery to a more proactive approach emphasizing prevention and mitigation, and the development of community capacities to provide a timely and effective response and recovery (UNISDR, 2009). This finding supports the Sendai Framework for Disaster Risk Reduction 2015-2030 (SFDRR), stipulating the need to ensure DRR collaboration among all sectors, including the health sector, to prevent, prepare for, respond to, and recover from disasters (Aitsi-Selmi et al., 2015). The formulation of DRR-health algorithm can be helpful in calculating the probability of disaster in a given locale.

Specifically, the DRR-health mathematical model may be used to assess the health risk of people exposed to disaster. The model also measures the extent of the hazard, exposure, vulnerabilities, and adaptive capacity of
residents affected by the disaster. Overall, the mathematical model intends to prepare the communities when disaster strikes, making them resilient, thereby saving more lives.

**Objectives**

The study aimed to conduct Health Risk Assessment and Disaster Risk Reduction (DRR) modeling and prediction to disaster-prone areas in Bukidnon. Specifically, the study sought to develop DRR mathematical model for health; and validate DRR-Health mathematical model in terms of risk, adaptive capacity, and DRR of the identified barangays.

**Conceptual Framework**

This investigation anchors on the three (3) global and national agenda produced namely, the Sustainable Development Goals (SDGs), the Sendai Framework for Disaster Risk Reduction 2015-2030, and Mainstreaming Disaster Risk Reduction in Subnational Development and Land Use/Physical Planning in the Philippines (2008).

The SDG goals specifically item 13 on climate change aims to take urgent action to combat climate change and its impacts. In the said SDG it targets on: strengthening resilience and adaptive capacity to climate-related hazards and natural disasters in all countries; integration of climate change measures into national policies, strategies and planning; improvement of education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning; and promotion of mechanisms for raising ability for concrete climate change-related planning and management in the least developed countries (UN Climate Change Secretariat, 2017). These SDGs address disaster-related impacts.

Also, the Sendai Framework solidifies the paradigm shift from managing disasters to managing current and future risks, bringing in resilience-building as the core target to be reached by 2030 (UN Climate Change Secretariat, 2017). There are four priorities of action according to the framework; these are understanding disaster risk, strengthening disaster risk governance, investing in resilience, and enhancing and leveraging disaster preparedness. Together, these four priorities aim for “the substantial reduction of disaster risk and losses in lives, livelihoods, and health in the economic, physical, social, cultural and environmental assets of persons, businesses, communities, and countries (UN General Assembly, 2017). The Sendai Framework is the first disaster risk reduction framework to include specific targets against which progress can be measured. By using these indicators, countries will be able to quantify their efforts to reduce disaster losses by 2030, including mortality, numbers of people affected, economic losses and damage to critical infrastructures such as water, transportation, telecommunications, schools, and hospitals. These indicators ensure coherence with the measurement of progress towards relevant targets of the SDGs. The target-based nature of the framework is closely related to the SDGs, with the possibility of setting customizable indicators tailored to the specific circumstances of each country and creating an opportunity for more coherence with other relevant policy priorities such as adaptation (UN Climate Change Secretariat, 2017).

Locally, the Philippines has created a tool to enhance subnational (regional and provincial) planning analyses by recognizing risks posed by natural hazards. The Mainstreaming Disaster Risk Reduction in Subnational Development and Land Use/Physical Planning (2008) highlights the use of development criteria or indicators as measures to identify and describe vulnerability (or resilience). Also, guidelines created a unique feature, which is the development of methodologies for risk estimation and valuation. The use of the said disaster risk assessment is seen as an essential tool in the planning analysis, as risk estimates provide prioritization of areas for further evaluation of vulnerability. Figure 1 illustrates the integration of concepts in the conceptualization of this paper.
Based on the said agenda, there are three main concepts drawn: disaster integration, understanding risk, and action (DUrA). In disaster integration, the notion strongly emphasized the assimilation of disaster concepts in various policies, planning, and management from global to local levels. This observation means that disaster management has to be integrated not only at the international and national level but importantly, in the barangay level, ensuring accessibility of various services, specifically health-related services at the grassroots. In terms of understanding risk, it strongly recommended the implementation of several activities such as the development of criteria and indicators, measuring vulnerability or resilience, risk estimation and valuation, education, and awareness-raising. These activities were the core of this study since it aimed to develop an assessment tool to assess the health risk of residents prone to disaster.

The DUrA concepts evaluate the risk assessment of the locale. Risk assessment, in turn, requires information on the three components: hazards (H), elements at risk/exposure (E), and vulnerability (V). Figure 1 shows the interplay of the HEV of risk. The idea of risk connotes losses and negative impacts of disasters and calamities. It involves the related notions of exposure (E), hazard (H), and vulnerability (V) about the general framework for disaster risk. These elements are relative to the HEVAC Model of Padua (2014), stating that communities are at risk if hazard, exposure, and vulnerability are present. Further, the model stressed that there is reduction of risk when there is sufficient adaptive capacity.

Armed with this information, any activity, resources, and means focused on reducing risk is disaster risk reduction (DRR). Disaster risk reduction (DRR), therefore, is to lessen the interaction between the H, E, and V in an affected community. In simple terms hypothetically, if exposed population (E) transfers to areas that are less hazardous (H); if community experienced more disaster related morbidity and mortality (V), then, disaster can be reduced to a minimal number.

**Methodology**

The study utilized a mixed-method using both qualitative and quantitative research approaches. Explicitly, the development of a DRR mathematical model for health used in-depth analysis. The gathered studies and literature created themes and concepts in the formulation of health DRR mathematical model. Also, the study utilized the Delphi method, consulted five experts in the formulation of the mathematical model. The experts were consultants in the field.

*Figure 1. Schematic diagram showing the parameters of the study.*
of mathematics, statistics, health, research, and disaster risk reduction. The conduct of actual observation and interview with focal groups were part of the study for validation of the mathematical model.

Research Design and Data Collection

This exploratory type of research has investigated the effect of the calamity on health looking into the elements at risk, the presence of a hazard, and the vulnerability of the barangay. Specifically, health indicators examined in the study were morbidity and mortality occurrence related to disaster, and the inclusion of health resources and health capacity. Also, the study looks into the adaptive capacity and the probability of disaster risk reduction in selected disaster-prone areas in Bukidnon. The DRR mathematical model for health was used to assess the risk, adaptive capacity, and disaster risk reduction of the affected areas.

Research Site

The study was conducted in flood and landslide-prone areas in Bukidnon. The identified areas were: Barangay Guihean of Impasug-ong, Barangay Aglayan of Malaybalay; Barangay Batangan of Valencia; Barangay Magsaysay of Kibawe, and Barangay Palacapao of Quezon. These barangays were found to be affected by disaster as seen in various literature (Medina & Arche, 2015; Madera, 2018; Veracruz, Garcia, Pagaduan, Gasmen, Razon, & Gases, 2017).

Respondents of the Study

In the application of the mathematical model, the respondents of the study were DRR focal persons, barangay health workers, and barangay officials of the affected barangay. Inclusion criteria included the respondents who lived in the area for at least three years. Focus group discussions were conducted, and their responses validated the applicability of the mathematical model.

Research Instrument

A researcher-made questionnaire was constructed and validated through the Delphi method. The tool contained items that identify risk and adaptive capacity of selected barangay. In discovering the health risk, the questionnaire included three concepts, namely hazard, vulnerability, and exposure. The concept hazard identified the number of disaster occurrences per area and municipality. For vulnerability, the total number of morbidity and mortality related to disaster and the affected populations were identified, regardless of age and gender, as long as they were affected by disaster in a given community they were counted as part of the study. Lastly, the exposure looked into the number of people exposed/affected by the disaster.

In assessing the adaptive capacity, the questionnaire contained two concepts: efficiency and readiness. In terms of efficiency, it identified the number of disaster-related training per year, including the number of participants who were requested to attend and who attended and responded to the seminar. On readiness, the questionnaire contained two factors, namely: health resources and health capacity.

Results and Discussion

Development of DRR mathematical model for health

The systematic reviews from different published literature and studies produced significant themes describing and demonstrating the disaster risk reduction mathematical model especially for health. Table 1 illustrates the concepts/themes that emerged from the related literature search, and its corresponding derived meanings.
Table 1.
Significant Statements and Corresponding Formulated Meanings and Themes Emerging from related literature search

<table>
<thead>
<tr>
<th>Concept</th>
<th>Theme</th>
<th>Derived Meaning</th>
<th>Study &amp; Author/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disaster risk</td>
<td>Adaptive capacity</td>
<td>The presence of risk and insufficient capacity leading to potentially negative consequences</td>
<td>International Federation of Red Cross, 2019</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>WHO, 2002</td>
</tr>
<tr>
<td></td>
<td>Vulnerability</td>
<td>Probability of occurrence of threatening events over time in a given area</td>
<td>NEDA, 2008</td>
</tr>
<tr>
<td></td>
<td>exposure</td>
<td></td>
<td>UNDRR, 2015</td>
</tr>
<tr>
<td></td>
<td>occurrence</td>
<td></td>
<td>World Meteorological Organization, 2014</td>
</tr>
<tr>
<td>Hazard</td>
<td>Probability</td>
<td>Probability of occurrence of threatening events over time in a given area</td>
<td>NEDA, 2008</td>
</tr>
<tr>
<td></td>
<td>occurrence of threatening event</td>
<td></td>
<td>UNISDR, 2004</td>
</tr>
<tr>
<td></td>
<td>time scale</td>
<td></td>
<td>NEDA, 2008</td>
</tr>
<tr>
<td></td>
<td>area</td>
<td></td>
<td>UNISDR, 2004</td>
</tr>
<tr>
<td></td>
<td>percentage of loss</td>
<td>Mathematically expressed as the percentage of loss (death, injury, illness) resulting from a threatening event over time in a given area</td>
<td>NEDA, 2008</td>
</tr>
<tr>
<td></td>
<td>time scale</td>
<td></td>
<td>UNISDR, 2004</td>
</tr>
<tr>
<td></td>
<td>area</td>
<td></td>
<td>NEDA, 2008</td>
</tr>
<tr>
<td>Exposure</td>
<td>Population</td>
<td>The population exposed to hazard in a period of time and area</td>
<td>NEDA, 2008</td>
</tr>
<tr>
<td></td>
<td>time scale</td>
<td></td>
<td>UNISDR, 2004</td>
</tr>
<tr>
<td>Disaster Risk</td>
<td>Risk</td>
<td>The ability to prepare, adapt, and reduce effects of risk.</td>
<td>Aitsi-Selmi, et. al. 2015</td>
</tr>
<tr>
<td>Reduction</td>
<td>Adaptive capacity</td>
<td></td>
<td>WHO, 2007</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>UNISDR, 2013</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>NEDA, 2008</td>
</tr>
<tr>
<td>Adaptive capacity</td>
<td>Readiness and preparedness</td>
<td>The readiness of community to prepare health resources and enhance barangay &amp; workers' health capacity, without wasting materials, time and energy</td>
<td>Birkmann, et.al, 2014)</td>
</tr>
<tr>
<td></td>
<td>Health resources</td>
<td></td>
<td>NEDA, 2008</td>
</tr>
<tr>
<td></td>
<td>Barangay capacity</td>
<td>The ability of the barangay and health workers to manage and respond to the effects of disaster</td>
<td>WHO, 2012</td>
</tr>
<tr>
<td></td>
<td>Health workers capacity</td>
<td></td>
<td>UNISDR, 2004</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>UNDRR, 2015</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>NDRRMC, 2013</td>
</tr>
</tbody>
</table>

The combined themes and derived meanings in Table 1 create qualitative risk estimation and disaster risk reduction computation. The computation considers the significant concepts as defined according to its usage in the paper. Specifically, disaster is the presence of risk and insufficient capacity leading to potentially destructive consequences. The derived meaning is consistent with the WHO’s (2002) definition of disaster, stating that it is a disruption of usual conditions of existence and causes a level of suffering that exceeds the capacity of adjustment of the affected community. In other words, for a disaster (1) to occur, the risk and insufficient
capacity must be present.

(1) Disaster = Risk + Insufficient Capacity

In terms of risk, the definition of WHO (2007) was considered and categorized as the probability of harmful consequence, or expected losses (death, injuries, livelihood, or environment damaged) resulting to interactions between hazards and vulnerability. However, the definition does not include elements of exposure, which according to the Mainstreaming Disaster Risk Reduction in Subnational Development and Land Use/Physical Planning (2008) should be part of the computation of risk. To harmonize the idea, the risk is, therefore, the probability of the intersection of hazard, vulnerability, and exposure, where:

\[
\text{Risk} = f (H \times V \times E_x)
\]

where:

- \(H\) = hazard
- \(V\) = vulnerability
- \(E_x\) = exposure

That risk (2) is the function of the product of hazard, vulnerability, and exposure. Risk is also dependent on the three elements; as one element increases, the risk also increases. This finding means that these three elements are directly proportional to risk.

To further understand risk, each of its elements was quantified based on the themes that emerged from the related literature search. In detail, in terms of hazard, NEDA (2008) mathematically expressed it as the probability of occurrence of a threatening event. These data further support the findings of UNDRR (2015), observing that hazards occur at different intensities/magnitude over different time scales. Overall, hazard (3) is the probability of the occurrence of threatening events over time in a given area. The data considers three themes, namely: Occurrence, Time, and Area.

\[H = \frac{\text{Total number of disaster occurrence in the Area for the past three years}}{\text{Total number of disaster occurrence for the past three years}}\]

Total number of disaster occurrence for the past three years

Vulnerability (V), on the other hand, is defined by NEDA (2008) as the degree of loss resulting from the potentially damaging events. Consistently, UNISDR (2004) sees vulnerability as the conditions determined by factors, which increases the susceptibility of a community to the impact of hazards in different times. In application, \(V\) (4) is the percentage of loss (mortality/death, morbidity/injury or illness) resulting from a threatening event over time in a given area. Key themes include Loss, Time Scale, and Area. Thus,

\[V = \frac{\text{Total number of morbidity& mortality related to disaster in a given area for the past three years}}{\text{Total number of affected population for the past three years}}\]

Total number of affected population for the past three years

In terms of elements of exposure (\(E_x\)), these are populations exposed to hazards in a given time and area. These are indirectly related to NEDA’s (2008) definition of exposed population in a given disaster prone area. However, since the risk is a probability, then, \(E_x\) (5) is expressed as the percentage of people exposed to hazard in a given time and area:

\[E_x = \frac{\text{Percentage of people exposed/affected by disaster in a given area for the past three years}}{\text{Total number of affected population for the past three years}}\]

Conversely, aside from the concept of disaster, various literatures have also identified ways to reduce the effects of calamity through preparation, adaptation, and reduction of risk. Disaster Risk Reduction is actions designed to lessen the distribution, intensity, or severity of hazards (WHO, 2007). Two themes emerged in DRR computation: risk and adaptive capacity, where risk is the combination of \(HE\). In contrast, adaptive capacity is the ability of the community to mitigate \(HE\).

The in-depth analysis showed literature identifying and recognizing adaptive capacity as a vital area in disaster risk reduction. Adaptive capacity is the ability of systems, institutions, humans, and other organisms to
adjust to potential damage, to take advantage of opportunities, or to respond and recover from consequences (Birkmann, Cardona, Carreño, Barbat, Pelling, Scheiderbauer, Kienberger, Keiler, Alexander, Zeil, & Welle, 2014). Adaptive capacity (6) is the readiness of the community to prepare health resources and enhance barangay and workers/volunteers' health capacity without wasting materials, time, and energy. Two ideas surfaced in the definition of adaptive capacity: readiness and efficiency. Thus,

\[ AC = RF \times E_f \]  

(6) where:

\[ RF = \text{Readiness Factor} \]
\[ E_f = \text{Efficiency} \]

Where, readiness includes preventative strategies, which involve making choices to avoid an event and impact-minimizing strategies, which seek to facilitate recovery (Jabeen et al., 2010). For a community to halt disaster, it should have resources and means that would prepare and prevent their locale from a catastrophe. In this study, there were two prior concepts concerning health readiness, namely: health resources and health capacity. To sum up, \textit{readiness} (7) is the percentage of preparedness of the community to the possible occurrence of disaster, expressed as:

\[ \text{Readiness Factor} = \delta_1 \times \delta_2 \]  

(7) Where:

\[ \delta_1 = \text{Health Resources} \]
\[ \delta_2 = \text{Health Capacity} \]

In terms of health resources readiness, there are two main concepts identified. One is the physical health resources, which refers to the material things/equipment and facilities available in a given barangay. Management health resources, on the other hand, refers to administrative resources that conduct, control, direct, guide, and handles the operation of the barangay before disaster strikes. Health Resources incorporates physical and management factors, where:

\[ \delta_1 = \text{Number of available health resources} \]
\[ \text{Total number of health resources (see Table 2)} \]

Based on Delphi and the literature review, there are six physical health resources that should be available in various communities as seen in Table 2. These include presence of barangay health center, availability of all essential disaster-related equipment, presence of evacuation centers, proportionate ratio of health responders to residents, presence of disaster-related supply system, and presence of communication system. Specifically, the essential disaster-related equipment are inflatable boats, megaphones including sirens and portable generator set, fire extinguisher, flood light, chainsaw, ax, ropes, ladder, breathing apparatus, flashlight and the like (NDRRMC, 2013). In terms of management health resources, four resources should be available. These resources include the presence of disaster plan, budget allocation for disaster-related activities, presence of hazard maps, and presence of early warning system such as

| Table 2.
| Extent of Availability of Health Resources of Community (Physical & Management) |
|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|

On the other hand, the health capacity readiness looks into the capacity of health workers and barangay in terms of managing disaster as seen in Table 3. Interview and literature search identified four essential ideas to assess health worker’s capacity, namely: health workers can manage disaster-related diseases like diarrhea,
leptospirosis, skin diseases and other disaster-related illness. In addition, evaluation of the health capacity readiness includes: Healthcare workers can perform first aid procedures, presence of responders with updated training, and presence of volunteers. There were also six vital concepts to assess the barangay’s disaster health capacity. This includes regular disaster-related capacity building activities, presence of public-private partnership, awareness of the barangay’s disaster focal person, presence of comprehensive disaster-related data/record, and presence of disaster task force and committees with identified roles/functions.

Health capacity of community is computed as:

\[ \delta = \frac{\text{Number of barangay and health workers capacity}}{\text{Total number of health capacity (see table 3)}} \]

Table 3.
**Extent of Health Capacity (Barangay and Health Workers)**

| 1. | 100% of Health workers can manage disaster-related diseases |
| 2. | 100% of healthcare workers can perform first aid procedures |
| 3. | Presence of responders with updated first aid and disaster related training |
| 4. | 50% of organized disaster volunteers able to manage disaster-related diseases |
| 5. | Conducts regular disaster-related capacity building activities to identified responders and community volunteers |
| 6. | Presence of easily understandable information on Disaster Risk (ICT materials) |
| 7. | Presence of public-private partnership |
| 8. | Awareness of the barangay’s disaster focal person |
| 9. | Presence of comprehensive updated disaster-related database and hard copy records |
| 10. | Presence of disaster task force and committees with identified roles/functions |

Efficiency (8), on the other hand, is based on the definition of Ozen (2018) stating that it is the reduction in waiting time experienced by the victims, maximizing the total number of victims that are served, and the effective usage of available disaster related materials/resources and volunteer capacity. In application, efficiency would also mean an effective use of available resources thereby maximizing community capacity without wasting time and effort. The computation of efficiency uses a standard formula in physics, where efficiency = output/input, multiplied by 100 to get work efficiency as a percentage. Although the formula is used across different methods of measuring energy/work, it can be simplified in terms of its application in the study expressed as:

\[ \text{Efficiency (Health)} = \frac{\text{Total number of residents utilizing available disaster related materials/resources and volunteer capacity}}{\text{Total number of populations affected by disaster}} \times 100 \]

Table 4 illustrated the risk assessment using the mathematical model for health at five barangays in Bukidnon. In terms of hazard usage of available disaster related materials/resources and volunteer capacity. In application, efficiency would also mean an effective use of available resources thereby maximizing community capacity without wasting time and effort. The computation of efficiency uses a standard formula in physics, where efficiency = output/input, multiplied by 100 to get work efficiency as a percentage. Although the formula is used across different methods of measuring energy/work, it can be simplified in terms of its application in the study expressed as:

\[ \text{Efficiency (Health)} = \frac{\text{Total number of residents utilizing available disaster related materials/resources and volunteer capacity}}{\text{Total number of populations affected by disaster}} \times 100 \]

Table 4 illustrated the risk assessment using the mathematical model for health at five barangays in Bukidnon. In terms of hazard
assessment, Barangay Batangan had the highest hazard result at 100% amongst identified barangays. Also, the probability of disaster occurrence in the other barangays was at more than 40%. The high hazard result is due to the geographical location of the five barangays, where they are prone to landslide and floods.

Table 4.  
Summary of Risk per Barangay

<table>
<thead>
<tr>
<th>Barangay</th>
<th>Hazard</th>
<th>Vulnerability</th>
<th>Elements of Exposure</th>
<th>RISK*</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGLAYAN</td>
<td>0.710</td>
<td>0.010</td>
<td>0.410</td>
<td>0.003</td>
</tr>
<tr>
<td>BATANGAN</td>
<td>1.000</td>
<td>0.020</td>
<td>0.500</td>
<td>0.010</td>
</tr>
<tr>
<td>GUIHEAN</td>
<td>0.500</td>
<td>0.010</td>
<td>0.250</td>
<td>0.001</td>
</tr>
<tr>
<td>MAGSAYSAY</td>
<td>0.460</td>
<td>0.030</td>
<td>0.500</td>
<td>0.007</td>
</tr>
<tr>
<td>PALACAPAO</td>
<td>0.400</td>
<td>0.010</td>
<td>0.250</td>
<td>0.001</td>
</tr>
</tbody>
</table>

*Risk = Hazard x Vulnerability x Elements of Exposure

For the vulnerability assessment, barangay Magsaysay and Batangan displayed the highest vulnerability, with 3% and 2%, respectively, among the respondent barangays. It concludes that vulnerability is directly proportional to the occurrence of risk. The higher the vulnerability and hazard, the riskier are the barangays to disaster. This finding is consistent with the focus group discussion revealing that there were cases of morbidity in their area. However, as years passed and mitigation measures were initiated, barangay officials observed a decrease in the number of disaster-related mortality and morbidity cases.

Furthermore, the elements of exposure assessment showed that Barangay Batangan and Barangay Magsaysay have the highest people exposed to hazard at 50% probability. The result illustrates that the two barangays had the most population exposed and at risk of the effects of the disaster. This finding is evident with the location of Barangay Batangan, where a large portion of their area is near the Pulangui River. Their location and low land area exposed different residents to the occurrence of a flood. While in Barangay Magsaysay, three puroks were usually affected by landslide brought about by critical ground movements on the surface and significant subsurface ground movements. As reported by Veracruz et al. (2017), the analysis of long-term ground movement shows that landslides in Barangay Magsaysay are always preceded by recurring short-duration heavy rainfalls that exceeded half of the one day.

Overall, the risk assessment revealed that Barangay Batangan had the highest probability of consequences from the combination of hazard, vulnerability, and exposure. It connotes that the higher the hazard, vulnerability, and exposure, the higher the occurrence of the risk.

Table 5.  
Summary of Adaptive Capacity per Barangay

<table>
<thead>
<tr>
<th>Barangay</th>
<th>Efficiency</th>
<th>Readiness Factor</th>
<th>Adaptive Capacity*</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGLAYAN</td>
<td>0.630</td>
<td>0.560</td>
<td>0.354</td>
</tr>
<tr>
<td>BATANGAN</td>
<td>0.530</td>
<td>1.000</td>
<td>0.529</td>
</tr>
<tr>
<td>GUIHEAN</td>
<td>0.450</td>
<td>0.250</td>
<td>0.113</td>
</tr>
<tr>
<td>MAGSAYSAY</td>
<td>0.580</td>
<td>0.250</td>
<td>0.144</td>
</tr>
<tr>
<td>PALACAPAO</td>
<td>0.530</td>
<td>0.250</td>
<td>0.130</td>
</tr>
</tbody>
</table>

*Adaptive Capacity = Efficiency x Readiness Factor

Tabular values show the adaptive capacity, particularly efficiency and readiness factor of the five barangays. In terms of efficiency, Barangay Aglayan has the highest result, which means more participants have utilized their learnings from disaster-related capacity building activities as verbalized by respondents in the barangay.

However, in terms of readiness factor, Barangay Batangan showed 100% readiness in terms of health resources and health capacity. In terms of physical health resources, the barangay had the following: functional health center, available essential disaster-related equipment, presence of evacuation centers, presence of disaster-related supply and communication system, proportionate ratio of health responders and volunteers to affected residents. Moreover, in terms of management health resources, they had disaster plan and committee that was strategically seen in the community, budget allocation for disaster-related activities.
was evident, and there were hazard maps and presence of early warning system. These findings were consistent with the awards and distinction received by the barangay related to their disaster preparedness. As claimed by one barangay official, the barangay was regularly visited by various local government units (LGUs) nationwide to benchmark on their disaster-related preparedness and response.

In total, the barangay with the highest adaptive capacity was Barangay Batangan with more than 50% adaptive capacity. The data showed that Barangay Batangan had the resources and means that would prepare, and prevent their community from a disaster. On the other hand, Barangays Guihean, Magsayasay and Palacapao had low adaptive capacity due to their geographic location- away from their main municipal DRR unit, where most of the disaster related resources were available.

Table 6.
Summary of Risk Assessment (Hazard, Vulnerability and Elements of Exposure), Adaptive Capacity and Disaster Risk Reduction (DRR) by Barangay

<table>
<thead>
<tr>
<th>BARANGAY</th>
<th>RISK</th>
<th>ADAPTIVE CAPACITY</th>
<th>DRR*</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGLAYAN</td>
<td>0.003</td>
<td>0.354</td>
<td>-0.350</td>
</tr>
<tr>
<td>BATANGAN</td>
<td>0.010</td>
<td>0.529</td>
<td>-0.520</td>
</tr>
<tr>
<td>GUIHEAN</td>
<td>0.001</td>
<td>0.113</td>
<td>-0.112</td>
</tr>
<tr>
<td>MAGSAYASAY</td>
<td>0.007</td>
<td>0.144</td>
<td>-0.137</td>
</tr>
<tr>
<td>PALACAPAO</td>
<td>0.001</td>
<td>0.130</td>
<td>-0.130</td>
</tr>
</tbody>
</table>

* DRR = Risk – Adaptive Capacity

Table 6 illustrates the DRR results of the identified barangays. The negative DRR results show that there is a decreasing effect of catastrophe in a given area. It is interesting to note that Barangay Batangan has the highest reduction (52%) of disaster among the five barangays. Although Barangay Batangan has the highest risk, their adaptive capacity is also high, resulting in high-risk reduction. It can be deduced that DRR is directly proportional to the adaptive capacity of the barangay.

Since DRR is dependent on the adaptive capacity, then LGUs and NGOs must prioritize measures, means, and resources needed to prepare and combat the disaster. Main areas that should be strengthened by the government are Health resources and Health Capacity, which are essential to halt the effects of calamity.

Sensitivity Analysis

The mathematical model for health provided substantial leverage in the creation of the following parameter, as seen in Figure 2. As shown, disaster risk reduction is dependent on the adaptive capacity. Specifically, if there is an increase in risk and a decrease of adaptive capacity, then there is a decrease in risk reduction, resulting in more mortality and morbidity. In contrast, when there are less risk and increase in adaptive capacity, then there is an increase in risk reduction, thereby having less mortality and morbidity among the affected community. Furthermore, a negative result would mean a reduction of disaster and its effect. Conversely, a positive result shows no reduction and is prone to disaster effects.

The DRR parameter is consistent with the observations conducted in various barangays in Bukidnon. For instance, Barangay Batangan, which is a flood-prone area, is known to have higher risk compared to other barangays. This risk is due to its geographical location, where the barangay is situated along the river banks of Pulangui. Despite the risk, the barangay was able to manage disasters through several adaptive capacity measures. These AC activities were the presence of disaster committees, volunteers, supplies, equipment, regular training, and plan to reduce the risk of disaster in the said area. Also, it was a recipient of various awards and distinction from national and local governments on disaster risk reduction management. With the marked increase in the barangay’s DRR activities, their morbidity and mortality reports also have decreased since 2017.
**Figure 2.** Disaster risk reduction sensitivity analysis as shown in the three boxes.

This shows that the DRR mathematical model for health is sensitive to the H, E, V and AC of a certain area under specific conditions. The model can predict the occurrence of risk and disaster risk reduction in the community.

**Conclusion**

The developed Disaster Risk Reduction (DRR) Mathematical Model for health is used to assess risk reduction among barangays. Hazard, vulnerability, and exposure are key components in assessing risk in disaster-prone areas. The higher the hazard, vulnerability, and exposure, the higher the occurrence of the risk. Also, DRR is dependent on the adaptive capacity of identified barangays, regardless of the magnitude of risk.

**Limitation of the Model**

Disaster Risk Reduction (DRR) Mathematical Model is limited to assessing the effects of disaster to health. Specifically, in terms of hazard, the study focused on the recent disaster occurrence for the past three years. For vulnerability, it focuses on the number of disaster related diseases in terms of morbidity and mortality, while exposure limits to the percentage of people exposed by disaster for the past three years. The inclusion of readiness factor is limited to two identified areas namely health resources and health capacity. There are only ten indicators used for assessing health resources and health capacity. These indicators are based on literature review, actual observations and consultations with DRR experts.

**Recommendations**

The outcome of the study led to the formulation of the following recommendations: a) The DRR mathematical model for health can be used by LGUs to assess risk reduction in their barangays; b) the Commission on Higher Education can fund a study that will further validate the mathematical model through nationwide assessment; c) develop an extension program that will capacitate communities in preparing Health Resources and Health Capacity to reduce disaster effects on health; and, d) other interested researchers can use the mathematical model for further validation.

**References**


National Disaster Risk Reduction and Management Council (2013). Department of Budget and Management and Department of Interior and local Government Joint Memorandum Circular No. 2013-1. ndrrmc.gov.ph


