5.9 INFORMATION EXTRACTION FROM A SOILS AND TERRAIN DIGITAL DATABASE

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5.9.1. Introduction.

The complexity and increasing volumes of available information, and the demand for the storage, analysis and display of large quantities of environmental data, has led in recent years to rapid development in the application of computers to environmental and natural resources data handling, and the creation of sophisticated information systems (Tomlinson et al., 1976). Increasingly data of all types are being collected and converted to digital format. Extensive digital geographically oriented databases are being developed, and automated spatial information systems are used for storage, retrieval, manipulation, analysis and display of information (Tom and Miller, 1975; Knapp, 1978; Jerie et al., 1980; Marble and Peuquet, 1983). Effective utilization of large spatial data volumes is dependant upon the existence of an efficient geographic handling and processing system that will transform these data into usable information. The major tool for handling spatial data is the geographic information system (Marble and Peuquet, 1983).

A digital geographic information system (GIS), is a computerized system designed to store, process and analyse spatial data and their corresponding attribute information. Advances in computer technology and techniques have made it possible to integrate a wide range of information (Gribbs, 1984). Technological advances have increased input techniques, storage, analysis and retrieval capabilities. Furthermore, there has been a reduction in costs and an increase in accessibility, so that a larger user community has developed (Moellering, 1982). Geographic information systems have provided planners with a readily accessible source of objective earth-science-related facts and an inexpensive, rapid and flexible tool for combining these facts with various other products to create decision alternatives (van Driel, 1975; Stow and Estes, 1981; Stoner, 1982).

Basic information on the location, quantity and availability of natural resources is indispensable for planning more rationally their development, use and/or conservation. The demand for specific, accurate, and rapid soil information is growing in our modern society. Soils, because of their importance in agricultural and non-agricultural matters, and their inherent relationships with other environmental resources are a basic and fundamental component of any complete geographic information system. Johnson (1975) points out that the conventional preparation of soil interpretive maps combining information of the soil resource with other resource information are excessively expensive, especially if various source maps have to be converted to a common scale, and if the interpretive requirements are complex. Automatic data processing systems have created immense opportunities for storing and disseminating soil data (Bertelli, 1979). As the demand for interpretive maps increases, computers are used to speed up and cut down costs of the processes (Bertelli, 1966; Shields, 1976; Bertelli, 1979; Bie, 1980; Valenzuela, 1985). The national Soil Handbook of the USDA Soil Conservation Service (1983), indicates that computer generated interpretive maps are encouraged where the soil survey has been digitized, because they cost less than maps perpared by other means.

5.9.2 Methodology.

The digital geographic information system used for this study basically consists of five major subsystems: 1.- Input subsystem; 2.- Database subsystem; 3.- Management subsystem; 4.- Modelling and analysis subsystem, and 5.- Output subsystem.

The soil association map of Indiana, U.S.A., was prepared by the Indiana soil survey staff of the United States Department of Agriculture Soil Conservation Service and Purdue University Agricultural Experiment Station and made available to users as publication AY 209, at a scale of 1:500,000 in 1980.

The soil association map was digitized using the Purdue/LARS digitizing system. The system is composed of a Talos table digitizer and an APPLE II Plus microcomputer. A complete documentation of this menu-driven system was prepared by Phillips (1983). The data capture consisted of the transformation of three (3) map primitives, i.e., control points, boundaries (limits of soil units), and centroids, into a format compatible with digital computers. After the process of data capture was completed, the computer compatible data were transferred from the APPLE II Plus microprocessor to the host (main) computer (IBM 360/158), where the data were stored and the activities of editing, coordinate transformation and rasterization were performed. Editing the data was accomplished by manual and automatic editing routines using a Tektronics 4054 graphics terminal. Twelve (12) control points were used to derive statistically a biquadratic regression model required to transform the digitized X and Y values into longitude and latitude geographic coordinates. These data were subsequently transformed into an Albers equal-area cartographic projection.

The final step in the map input procedure was the rasterization process. During this process, the boundary and centroid files stored in addresses corresponding to the Albers cartographic projection, were converted into an image file. The map units were filled-in cells according to a predefined grid (500 m x 500 m on the ground, or, 1mm x 1 mm on the map), and subsequently each cell was assigned with a class code (0 to 255) associated with the centroid file. The codes (fill characters) assigned to each of the 55 soil associations present in the map and to the portion of Lake Michigan in Indiana are shown in Table 5.9.1.

For the construction of the attribute database (hierarchical), extensive use was made of the available information generated for the state soil associations of Indiana (Galloway et al., 1975). Other information not readily available in tables or maps, were obtained by generalization of the information present in the description of the soil series forming each soil association (Galloway and Steinhardt, 1981; Franzmeier and Sinclair, 1982). Information generated by visual and digital interpretations of LANDSAT data from Indiana were also used. Figure 5.9.1 illustrates a LANDSAT mosaic covering the whole state.

For display purposes and generation of color outputs of the computer generated interpretive soil maps, the rasterized image file was transfered to the image processing device IBM 7350 (HACIENDA).

5.9.3 Results.

Once the input of the data is completed and the rasterized data set and their attribute information are stored in the database, this spatial information can be easily retrieved, handled, analysed and displayed. The degree of the analytical capabilities implemented in a system depends on the nature, purpose and objectives of the principal user. However, a well thought-out system will be one that is flexible enough to respond to the needs for input, analysis and display of different kinds of data required by the user.

In almost every digital geographic information system currently operational, one element appears to be present to satisfy the requirements of the main user. It is the element soils, depicting soil types as obtained from soil surveys. This is the result of its relation to the fauna, vegetation and climate, and its strong interaction with other natural resources elements. The nature and type of information available from a soil survey enables the generation of several interpretive soil maps. These maps can be used as new variables for analysis or modelling of resources to predict changes that may occur through time.

The soil association of Indiana in digital format displayed in the High Level Image Processing System (HLIPS) device IBM 7350 are shown in Figure 5.9.2. The area estimates and percentage of occurance of each soil association in Indiana are presented in Table 5.9.1. Soil association Crosby-Brookston present on nearly level surfaces of Wisconsin age glacial till plains in Central Indiana, constitutes the largest association covering an area of approximately 703,050 ha or 7.4% of the state. Figure 5.9.3 illustrates the parent materials from which Indiana soils were developed. It depicts the various kinds of materials, including old sedimentary rocks in the southern part of the state; different thickness of loess deposits over glacial till; alluvial, lacustrine and eolian deposits from which the soils were developed.

The potential soil erosion was calculated using the Universal Soil Loss Equation (USLE). The factors of the USLE for each soil association were estimated by Brentlinger et al. (1979). This information was used to reclassify the digital soil association map into four (4) potential soil erosion groups; Low, Medium, High and Very High. The potential soil erosion map is illustrated in Figure 5.9.4. This interpretive information can be used in conjunction with landuse/landcover data to predict the erosion hazard or gross erosion in the state. It can also be related to slope, landuse and proximity to streams to determine agricultural pollution due to erosion and to estimate sedimentation hazards, and the related dangers of floodings. The dominant drainage, as determined by the characteristics of the soil associations, is shown in Figure 5.9.5. This information is very important for the planning, design and construction of septic systems in the state.

Soil maps in Indiana are used in the assessment of agricultural potential. The basic aim of any assessment activity is the equal treatment of all individual land owners. Yahner (1979) described the procedures employed in agricultural land reassessment using stimates of corn yields. Each soil association has been assigned an estimated corn yield value. Figure 5.9.6 illustrates the corn yield estimate map of Indiana. Table 5.9.2 presents the corn yield values for each soil association. Because of the resolution (scale) of the data and the generalization involved in the creation of the soil associations, some problems and difficulties exist in the assessment of individual farms. However, it can be used to obtain rapid information on the approximate value of agricultural land. Figure 5.9.7 illustrates the soil associations depicting organic matter levels for the state of Indiana. This figure shows weighted averages of organic matter content, which were calculated taking into consideration the relative occurrence of soil series forming the soil associations, as tabulated by Galloway et al. (1985).

Figure 5.9.8 shows the digital county map of Indiana. This information was combined with the digital soil information and it was used to calculate the areas of soil associations present in each county, which is very important for planning the allocation of resources at county level. Table 5.9.3 includes the soil associations and their corresponding areas for some counties in the state.

Table 5.9.4 presents all the soil associations in the state with their respective information used to generate the interpretive maps and tabular information. The production of digital interpretive maps does not involve any changes in the original data set. It uses atribute files to regroup the original units into interpretive classes in real time. These new data (interpretive) can be used in analysis and modelling with other data sets available in the database. Figure 5.9.9 illustrates the county boundaries and the soil association original data sets, and the interpretive information generated using the analysis capabilities of the GIS.

5.9.4 References.

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Table 5.9.1 Area estimates and percentage of occurence of soil associations in Indiana.

CODE	SYMBOL	SOIL ASSOCIATIONS	AREA IN HA	PERCENT
1	A1	GENESSE-EEL-SHOALS	202,050	2.13
2	A2	FOX-GENESSE-EEL	187,825	1.98
3	A3	SLOAN-ROSS-VINCENNES-ZIPP	44,225	0.47
4	A4	STENDAL-HAYMOND-WAKELAND-NOLIN	400,000	4.23
5	A5	WHEELING-HUNTINGTON-LINDSIDE	65,800	0.69
6	B1	HOUGHTON-ADRIAN	70,600	0.74
7	B2	MAUMEE-GILFORD-SEBEWA	333,350	3.51
8	C1	RENSSELAER-DARROCH-WHITAKER	131,450	1.39
9	C2	SEBEWA-GILFORD-HOMER	30,150	0.32
10	C3	LYLES-AYRSHIRE-PRINCETON	15,600	0.16
11	D1	MILFORD-BONO-RENSSELAER	23,900	0.25
12	D2	PATTON-LYLES-HENSHAW	51,350	0.54
13	D3	ZIPP-MARKLAND-MCGARY	38,275	0.40
14	E1	TRACY-DOOR-LYDICK	91,475	0.96
15	E2	ELSTON-SHIPSHE-WARSAW	77,325	0.82
16	E3	OSHTEMO-FOX	219,100	2.31
17	E4	FOX-OCKLEY-WESTLAND	208,825	2.20
18	E5	PARKE-NEGLEY	22,175	0.23
19	F1	OAKVILLE-ADRIAN	19,450	0.21
20	F2	PLAINFIELD-MAUMEE-OSHTEMO	198,475	2.09
21	G	PRINCETON-BLOOMFIELD-AYRSHIRE	98,100	1.03
22	H	ALFORD	173,350	1.83
23	I1	RAGSDALE-RAUB	45,225	0.48
24	I2	SABLE-IPAVA	17,300	0.18
25	I3	FINCASTLE-RAGSDALE	273,700	2.88
26	I4	REESVILLE-RAGSDALE	99,050	1.04
27	I5	IVA-VIGO	62,200	0.66
28	J1	BROOKSTON-ODELL-CORWIN	155,300	1.64
29	J2	CROSIER-BROOKSTON	135,300	1.43
30	J3	CROSBY-BROOKSTON	703,050	7.41
31	K1	BLOUNT-PEWAMO	517,925	5.46
32	K2	HOYTVILLE-NAPPANEE	28,375	0.30
33	L1	PARR-BROOKSTON	102,700	1.08
34	L2	RIDDLES-TRACY-CHELSEA	13,500	0.14
35	L3	MIAMI-CROSIER-BROOKSTON-RIDDLES	387,700	4.09
36	L4	MIAMI-CROSIER-BROOKSTON	493,400	5.20
37	L5	MIAMI-HENNEPIN-CROSBY	72,475	0.76
38	L6	MIAMI-RUSSEL-FINCASTLE-RAGSDALE	490,425	5.17
39	L7	RUSSEL-HENNEPIN-FINCASTLE	67,700	0.71
40	M1	MARKHAM-ELLIOT-PEWAMO	42,950	0.45
41	M2	MORLEY-BLOUNT-PEWAMO	636,825	6.71
42	N1	BARTLE-PEOGA-DUBOIS	72,000	0.76
43	N2	WEINBACH-WHEELING	43,325	0.46
44	N3	AVONBURG-CLERMONT	135,850	1.43
45	O1	HOSMER	152,575	1.61
46	O2	ZANESVILLE-WELLSTON-TILSIT	125,100	1.32
47	O3	CINCINNATI-VIGO-AVA	246,575	2.60
48	O4	CINCINNATI-ROSSMOYNE	383,950	4.05
49	P	WELLSTON-ZANESVILLE-BERKS	461,950	4.87
50	Q1	CRIDER-BEDFORD-LAWRENCE	25,675	0.27
51	Q2	CRIDER-HAGERSTOWN-BEDFORD	284,925	3.00
52	Q3	CRIDER-BAXTER-CORYDON	63,125	0.67
53	R1	BERKS-GILPIN-WEIKERT	185,675	1.96
54	R2	CORYDON-WEIKERT-BERKS	56,725	0.60
55	R3	EDEN-SWITZERLAND	138,525	1.46
60		LAKE MICHIGAN	62,500	0.66

Table 5.9.2 Weighted average corn yield estimates for soil associations in Indiana.

SOIL ASSOCIATIONS	MAP SYMBOL	CODE	CORN*
GENESSE-EEL-SHOALS	A1	01	115
FOX-GENESEE-EEL	A2	02	106
SLOAN-ROSS-VINCENNES-ZIPP	A3	03	119
STENDAL-HAYMOND-WAKELAND-NOLIN	A4	04	116
WHEELING-HUNTINGTON-LINDSIDE	A5	05	116
HOUGHTON-ADRIAN	B1	06	120
MAUMEE-GILFORD-SEBEWA	B2	07	109
RENSSELAER-DARROCH-WHITAKER	C1	08	128
SEBEWA-GILFORD-HOMER	C2	09	109
LYLES-AYRSHIRE-PRINCETON	C3	10	121
MILFORD-BONO-RENSSELAER	D1	11	122
PATTON-LYLES-HENSHAW	D2	12	138
ZIPP-MARKLAND-MCGARY	D3	13	105
TRACY-DOOR-LYDICK	E1	14	112
ELSTON-SHIPSHE-WARSAW	E2	15	099
OSHTEMO-FOX	E3	16	091
FOX-OCKLEY-WESTLAND	E4	17	106
PARKE-NEGLEY	E5	18	082
OAKVILLE-ADRIAN	F1	19	076
PLAINFIELD-MAUMEE-OSHTEMO	F2	20	083
PRINCETON-BLOOMFIELD-AYRSHIRE	G	21	099
ALFORD	H	22	103
RAGSDALE-RAUB	I1	23	141
SABLE-IPAVA	I2	24	142
FINCASTLE-RAGSDALE	I3	25	132
REESVILLE-RAGSDALE	I4	26	130
IVA-VIGO	I5	27	126
BROOKSTON-ODELL-CORWIN	J1	28	131
CROSIER-BROOKSTON	J2	29	118
CROSBY-BROOKSTON	J3	30	117
BLOUNT-PEWAMO	K1	31	109
HOYTVILLE-NAPPANEE	K2	32	118
PARR-BROOKSTON	L1	33	123
RIDDLES-TRACY-CHELSEA	L2	34	094
MIAMI-CROSIER-BROOKSTON-RIDDLES	L3	35	107
MIAMI-CROSBY-BROOKSTON	L4	36	100
MIAMI-HENNEPIN-CROSBY	L5	37	090
MIAMI-RUSSELL-FINCASTLE-RAGSDALE	L6	38	104
RUSSELL-HENNEPIN-FINCASTLE	L7	39	086
MARKHAM-ELLIOTT-PEWAMO	M1	40	103
MORLEY-BLOUNT-PEWAMO	M2	41	097
BARTLE-PEOGA-DUBOIS	N1	42	107
WEINBACH-WHEELING	N2	43	107
AVONBURG-CLERMONT	N3	44	110
HOSMER	O1	45	093
ZANESVILLE-WELLSTON-TILSIT	O2	46	068
CINCINNATI-VIGO-AVA	O3	47	087
CINCINNATI-ROSSMOYNE	O4	48	079
WELLSTON-ZANESVILLE-BERKS	P	49	058
CRIDER-BEDFORD-LAWRENCE	Q1	50	086
CRIDER-HAGERSTOWN-BEDFORD	Q2	51	085
CRIDER-BAXTER-CORYDON	Q3	52	086
BERKS-GILPIN-WEIKERT	R1	53	041
CORYDON-WEIKERT-BERKS	R2	54	042
EDEN-SWITZERLAND	R3	55	022
LAKE MICHIGAN		60	

* = Bu/acre

Table 5.9.3 Soil associations and area estimates for some counties in Indiana.

COUNTY	CODE	SYMBOL	SOIL ASSOCIATIONS	AREA IN HA
BENTON	4			
	8	C1	RENSSELAER-DARROCH-WHITAKER	10,500
	28	J1	BROOKSTON-ODELL-CORWIN	68,725
	33	L1	PARR-BROOKSTON	24,225
	36	L4	MIAMI-CROSBY-BROOKSTON	2,700
CARROL	8			
	1	A1	GENESSE-EEL-SHOALS	8,650
	17	E4	FOX-OCKLEY-WESTLAND	18,625
	25	I3	FINCASTLE-RAGSDALE	33,800
	30	J3	CROSBY-BROOKSTON	975
	35	L3	MIAMI-CROSIER-BROOKSTON-RIDDLES	175
	36	L4	MIAMI-CROSBY-BROOKSTON	25
	37	L5	MIAMI-HENNEPIN-CROSBY	25
	38	L6	MIAMI-RUSSELL-FINCASTLE-RAGSDALE	34,125
CLINTON	12			
	23	I1	RAGSDALE-RAUB	8,100
	25	I3	FINCASTLE-RAGSDALE	17,225
	30	J3	CROSBY-BROOKSTON	28,525
	36	L4	MIAMI-CROSBY-BROOKSTON	46,600
	38	L6	MIAMI-RUSSELL-FINCASTLE-RAGSDALE	4,100
FOUNTAIN	24			
	1	A1	GENESSE-EEL-SHOALS	5,650
	15	E2	ELSTON-SHIPSHE-WARSAW	10,600
	17	E4	FOX-OCKLEY-WESTLAND	23,825
	23	I1	RAGSDALE-RAUB	7,850
	26	I4	REESVILLE-RAGSDALE	17,375
	37	L5	MIAMI-HENNEPIN-CROSBY	25
	39	L7	RUSSELL-HENNEPIN-FINCASTLE	41,625
JASPER	37			
	1	A1	GENESSE-EEL-SHOALS	200
	6	B1	HOUGHTON-ADRIAN	6,100
	7	B2	MAUMEE-GILFORD-SEBEWA	59,900
	8	C1	RENSSELAER-DARROCH_WHITAKER	35,125
	20	F2	PLAINFIELD-MAUMEE-OSHTEMO	15,200
	28	J1	BROOKSTON-ODELL-CORWIN	10,350
	33	L1	PARR-BROOKSTON	19,000
MONTGOMERY	54			
	17	E4	FOX-OCKLEY-WESTLAND	18,950
	23	I1	RAGSDALE-RAUB	6,700
	25	I3	FINCASTLE-RAGSDALE	19,600
	26	I4	REESVILLE-RAGSDALE	2,950
	33	L1	PARR-BROOKSTON	3,325
	36	L4	MIAMI-CROSBY-BROOKSTON	5,475
	37	L5	MIAMI-HENNEPIN-CROSBY	7,825
	38	L6	MIAMI-RUSSELL-FINCASTLE-RAGSDALE	64,225
	39	L7	RUSSELL-HENNEPIN-FINCASTLE	1,650

Table 5.9.4 Soil associations and corresponding interpretive information in the State of Indiana.

CODE	SYMBOL	AREA IN HA	EROSION	SLOPE	DRAINAGE	FARM	CORN	%O. M.
1	A1	202,050	1	1	1	2	3	2
2	A2	187,825	1	1	1	2	3	2
3	A3	44,225	1	1	4	1	3	2
4	A4	400,900	1	1	1	2	3	1
5	A5	065,800	2	1	1	2	3	2
6	B1	70,600	1	1	4	2	3	4
7	B2	333,350	1	1	4	1	3	2
8	C1	131,450	1	1	4	1	4	3
9	C2	30,150	1	1	4	1	3	2
10	C3	15,600	1	1	4	1	3	1
11	D1	23,900	1	1	4	1	3	3
12	D2	51,350	1	1	4	1	4	3
13	D3	38,275	2	1	3	1	3	2
14	E1	91,475	1	2	1	1	3	2
15	E2	77,325	1	1	1	1	2	2
16	E3	219,100	1	2	1	2	2	1
17	E4	208,825	2	1	1	2	3	2
18	E5	22,175	4	3	1	3	2	1
19	F1	19,450	1	3	1	3	2	1
20	F2	198,475	1	2	1	3	2	1
21	G	98,100	2	3	1	2	2	1
22	H	173,350	3	3	1	2	3	1
23	I1	45,225	1	1	4	1	4	3
24	I2	17,300	1	1	4	1	4	4
25	I3	273,700	1	1	3	1	4	2
26	I4	99,050	1	1	3	1	4	2
27	I5	62,200	1	1	3	1	4	2
28	J1	155,300	1	1	4	1	4	3
29	J2	135,300	1	1	3	1	3	2
30	J3	703,050	1	1	3	1	3	2
31	K1	517,925	1	1	3	1	3	3
32	K2	28,375	1	1	4	1	3	3
33	L1	102,700	1	2	1	2	3	3
34	L2	13,500	1	3	1	3	3	1
35	L3	387,700	2	3	3	2	3	2
36	L4	493,400	2	3	1	2	3	2
37	L5	72,475	3	3	1	3	2	1
38	L6	490,425	3	3	3	2	3	1
39	L7	67,700	3	3	1	3	2	1
40	M1	42,950	2	3	3	1	3	3
41	M2	636,825	2	3	3	2	2	2
42	N1	72,000	2	2	3	1	3	1
43	N2	43,325	2	1	3	1	3	2
44	N3	135,850	2	1	3	1	3	1
45	O1	152,575	3	3	1	2	2	1
46	O2	125,100	3	3	1	3	1	2
47	O3	246,575	3	3	3	3	2	1
48	O4	383,950	3	3	1	3	2	1
49	P	461,950	4	4	1	3	1	1
50	Q1	25,675	3	3	1	2	2	1
51	Q2	284,925	3	3	1	3	2	1
52	Q3	63,125	3	4	1	3	2	1
53	R1	185,675	4	4	1	3	1	1
54	R2	56,725	4	4	1	3	1	1
55	R3	138,525	4	4	1	3	1	2
60		LAKE MICHIGAN						

where:

Erosion	1(low), 2(medium), 3(high); 4(very high)
Slope	1(nearly level), 2(undulating), 3(rolling), 4(hilly)
Drainage	1(well), 2(moderately well), 3(somewhat poorly), 4(poorly)
Prime farm	1(>75 %), 2(25-75 %), 3(<25 %)
Corn yield	1(low), 2(medium), 3(high), 4(very high)
Org. Matter	1(<1.5%), 2(1.6-2.5%), 3(2.6-3.5%) 4(>3.6%)

FIGURE 5.9.1 Landsat mosaic

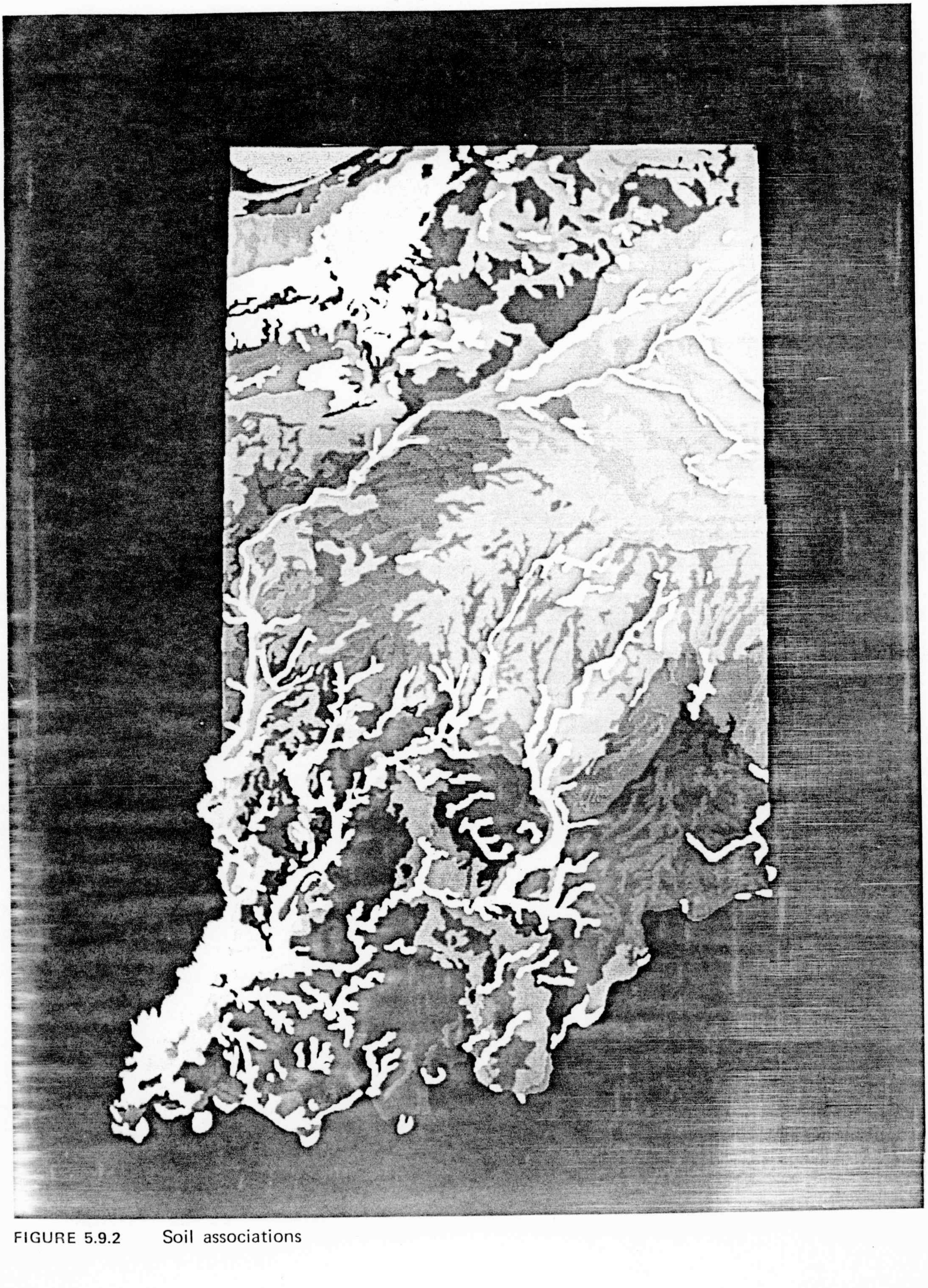

FIGURE 5.9.2 Soil associations

FIGURE 5.9.3 Parent materials

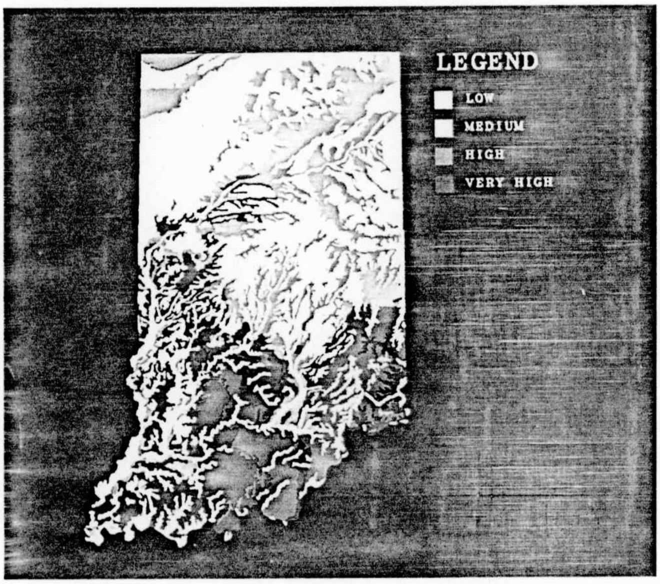

FIGURE 5.9.4 Potential erosion hazard

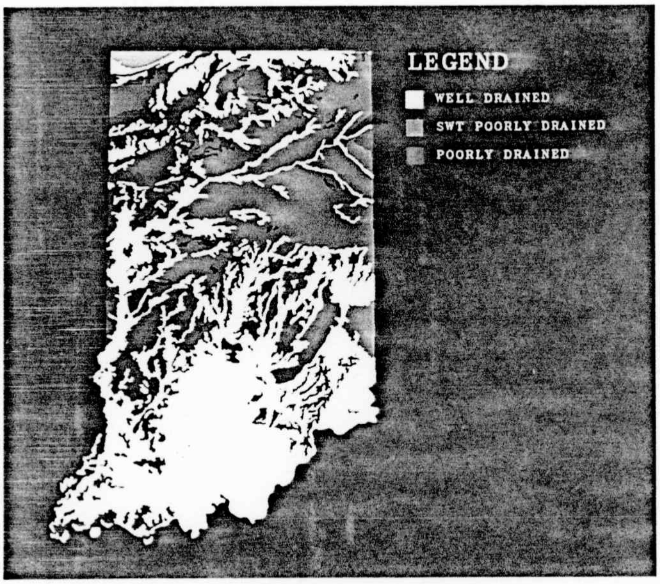

FIGURE 5.9.5 Dominant drainage

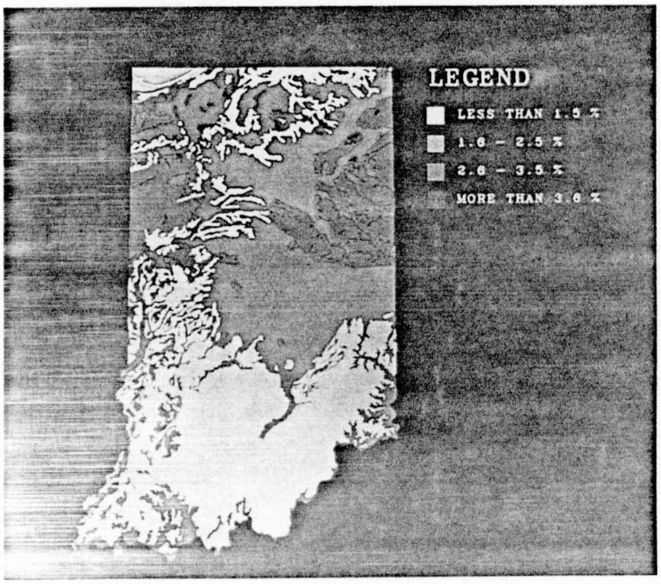

FIGURE 5.9.6 Organic matter content

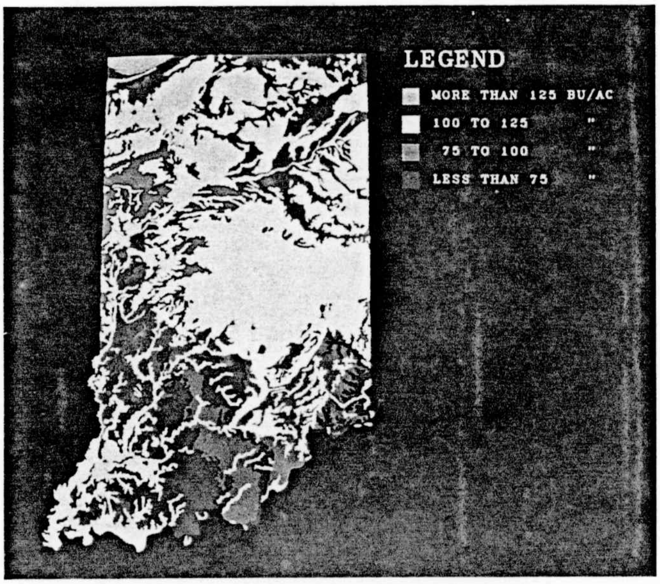

FIGURE 5.9.7 Estimated maize yields

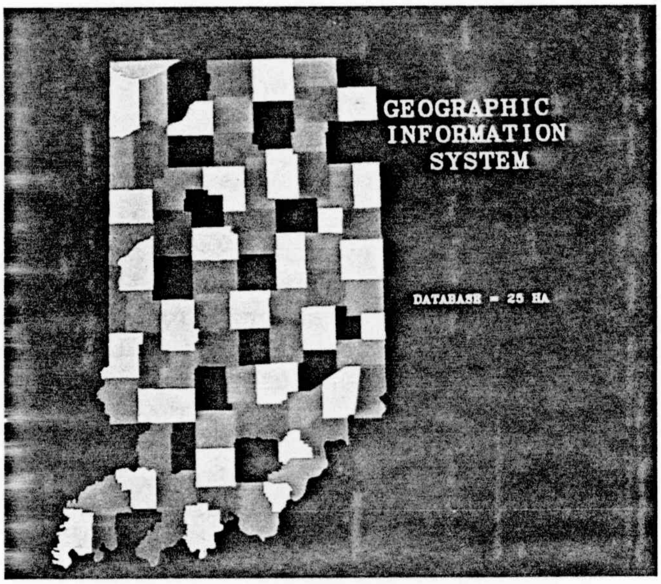

FIGURE 5.9.8 Administrative (county) units

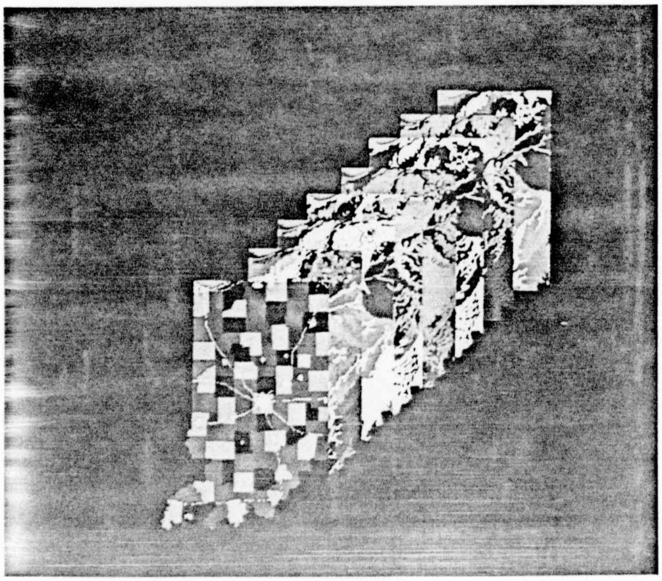

FIGURE 5.9.9 Image database