A LOCALIZED DISASTER-RESILIENCE INDEX TO ASSESS COASTAL COMMUNITIES BASED ON AN ANALYTICAL HIERARCHY PROCESS (AHP)

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ABSTRACT

The increased number of natural hazards due to climate variability has resulted in numerous disasters in developing countries. In the Philippines, these are expected to be more common in coastal areas. The common approach to mitigating disasters in this area is to enhance the inherent capabilities of local communities to reduce the effects. Thus, this study proposed an index for a disaster-resilient coastal community at the local level. The composites of the index were determined through a process of prioritizing national-level components of a risk-management and vulnerability-reduction system. The process followed a Delphi technique, wherein 20 decision makers in Baler, Aurora, the Philippines identified criteria and elements that can be used to reduce the vulnerability of coastal communities using paired comparisons for the Analytic Hierarchy Process (AHP). The results showed that environmental and natural resource management, sustainable livelihood, social protection, and planning regimes were very important and represented ≥70% of the overall weights of criteria subjected to comparisons. These criteria and their elements represented the local-level outcome indicators of the composite index for a disaster-resilient coastal community, which was measured using a weighted linear combination (WLC) approach to both outcome and process indicators. The index could be used by local governments as a tool to facilitate meaningful disaster-risk reduction and management.

Keywords: Disaster-resilience index, resilience components, coastal communities, analytic hierarchy process (AHP), Delphi technique

1. INTRODUCTION

The number of people affected by disasters has increased considerably over the last 30 years. Droughts, floods, and tropical storms accounted for approximately 100 thousand fatalities and US $250 billion of damage in 2005 [1,2] and for 80% of life-threatening natural hazards worldwide [3]. Based on distribution, developing countries experienced the greatest impact and loss [4], accounting for 97% of the affected communities worldwide [5]. Because coastal zones within 200 km of the oceans are home to about half of the global population [6] and are more prone to hazards [7,8], a large number of people are at risk. This population is often composed of communities that lack the capacity to effectively plan for and respond to hazards [9].

If vulnerable people and property are not considered, hazards can be regarded as simply natural environmental processes [10]. Based on this view, hazard-risk management and disaster solutions have shifted from the typical technical solutions provided by hard science toward understanding conditions associated with the human aspects of disaster occurrences [11]. This includes the application of systems that increase security through social and ecological resilience [12]. Likewise, factors that diminish the adverse hazard effects must be understood, as these may improve the capacity of a community to respond to and recover from subsequent hazard events [13]. By strengthening their local capacity, it is possible to develop invulnerable communities [14].

Resilient communities experience less damage and tend to recover quickly from disasters [15]. These communities absorb stress either through resistance or adaptation, manage and maintain basic functions despite effects, and can recover with specific behavioral strategies for risk reduction [16]. To determine and to measure the factors to enhancing resilience of coastal communities in the face of disasters, we performed a case study of local indicators of a disaster-resilient coastal community in the Philippines.

1.1. Disasters and local coping mechanisms in the Philippines

The Philippines lie between the Pacific and Eurasian plates along the Western Pacific basin, a location frequented by climatic conditions such as typhoons, sea surges, and volcanic eruptions. According to the Center for Research on the Epidemiology of Disasters (CRED), the country was the most disaster-stricken nation in the world in 2009 [17], with a total of 191 natural and human-induced disasters reported to have killed 903 persons and affecting more than 2.8 million families [18].

Meanwhile, a huge gap between recognition and active implementation of disaster-management programs exists in the Philippines, which is often attributed to the failure of the government to provide adequate resources, education, and awareness related to mitigating various hazard threats [19]. Destruction in different parts of the country had clearly manifested in poor disaster prediction and forecasting failures, especially in the local levels. Local capability to undertake risk mitigation is lacking and local governments rarely performed risk assessments without external support [19,20]. Expected investments of funds in local risk-management policies also posed a significant challenge in terms of political support, which often resulted in a biased implementation and community participation in disaster-management programs [19,20].

Within these situations, disasters are caused not only by natural events but also by the dysfunctional social institutions and inherently vulnerable nature of the community [11]. In the coastal areas, for instance, where 60% of the Philippines’ population resides, a large portion of people and property must make adjustments when disasters occur [21], including many fisherydependent communities that were constantly affected by poverty and a lack of social services [21,22].

Nonetheless, unique local mechanisms or indigenous response systems become typical in some disaster-prone areas in the country [19,23]. An example of this is the flood-prone communities in the municipality of Bula, Camarines Sur, which established management teams and implemented systems for response and recovery from disasters [24]. Projects such as the Citizen-Based and Development-Oriented Disaster Response (CBDODR) and Community-based Disaster Risk Management (CBDRM), implemented by non-government organizations, have added to this context, as they transformed at-risk communities into disaster-resilient organizations [19].

NEDA et al. [20] has incorporated some activities of these projects in an approach that mainstreamed disaster-risk reduction (DRR) to the sub-national level. A tool to assess the factors that could enhance local resilience from disasters, however, would significantly contribute for a localized DRR approach.

1.2. Local-level disaster-risk reduction

UNISDR [25] highly recognized the capacity of local communities as cornerstones to the overall global movement for disaster-risk reduction. Practically, this means putting greater emphasis on what people can do for themselves and how to strengthen their capacity for resilience, rather than concentrating on their vulnerability to disaster or their needs in an emergency [16]. This concept recognizes that, by focusing on the capability and ability to adapt, people and communities affected by disasters are not just passive victims but capable agents [26].

In this paper, we adopted the term resilience from ecosystem resilience concepts [27] within the ecological literature. This type of resilience occurs after a disturbance and is related to the system's ability to adapt, reorganize, undergo change, and still maintain its basic structure, function, identity and feedbacks [28]. The concept can be explained broadly as the capacity of a community, a group or an organization exposed to a hazard to maintain functional level, withstand loss or damage or to recover from the impact of a disaster and reorganize for future protection [4].

Community resilience is increasingly being seen as a key step towards disaster risk reduction, and the ability to measure it is largely considered by researchers [13]. How researchers were viewing resilience, however, influenced the proposed measurements, for instance, as a process in the ecological perspective [29] or as an outcome in the social perspective [30]. Moreover, tool development has remained to be a challenge despite numerous theoretical underpinnings that tackle this concept in various scales. Only few procedures within the existing literature (e.g., Cutter et. al. [31]; Peacock et. al [32]; Sherrieb et al. [33]), however, suggested how the concept could be quantified and be used to categorize or to compare communities.

1.3. Disaster-resilient components based on Analytic Hierarchy Process

This study proposed a novel approach to developing a tool for quantifying disaster resilience in the Philippines by synthesizing national-level disaster resilience components using the Analytic Hierarchy Process (AHP). The AHP is a methodological approach to decision making that can be applied to resolve highly complex problems involving multiple scenarios, criteria, and actors [34]. This approach has been used in various studies that aimed to enhance development in different sectors such as tourism [35,36], environmental and natural resources [37], forestry [38], coastal management [39], and disaster and risk management [40,41].

As a decision system, the AHP is valuable for using human cognition in determining the relative importance among a collection of alternatives using paired comparisons [42]. Corollary, the important alternatives can be used to develop an evaluation tool for assessing performance of business firms [43] or to select the best design concept in product development [44]. On the other hand, it is found effective when assigning weights for indicators of disaster risks and vulnerability indices [45] or when ranking risk factors in a flood risk assessment model [46]. With the AHP, important household attributes can also be selected to serve as indicators that measure and categorize household vulnerability to climatic risk [47].

In this study, the AHP was used to determine the criteria and elements that best described a disaster-resilient coastal community at the local level by subjecting the components of a risk management and vulnerability reduction system in the Philippines [16,20] in a process of prioritization. An outcome framework for disaster-resilient coastal communities was designed based on priority components and were used to determine the outcome indicators of a composite index for a disaster resilient coastal community. The development of an index, with participation of selected members from a low vulnerability coastal community, was primary in the country. This tool can then be used to evaluate the resilience of local coastal communities from disasters.

2. MATERIALS AND METHODS

2.1. Development of the AHP Model

The components that best described a disaster-resilient coastal community were presented on a three-tier hierarchy representing relevant aspects of community resilience in an AHP model (Figure 1), wherein the top tier represented a goal related to the problem. The second tier consisted of seven criteria determined based on resilience components in Twigg [16]. These included Environmental and Natural Resource Management (ENRM), Human Health and Well Being (HWB), Sustainable Livelihoods (SL), Social Protection (SP), Financial Instruments (FI), Physical Protection and Structural and Technical Measures (PPST), and Planning Regimes (PR).

Finally, attribute elements for each criterion characterizing disaster-resilient communities represented by *C* and risk-reduction-enabling environments represented by *E* formed the bottom tier. For example, the elements that characterized disaster-resilient communities for the criterion ENRM were ENRMC1, ENRMC2…, and ENRMC5, while the elements that characterized risk-reduction-enabling environment were ENRME1, ENRME2…, and ENRME5, wherein the numbers *1,2,… n* correspond to a specific attribute element (Table 1).

In each tier, the number of criteria and their elements compared were maintained within the suggested limits in a comparison scheme where seven is the maximum [42]. With this consideration, decision makers reduced attribute elements of the PPST and SL criteria to seven components based on their relevance and applicability in the local context.

2.2. Local decision makers

The process of prioritization for components of a disaster-resilient coastal community was conducted in March 2012 in the municipality of Baler, province of Aurora, the Philippines (Figure 2). In this municipality, Zabali was considered the least vulnerable coastal community in an assessment that measured their susceptibility to various hazards [48]. The familiarity and experience of communities in Zabali in mitigating the sources of vulnerability were the major reasons for considering them as local experts. These community members, along with service providers on coastal management and disaster planning from academia and local governments, were considered decision makers during the prioritization. They were all selected based on their experience, skills, knowledge and practices related to different aspects of addressing vulnerable communities.

2.3. Weights of alternatives in a consistent matrix

With reference to the AHP model, important alternative criteria and elements associated with achieving a disaster-resilient coastal community were identified using paired comparisons and ratio-scale measurement. This is described by the formula:

$$n \cdot (n-1)/2, \qquad \text{(Eq. 1)}$$

where *n* is the number of alternative criteria or elements $(a_1, a_2, \ldots a_n)$ in a judgment of prioritization [42,49]. In this case, there were 21 comparisons involved in a matrix for seven alternative criteria, while comparisons of attribute elements for each criterion varied from three to 21 and were composed of three to seven alternatives.

Each product of a paired comparison was considered an expression of the decision maker's relative preferences for one alternative over another based on a set of fundamental scales (Table 2) composed of values ranging from 1 to 9 [34,49]. Coyle [50] explained that when a decision maker decided that alternative *i* was equally important to another alternative *j*, a comparison represented by $a_{ij} = a_{ji} = 1$ was expected. Nonetheless, when alternative *i* was considered extremely important compared with alternative *j*, the calculation matrix score was based on a_{ij} = 9 and a_{ji} = 1/9. The distribution of these scores in a square matrix resulted in a reciprocal matrix [51], represented as:

$$A = [a_{ij}] = \begin{Bmatrix} 1 & a_{ij} & \cdots & a_{1n} \\ 1/a_{ij} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & & \vdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{Bmatrix}, \qquad \text{(Eq. 2)}$$

where A = [a_{ij}] is a representation of the intensity of the decision maker's preference for one over another compared alternative a_{ij} and for all comparisons *i,j= 1,2,…n*. Decision makers facilitated the comparisons of alternative criteria or elements in two rounds until the scores were considered stable. Stability was reached when a certain consensus on a sum of scores was achieved.

Multiplying together the comparison scores of alternative criteria or elements in each row of the reciprocal matrix and then taking the nth root of that product generated a good approximation of the element weights for each alternative [50], as follows:

$$Element\ weight = \sqrt[n]{a_{ij} \cdot a_{nj} \cdot \cdots a_{nn}}. \qquad \text{(Eq. 3)}$$

The weights in a column were summed, and that sum was used to obtain the normalized eigenvector w_{ij} for that alternative, as shown by the formula:

$$w_{ij} = \frac{Element\ weight}{\sum Element\ weights\ in\ column}. \qquad \text{(Eq. 4)}$$

When matrix A was multiplied by the vector w_{ij}, the operation resulted in a new priority vector nw_{ij}. A similar nw_{ij} value was obtained when w_{ij} was multiplied by the maximum eigen value λ_{max} [52].

The importance of criteria and elements in achieving a disaster-resilient coastal community was determined by a high nw_{ij} value for each criterion or element. This vector is the sum of products of elements in each row and the normalized w_{ij} in each column [50], as follows:

$$nw_{ij} = \sum_{i,j=1,2}^{n} a_{ij} w_{ij}. \qquad \text{(Eq. 5)}$$

In a consistent matrix, nw_{ij} values for each criterion or element became weights, from which the rank of each of the other alternatives in the respective set of components was determined.

2.4. Consensus building

A consensus on the final scores of every paired comparison of criteria or elements was reached in a process involving the Delphi technique [53.54]. The final scores were computed based on a geometric mean of all scores given by decision makers for each paired comparison [55]. Once a consensus was reached, a summary of final scores for each paired comparison was entered into a matrix or decision table.

The scores, as well as their nw_{ij} values, were accepted when they reached a certain level of consistency, as determined by a consistency index *CI* computed by Eq. 6:

$$CI = (\lambda_{max} - n)/(n-1), \qquad \text{(Eq. 6)}$$

where λ_{max} is the maximum eigen value computed by averaging all individual eigen values λ, and n is the number of elements (or criteria) subjected to a priority judgment. Each individual λ was computed by dividing the nw_{ij} by their normalized values w_{ij}

$$\lambda = \frac{nw_{ij}}{Normalized\ w_{ij}} \quad . \qquad \text{(Eq. 7)}$$

The computed *CI* was then compared with a random consistency index *RI* of the generated paired comparison matrix to determine the consistency ratio *CR* (Table 3). The *CR* established whether the decision maker's judgment scores or weights were accepted, where *CR* ≤0.10 was deemed acceptable [49,52], based on Eq. 8:

$$CR = \frac{CI}{RI}. \qquad \text{(Eq. 8)}$$

A top-down process was applied to select and evaluate the criteria and elements. In this process, all criteria were first evaluated, and once a criterion was found desirable for achieving a disaster-resilient coastal community, its attribute elements were selected and subjected to comparisons. New priority vector nw_{ij} values of the criteria and elements that fell within the acceptability range of *CR* ≤0.10 were adopted as their respective weights, and were used as basis to determine their rank within their respective group.

In each tier of the hierarchy, an exploratory approach to adopt ≥70% representation of the criteria and elements that had been subjected to paired comparisons was considered. This means that the sum of the ratio of weights of the top criteria or elements to their respective overall weight was ≥70%, as shown in Eq. 9.

$$\sum \frac{Individual\ nw_{ij}}{Overall\ nw_{ij}} \geq 70\% \quad . \qquad \text{(Eq. 9)}$$

This percentage was thought to provide an optimal number of criteria and elements to represent each level. Hence, other criteria or elements were disregarded as being of low importance and having relatively small impact on the overall objective.

3. RESULTS

3.1. Selected criteria and elements

The comparison matrix at the criterion level was consistent with a value of 0.09 (Table 4). Based on the weights of alternatives at this level, Environment and Natural Resources Management (ENRM) and Physical Protection and Structural Technical Measures (PPST) were ranked as the highest and lowest criteria, respectively. The highest ranked criteria, i.e., Environment and Natural Resources Management (ENRM), Sustainable Livelihood (SL), Social Protection (SP), and Planning Regime (PR), were selected by the sum of their weights and accounted for 72% of the overall weights of the criteria being compared. Their attribute elements were then subjected to further comparison, and high-ranking elements were subsequently selected.

For Environment and Natural Resources Management (ENRM), the elements that characterized disaster-resilient communities were ENRMC1, ENRMC2, and ENRMC4, which accounted for 74% of the overall alternatives (Table 5), whereas the combination of ENRMC1, ENRMC2, and ENRMC3 accounted for 71% of the most important attributes that describe risk-reduction-enabling environment. The matrices of comparisons for these attribute elements fell within a *CR* value of 0.10 and 0.09, respectively.

Subsequent procedures for selecting and evaluating attribute elements were conducted for Sustainable Livelihood (SL), Social Protection (SP), and Planning Regime (PR). For Sustainable Livelihood (SL), the elements SLC1, SLC3, SLC4, SLC5, and SLC7 were selected as elements that describe disaster-resilient communities, whereas SLE1, SLE2, SLE3, and SLE7 were selected as elements that describe risk-reduction-enabling environment (Table 5). These elements accounted for 78% and 75%, respectively, of each attribute group.

For Social Protection (SP), the elements SPC1, SPC2, and SPC3 (77%) and SPE1 and SPE3 (80%) were selected to represent elements that described disaster-resilient communities and that described risk-reduction-enabling environment, respectively. Finally, the elements PRC1 and PRC3 (80%) that described disaster-resilient communities, as well as PRE1, PRE2, and PRE4 (82%) that described risk-reduction-enabling environment were considered the most important elements for criterion Planning Regime (PR).

4. DISCUSSION

4.1. Priority criteria and elements

Environmental and Natural Resources Management (ENRM) was the most important criterion for describing disaster-resilient communities because ecosystem benefits are crucial to communities. Orencio and Fujii [48] referred to coastal resources in Baler as an important resource, as most individuals depend on such resources for food and livelihood. This recognition of ENRM as an important criterion for resilience can be attributed to the decision maker's idea of sustainable ecosystem services that can be derived from a healthy resource [56].

Sustainable Livelihoods (SL) and Social Protection (SP) represented the desires of communities to achieve systems that ensure livelihood and security, respectively, based on the recognition of environmental and social hazards that affect their lives. Communities understood that their level of susceptibility to hazards was caused by their fragile livelihood systems. For instance, most people in coastal villagers tended to seek employment in fishing industries, whereas upland people focused on farming and raising livestock [57]. Others became self-employed and ventured into small-scale businesses.

Typically, the open-access system and minimal capitalization of fisheries allows this to be a common safety net for individuals who cannot find permanent employment. Because of the very limited resources and lack of security and income stability, however, communities found it difficult to cope when struck by recurring hazards. Thus, communities believed that their ability to adapt and recover was related to sustainable livelihood, and this could be enhanced by the support of an institution that promotes equitable distribution of resources.

The Planning Regimes criterion (PR) describes community aspirations to achieve a process that facilitates implementation mechanisms based on participation by communities as a vital element of success. Most communities regard implementation as an offshoot of careful planning. Therefore, they recognized that many institutions lacked proper policy and management of important resources because communities were not adequately consulted during the planning process [57]. Hence, the interest of communities in participate in planning could be considered a prelude to informed decision making.

4.2. Delphi and AHP

To obtain a consensus on the scores in a paired comparison of alternatives in the AHP model, the Delphi technique was found to be effective in a multi-stakeholder decision-making process. However, the process required a strong facilitator who could harmonize the different perspectives of decision makers into a single objective. Despite similar experiences and exposures to risk and disasters, the social status (e.g., education) and level of engagement in disaster management systems varied among decision makers, resulting in a variety of opinions about each alternative.

The Delphi was particularly important during the comparison of the alternatives at the level of attribute elements. Decision makers tended to regard alternatives as having similar objectives, which made comparison difficult. The role of the facilitator was to expound on the differences among alternatives and to organize the opinions of stakeholders. In this case, the group was able to establish a common view on each alternative prior to the paired comparison.

The use of the basic scale (Table 2) in scoring each paired comparison was difficult for decision makers because some had not used a quantitative measure to assess importance and to compare two alternatives. Comparisons were far more difficult and time consuming when there were seven alternatives because this could require 21 comparisons. Decision makers resolved a matrix that involved only three alternatives, as shown by their high consistency rates (Table 5). Less consistent rates were obtained in two rounds when there were more than three alternatives.

To simplify scoring paired comparisons, the two alternatives located diagonally across from each other in the matrix (Eq. 2) were scored following a rule of thumb. In this rule, when a judgment favored the alternative on the left-hand side of the matrix, an actual judgment value (e.g., 1, 2,…9) was used for scoring, and the reciprocal value (e.g., $\frac{1}{2}, \frac{1}{3}, \dots \frac{1}{9}$) was used when the judgment favored the alternatives placed on the right-hand side of the matrix [58].

4.3. Framework index and metrics to evaluate disaster-resilient communities

With reference to important criteria and attribute elements selected using the hierarchical structure in the AHP model, the top four criteria were considered when designing the disaster-resilience outcome framework (Figure 3). This framework was used as a basis for developing the outcome indicators for the composite index, which will serve as a tool to evaluate a disaster-resilient coastal community at the local level.

To view disaster resilience only with its outcome, however, creates a limitation in placing emphasis on the human role in disaster-risk management [29]. While, outcome components are important for the real achievements in terms of community empowerment and capacity building, process components should also be considered to provide for an understanding of a community and for the sustainability of a disaster-resilience program [59]. Hence, the measure of coastal community disaster-resilience was developed with consideration on both outcome and process components that the community had achieved and implemented.

Meanwhile, since only criteria and elements as outcome components were provided by the AHP (Figure 4), process components were developed with respect to the Integrated Community-based Risk Reduction (ICBRR) model of the Canadian Red Cross (CRC) and the Indonesian Red Cross Society (PMI) (Figure 5). This framework has 10 specific activities for establishing disaster-resilient communities, which include implementation of risk-reduction measures [59]. As a result, a composite index for a disaster-resilient coastal community (Figure 6) was developed based on a aggregate measure of an overall outcome indicator computed based on four important AHP criteria and their elements, and an overall process indicator that was quantified from 10 specific activities of the ICBRR.

The fundamental metrics for the index followed a weighted linear combination (WLC) of indicators for outcome and process components. For the WLC, outcome indicators were assigned weights based on a weighting system to provide a basis for intensifying the indicator scores. These were taken from the nw_{ij} values that determined the ranks in the AHP model and were computed with the minimum–maximum method following Eq. 10:

$$W_n = (W_{act} - W_{min})/(W_{max} - W_{min}), \qquad \text{(Eq. 10)}$$

where W_n is the normalized weight of a criterion or element, and W_{act} is the actual weighted values of a criterion or element within the compared set of alternatives, whereas W_{max} and W_{min} are the maximum and minimum weights, respectively, of criteria or elements within that set. The normalized weights of the selected criteria and elements were shown in Table 6.

During the design of the metric computations for the attribute elements for ENRM, SL, SP, and PR, only two elements characterizing disaster-resilient communities for the criterion PR and the external enabling environment for the criterion SP were selected. These criteria only had three elements that are used for comparison, and inclusion of the lowest ranking alternative resulted in a normalized weight of zero. Because weights were used to intensify the scores in the proposed assessment, those elements with weights of zero were excluded from the selection.

Initially, to compute for the outcome indicator, each criterion was measured based on attribute element scores *ES*. The *ES* were based on a level of attainment or success in designating a distinct step in disaster risk reduction (DRR) [16]. Using this scale, Level 5 was considered the highest, and Level 1 was the lowest in terms of degrees of implementation. However, we proposed the addition of another level to modify this to a six-point scale, where 0 was the lowest and referred to situation where DRR activities were non-existent and were not implemented (Table 7).

All *ES* corresponding to the criterion were summed to obtain the criteria scores using Eq. 11:

$$CS = \sum_{j=0}^{j=5} C(W_i ES_j) + \sum_{j=0}^{j=5} E(W_i ES_j), \qquad \text{(Eq. 11)}$$

where *CS* represents the overall criterion score, *C* represents the attribute elements for disaster-resilient communities, *E* represents the attribute elements for risk-reduction-enabling environment, W_i represents the weights of all attribute elements *i*, and R_j represents the rank or values of attribute elements *j*. All *CS* values were combined to determine the overall outcome-indicator score, as shown in Eq. 12:

$$OS = \sum_{j=0}^{j=5} C(W_i CS_j), \qquad \text{(Eq. 12)}$$

where *OS* is the overall outcome-indicator score, *C* represents the criteria, W_i represents the weights of criteria *i*, and CS_j represents the scores for each criterion *j*.

The overall process-indicator score, on the other hand, was determined by Eq. 13:

$$PS = \sum_{j=0}^{j=5} P(W_i R_j), \qquad \text{(Eq. 13)}$$

where *PS* represents the overall process-indicator score, *P* represents process indicators based on the 10 activities of the ICBRR model, W_i represents the weights of indicators *i* with equal values that sum to 1, and R_j represents the ranks or values of process indicator *j*. Similarly, the ranking or scoring of indicator values followed the modified six-level scale (Table 7), with 5 representing completely attained. It should be noted that because indicators have W_i, the sum of which equals 1, W_i for each corresponding process indicator was 0.10.

Finally, the overall index score was determined by combining the process- and outcome-indicator scores, as shown in Eq. 14:

$$IS = PSW_i + OSW_i, \qquad \text{(Eq. 14)}$$

where *IS* represents the overall index score, *PS* represents the overall process-indicator score, *OS* represents the overall outcome-indicator score, and W_i represents the weights of the process and outcome indicators *i*. Because the process and outcome indicators have equal W_i, the sum of which equals 1, W_i for each indicator was 0.50.

4.4. Limitations of the proposed index

In this study, we developed an index for a disaster-resilient coastal community with the ability to objectively assess the degree of attainment of each critical indicator for both process and outcome components. The outcome indicators were developed from the synthesis of disaster resilience components using the AHP. However, the process indicators developed based on the Integrated Community-based Risk Reduction (ICBRR) model to assess disaster-resilience of a coastal community still depend on some assumptions, as risk-reduction programs implemented at the community level in the Philippines followed the Citizen-Based and Development-Oriented

Disaster Response (CBDODR) and the Community-Based Disaster Risk Management (CBDRM) approaches. Concepts may vary among approaches, but most activities were similar. Hence, the proposed process indicators could be assessed at the activity level to limit bias resilience measurements.

The proposed WLC measurement for the disaster-resilience index relied on the weights and scores assigned to each indicator. The weights for the outcome indicators varied since they were based on values derived from the AHP, but equal weights were assigned to process indicators. Since weights were used to intensify the scores in the assessment, this may pose some limitations in providing a quality measure for process indicators. This limitation can be resolved by undertaking a further AHP for the process indicators. Nevertheless, a score range of 0 to 5 to rank both process and outcome indicators could be used for more objective evaluation.

Further agreements on the use of the ICBRR approach to model disaster-resilient communities could be considered, as this may also serve as a framework to evaluate local DRR activities. Reports regarding the International Federation of the Red Cross' intentions to implement this approach in Southeast Asia and to develop communities into disaster response teams could provide a good opportunity to enhance the Philippines' local disaster-management and risk-reduction system.

4.5. Pilot assessment

The next important step in the process is a pilot assessment in a coastal community using the composite index. The community-based assessment will involve individuals in scoring and ranking both process and outcome indicators based on a fundamental rating scale that was developed to categorize the quality of community interventions in undertaking DRR. A sensitivity analysis will be applied to identify important flaws and subsequent development needs. This analysis will further refine the exploratory approach for criterion and element selection, such as the arbitrary decision to select overall criterion and element scores that summed to ≥70%. In this way, the relationship that existed between selected criteria and elements could be properly defined, and the underlying structure would likely provide a quality benchmark measure of disaster- resilient coastal communities.

5. CONCLUSIONS

At the national scale, a number of disaster- and risk-management-related systems have been developed, but there have been limited attempts to synthesize their components and select the most important ones to be used in undertaking local assessments. The Analytic Hierarchy Process (AHP), which involves paired comparisons of various alternatives, provided a potential method for this purpose. AHP was found effective in selecting the criteria and elements that best described a disaster-resilient coastal community with the participation of local decision makers.

The consensus-building process by which criteria and elements were to be selected and evaluated was simplified by a top-down approach. A Delphi technique, as facilitated by a strong facilitator however, was noteworthy to achieve the objective preferences of decision makers. Based on the results, four criteria, i.e., Environmental and Natural Resource Management (ENRM), Sustainable Livelihoods (SL), Social Protection (SP), and Planning Regime (PR), were considered the most important criteria to describe outcomes for a disaster-resilient coastal community.

With reference to a weighted-linear combination of the process and outcome components, a composite index for disaster resilient coastal community was designed. The important criteria and their representative attribute elements from the AHP served as outcome indicators, whereas process indicators were developed in consideration of the Integrated Community-Based Risk Reduction (ICBRR) model of Canadian Red Cross and the Indonesian Red Cross Societies. This tool is expected to contribute to a quantified measurement of disaster-resilience, to minimize a bias local assessment and to enhance a localized disaster-risk reduction approach.

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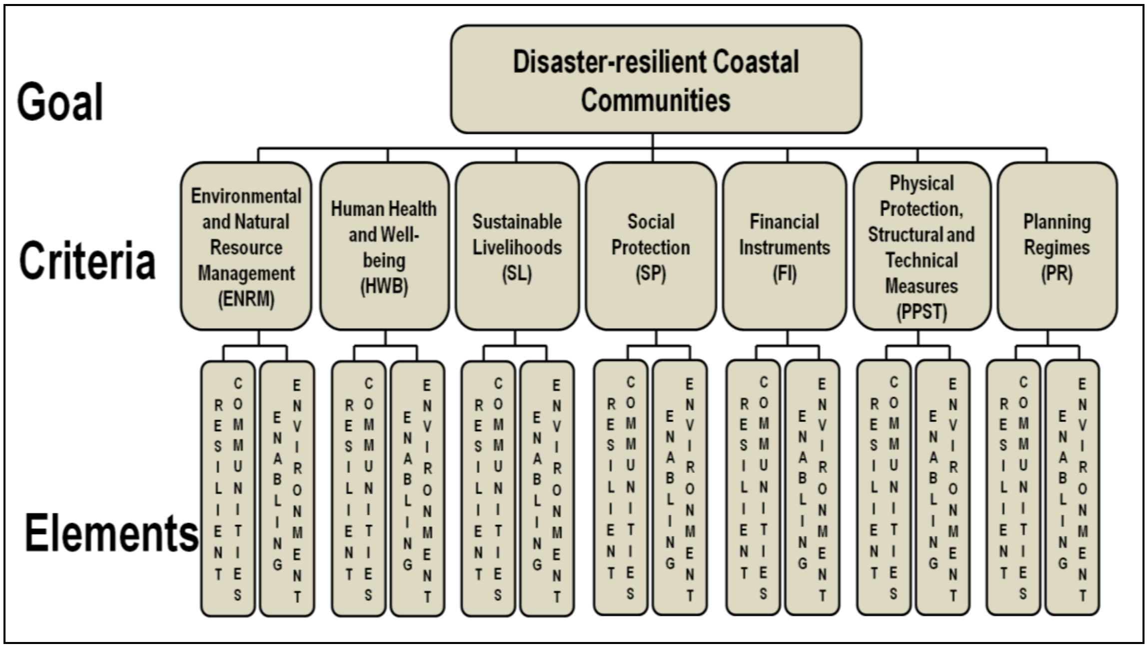

Figure 1. AHP model used in the process of prioritizing criteria for a disaster-resilient coastal community

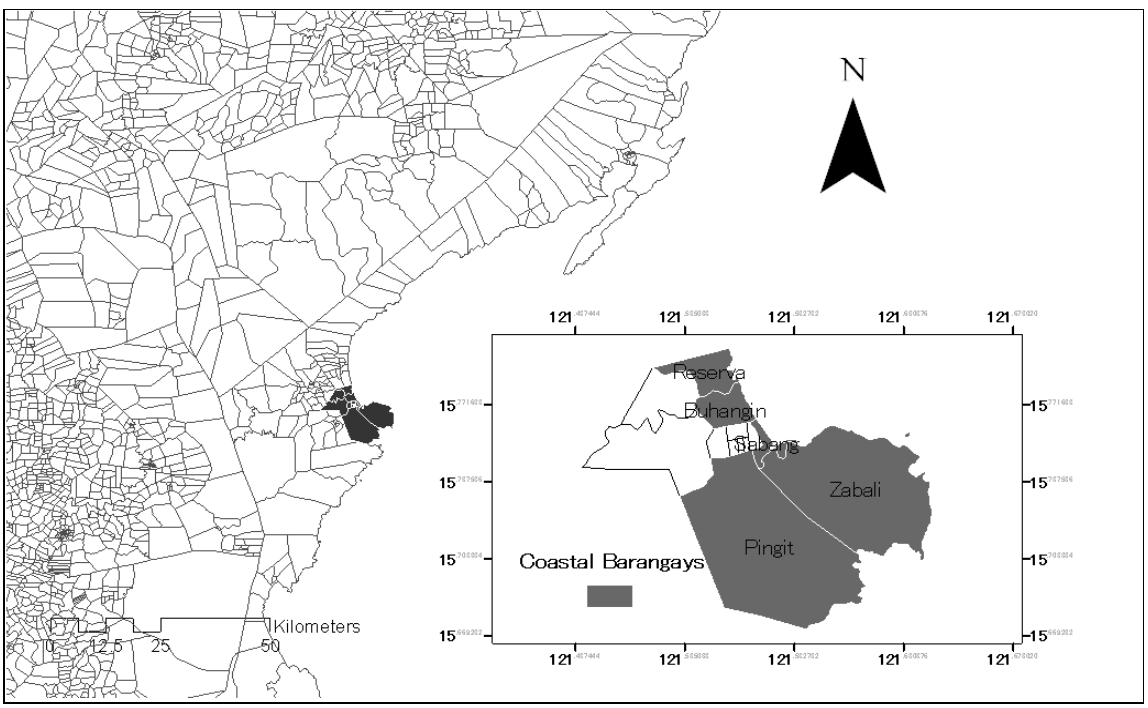

Figure 2. Map of the northeastern Philippines showing Baler, Aurora (inset map shows the five coastal communities)

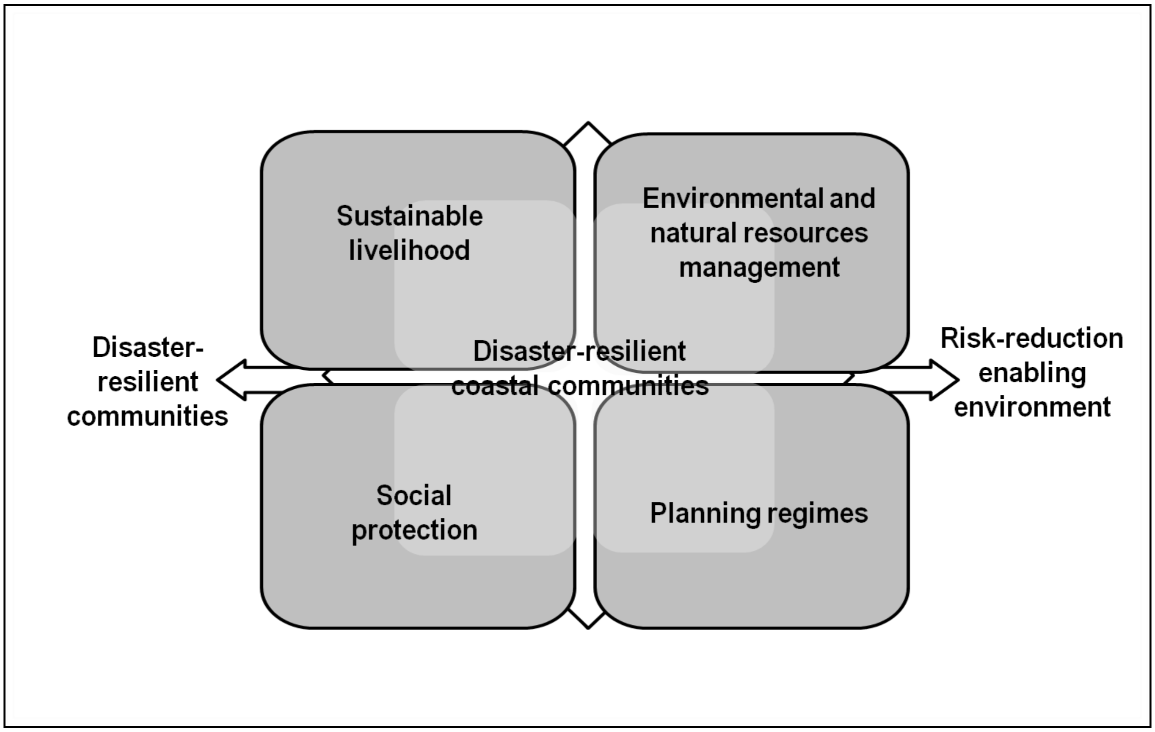

Figure 3. The AHP-designed coastal community disaster-resilience outcome framework for Baler, Aurora in the Philippines

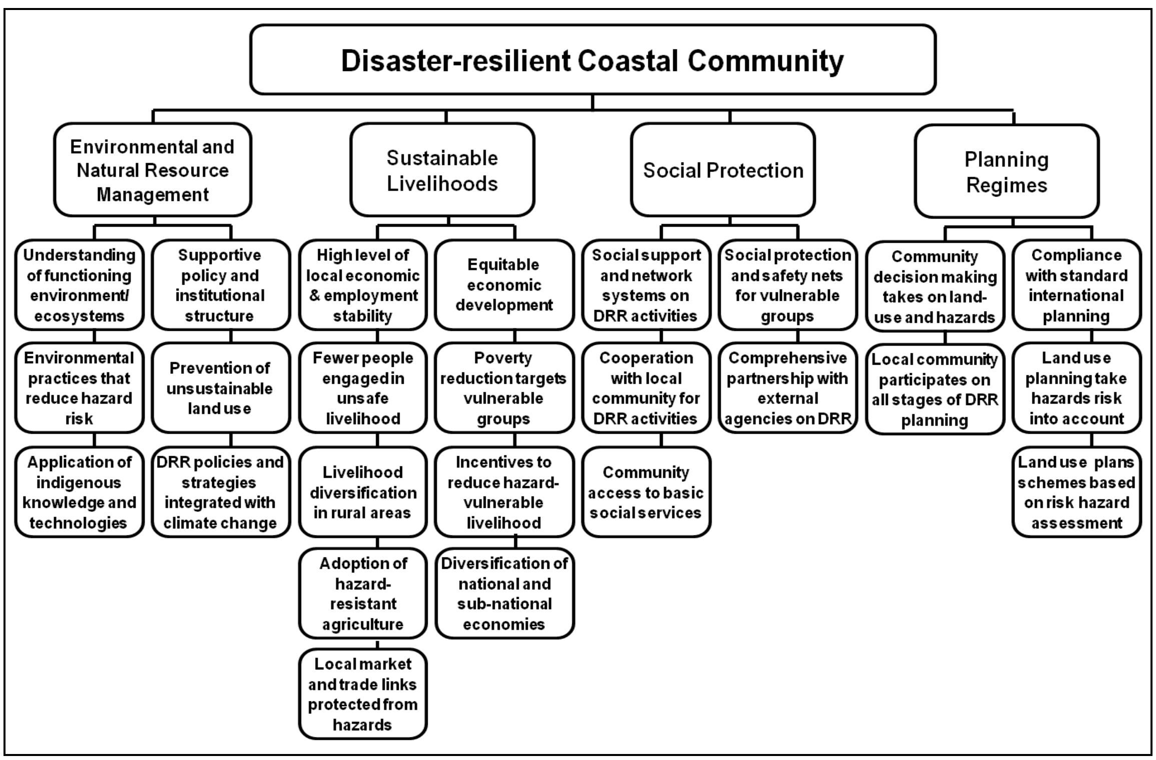

Figure 4. The criteria and elements for outcome components of a disaster-resilient coastal community from the AHP model

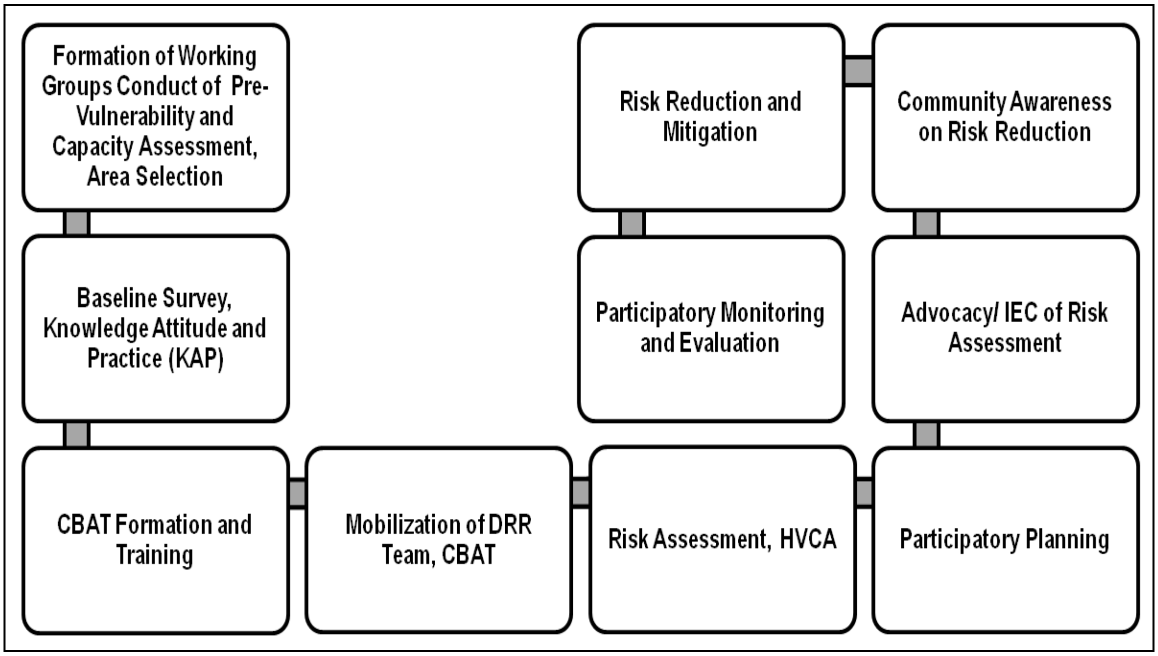

Figure 5. The ICBRR model used by the Canadian Red Cross and the Indonesian Red Cross Societies for building disaster-resilient organizations at the local level [59]

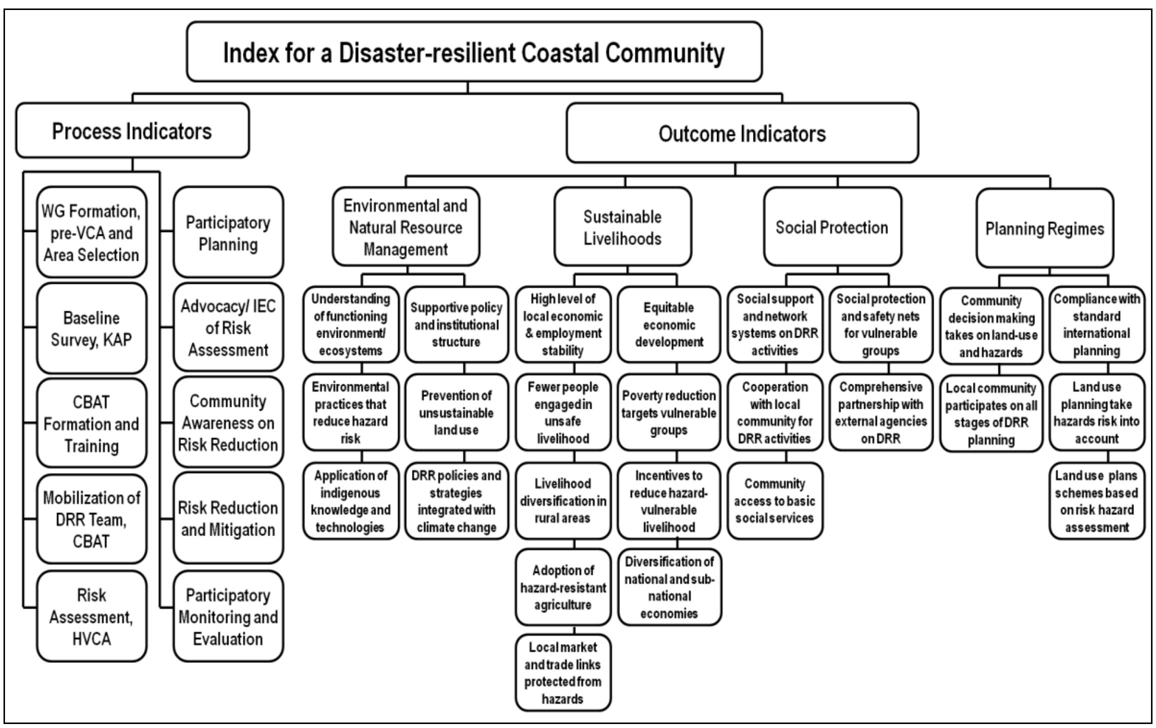

Figure 6. The process and outcome components of the composite index for a disaster-resilient coastal community

Table 1. Components of risk-management and vulnerability-reduction systems [16,20]

Criteria		Elements of Disaster-resilient Communities		Elements of Risk-reduction-enabling Environment	
ENRM	Environmental and natural resource management	ENRMC1	Understanding of functioning environment and ecosystems	ENRME1	Supportive policy and institutional structure
		ENRMC2	Environmental practices that reduce hazard risk	ENRME2	Prevention of unsustainable land use
		ENRMC3	Preservation of biodiversity for equitable distribution system	ENRME3	Policy linking environmental management and risk reduction
		ENRMC4	Application of indigenous knowledge and technologies	ENRME4	DRR policies and strategies integrated with climate change
		ENRMC5	Access to community-managed common property resources	ENRME5	Availability of local experts and extension workers
HWB	Health and well-being	HWBC1	High physical ability to labor and good health	HBWE1	Public health structures integrated into disaster emergency plans
		HWBC2	High level of personal security and freedom psychological threats	HBWE2	Community structures integrated into public health systems
		HWBC3	Secured food supply and nutritional status during crisis	HBWE3	Health education programs relevant to crisis
		HWBC4	Access to water for domestic needs during crises	HBWE4	Policy for food security through market and nonmarket interventions
		HWBC5	Awareness of means and possession of skills of staying healthy	HBWE5	Multi-sector engagement for managing food and health crises
		HWBC6	Management of psychological consequences of disasters	HBWE6	Emergency plans provide buffer stocks of food, medicines, etc.
		HWBC7	Trained workers to respond to physical and mental consequences of disasters		
SL	Sustainable livelihoods	SLC1	High level of local economic and employment stability	SLE1	Equitable economic development
		SLC2	Equitable distribution of wealth and livelihood in community	SLE2	Diversification of national and sub-national economies

Criteria		Elements of Disaster-resilient Communities		Elements of Risk-reduction-enabling Environment	
		SLC3	Livelihood diversification in rural areas	SLE3	Poverty-reduction targets vulnerable groups
		SLC4	Fewer people engaged in unsafe livelihood	SLE4	DRR reflected as integral part of policy for economic development
		SLC5	Adoption of hazard-resistant agriculture	SLE5	Adequate and fair wages guaranteed by law
		SLC6	Small enterprises with protection and business continuity/ recovery plans	SLE6	Supportive policy on equitable use and access to common resources
		SLC7	Local market and trade links protected from hazards	SLE7	Incentives to reduce vulnerable livelihood
SP	Social protection	SPC1	Social support and network systems on DRR activities	SPE1	Social protection and safety nets for vulnerable groups
		SPC2	Cooperation with local community for DRR activities	SPE2	Coherent policy and networks for social protection and safety nets
		SPC3	Community access to basic social services	SPE3	Comprehensive partnership with external agencies on DRR
		SPC4	Established social information and communication channels		
		SPC5	Collective knowledge and experience of management of previous events		
FI	Financial Instruments	FIC1	Enough household and community asset bases to support crisis-coping	FIE1	Government and private sector support for financial mitigation
		FIC2	Costs and risks of disasters shared through collective ownership of assets	FIE2	Economic incentives for DRR actions
		FIC3	Access to savings and credit schemes, and microfinance services	FIE3	Microfinance, cash aid, credit loan guarantees made available
		FIC4	Community access to affordable insurance from viable institutions		

Criteria		Elements of Disaster-resilient Communities		Elements of Risk-reduction-enabling Environment	
		FIC5	Community disaster fund to implement DRR activities		
		FIC6	Access to money transfers and remittances from members abroad		
PPST	Physical protection; structural and technical measures	PPSTC1	Decisions and plans on built environment consider hazard risks	PPSTE1	Compliance with international standards that consider hazard risks
		PPSTC2	Security of land ownership/tenancy rights	PPSTE2	Compliance of public infrastructure with standards
		PPSTC3	Adoption of hazard-resilient construction and maintenance practices	PPSTE3	Carry out vulnerability assessment for all infrastructure system
		PPSTC4	Community capacities and skills to build, retrofit, maintain structures	PPSTE4	Retrofitting critical public facilities and infrastructure in high risk areas
		PPSTC5	Infrastructure and public facilities to support emergency management needs	PPSTE5	Security of access to public health and other emergency facilities
		PPSTC6	Resilient and accessible critical emergency facilities	PPSTE6	Legal systems protect land access and ownership and tenancy rights
		PPSTC7	Resilient transport/service infrastructure and connections	PPSTE7	Legal and economic systems respond to population patterns
PR	Planning regimes	PRC1	Community decision making takes on land use and hazards	PRE1	Compliance with standard international planning
		PRC2	Local disaster plans feed into local development and land use planning	PRE2	Land use planning takes hazard risks into account
		PRC3	Local community participates in all stages of DRR planning	PRE3	Effective inspection and enforcement regimes
				PRE4	Land use plan schemes based on risks assessments

Table 2. Rating scale for judging preferences used for the pair-wise comparison of various criteria and attribute elements of a disaster-resilient coastal community

Scale	Judgment of Preference	Description
1	Equally important	Two factors contribute equally to the objective
3	Moderately important	Experience and judgment slightly favor one over the other
5	Strongly important	Experience and judgment strongly favor one over the other
7	Very strongly important	Experience and judgment very strongly favor one over the other, as demonstrated in practice
9	Extremely important	The evidence favoring one over the other is of the highest possible validity
2, 4, 6, 8	Intermediate preferences between adjacent scales	When compromise is needed

Table 3. The order of the random index of consistency with a number of alternatives

N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

Table 4. Weights and ranks of various criteria of a disaster-resilient coastal community

Codes	Criteria	Weight	Rank
ENRM	Environmental and natural resource management (including natural capital and climate change adaptation)	1.90	1
HWB	Health and well-being (including human capital)	0.77	6
SL	Sustainable livelihoods	1.50	2
SP	Social protection (including social capital)	1.26	3
FI	Financial instruments (including financial capital)	0.81	5
PPST	Physical protection; structural and technical measures (including physical capital)	0.57	7
PR	Planning regimes	0.92	4
		λ_{max} = 7.69; CI = 0.11; CR = 0.09	

Table 5. Weights and ranks of various elements that characterized the selected criteria to produce a disaster-resilient coastal community

Criteria	Elements of Disaster-resilient Communities		Weights	Rank	Elements of Risk-reduction-enabling Environment		Weights	Rank
ENRM	ENRMC1	Understanding of functioning environment and ecosystems	1.62	1	ENRME1	Supportive policy and institutional structure	1.31	2
	ENRMC2	Environmental practices that reduce hazard risk	1.58	2	ENRME2	Prevention of unsustainable land use	1.51	1
	ENRMC3	Preservation of biodiversity for equitable distribution system	0.76		ENRME3	Policy linking environmental management and risk reduction	1.03	3
	ENRMC4	Application of indigenous knowledge and technologies	0.85	3	ENRME4	DRR policies and strategies integrated with climate change	0.59	
	ENRMC5	Access to community-managed property resources	0.67		ENRME5	Availability of local experts and extension workers	0.97	
		λ_{max} = 5.47 ; CI = 0.12 ; CR = 0.10				λ_{max} = 5.41 ; CI = 0.10 ; CR = 0.09		
SL	SLC1	High level of local economic and employment stability	1.28	2	SLE1	Equitable economic development	1.62	2
	SLC2	Equitable distribution of wealth and livelihood in community	0.74		SLE2	Diversification of national and sub-national economies	0.79	4
	SLC3	Livelihood diversification in rural areas	1.33	1	SLE3	Poverty-reduction targets vulnerable groups	2.19	1
	SLC4	Fewer people engaged in unsafe livelihood	1.18	4	SLE4	DRR reflected as integral part of policy for economic development	0.77	
	SLC5	Adoption of hazard-resistant agriculture	1.23	3	SLE5	Adequate and fair wages guaranteed by law	0.77	
	SLC6	Small enterprises with protection and business continuity/ recovery plans	0.98		SLE6	Supportive policy on equitable use and access to common resources	0.42	
	SLC7	Local market and trade links protected from hazards	1.07	5	SLE7	Incentives to reduce vulnerable livelihood	1.16	3
		λ_{max} = 7.83 ; CI = 0.14 ; CR = 0.10				λ_{max} = 7.76 ; CI = 0.13 ; CR = 0.10		

Criteria	Elements of Disaster-resilient Communities		Weights	Rank	Elements of Risk-reduction-enabling Environment		Weights	Rank
SP	SPC1	Social support and network systems on DRR activities	1.87	1	SPE1	Social protection and safety nets for vulnerable groups	1.25	1
	SPC2	Cooperation with local community for DRR activities	1.63	2	SPE2	Coherent policy and networks for social protection and safety nets	0.61	
	SPC3	Community access to basic social services	0.72	3	SPE3	Comprehensive partnership with external agencies on DRR	1.16	2
	SPC4	Established social information and communication channels	0.62					
	SPC5	Collective knowledge and experience of management of previous events	0.67					
		λ_{max} = 5.42 ; CI = 0.11 ; CR = 0.09				λ_{max} = 3.03 ; CI = 0.02 ; CR = 0.03		
PR	PRC1	Community decision making takes on land use and hazards	1.27	1	PRE1	Compliance with standard international planning	0.91	3
	PRC2	Local disaster plans feed into local development and land use planning	0.61		PRE2	Land use planning takes hazard risks into account	1.47	1
	PRC3	Local community participates in all stages of DRR planning	1.15	2	PRE3	Effective inspection and enforcement regimes	0.75	
					PRE4	Land use plan schemes based on risks assessments	1.02	2
		λ_{max} = 3.04 ; CI = 0.02 ; CR = 0.03				λ_{max} = 4.16 ; CI = 0.05 ; CR = 0.06		

Table 6. Weights of criteria and element indicators that describe a disaster-resilient coastal community

Criteria	Normalized Weights	Elements of Disaster-resilient Communities		Normalized Weights	Elements of Risk-reduction-enabling Environment		Normalized Weights
ENRM	0.40	ENRMC1	Understanding of functioning environment and ecosystems	0.47	ENRME1	Supportive policy and institutional structure	0.35
		ENRMC2	Environmental practices that reduce hazard risk	0.44	ENRME2	Prevention of unsustainable land use	0.44
		ENRMC4	Application of indigenous knowledge and technologies	0.09	ENRME3	Policy linking environmental management and risk reduction	0.21
SL	0.28	SLC1	High level of local economic and employment stability	0.23	SLE1	Equitable economic development	0.29
		SLC3	Livelihood diversification in rural areas	0.25	SLE2	Diversification of national and sub-national economies	0.09
		SLC4	Fewer people engaged in unsafe livelihood	0.18	SLE3	Poverty-reduction targets vulnerable groups	0.43
		SLC5	Adoption of hazard-resistant agriculture	0.21	SLE7	Incentives to reduce vulnerable livelihood	0.18
		SLC7	Local market and trade links protected from hazards	0.14			
SP	0.21	SPC1	Social support and network systems on DRR activities	0.53	SPE1	Social protection and safety nets for vulnerable groups	0.54
		SPC2	Cooperation with local community for DRR activities	0.43	SPE3	Comprehensive partnership with external agencies on DRR	0.46
		SPC3	Community access to basic social services	0.04			
PR	0.11	PRC1	Community decision making takes on land use and hazards	0.55	PRE1	Compliance with standard international planning	0.14
		PRC3	Local community participates in all stages of DRR planning	0.45	PRE2	Land use planning takes hazard risks into account	0.63
					PRE4	Land use plan schemes based on risks assessments	0.23

Table 7. Six-level scale for ranking indicators as modified from Twigg's [16] five-level scale for ranking distinctive disaster risk-reduction interventions

Levels	Distinctive Disaster Risk-reduction Intervention
Level 0	Absence of a clear and coherent activity/ activities in an overall disaster risk reduction program.
Level 1	Little awareness of the issue(s) or motivation to address them. Actions limited to crisis response.
Level 2	Awareness of the issue(s) and willingness to address them. Capacity to act (knowledge and skills, human, material and other resources) remains limited. Interventions tend to be one-off, piecemeal and short-term.
Level 3	Development and implementation of solutions. Capacity to act is improved and substantial. Interventions are more numerous and long-term.
Level 4	Coherence and integration. Interventions are extensive, covering all main aspects of the problem, and they are linked within a coherent long-term strategy.
Level 5	A "culture of safety" exists among all stakeholders, where Disaster Risk Reduction (DRR) is embedded in all relevant policy, planning, practice, attitudes and behavior.