

A SPATIAL DECISION SUPPORT SYSTEM FOR ASSESSING AGRICULTURAL NONPOINT SOURCE POLLUTION¹

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Abstract: A spatial decision support system (SDSS) was developed to assess agricultural nonpoint source (NPS) pollution using an NPS pollution model and geographic information systems (GIS). With minimal user interaction, the SDSS assists with extracting the input parameters for a distributed parameter NPS pollution model from user-supplied GIS base layers. Thus, significant amounts of time, labor, and expertise can be saved. Further, the SDSS assists with visualizing and analyzing the output of the NPS pollution simulations. Capabilities of the visualization component include displays of sediment, nutrient, and runoff movement from a watershed. The input and output interface techniques/algorithms used to develop the SDSS, along with an example application of the SDSS, are described.

(KEY TERMS: distributed nonpoint source pollution modeling; GIS; decision support system; Universal Soil Loss Equation; integration; visualization.)

INTRODUCTION

In the past, erosion estimates were commonly predicted using empirically derived equations including the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978). More recently, soil erosion and chemical movement models have been based on the major processes of soil erosion and water movement such as the detachment and transport of particles by rainfall and runoff (Beasley *et al.*, 1980; Young *et al.*, 1985). Existing soil erosion models such as EPIC (Erosion Productivity Impact Calculator) (Williams *et al.*, 1984), CREAMS (Chemicals, Runoff, Erosion from Agricultural Management Systems) (Knisel, 1980), WEPP (Water Erosion Prediction Project) (Foster and Lane, 1987; Lane and Nearing, 1989), ANSWERS (Areal Nonpoint Source Watershed

Environment Response Simulation) (Beasley *et al.*, 1980), and AGNPS (AGricultural NonPoint Source) (Young *et al.*, 1987 and 1989) provide users with analytical tools that allow them to predict erosion characteristics of slopes, fields, watersheds, and channels. These models also allow evaluation of management practices that influence certain factors contributing to erosion and provide significant insight into the processes of soil erosion. However, they have a number of limitations that restrict their widespread use.

Factors that have limited the use of simulation models as management tools include large data and input parameter requirements, parameters that are difficult to estimate or obtain, and uncertainty in inputs. Researchers have successfully shown that integration of simulation models with spatial databases and coded expertise to minimize input required from the user was consistent and complete enough in generating input data files for the simulation models (Arnold and Sammons, 1989; Heatwole, 1990; Shanholtz and Zhang, 1989).

Another major factor limiting the use of simulation models is a lack of assistance in analyzing the model results. The complex programs used to study erosion prediction can provide an overwhelming amount of data for analysis in even a small watershed. Use of graphics to visualize the spatially varying data and time dependent data such as runoff or sediment yield at the outlet can greatly enhance the ability of conservation managers to conduct further analysis and to make proper decisions (Bingner, 1989; Shoup and Becker, 1985; Barringer *et al.*, 1987).

One of the strongest reasons to implement an automated approach to resource planning is the ability to

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change questions, scenarios, or assumptions quickly and easily. Within a short time (especially compared to the time it would take to do manual calculations for a new query and then hand-draft maps), a complex analysis can be performed, using a combination of simple GIS analyses such as map overlays and boolean operations in GIS. Geographic Information Systems (GIS) are tools to collect, manage, store and display spatially varying data.

This paper is focused to achieve the following objectives:

- Develop methods to extract the input data from GIS for an NPS model using a hydrologic toolbox.
- Develop methods for visualizing agricultural nonpoint source pollution simulation results such as erosion, runoff, and chemical movement estimates.
- Demonstrate and discuss the benefits of the methods developed in the above objectives using an example data set.

BACKGROUND INFORMATION

Bekdash et al. (1991) performed best management practices (BMPs) evaluations using a linkage between GIS and the CREAMS model. The authors suggested that interpolation of maps for the delineation of stream channels and the watershed boundary is time consuming and felt that a systematic approach of extracting the required data is the right way of addressing the problem. Panuska et al. (1991) integrated two terrain-enhancing programs, TAPES-C and TAPES-G (Moore, 1988), into the AGNPS pollution model to automate the input of data including slope, slope length, channel slope and flow direction. Sasowsky and Gardner (1991) used a raster-based GIS to extract inputs for the Simulation of Production and Utilization of Rangelands (SPUR) model, a quasi-physically based surface runoff model in which a watershed is configured as a set of stream segments and contributing areas. Rewerts and Engel (1991) integrated a watershed simulation (ANSWERS) with a raster GIS. Their Project Manager can be used to gather information from the user, extract data from a GIS, create an ANSWERS input file, and read ANSWERS output into new GIS layers. The authors estimated that the time required to prepare an input data set for the ANSWERS model could be significantly reduced by using the Project Manager, possibly by 7 to 10 times.

Hession (1990) suggested that once the base coverage exists in a GIS, it is merely a two- to three-hour process to build a new AGNPS input file for a different cell size, a different subwatershed, or updated

land use conditions. In comparison, to build a new AGNPS input file at a different cell resolution using manual techniques, the process must essentially be started from scratch. Further, Hession (1990) stated that it takes from three person days for a 200 hectare (500 acre) watershed to one person month for a 9,300 hectare (23,000 acre) watershed to prepare input data for an AGNPS run. These estimates are based on a cell size of 16 hectares (40 acres).

DEVELOPMENT OF SDSS

Due to the difficulties in using NPS pollution models, an alternative approach suggested by various researchers is to collect or derive the necessary data from a spatial data base (i.e., a GIS). The NPS pollution model and the GIS used for the SDSS were AGNPS (Young et al., 1985) and GRASS (Geographical Resources Analysis Support System) (U.S. Army, 1987). The following sections describe the NPS pollution model, the GIS, their integration, and supporting tools (i.e., the hydrologic toolbox). The hydrologic toolbox is a collection of procedures that describe the interactions between various hydrologic parameters and was developed within the GRASS GIS environment. Thus, any hydrologic models that use these parameters can utilize the hydrologic toolbox.

Integration Approach

The user's view of the SDSS and interactions between different components of the system are shown in Figure 1. The components include the input interface to the NPS pollution model, output interface (*Visualization*) to the NPS pollution model, and the hydrologic toolbox to facilitate the input/output interfaces to this and other models. All components in this system are modular and interact through the GIS tool, which serves as the core of the system. By keeping the components of the spatial decision support system modular, one can use any of the components as a stand-alone module, in combination with other modules, or add/modify new/existing components.

NPS Pollution Model

The distributed parameter model AGNPS was used in the development of the SDSS. The AGNPS model was developed to serve as a land management tool for estimating sediment and nutrient yields in surface water runoff from agricultural lands and to compare

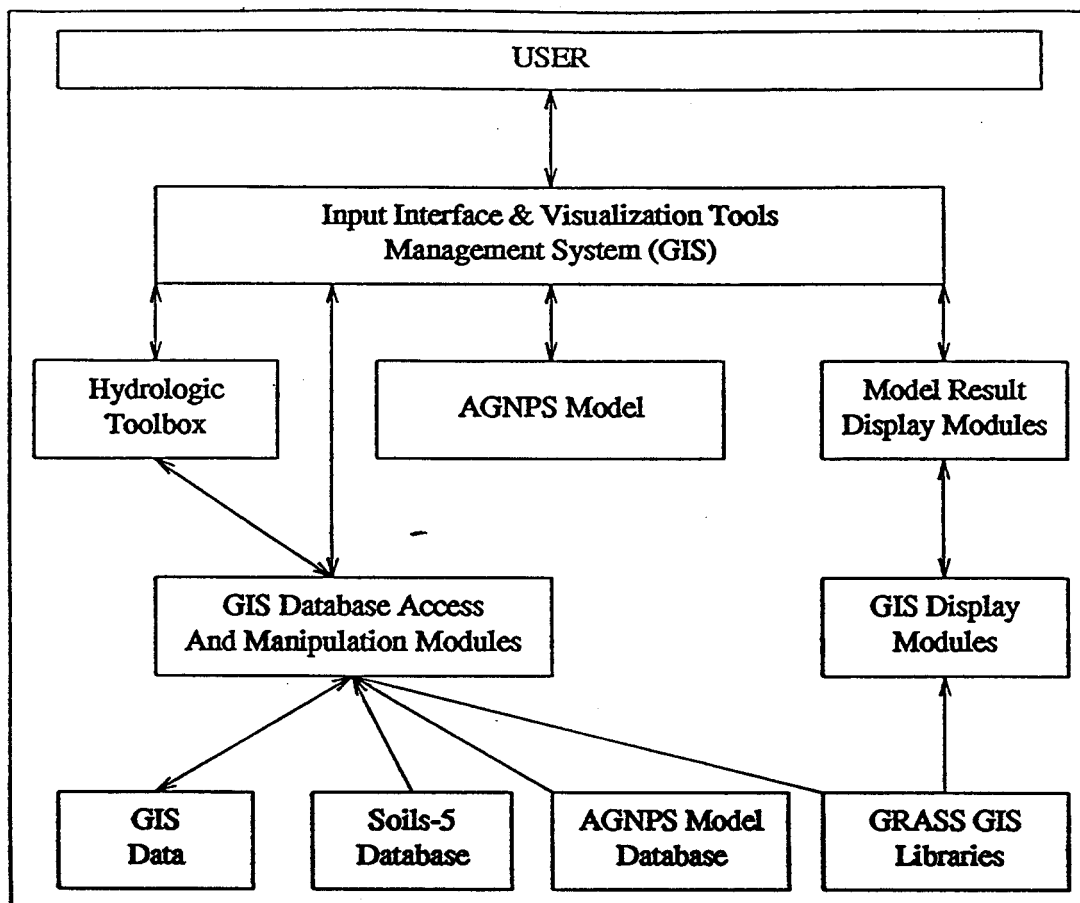


Figure 1. User's View of SDSS.

the potential impacts of various land management strategies on the quality of surface water runoff (Young *et al.*, 1985). AGNPS is used to estimate changes in concentrations of sediment, nutrients (N, P), and chemical oxygen demand (COD) in runoff waters from agricultural watersheds (Young *et al.*, 1985). It is a storm (event-based) model, uses distributed parameter inputs, and operates on a cell basis (uniform square areas subdividing the watershed). The primary advantage of this distributed parameter approach is the potential for providing a more accurate picture of the hydrologic and pollutant transport system under alternative management conditions. The AGNPS model has been modified to run on UNIX platforms (Srinivasan, 1992), which helps its integration with the GRASS GIS tool. GRASS is a public domain raster GIS designed as a general purpose, raster graphic modeling and analysis package initially developed for land and environmental planners at military installations. GRASS is also capable of some vector GIS operations, image processing, and graphics production. GRASS data layers can be transported to and from several other GIS platforms.

Hydrologic/Other GIS Based Tools

Several hydrologic GIS-based and/or other generic tools were used in developing the NPS pollution-GIS tool interfaces (AGNPS-GRASS links) to keep the SDSS structure as modular as possible (Figure 1). The following tools are used either in the AGNPS-GRASS input interface or the AGNPS-GRASS output interface (*Visualization Tool*). These tools can be classified into one of two categories: (1) hydrologic tools (*r.cn*, *r.soils5*, and *r.fill.direct*); or (2) other generic tools (*d.rast.arrow*, *d.rast.number*, *d.rast.zoom*, and *d.rast.edit*). These tools can be used as stand-alone modules or can be integrated with other modules or tools within a GIS environment.

r.cn

The Soil Conservation Service curve number (SCS CN) procedure is used to predict runoff volume from watersheds. *r.cn* is the curve number tool written in

the 'C' language and incorporated as a tool in the GRASS GIS. *r.cn* generates a curve number map for a watershed based on four layers (Hydrological soil group, Hydrologic condition, Management practice, and Land use) of information using the rules stipulated by the SCS Hydrology Handbook (USDA, 1972) and can convert from AMC (antecedent soil moisture condition) II to either AMC I or III (Arnold et al., 1990).

r.soils5

r.soils5 extracts soils information from the Soils-5 database for a GRASS soil series layer and creates layers for the soil properties of interest. The Soils-5 database (Goran, 1983) is a national database providing hundreds of soil properties for each soil series. *r.soils5* allows the user to classify a soil series layer with Soils-5 database information and can be directly used as input for many hydrologic models.

r.fill.direct

Digital elevation models (DEMs) can be used to derive a wealth of information about the morphology of a land surface using neighborhood operations to calculate slope, aspect, and shaded relief (Klingebiel et al., 1988) and points of inflection (Peucker and Douglas, 1975). From past research, it has been recognized that depressions, areas surrounded by higher elevation values in the DEM data, are the nemesis of hydrologic flow routing.

r.fill.direct was developed to generate a depressionless DEM data layer and unique flow direction (aspect) layer based on work by Jenson and Domingue (1988). The resulting depressionless elevation layer can further be manipulated to derive slopes and other topographic attributes required by hydrologic models.

d.rast.arrow

d.rast.arrow is a GRASS GIS tool that displays arrows on aspect maps to indicate flow directions. *d.rast.arrow* is designed to help the user better visualize surface water flow direction indicated by an aspect cell map. The *d.rast.arrow* tool is used in the *Visualization Tool* to show the flow and routing direction used in AGNPS. An arrow can point in one of eight directions for AGNPS.

d.rast.num

d.rast.num is a GRASS GIS tool to display cell category numbers on maps. After displaying a cell map, the *d.rast.num* program may be run to draw the corresponding cell value over each cell to indicate to which category that cell belongs. The *d.rast.num* tool is used in the *Visualization Tool* to show the cell number map, since AGNPS keeps track of its data through cell numbers.

d.rast.zoom

d.rast.zoom is an interactive GRASS GIS tool to zoom in or zoom out on a cell map displayed on the graphics monitor. This tool is used in the *Visualization Tool* to allow one to closely view outputs for an area of interest.

d.rast.edit

d.rast.edit is a graphical raster map editor in the GRASS GIS tool. The *d.rast.edit* program facilitates editing cell values in a layer using the mouse cursor on the graphic display monitor. Within the *d.rast.edit* program, previously defined tools (*d.rast.arrow*, *d.rast.zoom*, and *d.rast.num*) can be invoked, allowing one to edit a flow direction map and view the corrected map. This tool can be used in both AGNPS-GRASS input and output interfaces to change cell values for an area to study the effects on the output of the model.

AGNPS-GRASS INPUT INTERFACE

The major objective of the AGNPS-GRASS input interface is to minimize the user interaction in preparing the input data for the AGNPS model and to minimize the number of user supplied/developed GIS database layers. Figure 2 shows a schematic of the AGNPS-GRASS input interface. Of the 22 input parameters required by the AGNPS model for each cell (Table 1), the interface prepares the input data from 7 GIS database layers (see Figure 2) and a watershed layer that shows the watershed boundary. A few parameters, such as rainfall amount and its corresponding energy intensity value, are needed for the whole watershed and therefore are obtained from the user. The major asset of the GIS approach is its flexibility, data analysis capabilities, data preparation

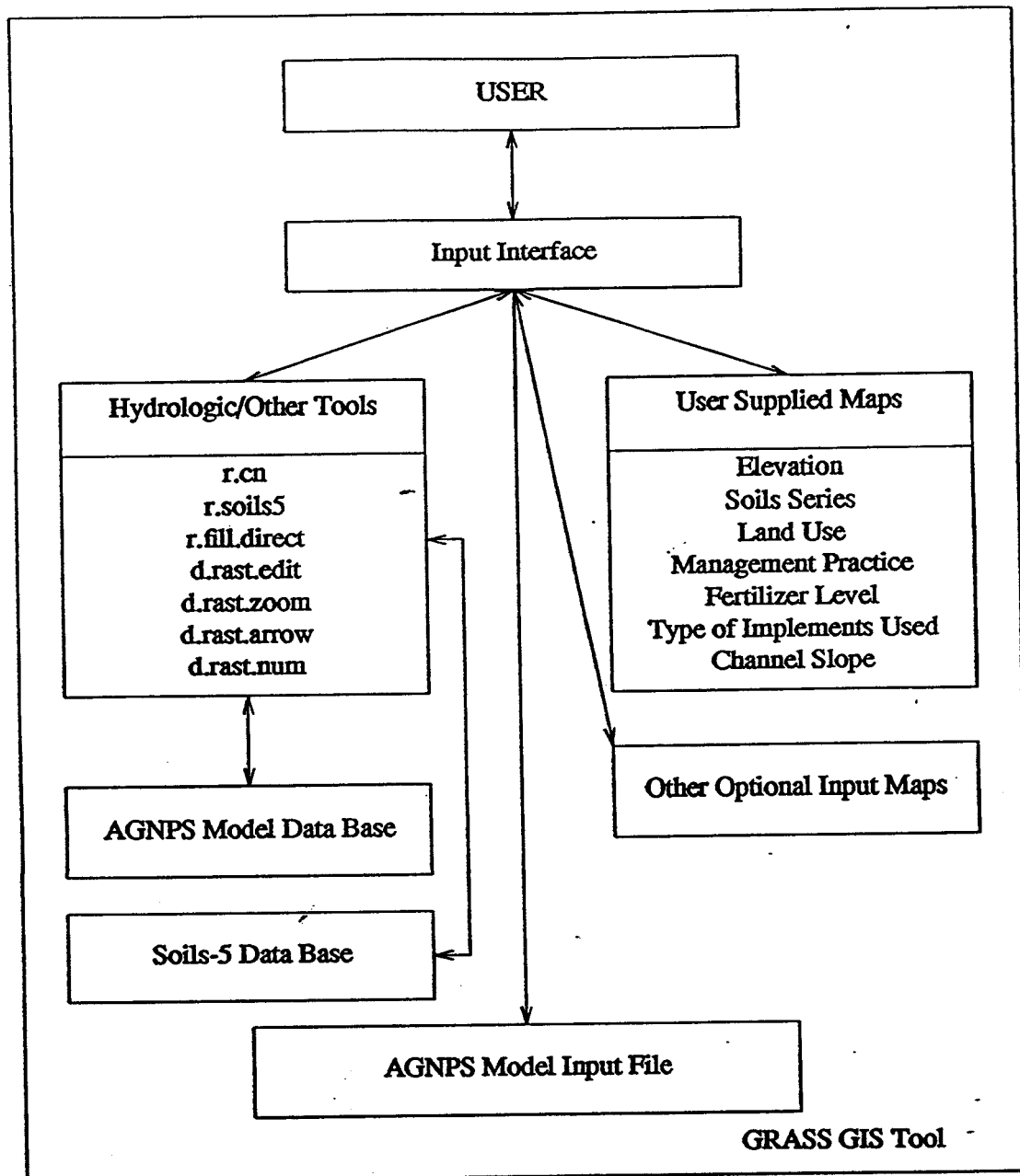


Figure 2. Schematic of the AGNPS-GRASS Input Interface.

capabilities, potential for reuse, and ease of updating as compared with a manual approach.

The AGNPS manual is the primary source for determining input values. Even though the AGNPS user's manual and the Soils-5 data base provide most of the input data needed by the model, considerable expertise is still required for selecting parameters. The AGNPS-GRASS input interface (see Figure 2) development for extracting 22 input parameters (see Table 1) for the AGNPS model was done using programs written in the 'C' language and using GRASS

subroutines to manipulate the GRASS GIS data layers directly. Extraction of the 22 parameters using the input layers and GIS procedures are summarized in Table 1, and a more detailed description can be found in Srinivasan (1992). To obtain default values for input parameters, either the AGNPS User's Manual suggested procedures or tables are used.

TABLE 1. List of AGNPS Cell Input Parameters, Descriptions, Input Layers, and GIS Procedures.

No.	AGNPS Parameters	Descriptions	Input Layers/GRASS Tools
1	Cell number	A cell number layer is generated in GRASS	watershed
2	Number of cells into which it drains	An aspect layer	elevation/r.fill.direct
3	SCS curve number	Curve number	land use, management, hydrologic condition, and hydrologic soil group/r.cn
4	Average slope percent	Overland slope	elevation/r.slope.aspect
5	Slope shape factor	Overland flow shape; assumed to be uniform	
6	Average field slope length	Derived using unit stream power theory (Moore and Burch, 1986a, 1986b)	aspect and elevation
7	Average channel slope (percent)	User input, else 50 percent of overland slope	channel slope
8	Average channel side slope (percent)	Use soil texture information	soils/r.soils5
9	Mannings n	Use standard table	soil texture and land use
10	USLE K factor	Use soils-5 database	soils/r.soils5
11	USLE C factor	Use SCS technical guide	C factor
12	USLE P factor	Use SCS technical guide	P factor
13	Surface condition constant	Use AGNPS Manual	land use and management
14	Aspect	An aspect layer	elevation/r.fill.direct
15	Soil texture	Use soils-5 database	soils/r.soils5
16	Fertilization level	Use field information	nutrient levels
17	Incorporation factor	AGNPS Manual	management
18	Point source indicator	User provided	
19	Gully source level	User provided	
20	Chemical oxygen demand	AGNPS Manual	land use
21	Impoundment factor	User provided	
22	Channel indicator	User provided	

AGNPS-GRASS OUTPUT INTERFACE (VISUALIZATION TOOL)

The complex programs used to study erosion prediction can provide an overwhelming amount of data for analysis in even a small watershed. Graphical displays of the results have proven to be a more effective and efficient way of interpreting results and in making decisions than scanning through pages of numerical output in the form of tables. Visual displays can convey more data in a short time period than other methods. AGNPS provides detailed output; however, users often cannot make use of it due to a lack of analytical and visual aid tools.

Primary output given by AGNPS for watersheds being analyzed includes estimates of runoff volume, peak flow rate at the watershed outlet, area-weighted erosion for both upland and channel areas, sediment delivery ratio, sediment enrichment ratio, mean sediment concentration, and total sediment yield for each of five sediment particle size classes. A nutrient analysis is also available that includes N, P, and COD mass per unit area for both soluble and sediment adsorbed phases.

The *Visualization Tool* allows the user to display sediment, runoff and chemical movement in a watershed and produces simple statistics of both inputs and outputs of the AGNPS model for a cell or an average for an area. This tool greatly assists the decision making process. With visualization capabilities such as those described here, distributed parameter NPS models become more useful. More information about the *Visualization Tool* interface can be found in Srinivasan (1992).

The interface for visualizing and analyzing (Figure 3) the results of the AGNPS model was implemented using the GRASS GIS tool and programs written in the 'C' language. Initially the visualization interface generates 17 GIS layers (Table 2) from the ASCII output files of an AGNPS run. The layers generated can be saved for future evaluation of output.

The inputs required for the *Visualization Tool* include the watershed boundary map, the cell size, the flow direction (aspect) layer for the watershed, and the ASCII AGNPS input and output file names. Once data are extracted, a menu (see Figure 3) with choices as described in Table 3 is used to begin the decision making process based on the model results.

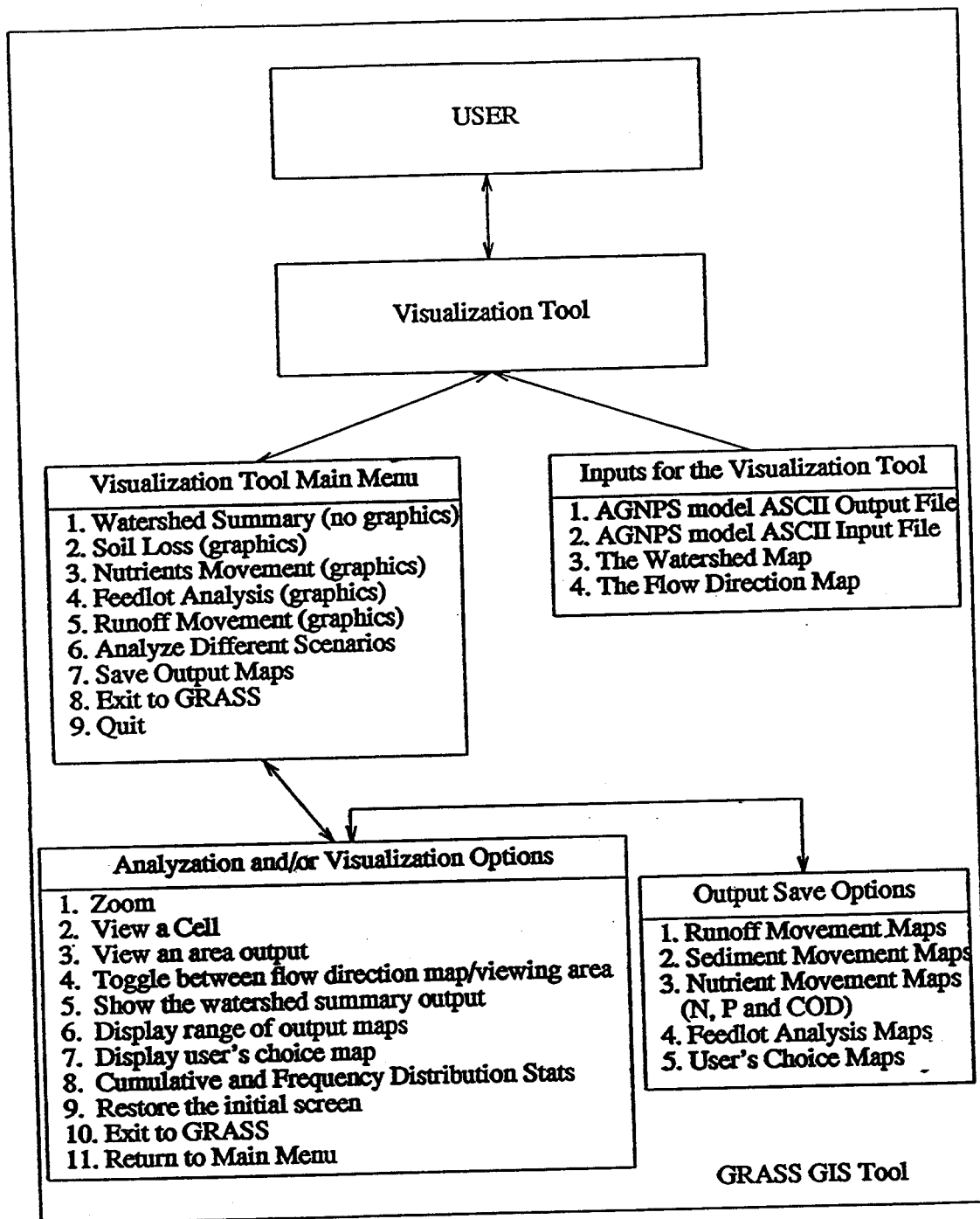


Figure 3. Schematic of the AGNPS-GRASS Output Interface (Visualization Tool).

The *Visualization Tool* splits the screen into various screens to display the output of the model. The number of windows created depends on the type of output displayed. The tool always reserves an ASCII terminal (non graphics) for interacting with the user. The first screen (see Figure 3) provides various options including a watershed summary (no graphics) and spatially distributed soil loss, nutrients, runoff, and feedlot movement output (graphics) of a watershed.

VISUALIZATION TOOL OPTIONS

Option 1 (see Figure 3) displays the watershed summary for soil loss, runoff and nutrient movement at the watershed outlet in the non-graphics window. Options 2-5 (see Figure 3) move to the next screen (Figure 3) where the appropriate options are displayed. The display screen layout for option 2 (see

Figure 3), soil loss, is shown in Figure 4. The top row windows display the output maps (see Table 2). A legend for each of the output maps is displayed, showing the color and the numerical value associated with it. The right hand top corner window displays the watershed map with cell numbers by laying a grid on top for reference using the *d.rast.num* program. Below this cell number map, the aspect map of the watershed with arrows pointing in the flow directions is displayed using the *d.rast.arrow* program. In the bottom row, two windows display the input and output statistics for a cell or area in the left and right windows respectively. The left bottom window shows cell

inputs. For example, for soil loss (see Figure 4), the bar chart shows the amount of erosion, deposition, and sediment movement in tons for a cell or average values for a group of cells. Cell statistics, including accumulation area in acres, percentage of deposition, and weighted average erosion are displayed. The *Analyze Different Scenarios* option (see Figure 3) allows one to visualize and analyze a different simulation for the same resolution as the current scenario. Table 3 summarizes the spatially distributed input and output options.

TABLE 2. AGNPS Output Maps Created Using Visualization Tool.

AGNPS Output	Maps Generated
Hydrology Output	Cell number Runoff generated Runoff from upstream Runoff to downstream
Sediment Output	Erosion Deposition Sediment leaving the cell
Chemical Output	Nitrogen associated with sediment (generated) Nitrogen associated with sediment (leaving) Nitrogen associated with runoff (generated) Nitrogen associated with runoff (leaving) Phosphorus associated with sediment (generated) Phosphorus associated with sediment (leaving) Phosphorus associated with runoff (generated) Phosphorus associated with runoff (leaving) COD associated with runoff (generated) COD associated with runoff (leaving)

TABLE 3. Spatially Distributed Output Options and Descriptions (*Visualization Tool*).

Option No.	Option Name	Description
1	Zoom	Adjusts viewing region of maps displayed; allows zooming in or zooming out.
2	View a cell	Displays a selected cell's input and output statistics in the bottom row of windows (Figure 4).
3	View an area output	Displays a selected area's average input and output statistics in the bottom row of windows (see Figure 4).
4	Toggle option	Toggles between the current viewing area within the watershed and the flow direction map.
5	Watershed summary	Displays the summary at the outlet of the watershed for all the outputs in the ASCII (nongraphics) window.
6	Display ranges of output	Displays output layers (see Table 2) for a specified range of values (see Figure 3) and allows the maps to be saved.
7	Display user's choice of maps	Displays the user's choice of maps.
8	Cumulative and frequency distribution	Displays the cumulative and frequency distribution area curves for any of the output variables.

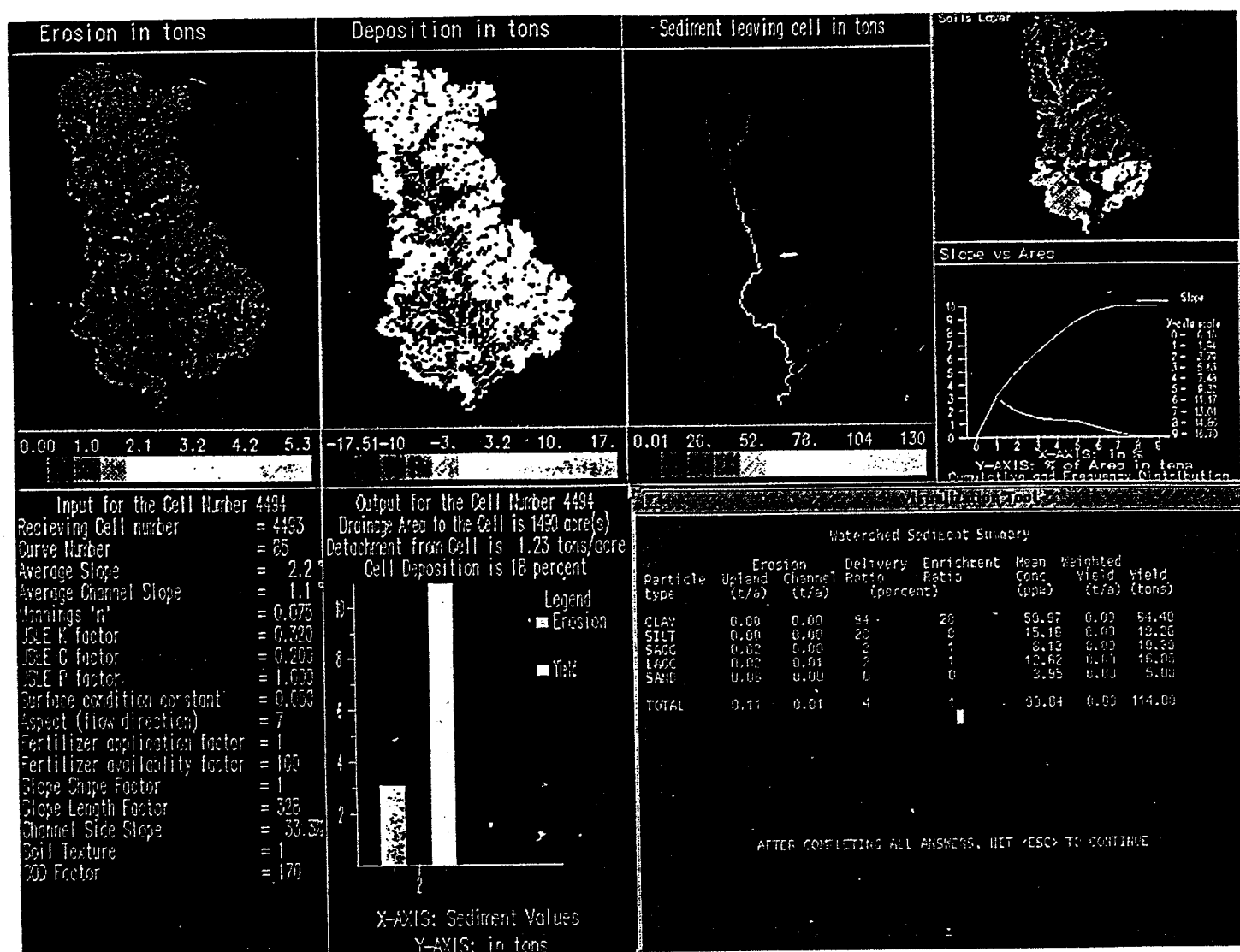


Figure 4. Sediment Output Screen of Visualization Tool for Seco Creek Watershed.

APPLICATION OF THE SDSS

The SDSS was applied to several watersheds, including the upper drainage basin of the Seco Creek watershed located in south central Texas (see Figure 4). The total area of the basin is 11,641 hectares. The basin was modeled using a square 1 hectare grid (100 X 100m). To date, the AGNPS model has not been applied to a basin this large with such a small cell size because the PC-version of the AGNPS model is limited to 1900 cells. More than 98 percent of the Seco Creek basin is rangeland. The base GIS layers

were digitized by the SCS-Fort Worth GIS center. The elevation contours were digitized at a 1:24000 scale from USGS 7.5 minute maps. The field boundary map and soils map were also digitized at 1:24000 scales from county records. From the three base layers, the remaining layers were created/ reclassified to model the basin using the SDSS. The soils in the watershed are primarily the Tarrant soil series, which has a high clay content. The basin has been monitored by the USGS since 1966. Unfortunately, the water quality data were sampled once every 90 days. Hence, only the simulated runoff outputs were compared to the USGS average daily flow records.

Table 4 shows the simulated versus observed runoff flow and their mean values for 13 storms that were modeled using the SDSS. The runoff values at the outlet of the watershed were generally underpredicted. One of the reasons attributed to the underprediction was that the rainfall was assumed by the model to be uniform across the watershed. However, in this application, only one weather station was located near the outlet of the watershed. Of the events simulated, the model tended to underpredict during the winter season and either overpredict or more closely predict values during the summer season (see Table 4). The R^2 of observed and simulated runoff was 0.64, and the slope of the regression line was 0.588. The standard deviations of measured and predicted runoff were 4.86 mm and 3.56 mm, respectively.

TABLE 4. Observed and Simulated Runoff Results for the Upper Seco Creek Watershed.

Date	Rainfall (mm)	AMC	Runoff	
			Observed (mm)	Predicted (mm)
09/14/90	40.6	I	0.07	0.01
05/02/91	59.4	I	4.69	0.26
07/21/91	51.1	I	0.87	0.09
11/17/91	38.1	II	1.51	0.77
12/19/91	53.1	II	1.74	2.10
12/20/91	52.6	III	17.60	9.74
01/26/92	39.1	I	1.76	0.01
02/03/92	47.8	II	2.63	1.60
03/03/92	29.2	I	0.16	0.01
03/04/92	39.1	III	7.25	4.08
03/27/92	84.3	I	6.82	1.46
06/07/92	41.9	III	2.66	5.73
06/09/92	52.1	III	8.51	9.94
Mean			4.33	2.74

The Antecedent Soil Moisture Condition (AMC) has significant influence on the runoff prediction, and it is difficult to observe the runoff from an individual storm when the duration is more than a day. In addition, the base flows were also included in the observed data. There could be a better match between observed and simulated if the base flow from individual storms was removed and then compared. The purpose of this application was to demonstrate the capabilities of the SDSS using existing spatially distributed data and not to validate the AGNPS model.

One of the major advantages of the SDSS is its capability to simulate several hundred scenarios within a short time. In this application, a lack of monitoring of all the constituents at the outlet and at various locations within the watershed prevented performing a detailed validation of the AGNPS model.

The concept of spatially distributed modeling is evolving and more careful monitoring has to be planned to validate spatial predictions. However, the integrated system presented is intended for the comparison of management and land use practices, and it is likely that the users will often make only a best estimate of the prevailing conditions for a single event.

Figures 4 and 5 show the sample outputs from the *Visualization Tool*, described schematically in Figure 3. Figure 4 shows the sediment movement results of the December 20, 1991, event. The upper three windows show simulated erosion, deposition and yield movement within the watershed. The right most window on the top row shows the soils layer for the watershed. The bottom two windows in Figure 4 show the input and output statistics of cell 4494 (see Figure 4) from the AGNPS model. The ASCII window shows the sediment delivered to the outlet of the watershed and particle size distributions of the sediment. The information, as shown in Figure 4, helps managers spatially identify problem areas and can help them understand the causes by providing information about the model inputs. Once problem areas are identified, land use, management, and structural practices can be proposed to rectify them, and the practices' effectiveness can be simulated using the decision support tool. In Figure 5, two simulation results were compared and displayed. For the same event, the outputs due to range and crop conditions were simulated and the runoff outputs were displayed. The bottom two windows show average statistics for a selected area in one of the top row windows for both simulations. The bottom right two windows show the difference in runoff for the current (range condition) and the selected (cropped condition) land uses. It is believed that the *Visualization Tool* will be a powerful tool for assisting decisionmaking processes by manipulating and displaying NPS pollution model input and output data graphically in a quick and easy manner.

SUMMARY AND CONCLUSIONS

A spatial decision support system (SDSS) was developed that consists of input, output (*Visualization*), and simulation model components. The SDSS is a loosely integrated system using the AGNPS (AGricultural NonPoint Source) pollution model and the GRASS GIS tool. Several additional GIS tools were developed that can be used either to derive inputs or visualize outputs of various nonpoint source pollution models, including AGNPS. The SDSS can be used to assist with management of runoff, erosion, and nutrient movement in agricultural watersheds.

A Spatial Decision Support System for Assessing Agricultural Nonpoint Source Pollution

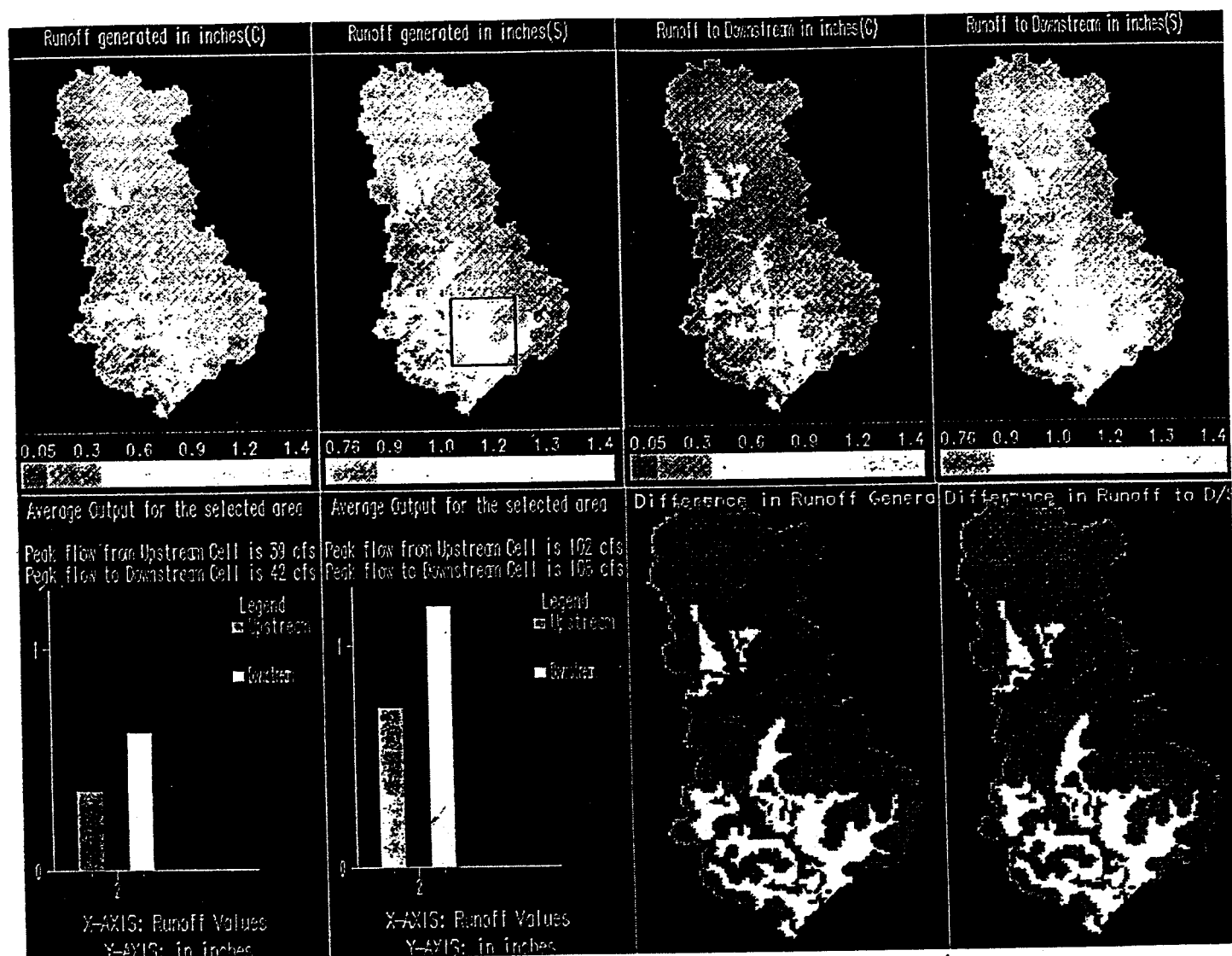


Figure 5. Runoff Output Screen of Two Scenarios in Visualization Tool for Seco Creek Watershed.

The integrated system assists with development of AGNPS input from GIS layers, running of the model, and interpretation of the spatially varying results. The system is currently being evaluated on numerous watersheds within the United States, Portugal, and Australia, and preliminary results suggest that the integrated GIS/AGNPS model significantly reduces the time required to obtain the data needed by AGNPS, simplifies operation of AGNPS, and most importantly, allows the identification of problem areas very quickly. Once problem areas are identified, land use, management and structural practices can be proposed to rectify them, and the practices' effectiveness can be simulated using the decision support tool. The

SDSS was applied to the Seco Creek, Texas, watershed and simulated runoff values were compared with the observed values.

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