Application of SWAT for the Upper Mississippi River Basin

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Introduction

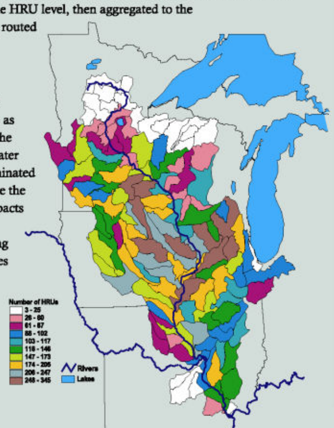
The Mississippi River Watershed covers 3.2 million km² across parts or all of 31 states. Excess nitrogen, phosphorus, and sediment loadings have resulted in water quality degradation within the Mississippi and its tributaries. The nitrate load discharged from the mouth of the Mississippi River has also been implicated as the primary cause of the seasonal oxygen-depleted hypoxic zone that occurs in the Gulf of Mexico, which covered nearly 20,000 km² in 1999 (Rabalais et al., 2002). Approximately 90% of the nitrate load to the Gulf is attributed to nonpoint sources; 56% of this nonpoint source load is estimated to originate above the confluence of the Ohio and Mississippi Rivers (CENR, 2000). The Upper Mississippi River Basin (UMRB), which is dominated by agriculture (67% of the landuse), is the major source of the nitrate load that originates upstream from the Ohio River. Applications of nitrogen and phosphorus via fertilizer and/or livestock manure account for most of the nonpoint source nutrient inputs to agricultural cropland in the region. A simulation study using the Soil and Water Assessment Tool (SWAT) model (Arnold et al., 1998) has been initiated to assess current and alternative nutrient, cropping, and other practices that could lead to improved water quality in the UMRB stream system and ultimately the Gulf of Mexico.

Simulation Methodology

This study builds on a previous "SWAT UMRB mononculture simulation" (Arnold et al., 2000) by incorporating more detailed crop rotations and an array of nutrient and tillage management schemes, derived from the U.S. Department of Agriculture (USDA) National Resources Inventory(NRI) database (Nusser and Goebel, 1997) and other sources, that more accurately reflect current practices in the UMRB and better facilitate policy analyses for the region. The input data and run execution process is managed with the i_SWAT software package (http://www.public.iastate.edu/~elvis/), which translates the input data from an Access Database into the required SWAT input formats, executes SWAT, and extracts and stores desired outputs back into the Access database. Delineation of the UMRB into smaller spatial units suitable for the SWAT simulations consists of two steps: (1) subdividing the overall basin into 131 subwatersheds that coincide with the boundaries of U.S. Geological Survey (USGS) 8-digit Hydrologic Cataloging Unit (HCU) watersheds (Seaber et al., 1987), and (2) creating smaller Hydrologic Response Units (HRUs) located within each of the 131 8-digit watersheds that consist of homogeneous landuse, management, and soil characteristics (the exact spatial locations of the HRUs are not known). Nutrient and sediment losses are simulated at the HRU level, then aggregated to the 8-digit watershed level, and finally routed to the UMRB outlet.

HRU Densities

The HRU densities for the UMRB SWAT simulations are shown here as a function of 8-digit watersheds. The density of the HRUs are much greater in the UMRB regions that are dominated by intensive agriculture, to facilitate the accuracy required to assess the impacts in variations between agricultural management practices and cropping systems. Further sensitivity analyses will be performed to determine what the optimal number of HRUs is for the URMB simulations; the total number of HRUs may be reduced, especially in the areas dominated by agriculture.

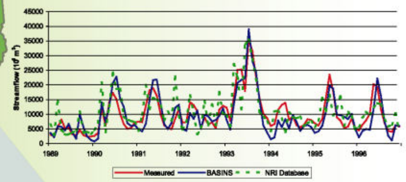


Upper Mississippi River Basin subdivided into USGS 8-digit watersheds, including the location of the Raccoon River Watershed

Configuration of the 38- and 2-subwatershed simulations with locations of associated climate stations (locations represented by geographic centroids for the 2-subwatershed simulation)

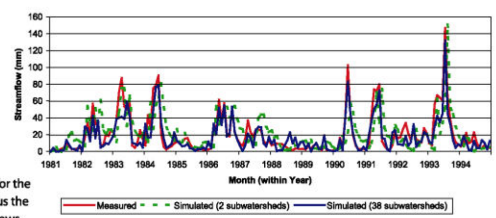
Flow Comparisons at Grafton, IL

Flow comparisons between simulated and measured flows are being performed at USGS stream gauge # 05587450 located on the Mississippi River at Grafton, IL, just above the confluence of the Mississippi and Missouri Rivers. The gauge at Grafton captures flow from 119 of the 131 8-digit watersheds, which is assumed representative of the entire UMRB. An initial SWAT UMRB study was performed (Jha et al., 2003) in which topographic, landuse, and soil data were obtained from the Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) package version 3 (http://www.epa.gov/ost/BASINS/). Calibration and validation of SWAT were performed for this study, resulting in a good agreement between the predicted and measured cumulative monthly flows (r^2=.79 for the validation period shown here). Preliminary cumulative monthly flows for the NRI-based SWAT simulation have also been generated. These results tracked the measured data reasonably well (r^2=.53); however, further calibration is required to obtain more accurate results.



Subwatershed Sensitivity Analyses

Sensitivity analyses are being performed as part of the SWAT calibration phase for specific UMRB subwatersheds, including the Raccoon River Watershed that comprises two USGS 8-digit watersheds. Two uncalibrated SWAT simulations have been performed for the Raccoon River Watershed so far: (1) a two-subwatershed simulation reflective of the UMRB simulation methodology, and (2) a 38-subwatershed simulation. The identical set of 300 HRUs that were generated from the NRI was used for both simulations. However, guidance from other landuse data was used to determine which subwatersheds the HRUs should be located in for the 38-subwatershed simulation. In addition, ten climate stations were used for the 38-watershed simulation while only two climate stations were used for the two-subwatershed simulation. The predicted cumulative monthly flows for the two SWAT simulations versus the corresponding measured flows for 1981-94 are shown here. The 38-subwatershed simulation clearly tracked the measured flows more accurately, although the two-subwatershed simulation also followed the general pattern of the measured flows. The results underscore the need for further calibration, especially for the two-subwatershed approach based on the USGS 8-digit watersheds.



Conclusions

A SWAT simulation has been constructed for the UMRB based on NRI landuse data and subwatershed boundaries coincident with USGS 8-digit watershed boundaries. Preliminary results indicate that the method is viable for predicting UMRB flows, although further calibration and validation of the flows are required. The next phase of the NRI-based UMRB SWAT study will focus on calibration and validation of the simulated sediment and nutrient losses following completion of the flow testing process,.

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