ASSESSMENT OF FLOOD IMPACT ON LOCAL SOCIO-ECONOMIC DEVELOPMENT IN THE DAVAO RIVER FLOODPLAIN, PHILIPPINES

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ABSTRACT

Flood disasters which happen every year in the Philippine river floodplains interrupt not only the lifestyle of the society but also immobilize the economy. This study aims to assess flood risk in the three districts of Davao River floodplain which is a product of flood hazard, vulnerability, and exposure divided by coping capacity (Risk = H x V x E/CC). In flood hazard, four return periods of flood for 10, 25, 50 and 100-year were computed using the Rainfall Runoff Inundation (RRI) model while for flood vulnerability and exposure, socio-economic factors used and also the elements at risk are population, declared number of employees, and Micro Small and Medium scale Enterprises (MSMEs). In addition, coping capacity elements (e.g. floodway mitigation, number of schools and health centers) were integrated. To produce the flood risk maps of the three districts a risk matrix was utilized. The flood risk maps can be employed as a tool for the local leaders, disaster managers and planners for the improvement of their decision- making processes, contingency plans and protocols and for the community used to spatially analyze the level of flood risk in their respective district.

Keywords: *Flood risk, flood hazard, vulnerability assessment, coping capacity, exposure*

INTRODUCTION

Davao River Basin (DRB) is one of the major river basins in the Philippines and considered as one of the priorities of the government in master planning due to its importance to the economy. Davao City is a delta and the largest city in the country in terms of land area and composes 67% of the area of DRB. It is one of the economic hubs of the country and premier in the island of Mindanao. Also, 5th richest city in the Philippines in terms of local income and Internal Revenue Allotment (IRA). The study will focus on the three (3) main districts of the city (Agdao, Poblacion and Talomo) that are located in the Davao River floodplain (Figure 1). These districts are flood prone areas, highly urbanized and have a high concentration of Micro, Small and Medium scale Enterprises (MSMEs). MSMEs play a significant role of in the society (Gunathelaka, 2018) one of these important roles is in the economic development of the country of which it comprises 99.6% of the whole Philippine's business enterprises as of year 2010 (Senate Economic Planning Office, 2012). To alleviate the impact of flood to the local-socio economy of the 3 districts one effective approach is the flood risk assessment which is considered as a soft countermeasure in dealing with disasters.

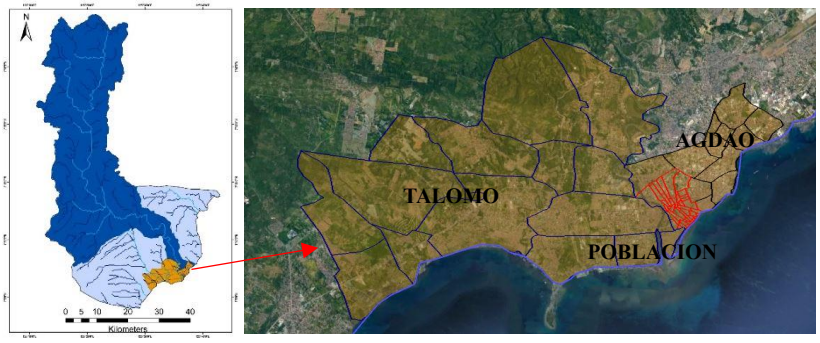

Figure 1. Davao River Basin (Blue) & Floodplain (light blue) and the 3 Districts (Agdao, Poblacion and Talomo)

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METHODOLOGY

The methodology of the study has 3 main parts: The flood inundation analysis, vulnerability assessment and lastly, the flood risk assessment.

A. Flood Inundation Analysis

RRI model was used in the estimation of flood hazard. Flood frequency analysis is needed to compute for the four (4) return periods (10, 25, 50 and 100-year) of flood. Before the computation, the RRI model should be first calibrated. The rainfall data from four gauges were used and the comparison of the simulated discharge to the observed discharge is done using one water level station. The data used is the January 2002 flooding event discharge data. Model validation was also conducted, it is essential in checking the stability of the model's efficiency in which the discharge data October 15-22, 2008 was utilized. The calibration and validation efficiencies of the model were checked using the three criteria, the Nash-Sutcliffe Efficiency (NSE), Coefficient of determination (r^2) and Index of Agreement (d). The model efficiency results for calibration are: NSE= 0.62, R^2= 0.87 and d= 0.92 while for validation: NSE= 0.58, R^2 =0.84 and d= 0.88, which were considered in an acceptable range. For further validation, one flood event (December 2017) was simulated in which RRI model and (National Disaster Risk Reduction and Management Council) NDRRMC report estimated affected barangays and population were compared. Also, Modified Land Surface Water Index (MLSWI) was utilized as a second approach for validation, the same flood event was used and compared to MODIS 8-day, Dec. 19-26, 2017 composite data. The outputs of both validations are fairly acceptable.

The flood depths per hazard level used in this study were based on one of the past flood hazard assessment made in the study area by Department of Science and Technology (DOST) (Lagmay et. al.,2015) which is depicted in Figure 2 (A).

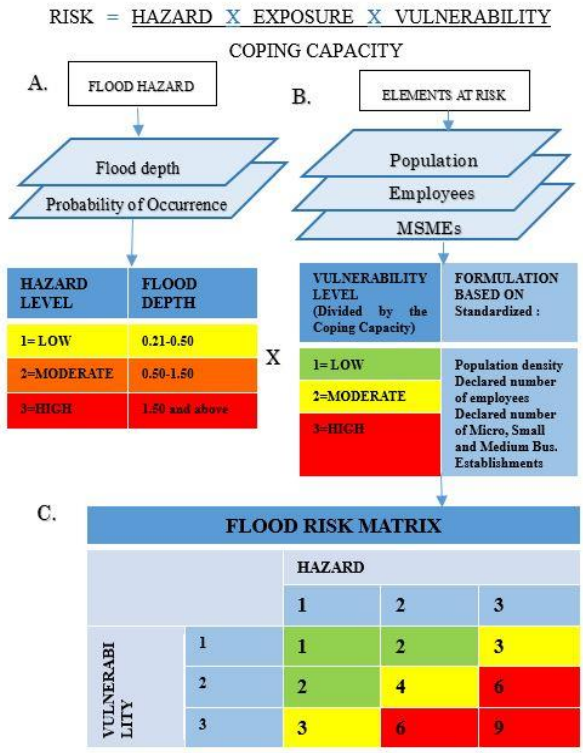

Figure 2. Methodological Approach

Vulnerability Index	A	B	C
	Population Density (pop/sq. km)	Employees	MSMEs
Low	≤ 8,257	≤ 33%	≤ 33%
Moderate	8,257 <X< 13,704	33<X<50%	33<X<50%
High	X> 13,704	X>50%	X>50%

Coping Capacity Scores		
Floodway Mitigation	Number of Schools	Number of Health Centers
NO= 0	0-10 =1	0=1
YES= 1	11-20= 2	1-2 = 2
	21-30=3	3-5 = 3

VULNERABILITY LEVEL	FORMULATION
1 (LOW)	(A+B+C)/ CC < 1.5
2 (MODERATE)	1.5 < (A+B+C)/ CC < 2.5
3 (HIGH)	(A+B+C)/ CC > 2.5

Figure 3. Formulation of Vulnerability

B. Flood Vulnerability Assessment

The elements at risk that were considered for the identification of vulnerability indices are each district's barangays population densities, declared number of employees where the employees of large enterprises were included because all employees are considered as vulnerable people in times of flood disasters and the declared number of MSMEs. In the formulation of vulnerability levels (low, moderate and high) the data were first normalized and ranked based on Figure 2. Also, integrating the coping capacity elements such as floodway mitigation, schools which serves as evacuation centers and health centers with corresponding scores as what is depicted in Figure 3, coping capacity scores.

C. Flood Risk Assessment

For managing flood risk, flood analysis and flood disaster risk assessment are very important (Shrestha et al., 2016) and for identification of the flood risk in this study, risk matrix which is shown in Figure 2 (C) was applied. The flood risk levels of the produced risk maps for the three districts are based on the color codes of the flood risk matrix. Green for low risk, yellow for moderate and red for high.

DATA

To obtain the results for this study, data for RRI model simulations and local socio-economic are essential. For RRI model, the Digital Elevation Model (DEM) data of the DRB which was also used for the calculation of flow direction and accumulation is an Interferometric Synthetic Aperture Radar (IfSAR) data from the National Mapping and Resource Information (NAMRIA), Philippines. This is a 5m grid size and up-scaled into 200m resolution for ease on computation and calculation time. Furthermore, the 11 land use types shapefile data used in which was simplified into a three land use types (Forest, paddy field and built-up) for RRI model came from the same agency. The rainfall data used from 4 rain gauges for calibration and validation of the model are from the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA). Also, the 64-year annual daily maximum rainfall data (1951-2015) of Davao Station which was utilized for flood frequency analysis for the calculation of the 10, 25, 50, and 100-year return periods using the Gumbel distribution came from the same source. The discharge data at Lacson Station originated from the Department of Public Works and Highways (DPWH). The local socio-economic data, 2015 population came from Philippine Statistics Authority (PSA). Lastly, the declared number of MSMEs and employees, number of floodway mitigation, schools and health centers were from the Davao City Business Bureau 2015.

RESULTS AND DISCUSSION

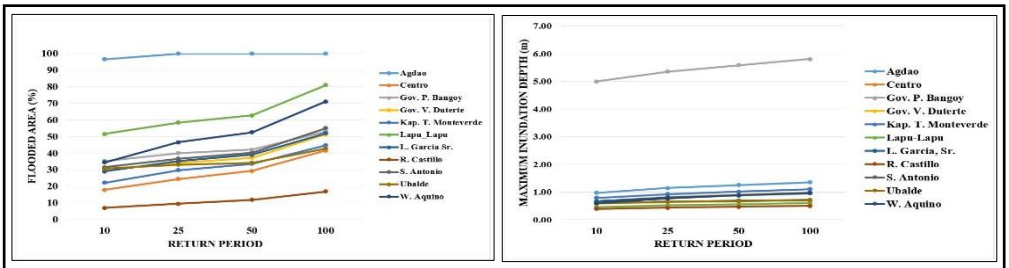

Figure 4. Agdao District Barangays %Flooded Area (Left), Maximum Inundation Depth (Right) for 10, 25, 50 and 100-year return periods

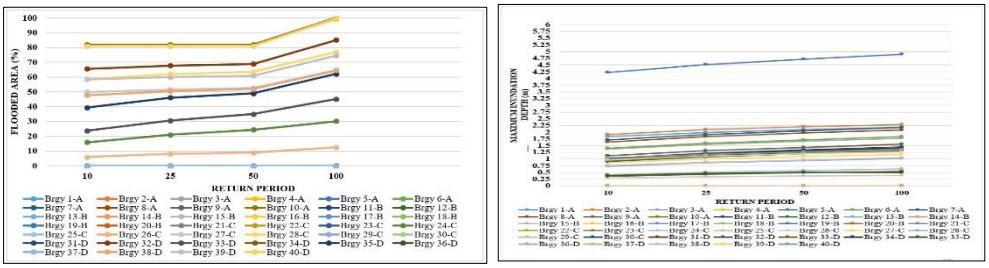

Figure 5. Poblacion District Barangays %Flooded Area (Left), Maximum Inundation Depth (Right) for 10, 25, 50 and100-year return periods

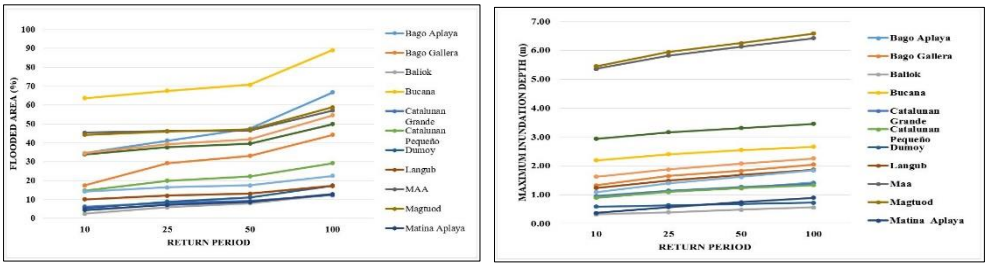

Figure 6. Talomo District Barangays %Flooded Area (Left), Maximum Inundation Depth (Right) for 10, 25, 50 and100-year return periods

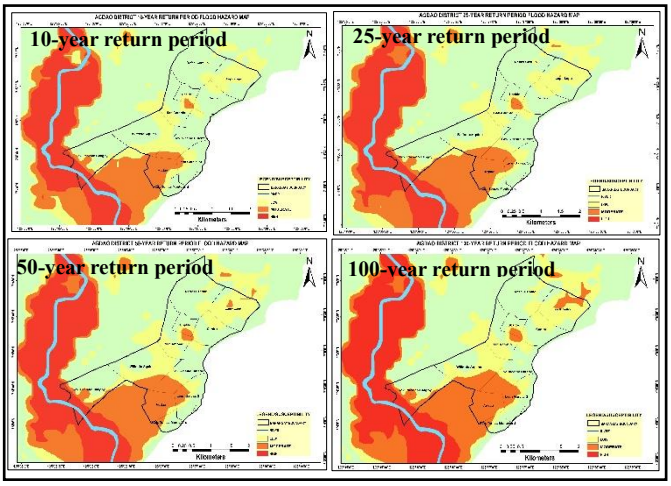

Figure 7. Agdao District Flood Hazard Maps
(10, 25, 50 and 100-year return periods)

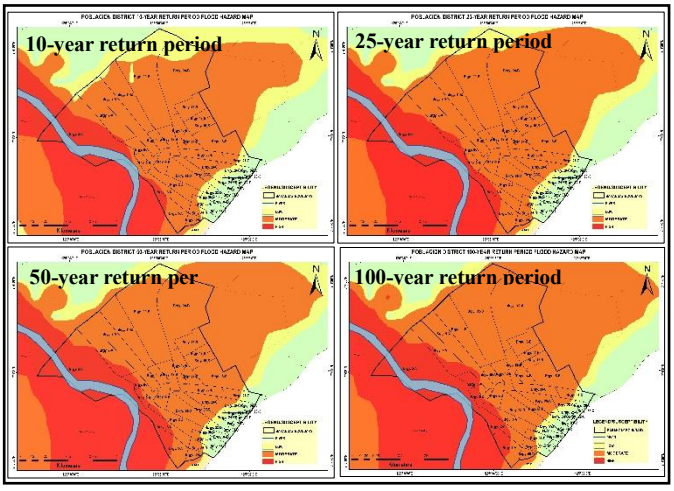

Figure 8. Poblacion District Flood Hazard Maps
(10, 25, 50 and 100-year return periods)

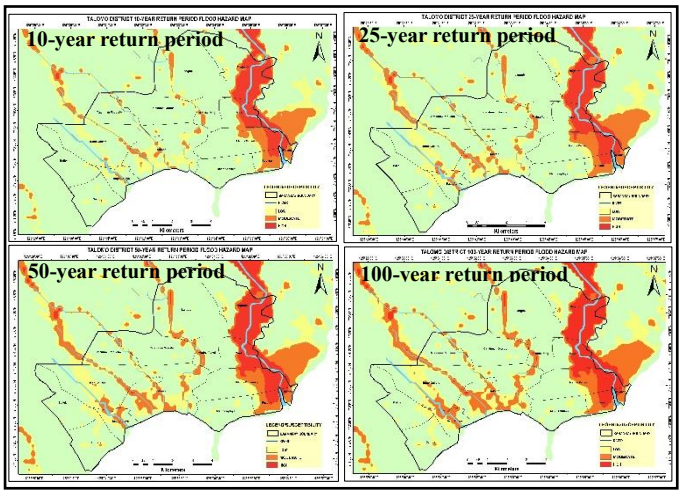

Figure 9. Talomo District Flood Hazard Maps
(10, 25, 50 and 100-year return periods)

In the flood hazard assessment and mapping, the calculation for different return periods were done using the RRI model (Sayama et al., 2012). The summary of the maximum flood depth and the percentage of the flooded areas per district's barangay are shown in Figures 4-6. Also, the flood hazard maps of the three districts per return period are depicted in Figures 7-9.

In Agdao District, the worst inundated barangay is the Brgy. Agdao which is near the Davao River and the area is flat compared to the other areas in the district while Brgy. Gov. Pociano Bangoy has the maximum inundation depth. In the Poblacion District which has 40 barangays with high population density, 23 barangays are severely inundated. In 3 return periods (10, 25 and 50) the percent of inundation is constant which 81% of the area of each barangay whereas, in the 100-year return period these 23 barangays are fully inundated. Seven barangays are not affected by the riverine flooding as per RRI model output simulations. Lastly, in Talomo District, the Brgy. Bucana is the worst inundated area among the 14 barangays in this district. Maa and Magtuod have the highest inundation depth because these barangays are adjacent to Davao River.

The flood vulnerability maps for the districts are shown in Figure 10.The levels of vulnerability color codes used are different from the flood hazard maps, where green is for low vulnerability, yellow for moderate and high is red.

Although there are presence of other small rivers in the area like Talomo and Matina Rivers which are also contributors of inundation in the area but due to its high coping capacity, Talomo District is less vulnerable to flood hazard. The number of schools (one of coping capacity elements) which are being utilized as evacuation centers are more concentrated in this district. In the case of Poblacion District, which is very close to the Davao River, although by distance and population density, this district appears highly vulnerable but due to the existence of the floodway mitigation in most of its barangays, the vulnerability level is reduced. In Agdao District, out of the three districts, the level of vulnerability is high due to the following reasons: the district is highly populated area and the presence of employees and MSMEs are substantial. In addition, the coping capacity value of the district is low. As per the record, the district doesn't have a floodway mitigation and has few number of schools.

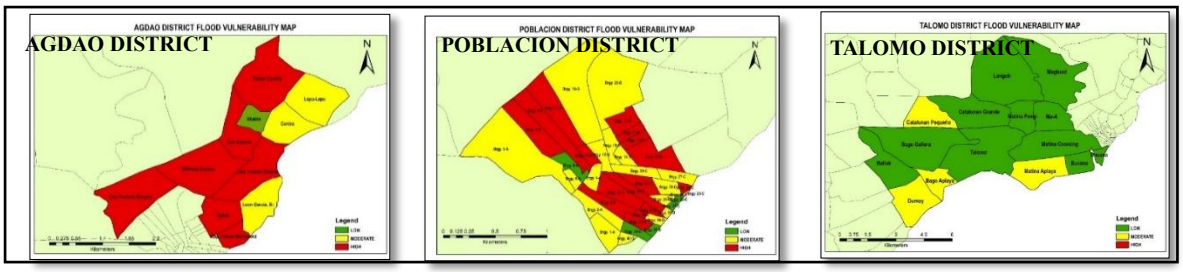

Figure 10. Agdao, Poblacion and Talomo Districts Flood Vulnerability Maps

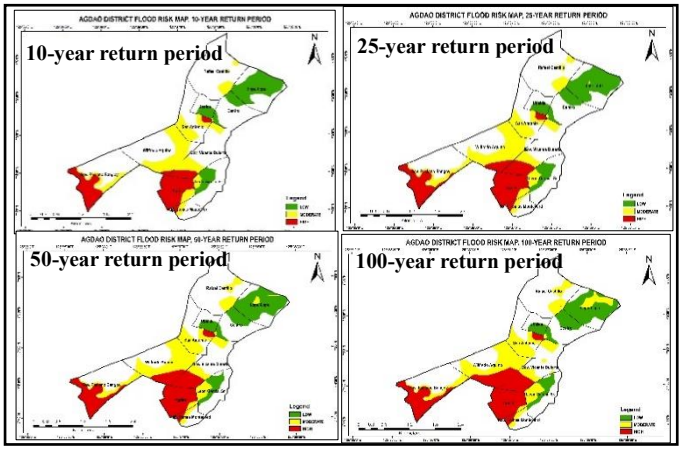

Figure 11. Agdao District Flood Risk Maps
(10, 25, 50 and 100-year return periods)

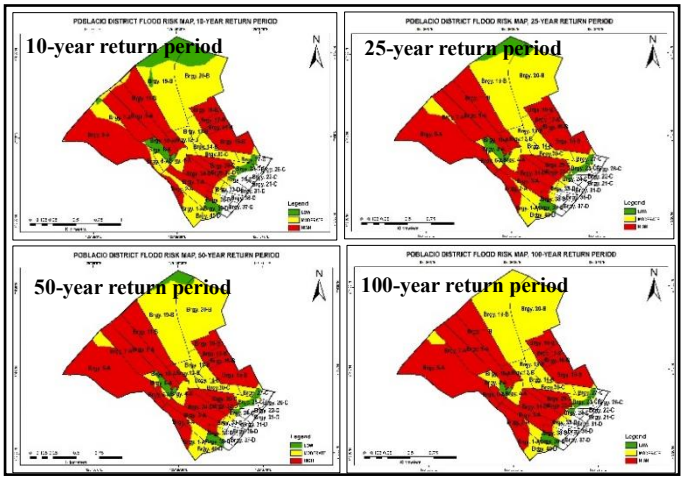

Figure 12. Poblacion District Flood Risk Maps
(10, 25, 50 and 100-year return periods)

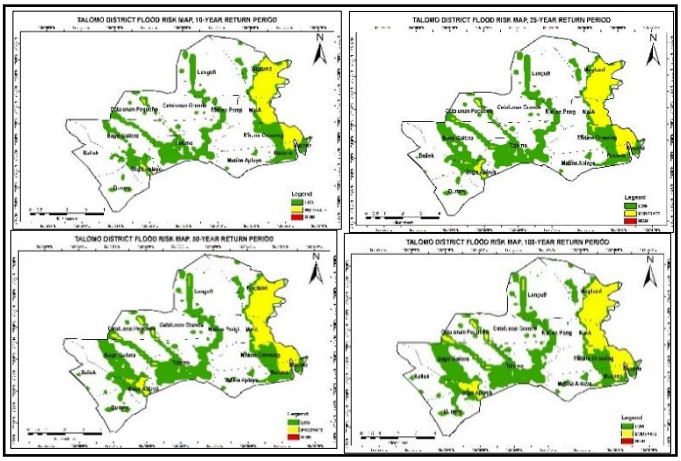

Figure 13. Talomo District Flood Risk Maps
(10, 25, 50 and 100-year return periods)

The final output of this study is the flood risk maps of the three districts per return period (Figures 11-13). The maps are the products of the integration of the flood hazard and vulnerability considering the exposure and coping capacity which were introduced earlier in this study where green means low risk, yellow is for moderate and red for high risk.

The Poblacion is the district that has a high level of flood risk. Based on its topography and the location which is flat and the nearest district to Davao River, this made Poblacion the most flood prone district among the three and the coping capacity of the district is insufficient to reduce its high degree of flood risk. On the other hand, in Agdao district although the hazard level is quite low compared to Poblacion there are still areas of the district like Barangays Agdao, Gov. Paciano Bangoy, Gov. Vicente Duterte and Wilfredo Aquino that have a high level of flood risk. The situation in in Talomo District is quite different, the level of risk is up to moderate only. In Talomo, the coping capacity has a great impact which alleviate the degree of its flood risk. Aside from this reason there are areas/barangays that have a steep topography, which is in contrast with the other two districts which are flat. The changes of the level of flood risks per return period in each district and even in their barangays can be spatially analyze using the flood risk maps produced.

CONCLUSION AND RECOMMENDATION

This study reaches to the following conclusions: 1.) By the application of RRI model the level of the flood hazard in the three districts were identified. The inundation depth and extent per barangay in each district were also known. 2.) Based on the calculation of vulnerability, although the district has a high level of vulnerability if the

degree of its coping capacity (floodway mitigation, number of schools and health centers) is high, the resulting level of its risk is low like the Talomo District. 3) In the formulation of flood risk maps, the level of hazard, vulnerability and the exposure of the elements at risk are the three main factors for the identification of the level of risk of the districts. In addition, a very important factor that should also be considered is the coping capacity.

The flood risk matrix is a one of a widely used approach which can be used in the assessment of risk (Chunbing, B. et. al 2017). Although it is known that the approach is a subjective type but due to some limitations faced, the risk matrix is one of the approaches that is plausible to use in this study. The assessment of flood risk using the method is useful for local leaders, disaster managers and planners and also to the local community to spatially identify the level of risks in the three districts of Davao City, in which in this city most of the flood hazard researches and projects made gave emphasis to the development of flood hazard maps but not on the impact of flood to the local socio-economy. In this study it focuses on socio-economic elements such as the population, declared MSMEs and number of declared employees of MSMEs including the employees of large enterprises. Furthermore, the maps will serve as tools in analyzing the flood risk present even in the smallest government unit in the country which is the barangay/ village which may increase the level of awareness, preparedness and resiliency of the society to alleviate the loss of lives, properties and livelihoods due to flood disasters. Though the study is made only for the three main districts of Davao City, it can also be applied to the other districts of Davao City and to other key cities of the country which are flood prone.

The flood risk assessment has different approaches and each approach has its own limitations, in this study the identified limitation is the data availability. Data for the RRI model simulations are limited, for data in only one water level station was utilized, the number of rain gauges is sparse and ground truth validation is required. Also the socio-economic data used for the calculation of vulnerability and data for coping capacity are insufficient. In the assessment of flood risk, data is very important to come up with a reliable output.

ACKNOWLEDGEMENT

An expression of warm gratitude and respect to my Supervisors, Dr. Shinji Egashira, Dr. Badri Bhakta Shrestha and Dr. Yoshihiro Shibuo for sharing their invaluable knowledge and expertise in the field of Disaster Management and also for their time and patience which keep me directed up to the completion of this study. Also, to Dr. Toshio Koike, ICHARM Director, Mr. Yoshio Tokunaga and Mr. Hiraoki Shirai, my appreciation to all the inputs, suggestions and comments that they had extended.

I acknowledge ICHARM, GRIPS and JICA for this rare opportunity that they provide to aspiring government employees who want to earn knowledge and experiences in the field of water-related disaster management and my PAGASA family, thank you is not enough as an expression of how grateful I am for the chance they had given me.This research would not be possible without the other people who in their own little ways extended their support and encouragements, for that, maraming salamat po!

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