RAINFALL-RUN OFF SIMULATION AND THE ASSOCIATED EXTENT OF FLOODING IN THE SOUTH OF BANDUNG, INDONESIA

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Abstract

Flood in Bandung Regency become more severe in the last decade. In the early 2016, recent flood was larger than years before. It is thought that land cover change seems to be the main factor of the flood instead of climate change. This research aims at investigating the correlation between river flow discharge -which are controlled by rainfall and land cover- and flooding extents. Here, flow discharge is computed by utilizing STREAM (Spatial Tools for River Basins and Environment and Analysis of Management Options). Land cover, rainfall, and air temperature are the main input for the model. The computation domain covers the entire Upper Citarum Catchment. Evaluation of discharge is focused in Dayeuhkolot, as inundated areas recorded in 1994, 1997, 2001, and 2005. We find that there is meaningful correlation between flow discharge computed by our model and inundation area. The result of this study needs to be explored for further projected flood event as a result of climate and land cover change. In order to construct an appropriate planning and protection measures, an associated flooding area from the magnitude of flow discharge shall be taken into consideration. Flow discharge and inundation area can be projected by extreme value analysis.

Keywords: hydrological model, discharge, inundation

INTRODUCTION

Land Use and Land Cover Change (LULC) affect the processes of surface run off and peak discharge in a catchment area. These could contribute to the increased of floods intensity (Jothityangkoon et al., 2013; Prasena and Shrestha, 2013). The simplified generic relation between rainfall and output, can be described as:

$$RO = P - AET \pm \Delta S \quad (1)$$

where RO = run off, P = precipitation, AET = evapotranspiration, and ΔS = water storage in watershed (Charlton et al., 2006). In equation (1), AET and ΔS are influenced by land cover condition in a watershed and sensitive to its change. Hence, expansion of urban area and deforestation may increase run off in certain area (Liu et al., 2005). Precipitation also becomes a factor of increasing of run off, so that it has contributing role into flooding.

Based on available recorded data from Water Resources Management Centre of West Java (2007) major flood occurred in this area since 1931 and happened again in 1986 which inundated approximately 7,450 ha and resulted in loses as 10 Billion IDR of material.These recent years, big flooding has been just occurred in March 2016 (Figure 1). The inundation area is mainly located in the built up area, such as residential and industry. It causes damage and makes loss of life. Hence, it is useful to predict the extension of flood in this area through this research that investigate the correlation between run off and flood extension.

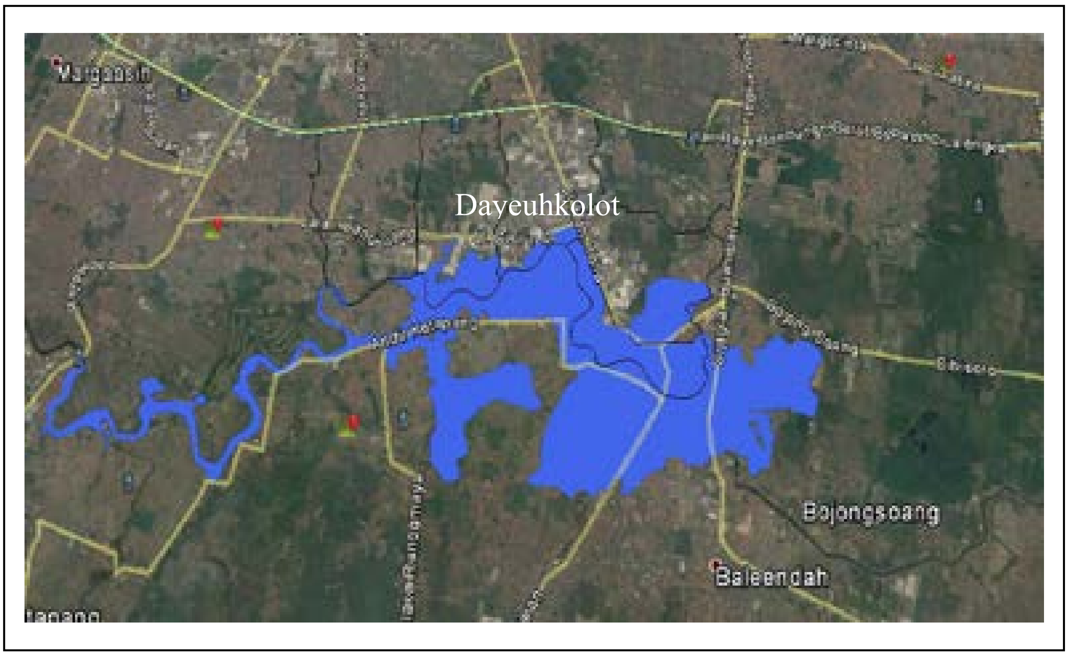

Figure 1. Inundation area (blue) in Dayeuhkolot (Weather and Climate Prediction Laboratory - ITB, 2016)

This research aims at associating discharge computation in the Upper Citarum Basin with the extent of flooded area in the South of Bandung, Indonesia. This area is a part of the Bandung Metropolitan Area (BMA) that has an important role in development as one of the national development priority area. Due to the frequent flood in Southern Bandung with Dayeuhkolot being the centre of attention, the economic activities have been often disrupted and their functions declined. As far as Dayeuhkolot area as concern, we feel the need of associating flow discharge and the flooding area. The occurrence is typical and demands specific investigation.

MATERIALS AND METHODS

We use STREAM (Spatial Tools for River Basins and Environment and Analysis of Management Options) (Aerts et al., 1999) rainfall-run off model that consider land cover, precipitation, and temperature as the primary input.STREAM calculates the water balance per grid cell using the Thorthwaite equation for potential evapotranspiration (Thorthwaite, 1948) and the Thorthwaite and Mather equations for actual evapotranspiration (Thorthwaite and Mather, 1957) (Figure 2). Storage of water in a grid cell is estimated according to the difference between evapotranspiration and precipitation. Finally, discharge per time step is calculated according to excess of water in each grid cell and baseflow from groundwater storage.

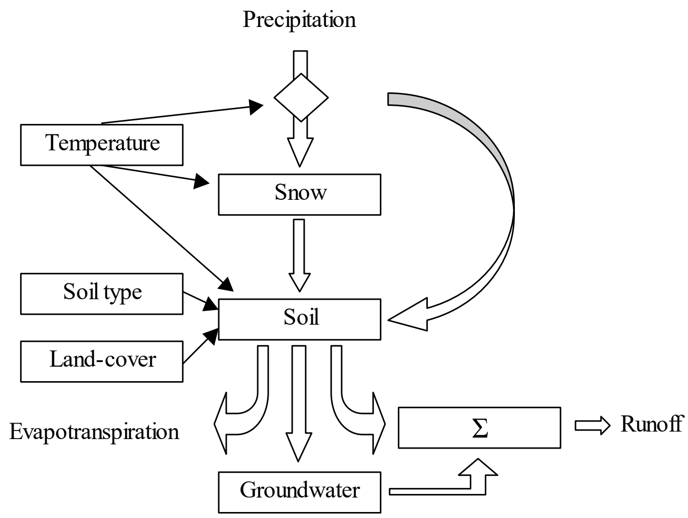

Figure 2. Water balance component of the STREAM model (Aerts et al., 1999)

Calibration and validation of the STREAM model is adapted from Poerbandono et al. (2009). The modelling area is in Upper Citarum (Figure3) that consists of five sub-watersheds. Climate data is obtained from Climate Research Unit (CRU) from East Anglia University that consist of rainfall and temperature data in monthly magnitude. It is time series data version 3.00 (CRU TS 3.00). Here, we use data from January 1976 to June 2006. For land cover map, we used the map from Geospatial Information Agency (BIG) with scale 1:50.000. Selection of land cover map is based on available record of flooding extent in 1994, 1997, 2001, and 2005 (Table 1).

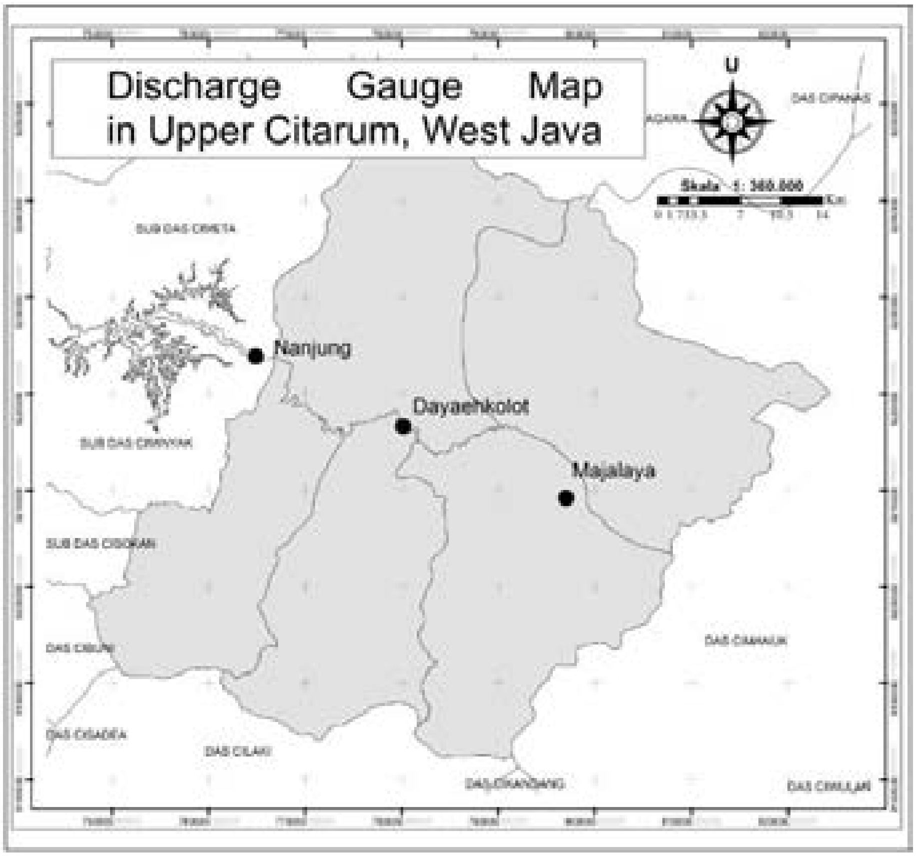

Figure 3. Upper Citarum that located in Southern Bandung (Source: Citarum-Ciliwung Watershed Management Agency)

Table 1. Flood event, discharge and inundation area in Southern Bandung(Water Resources Management Centre of West Java, 2007)

Flood Events	**Discharge Modelling (m^3/s)**	**Inundation Area (ha)**	**Watershed**	**Inundation Location (Sub District)**
1994	178.66	4171	Citarum, Citarik, Cikeruh	Dayeuhkolot, Bojongsoang, Baleendah, Majalaya, Ciparay, Katapang, Rancasari
1997	134.44	315	Citarum, Cisangkuy	Dayeuhkolot, Majalaya, Ciparay, Paseh, Pameungpeuk
2001	96.39	425	Citarum, Citarik, Cikeruh	Dayeuhkolot, Baleendah, Bojongsoang, Rancaekek, Solokan Jeruk
Apr-05	159.52	1000	Citarum	Dayeuhkolot, Baleendah, Bojongsoang,

RESULTS AND DISCUSSION

Discharges were computed from 1976 to 2006 in monthly average. From these results, the trends for each season (dry and wet seasons) were calculated (Figure 4 and 5). We assumed that flood events occur in wet season. It was found that the trend of computed discharge in wet season is higher than the trend in dry season.

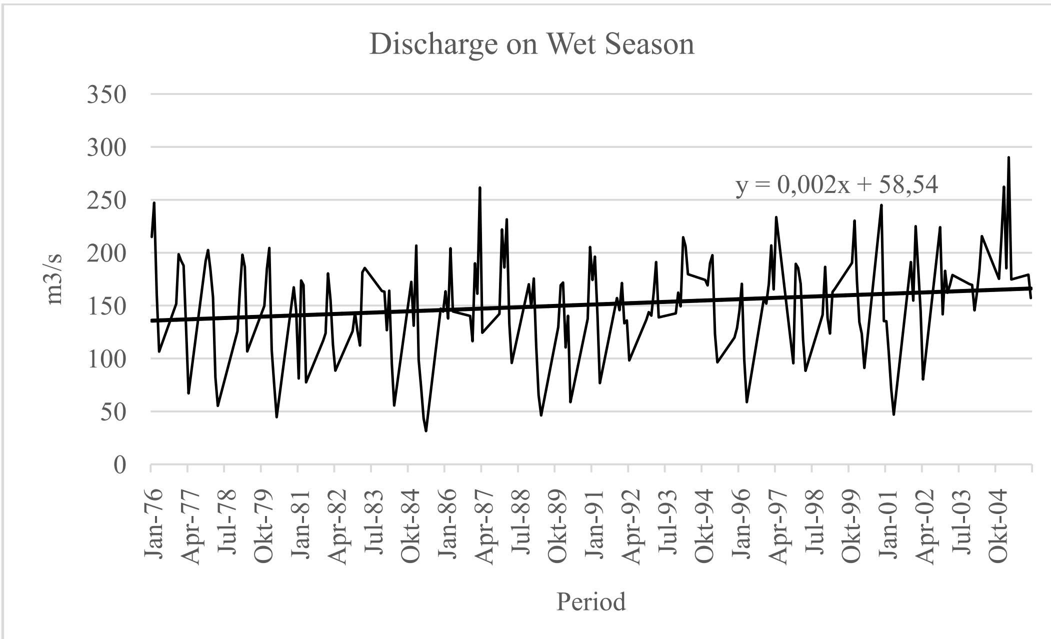

Figure 4. Time series of computed discharges in Dayeuhkolot station

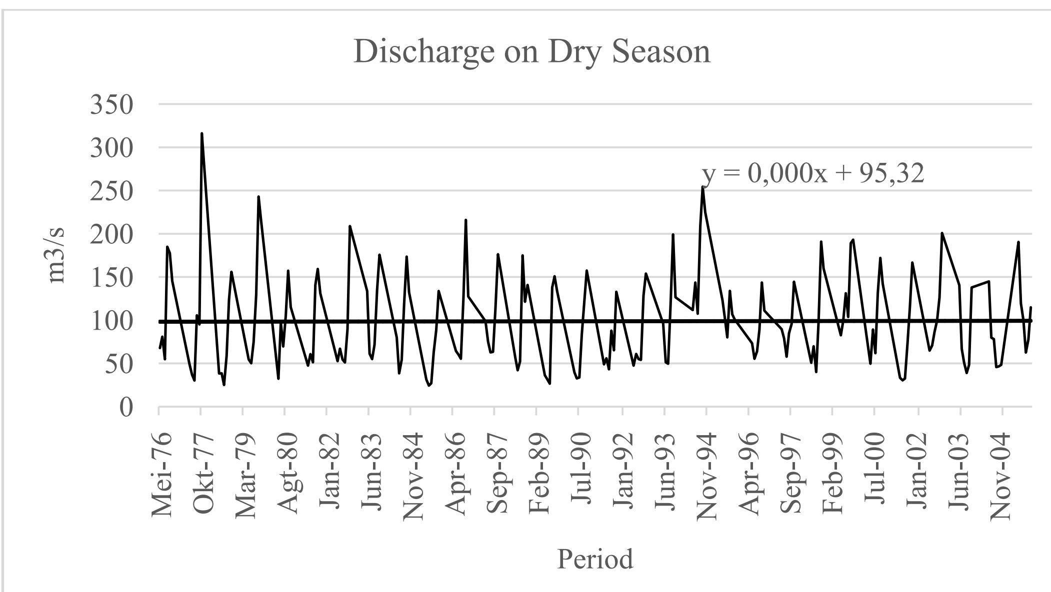

Figure 5. Time series of computed discharges in Dayeuhkolot station

Then, we used the selected computed discharges for representative recorded flood events. To explore the correlation between computed discharge and inundation area during the flood event, linear regression was applied (Figure6).Big floods occurred in 1994 and 2005 are respectively associated with discharge of 178.66 m^3/s and 159.52 m^3/s. However, the flooding event in 1997, i.e. 134.44 m^3/s on model, is associated with far smaller extent of inundation, i.e. 315 ha. This exploration suggests a factor of 0.57 to empirically associate discharge and flooding. It means that 57.52% of the variability in inundation is accounted for by variation in computed discharge.

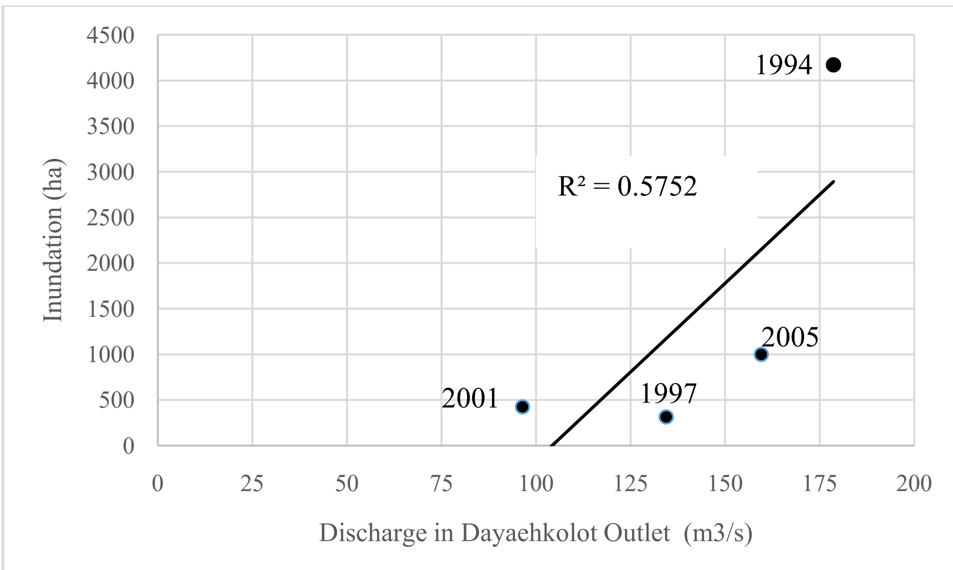

Figure6. Computed discharge from STREAM simulation and record of extent of inundation in Dayeuhkolot in 1994, 1997, 2001, and 2005

CONCLUSION AND RECOMMENDATION

This study indicates empirical approximation of flood happened for a given computed discharge in the investigation domain. STREAM was used to simulate the river discharge. Linear regression was applied to explore the correlation of flood inundation and computed discharges. We found that 57% of the variability in inundation is accounted for by the least squares linear regression on computed discharges. The result of this study needs to be explored for further projected flood event as a result of future projection of climate and land cover change. In order to construct an appropriate planning and protection measures, an associated flooding area from the magnitude of flow discharge shall be taken into consideration.With minor exception that might require further elaboration, our simulation can be used to correlate historical floods with the simulated discharges.

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