Flood inundation damage estimation model for the Bago basin, Myanmar

Seemanta Sharma BHAGABATI and Akiyuki KAWASAKI

Abstract:

Occurrence of floods is a natural phenomenon all over the world and with the increase in population and human activity in the flood plains, flood damages represent an increasing hazard in many countries. Myanmar is vulnerable to floods multiple times a year. These events cause substantial losses, both structural and socio-economical. In this research we are developing a hydrological model WEB-DHM (Water and Energy Budget-based Distributed Hydrological Model) coupled with RRI (Rainfall-Runoff- Inundation model).By developing a relationship between inundation depth and flood damage, using economical indices, the flood damage loss reduction will be estimated.

Keywords: Hydrological modelling, RRI, Flood, Inundation, Bago, Myanmar

1. Introduction

Flood protection has always been among the most pressing hydraulic engineering tasks and therefore hydrological models for obtaining design floods have a long tradition. Although floods happen almost annually in monsoon-affected countries, many countries still lack flood modelling and subsequent hazard maps to prevent or mitigate such damages.

An estimate of losses from future floods is essential to preparing for a disaster and facilitating good decision making at the local, regional, state, and national levels of government. Hydrological models helps us understand such complex natural systems by providing detailed information about the region. They also help us to forecast the effects of different water resource management scenarios (eg. Cartwright et al., 2006, and Li et al., 2010).

Since becoming a civilian democracy in 2011, Myanmar has undergone large scale economic growth, which leads to growing disaster risk due to poor existing infrastructures. This paper presents a distributed hydrological model applied to the Bago river basin of Myanmar. The output of the model is used for flood damage estimation in the basin.

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2. Study Area

The study area is the Bago river basin which is a flood prone area of Myanmar. The Bago River (335 km) originates from the Bago Yoma mountainous region and it flows into the Yangon River finally draining to the Gulf of Mottama. It has a catchment area of 4,893 km^2 and is one of the most populous regions of the country (Ye Htut et al., 2014). The average annual total rainfall at the Bago station is around 3,000 mm. Only two meteorological stations (Bago and Zaung Tu) are located in the basin. As of 2010, there were 5 meteorological stations (Bago, Kabaraye, Shwegyin, Tharawady and Zaung Tu) in and around the Bago river basin along with a newly installed Automatic Weather Station (AWS) at Zhaungty weir. As seen from the fig. 1, the lower basin is relatively flat compared to the mid and upper basin.

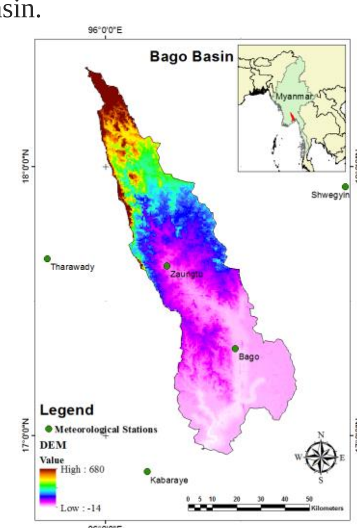

Fig.1: The Bago river basin with the Meteorological stations.

3. Water and Energy Budget based Distributed Hydrological Model (WEB-DHM)

The Water and Energy Budget-based Distributed Hydrological Model (WEB-DHM) (Wang et al., 2009a,b), was developed by coupling a simple biosphere scheme (SiB2) (Sellers et al., 1986) with a geomorphology-based hydrological model (Yang, 1998) to describe water, energy and CO_2 fluxes at a basin scale. It calculates evapotranspiration based on both water and energy balances in each model grid and therefore has a more solid physical foundation relative to the traditional hydrological models. The overall structure of WEB-DHM is shown in fig. 2. The fig. 2 (a) shows the sub-basin; (b) shows the sub-division from sub-basin to flow intervals; (c) shows the discretization from a model grid to a number of geometrically symmetrical hillslopes; and (d) shows the detailed process descriptions of the water moisture transfer from atmosphere to river, including downward solar radiation, downward long wave radiation, sensible heat flux and the latent heat of vaporization. A better description of this model can be found in Wang et al. (2009b).

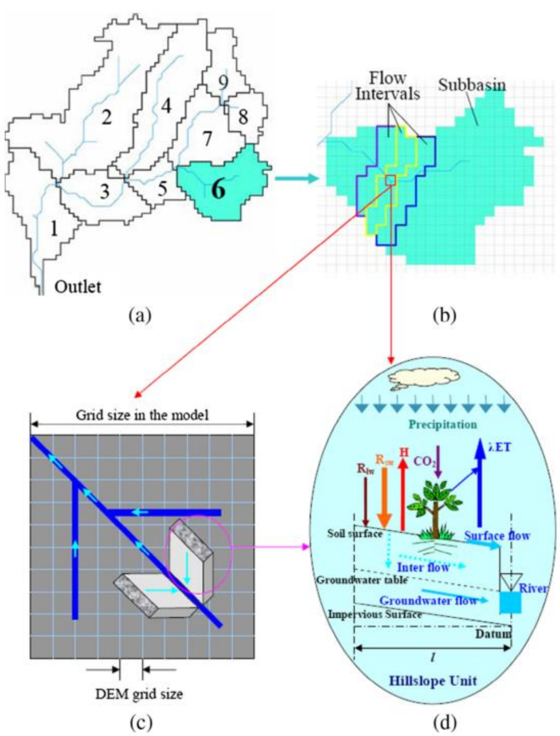

Fig. 2: Overall structure of WEB-DHM model

4. Rainfall-Runoff-Inundation (RRI)

Rainfall-Runoff-Inundation (RRI) model is a two-dimensional model capable of simulating rainfall-runoff and flood inundation simultaneously (Sayama et al., 2012). The model deals with slopes and river channels separately. It simulates flows on land and in river and their interactions at a river basin scale. It simulates lateral subsurface flow in mountainous areas and infiltration in flat areas. The flow interaction between the river channel and slope is estimated based on different overflowing formulae, depending on water-level and levee-height conditions.

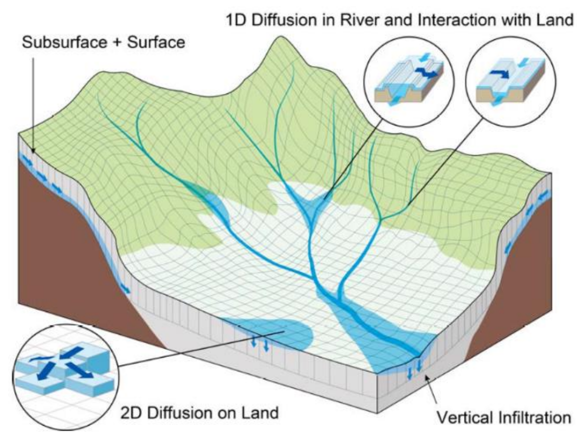

Fig. 3: Schematic diagram of Rainfall-Runoff-Inundation (RRI) model

5 Data sets used

5.1 Meteorological data

WEB-DHM uses the following as input data: precipitation, humidity, wind speed, air pressure, air temperature and downward solar radiation (short wave radiation, long wave radiation). Precipitation data were obtained from the Department of Meteorology and Hydrology (DMH), Myanmar. Due to low number of observation stations, GSMaP data was used to run the model. However it was found that GSMaP overestimates rainfall leading to much higher discharge values. Hence observed station data was used. The remaining meteorological data were obtained from the Japanese 55-year Reanalysis (JRA-55) (http://jra.kishou.go.jp/JRA-55/index_en.html). The JRA-55 data is available globally.

5.2 DEM and remote sensing data

For digital elevation data, the 3-sec Conditioned DEM data product of HydroSHEDS (**Hydro**logical data and maps based on **SH**uttle **E**levation **D**erivatives at multiple **S**cales) were used. HydroSHEDS is a mapping product that provides hydrographic information for regional and global-scale applications in a consistent format. It is based on high-resolution elevation data obtained during a Space Shuttle flight for NASA's Shuttle Radar Topography Mission (SRTM) (http://hydrosheds.cr.usgs.gov/index.php).

Land-use data were obtained from the USGS (http://edc2.usgs.gov/glcc/glcc.php). The land use types are reclassified as per the SiB2 land-use types (Sellers et al., 1996). For soil data, the global data product (2003) of Food and Agriculture Association (FAO) were used.

6. Flood damage estimation model

This methodology is based on GIS and statistical data which is an integrated approach combining a physically based hydrologic model for flood inundation simulation and a loss estimation model.

Firstly damage are categorized as urban damage, rural damage and infrastructure damage. Then using geostatistical analysis using historical data a priority map is developed which gives us the damage estimation values for each land cover feature. Using it, we calculate the flood damage in each grids for each type of damage. Finally we estimate the distributed flood damage for the entire basin.

Figure 1 shows a schematic diagram of the integrated model.

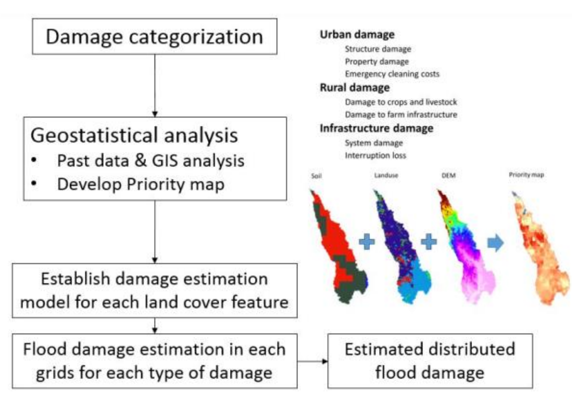

Fig. 4: Flowchart of the damage estimation model

7. Results and discussions

The WED-DHM model was run for the year 2010. Figure 4 shows the model output. The horizontal axis shows the time period. The vertical axis shows the Discharge at the Zaung Tu station; the observed discharge in blue and model discharge in orange. The inverted vertical axis shows the gridded rainfall of the basin, upstream if the Zaung Tu station.

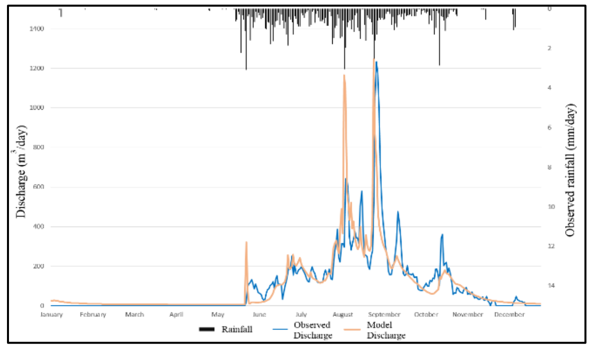

Fig. 4: WEB-DHM Model discharge for the year 2010.

Figure 5, shows the model output of the RRI model. The model was able to closely depict the inundation in the lower basin.

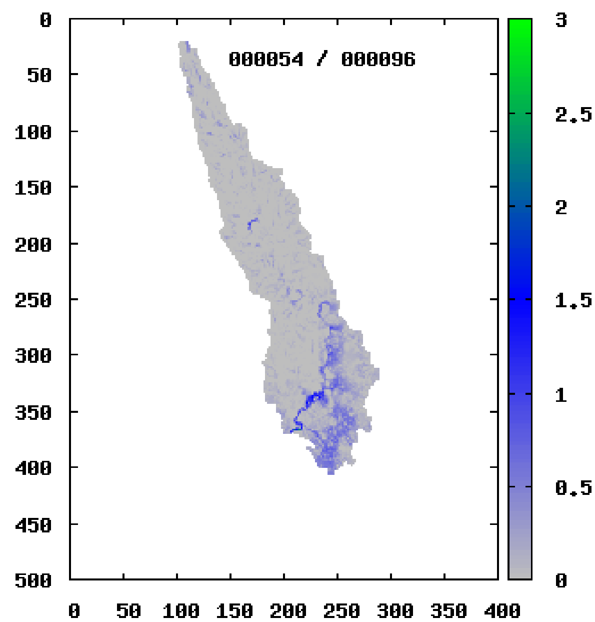

Fig. 5: Output of RRI model

5.1 Further improvement of the model

Initially WEB-DHM has been developed for hourly data. However, recently AWS data (data recorded every 10 mins) has become available. As the next step of this research, the new input data will be used and the model will be calibrated accordingly. It is expected that the model will provide better results.

New rating curves are now available, hence a better discharge measurement is now possible. With the new discharge values, better inundation mapping should be achieved

6. Conclusion

A distributed hydrological model (WEB-DHM) has been developed for the Bago river basin in Myanmar. The model was able to show good resemblance with the observed discharge Using this discharge as an input to the RRI model, flood inundation has been successfully mapped. Relationships between inundation depth and flood damage has been established.

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