EVALUATION OF FLOOD-PRONE AREAS IN BICOL RIVER BASIN, PHILIPPINES: COMPARISON OF FLOOD HAZARD MAPPING USING HYDRO-GEOMORPHIC AND HYDROLOGIC MODELLING METHODS

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ABSTRACT

Flooding has been a perennial problem in the Bicol River basin in the Philippines. Flood hazard mapping using hydro-geomorphic approach has been conducted by the Mines and Geosciences Bureau to map flood hazard zones in the Bicol River basin. On the other hand, this study applies hydrologic modelling approach using Rainfall Runoff Inundation (RRI) model to simulate across a range of design rainfall for different return periods of flood. The result was compared with the existing flood hazard map generated from the former method. The hydro-geomorphic method was able to create a qualitative representation of potentially flood susceptible areas like frequently-and occasionally flooded areas, whereas the hydrologic modelling was able to show the possible inundation depth of submerged areas related to a specific flood return period. As a final output, a composite map was generated from the combination of both methods to address uncertainty in flood hazard mapping.

Keywords: Flood hazard mapping, hydro-geomorphic method, hydrologic modelling method, return period, rainfall runoff inundation.

INTRODUCTION

Flooding is the most frequent and the most devastating water-related disaster in the world. Identifying flood prone areas through flood hazard mapping can be one of the solutions to prevent flood losses to human lives and properties. Flood hazard mapping can be performed using two approaches, the hydro-geomorphic method and hydrologic modelling method. The first method is based on the geomorphic analysis using information from examination of aerial photographs and field evidence of inundation. Meanwhile, the latter method calculates the peak flows for specific events or return periods.

In the Philippines, natural hazards are common due to its geographic location and geologic setting. The Philippines experiences world's highest frequencies of tropical cyclones, averaging 20 per year. The lives and livelihood of people living in the Bicol River basin are continually threatened by extensive flooding caused by typhoons (Figure 1). As part of disaster risk reduction efforts to mitigate flood hazards in the Bicol River basin, the Mines and Geosciences Bureau Regional Office No. 5 prepares flood hazard maps employing hydro-geomorphic method.

There are very few empirical studies that compare and validate flood hazard maps created by hydro-geomorphic approaches and those based on hydrologic modelling. By comparing the results of both methods, their pros and cons will be determined and could pave way for the improvement of the two flood hazard mapping methods. In particular, there may be opportunity to improve flood mapping in the basin considering uncertain future climate conditions.

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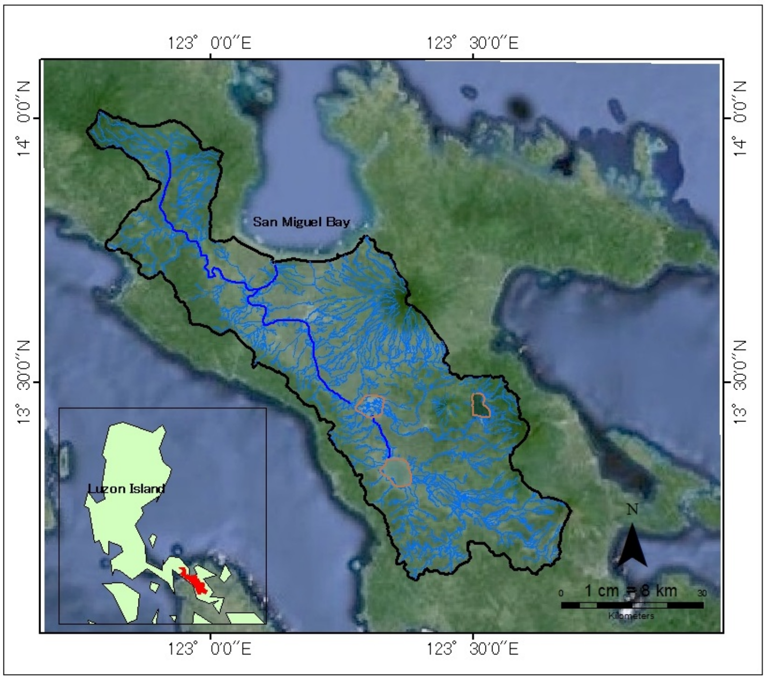

Figure 1: Map of the study area

THEORY AND METHODOLOGY

Geomorphic analysis is recognized as an essential part of our understanding of floodplains, based on the simple principle that the floodplain boundaries of a stream correspond to the envelope curve of its past floods. Hydro-geomorphic method is essential and potentially more effective than one-dimensional hydrologic models in rivers where channel and floodplain morphology is highly variable or when there is limited or inaccurate data of river discharge and rainfall. On the other hand, the use of hydrologic modelling is essential to predict spatially distributed estimates of the hydraulic variables such as flood inundation extent and depth.

The Mines and Geosciences Bureau uses such hydro-geomorphic technique to identify potentially flooded areas in the Bicol River basin. Fluvial geomorphology were characterized by interpreting aerial photographs to come up with a geomorphic map. The interpreted geomorphic units were validated in the field and likewise recorded geomorphic evidence of historic flooding. Depth and extent of prior inundations were also mapped based upon interviews to residents. Finally, flood hazard zones were delineated based upon qualitative categorization of flood frequency (Figure 2).

This study employs Rainfall-Runoff Inundation (RRI) model, a two-dimensional model that is capable of simulating rainfall-runoff and flood inundation simultaneously. Three input parameters were used in RRI modelling, these are the Digital Elevation Model (DEM) to represent the topography, landcover map that was converted to surface roughness and rainfall data to force the model. Two-day maximum rainfall from the record of 27 years were computed first using Rain Thiessen Polygon Method. The Generalized Extreme Value (GEV) probability distribution function was used to calculate the expected values of rainfall from a corresponding return period.

Calibration of the model was done using daily discharge data during November 1987 flood event. On the other hand, validation was made by comparing simulated inundation with extents and depths of inundation records during November 1995 and November 2006 flood events. After concluding that the set of parameter values such as Manning's roughness on river channel and slope, soil depth, effective porosity and infiltration loss are acceptable, simulation for different return periods of rainfall was conducted.

The simulated results of RRI model were then compared with the flood hazard map prepared using hydro-geomorphic method. After evaluating the results by two methods for the different areas in the basin, a composite map was made. The author used his professional judgment and knowledge of the river basin to select which result from both methods for a specific area will be more reliable.

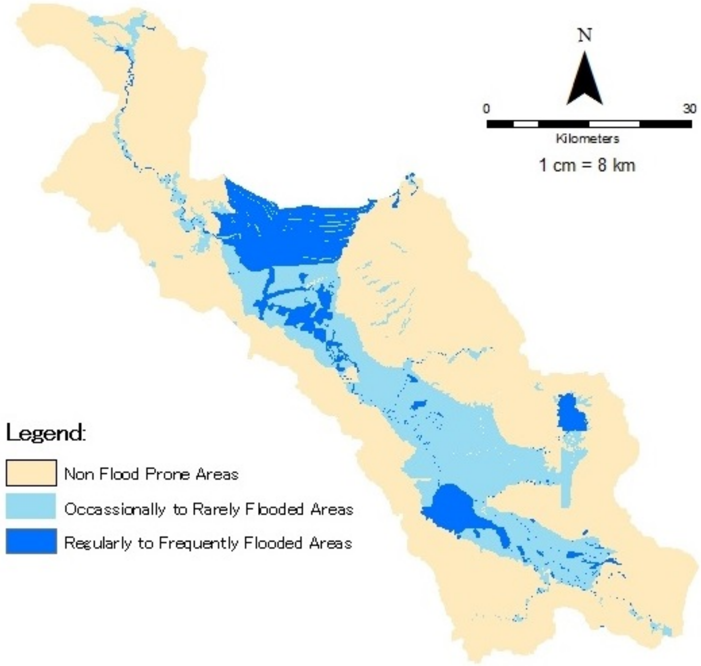

Figure 2: Flood hazard map of Bicol River basin from hydro-geomorphic method.

DATA

The topographical data consisting of DEM, flow accumulation and flow direction with 15 s resolution were downloaded from Hydrological data and maps based on Shuttle Elevation Derivatives at multiple Scales (HydroSHEDS) website. This is based on high-resolution elevation data obtained during a Space Shuttle flight for NASA's Shuttle Radar Topography Mission (SRTM). Watershed boundary of the Bicol River basin was delineated after processing the topographical datasets in ArcGIS 10.1 software.

For the general classification of landcover within the Bicol River basin, the Global Land Cover Characterization (GLCC) map from United States Geological Survey (USGS) with a 1 km resolution was used. Three major classes of landcover in the basin were identified in the GLCC map. Each landcover has its own corresponding parameters to be adjusted for the calibration of the model.

Daily rainfall data from the year 1981-2008 that were used for the frequency analysis as well as for the design rainfall were obtained from Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA). The river discharge data that were used for the calibration of the model were obtained from the Bureau of Research and Standards (BRS) in Manila. Lastly, records of past inundations through field interviews that were used for the validation of the model as well as the existing flood hazard map for the Bicol River basin were provided by the Mines and Geosciences Bureau 5.

RESULTS AND DISCUSSION

The calibrated hydrologic model produced a reasonable representation of discharge at Nabua station although it can be observed that the model underestimates discharge volume. Additionally, the simulated hydrograph indicates that peak discharge at Nabua station occurs on November 25, 1987, whereas the hydrograph peak is observed on November 27, 1987. Nonetheless, the shape of both hydrographs have almost the same pattern except that the simulated hydrograph has more variation between peaks and troughs of the hydrograph signal compared to the observed one which has relatively stable signal (Figure 3).

The validation result for the November 1995 flood event indicates acceptable correlation between the observed depths of inundation with the expected depths from the simulation of the model in the scatter plot diagram and in the RRI simulation (Figure 4). The validation using observations from the November 2006 flood event shows a noticeable underestimation of the simulated inundation depths specifically compared to the observed one in the scatter plot diagram. These points correspond to the southern portion of the basin, just upstream of the lakes that was affected by lahar deposition from Mayon Volcano between July and November 2006. When observation points from lahar-affected channels are removed the relationship between observed and simulated points improves substantially.

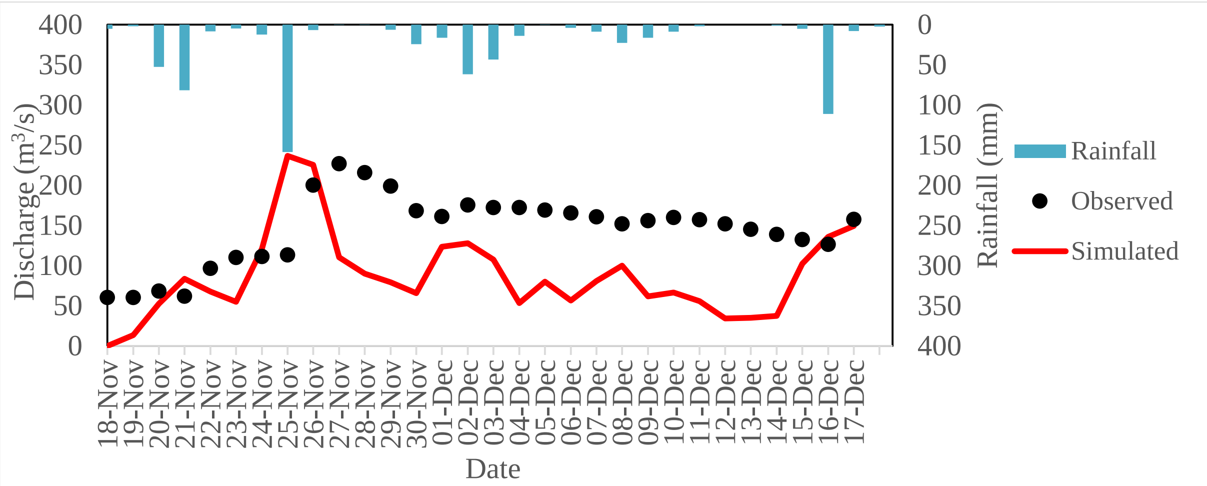

Figure 3: Observed and simulated hydrograph at Nabua station for November 18 to December 17, 1987.

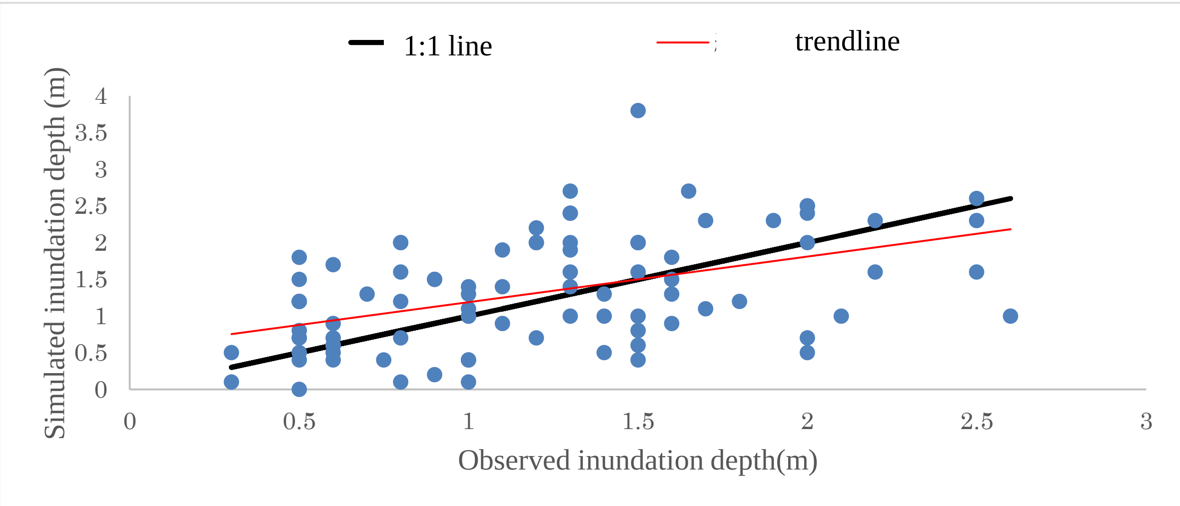

Figure 4: Scatter plot diagram of the observed and expected inundation depths of the 1995 flood event simulation.

The model simulations were carried out for design rainfall of 2, 5, 10, 25, 50 and 100 years return period with 72 hours of simulation time. The simulated return periods of 50 year and 100 year indicate only slight differences in the areas that become flooded. Maximum inundation depth in the central floodplain of the Bicol River basin, where most of the population is concentrated will likely reach about 2.5 m particularly in areas adjacent to Bicol River as the result of RRI simulation for design rainfall with 50 year and 100 year return periods indicate (Figure 5).

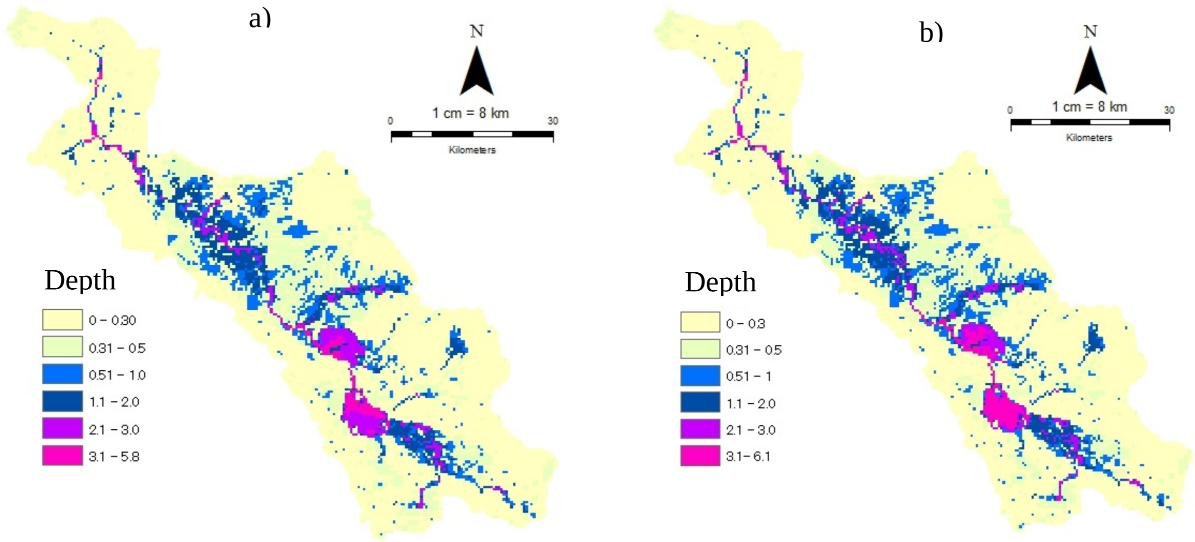

Figure 5: Simulated inundation extent and depth for a) 50 year return period and b) 100 year return period.

The composite map generated from hydro-geomorphic method and hydrologic modelling method with a 100 year return period simulation using RRI model features the strengths of each method. Since RRI model could give specific height of expected inundation given a 100 year return period for example, most of the delineated potentially flooded areas were selected from the latter method. The lower Bicol River basin which is constantly affected by storm surge and daily fluctuations of sea water due to tidal action was likewise represented in the composite map (Figure 6).

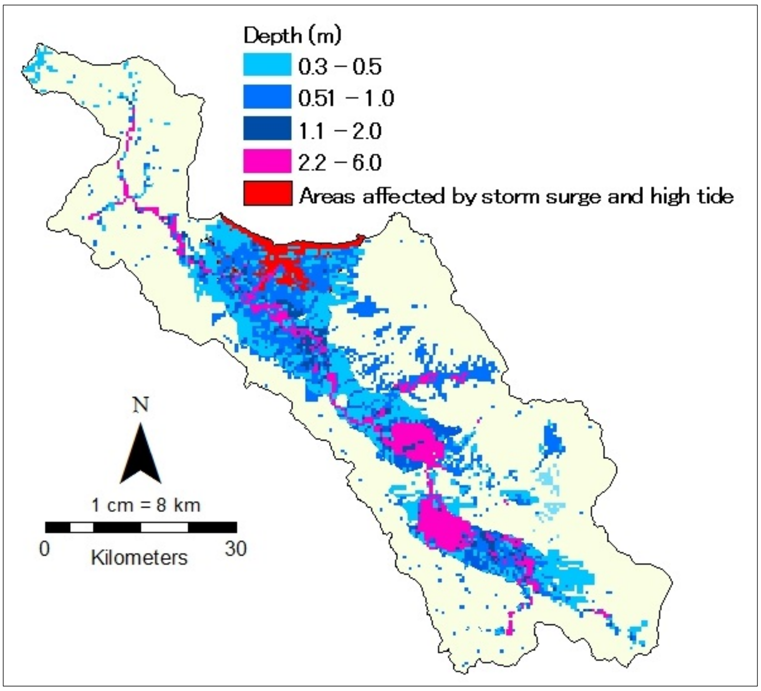

Figure 6: Composite Map from hydro-geomorphic method and hydrologic modelling method with design rainfall of 100 year return period.

RECOMMENDATIONS

Flooding in the basin has been aggravated by rapid sedimentation particularly from the series of eruptions of Mayon Volcano. It is recommended therefore to model flooding in the portion of the basin affected by lahar deposits with the consideration of riverbed changes due to the accumulation of sediments in the channel. Additionally, the complementary use of both the hydro-geomorphic and hydrologic modelling method to delineate flood prone areas should be improved and be used more thoroughly.

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