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Vulnerability Index For Urban Flooding: Understanding Social Vulnerabilities And Risks

Mae Brigitt Bernadel Loyloy Villordon

Philippe Gourbesville

VULNERABILITY INDEX FOR URBAN FLOODING: UNDERSTANDING SOCIAL VULNERABILITIES AND RISKS

Mae Brigitt Bernadel L. Villordon[1], Philippe Gourbesville[2]
[1]*Nice Sophia Antipolis / Polytech Nice Sophia / URE 005 Innovative CiTy, 930 Route des Colles, 06903 Sophia Antipolis, FRANCE*
[2]*Nice Sophia Antipolis / Polytech Nice Sophia / URE 005 Innovative CiTy, 930 Route des Colles, 06903 Sophia Antipolis, FRANCE*

According to the World Risk Report released by the United Nations University Institute for Environment and Human Security, the Philippines is ranked third globally in terms of disaster risk. One of those disaster risks is flooding which poses a serious challenge to development and the lives of the people. Public health risks and social vulnerability were usually overlooked, undermined and only very little attention is given. Thus, this study focuses on these aspects. This study was an exploratory step towards assessing vulnerability particularly to fluvial flooding, it was a rapid assessment of the Knowledge, Attitudes, and Practices (KAP) of the community people including their socio-demographic profile, physical environment, exposure to microorganisms such as E.coli, Liptospirosis and the Dengue Fever mosquito, and local indicators were formulated and developed. These are important factors to be assessed in order to establish correlations and relationships in understanding social vulnerabilities and its indicators which can be incorporated in the hydroinformatics. The survey was done from March 2013 to July 2013. A total of 361 household respondents from the 12 communities and 30 respondents from the LGU and NGO were surveyed. Results of the study revealed an overall Flood Vulnerability Index (FVI) of 39.34%. Barangay Tabuc-tubig (53.39%) topping from all the 12 communities surveyed using the local indicators of the five major components namely; hydro-geological, social, economic, socio-behavioral and the politico-administrative component. This study also reveals the most vulnerable communities from each of those 5 major components surveyed. It is interesting to note that Flood Vulnerability Index remains low in spite that the exposure indicators are high. The low FVI can be attributed to the community's high resilience in its coping and adaptation strategies. In this study, the Flood Vulnerability Index is significantly sensitive to susceptibility and flood resilience variables.

Keywords: Flood vulnerability components and indicators, Knowledge, Attitude and Practice (KAP) on flood resilience, E.coli, Liptospirosis and Dengue Fever mosquito exposure, Flood resilience

1. INTRODUCTION

According to the World Risk Report released by the United Nations University Institute for Environment and Human Security, the Philippines is ranked third globally in terms of disaster risk [UNDP (2011)] [6]. Typhoon which usually followed by flooding in some areas is one of those disaster risk that is frequency occurring in the Philippines, twenty or more typhoons visits the country every year leaving devastations in many forms. It is a global phenomenon and due to climate change, this will continue. Urban fluvial flooding in particular caused havoc in many aspects in the society particularly to human health, infrastructure and the economy of the country. Public health risk in urban fluvial flooding are usually been overlooked, undermined and only very little attention is given. This would therefore hopefully serve as a baseline study. Diarrheal and other waterborne diseases still rank among the leading causes of morbidity worldwide and in the Philippines. It is therefore important to conduct studies related to vulnerability and resilience at the community level so issues on health and disaster risks will be addressed appropriately providing better understanding how each household perceive, relates and employs their attitudes and practices towards personal hygiene and protection, and to environmental sanitation and disaster risk.

This study was an exploratory step towards assessing flood vulnerability and resilience, a rapid assessment of the Knowledge, Attitudes, and Practices (KAP) of the community people towards flood resilience, health, environmental sanitation and including their socio-demographic profile and governance. These are important factors to be assessed in order to established correlations and relationships in understanding social vulnerabilities and its indicators so it can be incorporated in hydroinformatics. Measuring vulnerability and resilience is important, it mirrors how well are the people adapting to climate change and its impacts. Perhaps it is also important to note that gauging vulnerability may have a number of different reasons but understanding the context of people's vulnerability to hazards and why they are vulnerable in the first place, seems to be more useful for making a difference in their lives.

2. MOTIVATION AND OBJECTIVES

Several studies on disaster risk, flood vulnerability and resilience index have been conducted worldwide. Here is a brief review. On behalf of the Bündnis Entwicklung Hilft (Alliance Development Works), the UNU-EHS in Bonn, Germany has developed the WorldRiskIndex in 2011and calculated the risk values for 173 countries worldwide [UNDP (2004)] [5]. However, this report has failed to include some of the important component which has theoretical and practical significance due to lack of relevant data. These four sub-categories are, housing situation, social networks, disaster preparedness/early warning and adaptation strategies were not integrated into the overall calculation of the WorldRiskIndex in 2011 which are deemed to be relevant and significant. Thus, this study has focused on these categories. In 2004, the United Nation Development Programme (UNDP) also published a Global Report on Reducing Disaster Risk: A Challenge for Development [UNDP (2004)] [5]. Part of the recommendations from this report is to address the gaps in knowledge for disaster risk assessment. Measuring the KAP of the respondents from preparedness to recovery, and as well as the KAP on the exposures of the microorganisms in focus would give us a clue how community people perceived in these kinds of phenomenon which are translated into their attitudes and practices. A flood vulnerability index for coastal cities was developed by [Balica *et al.* (2012)] [1], using the system's components namely, the hydro-geological component, socio-economic and the politico-administrative components. It has been conducted to nine cities around the world. However, some local indicators were not included thus this study focuses and gives attention to these factors and indicators in developing this flood vulnerability index for urban flooding. In spite that the Philippines has a very good National and Local Disaster Risk Reduction and Management Council Structure yet there have been cases where emergency response and disaster recovery during and after a typhoon or flooding had experienced some delays due to some political issues or gaps among concerted actions from numerous actors across multiple sectors. It is important to know why such gaps exists thus soliciting surveys from LGU's and NGO's is a way of connecting these gaps. The aim of this study is to improve the limitation of the previous WorldDisasterIndex and other similar studies by developing new indicators and components for Flood Vulnerability Index that will be useful in the community level.

3. KEY CONCEPTS AND COMPONENTS FOR FLOOD VULNERABILITY INDEX (FVI)

There are 3 important factors to consider all throughout the components which determine the vulnerability index. These factors are exposure, susceptibility and resilience. In addition, the concept of vulnerability will also be described below to facilitate a complete understanding of the concepts and components. The selection for the sub-indicators for exposure was based primarily on the local threats that exposed the household respondents to river flooding and possible disease outbreak that goes with it. Within the Flood Vulnerability Index, exposure is related to the likelihood of acquiring and being affected by such phenomenon. This paper defines susceptibility as the elements exposed within the system, which influences the probabilities of being harmed at times of hazardous floods. In this study, the resilience factor is composed of the coping capacities and adaptive capacities of the individuals, communities and the government that may contribute in reducing the impacts of river flooding and disease outbreaks through direct actions and resources. In this research, vulnerability is the result of the interplay of the indicators in the exposure, susceptibility and resilience category. The five components for measuring the flood vulnerability index in this study are the following; hydro-geological, social, economic, socio-behavioral and politico-administrative component. The relationship between flood vulnerability components and its indicators is illustrated in Table 1.

The Catchment Area and Population

Dumaguete City Philippines is the study area of this research and is located 9^{o}18'28" north latitude and 123^{o}18'28" east longitude. It has a population of 120,883 people as of the 2010 Population census. Dumaguete City has an entire area of 3,426 hectares divided into 30 communities or barangays. The City's topography is generally flat from 2 to 6 kilometers from the shoreline. The highest ground elevation is located at the boundary of the municipality of Valencia, about 100 meters (300 feet) above mean sea level. About 93% of the land has slopes of less than 3%. The remaining areas have 3% to 5% slope. The Banica River Watershed (BRW) forms an elongated channel of approximately 18 kilometers from the mouth of Banica River in Dumaguete City to Casaroro Falls in Valencia. The difference in elevation from Dumaguete's shoreline to the peak of the watershed is 1,580 meters. The straight course of Banica River and high gradient signify a short residence time for surface runoff and hence, there is a greater risk and occurrence of flashfloods and riverbed drying. There is a big difference in the flow measurements between Candau-ay and Batingiuel sections of Banica River, which is attributed to high infiltration rates in Batinguel section [Institution of the Rehabilitation of Banica River Watershed (2000)] [3].

Table 1: Relationship between components and indicators

Flood Vulnerability Components	Vulnerability Indicators		
	Exposure Abb.	Susceptibility Abb.	Resilience Abb.
A. Hydro-Geological Components	A. Frequency of Flooding (FF) B. Height of flooding (HF) C. Houses reached by floods (HRF) D. Houses not on elevated area (HNE)	A. Number of Typhoons per year (50%) (NTY)	A. Land Use Management And Structural Design (LUMSD)
B. Social Components	A. Open disposal of animal waste (ODAW) B. Unwillingness to vacate and be relocated (UVR)	A. Educational Attainment (High School Level and below) (EA)	A. Water Treatment or Sterilization Practice (WT) B. Social Networks (SN)
C. Economic Components	A. Houses with NO access to improved sanitation (HNIS) B. Houses with NO access to an improved water source (HNIW) C. Presence of rats in the vicinity (PRV) D. Presence of water logged areas in the vicinity (PWLV)	A. Housing Conditions (semi-concrete, tent light materials, and plastic materials) (HC)	A. Family Income (3000-10,000) (FI) B. Property Insurance (PI)
D. Socio-Behavioral Components	A. PRACTICES of households on flood resilience (hazards, risks, exposure, preparedness, response, recovery, coordination, adaptation strategies) (PHFR) B. PRACTICES of households on E.coli (nature of E.coli, mode of transmission, prevention, signs and symptoms, it is fatal, treatment, financial cost of treatment) (PHEC) C. PRACTICES of households on Liptospirosis (same factors with letter B above) (PHL) D. PRACTICES of households on Dengue Fever (same factors with letter B above) (PHDF)	A. ATTITUDE of households on flood resilience (hazards, risks, exposure, preparedness, response, recovery, coordination, adaptation strategies) (AHFR) B. ATTITUDE of households on E.coli (nature of E.coli, mode of transmission, prevention, signs and symptoms, it is fatal, treatment, financial cost of treatment) (AHEC) C. ATTITUDE of households on Liptospirosis (same factors w/letter B above) (AHL) D. ATTITUDE of households on Dengue Fever (same factors with letter B above) (AHDF)	A. KNOWLEDGE of households on flood resilience (hazards, risks, exposure, preparedness, response, recovery, coordination, adaptation strategies) (KHFR) B. KNOWLEDGE of households on E.coli (nature of E.coli, mode of transmission, prevention, signs and symptoms, it is fatal, treatment, financial cost of treatment) (KHEC) C. KNOWLEDGE of households on Liptospirosis (same factors w/ letter B above) (KHL) D. KNOWLEDGE of households on Dengue Fever (same factors with letter B above) (KHDF)
E. Politico-Administrative Components	A. Land Use & Management & Structural Design (LUMSD) B. The River's Natural Resources & Natural Features Management and Program (RNRMP)	A. Governance (Warning and Evacuation, Emergency Response, Disaster Recovery) (G)	A. Post-risk Assessment and Integration (PRAI) B. Sustainable Community Livelihood Prog. (SCLP) C. Relocation Site Project (RSP) D. Health & Prevention Program of E.coli, Liptospirosis & DF (HPP)

4. FORMULATION OF FLOOD VULNERABILITY INDEX (FVI) FOR URBAN FLOODING

A total of 361 household respondents from the 12 communities and 30 respondents from the Local Government Units (LGU's) and Non-Governmental Organizations (NGO's) in Dumaguete City, Philippines were surveyed through sets of questionnaires and interviews from March 2013 to July 2013. The data were summarized per barangay (political/community unit) in frequency tables and their corresponding relative frequencies (%) as well the average of scores whenever appropriate. Variations in responses are expressed as standard deviation. For the calculation of the Flood Vulnerability Index (FVI) each of the components (hydro-geological, social, economic, socio-behavioral, and politico-administrative) is computed based on the general flood vulnerability index (FVI) formula (Eq. 1).

$$FVI = \frac{E*S}{R} \tag{1}$$

The general formula for FVI is computed by categorizing the indicators to the factors to which they belong (exposure (E), susceptibility (S) and resilience (R) according to Cendero and Fisher (1997) [2]. The indicators of exposure and susceptibility are multiplied and then divided by the resilience indicators, because indicators representing exposure and susceptibility increase the flood vulnerability and are therefore placed in the numerator. The resilience indicators decrease flood vulnerability and are thus part of the denominator. The Flood Vulnerability Index (FVI) for the hydro-geological, social, economic, socio-behavioral and politico-administrative components are expressed as follows (Eq. 2-9) and equations 10 and 10' is the formula for computing the total FVI.

$$FVI_{\text{hydro-geological}} = f\ \frac{FF, HF, HRF, HNE * NTY}{LUMSD} \tag{2}$$

$$FVI_{\text{social}} = f\ \frac{ODAW, UVR * EA}{WT, SN} \tag{3}$$

$$FVI_{\text{economic}} = f\ \frac{HNIS, HNIW, PRV, PWLV * HC}{FI, PI} \tag{4}$$

$$FVI_{\text{socio-behavioral on flood resilience}} = f\ \frac{PHFR * AHFR}{KHFR} \tag{5}$$

$$FVI_{\text{socio-behavioral on E. coli}} = f\ \frac{PHEC * AHEC}{KHEC} \tag{6}$$

$$FVI_{\text{socio-behavioral on Liptospirosis}} = f\ \frac{PHL * AHL}{KHL} \tag{7}$$

$$FVI_{\text{socio-behavioral on Dengue fever}} = f\ \frac{PHDF * AHDF}{KHDF} \tag{8}$$

$$FVI_{\text{politico-administrative}} = f\ \frac{RNRMP * G}{SCLP, RSP, HPP} \tag{9}$$

$$\text{Total FVI} = \frac{\text{Hydro-geological} + \text{Social} + \text{Economic} + \text{Socio-Behavioral} + \text{Politico-Administrative}}{5} \tag{10}$$

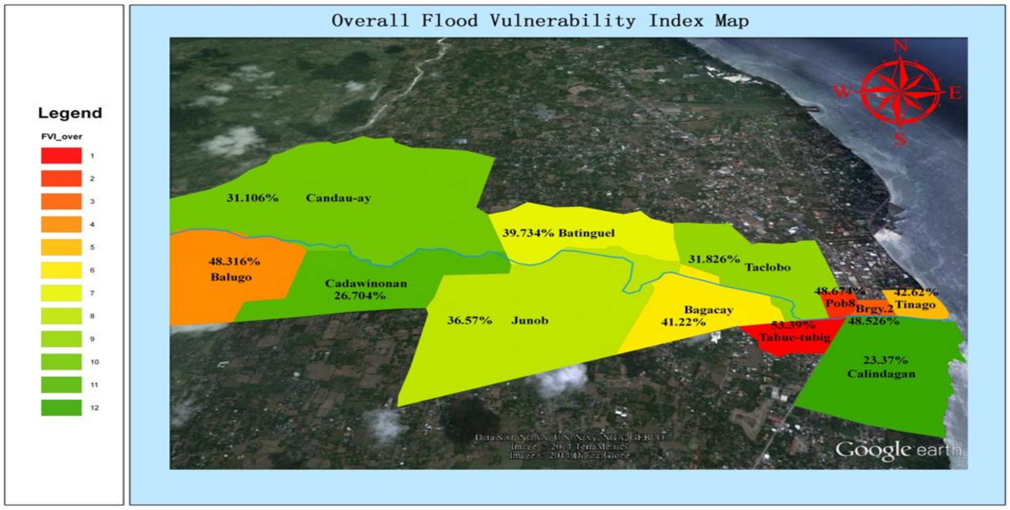
$$\text{Total FVI} = \left\{\left(\frac{FF,HF,HRF,HNE*NTY}{LUMSD}\right) + \left(\frac{ODAW,UVR*EA}{WT,SN}\right) + \left(\frac{HNIS,HNIW,PRV,PWLV*HC}{FI,PI}\right) + \left(\frac{PHFR*AHFR}{KHFR}\right) + \left(\frac{PHEC*AHEC}{KHEC}\right) + \left(\frac{PHL*AHL}{KHL}\right) + \left(\frac{PHDF*AHDF}{KHDF}\right) + \left(\frac{RNRMP*G}{SCLP,RSP,HPP}\right)\right\} \tag{10'}$$

The integrated Flood Vulnerability Index is a method to combine multiple aspects of a system into one number. On a global perspective, the results will be presented in values between 0% and 100% for better comprehension: 100% being the highest vulnerability found in the samples studied and 0% the lowest vulnerability. The flood vulnerability index percentile ratings are as follows with its corresponding interpretation: 0-19% very low; 20-39% low; 40-59% medium; 60-79% high; 80-100% very high vulnerability.

* Regardless if the community/city has a HIGH, MEDIUM, or LOW Flood Vulnerability Index, one should learn about and investigate the weaknesses identified during the process.

5. TABLES AND FIGURES

Figure 1: The Overall Flood Vulnerability Index for the 12 Communities



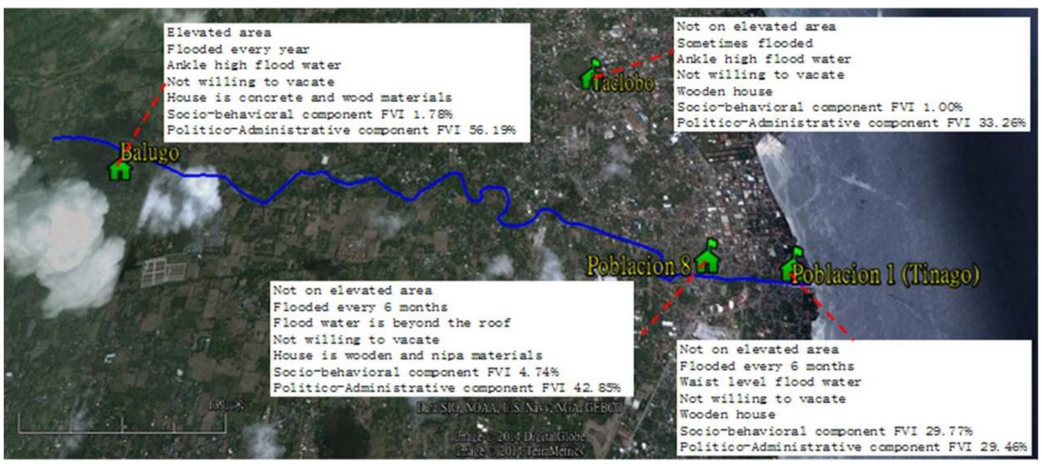
The Overall Flood Vulnerability Index (FVI) of the twelve communities examined is 39.34%. Tabuc-tubig is the most vulnerable to urban river floods (53.39%). Its vulnerability is owing to its high vulnerability index in economic and hydro-geological components and low resilience to the latter. Poblacion 8 ranks 2nd, followed by Barangay 2 (Lukewright), Balugo, Poblacion 1, Bagacay, Batinguel and Taclobo respectively. Barangay Candau-ay, Cadawinonan and Calindagan are the least vulnerable among the twelve communities respectively. All these three latter communities have very good resilience in most of the components examined. Their vulnerability differs from each other and can be found in Table 2 below.

Table 2: The overall FVI and FVI of the 5 Components

Community	OVERALL FVI	Hydro-geological FVI	Social FVI	Economic FVI	Socio-behavioral FVI	Politico-administrative FVI
Tabuc-tubig	53.39%	74.19%	39.13%	100%	3.96%	49.69%
Junob	36.57%	42.58%	13.59%	100.00%	13.25%	13.43%
Poblacion 1 (Tinago)	42.62%	60.15%	17.65%	100%	13.12%	22.18%
Calindagan	23.37%	37.76%	22.27%	48.24%	7.10%	1.47%
Balugo	48.32%	37.03%	38.21%	100.00%	10.15%	56.19%
Barangay 2 (Lukewright)	48.53%	67.14%	9.30%	94.77%	25.59%	45.83%
Poblacion 8	48.67%	82.07%	16.49%	92.43%	9.53%	42.85%
Cadawinonan	26.70%	43.75%	28.03%	27.79%	11.45%	22.50%
Bagacay	41.22%	50.37%	18.08%	100.00%	15.72%	21.93%
Taclobo	31.83%	55.31%	23.93%	39.75%	6.88%	33.26%
Candau-ay	31.11%	49.18%	24.48%	52.30%	13.51%	16.06%
Batinguel	39.73%	62.73%	6.08%	100.00%	8.76%	21.10%

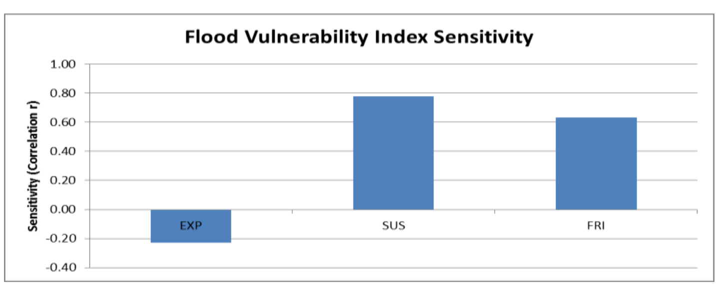
The values of the hydro-geological component indicators were used for Eq. 2. The result of the hydro-geological component is shown in Table 2. Six (6) indicators were used to determine the hydro-geological FVI values. After examining the hydro-geological components, Poblacion 8 (82.07%) is the most vulnerable. This can be attributed to a slightly lower value in the land use and management and structural design as part of its resilience strategies. The least vulnerable communities are Barangay Balugo (37.03%) and Calindagan (37.76%). The values of the social component indicators were used for Eq. 3, as described above. The results of the social component are shown in Table 2. There are five indicators from this component. Using these indicators, Tabuc-tubig (39.13%) stands out to be the most vulnerable to possible disease outbreak due to its high values in open disposal of animal waste (95.00%) and with very low values for water treatment or sterilization practice (20.00%). Batinguel and Barangay 2 (Lukewright) are the least vulnerable to fluvial flooding. Communities along the river have high social resilience. There are 12 indicators for the socio-behavioral component. The values were computed using Eq. 5-8 and the results are shown in Table 2. Using these indicators Barangay 2 (25.59%) is the most vulnerable when it comes to KAP to flood resilience and KAP to prevention and management of diseases from E.coli, Liptospirosis and Dengue Fever. On the other hand, the least vulnerable community is Tabuc-tubig (3.96%) followed by Taclobo and Calindagan respectively. The common pattern for this is usually, knowledge (resilience) score is sufficiently high and with extremely low bad attitude (susceptibility) or extremely low bad practices (exposure) against flood resilience and in the exposure of those diseases associated with flooding. The politico-administrative component of this study shows the involvement of institutional organizations in the flood management process, including those policies and programs that were laid prior to any catastrophic events and its long term adaptation strategies. The computation of the values uses Eq. 9 above. As seen in Table 2, the most vulnerable politico-administrative is Barangay Balugo (56.19%) followed by Tabuc-tubig and Barangay 2 respectively. Barangay Calindagan is the least vulnerable to this component with very high scores (76.29%) on its resilience strategies.

Figure 2. The Household Respondents at Glance



Here is a brief view of the household respondents in reference to their location from the river, the scenarios during flooding events, housing conditions and their vulnerability to the different components. Illustrations are shown using [Google Earth Map (2014)] [4].

Figure 3. Flood Vulnerability Index Sensitivity



The Flood Vulnerability Index in this study is significantly sensitive to susceptibility and flood resilience variables.

6. CONCLUSIONS

The results of the FVI of the 5 components and the overall FVI are summarized in Table 2. A new Flood Vulnerability Index (FVI) was developed in this study that incorporates the hydro-geological components, the socio-economic factors and perspectives of the community people in terms of its knowledge, attitude, and practices towards flood resilience, hygiene practices and disease outbreaks. The politico-administrative component was also included since it could have a profound effect in all of these components in the long run. The conclusion of this study covers four aspects and advantages: (1) The FVI methodology and use. The advantage of developing this FVI can make the community and the government aware of the different vulnerabilities that each community has and at the same time, this can be used as a network of knowledge to learn from each other and to increase the resilience of each community and which progress needs to be prioritized. With the FVI, the impacts can be predicted in different scenarios. In this way, it helps policymakers, environmental, water and disaster agencies to define what measurements must be taken and possible allocation for adaptation and reduction of flood vulnerability in urban areas. FVI is a powerful tool for mapping of vulnerable areas in the city. (2) FVI baseline results. Using these indicators one can clearly compare the vulnerabilities of communities in a thorough perspective which can later be used between cities and countries in the world. The focus of publishing the study is more of the holistic approach rather than just a political per se. (3) Local Authority and Stakeholders Involvement. For a FVI to be widely accepted, local authorities, community people and the non-governmental agencies has to be involved in the weighting of the indicators which this study has accomplished. It is only through this involvement that the interconnectedness of several indicators and local specificities will be thoroughly captured. (4) Flood Vulnerability Index Sensitivity. The Flood Vulnerability Index in this study is significantly sensitive to susceptibility and flood resilience variables. Precisely, the community people are vulnerable in the first place because of these variables.

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REFERENCES AND CITATIONS

[1] Balica, S.F., Wright, N.G..and van der Meulen, F. (2012). *A Food Vulnerability Index for Coastal Cities and Its Use in Assessing Climate Change Impacts*. Available at: http://download.springer.com/static/pdf/308/.

[2] Cendrero A, Fischer DW (1997) *A procedure for assessing the environmental quality of coastal areas for planning and management.* J Coast Res 13:732–744

[3] Institutionalization of the Rehabilitation of BANICA River Watershed, 2000.

[4] Google Earth Map. Image Lands at Data SIO, NOAA, U.S. Navy, NGA, GEBCO. Image Copyright 2014 DigitalGlobe.

[5] UNDP (United Nation Development Programme) (2004): *A Global Report Reducing Disaster Risk: A Challenge for Development*. Available at: http://www.undp.org/content/dam/undp/library/.

[6] United Nations University Institute for Environment and Human Security (UN World Risk Index) (2011): *Governance and Civil Society*. Available at http://www.ehs.unu.edu/file/get/9018.