FLOOD INUNDATION ANALYSIS AND RISK ASSESSMENT OF SITTOUNG RIVER BASIN

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ABSTRACT

Among water-related hazards, flood hazards have the most destructive impacts in Myanmar. Sittoung River Basin (SRB) is one of the flood affected basins in Myanmar. To prevent and reduce socioeconomic losses, the basin needs structural and non-structural countermeasures. Flood inundation maps are needed for flood risk management and the effectiveness of existing countermeasures should be examined for design return period flood events. In this study, Rainfall-Runoff-Inundation (RRI) model was used to develop the estimate flood inundations, to analyze the effectiveness of existing countermeasures, and to propose the new mitigation measures for future development works. The inundation analysis indicated that the existing countermeasures contribute to reduce inundated area, the affected paddy field and crops, and also peak-inundation depth. For the damage assessment, 110,454 hectares of paddy field will be inundated by 50-year return period as without countermeasure and the damage is about US $ 39 million. In case of existing countermeasure can reduce from 110,454 ha to 97112 ha and damage losses will be covered about US $ 5 million. Flood scenario for proposed countermeasure will be protected about 84000 ha of paddy field from flood inundation and about US $ 31 million will be saved from the flood losses. From the effectiveness of countermeasures for the pulse crop, about 211 km^2 (21149 ha) of pulse crop area is affected by 50-year return period flood and total damage is about US $ 6.1 million in vegetative stage and 7.8 million in reproductive stage. US $ 1.9 million in vegetative stage and 3.2 million in reproductive stage will be saved by existing countermeasure as well as estimate US $ 5 million in vegetative stage and 6.6 million in reproductive stage will be saved by proposed countermeasure.

Keywords; Sittoung River Basin (SRB), Flood inundation map, RRI Model, existing countermeasures, Damage assessment

INTRODUCTION

Sittoung River Basin extends over 33597 km^2 located between Latitude 16˚08´and 19˚42´North, Longitude 97˚17´and 97˚34´E (Figure 1). Sittoung River is the 4th largest river in Myanmar and 407 km long from north to south. Not only the basin is located in low lying area but also along the central part of basin is flattening, therefore the basin faces the flood at least one or two times almost every year. On the other hand, because of increasing the sand bank in the river and deforestation of the drainage area, flood inundation take places in the flood plain areas along the river bank as widespread flood. Non-structural counter measures such as flood early warning system, flood inundation analysis and production of flood hazard mapping also carrying out for mitigation of flood damages in SRB.

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Inundation analysis is one of the most effective non-structural measures for flood mitigation system. This study was conducted by using Geographical Information System (GIS) interfaced with a Rainfall-Runoff-Inundation (RRI) model (Sayama, et al.2012) which can analyze rainfall, runoff and inundation simultaneously. Damage assessment of crops is required as the farmers face huge losses every year during flood. Flood inundation analysis will help in estimation the loss that occurred to the paddy agriculture due to flood. Damage assessment of the crops has been done here in order to how many crops area are affected by flooding. In this study, possible damage percentage for various properties are assumed based on the peak inundation depth and duration resulted from RRI model simulation.

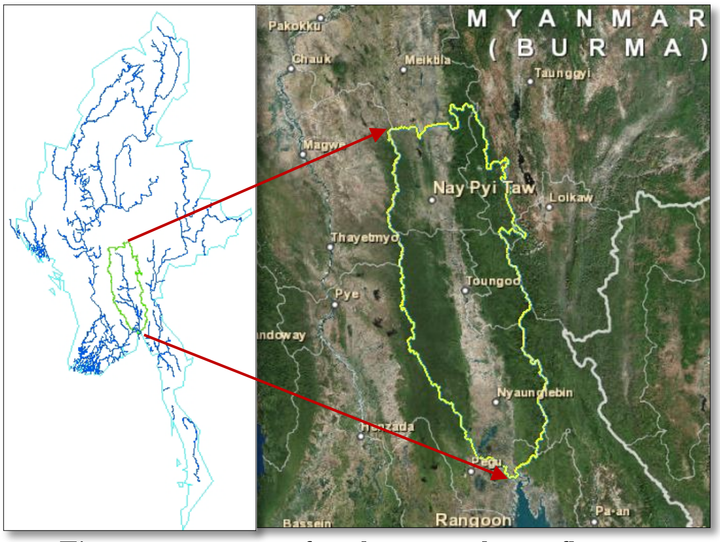


Figure 1 Location of study area and river flow in Myanmar

METHODOLOGY

To analyze the flood inundation of Sittoung River Basin, we used the topography data such as digital elevation model (DEM), flow direction (DIR) and flow accumulation (ACC) and observed rainfall data as input to Rainfall-Runoff-Inundation model (RRI). After parameterization, model run for simulation result. And the output result from the model is flood inundation map and simulation discharge. The model can produce inundation map with depth and duration but also can produce calculated discharge. It is necessary to calibrate the model and investigate the input parameter of the model to get the better output result.

RRI model was calibrated to the flood event in 1997 and 2004 considering the hydrograph at Madauk Station. The hydrograph is prepared with the simulated result of the model and is compared with observed hydrograph at Madauk Staion which is the discharge measuring station. Validation is the task of demonstrating that the model is reasonable representation of the actual system in SRB. In this study, validation of model simulation is carried out the comparison of simulation and observe discharge results that is before dam and after dam construction condition of severe flood events (as 2012 & 2013 flood events).

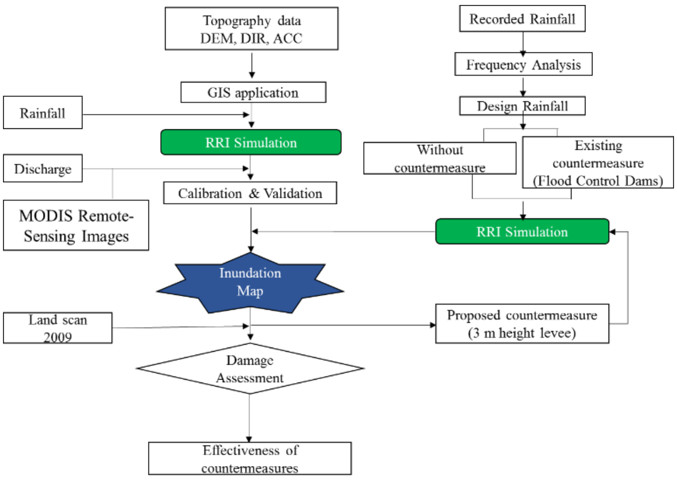


Figure 2 Schematic diagram of study approach

Flood frequency shows relationship between the magnitude of flood and how often the flood occurs. In this study, flood frequency analysis is done by using GEV and Gumbel distribution. The significance of the rainfall design data is necessary to predict the scenario extreme flood. Thiessen Polygon method was used to create the maximum average rainfall for the whole catchment and frequency analysis is conducted to obtain design hyetograph. To calculate the damage losses, global land cover map is downloaded and added to the ArcGIS software to identify the paddy field and crops land area. The inundated crop land and paddy fields are obtained for 50-year return period flood. The total values of paddy field and pulse crop damages are estimated with the help of hypothetical damage percent and total damage is estimated based on 50-year return period design flood.

In this study, moderate resolution imaging spectrometer (MODIS) satellite images (for 2013 flood event) were used to validate the model inundation simulation in Sittoung River Basin (SRB). Schematic diagram of the study approach is shown in Figure 2.

DATA

Daily observed rainfalls data is used to run RRI model and observed discharge is used to calibrate and validate the model. 17- year observe rainfall data from three meteorology and three hydro/meteorology stations are used for frequency analysis by GEV and Gumbel methods to obtain the design rainfall as 50-years return period. And we chose the 10 days maximum rainfall for 50 years return period as design rainfall pattern in this study. The observe discharge data are used to verify the accuracy of output result. Above those data are available from three meteorology stations (Yezin, Pyinma and Phyu) and three hydro/ meteorology stations (Toungoo, Madauk and Shwegyin) which are under the Department of Meteorology and Hydrology (Figure 3). The GIS data such as 30 seconds resolution data of Digital Elevation Model (DEM), flow accumulation (ACC) and flow direction (DIR) were downloaded from hydro SHEDS, USGS website.

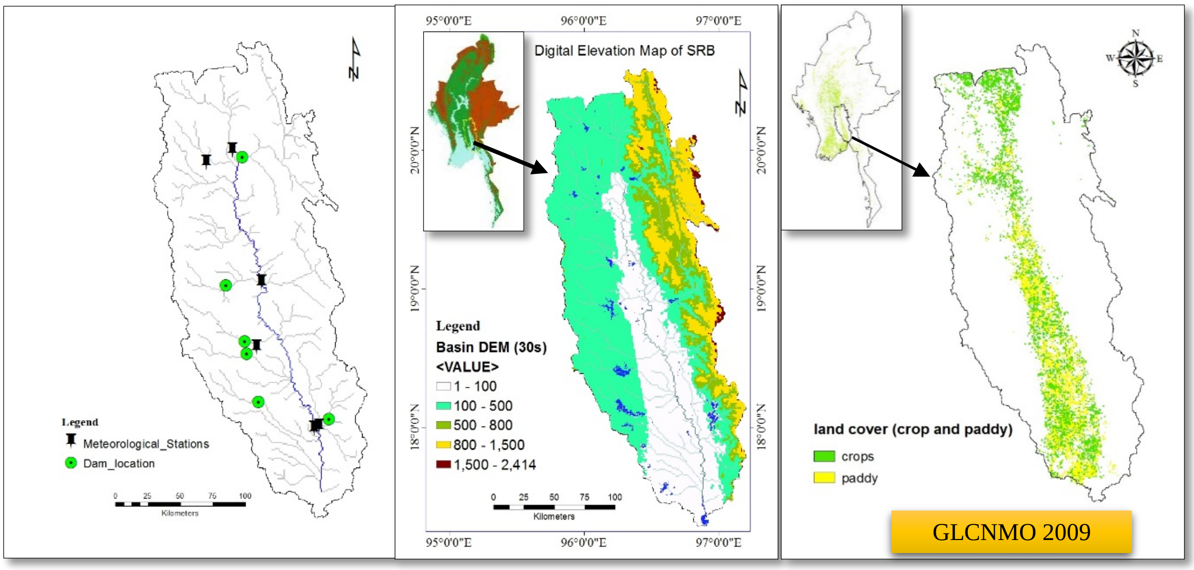


Figure 3 Meteorological stations and dams in SRB (left), Digital Elevation Map of SRB (center) and Land cover map (right)

Land use and land cover data from 2009 was downloaded from global map data download services to identify the paddy field, crop land and others land cover for estimation of agricultural damage assessment. For the existing countermeasures, we used the data from five hydropower dams which are locating in SRB. In case of proposed countermeasure, the construction of 3 m height levee along the left bank of river start from the Toungoo Township to the river outlet point was proposed the new additional countermeasures in the basin.

RESULTS AND DISCUSSION

The RRI model is calibrated and validated by using historical flood events rainfall and water discharge. Model calibration is done by using observed and simulated discharge to get the accuracy output result. Validation is also done by comparing observe discharge and simulated discharge data of 2012 and 2013 flood events. Although the model result hydrograph is a little different with the observe hydrograph in case of 1997 flood event, model simulation result gives satisfactory information for river discharge data on 2012 flood event after hydropower dams constructed. Figure 4 shows the model calibration and validation result of comparative hydrograph for 1997 flood event and 2012 flood event at Madauk Staion in SRB.

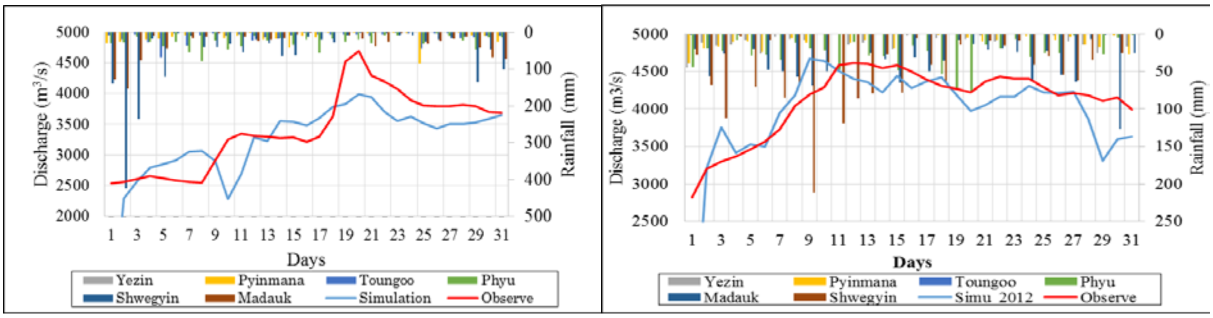


Figure 4 Model calibration result of comparative hydrograph for 1997 flood event (left) and validation result for 2012 flood event (right) at Madauk Station in SRB

Historical flood inundation maps are developed and these maps show that downstream area is the most flooded areas and peak inundation depth can reach above 4 m. The effectiveness of existing counter countermeasures in terms of inundation depth and duration against 50-year return period flood events are compared in Figure 5. According to the inundation analysis, the existing countermeasures can reduce the flooding area about 19% and proposed countermeasure can reduce 75% from the without countermeasures (50-year return period flood).

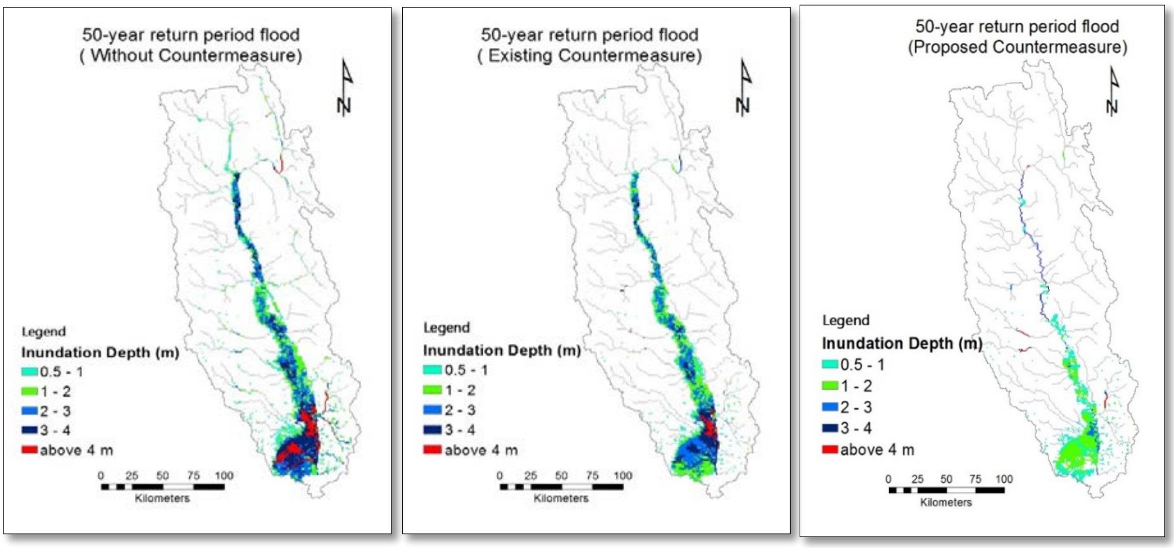


Figure 5 Flood inundation maps of SRB by without countermeasure (left), with existing countermeasures (center) and proposed countermeasure (right) against 50-year return period

To validate the flood inundation with model simulation, multi-temporal MODIS images and high resolution images of the 2013 severe flood were selected for inundation mapping with flood monitoring This study verified the flood extent area and flood inundation mapping with MODIS remote sensing images by modified land surface water index (MLSWI). Permanent water bodies and floodwaters were separated based on a simple threshold from MLSWI variation. Flood inundation area in SRB due to 2013 flood event were compared with two method as RRI Model simulation and MODIS Remote Sensing Images (Figure 6).

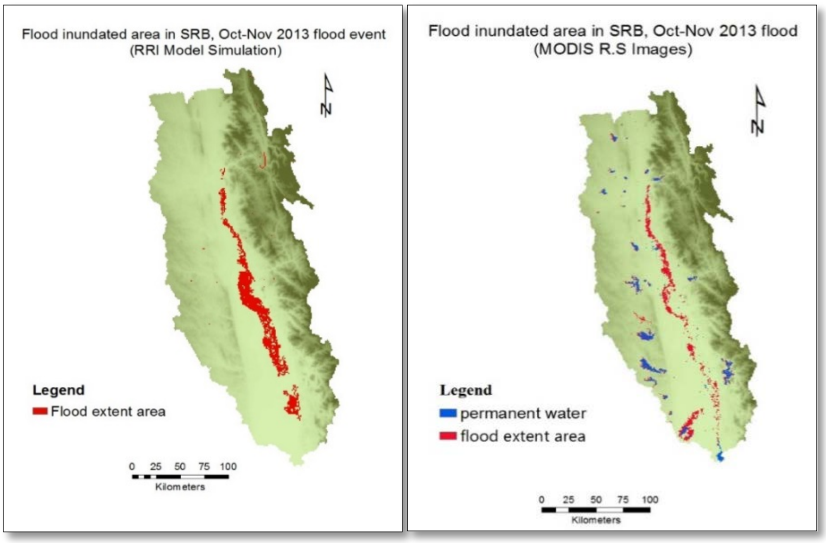
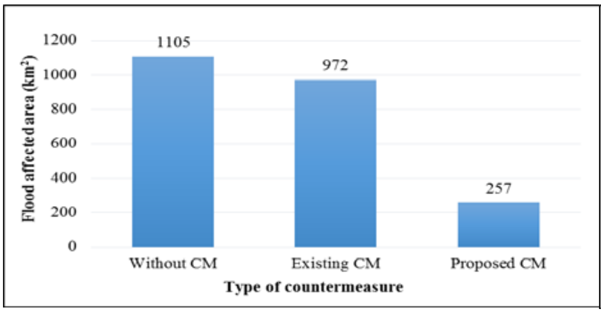


Figure 6 Flood inundation maps in SRB for 2013 flood event by RRI model simulation (left) and MODIS remote sensing images (right)

To access the damage assessment, the paddy field and pulse crop damage per hectare can be calculated by multiplying the damage percent to production cost for hectare. Damage percent varies according to the growth stage, flood depth and duration. Following Figures 8,9,10 & 11 show the flood affected area and damage value of paddy and pulse crop (in SRB) for 50-years return period flood with different type of countermeasures.



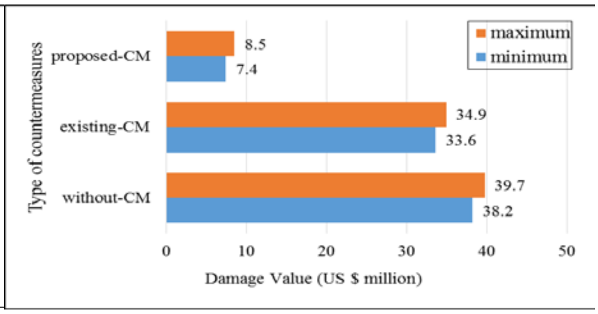
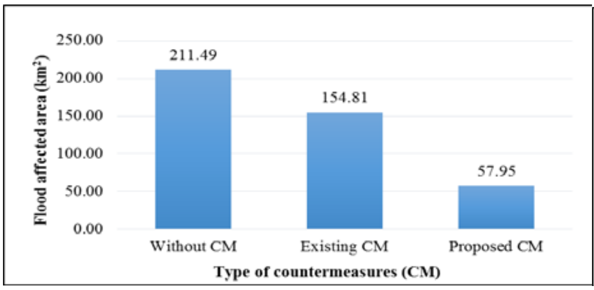


Figure 7 Flood affected area of paddy field (left) and Figure 8 Expected damage value of paddy field (right) in SRB by different types of countermeasure against 50-year return period flood



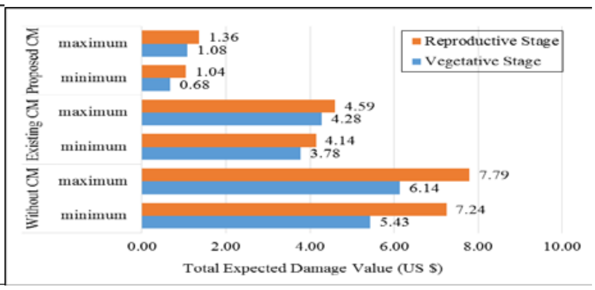


Figure 9 Flood affected area of pulse crop (left) and Figure 10 Expected damage value of pulse crop (right) in SRB by different types of countermeasure against 50-year return period flood

As per above figures, From the damage assessment of paddy field and pulse crop for 50-year return period flood event, it is observed that the flood affected area between paddy field and pulse crop is five times different as those of damage value however flood duration and inundation depth are different but also damage percentage which we used to calculate the damage losses are different.

CONCLUSIONS

In this study Rainfall-Runoff-Inundation (RRI) model is used for flood inundation analysis, flood inundation mapping and damage assessment. The main objective is to analyze the flood inundation pattern of the area for actual flood and predicted flood as design flood for 50-year return period. To obtain the specific result for this objective, different flood characteristic like flood extent, depth and duration were obtained for design flood from the RRI Model simulation. According to the RRI model simulation result, the total flood affected area in SRB is above 4200 km^2 by 50-year return period flood (without countermeasure). After the comparison between without countermeasure (design rainfall) and existing countermeasure, it is observed that 816 km^2 as 19% area can protect from flood inundation. However it is not enough to optimum condition and we considered to add the new countermeasures for the flood mitigation measures. After the model simulation for proposed countermeasure, the result is significantly different from without countermeasure. Flood inundation area will be reduced about 3000 km^2 as 75% area by proposed countermeasure from without existing countermeasure as designed rainfall extreme flood. The damage curve of paddy field and household are developed and it can be supported to estimate the total damage by flooding as damage assessment is necessary for the effective disaster management. It is observed that existing countermeasure will be saved about US $ 5 million and about US $ 31 million will be saved from the proposed countermeasure from damage value of paddy field. From the effectiveness of countermeasures for the pulse crop, about 211 km^2 (21149 ha) of pulse crop area is affected by 50-year return period flood and total damage is about US $ 6.1 million in vegetative stage and 7.8 million in reproductive stage. US $ 1.9 million in vegetative stage and 3.2 million in reproductive stage will be saved by existing countermeasure as well as estimate US $ 5 million in vegetative stage and 6.6 million in reproductive stage will be saved by proposed countermeasure.

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