Development of Mathematical Model for Storm Surge Vulnerability and Capacity Assessment of Coastal Communities in Camarines Norte

Asia Pacific Journal of Multidisciplinary Research
Vol. 6 No. 3, 41-46
August 2018
P-ISSN 2350-7756
E-ISSN 2350-8442
www.apjmr.com
CHED Recognized Journal
ASEAN Citation Index

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Date Received: March 11, 2018; Date Revised: July 7, 2018

Abstract – *This study was conducted to create a Mathematical Model through a simple mathematical equation that could assess the storm surge vulnerability and capacity assessment of coastal communities in Camarines Norte. The formulated equation can be solved using the parameters set - based on the needs assessment of the community. The researcher used a descriptive-evaluative method with the aid of a questionnaire and an in-dept interview assisted by the DRR officer of the Brgy. and duly validated by the Provincial Disaster Risk Reduction and Management Office and used convenience-sampling method in order to provide answers from various family. Respondents of this study were the community members of Brgy. Mangcamagong, Basud, Camarines Norte. The formulated Mathematical model is easy to adopt and may still be updated considering other factors and adding other possible variables. Moreover, the data may be regularly updated semi-annually to ensure accuracy of result. Further related studies may still be considered for a more complex and more accurate result that would be beneficial not only to the Municipal Disaster Risk Reduction Management Office (MDRRMO), Provincial Disaster Risk Reduction Management Office (PDRRMO), and other concerned offices, but most importantly to the entire coastal community of the province in general.*

Keywords – *Community Assessment, Storm Surge Reducion, Community Empowerment.*

INTRODUCTION

The province of Camarines Norte is found in the North-Western coast of the Bicol Peninsula, which forms the southeastern section of Luzon, the largest island in the Philippine Archipelago. Camarines Norte is located between Mount Cadig-Labo mountain ranges and the Pacific Ocean at 122°20’ to 123°05’ east longitude and 13°50’ to 14°30’ north latitude. The province is composed of nine (9) coastal municipalities with a coastline of 423 kilometers and has prominent river systems with its tributaries.

All nine (9) coastal municipalities of Basud, Daet, Capalonga, Jose Panganiban, Mercedes, Paracale, Sta. Elena, Talisay and Vinzons were identified as high risk to storm surge with a total area covered to 18, 924. 91 hectares or 8.15% of the total area of the province.

Coastal municipalities consisting of raised communities referred to this research as coastal communities are highly susceptible and have a very high risk of vulnerability to hazards, particularly storm surge that happens when the sea level rises beyond the normal tide levels, due to strong winds and low pressure from typhoons[1].

As expected, it is clear that flooding from short term events (storm surge) and slow onset climate change induced events (sea level rise) have cumulative impacts so managers tasked with designing actions to help reduce impacts from these should work together. [2]

Making decisions and efficiently allocating resources to reduce vulnerability of coastal communities requires, among other things, an understanding of the factors that make a society vulnerable to climate and hazards. [3] Vulnerability factors may be lessened because of the strategies formulated in different ways that certainly aims to lessen the impact of a calamity.

Flexible, adaptive management strategies that identify gaps in knowledge, develop alternative hypothesis, and gradually revise policies in response to new scientific findings and observations are necessary to produce management plans that openly address an uncertain future. [4]

Within this context, proper coastal zone management requires sustainable development of systematic assessment of vulnerability of an area or target population to be prepared for the wide range of storm-related hazards, particularly storm surge. Knowledge of vulnerability would enable people to anticipate and act on the adverse consequences of storm surge.

If the only output from a model is the prediction of some quantity, how can the user assess the accuracy of the prediction? Of course, this cannot be done, and the user is left in a take-it or leave-it situation. It would be better if the prediction were accompanied by an estimate of precision. These can be obtained from model studying or model testing. [5]

An important decision in modeling is choosing an appropriate level of detail for the problem at hand, and thus knowing what level of detail is prescribed for the attendant model. [6]

Focusing on the fact that coastal communities in Camarines Norte are under the threat of storm surge, this paper aimed to develop Mathematical model that could assess the vulnerability and capacity of coastal communities to storm surge. The researcher explored and quantified different key factors that contribute to the vulnerability of a particular coastal community.

OBJECTIVES OF THE STUDY

The main objective of this study is to develop Mathematical model that is represented by a simple equation that could assess the vulnerability and capacity of coastal communities to resist storm surge even without the aid of any advance technological factors, and can easily be used by the implementers.

MATERIALS AND METHODS

This study was anchored on the Modeling thoery of Albert Bandura who stresses on the social learning through observation. According to Bandura, effective modelling requires attention, retention, reproduction and motivation. [7] These factors were considered before the conduct of this study and to enable the researcher attain the best possible result of this study.

The researcher used descriptive-evaluative method thru a survey questionnaire and in-dept interview to measure two main factors : (1) Physical resources that includes Equiptments, structures and Agricultural Resources of the community, were administered to the Brgy. Officials and key persons of Brgy. Mangcamagong, Basud, Camarines Norte (20 persons). (2) Personal capacity, Individual Capacity, and Family Capacity were answered by the selected community members using Convenience-sampling method (30 persons), they have various capacity in order for the questionnaire and the researcher to address the strength and weakness of different family.

After the questionnaires were answered, two procedures are involved. First is the interpretation of data from the Brgy. Officials and key persons regarding the physical and agricultural resources of the Brgy. and the answers of the households chosen. The second one was the formulation of a solution through a simple mathematical equation friendly to every user with the supervision of the Brgy. Disaster Risk Reduction Officer-in-Charge to be validated by the Provincial disaster risk reduction management officer.

DISCUSSION

From the analysis of the answers gathered through survey questionnaire and interview, viriables were identified by the researcher and the DRR officer. A simple mathematical model represented by a simple mathematical equation was then formulated. This can answer the level of storm surge vulnerability of a family. Its validity was validated and tested by the researcher and DRR officer and results revealed that this equation is very user friendly and self-explanatory. The implementers themselves can identify and understand the variables used by the researcher to identify the communities' vulnerability to storm surge.

MATHEMATICAL MODEL AND ITS PARAMETERS

The mathematical equation formulated was:

$$\boldsymbol{V = 10 - (\bar{y} + \bar{x})}$$

where **V** is the range of vulnerability, $\bar{y}$ is the physical and agricultural resources of the community that could be outmost usefull to help before, during and after the disaster, and $\bar{x}$ is the personal capacity of an individual and the family.

$$\bar{y} = \frac{p_1 + A_1 + A_2 + A_3}{4}$$

P_1= Is the physical resources of the community (this may enable the administrators to allocate and properly account the possible numbers of evacuees on safe places, and what machineries are available to retrieve and help the people revive their living).

P_1= 5 is the physical resources of the community is available and adequate

P_1= 3 is the physical resources of the community is available but not adequate

P_1= 1 is the physical resources of the community is not adequate

P-ISSN 2350-7756 | E-ISSN 2350-8442 | www.apjmr.com
Asia Pacific Journal of Multidisciplinary Research, Vol. 6, No. 3, August 2018

P_1= 0 if there is no physical resources for the community

A_1= is the agricultural and natural resources of the community (beneficial for the community to have these resources, with this they can survive hunger for the entire duration of the calamity.)

A_1= 5 if the agricultural and natural resources of the community is ready for consumption during disaster
A_1= 3 if the agricultural and natural resources of the community is ready for consumption during disaster but not adequate
A_1= 1 if the agricultural and natural resources of the community is not ready for consumption during disaster
A_1= 0 if there is no agricultural and natural resources in the community is ready for consumption during disaster

A_2 = is the aquatic farm of the community (this may be a good source of food for the evacuees in lieu to meat)

A_2 = 5 if the aquatic farm of the community is ready for consumption during and after the disaster and adequate
A_2 = 3 if the aquatic farm of the community is ready for consumption during and after the disaster but not adequate
A_2= 1 if the aquatic farm of the community is ready for consumption
A_2= 0 if there is no aquatic farm in the community

A_3= is the animal farm of the community(These animals can be butchered and consumed if in case the relief from the government is not sufficient for their needs. Also these animals can be their source of income whenever they lost their source of living)

A_3 = 5 if the animal farm of the community is ready for consumption during and after the disaster
A_3 = 3 is the animal farm of the community is ready for consumption but not adequate
A_3 = 1 if the animal farm of the community is not ready for consumption
A_3 = 0 if there are no animal farm of the community

Variables used were: p_1, A_1, A_2, A_3 which have the same bearing or weight because of their important role in the community. Four (4) was used to divide the result in order to get the average value of capacity assessment based on the physical and agricultural resources, which is represented by the variable $\bar{y}$.

To get $\bar{x} = \frac{x_1+x_2+x_3+x_4+x_5+x_6+x_7}{7}$

Where:

x_1 = Family economic status (which represents the household economic standing that enables the family to sustain their needs, provide for the family and reestablish their losses because of uncertain impact of the storm surge.)

x_1 = 5 if the family is living on an above average living status
x_1 = 3 if the family is living on an average living status
x_1 = 1 if the family is living on a below average status

x_2 = Persons with disabilities or elderlies (which is automatically represents the vulnerable persons because of their age and limited capability. These factors must always be considered and they are the top priority to be saved or relocated as much as possible.)

x_2 = 5 if there are person/s with disabilities
x_2 = 3 if there are elderly member of the family, ranging 60 years old above
x_2 = 1 if there are person/s with disabilities and elderlies
Where:

x_3 = Trainings about Disaster Risk Reduction and Climate Change Adaptation (represents their knowledge on how they can resist and be prepared before, during and after the surge strikes. This factor must be considered since the more knowledge and trainings a family or an individual has, the lesser their chance of being vulnerable to uncertain surges.)

x_3 = 5 if they have an updated training/s about DRR and CCA
x_3 = 4 if they have training/s about DRR and CCA for the past year

x_3 = 3 if they have training/s about Disaster Reduction only
x_3 = 2 if they have training/s about Climate Change Adaptation only
x_3 = 0 if they do not have any trainings about DRR and CCA

x_4 = Types of housing/house structure (This is important to resist a hazard since the structure of the house will verify the resistance of the house itself. The tougher the materials and structure of the house, the lesser their vulnerability is.)

x_4 = 5 if the house is concrete and stable
x_4 = 4 if the house is half concrete and half nipa
x_4 = 3 if the house is nipa
x_4 = 2 if the house is made out of crap plywoods and nipa roof
x_4 = 1 if the house is not stable and they are an informal settler

x_5 = Location of dwellings (is may tell the possible impact the surge may give)

x_5 = 5 if the location of dwelling is far from shoreline, mountain edge, creek, irrigation and river
x_5 = 4 if the location of dwelling is far from shoreline, creek and irrigation
x_5 = 3 if the location of dwelling is far from river, creek and irrigation
x_5 = 2 if the location of dwelling is far from creek and irrigation, but near the shoreline
x_5 = 1 if the location of dwelling is far from the irrigation, but near the shoreline
x_5 = 0 if the location of dwelling is near from the shoreline, mountain edge, creek, irrigation and river

x_6 = Distance from the evacuation center (the estimated distance from evacuation center which represents their capacity to evacuate immediately in case of an emergency.)
x_6 = 5 if the distance from the evacuation center is 10m-50m
x_6 = 4 if the distance from the evacuation center is 51m-150m
x_6 = 3 if the distance from the evacuation center is 151m-250m
x_6 = 2 if the distance from the evacuation center is 251m-350m
x_6 = 1 if the distance from the evacuation center is 351m-450m
x_6 = 0 if the distance from the evacuation center is 451m and above

x_7 = Distance from the national road (easy access to help)
x_7 = 5 if the distance from the evacuation center is 10m-50m
x_7 = 4 if the distance from the evacuation center is 51m-150m
x_7 = 3 if the distance from the evacuation center is 151m-250m
x_7 = 2 if the distance from the evacuation center is 251m-350m
x_7 = 1 if the distance from the evacuation center is 351m-450m
x_7 = 0 if the distance from the evacuation center is 451m and above

The value of each variable used is equal, considering the factors that affect the weight of every variable are already stated. These factors should be carefully analyzed before rating. The result of the generated equation yields the range of vulnerability as stated below:

Range of vulnerability based on the result of the computation:
0 – 0.99 = very non – vulnerable (last priority for evacuation)
2.00– 3.99 = non - vulnerable (fourth priority for evacuation every time there is a calamity or disaster)
4.00 – 6.99 = less vulnerable (third priority for evacuation every time there is a calamity or disaster)
7.00 – 9.99 = vulnerable (second priority for evacuation every time there is a calamity or disaster)
10.00 = very vulnerable (priority for evacuation every time there is a calamity or disaster)

The higher their capacity to resist storm surge, the lower the result of the mathematical model would be.

Based from different concerned offices it is beneficial if the researcher would use ten as the perfect score for this model.

The researcher used additional formula to simply sum up the mean capacity of the community and individual capacity of every family in the coastal community.

VALIDATION

To prove that the mathematical model can really be used and can be implemented, a validation was executed.

A family with an average living economic status (x_1=3) with an elderly member (x_2=3), family members have trainings about DRR and CCA for the past year (x_3=4). The house structure is composed of concrete and very stable (x_4=5), their house is located far from creek and irrigation but near the shoreline (x_5=2). The distance from the evacuation center is 75m away (x_6=4), and 130m away from the national road (x_7=4).

The agricultural resources of the community are ready for consumption but are not adequate for a long period of time (p_1=3). The physical resources of the community are not adequate for immediate evacuation (A_1=3). The aquatic resources of the community are ready for consumption but not adequate for a long period of time(A_2=3). The animal farm of the community is ready for consumption (A_3=5).

From the given, we substitute the assessed value of the family to the equation formulated.

$$\bar{y} = \frac{p_1 + A_1 + A_2 + A_3}{4}$$

$$\bar{y} = \frac{3+3+3+5}{4}$$

$$\boldsymbol{\bar{y} = 3.5}$$

$$\bar{x} = \frac{3+3+4+5+2+4+4}{7}$$

$$\boldsymbol{\bar{x} = 3.571429}$$

To get the Vulnerability Assessment:
Solution:

$$V = 10 - (\bar{y} + \bar{x})$$

$$V = 10 - (3.5 + 3.571429)$$

$$\boldsymbol{V = 2.928571}$$

Non-Vulnerable Family (fourth priority for evacuation every time that there is a predicted storm surge approaching the community.

CONCLUSIONS

Majority of coastal communities in Camarines Norte, Philippines does not have internet access, with that the researcher thought of creating a way to help the assessors find out the vulnerability and capacity of these coastal communities.

The mathematical model through an equation formulated does not need any advance technological factors to be facilitated by an expert. This model is intended for coastal barangay workers - often undergraduate and not that literate to some technology and for the community itself, knowing that they know the most accurate answers to the questions and that it would yield them the answer they needed. They can compute this manually with the aid of the parameters indicated in this study.

This study also has its limitations (1) other variables can be added, (2) updated data from the current result is vital. Further approaches, innovations and updates to the equation is utmost important. Validation of data per family is also vital for the validity and accuracy of the equation.

ACKNOWLEDGEMENT

The researcher would like to extend his gratitude to every person who helped him materialized this study. PDRRMO – CN, MDRRMO Daet, Brgy. Council of Mangcamagong, Basud Camarines Norte, Ms. Jessica Salazar, and Ms. Kimberly Selvio.

REFERENCES

[1] Galvez, C., Ferrer, A., et al, (2012). Camarines Norte Provincial Disaster Risk Reduction and Management Plan. pp(2-4)

[2] Weis, S. W. M., Agostini, V. N., Roth, L. M., Gilmer, B., Schill, S. R., Knowles, J. E., & Blyther, R. (2016). Assessing vulnerability: an integrated approach for mapping adaptive capacity, sensitivity, and exposure. *Climatic Change*, *136*(3-4), 615-629.

[3] Blyther, Ruth et al. (2016). Assessing Vulnerability: An Integrated Approach for Mapping Adaptive Capacity, Sensitivity and Exposure. Michigan, Chicago, USA.

[4] Haunani H. Kane, Charles H. Fletcher, L. Neil Frazer, Tiffany R. Anderson, Matthew M. Barbee. (2015). Modeling sea-level vulnerability of coastal environments using ranked management concerns. doi: 10.1007/s10584-015-1377-3. Springer

[5] Glenn Marion, Bioinformatics and Statistics Scotland Given 2008 by Daniel Lawson and Glenn Marion (2008). An Introduction to Mathematical Modelling, URL: https://goo.gl/XgtPq1, Date Retrieved: March 2, 2018

[6] What is Mathematical Modeling, url: https://goo.gl/djAnKS, Retrieved March 2, 2018

[7] Modeling Theory. https://goo.gl/CE1g2d, Date Retrieved: July 2, 2018