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VALIDATION OF AGNPS FOR SMALL WATERSHEDS USING AN INTEGRATED AGNPS/GIS SYSTEM[1]

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ABSTRACT: The AGNPS (AGricultural NonPoint Source) model was evaluated for predicting runoff and sediment delivery from small watersheds of mild topography. Fifty sediment yield events were monitored from two watersheds and five nested subwatersheds in East Central Illinois throughout the growing season of four years. Half of these events were used to calibrate parameters in the AGNPS model. Average calibrated parameters were used as input for the remaining events to obtain runoff and sediment yield data. These data were used to evaluate the suitability of the AGNPS model for predicting runoff and sediment yield from small, mild-sloped watersheds.

An integrated AGNPS/GIS system was used to efficiently create the large number of data input changes necessary to this study. This system is one where the AGNPS model was integrated with the GRASS (Geographic Resources Analysis Support System) GIS (Geographical Information System) to develop a decision support tool to assist with management of runoff and erosion from agricultural watersheds. The integrated system assists with the development of input GIS layers to AGNPS, running the model, and interpretation of the results.

(KEY TERMS: agricultural hydrology; erosion, sedimentation; modeling/statistics; simulation; surface water hydrology.)

INTRODUCTION

Excessive runoff and soil erosion, and the associated nonpoint source pollution, have been serious problems for several years. Numerous models have been developed to predict runoff, erosion, and sediment and pollutant transport from field slopes and watersheds under various management regimes. Some of these models are watershed scale distributed parameter simulation models that require large input data bases because of the aerial distribution of parameters. Recently, researchers have adapted geographic information systems (GIS) to hydrologic and water quality modeling. If geographically distributed model parameters can be obtained from GIS data layers, considerable effort can be saved in the development of data bases for simulation. Thus, the ability to calibrate and validate model results to specific measured watershed results should be improved. Successive runs of a model, changing one or more parameters each time, would be more efficient when the characteristic of identical areas in a watershed can be easily changed in a GIS data layer. Thus, numerous simulation runs can be made with several known rainfall events, and the resulting data compared with measured runoff and sediment yield.

The objective of this study was to validate the AGricultural NonPoint Source (AGNPS) (Young *et al.*, 1989) model for small mild topography watersheds in East Central Illinois. The study was accomplished using the AGNPS model, the GRASS (Geographical Resources Analysis Support System) GIS, AGNPS-GRASS input/output interface tools developed by Srinivasan and Engel (1991a, b, c) and four years of rainfall, runoff, sediment yield, topographic, and land use data from seven small watersheds in East Central Illinois.

MODELS

Several models are being used for the prediction of sediment yield or nonpoint source pollution from fields and small watersheds. These models range from

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simple empirical models with geographically lumped parameters to geographically distributed models with algorithms that define physical phenomena as well as possible. CREAMS (Chemicals, Runoff and Erosion from Agricultural Systems) (Knisel, 1980) is a slope profile model that describes the field and its parameters in several overland segments. SWRRB (Simulator for Water Resources in Rural Basins) (Williams *et al.*, 1985) is a model in which the watershed may be divided into a number of homogeneous fields that drain into one or more channels; this model is a total storm rainfall event model. ANSWERS (Areal Nonpoint Source Watershed Environmental Response Simulation) (Beasley *et al.*, 1980) and AGNPS (Young *et al.*, 1989) are spatially distributed grid models with model parameters for each grid. AGNPS is a single event total storm model and ANSWERS is a single event model described with break point rainfall. AGNPS was originally developed for use in Minnesota, but has been expanded for use worldwide.

AGNPS Model

The AGNPS model was developed to analyze nonpoint source pollution in agricultural watersheds. This model uses a distributed parameter approach to quantify a watershed by dividing the area into square grid data units within geographic areas. Runoff characteristics and transport processes of sediment and nutrients are simulated for each cell and routed to the outlet. Thus, flow, erosion, and chemical movement at any point in the watershed may be examined. Upland sources contributing to a potential problem can be identified and locations can be prioritized for remedial action to improve water quality most efficiently. Runoff is predicted using the Soil Conservation Service (SCS) runoff curve method. Sediment yields are predicted using a modified version of the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978). Nutrient movement components have been adapted from the CREAMS model (Frere *et al.*, 1980). Chemical transport calculations are divided into soluble and sediment-absorbed phases. AGNPS can be used for watersheds up to 20,000 ha. in size with element size of 0.4 to 16 ha. The model is available for use on personal computers, but can also, with slight modifications, be run on UNIX work stations. The model has been used in many locations to prioritize watersheds for potential water quality problems. The AGNPS inputs required for each cell are shown in Table 1.

The distributed parameter approach of this model preserves spatial characteristics and makes it appropriate to use a GIS system for storage of those spatial characteristics. Thus, the characteristics of raster GIS storage, retrieval, and manipulation can be used effectively with the AGNPS model. The AGNPS model was chosen for this study because it had been linked to a GIS system for ease of data entry.

Several researchers have linked the AGNPS model with various GIS or terrain description methods. Panuska *et al.* (1991) used a terrain analysis method to interface with the AGNPS model. They developed two terrain-enhanced versions of the AGNPS model and tested these enhancements using five storms from a small watershed near Treynor, Iowa.

Feezor *et al.* (1989) used an ARC/INFO GIS system to develop AGNPS input files on an individual basis for the study of a watershed in western Illinois. Olivieri *et al.* (1991) developed a method for automatic generation of most data required by the AGNPS model, using Landsat imagery, soils maps, and USGS topographic maps with an ERDAS (Erdas, 1990) GIS system. Hession *et al.* (1989) linked the Virginia GIS (VIRGIS) with the AGNPS model. They accomplished preliminary model validation using three years of field data for a 1157 ha. watershed in Virginia. Line

TABLE 1. AGNPS Cell Input Requirements.

Cell Number	Cell into which it drains	SCS curve number
Average slope (percent)	Slope shape factor	Average slope length
Average channel slope	Slope length factor	Mannings *n* for channel
USLE K factor	USLE C factor	USLE P factor
Surface condition constant	Overland flow direction	Soil texture
Fertilization level	Fertilizer incorporation	Point source indicator
Gully source level	Chemical oxygen demand factor	Impoundment factor
Channel indicator		

and Coffey (1992) described using the output from the AGNPS model as a data source for GIS description of the results, thus visually defining the areas within a watershed that are critical from the standpoint of the pollutant loss under consideration.

Srinivasan and Engel (1991b, c) have developed a GIS linkage to the AGNPS model for both input and output. This interface was selected for use in this study because of its development for general use at the time this study was initiated and because it was available for a commonly used GIS work station.

AGNPS-GIS Interface

The AGNPS-GIS interface was developed as a GRASS GIS tool with programs written in the C language (Srinivasan and Engel, 1991b, c). GRASS uses a raster format to represent stored data. A tool box rationale was used to provide a collection of GIS programs to assist with model data development and analysis in integrating AGNPS and GRASS (Engel *et al.*, 1993). The basic GIS layers required for input are (1) watershed boundary, (2) soils, (3) elevation (or contour map from which digital elevation may be derived), and (4) field boundaries. From these basic four GIS layers, all 22 input parameters for the AGNPs model are obtained either by using GRASS routines or by reclassifying one of the original GIS layers. For instance, the USLE K factor, percent sand, percent clay, and hydrologic soil group are obtained by reclassifying the soils map GIS layer. The SCS curve number is obtained using a GRASS tool with other GIS layers of information available (Srinivasan and Engel, 1991a).

An AGNPS-GIS output/visualization tool is also available that provides GIS layers for 19 different parameters. A summary of the results at the watershed outlet is also available as text file hard copy. The GIS output layers are intended to be used in planning studies to determine locations within a watershed that are critical in the contribution of pollutants.

PROCEDURE

The Watersheds

Two watersheds with nested subwatersheds on the University of Illinois Allerton farms near Monticello, Illinois, were monitored for rainfall, runoff, and sediment concentration during 1980 through 1983. The watersheds are mildly sloping and were predominantly row-cropped in those years. Watershed 1A contains three nested subwatersheds – 1A1, 1A2, and 1A3; and watershed 1B contains two nested subwatersheds – 1B1 and 1B2. A topographic map of those watersheds is presented in Figure 1. Specific characteristics of the watersheds and subwatersheds are presented in Table 2. Soil types on the watersheds are primarily Drummer silty clay loam and Flannagan silt loam with a small amount of Sunbury silt loam (SCS Hydrologic Soil Group B). A map taken from a soil map of the watersheds is presented in Figure 2 and the distribution of those soils within each watershed is given in Table 2. Values for soil parameters required in the AGNPS model were determined from the soil survey data for those soils.

The land was cropped as defined by the field boundaries illustrated in Figure 2. The crops varied within those field boundaries, but were primarily corn or soybeans, except for the area south of the property boundary at the watershed outlets which has been in grass since 1949. A good record of all management operations on these fields was available from the farm manager. Thus, the management practices, nutrient levels, and fertilizer incorporation levels were available for each storm runoff event date.

Runoff Events

Twenty-nine rainfall events provided 94 monitored station-runoff events. However, not all of these 94 station-runoff events were of sufficient size to use in calibration and validation of a model. In fact, none of the monitored events from watershed 1B2 were large enough to use in this study. For each watershed, the monitored runoff events were placed in rank order by total sediment yield. Every other event was used for calibration and the remaining events were used for validation. After eliminating those events too small to provide useful results with the model, 50 station events remained to be used for calibration and validation of the model. These events happen to be arranged so that 25 events were used in calibration and 25 events were used for validation.

GIS Data

The information displayed in Figures 1 and 2 were manually digitized to provide basic GIS layers for watershed boundary, topographic (contour) information, soils, and field boundaries. The watershed boundaries were used to define the extent of the area under consideration and provide a boundary for the creation of model cells. Because of the small size of these watersheds, GIS data layers were created using

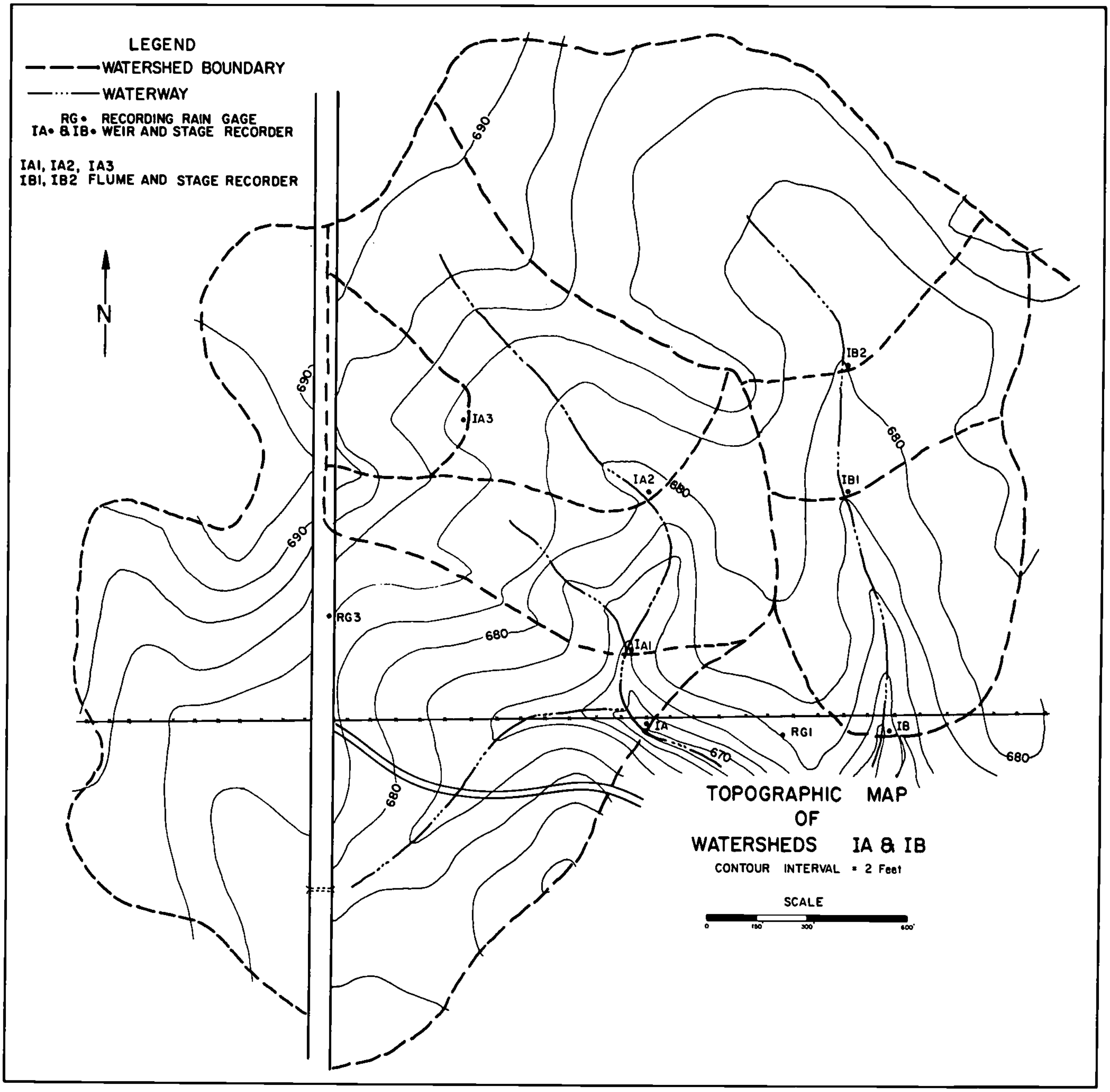

Figure 1. Topographic Map of the Allerton Watersheds.

a pixel size that represented 2 meters by 2 meters on the watershed. The digitized contour map was transferred into a digital elevation map which was used with GRASS routines to obtain aspect and average slope length descriptions. The soils map GIS layer was further classified as described earlier in this paper. The field boundary GIS layer was reclassified to define parameters having to do with cropping and management.

The AGNPS model further requires five watershed parameters which are watershed name, rainfall amount, erosivity index for the rainfall event, area of each cell, and the outlet cell number. The AGNPS-GIS interface determines the outlet cell number. Rainfall had been measured at the watersheds with a recording raingage from which breakpoint rainfall was extracted. Rainfall erosivity, as well as total rainfall for each storm, was computed from these breakpoint data.

TABLE 2. Characteristics of the Allerton Watersheds.

Watershed	Drainage Area (ha)	Average Slope (percent)	Percent in Each Soil Type: Drummer scl	Flannagan sl	Sunbury sl	Percent in Row Crop: 1980-1982	1983
1A	30.4	1.47	16	72	12	82	67
1A1	12.1	1.48	18	82		100	66
1A2	7.3	1.35	17	83		100	80
1A3	1.6	2.12	9	91		100	100
1B	18.2	1.15	36	53	11	99	34
1B1	13.4	1.00	42	58		100	31
1B2	10.2	1.01	42	58		100	26

AGNPS Sensitivity

Young *et al.* (1987) reported on the sensitivity analysis for predicted sediment yield using the AGNPS model. Of the parameters reported in that study, several of the most sensitive were not available for adjustment during the calibration procedure of this study because they were known or measured parameters. For instance, rainfall erosivities were obtained from rainfall records for each event. Land slope is a known quantity from the topographic map. Field slope length, although an arguable quantity, is not an extremely sensitive parameter with regard to sediment yield. The USLE K factor is a known value if one accepts the published values in the soil survey.

The USLE P factor was known because straight row cropping management was used all years. The SCS curve number was obtained using the curve number tool kit within GRASS that computes curve number based on the soil hydrologic group, antecedent rainfall, and crop condition. It was discovered later that antecedent moisture condition was the most sensitive parameter for these watersheds. Channel slope and channel side slope were only needed for a short section of the larger watersheds and were not sensitive parameters. The USLE C factor, which was reported to be a very sensitive parameter, was obtained for each field using a computer version of the Revised USLE (Renard and Weesies, 1990). This routine requires previous and present land use information to determine the C factor. Thus, the C factor used initially in the calibration was based on the best available information.

Calibration

Watershed 1B was used for the first set of calibrations because it has a single channel and, thus, should be easy to observe while learning the significance of parameter changes within the AGNPS model and the GIS tool kit linkage. During the initial calibration runs of watershed 1B, GIS cell sizes were varied from 20 x 20 meters to 80 x 80 meters. These calibration runs showed that the 20 x 20 meters cell size provided best simulations of peak runoff rate and sediment yield. Perhaps smaller cell sizes would have created even better simulations; however, computing time was also a consideration.

USLE C factors were varied upward or downward as required. A channel was included or excluded, but only marginally improved the simulation of peak runoff rate and sediment yield except for three events on watershed 1A where observed peak runoff rate was large and the inclusion of a channel increased peak runoff rate. Usually, inclusion of the channel increased peak flow rate greater than was required, but did not increase sediment yield. Varying the length of the channel had little effect.

Several attempts at adjusting slope length when slope was zero were used to determine that the best setting for these conditions was 0.3 meter slope length for a border cell slope of zero. Four different average slope estimation algorithms were attempted; there were no significant differences between the four methods; thus, the simplest method was used.

Forty-two different simulation attempts were conducted on one storm for the 1B watershed. That was followed by 32 simulation exercises with the remaining three rainfall events. Twenty-four separate calibrations were conducted using the four rainfall events on watershed 1B1. The 1A watersheds included the following simulation runs and rainfall event numbers: 1A, 38 simulations with five events, 1A1, 17 simulations with seven events; 1A2, 18 simulations with four events; 1A3, five simulations with one event. The best simulation for each rainfall event for each watershed is listed in Table 3 which contains the watershed name and size, the rainfall precipitation and erosivity; the observed runoff depth, peak runoff rate, and sediment yield; the five-day antecedent rainfall amount and the antecedent moisture condition number used in the model simulation; as well as the

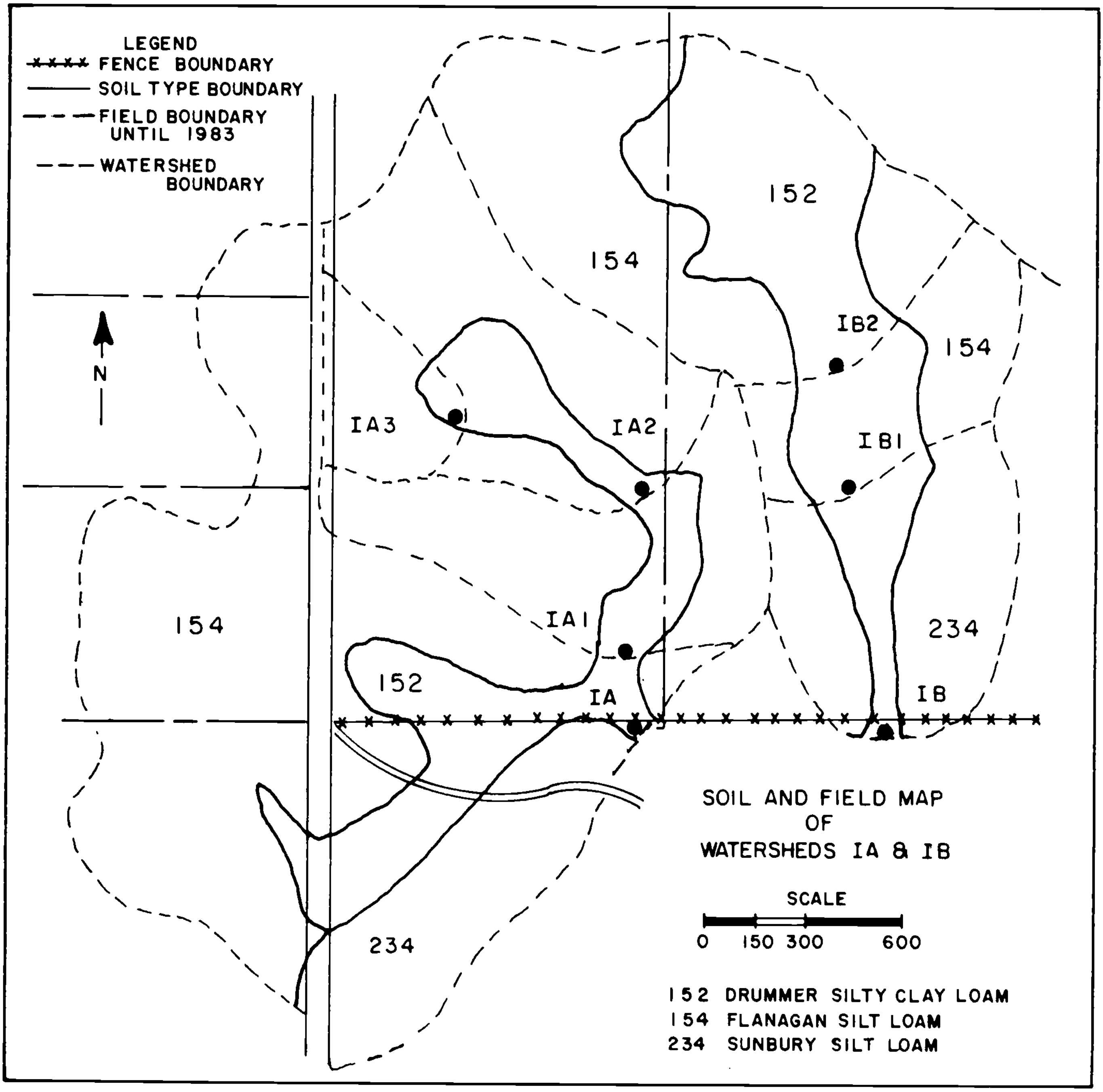

Figure 2. Soils and Field Boundary Map of the Allerton Watersheds.

runoff depth, peak runoff rate, and sediment yield results from the model simulation.

Adjustments in C factor had little effect on sediment yield. In fact, very few parameter adjustments had significant effect on peak runoff rate or sediment yield, except antecedent moisture condition (AMC) for the SCS runoff equation. One may note, looking at the five-day antecedent rainfall and the AMC used for the best simulation, that the dividing line for these are not the boundaries usually used for antecedent moisture conditions. It appeared that the best division for antecedent conditions for these watersheds was AMC 1 < 12 mm of five-day antecedent rainfall < AMC 2 < 41 mm < AMC 3.

TABLE 3. Observed and Simulated Data for Calibration Storms on Allerton Watersheds.

		Storm			Observed				Simulated			
WS	Drainage Area (ha)	Date	Five-Day Antec. Rain (mm)	Precip. (mm)	EI (MJ-m ha-h)	Runoff (mm)	Peak Runoff Rate (cum/sec)	Sed. Yield (Mg)	SCS AM	Runoff (mm)	Peak Runoff Rate (cum/sec)	Sed. Yield (Mg)
1A	30.4	7/02/82	21	134	1691	57	1.633	84.93	2	69	3.625	53.43
		6/15/81	41	27	293	7	1.307	13.81	3	10	0.934	15.60
		8/14/81	7	68	918	14	0.682	8.72	1	5	0.623	10.98
		7/27/81	11	53	463	4	0.269	1.15	1	3	0.255	2.27
		5/21/83	21	22	79	1	0.382	4.30	2	0	0.085	2.99
1A1	12.1	5/21/83	21	22	79	8	0.200	11.21	3	5	0.198	0.91
		4/29/83	31	120	895	21	0.312	19.39	2	56	1.388	5.53
		5/18/83	35	21	123	3	0.051	2.44	3	5	0.142	0.82
		5/17/81	58	31	290	16	0.133	11.87	3	13	0.368	2.90
		7/02/82	21	134	1691	1	0.193	10.92	1	41	1.048	7.71
		7/04/81	0	113	1632	12	0.238	8.03	1	28	0.736	5.72
		6/21/81	3	25	195	5	0.193	5.95	2	3	0.085	0.64
1A2	7.3	7/04/81	0	113	1632	6	0.058	6.72	1	28	0.510	8.62
		6/28/83	0	94	1621	3	0.118	3.85	1	15	0.311	5.17
		5/30/82	42	65	715	8	0.082	2.42	1	8	0.142	3.36
		5/21/83	21	22	79	1	0.059	0.94	2	0	0.028	1.09
1A3	1.6	7/02/82	21	134	1691	15	0.001	0.35	1.	43	0.255	5.26
1B	18.2	7/04/81	0	113	1632	21	0.726	17.41	1	30	0.991	15.97
		6/21/81	3	25	195	5	0.389	8.10	2	15	0.538	10.25
		5/17/81	58	31	290	13	0.226	1.53	2	5	0.255	1.81
		8/14/81	7	68	918	6	0.136	0.56	1	8	0.311	2.09
1B1	13.4	5/17/81	58	31	290	6	0.063	1.20	2	5	0.170	3.90
		6/15/81	41	27	293	2	0.074	1.33	2	3	0.113	3.36
		8/14/81	7	68	918	3	0.051	2.37	1	8	0.283	5.90
		4/29/83	31	120	895	5	0.205	1.60	2	30	0.878	1.00
					MEAN	**10**	**0.311**	**9.25**		**17**	**0.571**	**7.09**

VALIDATION

The runoff events not used for calibration for each watershed were used for validation. The events used, the observed event characteristics, and the simulated results are presented in Table 4. The 20 x 20 meters AGNPS cell size was used. USLE C factors were as obtained from the Revised USLE computer routine. A channel was not included; the calibration runs provided mixed results with channel and, although short waterways were present for about 100 m at the outlet of each large watershed, there were not well defined channels in the watersheds.

The AMC division determined during the calibration runs was used. All other parameters were as the recorded soils and cropping-management system dictated.

The results of a paired comparison of the observed and simulated runoff, peak runoff rate, and sediment yield for the validation events are presented in Table 5. These three simulation results are not significantly different at the 95 percent confidence level. However, it is well to note that the standard deviation of the difference between pairs is greater than the mean of either the observed or simulated characteristics (Table 5). Also, examination of the observed and simulated characteristics indicates a poor simulation of the real event. Thus, one must question the validity of the paired comparison in this instance.

The results of a paired comparison of the observed and simulated runoff, peak runoff rate, and sediment yield was also conducted for the calibration event (Table 5). Although the best calibration simulation was selected before moving to another event, the statistics for the paired comparison would indicate the validation simulations were closer to the observed data than were the best calibration simulations.

TABLE 4. Observed and Simulated Data for Validation Storms on Allerton Watersheds.

		Storm			Observed				Simulated			
WS	Drainage Area (ha)	Date	Five-Day Antec. Rain (mm)	Precip. (mm)	EI (MJ-m ha-h)	Runoff (mm)	Peak Runoff Rate (cum/sec)	Sed. Yield (Mg)	SCS AM	Runoff (mm)	Peak Runoff Rate (cum/sec)	Sed. Yield (Mg)
1A	30.4	5/17/81	58	31	290	9	0.336	16.49	3	10	1.019	12.07
		6/12/81	19	27	344	6	1.439	13.63	2	3	0.255	2.18
		6/21/81	3	25	195	5	0.868	5.90	1	0	0.000	0.00
		6/28/83	0	94	1621	16	2.054	1.46	1	13	1.303	14.70
1A1	12.1	6/28/83	0	94	1621	11	0.414	13.34	1	13	0.396	2.09
		5/21.83	21	22	79	8	0.200	11.21	2	0	0.028	0.27
		4/12/83	13	43	104	16	0.150	10.55	2	10	0.283	2.27
		6/15/81	41	27	293	6	0.219	7.14	2	3	0.113	0.82
		5/30/82	42	65	715	13	0.186	3.41	3	43	1.104	7.71
		5/13/81	82	34	12	9	0.099	0.96	3	15	0.425	3.18
1A2	7.3	4/12/83	13	43	104	8	0.056	6.23	2	10	0.198	4.26
		6/21/81	3	25	195	2	0.058	2.52	1	0	0.000	0.09
		6/15/81	41	27	293	3	0.065	1.90	2	3	0.085	1.91
		6/13/81	46	14	61	1	0.029	0.83	3	3	0.085	2.00
1A3	1.6	6/28/83	0	94	1621	1	0.004	0.30	1	15	0.113	1.91
		5/30/82	42	65	715	7	0.009	0.25	3	43	0.255	5.08
		6/02/80	33	14	50	2	0.004	0.20	2	0	0.000	0.09
1B	18.2	6/12/81	19	27	344	6	0.492	12.53	2	3	0.142	1.00
		6/15/81	41	27	293	9	0.656	1.70	3	10	0.396	2.54
		5/10/81	36	71	115	2	0.023	1.30	2	28	0.906	4.81
		5/13/83	9	29	129	0	0.019	0.40	1	0	0.000	0.09
		7/27/81	11	53	463	1	0.019	0.16	1	3	0.142	1.09
1B1	13.4	4/08/83	5	13	25	7	0.078	1.80	1	0	0.000	0.00
		7/02/82	21	134	1691	15	0.096	1.43	2	76	1.897	3.54
		7/04/81	0	113	1632	5	0.121	1.22	1	25	0.736	1.91
					MEAN	**7**	**0.308**	**4.67**		**13**	**0.395**	**3.02**

TABLE 5. Summary of Results of a Paired Comparison Between Observed and Simulated Runoff and Sediment Yield.

	Difference		
Characteristic	Mean	Standard Deviation	Prob > | t |
VALIDATION EVENTS			
Runoff, mm	6.3	16.5	0.066
Peak Runoff Rate, m^3/sec.	0.088	0.603	0.474
Sediment Yield, Mg	−1.65	6.00	0.1812
CALIBRATION EVENTS			
Runoff, mm	7.7	13.2	0.008
Peak Runoff Rate, m^3/sec.	0.260	0.486	0.013
Sediment Yield, Mg	−2.15	7.57	0.168

TIME CONSIDERATIONS

A major concern when planning a GIS or modeling effort is the time and effort involved. The time spent on this study by the senior author was recorded and is presented in Table 6. These times do not include time spent learning AGNPS, GIS systems in general, and the GRASS-GIS system specifically, which were considerable.

TABLE 6. Database Development and Simulation Time Requirement.

Activity	Hours
Digitizing and Rasterizing Allerton Data	99
Allerton Data Accumulation to Run AGNPS	103
Simulations (227)	54
TOTAL TIME FOR AGNPS TESTS	256

The time digitizing and rasterizing Allerton data (99 hours) was actually for a larger area. The watersheds used for this calibration were within a 158 ha watershed and adjacent to a 26 ha watershed; both were monitored for runoff, but not sediment yield. Elevation (contour lines), watershed boundaries, soils, and field boundaries were digitized for the approximately 200 ha area and entered into an ERDAS system for rasterizing. Conversion to the GRASS system was then made. The Allerton data were in good to excellent archival condition. However, numerous additional computations had to be made to accumulate parameters for the model. These data manipulations and rearrangements took approximately 103 hours.

Simulations were conducted in an intensive one week session (54 hours) at the Agricultural Engineering Department, Purdue University, Computer and GIS Laboratory. A total of 227 simulations were made which consisted of 176 calibrations, 25 validations, 22 post-validations, and four runs for pictures.

The total time for the entire simulation study was 256 hours. Data accumulation and organization accounted for 79 percent of the effort. This compares favorably with other systems that indicate database development to be 60 to 76 percent of the project costs (Goodchild and Kemp, 1991; Water Cycle Concepts, 1991).

CONCLUSIONS

Paired comparison of the validation events indicates that the AGNPS model with the GRASS-GIS linkage is acceptable in simulating runoff, peak runoff rate, and sediment yield from the Allerton watersheds. However, as noted previously, a closer look at the data causes one to question that conclusion. Young *et al.* (1989) reported some preliminary testing of peak runoff rate with data from 20 different watersheds and of sediment yield from three watersheds. The predicted vs. observed graphs they presented indicate data somewhat scattered, but well placed along a 1:1 slope. However, a close look at the graphs of Young *et al.* (1989) reveals that the data of this study would fall in the lower 3 percent of the peak runoff rate values and less than 1 percent of the sediment yield values. Thus, this study was with much smaller watersheds than those used in the graphical presentation. Also, Young *et al.* (1989) presented application examples using large watersheds in topography described as 'hilly and rolling.' Bingner *et al.* (1989) presented the results of testing AGNPS with three small watersheds that indicated variable results. Simulated total annual runoff varied from 65 percent to 151 percent of observed and simulated total annual sediment yield varied from 29 percent to 557 percent of observed. One of these watersheds was of mild topography, but the rest were greater slopes than the Allerton watersheds.

The Allerton watersheds may well have slopes that are less than the algorithms of AGNPS can describe well or are smaller than should be simulated with AGNPS. Certainly the mild slope was a factor in precision of the simulations. It was obvious during calibration run adjustments that the watersheds were transport limiting because doubling (or halving) the USLE C factor had little or no effect on sediment yield. However, adjusting AMC, hence, adjusting SCS Curve Number, resulted in a significant change in runoff, peak runoff rate, and sediment yield.

Despite these simulation problems, the AGNPS model is a valuable tool to analyze nonpoint source pollution in agricultural watersheds. Further improvements in accuracy and applicability are recommended. The GRASS input and output linkage to the AGNPS model has significantly enhanced model effectiveness.

Time considerations point out that one must be willing to expend considerable effort when developing a data base for GIS and modeling. However, because data layers with different attributes can be easily created from a base data layer, the time savings for data entry into a distributed model may offset the data base time commitment.

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