Flood Modeling using Gis and LiDAR of Padada River in Southeastern Philippines

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Abstract: Located along the typhoon belt in the Pacific, Philippines is visited annually by an average of 20 typhoons. This brought frequent flooding to communities and caused damage to flood prone residents. This study is aimed to generate GIS flood model to simulate flood inundation using Synthetic Aperture Radar (SAR) data and Digital Terrain Model (DTM) derived from Light Detection and Ranging (LiDAR) datasets. Open-sourced HEC-HMS and HEC-RAS Models were used. HEC-GeoRAS in ArcMap was used to preprocess geospatial data of Padada River basin in the Southern Philippines. The result of the study has identified inundated areas and communities for a 24-hour 5, 25, and 100- year return periods as well as flooded critical facilities in the flood plains. The output of this study can be used in planning and predicting flood risks for mitigation.

1 INTRODUCTION

Flood is one of the most disastrous phenomena that can occur in an area since it has damaging impacts to human lives, properties, and infrastructures such as death, spread of diseases, and destruction of livelihood (Siddayao et al, 2015).

Padada watershed is situated in the southern part of the Philippines with a total land area of 1,186.80 sq. km which drains to Padada river and occasionally flooding the downstream municipalities of Hagonoy, Padada, and Sulop affecting hundreds of households, damaging crops, livestocks and properties. Flooding aggravated hunger and resulted to poor health conditions among the villagers in these communities (General (Philippines, 2009):

To reduce flood effects and risks, prediction of the flood event is a vital information to locate the areas at risk and to quantify the damages it may result to. The extraction of this data can be acquired through simulating the event in a computer using flood model.

Flood modeling requires accurate assessment of water movement within flood-prone areas as a reliable basis for mitigation and resource management (Kim et al, 2016). Several techniques considering different parameters were used in practice. One of which is the Hydrologic Engineering Center-River Analysis System (HEC-RAS).

HEC-RAS is a one-dimensional model which is able to perform an unsteady flow simulation of a river (Hammerling et al, 2016). It has been applied to a range of applications such as bridge and culvert design, channel modification and floodplain management (Yuan and Qaiser, 2011). In implementing this tool, several studies have utilized high-resolution datasets like digital elevation models as inputs to capture the detailed profile of river channels and to achieve more precise results (Turner et al, 2013).

Light Detection and Ranging (LiDAR) is a digital elevation model with a topographic horizontal resolution of 1m. Due to its higher resolution, LiDAR gives more details and near to accurate topographic information compared to other DEMS such as Synthetic Aperture Radar (SAR) and Interferometric Synthetic Aperture Radar (ifSAR) (Suarez et al, 2014).

In the Philippines, some areas has experienced

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distinct changes in the weather patterns with disastrous results such as flooding (Yumul et al, 2013). With the disaster risk management program in place, a study was conducted that generates a flood model using Hydrologic Engineering Center-River Analysis System (HEC-RAS) as a tool and Light Detection and Ranging (LiDAR) data sets as digital elevation model. A case study is done in Padada River floodplain in Southern Philippines as in Figure 1.

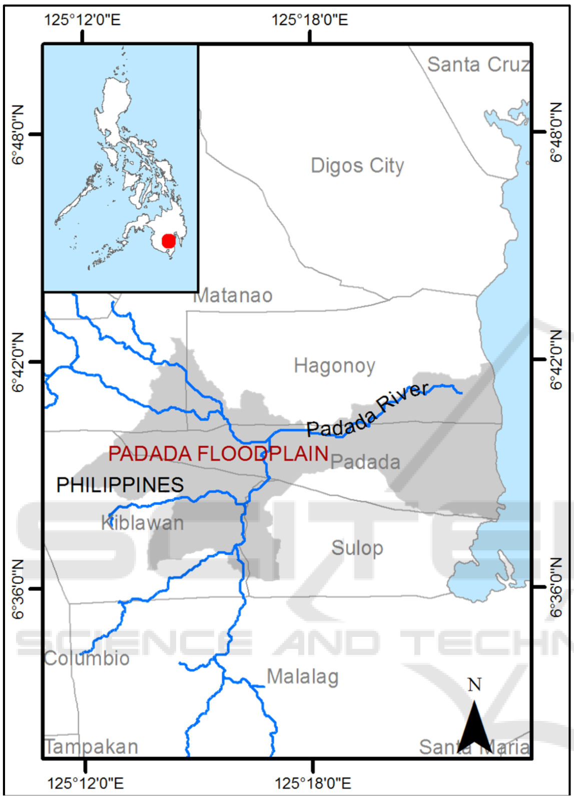

Figure 1: Location of Padada floodplain in Philippines.

2 METHODOLOGY

Presented in Figure 2 is the method of preparing the HEC-RAS Model of Padada floodplain. The process involves four major activities namely (i) Generating the River Digital Plot, (ii) Flood Model Preprocessing, (iii) Flood Modeling, and (iv)Identifying Flood Prone Communities.

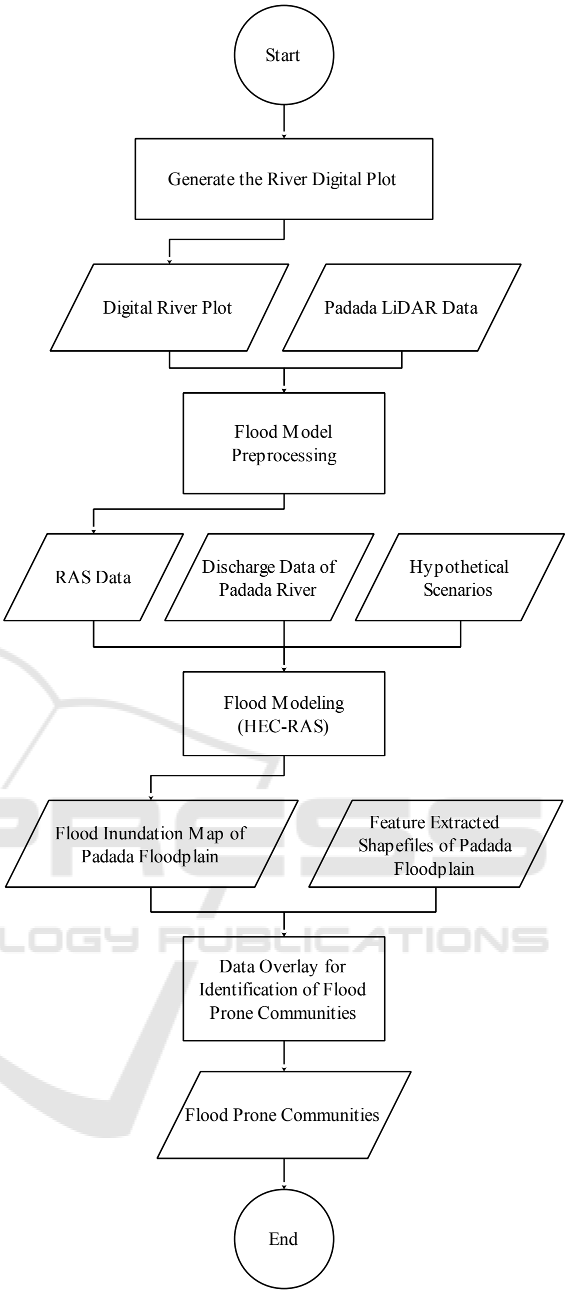

Figure 2: Process flow in generating HEC-RAS Model.

2.1 Generating the River Digital Plot

One of the prerequisites in flood model preprocessing is the river digital plot (RDP) which are polyline vector files that follow the centerline, left flow path, right flow path, left bank, and right bank of Padada River. In this study, LiDAR DTM with a 20 cm vertical accuracy and various satellite images were mainly used to verify and generate the RDP. The digitization of the RDP started from the project point where the discharge data was gathered going down to the outlet of the river. Once done, the generated river digital plot in Keyhole Markup Language (KML) file format was converted to a vector file.

2.2 Preprocessing

In generating the flood model, the LiDAR DEM and the river digital plot were prepared for processing the physical features of the river. The LiDAR DEM was initialized as the elevation data while the river digital plot was used to define the extent of the river. The digitized river lines were grouped into river data, containing the centerline, River banks data, containing the left bank and right bank, and flowpaths data, containing the right flow path, left flow path, and centerline of the river. The river centerline was assigned with a river code and a reach code to provide a name for the river. To define the flow direction of the river, each paths from the flowpaths data were assigned whether a right flow path, a left flow path, or a channel path. Using the LiDAR DEM as terrain and the river data as the centerline of the stream, the stream profile was generated to extract the changes in elevation along the river channel from upstream to downstream locations.

After generating the geometric attributes along the rivercenterline, the construction of the cross-section cutlines followed. Each cross-section cutline represents a station in the river where the data for the one-dimensional flood simulation was based on.The initial set of cross-section cutlines were uniformly distributed along the river centerline. Furthermore, these were adjusted so that there were no lines intersecting another line and that they have crossed a river bank only once. This was to avoid the overlapping of flood inundation among stations. Having the river data as the centerline of the stream, LiDAR DEM as terrain, and cross-section cutlines, the cross-section cutline profile was generated to extract the elevation data across the river in each station. In preparation for the export of the GIS data for HEC-RAS modeling, the generated datasets were initialized including the terrain, centerline of the stream, cross-section cutlines, cross-section cutline profiles, bank lines, flow path, and stream profiles.

2.3 Flood Modeling

The previously generated GIS Data in flood model preprocessing was converted into geometric data with a metric system of Système international d'unités or SI. The Manning's n values were supplied and Cross Section Point Filter was set in the process to initialize the roughness value and reduce the elevation data points that can be processed by HEC-RAS model for each river station, respectively. For the simulation, unsteady flow were used in utilising the discharge data and simulated 5, 25, and 100 Year Rain Return hypothetical scenarios of the target river. On the other hand, a friction slope value of 0.001 was set. Once all the previous parameters were set properly, computation of unsteady flow simulation followed. Afterwards, the result of the flood model simulation was produced. Lastly, generation of a flood inundation was done.

2.4 Identifying Flood Prone Communities

The 5, 25, and 100 Year flood inundation maps that were generated were overlaid to the feature extracted vector files of Padada floodplain to identify the flood prone communities. These were done in ArcMap 10.2.2.

3 RESULTS AND DISCUSSION

The digitization of the river digital plot started from Diversion Bridge (06°40'35.4"N, 125°19'47.9"E). The LiDAR elevation datasets used in preprocessing the RAS Model has a 1-meter resolution with 20cm vertical accuracy and is covering the Padada floodplain as in Figure 3. For the development of the model, the discharge data used was gathered in the same bridge with a base flow discharge of 3.35 m^3/s and was specifically set as input as the normal flow of Padada River.

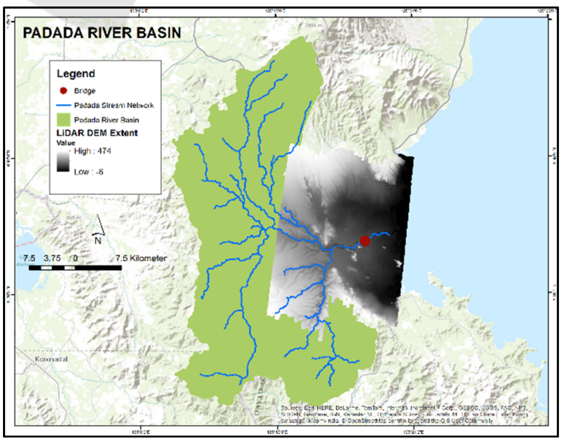

Figure 3: LiDAR Coverage of Padada River floodplain.

Riverbed cross-sections or the XS-Cutlines of the target watershed are crucial in the setup of HEC-RAS

Model. These cross-section data (Figure 4) were defined using the Arc GeoRAS tool and the LiDARDEM and were post-processed in ArcMap 10.2.2.

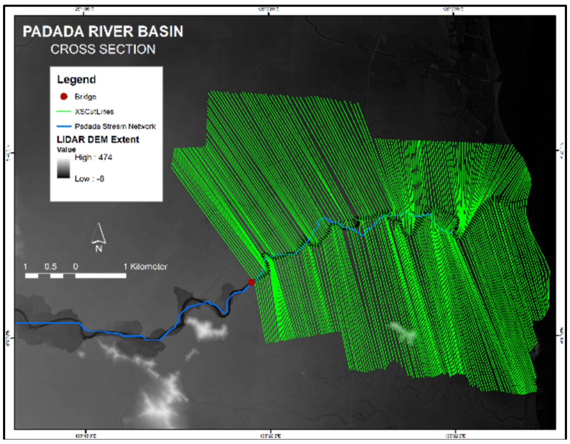

Figure 4: Padada riverbed cross-section data.

The Manning's n is dependent by the nature of the channel and surface. It is important to determine the correct roughness coefficient of the channel to have a good water flow simulation. The values used were based on the floodplain's land cover type and standardized Manning's n look-up table (Table 1).

Table 1: Look-up Table for Manning's n Values.

Land-cover Class	Manning's n
Barren Land	0.030
Built-up Area	0.015
Annual Crop	0.040
Perennial Crop	0.035
Fishpond	0.018
Inland Water	0.030
Grassland	0.030
Mangrove Forest	0.120
Shrub Land	0.100

The HEC-RAS Flood Model produced water level for every cross-section based on the discharge data that served as input. Initially, the actual discharge data were used in running the model to assure good simulation and afterwards, hypothetical scenarios of 5, 25, and 100 year rain return periods were then used as the input discharge. Right after running three simulations, 5, 25, and 100 year rain return flood inundation maps of Padada floodplain were generated as shown in Figures 5-7.

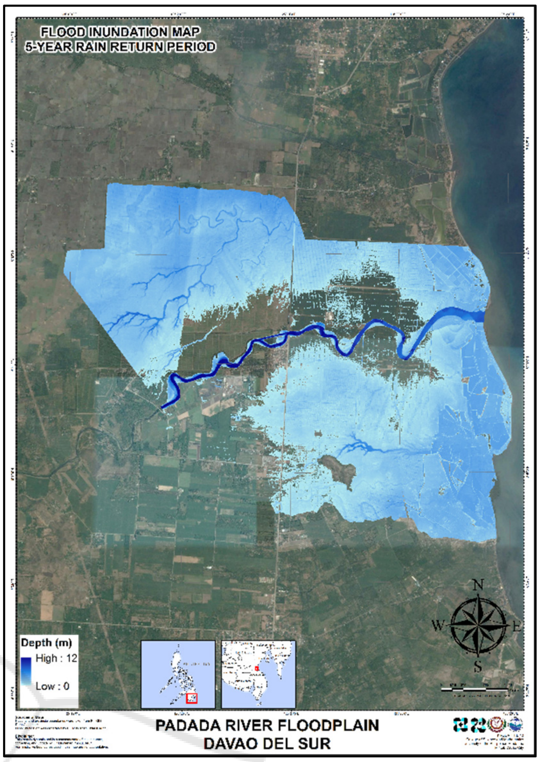

Figure 5: Padada Floodplain 5 Year Flood Inundation Map.

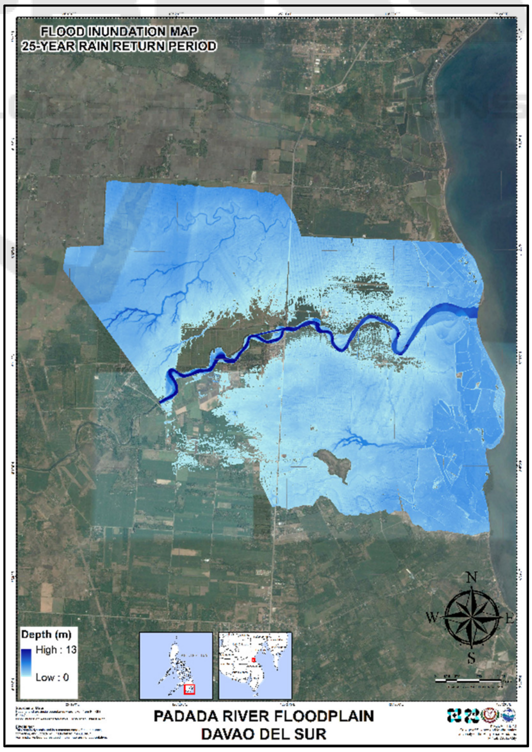

Figure 6: Padada Floodplain 25 Year Flood Inundation Map.

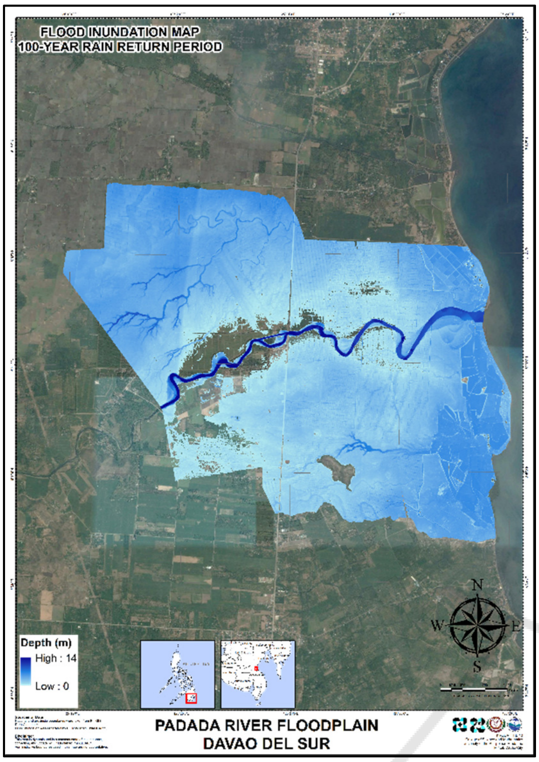

Figure 7: Padada Floodplain 100 Year Flood Inundation Map.

The generated flood inundation maps, together with the feature extracted vector files of the floodplain, were overlaid to identify the number of structures that will be affected in a given return period. For each rainfall return period, flood levels were categorized into low, moderate, and high. Structures affected with low flood level will experience below 0.5m flood depth while structures in the moderate level will have flooding between 0.5m and 1.5m deep. Structures with high flood level will encounter more than 1.5m flood depth. The result is shown in Table 2.

Table 2: Number of structures in Padada floodplain that will be affected during 5, 25, and 100 Year RIDF.

Flood Level	Number of Structures Affected in:		
	5-Year	25-Year	100-Year
Low	3,704 Structures	4,977 Structures	5,406 Structures
Moderate	951 Structure	1,800 Structures	2,999 Structures
High	23 Structures	65 Structures	143 Structures

4 CONCLUSIONS

Flood model geometric data preparation and model parameterization were made through HEC-RAS and ArcMap extension. The 24-hour 5, 25, and 100 Rainfall Intensity Duration Frequency (RIDF) curves of Padada river were used as input for the setup of HEC-RAS model. The HEC-RAS flood model produced a water level at every cross-section for every time step and for every flood simulation created. The resulting model was used in determining the flooded areas. The model demonstrated change in the behavior for the three different return periods. There are two communities that will be affected resulting from the hypothetical scenarios. A total of 4,678 structures in the floodplain will be flooded in a 5-year rain return period, 6,842 in a 25-year rain return period, and 8,548 for a100-year rain return period. The simulated results provided the maximum flood extent and inundation levels. As a result, the identification of those flood-prone areas at risk will help in the information and planning of a more effective emergency responses. The output of this study can help the local planning units to forecast and assess future flood risk for sustainable development.

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