GIS-based Watershed Modelling for Policy Analysis toward the Integrated Lake Basin Management

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Keywords: Integrated Lake Basin Management; Geographical Information System; Soil and Water Management Tool;Policy analysis

Abstract
This paper introduces the Soil and Water Assessment Tool (SWAT) as a tool of decision makings for the Integrated Lake Basin Management (ILBM). I show how the analytical framework is applied to one of drainage watersheds in Laguna de Bay in Philippines toward sustainable lake basin management through the ILBM-Governance project.

1. Introduction

To achieve the Integrated Lake Basin Management (ILBM) in successful manner, a lake drainage watershed is the logical starting point for planning and management actions (Rast 2008). To develop effective policies and decision makings for such watershed, hydrological simulation modelling based on sound science and the best available information is important and necessary step for the most recent lake basin management issues. This brief paper describes how watershed can be hydrologically modelled and how it can be used for policy analysis toward the ILBM.

There exist some studies analyzing watershed management alternatives using the GIS-based hydrologic watershed model. For example, Wu and Tanaka (2005) investigate the cost-effectiveness of alternative policies for reducing nitrate-nitrogen (NO_3-N) in the Upper Mississippi River Basin. Using the Soil and Water Assessment Tool (SWAT) and econometric models, they find that imposing tax on fertilizer nitrogen is much more cost effective than subsidies (payment programs) including the program implemented by the U.S. government. Baumgart and Fermanich (2008) analyze alternative management scenarios for reducing phosphorous load to Lower Green Bay in the State of Michigan using the SWAT and optimization models.

Under the ILBM-Governance project organized by the Shiga University and the International Lake Environment Committee (ILEC), I am currently developing the SWAT model in the Siniloan Watershed, which is one of drainage watersheds to Laguna de Bay in Philippines. This study is intended to find economically-sound and feasible policy options for reducing environmental pressure from the watershed to the lake. Next section describes the SWAT model and data used for developing the model.

2. Watershed Modelling using the SWAT

This study uses Soil and Water Assessment Tool (SWAT) is developed by the USDA Agricultural Research Service (ARS) to simulate water balance in a large scale watershed for a long period of time (up to 100 years). SWAT can predict the impact of crop practices on water, sediment, and agricultural chemical movements in large, complex watersheds with varying soils, land use, and management conditions over a long period of time (Neitsch *et al*. 2005). Because the SWAT is a physically based, no regression equation is necessary to predict the relationship between input and output variables. Instead, SWAT requires

wide-ranging detailed information including topography, soil properties, land management scenarios, and weather in the watershed.

SWAT uses topographic information to determine watershed and subbasin (subwatershed) boundaries and to digitize the streams (line representation of accumulated perennial water flow over the soil surface) in the watershed. This study uses the Shuttle Radar Topography Mission (SRTM) 90-meter digital elevation map (DEM) organized by CGIAR-CSI. To enhance the accuracy of this process, the digitized stream network provided by the Laguna Lake Development Authority (LLDA), is used as a complement to the DEM. As a result, a total of 5 subbasins are delineated by the hydrologic component of SWAT (figure 1).

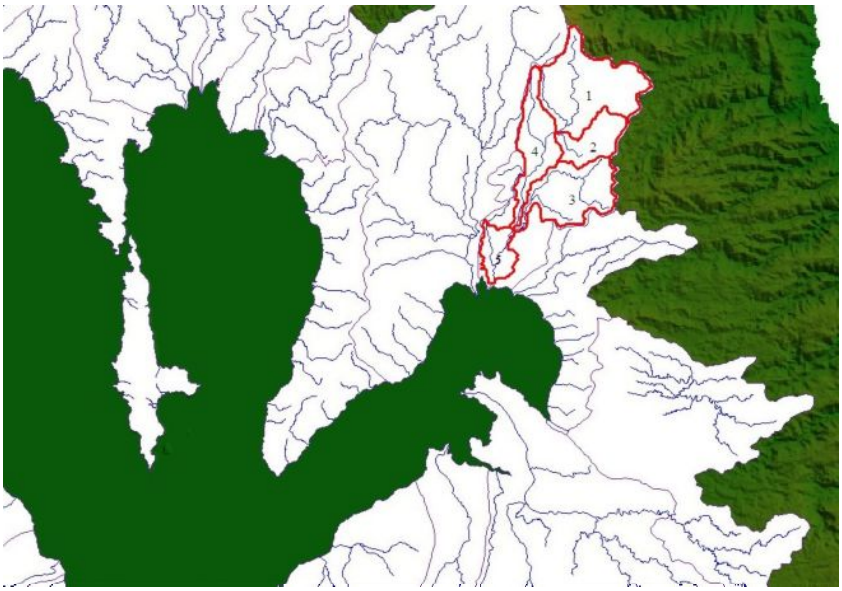

Figure 1. Watershed delineation in the Siniloan watershed in Laguna de Bay, Philippines

SWAT requires a geographical representation of soil distribution, which is used to define the soil's chemical and physical properties to simulate the watershed. The soil coverage is prepared from the FAO/UNESCO Soil Map of the World, which is based on a supra-national classification, also called World Soil Classification. This classification offers useful generalizations about soils pedogenesis in relation to the interactions with the main soil-forming factors. The scale of soil map is 1:5M.

Primary land use information is derived from the Global Land Cover Facility (GLCF) data developed by the University of Maryland. This data is based on the remotely-sensed satellite imagery data with 1-kilometer resolution. This data provides basic land use classification such as agriculture, forest, wetland, water, urban, and other land uses (figure 2).

The land management schedules describe management practices for each land use in the watershed (e.g. timing and amount of fertilizer application). The scenario for each land use can be either different across subbasins or identical in the entire watershed. In this study, we use the same management scenario for each land use. Detailed description of each agricultural land use management scenario is under development with assistance from the LLDA. Although many types of tillage operations are defined as conservation tillage, this study uses no-till as a representative. No-till is a method of farming where the soil is left undisturbed from the harvest of one crop to the beginning of next growing season. Thus, soil disturbance occurs only when fertilizer is applied before growing season, and crop is harvested. Non-agricultural land uses follow SWAT default land management scenarios.

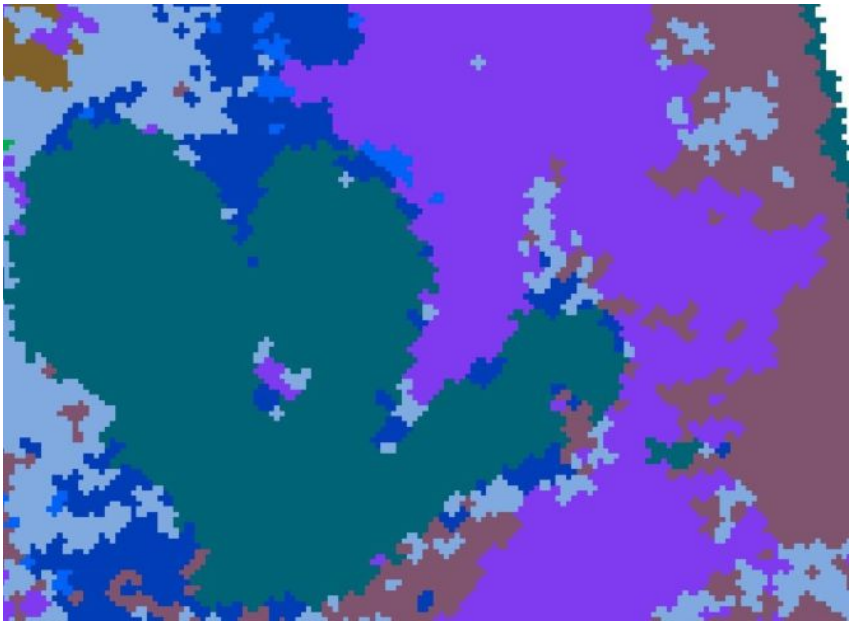

Figure 2. Major land uses in the Siniloan watershed in Laguna de Bay, Philippines

The weather variables required for SWAT simulations are the daily values of maximum and minimum air temperature, precipitation, solar radiation, wind speed, and relative humidity. We obtained historical observations of the daily temperatures and precipitation from National Oceanic and Atmospheric Administration (NOAA) in the U.S. The ArcGIS interface of SWAT (called ArcSWAT) gathers weather data reported from the weather stations in and around the Siniloan Watershed and chooses the variables reported from the nearest station for each subbasin. The daily values of solar radiation, wind speed, and relative humidity are simulated using SWAT built-in random weather generator.

3. Summary and next steps

This paper introduces the Soil and Water Assessment Tool (SWAT) as a tool of decision makings for the Integrated Lake Basin Management (ILBM). I show how the analytical framework is applied to one of drainage watersheds in Laguna de Bay in Philippines toward sustainable lake basin management through the ILBM-Governance project. In next fiscal year (second year of the project), I develop the SWAT model and analyze several possible management scenarios for reducing nutrient loads to the Siniloan Watersehd and Laguna de Bay. This study also considers carbon sequestration as positive side effect of the scenarios, and seeks for policy options for sustainable lake basin while contributing to reduction of the green house gases (GHGs).

References

Baumgart, P. and K. Fermanich. “Lower Fox River Suspended Sediment and Phosphorous Load Allocation and Reduction Strategies to Green Bay Using the SWAT,” Paper presented at *5th International SWAT Conference* (Beijing, China), 2008.

Neitsch, S. L., J. G. Arnold, J. R. Kiniry, R. Srinivasan, and J. R. Williams. *Soil and Water Assessment Tool Theoretical Documentation Version 2005*. Temple: Blackland Research Center. 2005. (URL: http://www.brc.tamus.edu/swat/downloads/doc/swat2005/SWAT%202005%20theory%20final.pdf)

Rast, W. “World Lake Vision: A Call to Action (On the Road to ILBM),” Paper presented at *Curso-Taller Latinoamericano de Manejo Integral de CUencas de Lagos* (Chapala, Mexico), 2008.
Wu, J. and K. Tanaka. "Reducing Nitrogen Runoff from the Upper Mississippi River Basin to Control Hypoxia in the Gulf of Mexico: Easements or Taxes?" *Marine Resource Economics*, 20: 121-144, 2005.