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EFFECTS OF GEOMETRIC MODEL COMPLEXITY ON COMPUTED WATERSHED RUNOFF AND EROSION: AN APPLICATION OF THE NEW AUTOMATED GEOSPATIAL WATERSHED ASSESSMENT TOOL[1]

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The Automated Geospatial Watershed Assessment (AGWA) tool is a GIS-based multipurpose hydrologic analysis software package for use by water- and land-resource managers and scientists in performing watershed- and basin-scale studies. It was developed by the USDA, Agricultural Research Service, Southwest Watershed Research Center (SWRC) to address four objectives: (1) to provide a simple, direct, and repeatable method for hydrologic model parameterization; (2) to use only basic, attainable GIS data; (3) to be compatible with other geospatial watershed-based environmental analysis software; (4) and to be useful for scenario development and alternative futures simulation work at multiple scales. In this study the impacts of geometric complexity on model results were explored using AGWA.

AGWA was created as an extension for ESRI's ArcView version 3.2 GIS software package, and provides the functionality to parameterize, run, and view results from two widely used, quasi-distributed watershed hydrologic models developed by the USDA-ARS: the Soil Water Assessment Tool (SWAT, http://www.brc.tamus.edu/swat); and the KINEmatic Runoff and erOSion model (KINEROS, http://www.tucson.ars.ag.gov/kineros). SWAT is a long-term simulation model with daily time steps for use in large (river-basin scale) watersheds, while KINEROS is a rainfall event-driven model designed for small ($< \sim 100$ km^2) semi-arid watersheds. The AGWA tool has intuitive interfaces for both models that provide the user with consistent, reproducible results in a fraction of the time formerly required with the traditional approach to model parameterization.

By dramatically reducing the time required to develop model input files, AGWA has made it possible to investigate important relationships between the complexity of the watershed discretization and watershed size. A threshold value of the contributing source area (CSA), the upland area required for channel initiation, is determined by the user. The CSA controls the number and size of planes and channels used to subdivide the watershed (geometric complexity). Four CSA values were used to subdivide the watersheds as a function of scale: 2.5, 5, 10, and 20% of the watershed area.

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For SWAT, 15 watersheds within the Upper San Pedro River Basin were used: 10 watersheds of approximately 100 km^2 and 5 watersheds of approximately 250 km^2. Rainfall was derived from NWS gages for a 13-year period. The experimental design for KINEROS was similar to that of SWAT: 10 watersheds of approximately 25 km^2 and 10 watersheds of approximately 100 km^2 were chosen. The 10-year 60-minute rainfall event was used as input.

Results

Results indicate that both models are highly sensitive to the level of complexity at which the watershed is delineated. Although results from individual watersheds within each size class had some degree of variation, consistent trends emerged when values were averaged. The trends presented below are based on an initial CSA value of 2.5% of the watershed area that was progressively increased to 20%.

SWAT results generally tended to have maximum values for total water yield, recharge and baseflow corresponding to a CSA value of 10%. For the 100-km^2 watersheds computed water yield increased almost 100% from a minimum in the most complex watershed configuration (CSA = 2.5%) to a maximum when a CSA value of 10% was used. Baseflow and recharge followed the same trend, but surface runoff peaked at the 5% CSA value and was lowest for a CSA of 20%. For the 250-km^2 watersheds water yield, baseflow, and recharge again peaked at a CSA value of 10%, but were lowest for the least complex watershed configuration (CSA = 20%). Surface runoff was highest for the most complex configuration, and approximately uniform for CSA values of 5-20%.

KINEROS results were consistent throughout the range of CSA values tested, although they varied significantly between the two watershed sizes. For the 25-km^2 watersheds sediment yield increased by 50% on average between CSA values of 2.5 and 20%, whereas runoff declined by 10%. Plane infiltration increased 10%, and channel infiltration decreased by 40%. For the 100-km^2 watersheds sediment yield decreased by 75% on average, and runoff declined by approximately 55%. Plane infiltration increased by approximately 8%, and channel infiltration decreased by 60%.

Discussion

A range of different rainfall-runoff and erosion processes predominate at different spatial scales. Quasi-distributed hydrologic models such as SWAT and KINEROS attempt to account for such variability through different sub-routines responsible for determining various portions of the water balance. As the numbers of planes and channels used to subdivide the watershed are altered, the processes controlling the water balance are represented differently in the model.

This study demonstrates that the impacts of changing the geometric complexity affect not only the manner in which the water balance is computed, but can also have profound effects on the simulated runoff response. As such, the contributing source area should be considered an important variable during model calibration. Although it was not possible to adequately define optimum complexity as a function of watershed size for this study, these steps should be taken where possible to ensure that the models are appropriately representing process-scale relationships.