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RESEARCH PAPER

MULTI-CRITERIA ANALYSIS OF EARLY WARNING SYSTEM FOR FLOOD RISK REDUCTION IN BARANGAY TUMANA IN MARIKINA CITY, PHILIPPINES

V. Agyei[1] , **C. Peprah[2]** and ***D.K. Ahadzie[3]**
[1, 3]Centre for Settlement Studies, KNUST, Kumasi
[2]Department of Planning, KNUST, Kumasi
**Corresponding author: dkahadzie.cap@knust.edu.gh*

ABSTRACT
With central emphasis on people at risk, property and cost effectiveness, flood early warning system has been recommended in most flood risk reduction literatures and global frameworks. For instance, the Sendai Framework for Disaster Risk Reduction, 2015-2030, on the seventh target emphasizes on the need for an increase in the availability and accessibility of early warning systems. The UN Sustainable Development Goal thirteen, also stresses on improving institutional capacity for early warning systems. To promote these development agenda, evaluating early warning system would help identify best practices that can be replicated in other communities. This study therefore evaluates flood early warning system in Barangay Tumana in Marikina City of the Philippines using Multi-criteria Analysis (MCA) and outline recommendations for its improvement. Lessons for implementation in other emerging economies are also outlined. Data were obtained from 100 households through questionnaire administering and key informant interview from the various institutions involved in flood risk reduction in the barangay. On a ratio scale of zero to one where one is the highest score and zero is the lowest score, the score for overall effectiveness of the warning system was 0.811. This indicates that, the system is extremely effective since failures associated in the operation of flood early warning system have been significantly reduced. Ghana and many other emerging countries which have recently installed early warning systems can therefore learn from the Marikina's experience.

Keywords: *Flooding, flood early warning system, flood risk reduction, Barangay Tumana, Marikina City*

INTRODUCTION

The Philippines is ranked fourth after United States, China and India as the countries with the highest number of disasters over the past twenty years (UNODRR and CRED, 2015). Flooding is the most frequent disaster experienced in the Country and Metropolitan Manila has been indicated as the most flood prone area. Marikina City which is part of Metro Manila is not exempted from the flooding problems faced by the Metropolis. Flooding in the city was reported to have intensified over the years, with some writers linking it to the year 1980 when impacts started to be felt by the population. In

1992, twenty-seven percent of Marikina was classified as a flood-prone area with an estimation of over 10,000 homes exposed to flooding (Zoleta-Nantes, 2000). Flooding has progressively become a perennial problem in which all the city dwellers have to endure. Salvador (2011) indicates that, flood risk reduction in the city started as far back as the year 1992. She adds that, measures adopted to reduce risk in the city were mostly structural, aiming to reduce probability of flooding. Methods adopted included: dredging of waterways, desilting of drainage outfalls, de-clogging of drainage laterals and designation of evacuation centers. The city, after realizing the impacts from Typhoon Ondoy in September 2009 decided to undertake impact reduction measures hence implemented flood Early Warning System in 2012.

With central emphasis on people at risk, property and cost effectiveness, flood early warning system has been recommended in most flood risk reduction literatures and global frameworks. For instance, the United Nations (2006) identified early warning system as a cost-effective tool that can significantly help reduce vulnerability, enhance preparedness and response to various natural hazards. The Sendai Framework for Disaster Risk Reduction on the seventh target emphasizes on the need for an increase in the availability and accessibility of early warning systems. In addition, the UN Sustainable Development Goal thirteen, which calls for urgent action against climate change intends in target three to improve the institutional capacity for early warning systems. Hence, evaluating early warning system would help identify best practices that can be replicated in other communities, factors threatening their sustainability and areas that need improvement for optimum operation. Evaluation will also help in identifying appropriate and innovative strategies in improving the system as called for during the multi-hazard early warning conference held in Mexico from 22-23 May 2017.

This paper therefore assesses the effectiveness of flood early warning system in Barangay Tumana in Marikina City of the Philippines and discusses implications and lessons for emerging countries such as Ghana that in partnership with UNDP recently has initiated the Community Resilience through Early Warning System (CREW) project in 2013 (United Nations Development Programme, 2012). The effectiveness of the early warning system was analyzed based on how it was able to persuade the population at risk to protect themselves before flooding and the effects it has had on reducing flood impacts. The paper starts with a theoretical understanding of flood early warning systems. This is then followed by an overview of the level of integration of early warning systems in flood risk management in especially developing countries. The next section describes the research methodology followed by the discussion of the findings including lessons that can be learnt by other countries. Conclusion and recommendation are represented at the last section of the paper.

Theoretical understanding of flood early warning system

Flood early warning is a system of data collection and analysis, undertaken to provide timely information on future or ongoing events to produce an appropriate response with the aim to reduce losses or damage (Sättele *et al*, 2015). According to United Nations (2006), an effective and people-centered early warning system comprises the following elements:

Knowledge of risk:
Risk to flooding has to be well understood by all stakeholders for effective prediction, timely and appropriate response.

Monitoring and forecasting of the hazards:
Urgent need for a reliable scientific basis for predictions and continuous monitoring which should not only be technical but most importantly people-centered.

Communicating alert and warnings:
Clearly stated message and cautiously selected dissemination channel with the targeted population at the center of the decision making.

Local capabilities to respond to the warning:
Need for appropriate response to the warnings. The initial duty rests on the emergency response agencies but is equally important.

for households to be aware of what they have to do during such times (Olurunfemi *et al* 2016).

Flood early warning system in developing countries

Developing countries have been indicated to be the most vulnerable to the impacts from climate variability and climate change. Considering developmental challenges such as uncontrolled urbanization, poverty, low adaptive capacities, limited funds for disaster risk reduction, implementing effective flood early warning system cannot be neglected in flood risk management in these countries. Very successful community-based flood early warning systems have been developed in the Asian countries such as India, Philippines, Nepal and Pakistan as indicated by Macherera and Chimbari (2016). On the contrary, in Africa, not much effort has been done in implementing effective flood early warning system. According to Ouikotan *et al* (2017), they are either not implemented in most of the countries or are ineffective at implemented places. For example, in Ghana though there are no implemented flood early warning system, however the meteorological department produces seasonal forecast and issues warnings on possible heavy rainfall. According to Attipoe (2014) and Aboagye (2012), these warnings most often do not get to the most vulnerable. This is because, the warnings are issued in English which is the official language of the country but most of the people staying at flood prone areas are illiterate who can't read, write or understand. Aboagye adds that, not all the vulnerable people at the flood prone areas have access to television, radio and print media where warnings are communicated and the few who have access, with the problem of frequent power outages only exacerbates their vulnerability to flooding. As in the case of Ghana, Nigeria has no flood early warning system but issues weather forecasts and seasonal rainfall prediction from the meteorological agency. According to Olorunfemi *et al* (2016), the messages are often too general and not targeted at any specific communities. In other African countries, Baudoin *et al.* (2016), Baudoin and Wolde-Georgis (2015) have indicated communication gap, lack of participation of vulnerable population (top down approach), trust issues as factors affecting effective forecasting and warning. These weaknesses affect the coping and response abilities of the most vulnerable population. What makes the early warning system implemented in Marikina City a best practice for other developing countries is its ability to significantly reduce these weaknesses.

In June 2010, Ghana recorded a massive flood disaster which resulted in destruction of properties such as houses, bridges and shops. Due to increased flood disasters in Ghana, investment in building a resilient early warning system is essential for saving lives and properties of citizens. As a result, Ghana has realized the necessity of early warning system and in partnership with UNDP has initiated the Community Resilience through Early Warning System (CREW) project in 2013. The objective of the CREW is to develop capacities in Ghana to reduce disaster risk by putting in place an integrated early warning system that is both scientific and people-centered. A Ghanaian study has established that creating of early warning system is influenced by departmental cooperation, human resource expertise, residents' awareness creation and provision of funds (Djimesah *et al*., 2018). The experiences of Marikina City can therefore serve as a great insight for the implementation of the project in Ghana.

RESEARCH SETTING AND METHODOLOGY

Research setting

The research was conducted in Marikina City which is one of the sixteen cities in Metro Manila Region of the Philippines. Marikina City has sixteen barangays but Tumana has been identified by authorities as the most vulnerable to flooding. Tumana, depicted by Fig.1 therefore served as the case for the study. Tumana, with a population of 43,239 according to the 2015 census, is the third most populated barangay in the city.

The location of the barangay renders it vulnerable to flooding since it is a low-lying area to which runoff from the Sierra Madre Mountains drains. In addition, the Marikina River, which is reported as the main source of flooding in the city, divides the barangay into two as shown in Fig 2. The Marikina River, with an entire length

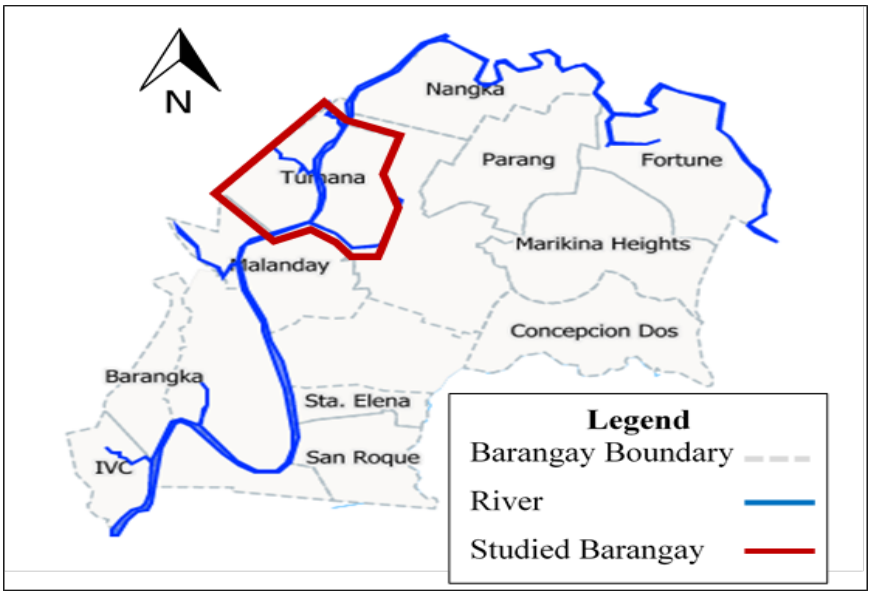

Fig.1: Barangay Tumana in Marikina City
Source: City Government of Marikina 2015 modified by authors

of 582 km^2 can increase from three meters water level to more than twenty-three meters. Flooding mostly occurs at the peak of the rainy season (July to September), although respondents indicate recent experiences in December, which they attribute to climate change. Tumana has undergone historical extreme flood events, but from the study, the recent ones for which the impacts are still felt are Ondoy (Ketsana) in September 2009 and Habagat or intensified southwest monsoon rains in 2012.

Typhoon Ondoy, internationally called Ketsana, has been recorded as one of the devastating events experienced in Metro Manila. Marikina City was reported as one of the areas hugely affected by the floods, with seventy casualties and more than Php27 million (US$605,000) worth of damage (Ramada 2014). The catastrophic flood event occurred on 26 September 2009 and brought with it rain of 453 mm/day, representing a whole month's worth of rain (DPWH and JICA 2011).

Intense rainfall caused by a habagat (southwest monsoon) brought floods for two consecutive years in Metro Manila. Habagat started in 2012 and was enhanced by three typhoons. Typhoon Jose, internationally called Halong, enhanced it in August 2014. In September 2014, Typhoon Luis, internationally called Kalmaegi, also enhanced it. Typhoon Mario, internationally called Fung-Wong, brought 220 mm of rain in 24 hours, and was the next to enhance the southwest monsoon. All these led to the rise in the level of the Marikina River to 19.9 meters, hence the call of alarm for evacuation and also forced evacuation. In total, 36,027 people were evacuated to thirty-nine evacuation centers (NOAH 2014).

The city experience with Ondoy and subsequent flood events encouraged the local government to develop a local early warning system to help reduce the impacts of flooding in 2012.

METHODOLOGY

The study uses Multi-Criteria Analysis (MCA) for the assessment. The ability of the tool to evaluate the overall performance of an objective or project is the main reason why it is used for effectiveness assessment in this study. The multi-criteria analysis as used in this study consists of six stages as shown by Fig. 2.

Three main parameters with their subsequent criteria were identified based on the reviewed literature. Other important considerations made before developing the parameters and their criteria include: the available time for the study hence data that can be collected and analyzed within the stipulated time was important. Availability of data was also a major consideration for the criteria development.

The identified parameters and their criteria depicted by Table 1 were presented to and approved by the two main institutions Marikina City Disaster Risk Reduction and Management Office (MCDRRMO) and Tumana Barangay Disaster Risk Management Officer (TBDRMO) involved in the operation of the system.

Priority ranking was applied for assigning weights to both parameters and their criteria. Positive integer values were assigned from a to z, where z is the total number of the parameters. Priority ranking is done by arranging the parameters according to the order of importance. In this study, one is highest in importance while three is the lowest. The ranking was subjectively determined based on the preference of the two main institutions responsible for the operation and monitoring of the system. The weight level of a parameter (W_i) was then calculated using the formula:

$$W_i = (n - R_i + 1) \Big/ \sum_{i=1}^{n} R_i \qquad (1)$$

Where: W_i = the weight level of a parameter
R = the priority rank of that parameter
n = the total number of parameters (three)

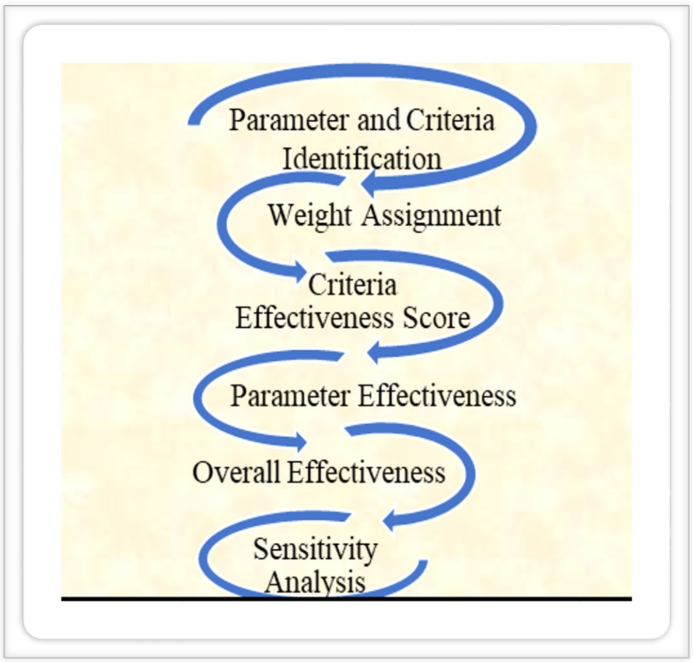

Fig. 2. Analytical framework

Table 1: Identified parameters and their criteria

Parameters	Criteria
Institutional Characteristics of the System	1. Laws/Ordinances backing the warning system
	2. Institutional effort to increase awareness of flood risk and the system
	3. Public awareness of warning system
	4. Public knowledge on how to respond
	5. Redundancy of communication network or procedure
Community Satisfaction with the System	1. Timing of the message
	2. Method of dissemination
	3. Content of the message
Reduction in Flood Losses	1. Loss of Lives
	2. Persons Injured
	3. Movable property damaged

Source: Parker and Fordham (1996): United Nations (2006) modified by author

Table 2: Conversion of class number to normalized value

Class No.	Class Value Range	Normalized Value (Mid-point of class value range)
1	0-0.2	0.1
2	0.2-0.4	0.3
3	0.4-0.6	0.5
4	0.6-0.8	0.7
5	0.8-1.0	0.9

Source: *Lorenzo, 2017*

The institutions assigned equal importance to the various criteria, hence the weight was calculated based on the formula: Weight of criteria in a parameter = one/ the total criteria in that parameter.

To identify the effectiveness score of a criterion, indicators with their unit of measurement were formulated. Likert scale was initially used for the measurement however since a ratio scale of zero to one as adopted from Parker and Fordham (1996) was used for the effectiveness measure, the recorded scale was normalized as depicted by Table 2.

To conclude on a parameter effectiveness, the criteria effectiveness weighted score was first calculated by multiplying the weight level of a criterion by its effectiveness score. The sum of the weighted effectiveness score of criteria within a parameter served as the effectiveness score of the parameter. The overall effectiveness is then determined by summing up the weighted effectiveness score of all the parameters. The parameter weights derived from the priority ranking made by the City Disaster Risk Reduction and Management (DRRM) Office was used for the calculation. The calculation was done by adding all the parameter weighted

effectiveness scores (weight of a parameter x the effectiveness score of the parameter).

Qualitative and quantitative data used for this study are from primary and secondary sources. Primary data were obtained from field survey, using instruments such as interview guides, questionnaires and field observation. The data were collected from key informants at Marikina City Disaster Risk Reduction and Management Office (MCDRRMO), Tumana Barangay Hall, City Engineering Office, Marikina City Planning and Development Office, Marikina City Settlement Office and finally Marikina City Environmental Management Office.

The household survey was administered in English and Tagalog depending on the respondent's knowledge and preferred option. The study adopted the definition of a household as used by the Philippine Statistics Authority, which defines it as an aggregate of persons, generally but not necessarily bound by ties of kinship, who sleep in the same dwelling unit and have common arrangements for the preparation and consumption of food. Household's heads or their spouse who have lived in the barangay before and after the introduction of the warning system were interviewed. The system was introduced in 2012 and was motivated by the devastating impact from flood event Ondoy that occurred in September 2009. Therefore, households who have lived in the barangay for a minimum of 8 years, which means they experienced the 2009 flood event, were chosen for the survey. A total of 100 questionnaires were administered. The Statistical Package for Social Sciences (SPSS 23) software was used by the researchers for processing and analyzing the responses from the household survey.

RESULTS AND DISCUSSION

Characteristics of early warning system

The operation of the early warning system is the responsibility of both the Marikina City Disaster Risk Reduction and Management Office (MCDRRMO) and Tumana Barangay Office. Specifically, the Central Communication and Command Section as well as Rescue 161 under the MCDRRMO are responsible for the operation. Rescue 161 is responsible for providing quick response during a disaster while the Central Communication and Command Section is liable for monitoring and dissemination of warning information. Fig. 3 shows how the system is operated in the city and the barangay.

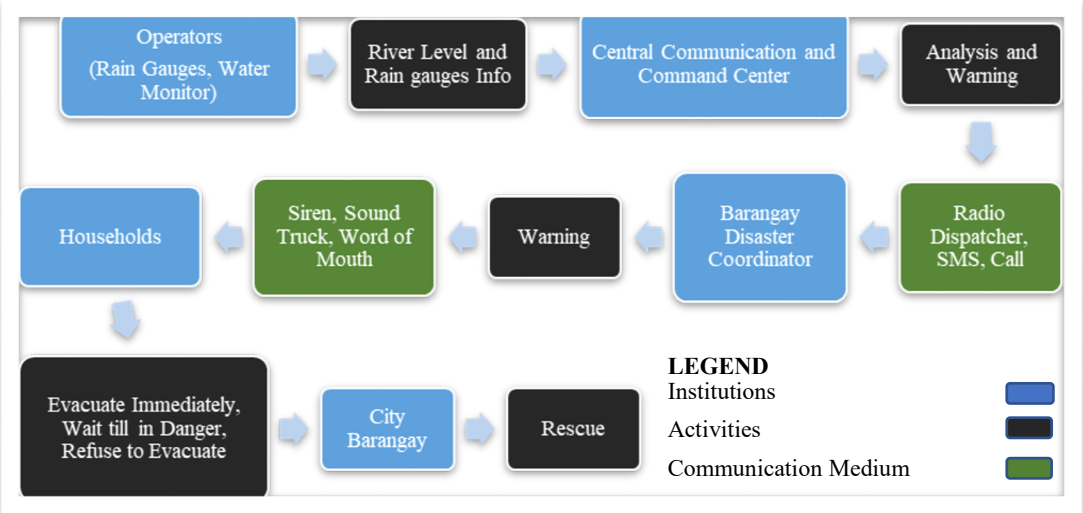

Fig. 3: Characteristics of the early warning system

The Command section uses the water level monitor and rain gauges to monitor the river and communicates the need for warnings when necessary. As exhibited in Fig. 4, the command office receives information on the water level and the rain gauges from the operators assigned in the various locations of the gauges and water level monitor. The operators are trained residents of the communities where the gauges are located. The city has a total of twelve rain gauges located in the upper stream of the Marikina River, and the water level monitor located at Sto. Nino Barangay is used by the city. Barangay Tumana also has a water level monitor installed in the Marikina River close to the barangay hall monitored by the Disaster Risk Reduction Department. Water level monitor is used to measure height of the river from sea level when it starts raining.

When the command center decides on the necessity to raise an alert, a radio dispatcher is then used to transmit the information to the city mayor, barangay DRRM coordinators and other officials for appropriate response. In cases where the radio dispatcher is not working, phone calls and SMS are used. The DRRM coordinator of Tumana, upon receipt of the warning information, then communicates to the residents through the use of a loud siren that can be heard within 1.5km. Since the siren is not heard by all households at risk, a sound truck or word of mouth is used to announce to the remaining people at risk. The city also has a radio station (Radio 1674 MHZ) where warnings are sometimes communicated. The alarm is raised four times, with each having a message to communicate as depicted by Table 3.

The first alarm is raised continuously for one minute to signal households to be alert for possible further warnings. The second alarm is raised for a two-minute intermittent airing to communicate to households to start preparing for possible evacuation. The third alarm which is raised continuously for five minutes calls for households to move to designated evacuation centers. The barangay officials at this time encourage evacuation, especially those in the low-lying areas or those staying close to the river.

Water level monitor at Sto. Nino Barangay Water level monitor at Tumana

Fig. 4: Water level monitor used by the city and the Barangay

Table 3: Warning levels and actions undertaken by Barangay officials in Tumana

WARNING LEVEL	CRITERIA	INTERPRETATION
15 meter	Continuous rain 1st Alarm	Alert and Monitoring Status
16 meters	Continuous heavy rainfall 2nd Alarm	Preparedness Status
17 meters	Overflowing 3rd Alarm	Evacuation Status
18 meters	Flooded 4th Alarm	Mandatory Evacuation
19 meters/up	Heavy flood	Forced Evacuation

Source: Barangay disaster risk reduction and management office, 2017

The fourth alarm is aired for five minutes continuous warning and it indicates mandatory and mass evacuation. Forced evacuation is then enforced if the water level reaches 19m. Since every part of Tumana is vulnerable, there is no evacuation center in the barangay. Evacuees are therefore sent to Concepcion Elementary School, Concepcion Integrated School Main, Immaculate Conception Church and H. Bautista Elementary School, all located in Barangay Concepcion Uno, outside Tumana.

Other responses include cancelation of classes and preparation by both institutions and households for any emergencies. Since evacuation centers are mostly schools, they are closed down during these emergency times to house evacuated families. Households are encouraged to prepare items such as canned foods, first aid and other basic necessities to carry with them to evacuation centers. The Rescue 161 section of the city DRRMO also prepares for emergencies that may need attention from the office. The command center uses the 100 CCTV cameras, GPS and other software during emergencies to locate victims and also give assistance. Ambulance, rescue boat, water rescue vehicles and other equipment are prepared by the city and the barangay office in case they are needed for any emergencies.

Effectiveness of the early warning system

As explained under the methodology, the effectiveness of the system was assessed based on eleven identified criteria grouped into three main parameters. A ratio scale of zero to one adopted and modified from Parker and Fordham (1996) where one is the highest score and zero is the lowest score was used for the assessment. By considering the indicators, unit of measurement and the score for evaluation, Table 4 presents the effectiveness of the parameters and their criteria.

Institutional characteristics of the system

The study identified that, the system operation is not backed by an ordinance however there are also no conflicting roles between institutions responsible for its operation. As indicated by key respondents, educational programs are organized in the months of the rainy season to create awareness and draw people's attention to be alert. The content of the programs is mostly on what households need to do in times of disaster or when they hear the warning. The MCDRRO has administrative/training/ information and education section, responsible for organizing the sensitization programs in the City upon request by barangay officials or other organizations in the barangay. In Tumana, there is no planned routine but officials always aim to organize a maximum of four and minimum of two sensitization programs in a year. The barangay has an education task unit of 12 people including volunteers who are not employed under the unit. From the survey, all respondents were aware of their risk to flooding.

Table 4: Criteria and parameter effectiveness

Parameters	Criteria	Criteria Weight Level (A)	Criteria Effectiveness (B)	Criteria Effectiveness Weighted Score (C) C = (A x B)	Parameter Effectiveness Score (D) D = Σ (C)
Institutional Characteristics of the System	Ordinances backing the system	0.2	0.7	0.14	0.82
	Institutional effort to increase awareness	0.2	0.7	0.14	
	Public awareness of the system	0.2	0.9	0.18	
	Public knowledge on response	0.2	0.9	0.18	
	Redundancy of communication network or procedure	0.2	0.9	0.18	
Community Satisfaction	Timing of the message	0.333	0.9	0.30	0.9
	Method of dissemination	0.333	0.9	0.30	
	Content of the message	0.333	0.9	0.30	
Reduction in Flood Losses	Loss of lives	0.333	0.9	0.30	0.77
	Persons injured	0.333	0.9	0.30	
	Property damaged	0.333	0.5	0.17	

Parameter effectiveness scale (Parker and Fordham, 1996)

0 – 0.2: Basic – Not effective. >0.2 – 0.4: Slightly effective. >0.4 – 0.6: Moderately effective >0.6 – 0.8: Very Effective. >0.8 – 1.0: Extremely Effective

Forty-seven percent attributed the source of the information to barangay authorities while forty percent got to know of their risk through experience with flood events over time. The remaining thirteen percent named their friends, landlord and relatives as the source of the information. To improve risk awareness, preparation of the community risk map included leaders from the various civil society organizations and religious bodies in the barangay. The study also identified that, not only are all households aware of their risk but they are equally aware of the existence of the early warning system.

From the survey, a total of 71 out of the 100 respondents heard of the early warning system in the same year it was introduced. In all the 3 years stated, 91 out of the 100 respondents heard the warning from barangay officials. This also attests to the effectiveness of the sensitization programs organized by the Barangay officials. It is indeed possible for one to know about the existence of the early warning and not know what it means or what to do if they hear of the warning. Awareness of the existence of the system is important so is the ability of households to understand and respond appropriately to the warning. From the study, all respondents were fully aware of what it means and what they are to do in case the warning is raised. Ninety-one percent of the respondents understood the warning and knew what to do from information delivered through announcements and seminars organized by barangay officials.

Though all respondents fully understand the warning and what to do after alarm is raised, not all respond as expected. The third alarm indicates households should move to the evacuation center, but 20% of the respondents of which 90% are males do not move. Respondents indicated that thieves take that opportunity to steal their belongings, hence the reason for their refusal to evacuate. The males, however, added that, they make sure their wives and children move to the evacuation centers as expected.

Since the siren which is the main medium for transmission is heard within 1.5km, sound truck is used by the barangay officials for the remaining areas. In addition to ensure the reliability of the communication network, the barangay offi-

cials together with barangay volunteers go from house to house to inform households and make sure they respond to the warnings. These show how redundant the system is.

Community satisfaction with the system

Since the barangay experience flooding at least twice in a year, warning is raised every year during the rainy season. From the survey, all respondents have experienced the warning more than once. To assess how satisfied respondents are with the time they had to prepare after the warning and before the flood event (lead time), they were asked to refer to their experience with any flood event and the warning. With reference to 2012 flood event (habagat), all respondents were satisfied with the timing of the warning, adding that, there was sufficient time for them to prepare before the flood event. Respondents added that, they are always alert in the rainy months, and since the warning alert is issued three times, they start preparation from the first warning and evacuate immediately when the third warning is issued. Forty-three percent of the respondents who were mostly those staying close to the Marikina River pointed out that, on the average, the time between the third warning and the flood event is between 30 minutes to 1 hour. Thirty percent also reported a time difference of one to 2 hours. Majority (76%) also reported a needed maximum time of 1 hour to prepare for evacuation. The study also established that since households are fully aware of their risk, preparation to evacuate begins after any suspicion of possible heavy rain. Respondents indicated that, their long experience with flood disasters make it possible for them to predict, based on the weather and the clouds.

The main medium used by the barangay officials is siren and sound truck of which households expressed their maximum satisfaction. Since households are fully aware of their risk, they do not only rely on the medium used by the barangay officials but also rely on mass media. They get information on the weather and other important forecasts from TV and radio. Respondent were asked if they were satisfied with the information associated with the warning or have other expectations that should be considered. All the surveyed households indicated a full satisfaction with the content of the warning.

Reduction in flood losses

This parameter covers how the system has been able to reduce flood losses after its introduction. According to the MCDRRMO, the main aim for the introduction of the system is to achieve zero casualties. Casualties include persons injured and lives lost. Property damage which are mostly movable was identified as a frequent impact suffered by residents hence the need to add it to the criteria. These three criteria were therefore used for assessing reduction in flood losses.

The city has no comprehensive catalog on the impacts of flooding but all respondents attested to the fact that lives lost from flooding was a big issue in the city and the barangay before the introduction of the system. After the introduction of the system, there are no recorded cases on live lost. Flooding still leads to death in other cities and areas in Philippines, Marikina City however continues to record no lives lost. One example cited by respondents was the flood event that happened in 2012, Habagat. Both institutional and household respondents attributed the reduction solely to the introduction of the system.

With respect to persons injured during flood events, the study identified that, the system has contributed immensely to reduce this impact. Since households have become more aware of their risk and are warned before any disaster, they are able to prepare before the event. Household's respondents reported that, before the introduction of the system, flood events took them by surprise, hence people get injured in the rush to keep their important properties safe. In addition, there were no designated safe areas for them to take shelter. The introduction of the system, on the other hand, has helped to reduce this effect in the barangay. Eighty-five percent of respondents therefore attributed the reduction as mainly the result of the system.

Based on the scale and the score for overall effectiveness (0.811) as shown in Table 5, it can be concluded that, the system is extremely effective. The institutional characteristics, com-

Table 5: Overall effectiveness

Parameters	Priority Rank	Weight Level (E)	Parameter Effectiveness Score (F)	Parameter Effectiveness Weighted Score G = (E x F)	Overall Effectiveness of system (H) H = Σ(G)
Flood Losses	1	0.5	0.77	0.385	0.811
Institutional Characteristics of the System	2	0.3	0.82	0.246	
Community Satisfaction	3	0.2	0.9	0.18	

Criteria effectiveness scale (Parker and Fordham, 1996)
0 – 0.2: Basic – Not effective. >0.2 – 0.4: Slightly effective. >0.4 – 0.6: Moderately effective >0.6 – 0.8: Very Effective. >0.8 – 1.0: Extremely Effective

munity satisfaction, as well as the contribution of the warning system to the reduction in flood losses all indicate that failures have been reduced in the operation of the system.

To identify how overall effectiveness of the system may change due to different priorities of the main institutions involved, sensitivity analysis was conducted. Flood losses were ranked first by both institutions since the main goal for introducing the early warning system is to achieve zero casualties. Marikina City Disaster Risk Reduction and Management Office ranked institutional characteristics of the system second because they were concerned with how the system operates to help achieve their aim. They pointed out that, the effective operation of the system will lead to high community satisfaction, hence ranking community satisfaction as the third priority. The Barangay officers, however, think otherwise and believe that, the system will be more effective if community members are satisfied with it and respond as expected. The Barangay officials therefore ranked community satisfaction as second priority. They indicated that since the response is expected from households, their satisfaction is very important for effectiveness assessment. The change in priority score affects the weight assigned to each parameter, altering the overall effectiveness score of the system. The sensitivity analysis is therefore undertaken to find out the degree to which the effectiveness score of the system changes with the different priorities. After calculation, overall effectiveness increased from 0.811 to 0.819 meaning the system is extremely effective no matter the different priorities of the main institutional stakeholders involved.

Lessons learnt from the early warning system in Tumana, Marikina City

It was realized from the study that, city authorities looked beyond only creating awareness to ensuring full understanding of risk and the system. This is shown by the appreciation of risk by households and their cooperation in flood risk management in the barangay. The understanding was achieved by making information accessible and accepted by everyone in the community, through ensuring full participation and partnership. For instance, in developing community flood risk map to ascertain risk zones and evacuation centers, community leaders, civil societies and religious leaders were all involved in the preparation. Volunteer groups were also formed to assist the barangay officials in educational programs and providing response. Educational programs with the assistance from volunteer groups were undertaken in

schools, from house to house and workshops at selected locations. Ensuring participation and the treatment of community/households as partners in flood risk reduction has led to the proactive role played by these stakeholders and their high motivation to take full responsibility for their safety. The use of siren as a medium for warning also provide simple and quick message to households. The siren system also has a battery back-up that cater for any power outage hence making the system more redundant. The operation of the system indeed serves as a good practice due to its ability to reduce all weaknesses mostly associated with flood early warning system operation. It is important for countries implementing early warning system such as Ghana to acknowledge that community ownership is a precondition for successful operation of the system.

CONCLUSION AND RECOMMENDATIONS

Flooding is a complicated disaster that cannot be addressed by only structural or non-structural solutions. Mitigation measures must also target impact reduction among households at risk. The appreciation of this fact led to the introduction of the early warning system in Tumana by Marikina City authorities. The findings from the study show that, the early warning system has overall been extremely effective, with a score of 0.811, in reducing the households' risk to flooding. This is because weaknesses mostly associated with the operation of the early warning system have been reduced. This is shown by the, effective institutional characteristics of the system, high community satisfaction and the perceived reduction in flood losses.

There remain, however, some issues that hinder the system from attaining the perfect score and also serve as a threat to its sustainability. These include the lack of ordinance or policy coverage to back the system and the refusal of some households to evacuate after warnings. It is an undeniable fact that, political turnovers may have a negative impact on the sustainable maintenance of the system. It is therefore necessary for the system to be well institutionalized with sufficient policy coverage including: ordinances, designated budget for improvement and maintenance. In addition, to ensure sustainability of the system, it is very necessary for barangay officials to coordinate with law enforcement agencies to develop a plan to ensure that household properties are still protected after evacuation. An investigation should be carried out after a flood disaster to find property lost and ensure that the culprits are punished according to the law to deter others from such act. Since the introduction of the flood early warning system, no assessment has been made by the city authorities to evaluate the performance of the system. It is necessary for the main institutions to develop some indicators for a regular evaluation of the system. It is also recommended that the City Disaster Risk Reduction and Management Office develop a comprehensive catalog that includes the impacts experienced during flood disasters. This will facilitate an assessment of the system and also provide reliable data for sustainable solutions in flood risk reduction.

Property damage was one of the impacts often experienced by residents during floods. The warning system has not and will not totally prevent this impact, especially for the immovable properties. Some respondents expressed their inability to recover their lost property after Ondoy and Habagat flood events. Residents can therefore consider other measures that will help in the recovery of property. The city authorities together with barangay officials can encourage households to undertake an insurance policy by educating them on the topic and also regulating the activities of private insurance companies to ensure that residents are not abused. The city can also partner with insurance companies or provide subsidies to reduce the burden on households if premiums are very expensive. This will greatly help families recover quickly and aid in recovering damaged properties. In general, the findings from this study are relevant to Ghana and many other emerging countries which have recently installed early warning systems to reduce flood risks.

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