RESEARCH ARTICLE

Pre-flood Vulnerability Capacity Assessment Approach for Buildings Located in Floodplain Areas: A Method Applied in the Case of Kabacan, North Cotabato, Philippines

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Abstract

This paper develops a new methodology for pre-flood vulnerability assessment approach for buildings located in floodplain urban areas of the Philippines. This method aims to provide baseline data on the location of vulnerable buildings and their flood vulnerability capacities useful in enhancing flood resistivity design and reducing potential flood damages on structures. The five-stage process of the method was tested in the floodplain areas of the Municipality of Kabacan, North Cotabato, Philippines. Results showed flood vulnerability capacities of buildings, namely, threshold, coping, recovery, and adaptive capacities, which became the basis for determining the flood vulnerability index (FVI) of the area. The determinants of vulnerability of buildings were also identified using the proposed assessment method. A map of vulnerable buildings as the final output of the proposed method targets vulnerable areas for flood emergency planning and flood risk management considerations. Further comparative studies on the use of this approach to other areas and studies to include other design parameters, flood exposure, and water flow intensity levels were recommended.

Keywords: case study • flood vulnerability assessment • Kabacan, North Cotabato, Philippines

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Introduction

THE SPATIAL NEEDS in the urban areas is projected to increase from 3.6 billion in 2011 to 6.3 billion over the next 40 years (UN DESA, 2011; Matyas and Pelling, 2012). An unwanted side effect of this rapid urbanization is urban centers expanding into adjacent floodplain areas, thereby increasing susceptibility towards floods as the result of the concentration of people and assets in these risk areas (Zevenbergen et al., 2008). Because of the increase in human activities in these risk areas, there is also higher instance of damage to property and risk to human lives as observed in recent decades (Luino et al., 2012).

In 2012, the Climate Risk Index of the Philippines reached its second highest because of its vulnerability to floods (Kreft and Eckstein, 2014). Despite flood exposure, many Filipinos still continue to build houses in floodplains due to spatial needs. According to a report by the United Nations Office for Disaster Risk Reduction (2015), urbanization has not benefited the Philippines unlike other countries due to losses from the damages to properties caused by recurring floods, particularly during rainy seasons (Galang, 2014). The country is often visited by at least 20 typhoons every year that affect most of the urban localities, particularly those located in flat, low-lying areas and those near rivers and coastlines. In fact, the Philippines has lost US$24.3 billion due to flood damages, ranking it fourth in the world for highest gross domestic product value losses between 1998 and 2009 according to a report by the UN-led Intergovernmental Panel on Climate Change (IPCC) (UNISDR, 2013).

The reduction of flood damages is one of the impetus for passing Republic Act 10121 or the Philippine Disaster Risk Reduction and Management Act of 2010, which saw the creation of the Disaster Risk Reduction and Management Council (DRRMC). The organization covers disaster preparedness, response, prevention and mitigation, and rehabilitation and recovery aspects. However, it is more active in the effective delivery of humanitarian assistance.

In other countries, flood resistive design is now required for structures built in floodplains and flood-exposed areas. The physical conditions of these buildings are actively being assessed to ensure compliance with this requirement. Some European countries use pre-flood vulnerability assessment tools to calculate and estimate potential damages for every house or every hectare of land, which considers three types of damages: damage to the house itself, damage to the contents of the house, and damage to vehicles (Sagala, 2006; Bowker, Escarameia, and Tagg, 2007). Other assessment methods usually disregard vehicles as part of the calculation since these can be moved before the event of a flood if given enough time.

In the United States, the Department of Homeland Security has instituted the National Flood Insurance Program under the Federal Insurance and Mitigation Administration (FEMA). The program uses a numerical rating system to assess the vulnerability of buildings located in special flood hazard areas. The purpose of the vulnerability assessment is to identify building design issues, evaluate the type and level of threat, and determine the level of protection sought for each mitigation measure against threat to further guide risk management decisions (FEMA, 2008).

In the Philippines, several vulnerability assessment approaches have been implemented at micro and macro levels. Moret (2014) presented a number of population level as well as individual- and household-level measures that can be used to assess vulnerability, including their uses, benefits, and drawbacks. However, there are limited studies conducted on the household level to study flood damages based on building design measures in a potentially flood risk area. A few studies have used approaches using actual damage assessment conducted after a flood event—for example, Sagala (2004) in Naga City, Shrestha et al. (2015) in the Pampanga river basin area, and the International Organization for Migration (2014) after Typhoon Haiyan.

The extent of susceptibility to damage from flood determines a structure's vulnerability. The damages to buildings are usually analyzed per component, the structural and non-structural. While structural elements provide a building structural support, rigidity, and integrity (FEMA, 2008), the non-structural components, which are attached to or housed in a building or building system but are not part of the main load-resisting structural system, constitutes majority of the structure (Mondal and Jain, 2005). Thus, in case of floods, the non-structural elements are primarily exposed to the water's intensity for longer periods and under deeper depths, which result in building impairment. Damage to non-structural elements of the building contribute greatly to the usability of the entire structure. Hence, a pre-flood vulnerability assessment of non-structural components of a building can provide baseline data about a building's potential risk of damages during a flood event.

This study therefore aims to focus on developing a new approach for pre-flood vulnerability assessment of non-structural design characteristics of buildings located in urban floodplain localities. This approach will then be applied to the case of the Municipality of Kabacan, North Cotabato, Philippines. The study will first review the literature on various types of flood vulnerability assessment approaches that have been proposed or implemented in the country. This study will also review indicators of a flood-resistant design or flood capacity of buildings necessary to develop a framework for the development of a rapid pre-flood vulnerability assessment method.

The Concept of Vulnerability

There are various types of vulnerability, namely, social, physical, ecological, economic, individual, and urban (Müller, Reiter, and Weiland, 2011). From the pressure and release (PAR) model developed by Wisner et al. (2003) to the coping capacity and resilience model by Thywissen (2006), vulnerability has also evolved with different conceptual frameworks, given that vulnerability is multi-dimensional. For instance, vulnerability can mean different things if one focuses on design and location of structures, on the exploitation of natural resources, and solely on the population (Hualou, 2011).

Focusing on natural environment functions, Klein and Nicholls (1999) focused on three main components: resistance, resilience, and susceptibility. Mitchell (2002; cited in Müller, Reiter, and Weiland, 2011), on the other hand, retains resistance and resilience but substitutes exposure for susceptibility. Messner and Meyer (2006) and Merz, Thieken, and Gocht (2007) thought of vulnerability as a function of elements at risk, exposure (damage potential), and (loss) susceptibility. Meanwhile, Balica, Douben, and Wright (2009) focus on exposure, susceptibility, and resilience as functions of vulnerability. This study adopts Pelling's (2003) model, which considers exposure, resilience, and resistance as factors that contribute to vulnerability (Figure 1).

It is possible to reduce vulnerability of structures located in floodplains by enhancing their resilience and resistance. This study therefore looks into these two components: at a micro scale, the household level of vulnerability focusing on assessing vulnerability capacities, and at the macro scale, the physical characteristics of each buildings as factors of flood vulnerability. Looking into more specific elements of buildings—the vulnerability of non-structural design components primarily exposed to potential and recurring flood hazards—affects the vulnerability capacities of buildings. Thus, the analysis of the relationship

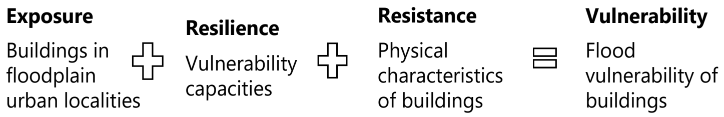

FIGURE 1 Theoretical framework

between non-structural design components and vulnerability capacities of buildings can describe the potential determinants of flood vulnerability. In this research, the vulnerability of buildings are explored based on four capacities adopted from the framework of De Graaf (2008): “threshold” as capacity to prevent damage; “coping” as the capacity to reduce damage; “recovery” as capacity to react to damage; and “adaptive” as the capacity to anticipate damage reflected on the physical characteristics of each building (Figure 2).

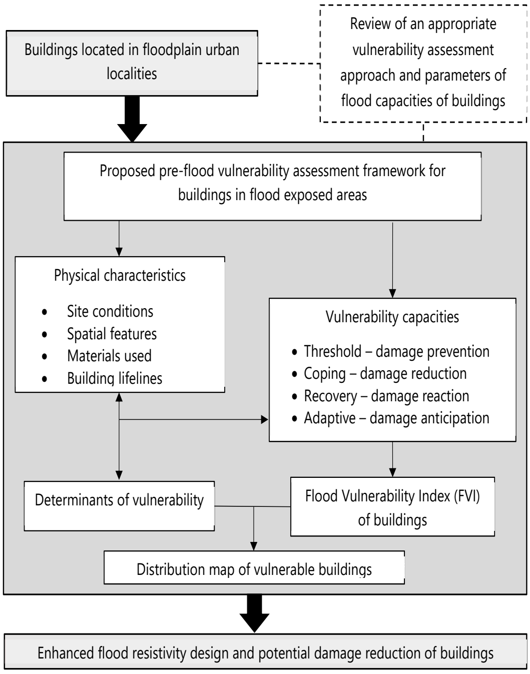

FIGURE 2 Conceptual framework

Review of Various Vulnerability Assessment Approaches

There is a wide range of approaches in measuring vulnerability, and these can be grouped into three: vulnerability matrices, curves, and indicators. Papathoma-Köhle et al. (2017) provide an outline of the gaps and future improvement needs on the application of these approaches by exploring a wide range of case studies on physical vulnerability assessment, and they recommended improving, combining, and expanding on these various methods. Vulnerability assessments should be informed by a strong conceptual framework, including parameters for defining vulnerability, accounting for both risk and coping mechanisms (Moret, 2014) and should have a predictive function (Naudé, Santos-Paulino, and McGillivray, 2009).

The framework should also answer the five questions posed by Hoddinott and Quisumbing (2003): What is the extent of vulnerability? Who is vulnerable? What are the sources of vulnerability? How do households respond to shocks? and, What gaps exist between risks and risk management mechanisms? There are several factors to consider in selecting methods, such the time and resources available to undertake the study, especially in developing countries where data constraints are an important consideration (Moret, 2014).

Flood vulnerability approaches can be grouped into four methods (Huang et al., 2012; Nasiri and Kalalagh, 2013), with different characteristics, tools of analysis and orientation with different strengths and weaknesses (Table 1).

Flood Capacity of Buildings

The literature on flood capacity of buildings cites parameters for defining vulnerability and identifies its vulnerable design components and measures for coping with, strength against, and resources to adapt to floods. Buildings located in flood hazard areas are advised to adopt flood resistive design and to ensure construction performance can withstand floods. The International Building Code (IBC) highlights various structural and non-structural design of buildings as performance requirements in flood hazard areas. The American Society for Civil Engineers (2015) provides the minimum design performance of flood-exposed dwellings on siting considerations, architectural and engineering designs, building materials, building utilities, and equipment. Likewise, the Australian government has developed a standard for the design and construction of buildings in flood exposed areas to reduce risk. Nevertheless, a flood-resistant design requires additional precautionary measures. The design also involves a combination of effective land use planning that considers flood hazard, flood mitigation measures, flood warning and emergency response strategies for flooding, and building standards (ABCB, 2012).

TABLE 1 The four groups of flood vulnerability approaches

Approach	Characteristics	Tool of analysis	Orientation	Remarks	Literature and assessment studies
Vulnerability indicator	Adapted to use available data for providing a logical image of the place vulnerability	Standardization, weighting and aggregation methods	Potential damage survey however short-term instability	Preferred by policy makers for its clear vulnerability image over space; pertain to complex indices and weighting of their characteristics according to their importance based on expert judgment	Pistrika and Tsakiris (2007); Nasiri and Kalalagh (2013); Papathoma-Köhle et al. (2017)
Vulnerability curve	Used to measure damages that happen immediately after a flood	Real damage analyses	Actual damage survey	Data from documented case studies restricted to a specific area after the flood experience and is not applicable to other regions	Sagala (2006); Nasiri and Kalalagh (2013); Shrestha (2015)
Disaster loss data	Simple measure of actual damages and losses after a flood	Real flood hazard and real damage analyses	Real damage survey	Data collected from various flood experience that are constructed for measuring damages of future events; simple approach but needs careful treatment	Sagala (2006); Nasiri and Kalalagh (2013)
Modelling method	Usually used in a geographical scale	2D mapping and geo-referenced using an input data modelling (GIS)	Potential damage survey	Accuracy depends on availability of detailed data on topography, hydrography, and economy of area; can assess vulnerability in local scale more sensitive than others by considering specific local factors; however, cannot describe clear link between predicted map and level of real flood damage	Lein and Abel (2010); Nasiri and Kalalagh (2013)

The Pre-flood Vulnerability Capacity Assessment Approach

Using weights and aggregation methods, the proposed pre-flood vulnerability assessment approach of this study applied the combination of disaster loss data and an indicator-based method. The profile and characteristics of non-structural components and the vulnerability capacities and index of buildings exposed to the same level of hazards were gathered using checklists and a questionnaire developed by the author. The author likewise developed the indicator of the four vulnerability capacities and weighted score tools. These were used to provide a logical image of the physical characteristics and the vulnerability capacities of buildings. The pre-flood vulnerability process was simplified into five progressive stages: **Stage 1** – Identification of potentially at-risk buildings (flood-exposed area); **Stage 2** – Documentation of potentially flood-exposed components of buildings; **Stage 3** – Analysis of vulnerability capacities and vulnerability index; **Stage 4** – Determinants of flood vulnerability, and **Stage 5** – Mapping of vulnerable buildings.

Stage 1. In the first stage, potential high-risk or flood-exposed areas will be identified by overlaying various maps such as the flood hazard map, topographic map, urban zoning and build-up maps, and satellite map gathered from various planning agencies such as the local Disaster Risk Reduction and Management Council Office (DRRMCO) and the local Planning and Development Office (PDO) of a municipality or city. The map produced will show the streets, the slope, and the location of buildings exposed to flood given the assumption target buildings have the same level of exposure. Buildings will be randomly selected along both sides of the flood-exposed streets for the vulnerability study. Slovin's formula was used to determine appropriate sample size of buildings at 95 percent confidence level.

Stage 2. In the second stage, potential flood-exposed components of buildings will be documented using a checklist for profiling the characteristics and components of the sample buildings. Survey tools such as camera, steel tape, and global positioning system (GPS) tool, as well as a survey checklist of non-structural design components, will be used to gather data (Table 2). Data were classified per type of usage of buildings and profiled by age, number of storeys, footprint, and street and ground elevation of buildings. The data gathered for the non-structural components were characterized by type of applications such as site condition, spatial features, materials used, and building lifelines, which are relevant for the assessment of flood vulnerability (Müller, Reiter, and Weiland, 2011).

The checklist of non-structural design components of buildings exposed to flood hazards adopts various vulnerability considerations of FEMA (2008; 2013). Moreover, photographic documentation method will be used to record physical profile of buildings while a measuring tool and GPS tracking device were used to determine the actual height of base flood elevation (BFE), boundaries, earth position and geometry of site features, or building components present on site during the actual visit. The base flood is flood that has a one-percent chance of being equalled or exceeded in any given year commonly called the hundred-year flood (FEMA, 2008). Descriptive statistics will be used to describe the average profile of buildings and non-structural design components of buildings in the study area.

Stage 3. In the third stage, the vulnerability capacities will be analyzed and the flood vulnerability index will be generated. The vulnerability capacities and flood vulnerability index of buildings combine the four sub-components: threshold, coping, recovery, and adaptive capacities (Table 3). The total weighted score of design indicators of each sub-component applied in buildings will reveal its flood vulnerability index. The indicators are signs that buildings implement design for flood sensitivity and resilience. For the matrix of vulnerability capacities indicators, design indicators were selected that best describe the four capacities with a corresponding weighted score based from various survey and scoring tools and rating system by LEED, a nonprofit U.S. Green Building Council that evaluates the design, construction, operation, and maintenance of green buildings. Some adjustments on the parameters were done purposely to fit the minimum building design requirements of the Philippines.

Higher percentage rating of total vulnerability capacity scores entails lower flood vulnerability index. A building is considered vulnerable with less capacity to resist flood damages if the percentage rating of vulnerability capacity is lower than 50 percent. This is based on the substantial damage and substantial improvement scale used by the National Flood Insurance Program developed by the U.S. Federal Emergency Management Agency (FEMA). The flood vulnerability of buildings is therefore measured inversely by the vulnerability capacity score. A building with a lesser vulnerability-decreasing design indicators is found to have potential damage during a probable occurrence of a hundred-year flood as expressed on a scale from 0 (no damage) to 1 (total damage).

TABLE 2 Checklist of non-structural design components of buildings exposed to flood hazards

Type	Non-structural components	Selection
Site condition	Lot area; elevation from street level; footprint; open permeable areas	One (1) if open permeable area is less than 10% of the lot area and building footprint, lower than street level; zero (0) if otherwise (section 708 of National Building Code of the Philippines: minimum requirement for lot occupancy)
Spatial features	Number of storeys; number of enclosed spaces below base flood elevation; type of openings	One (1) if number of storeys is lower than base flood elevation (BFE), with occupying space below BFE, unsealed openings; zero (0) if otherwise (adopted from FEMA standards)
Materials used (below BFE)	Building shell; walls/partitions; window type; door types; interior finishes; type of flooring; ceiling materials; vertical circulation/stairs; roofing	One (1) if unacceptable building materials were used in non-structural components below the BFE; zero (0) if otherwise (adopted FEMA standards)
Building lifelines (above BFE)	Potable water tank; back-up water storage; hazards and critical components; back-up power generators	One (1) if building lifeline components were unavailable above the BFE; zero (0) if otherwise. (adopted from FEMA standards)

Stage 4. In the fourth stage, the determinants of flood vulnerability of buildings will be identified using logistic regression analysis. The logistic regression model describes the results of the analysis of the relationship between non-structural design components and flood vulnerability capacities.

$$\ln Y_i = \ln \beta_0 + \sum_{i=1}^{n} \beta_i X_i$$

$$\text{where:} \quad Y_i = \begin{cases} 1, & \textit{if the building is vulnerable} \\ 0, & \textit{otherwise} \end{cases}$$

The mathematical model is derived by using data gathered from the checklist of the profile and non-structural design components of buildings in stage 2 as independent variables and the flood vulnerability capacity indicator weighted scores from the stage 3 as dependent variables and processing these through a statistical package software. The statistical analysis will consider a 10-percent level of significance where non-structural design components is considered significant if the probability is less than 0.10 and not significant if the probability is more than 0.10. The regression model will be accepted if the value of R-squared (Nagelkerke) or the coefficient of determination of variability is between 0.20 and 0.80, with −2 Log likelihood of above 35.

Stage 5. The last stage of the process is mapping vulnerable buildings in the study area using data gathered from the GPS and the results of the FVI done in stage 3 with the help of a mapping software. The distribution map is intended to locate vulnerable structures that can be potentially damaged after a predicted hundred-year flood.

Case Study: Kabacan, North Cotabato

The Municipality of Kabacan was selected as a case study mainly because of its physical, socioeconomic condition, and the accessibility and availability of data for study. Kabacan is a flat and low-lying area of the southern part of Mindanao island of the Philippines (Figure 3) located near two major bodies of water: the Ligwasan Marsh and the Kabacan River. The river contributes to frequent flooding of the municipality, particularly in built-up areas. The municipality has a population density of 10.60 people per hectare and 46 percent of its population lives in the urban areas across four *barangay*s or villages, namely, Poblacion, Osias, Katidtuan, and Kayaga. Kabacan's urbanity increased from 29.25 percent in 1990 to 40 percent in 2000 and 45.58 percent in 2007, and the expansion of the built-up area has seriously affected agricultural lands.

TABLE 3 Vulnerability capacity indicators and weighted score

Vulnerability capacities	Vulnerability-decreasing design indicators or parameters	Highest scores
Threshold (Damage prevention)	Regular schedule for building repair and maintenance	1
	External envelope/walls designed to break away does not produce debris that can damage structures	3
	Insulated and raised utilities (mechanical, heating, ventilation, and air conditioning elements located on the landward side of structures or above base flood elevation).	3
	Flood proofing design and constructed stairs and ramps to resist flood loads	5
	Use of natural ventilation and flood openings	2
	Storm water management	3
	External shading designs and erosion control features	1
	Use of flood damage-resistant finishing materials	1
	TOTAL THRESHOLD CAPACITY (Tc)	19/19
Coping (Damage reduction)	Proximity to site barriers	2
	Availability of flood warning devices such as radio and alarms	1
	Open permeable areas	1
	At least one exit or emergency exit door at upper level	1
	Open plan or minimum number interior enclosures at ground level	1
	Flood plan that addresses specified elements and actions	2
	TOTAL COPING CAPACITY (Cc)	8/8
Adaptive (Damage reaction)	Availability of building insurance	6
	Availability of emergency savings accounts/potential funding sources	6
	Availability of back-up potable water source	1
	Possibility for retrofitting, facility alterations, and additions	5
	Removal or relocation or substitution of hazardous or unsafe materials	6
	Available area for protective walls or flood resilient design	6
	TOTAL ADAPTIVE CAPACITY (Ac)	29/29
Recovery (Damage anticipation)	Capital improvement plans and budgets support development	6
	Durable construction, anchorage, and reinforcement of utilities and other non-structural components	1
	Designated emergency facilities safe areas	1
	Flexibility of design and building performance	1
	Sustainable innovations	1
	TOTAL RECOVERY CAPACITY (Rc)	10/10
	Overall total vulnerability capacity score (100%)	66/66

* The lower the vulnerability capacity scores the higher the vulnerability

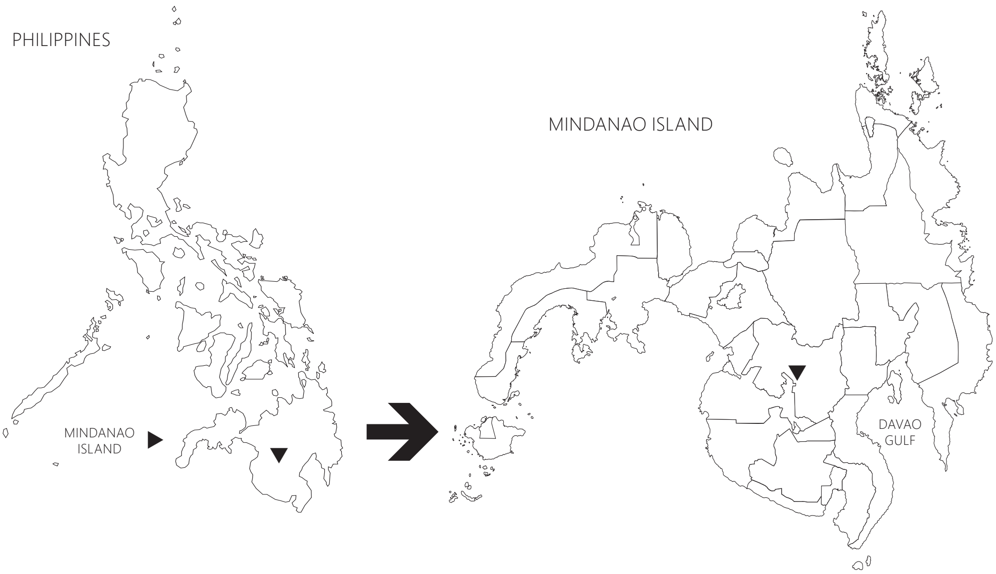

FIGURE 3 Location of Kabacan, North Cotabato, in Mindanao, Southern Philippines

Stage 1 – Identification of Potentially At-risk Buildings (Flood-Exposed Area)

Using the latest Google satellite map overlaid with the 2010 flood hazard map, urban built-up or land-use maps, and topographical map of the municipality, an estimated total urban land area of 1063.13 ha, out of the total 44,810 ha of the municipality, covering some zones of *barangay*s Kayaga and Poblacion were identified to have a high level of flood risk, with Kayaga having 63.82 ha of built-up area out of the total 133.77 ha land area and Poblacion having 214.92 ha of built-up area out of the total 929.36 ha land area. The traced area referred as Map A (Figure 4) was predicted to be highly exposed to a hundred-year flood of about 1.5 m high. Map A also shows the building footprints and topographical data such as terrain slope, green areas, and elevation of various streets. A total of 97 residential and 44 non-residential buildings occupying 110.45 ha and 50.09 ha, respectively, were selected by transect sampling technique from the list of exposed streets as the sample of this study.

Stage 2 – Documentation of Potentially Flood-Exposed Components of Buildings

The profile of potentially flood-exposed buildings in Kabacan were gathered in two stages: first, the physical profile data of sample buildings were gathered through actual visual observation and documentation using photo and video camera while the actual level of base flood elevation (BFE) was measured using steel tape; and second, a checklist of non-structural design components were analyzed and categorized accordingly.

Results show that most buildings in Kabacan are one-storey high with an elevation a meter lower than the street level and having an average building height of 5.77 m (Table 4). Results using the checklist of flood-exposed non-structural design components show that most of the buildings in Kabacan generally use acceptable type of building materials, but only most of the

TABLE 4 Profile of buildings (n = 141) in Kabacan

Building profile	Min	Max	Mean	SD
Building age (years)	3.00	48.00	18.78	10.74
Footprint (sq m)	19.75	4450.00	142.14	386.23
Storeys	1.00	3.00	1.33	0.54
Building height (m)	3.40	7.50	5.77	2.07
Street elevation*	31.00	50.00	37.13	5.07
First floor level elevation*	30.00	50.00	36.86	4.77

*meters above sea level

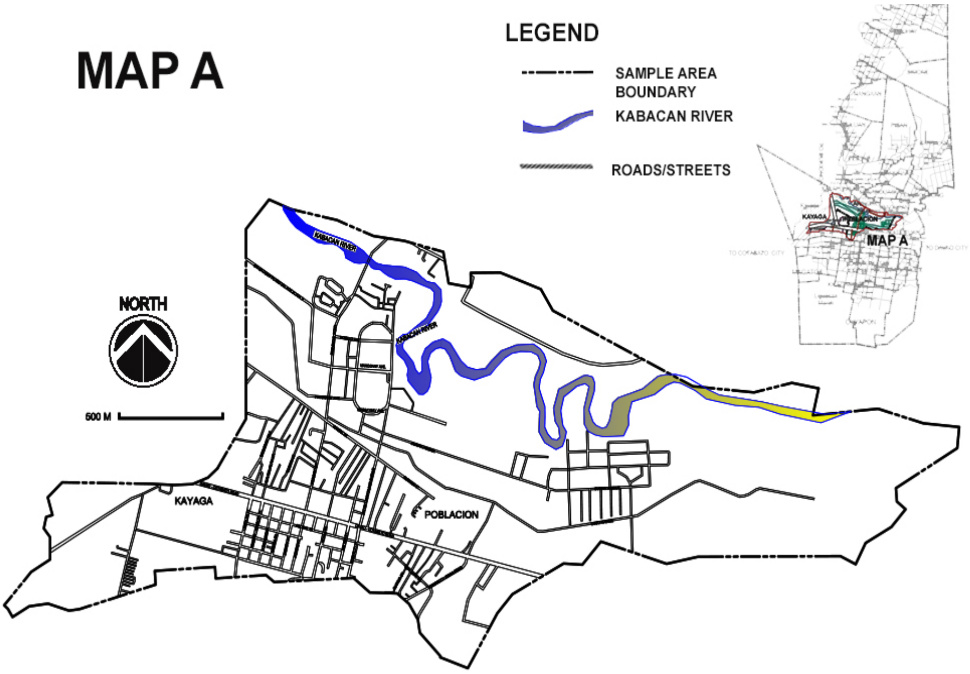

FIGURE 4 Map A - The study area with high flood risk level.

residential buildings have available building lifelines (Table 5).

Stage 3 – Analysis of Vulnerability Capacities and Vulnerability Index

The vulnerability-decreasing design indicators score table is a specific and rapid evaluation tool in determining the flood vulnerability capacity of buildings in Kabacan. Results showed that residential buildings in the locality were threshold and recovery capacity vulnerable while non-residential buildings were threshold vulnerable. This means that the both types of buildings were not designed to prevent future flood damages and residential buildings will have difficulty recovering after a predicted flood event (Table 6). This is due to the building design and quality of the structures, which may collapse and injure people. According to Marfai and Njagih (2002), the vulnerability of buildings may also be due to the nature of the construction and the materials used, which will greatly determine the kind of potential injuries inflicted. Nevertheless, most of the buildings in Kabacan were found to have the ability to cope and adapt in case of future flood events. The ability to cope with future flood events can be credited to the presence of a flood plan, open plan design, open permeable areas, existing warning devices above BFE, and availability of emergency exits in a building. These buildings are expected to recover because of the prospect of retrofitting of its design, availability of back-up water source, and expansion area for future development. Overall, the flood vulnerability index of some buildings in Kabacan were not vulnerable to future flood events upon considering the combination of the four flood vulnerability capacities.

In this method, the FVI is grounded by the following assumptions: level of exposure is the same and flooding is assumed to be passive, having low sediment load in which flood water flows easily with a maximum depth of 1.5 m. The assumed depth is deadly and uniformly distributed. The vulnerability capacity of buildings index gives a number from 0 to 1, signifying low or high flood vulnerability capacity useful for improving design strategies for flood hazard.

Stage 4 – Determinants of Flood Vulnerability

Since the results show that most of the buildings in Kabacan are not vulnerable to flood

TABLE 5 Profile of non-structural components of residential and non-residential buildings exposed to flood hazards

Type	Non-structural components	Residential (n = 97)	Non-residential (n = 44)
Site features	Lot (sq m)	291.37	327.77
	Building elevation from street (m)	−00.15	00.17
	Footprint (sq m)	291.37	327.77
	Open permeable areas (sq m)	180.49	234.69
Architectural features	Number of storeys	1.00	1.00
	Number of enclosed spaces	5.00	4.00
Flood acceptability of materials used based on ratings by the Federal Insurance and Mitigation Administration (FEMA) (below BFE)	Building shell	Acceptable	Acceptable
	Walls/partitions	Not Acceptable	Acceptable
	Window type	Acceptable	Acceptable
	Door types	Acceptable	Acceptable
	Interior finishes	Not Acceptable	Acceptable
	Type of flooring	Acceptable	Acceptable
	Ceiling materials	Not Acceptable	Not Acceptable
	Vertical circulation/stairs	Not Acceptable	Acceptable
	Roofing	Acceptable	Acceptable
Availability of building lifelines (above BFE)	Potable water tank	Available	Not available
	Back-up water storage	Available	Not available
	Hazards and critical components	Not available	Not available
	Back-up energy source	Available	Not available
	Waste treatment/septic tank	Available	Available

damages, further analysis was conducted to identify factors that may affect flood vulnerability. This study found 7 non-structural design components that have a significant relationship to flood vulnerability of buildings in the area. Through regression analysis, the study found that the open permeable areas, building footprint, window type, roofing type, interior finish, and footprint areas and two variables of building lifelines such as back-up water source and non-potable water tank (Table 7) showed less than 10 percent probability of significance. Results show that the variables such as open permeable areas, window material, and roofing have inverse relationship to flood vulnerability. Thus, an increase in the area of permeable spaces, increase in the use of non-potable water storage above BFE, and the use of acceptable window material and roofing materials by one unit decreases vulnerability by the amount of its equivalent Exp(B) as shown.

TABLE 6 Percentage mean of the flood vulnerability capacities of residential and non-residential buildings (n = 141)

Flood vulnerability capacities	Residential	Non-residential
Threshold	29.69	30.57
Coping	84.83	82.14
Adaptive	85.82	58.45
Recovery	33.81	79.83
Total mean	58.53	62.75

*Vulnerable if <50%; not vulnerable >50%

The large contribution of these non-structural design components to the regression model indicates the likelihood that buildings in the locality are not vulnerable. On the other hand, the results of the regression analysis also show that variables such as interior finish, footprint, and back-up water source have a corresponding relationship to flood vulnerability of buildings. An

TABLE 7 Non-structural design components regression output

Variables (n)	B	S.E.	Wald	Sig.	Exp(B)
Lot elevation	–0.127	0.352	0.130	0.719	0.881
Open permeable areas	–0.008	0.003	8.496	0.004	0.992*
Building shell	0.009	0.905	0.000	0.992	1.009
Exterior finish	1.017	0.915	1.234	0.267	2.764
Window material	–2.734	1.099	6.186	0.013	0.065*
Roofing	–2.235	1.000	4.990	0.025	0.107*
Enclosed areas	0.325	0.284	1.316	0.251	1.384
Partitions	1.838	1.150	2.556	0.110	6.285
Type of flooring	0.103	0.678	0.023	0.879	1.109
Ceiling material	0.898	4775.312	0.000	0.998	2.455
Vertical circulation	–2.048	1.499	1.868	0.172	0.129
Interior finish	3.237	1.168	7.679	0.006	25.454*
First floor elevation	0.060	0.334	0.033	0.856	1.062
Footprint area	0.015	0.007	4.921	0.027	1.015*
Potable water	0.000	0.003	0.006	0.937	1.000
Potable water tank	–0.497	1.780	0.078	0.780	0.609
Back-up water source	1.932	0.938	4.241	0.039	6.901*
Non-potable water	–3.163	1.634	3.746	0.053	0.042*
Sanitary lines	0.339	0.495	0.469	0.493	1.403
Waste treatment / septic tank	1.503	0.871	2.975	0.085	4.494
Hazards and critical components	0.037	0.595	0.004	0.951	1.037
Electrical	0.001	0.001	0.259	0.611	1.001
Back-up electrical source	–0.677	1.364	0.246	0.620	0.508
Constant	1.370	4.039	0.115	0.734	3.936

-2 Log likelihood = 75.630a; Cox & Snell R Square = 0 .343; Nagelkerke R Square = 0.557;
* less than 10% significance level

increase of one unit on the area for interior finishes, footprint, and availability of back-up water source has the probability to increase the level of flood vulnerability by the amount of its equivalent Exp(B). The absence of these components can reduce vulnerability of buildings in a pragmatic sense. However, the flood resistive building design prescribed by FEMA (2013) suggests the need to move or elevate the floor level, provide potable water storage, and add room partitions above the defined flood elevation to further reduce the flood vulnerability of buildings.

Stage 5 – Mapping of Vulnerable Buildings

Flood vulnerability is defined in this study as the non-structural design condition of buildings measured from the total weighted percentage score of the combination of four vulnerability capacities decreasing design indicators. Figure 5 shows the flood vulnerability distribution map of buildings in the urban center of Kabacan. Green dots and magenta squares are vulnerable residential and non-residential buildings, respectively.

Summary of Findings of the Case Study

Stage 1 of the pre-flood vulnerability assessment approach identified potentially at-risk buildings and estimated the total flood exposed area in Kabacan through a map overlaying technique. The 97 residential and 44 non-residential sample buildings were located in Barangay Poblacion and some parts of Barangay Kayaga. Most of the buildings found in these high flood risk areas are one-storey high with a

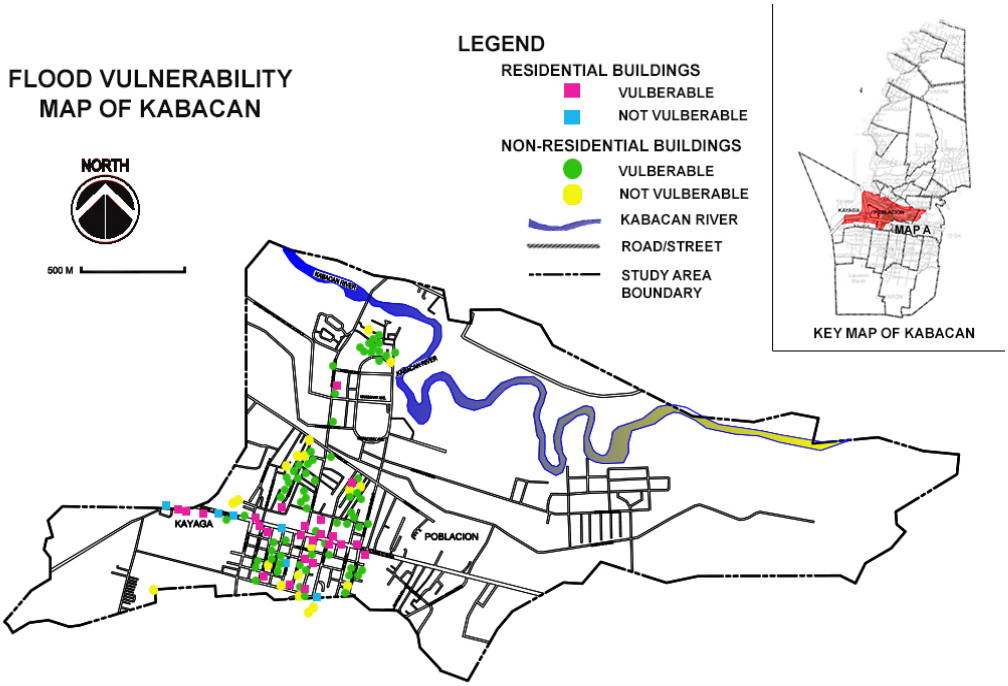

FIGURE 5 Map of flood vulnerable and non-vulnerable buildings of Kabacan urban center

ground floor finished elevation lower than the street level. In stage 2, the study area was visited and potentially flood-exposed non-structural design components of buildings located below the projected 1.5-m height of base flood elevation (BFE) were documented. Profile of buildings were described by type of site and architectural features, flood acceptability of materials used, and availability of building lifelines above BFE. In stage 3, the analysis of vulnerability capacities and vulnerability index, which uses the total weighted score of flood-decreasing design indicators of the four vulnerability capacity of buildings, was conducted. Results show that most of the buildings in Kabacan are not flood vulnerable but have been found to have less design considerations for threshold and recovery capacity, especially the residential buildings. Stage 4 identified the determinants of vulnerability, which found 7 non-structural components with a significant probability to cause the flood vulnerability of buildings in Kabacan. Lastly, the vulnerable buildings are plotted in a distribution map for the identified study area in the urban center of Kabacan municipality.

Strength and Weaknesses of the New Approach

The results of the application of the proposed new flood vulnerability approach in the case of the urban floodplains of Kabacan, North Cotabato, Philippines, has identified and located flood vulnerable structures recommended for flood management interventions. However, each process of the five stages of this proposed approach were evaluated purposely to validate its strength and weaknesses for future improvement (Table 8).

Conclusions

This study provides a review of various vulnerability approaches on flood capacity of buildings as parameters for measuring the four vulnerability capacities, namely, threshold, coping, recovery, and adaptive capacities, as part of the proposed pre-flood vulnerability assessment for non-structural design characteristics of buildings. The proposed vulnerability assessment recognizes the different design characteristics of buildings, allowing a more in-depth analysis and interpretation of vulnerability using

TABLE 8 Strength and weaknesses of each stages of the new approach

Stages	Description	Characteristics	Strengths	Weaknesses
Stage 1	Identification of potentially at risk (flood-exposed) buildings	Uses physical maps of a locality	Identifies specific floodplain areas and streets of a locality with the same level of risk	Availability of latest hazards and constraints maps and the accuracy of the mapping tool used.
Stage 2	Documentation of potentially flood-exposed components of buildings	Uses global positioning system (GPS), camera, and other measuring tools, including the checklist of non-structural components	Data were collected by observing the physical design characteristics and non-structural components of buildings	Accuracy depends on the expertise of the observant of the components and design of buildings. The study did not consider exposure to different flood water intensity.
Stage 3	Analysis of vulnerability capacities and vulnerability index	Uses vulnerability capacity indicators and weighted score adopted from another country (US) and vulnerability analysis adopted the substantial damage and substantial improvement scale from FEMA	Level of vulnerability are collected based from the table of indicators	Vulnerability indicators depends on judgment of experts (Pistrika and Tsakiris, 2007) and vulnerability capacity indicator may differ in the Philippine setting.
Stage 4	Determinants of flood vulnerability	Uses a statistical tool to identify significant factors of vulnerability	Scores depends on the results of the previous stages	Analysis depends on the accuracy of data collected from the observation.
Stage 5	Mapping of vulnerable buildings	Uses mapping tools/ software	Maps target vulnerable building locations for flood design interventions	Accuracy depends on the scores from previous stages and availability of mapping tool.

non-structural design vulnerability capacity indicators assuming that target buildings are at the same level of exposure. The flood vulnerability assessment has five major stages: (1) identifying potentially at-risk buildings, (2) documentation of non-structural design components of potentially flood-exposed buildings, (3) analysis of vulnerability capacities and vulnerability index, (4) finding determinants of flood vulnerability, and (5) mapping vulnerable buildings. Each stage of the vulnerability assessment process was described with different characteristics, survey and analysis tools, strength and weakness that can be used and developed to meet the local building design requirements. The flood vulnerability index and the anticipated determinants of vulnerability of buildings were also determined in this proposed assessment method which can be used as basis in identifying flood design interventions to enhance vulnerability capacities and potentially reduce flood damages of buildings. Mapping the location of the vulnerable buildings as the final output of the proposed method can help identify vulnerable areas for flood emergency planning and flood risk management considerations.

Recommendations

For a more accurate and updated built-up profile and location of buildings, the pre-flood vulnerability assessment method recommends the use of the latest physical maps and data from local planning agencies. Thorough inspection process of the non-structural design components using new technologies such as the use of 3D building scanner and an up-to-date list of flood resistive materials are recommended for a more accurate analysis of the four flood vulnerability capacities and flood vulnerability index.

It is also recommended that further testing of the approach in other places are needed to explore different levels of flood exposure and flood water flow intensity. Future studies may also include structural components on the flood vulnerability assessment of buildings to enhance structural design measures as threshold capacity parameters of buildings. A comparative study in other areas is recommended to develop literature of application and flood design parameters based on the Philippine setting to further improve the process. This method is primarily developed and recommended for utilization of the local government unit's disaster management council to provide baseline data on the capacities of buildings for flood-risk management that should be updated together with the built-up map, building insurance programs, and other emergency plans of a locality. Determinants can be used as baseline data to develop future flood design guidelines to reduce vulnerability in the study area.

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