THE EFFECT OF GIS DATABASE GRID SIZE ON HYDROLOGIC SIMULATION RESULTS

by

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Abstract

The use of geographic information systems (GIS) for assessing the hydrologic effects of management is increasing. In the near future most of our spatial or "mapped" information will come from GIS. The direct linkage of hydrologic simulation models to GIS should make the assessment process more efficient and powerful, allowing managers to quickly evaluate different landscape designs. This study investigates the effect the resolution of GIS databases have on hydrological simulation results from an urban watershed. The hydrologic model used in the study was the Soil Conservation Service Curve Number Model which computes the volume of runoff from rainfall events. A GIS database was created for High School Wash, a urban watershed in Tucson, Arizona. Fifteen rainfall-runoff events were used to test the simulation results. Five different grid sizes, ranging from 25x25 square feet to 300x300 square feet were evaluated. The results indicate that the higher the resolution the better the simulation results. The average ratio of simulated over observed runoff volumes ranged from 0.98 for the 25x25 square feet case to 0.43 for the 300x300 square feet case.

Introduction

Geographic information systems (GIS) are being increasing used in hydrologic analysis (White 1988; Muzik 1989; Stuede and Johnston 1990). GIS are computer programs designed to collect, store, retrieve at will, transform and display spatial data from the real world for a particular set of purposes. Hydrologic models have spatially distributed parameters defined in terms of landuse, soils and topography across a watershed that must be identified. GIS have the potential to generate these input parameters and allow planners to interactively evaluate the hydrological effects of different management alternatives (Stuebe and Johnston 1990).

In a raster based GIS the spatial data is represented by a rectangular array of square cells, each with an assigned value. As the cell size increases information can be loss because the surface variation is "smoothed." Smaller cells (i.e. high resolution) will yield the most accurate representation of a watershed characteristics, but at the cost of increase storage requirements and computer processing time. High resolution GIS databases are also very costly to create and there is a minimum cell size that can be used given the quality of the original data. The objective of this study is to evaluate the affect cell size of a raster based GIS has on the simulation results from a simple hydrologic model.

Procedures

SCS Curve Number Model

Stormflow response to a rainfall event was simulated using the SCS Curve Number Model (USDA - SCS 1986) in the following form:

$$Q = (P - 0.2S)^2 / (P + 0.8S) \quad \text{for } P > 0.2S$$

where

Q = runoff volume (inches)
P = rainfall volume (inches)
S = watershed storage index (inches)

S is related to the soil and cover conditions of a watershed through the runoff curve number (CN) where S is computed by:

$$S = (1000/CN) - 10$$

In this study curve numbers where assigned to each cell in the watershed as the function of soil and cover type. The antecedent moisture condition I was used for all the events based on prior rainfall. In using the model with a GIS, the weighted runoff volume was computed for each cell in the watershed and then the cells were summed to yield the total runoff volume for the watershed (White 1988).

Study Site Description

The study was conducted on the High School Wash Watershed located in Tucson, Arizona. High School Wash is a small urban watershed about one square mile in size. The landuse is primarily residential with six land cover types represented; grass, tree canopies, paved roads, buildings, bare soil, and desert urban landscaping. Two soil types are represented, Mohave and Cave, belong to the hydrologic soil groups B and C, respectively. Table 1 contains the curve numbers used in this study. The curve numbers are from USDA-SCS (1986) and adjusted to antecedent moisture condition I according to Dunne and Leopold (1978).

Table 1: Curve numbers for antecedent moisture condition I.

	Hydrologic Soil Group	
Land Cover Type	B	C
Grass	40	63
Paved Roads	98	98
Buildings	98	98
Bare Soil	62	77
Desert Landscaping	89	89
Tree Canopy	40	62

Rainfall and runoff data were collected on High School Wash for twenty years, from 1968 to 1988. Fifteen summer rainfall events were used in this study, ranging in size from 0.69 to 1.76 inches. Rainfall was collected in four recording rain gauges and the arithmetic average rainfall for the watershed was computed for each event. Runoff was measured at the watershed outlet using a H-type flume.

Geographic Information Systems

The GIS database was created for High School Wash using AutoCAD (Autodesk 1989). In this study two data themes were required, soils and land cover. The land cover theme was digitized from black and white aerial photographs with an 1:2400 scale. The vector information was converted to five different cell sizes; 25x25, 50x50, 100x100, 200x200 and 300x300 square feet. This study was primarily done using the GIS program IDRISI (Eastman 1989), with the Map Analysis Package (Tomlin 1986) being used for data transfers.

Results

Decreasing the resolution of the database influenced the the distribution of land cover (Table 2) and model performance (Table 3). As the cell size increased the percent of the watershed represented by vegetation (grass and tree canopies) and impervious area (paved roads and buildings) decreased and bare soil increased. The percent of the watershed in desert landscaping and the distribution of soil types did not significantly change. Hydrologically the conversion of impervious areas (CN = 98) to bare soil is important. Impervious areas are the primary source of storm runoff in an urban area and a decrease in their representation would be expected to result in a decrease in storm runoff.

Table 2: Affect of cell size on land cover type percentages (vegetation = grass and tree canopy; impervious = paved roads and buildings).

Cell Size (square feet)	Vegetation (%)	Bare Soil (%)	Impervious (%)
25x25	30.9	25.5	40.4
50x50	29.7	28.8	38.6
100x100	28.6	31.6	36.7
200x200	26.8	38.2	32.4
300x300	23.0	43.7	30.5

The effect of the change in impervious area can be seen in the model performance results (Table 3). With small cell sizes, 25x25 and 50x50, the model predicted storm runoff well, with an average ratio of predicted over observed runoff of 0.98. A "perfect" comparison of predicted to observed runoff would yield an average ratio of 1.0 for the fifteen events with a standard deviation of 0.0. As the resolution of the database decreased the model under predicted runoff to the point that for the 300x300 cell size the model on the average only predicted 43% of the observed runoff.

Table 3: Affect of cell size on hydrologic simulation results.

	Ratio of Simulation/Observed Runoff Volume	
Cell Size (square feet)	Average Ratio (ND)	Standard Deviation (ND)
25x25	0.98	0.12
50x50	0.98	0.13
100x100	0.65	0.14
200x200	0.50	0.15
300x300	0.43	0.14

Conclusion

The resolution of a raster GIS database influenced the performance of a simple hydrologic simulation model. The results indicate that higher resolution GIS databases may be required to do hydrologic assessments in urban areas. In urban areas land cover is very heterogenous, so important features, such as roads and buildings, are poorly represented as the resolution of the database decreases. Planners should be careful when they are developing their GIS databases that the are of sufficient resolution to meet their hydrologic modeling needs.

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