ACCURACY OF MAPWINDOW AND SWAT WATERSHED MODEL IN SIMULATING HYDROLOGIC CHARACTERISTICS OF CISADANE WATERSHED, WEST JAVA INDONESIA

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ABSTRACT

Pressure of population growth has induced land use change around Cisadane Watershed. Land use change in this watershed had caused negative effects on the hydrological characteristics of the watershed, To be able to predict impact of land use on hydrologic characteristics of the watershed in the future, a tool is required. Combination of Map Window and SWAT Watershed Model were tested for this purpose. The research objectives were 1) to examine the accuracy of MapWindow and SWAT in delineating the sub-watershed boundary compared to existing maps, and 2) to determine accuracy of MapWindow and SWAT in simulating river discharge based on a particular land use in Cisadane Watershed.

Research was carried out in two steps, these are geographic data processing using MapWindow-SWAT and determination of model prediction accuracy. Level of prediction accuracy was determined using Nash-Sutcliffe coefficient. Boundaries of sub-watersheds were delineated using DEM map from SRTM (*Shuttle Radar Topography Missions*) Z_58_14. tiff with 90x90 m resolution. Land use map was derived using Landsat TM image path 122 row 064 and row 065.

Sub-watershed boundaries that were delineated using MapWindow and SWAT showed 90 % accuracy with existing maps with some deviations in the lower part of the watershed where topography was quite flat. Higher resolution of DEM map would give better result. Combination of MapWindow and SWAT were able to predict river discharge giving Nash-Sutcliffe coefficient of 0.7. This coefficient showed a good performance of MapWindow and SWAT in predicting river discharge in Cisadane Watershed. With this performance, combination of MapWindow and SWAT can be used to predict future impact of land use change on hydrologic characteristics in Cisadane Watersheds.

Keywords: *MapWindow and SWAT, Watershed, River Discharge, hydrologic characteristics*

INTRODUCTION

Watershed function as regulator for water resources are of high importance. Many strategic water users at downstream such as irrigation, domestic water use depend on the sustainability of such water resources.

Number of degraded watershed in Indonesia is steadily increasing. In 2008, some 61 out of 450 watersheds in Indonesia are severely degraded. In Java Island itself 16 out of 144 watersheds are severely degraqded.

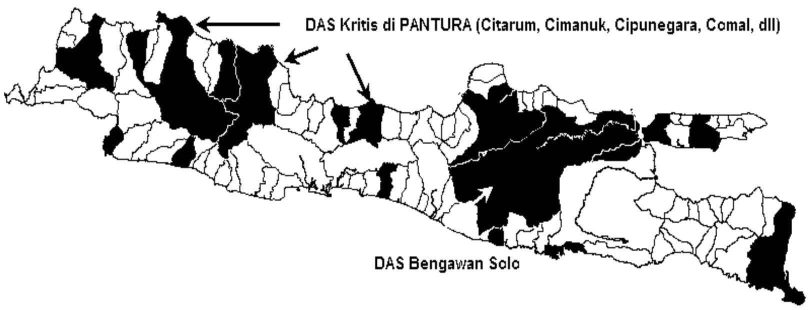

Figure 1. Watersheds in Java Island-Indonesia (Some are severely degraded)

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The degradation is caused by uncontrolled human intervention on watershed ecology. To be able to select best management practice to rehabilitate that watershed a simulation model is required. Interaction among physical component of a watershed is very complex; therefore a comprehensive and robust model is required to predict impact of human intervention in degraded watershed. Besides, a capability to process and to analyze huge spatial data such as satellite imagery is additional requirement for watershed modeling.

Well-known models that are commonly applied at watershed scale are Hydrologic Engineering Centre Hydrologic Modeling System (HEC, 2000), ANSWERS and Soil and Water Assessment Tool (SWAT, Arnold et al, 1998), amongst others. These models have the capability to spatially incorporate physical data and produce discharge hydrograph and water yield volume for a watershed scale. Some of these models can also be interfaced with Geo Information System for input data processing.

In this research, MWSWAT model was selected for the following reason: a) Its coupling with remote sensing data, and b) Its ability to identify part of sub-basin that have the most severe problem needed to be addressed. MWSWAT is a SWAT model interfaced with MapWindow GIS. MapWindow GIS is an open source software.

Within the SWAT conceptual framework, the representation of the watershed hydrology is divided in to two parts : a) The land phase of the hydrological cycle, and b) the routing of runoff through the river network. For the land phase, the watershed is divided into sub-watersheds, each one of which is composed of one or several hydrologic response units (HRUs), which are areas of relatively homogenous land use /land cover and soil types. The characteristics of the HRUs define the hydrologic response of sub-watershed. For a given time step, the contribution to the discharge at each sub-watershed outlet point is controlled by the HRU water balance calculation (land phase). The river network then connects the different sub-watershed outlets, and ten routing phases determines movement of water through this network towards internal control points, and finally towards the basin outlet (Neitsch et al., 2005).

MATERIALS AND METHODS

Description of study area

Cisadane watershed is situated in West Java, between 6° 0' 59'' – 6° 47'02''South Latitude and 106°20'50'' - 106°28'20'' East Longitude and flowing to the north of Java Island. It encompasses a total area of 156,043 ha. The length of the main river is 122 km. It has elongated shape with compact factor of 0.33. Time to peak is 18 hours.

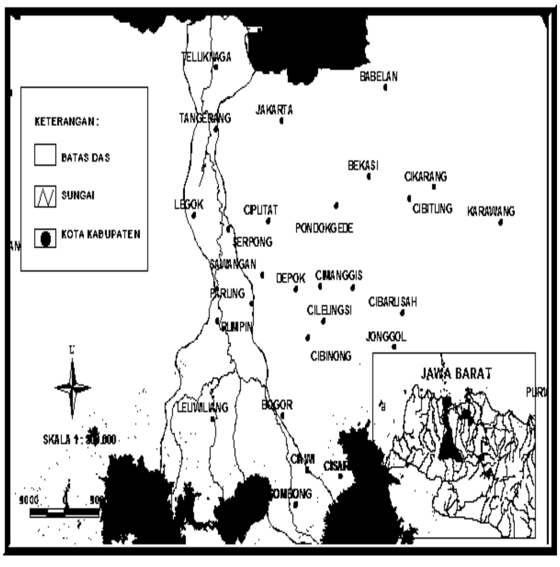

Figure 2. Research Location

The topography is flat to hilly. Ultisols is the dominant type of soil in Cisadane watershed. Average annual rainfall ranges from 1,731 to 5,098 mm. Dominant land use in the area: forest 21 %, dry land farming 47, and settlement 17%.

Preparation of model inputs

Spatial data required by SWAT model includes digital elevation model (DEM), land use map and soil map. In this research DEM was prepared using Shuttle Radar Topography Missi on (SRTM) from US Geological Survey for SRTM Z_58_14.tiff dengan resolusi spasial 90x90. The SRTM data processing was carried out using MapWindow. First, the SRTM was clipped using research location map and then the result was exported to ASCII grid and finally converted to UTM projection.

Model application and testing

MWSWAT version 1.4 was used for the watershed modeling. Modeling was carried out using land use and climate data of year 2005. Model running started by delineating watershed and sub-watershed boundaries and then followed by formation of river network. The delineation process can be controlled by providing masking map of the watershed, river network map and watershed outlet

Output of the model consisted of river hydrograph and water yield. Model

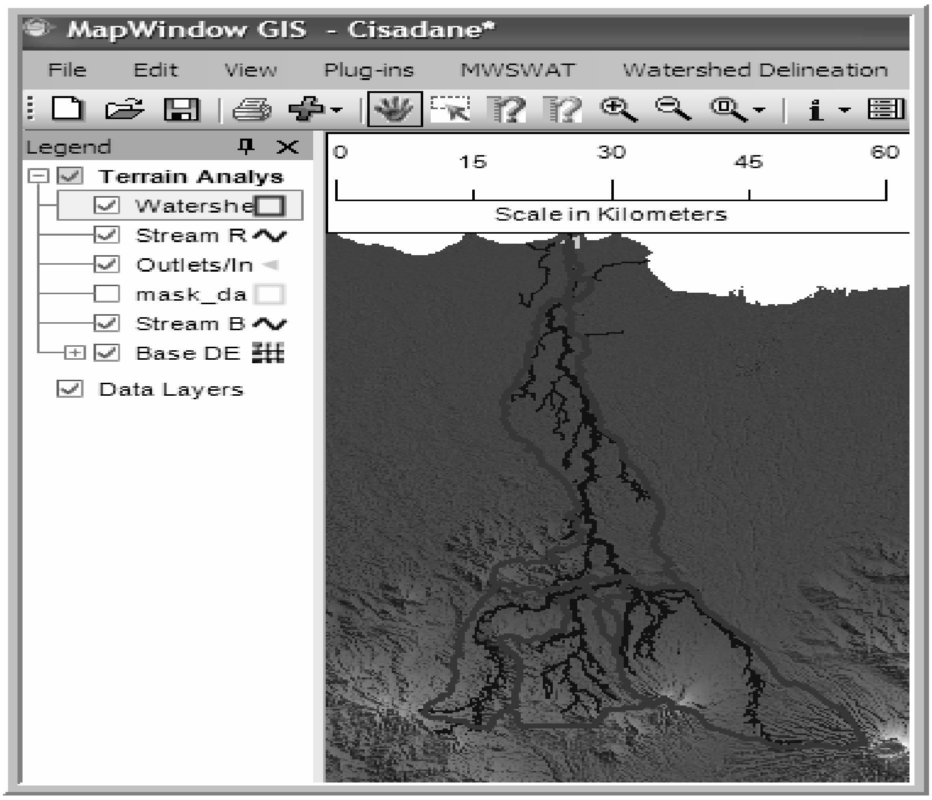

Figure 3. Using MWSWAT and SRTM DEM Map to Delineate Watershed Boundary

Land use map was classified using TM (Thematic Mapper) path 122 row 064 and row 065 year 2005, scale 1:250,000 Soil map has scale 1: 250,000. All maps are raster in UTM coordinate projections.

The watershed has 12 rain gauges and 4 climate stations in its vicinity. Five year climate data from these stations used to create climatic data generator.

output was compared to the actual value in two different river stations: Legok Muncang and Batu Beulah. The degree of accuracy between observed and predicted value was expressed using Nash-Sutcliffe coefficient.

..........(1)

Where Nash-Sutcliffe coefficient = E_{NS}, Qs = Simulated discharge, QM = Measured discharge. Nash-Sutcliffe coefficient (E_{NS}) can be classified as following: a) Good, if E_{NS} e” 0.75, b) Satisfied if 0.75> >, and c) Less satisfied E_{NS}d”0.36.

RESULT AND DISCUSSION

Delineation of Sub-watershed Boundaries

Automatic delineation of sub-watershed by MWSWAT is very useful inwatershed modeling. Delineation of sub-watershed boundaries requires DEM map, watershed location (masking map), river network map and location of watershed outlet.

Automatic delineation by MWSWAT model using SRTM DEM map with 90x90 m resolution will produce some 50 sub-watersheds with total area of 137,134 ha (Figure 3). Actual area of Cisadane watershed is 156.043 ha. Total area of Cisadane delineated by MWSWAT is smaller 12% than actual area. It seems that the model delineated smaller area in the downstream area where the topography is flat. This condition does not change with the use of more detail topographic map (with scale 1:50.000).

River discharge Simulation

To simulate river discharge, each sub-watershed was further divided into hydrologic response units (HRU) by overlapping the slope map, soil and land use map. Some 778 HRUs were created during the process. Each HRU had map unit with different combination of soil, land use and soil data.

Figure 4. Boundariy delineation by MWSWAT model using SRTM DEM map Produced some 50 sub-watersheds

River discharge was simulated using year 2005 land use data. The result was compared with observed data in two sub-watersheds having different size. The first sub-watershed was Legok Muncang with an area of 197 km^2 and the second-watershed was Batu Beulah having an area of 858 km^2 (Figure 5).

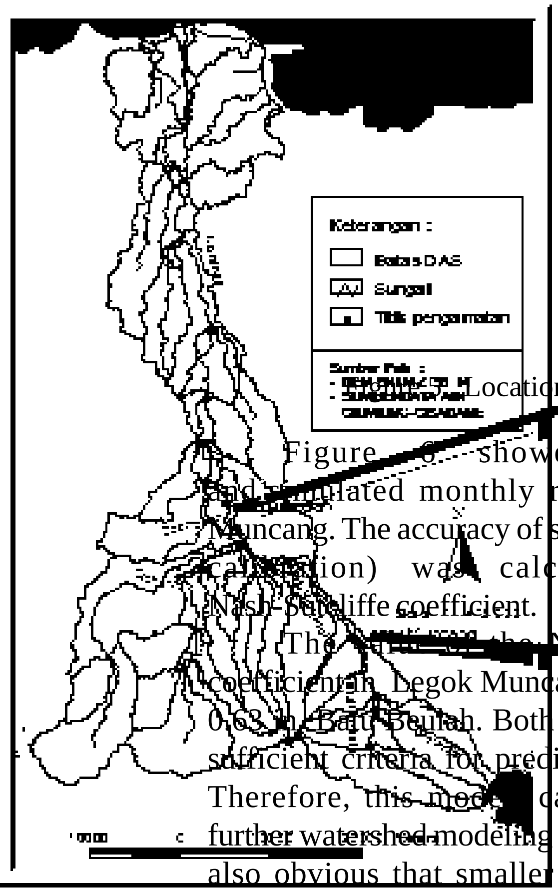

Figure 5. Location for MWSWAT Model Calibration and Validation

Figure 6 showed observed and simulated monthly river in Legok Muncang. The accuracy of simulation (after calibration) was calculated using Nash-Sutcliffe coefficient.

The value of the Nash-Sutcliffe coefficient in Legok Muncang was 0.7 and 0.63 in Batu Beulah. Both value represent sufficient criteria for prediction accuracy. Therefore, this model can be used for further watershed modeling purposes. It was also obvious that smaller sub-watershed (Legok Muncang) had higher accuracy compared to bigger sub-watershed (Batu Beulah).

Relative Discharge and Erosion Contribution of Each Sub-watershed

Complexity of problems in a watershed is very high. Solving all problems simultaneously is almost impossible.Using MWSWAT it is possible to identify sub-watershed that has a highest priority to solve. In this research MWSWAT was used to identify sub-watershed that has highest contribution to surface flow and flooding.

Figure 6. Predicted and Observed River Discharge in Legok Muncang

Figure 7. Predicted and Observed River Discharge in Batu Beulah

As it is obvious from the model result that highest contribution of surface flow was made by sub-watershed that had higher proportion of settlement and agriculture area. Using this result, the watershed manager will be able to allocate limited resources to first solve problem in these sub-watersheds.

CONCLUSION

Watershed modeling often involves processing of huge spatial data such as DEM map derived from satellite image. Coupling GIS software with SWAT watershed model is very powerful in spatial data processing.

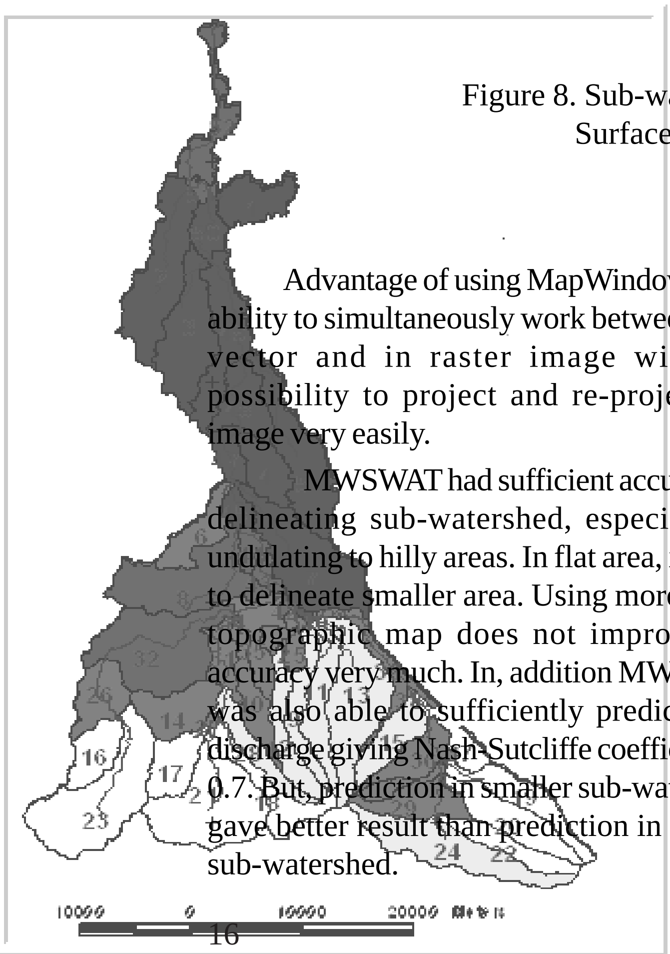

Figure 8. Sub-watershed with Highest Contribution to Surface as Indicated by darker Color.

Advantage of using MapWindow is the ability to simultaneously work between both vector and in raster image with the possibility to project and re-project the image very easily.

MWSWAT had sufficient accuracy in delineating sub-watershed, especially in undulating to hilly areas. In flat area, it tends to delineate smaller area. Using more detail topographic map does not improve the accuracy very much. In, addition MWSWAT was also able to sufficiently predict river discharge giving Nash-Sutcliffe coefficient of 0.7. But, prediction in smaller sub-watershed gave better result than prediction in greater sub-watershed.

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