LARS Contract Report 012391

NASA APPLICATIONS PROJECT IN MIAMI COUNTY, INDIANA

Progress Report - Grant NAGW-1472

June 1990

Prepared by

Chris J. Johannsen
R. Norberto Fernández
D. Fabián Lozano-García

with the assistance of

Miami County cooperators, Purdue University investigators and graduate students

Laboratory for Applications of Remote Sensing

Purdue University

West Lafayette, Indiana, 47907

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IN-43-CR
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P62

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Executive Summary

for

APPLYING REMOTE SENSING AND GIS TECHNIQUES IN SOLVING RURAL COUNTY INFORMATION NEEDS

Laboratory for Applications of Remote Sensing

Purdue University

June 1990 NASA Review, Annapolis, Maryland

This project was designed to acquaint county government officials and their clientele with remote sensing and geographic information systems (GIS) products that contain information about land conditions and land use. The specific project objectives are:

1) to investigate the feasibility of using remotely sensed data to identify and quantify specific land cover categories and conditions for purposes of tax assessment, cropland area measurements and land use evaluation;

2) to evaluate the use of remotely sensed data to assess soil resources and conditions which affect productivity;

3) to investigate the use of satellite remote sensing data as an aid in assessing soil management practices;

4) to evaluate the market potential of products derived from the above projects.

We will have completed two years of effort on our project by July 1, 1990. During this time we have achieved the following:

1) We have selected 28 square miles (28 sections) for our study area in Miami County, Indiana. This includes 14 sections as development sites and 14 as evaluation sites.

2) Communication with the county officials has been a key aspect for the success of this project. We hold meetings on a regular basis with the Miami County Cooperators. In addition, an annual workshop is held, the first in April 1989 and a second planned for late Fall 90-early Spring 91. Approximately 50 persons attend these workshops.

3) We have defined an area of 4 square miles to develop the geographic information system. For that area we have digitized detailed soil maps, land ownership maps, roads,

surface drainage, ditches and contour line maps. All information is registered to a common geodetic framework.

4) We have sampled soils in different slope positions to study the relationship between soil spectral data, selected soil parameters, and potential soil erosion conditions. Laboratory analyses included: organic carbon, iron oxides, manganese, particle size, and soil color using spectral data. Statistical analyses were performed in order to select the best spectral regions to detect soil erosion.

5) We developed a "ground-truth form" for gathering information on soil management during the 1986-88 period for selected areas within the county. Cooperators were identified in those areas in order to obtain historic information on land management practices and crop rotations.

6) We have obtained landowner/cooperator records from the County Surveyor, Soil Conservation Service and the Agricultural Stabilization and Conservation Service to complement the ground truth information.

7) Because of the large amount of data included in the ownership records and the soil maps, we have developed large spatial databases for these two variables. These databases can be used to generate reports, or in combination with the cartographic databases within the GIS environment. This information will be used for future modeling. We have used high-level data models in designing these databases.

8) The State office of the Soil Conservation Service has provided us with computerized soils information for Miami county. We have used these data to load our soil database.

9) We have performed digital classifications of four different Landsat TM scenes over the entire county for land cover/land use. Selected sites were analyzed using SPOT data for two different dates. All these information will be used for temporal analysis in order to accurately identify different land cover types for specific uses. The classifications are evaluated using ground truth information (as described in 5 and 6) plus aerial photographs provided by the ASCS.

10) During our work in database design we have determined that the commercial cooperator was making serious errors with the land appraisal work for the County. Since then we have been assisting the Miami County officials in alternatives to overcome those problems.

PLAN FOR YEAR THREE

-Complete the analysis for TM and SPOT data

-Temporal analysis to improve discrimination of land cover categories

-Select new site for soil erosion-soil spectral properties studies

-Continue with soil management research, and models for erosion/sedimentation

-Selection of a new commercial firm to complete the tax assessment

-Major analysis effort with ASCS during the Fall of this year

-Cooperative work with SCS to determine eroded areas using satellite data

-Production of several maps to show potential applications of remote sensing and GIS in rural planning (with County Surveyor and County Extensionist)

MATERIALS

1. Satellite Data:
   1a. Landsat-5 TM:
   March 23, 1987 — April 26, 1988
   July 29, 1987 — June 13, 1988
   August 16, 1988

   1b. SPOT:
   March 17, 1987 — November 6, 1987

2. Ground-truth:
   2a. Farmers' information
   2b. Aerial photographs

3. Geographic Information System:
   3a. Maps: Land property: 1:4800
   Soils: 1:20000
   Roads, Drainage, Topography: 1:24000

   3b. Databases:
   -Land ownership (existing),
   -Soils (Soil Conservation Service)

4. Soil Erosion:
   4a. Soil samples for selected areas
   4b. Satellite data
   4c. Farmers' information (selected)

5. Soil Management:
   5a. Farmers' information (collaborators)
   5b. Satellite Data

Figure 1. Indiana Counties showing location of Miami County, the study site for this research.

STATE OF INDIANA
MIAMI County

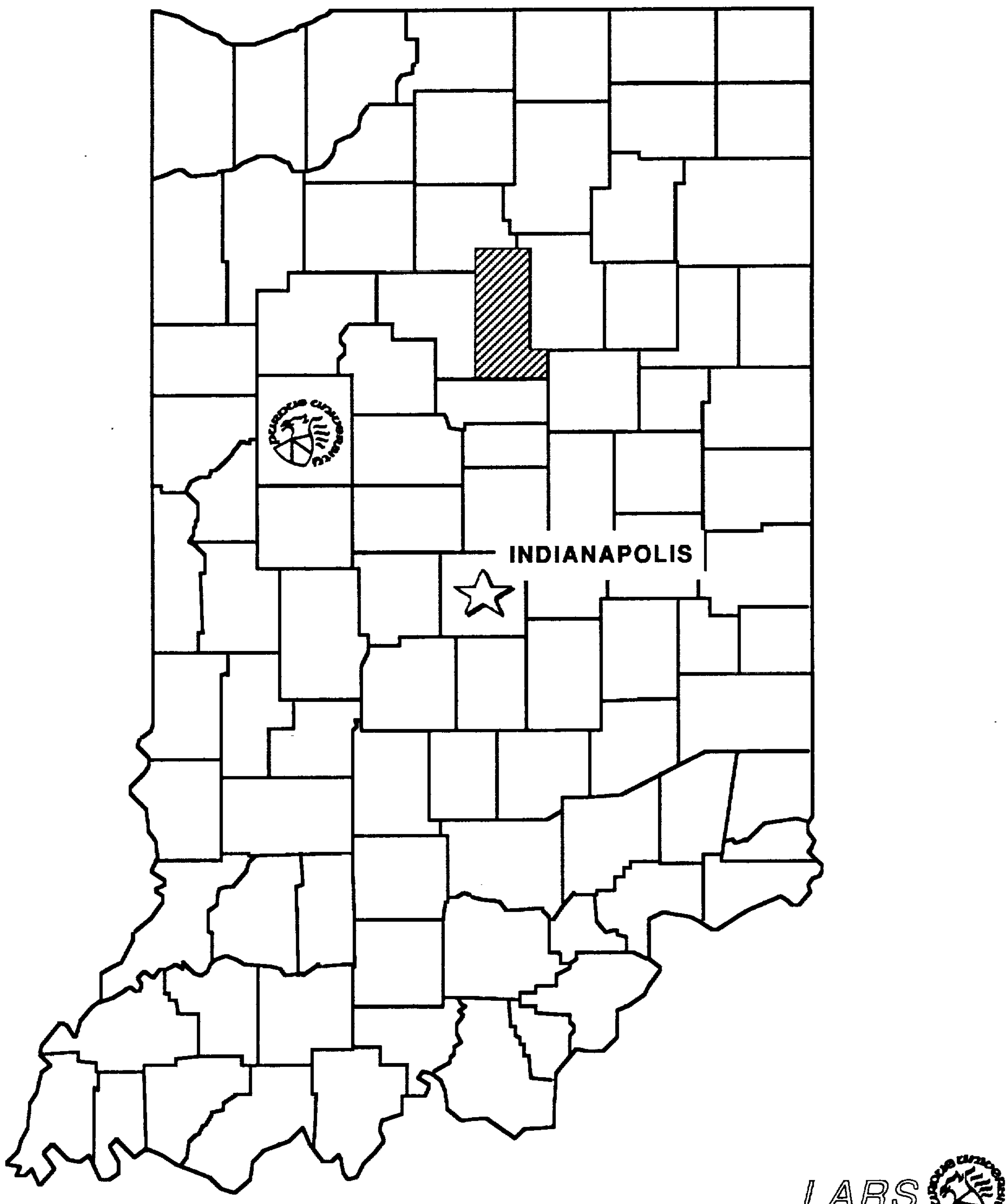
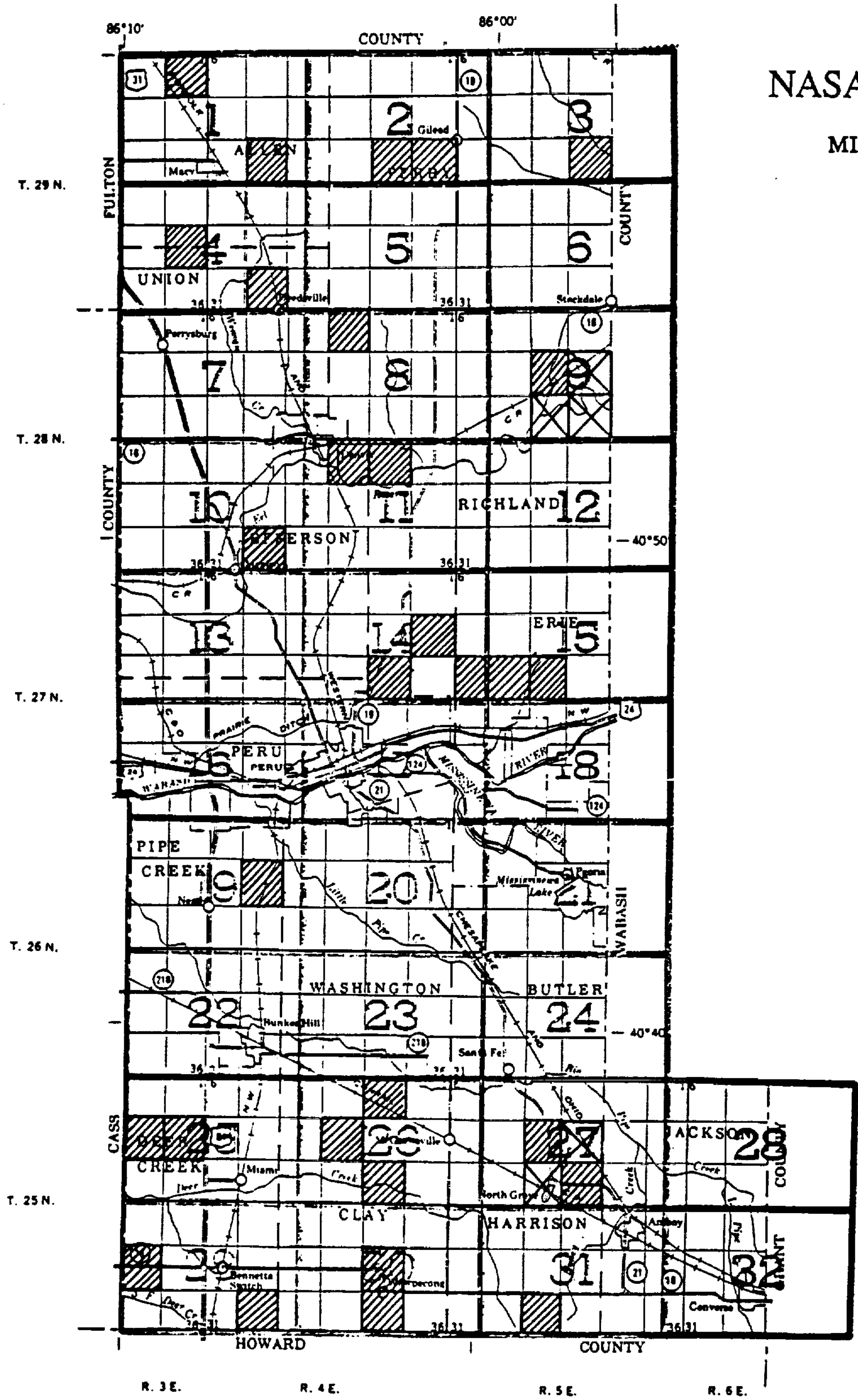


Figure 1

Figure 2. 28 square miles were selected randomly for development and evaluation of the satellite data analysis and the geographic information system. 14 out of the 28 sq. miles are used in developing the analysis methodologies; the remaining 14 sections are used to evaluate the land cover/land use classifications. There are additional sections (five) marked with an X that were added later in developing the geographic information system (GIS).

DEVELOPMENT AND EVALUATION SITES



NASA Applications Project

MIAMI COUNTY, INDIANA

Scale 1:190,080

1 0 1 2 3 4 Miles

Figure 2

Figure 3. Steps followed in the digital analysis of satellite data. Satellite images were geometrically corrected to sub-pixel accuracy so they could be overlaid and interacted with other maps. The registration was accomplished using USGS 7.5 minute (topograhic) series maps. Training statistics were developed using a supervised approach; the statistics were then analyzed and refined in order to find those clusters or categories that were separable. The resulting statistics were used to run classifications for the test areas. The classification results were then evaluated; if the results were acceptable the entire county is classified. Otherwise, the process is repeated from the beginning and new statistics are developed. The final classes were recoded for tax assessment; i.e., the different classes that were first obtained, for example corn, soybean and pasture, were recoded as "tillable land". The final step of the analysis was the transferring of the information from a remote sensing analysis system to a geographic information system so that users can make use of the data.

SATELLITE DATA ANALYSIS

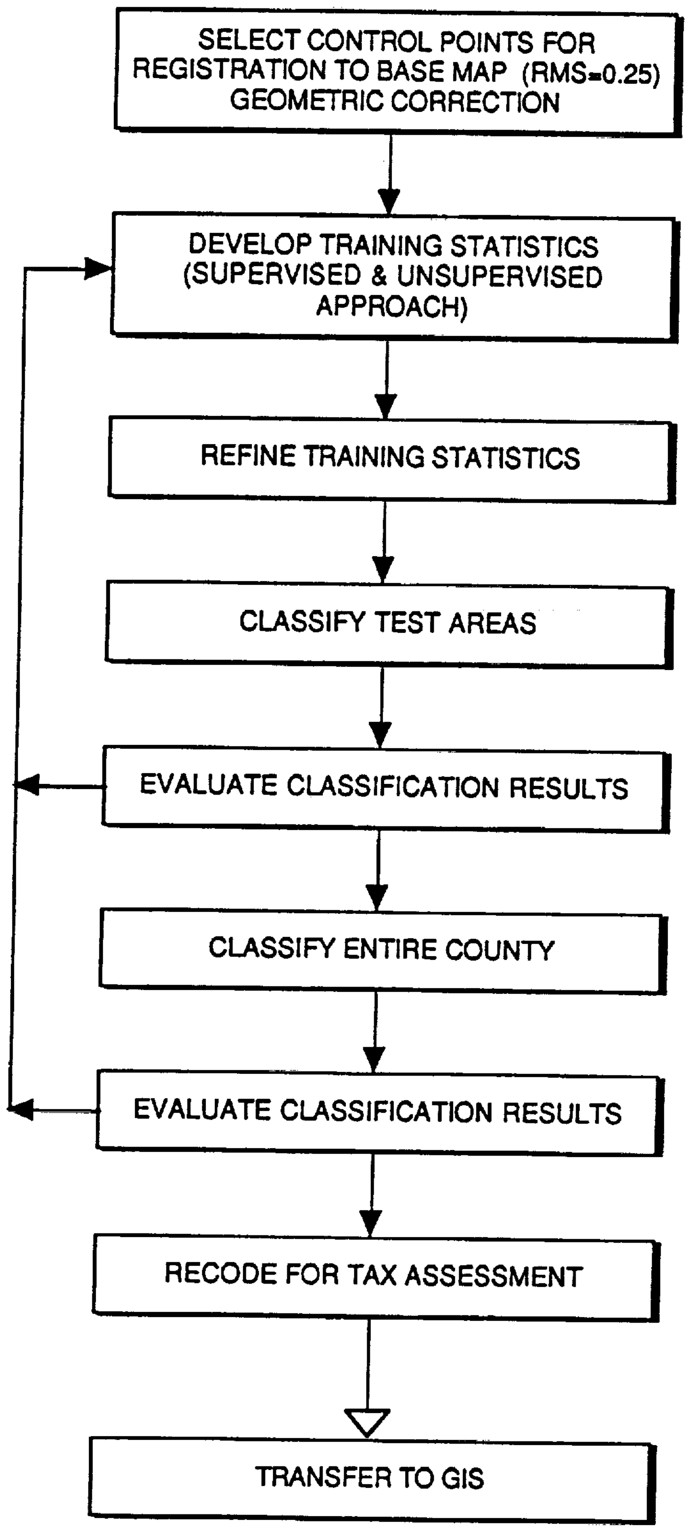


Figure 3

Figure 4. Classification results for the LANDSAT scene acquired on April 26, 1988. This data has a resolution or resolvable area (pixel size) of 30 x 30 meters. This is a good date for discriminating among different soil types because the row crop fields have been plowed. This classification shows good separation between low, medium and high reflective soils. Ground reflectance is basically related to soil moisture and organic matter content - the higher moisture and organic matter soils have the lowest reflectance. There also is good separation between forest and the other vegetation types. The river was very well differentiated since it is in sharp contrast to the trees and other vegetation along the banks.

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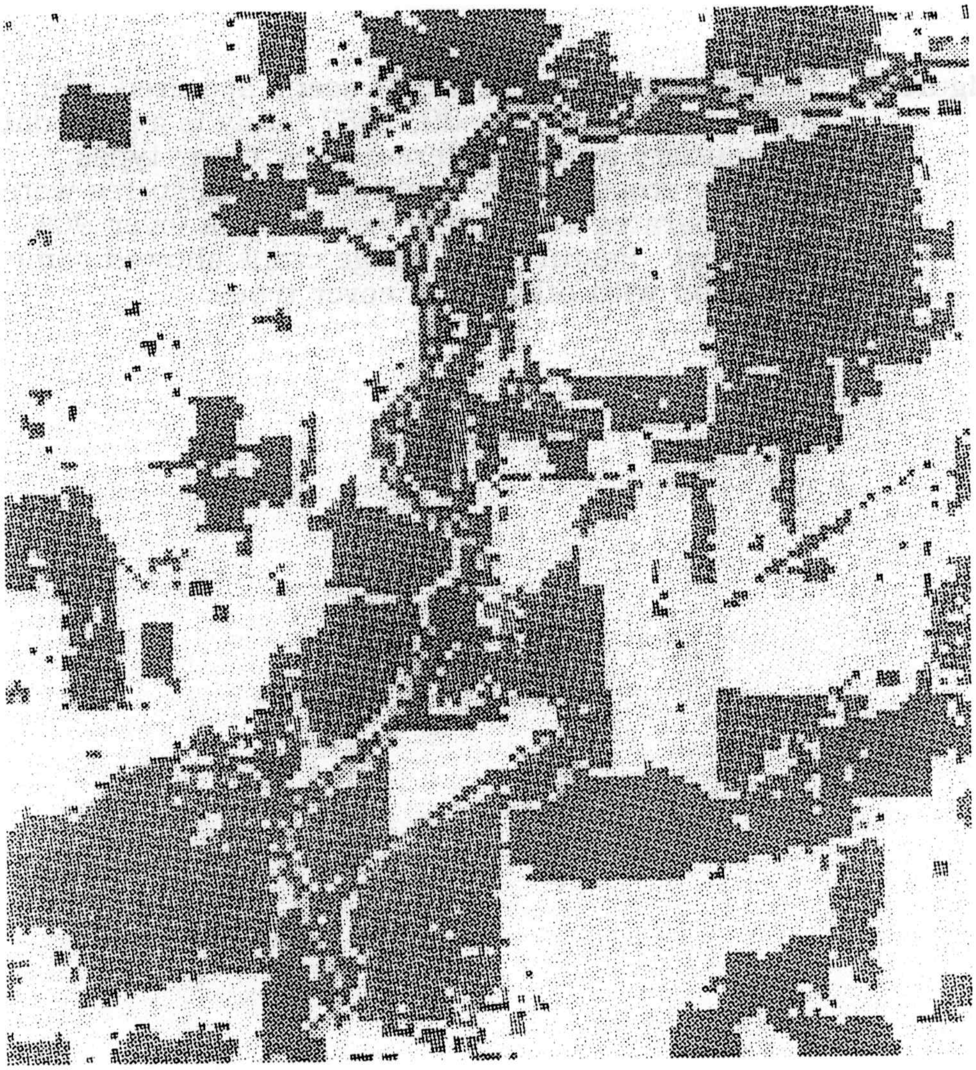
Miami Co.



Landsat-TM Classification (April 26, 1988), Sections 3,4,9,& 10, T28N, R5E

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Figure 4

Figure 5. Classification of a LANDSAT scene acquired over Miami County on July 29, 1987. July is a good date to differentiate among different land cover types, specially crops. Corn, soybeans and pastures were well separated from other cover types (over 90% accuracy). Pasture and forage crops showed some confusion with other land cover types.

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Miami Co.

Landsat-TM Classification (July 29, 1987), Sections 3,4,9,& 10, T28N, R5E

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Figure 5

Figure 6. Classification of SPOT data for March 17, 1987. SPOT, with a pixel size (resolution) of 20 x 20 meters, offers more resolution than LANDSAT TM (30 x 30 meters pixel size). This increased resolution of SPOT allows better recognition of line features such as field-edges and roads. Land ownership boundary identification is also better accomplished with SPOT data. SPOT allowed a good discrimination for forest and natural features such as the river. On the other hand, the larger amount of data (smaller pixel size) and the wavelength band information of SPOT increases the variability within classes (salt-and-pepper effect).

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Miami Co.

SPOT Classification (March 17, 1987), Sections 3,4,9,& 10, T28N, R5E

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Figure 6

Figure 7. Raw LANDSAT TM data for the entire Miami County, April 26, 1988. The lighter field patterns in the southern part of the county are due to the fact that there is more intense row crop production in this area since many of the fields have been plowed by this date. The Eel and the Wabash Rivers cutting through the center of the County with their low reflectance (dark colors) have a sharp contrast to the land cover around them.

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Landsat-TM data (April 26, 1988),
TM-4=Red, TM-5=Green, TM3=Blue

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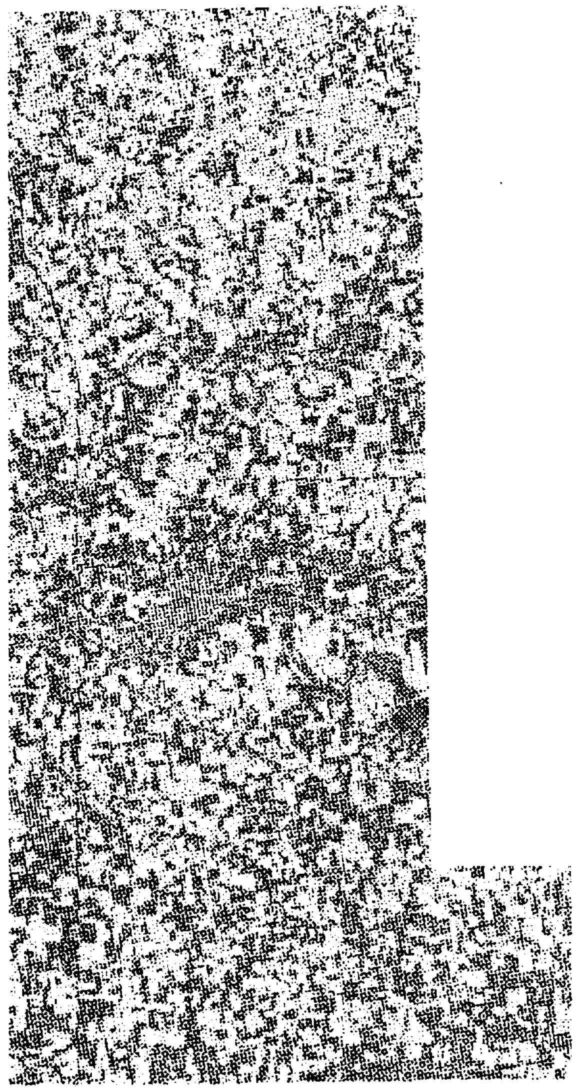
Figure 7

Figure 8. Classification of LANDSAT TM data for the entire Miami County, April 26, 1988. The separation of the soil reflectance into low, medium and high contrasts shows that much of the county has been tilled (light areas) in preparation for the planting of corn and soybeans. The urban area of Peru as well as Grissom Air Base are also distinctive.

NASA Applications Project
Miami Co.



Landsat-TM data (April 26, 1988), Classification

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Figure 8

Figure 9. Results of the digital classification of Landsat TM data,obtained on July 29, 1987. The results in this table are presented so that one can see how the sample points were actually recognized. Corn and soybeans were differentiated from the rest of the land cover types with high accuracies. There was some confusion in distinguishing pasture from other kinds of cover types, such as roads, field-edges, and forage crops. This pasture category contained fields with trees and brush. A second category of pasture which contained open fields and haylands was well differentiated, as were the forest and the river categories. Overall, these results show that the classification was acceptable for the purpose of the project and it can still be improved using adding data from another satellite pass and using a temporal analysis technique.

NASA Applications Project
Miami Co.

Landsat-TM Classification (July 29, 1987),
Sections 3,4,9,& 10, T28N, R5E

	No. of Points	Percent Correct	Corn	Soybean	Pasture	Forest	River	Other
Corn 1	117	95.7	112	0	0	5	0	0
Corn 2	202	100.0	202	0	0	0	0	0
Soybean 1	138	95.6	0	132	0	0	0	6
Soybean 2	65	100.0	0	65	0	0	0	0
Pasture 1	123	56.1	0	0	69	0	0	54
Pasture 2	57	91.2	0	0	52	0	0	5
Forest 1	32	87.5	4	0	0	28	0	0
River	36	94.4	0	0	0	2	34	0

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Figure 9

Figure 10. Flow chart showing the current manual or traditional approach used to calculate land appraisal for tax assessment. Maps published by the Soil Conservation Service at the scale of 1:20,000 are photomechanically enlarged to the scale 1:4,800 (approximate). Land ownership maps are drawn at 1:4,800 scale. Land cover maps are derived from visual interpretation of black and white aerial photography. The final land cover types are shown at the scale of, approximately, 1:4,800. These maps are then manually overlaid to create a new map that shows a combination of ownership, soils, and land cover. Area calculations are done on this final map using a planimeter. Another product is the tax form which is completed for each farm showing the different land cover and soil types, as well as soil productivity factors. Most of the data that ~~is~~ are included in this tax form ~~is~~ are derived from an existing automated database.

TRADITIONAL APPROACH

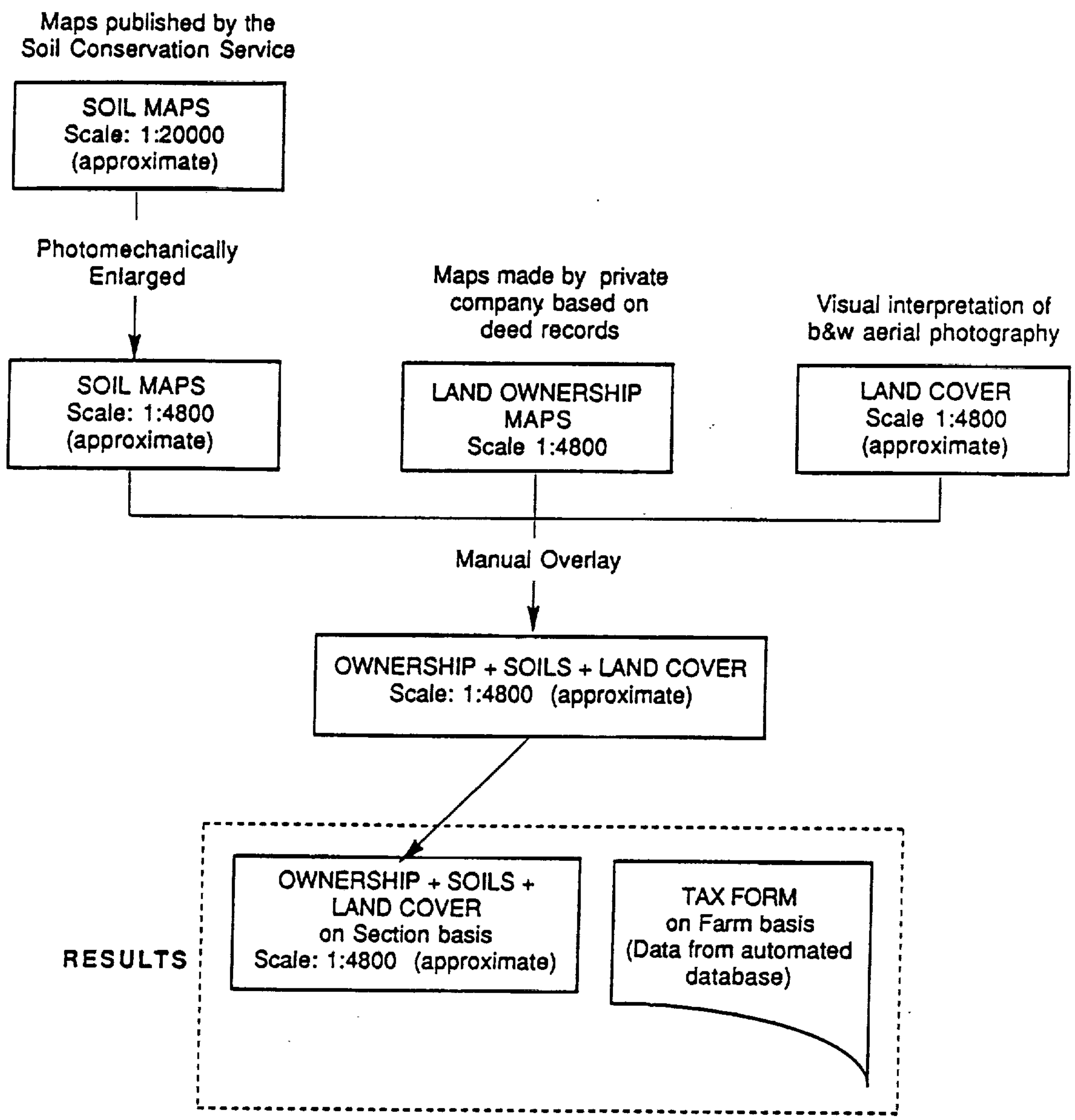


Figure 10

Figure 11. Representation of the spatial database of a geographic information system. The GIS developed for Miami County includes LANDSAT and SPOT data, land cover/land use, land ownership, drainage, road network, and watersheds. These layers are registered to a common base (the reference framework) which is the USGS 7.5 minute series map (1:24,000 scale).

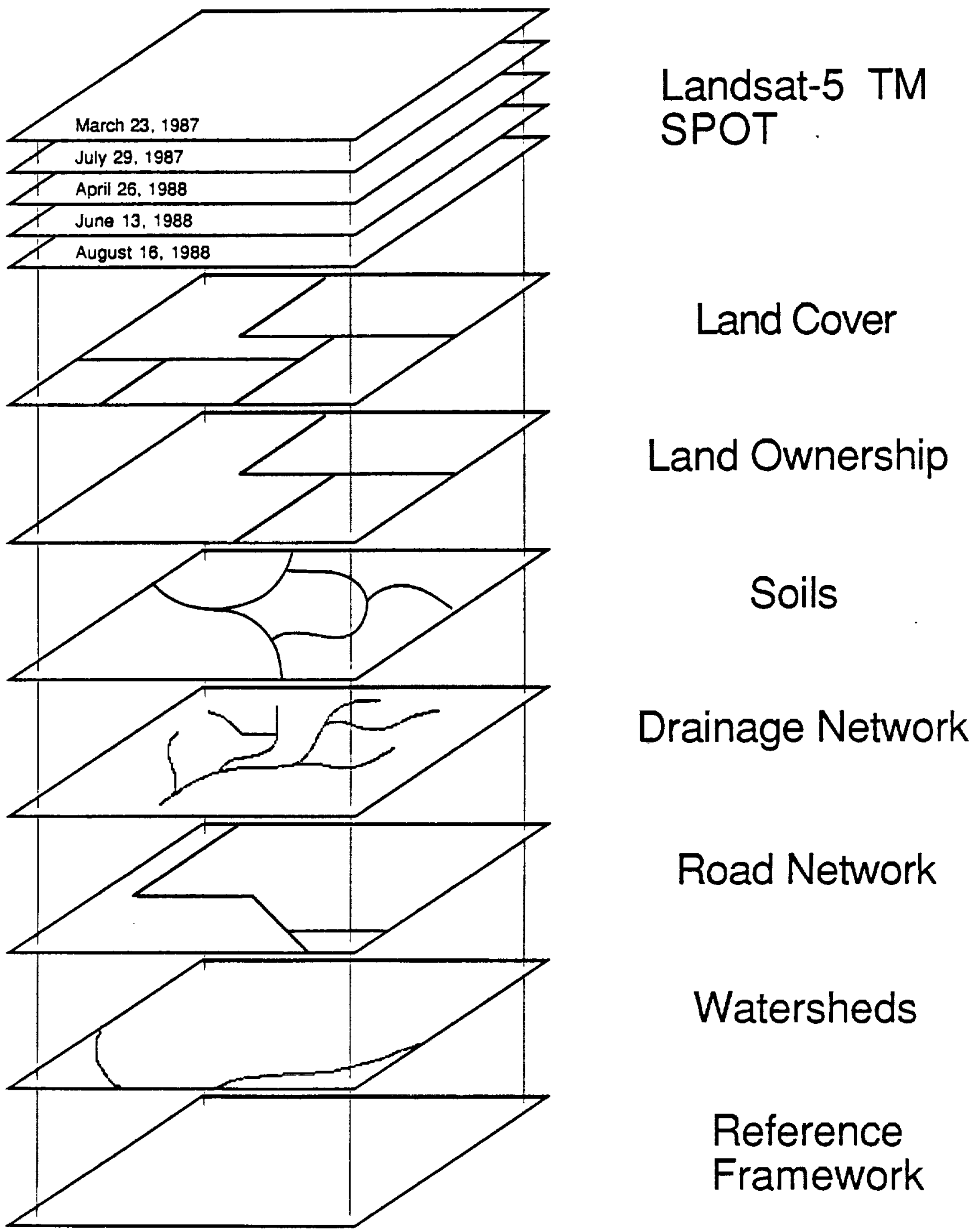

March 23, 1987
July 29, 1987
April 26, 1988
June 13, 1988
August 16, 1988
Landsat-5 TM
SPOT
Land Cover
Land Ownership
Soils
Drainage Network
Road Network
Watersheds
Reference
Framework

Figure 11

Figure 12. Diagram showing the GIS approach used in this research. The model takes into account temporal land cover information derived from satellite data through digital analysis, land ownership maps redrafted on a scale of 1:24,000, soil maps (originally published at a scale of 1:20,000) adjusted and redrafted at 1:24,000 scale, roads derived from USGS 7.5 minute quads, and drainage networks derived from the combination of USGS maps, aerial photography and soil maps. All these layers were registered to the USGS 7.5 minute quads (1:24,000). These maps are stored in the spatial database on a section basis. We have also designed two non-spatial databases (land ownership and soils) to store attribute data related to the maps. With both, the spatial (maps) and attribute databases in place it is possible to perform different kinds of analysis. Proximity analysis were used to calculate easements and right-of-ways for ditches and roads. Ownership, soils and land cover maps are combined using standard GIS functions to produce a final map that shows these three variables plus easements. Maps can be produced for a section, a farm, or the entire county if requested. Area calculations are done automatically by the system and the results are included in the tax form, along with information stored in the attribute databases.

GIS APPROACH

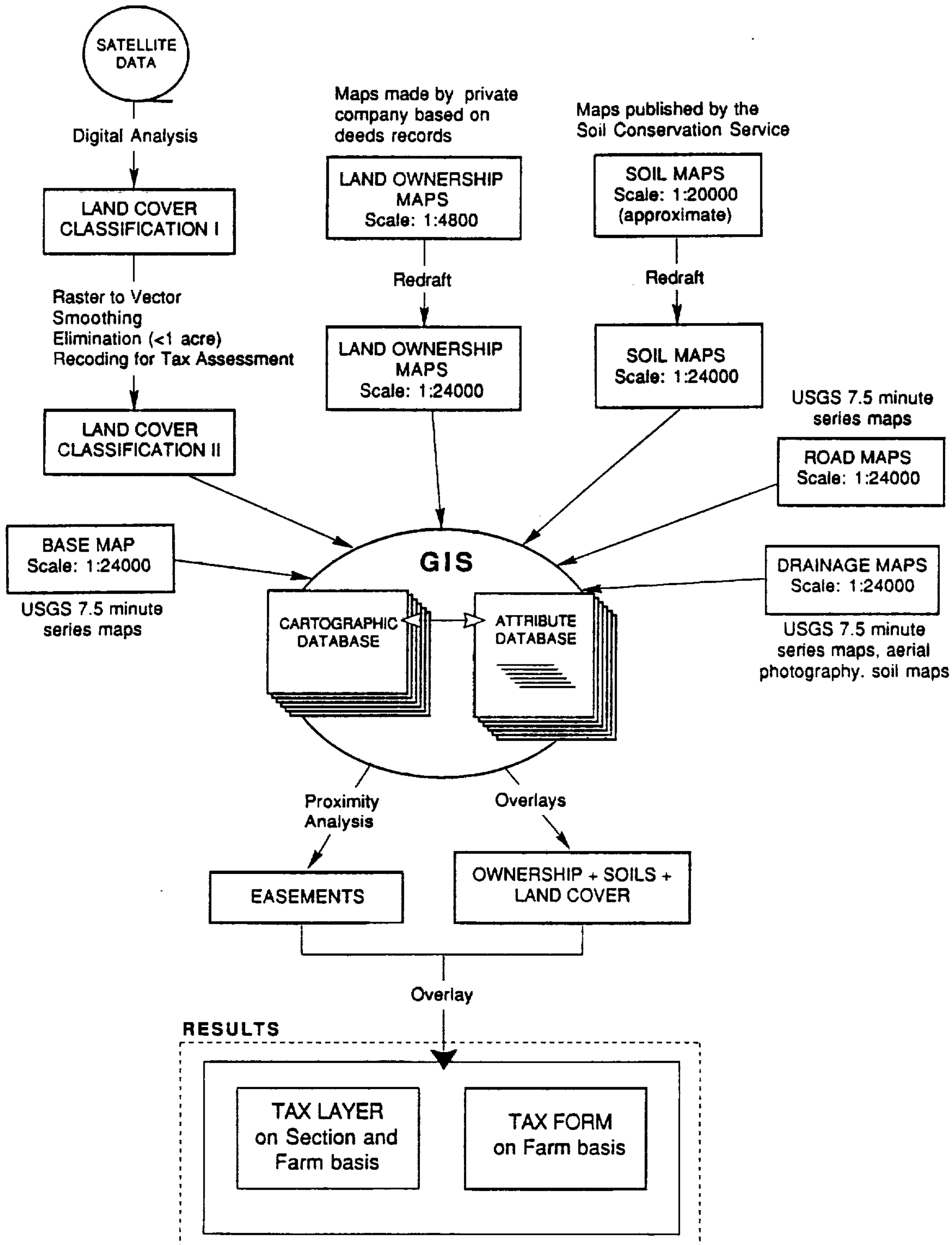
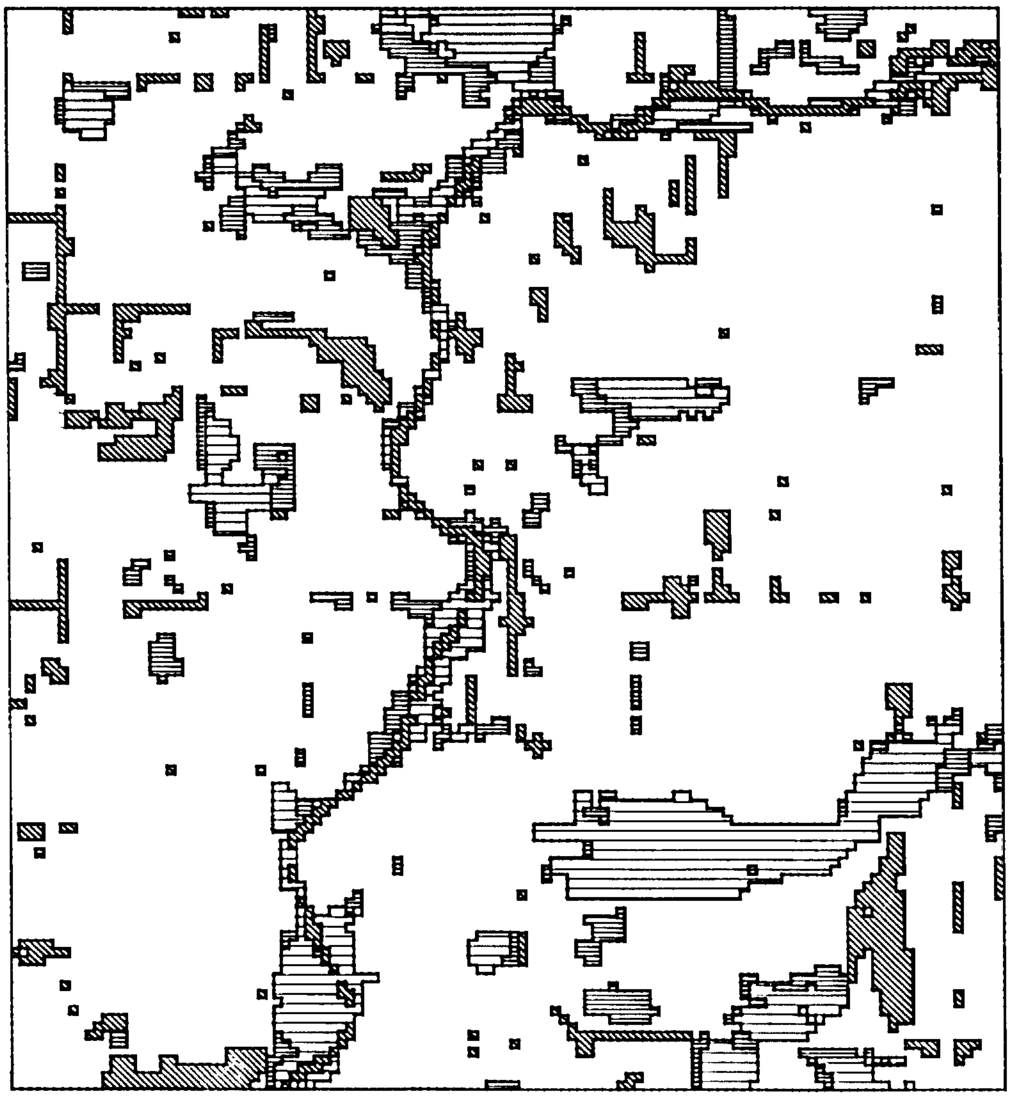


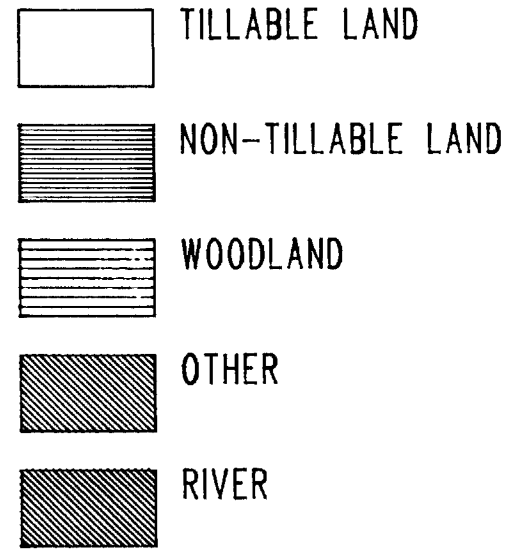
Figure 12

Figure 13. Land cover types derived from LANDSAT TM data for July 29, 1987. This map was obtained as a result of digital analysis of satellite data using the ERDAS system and appears in a "blocky" format since the satellite data covers areas of 30 x 30 meters (about 100 x 100 feet). The original 25 land cover classes were recoded for agricultural reassessment. For example, crops such as soybean and corn, and pasture were recoded as "tillable land". This map shows the land cover types for four (4) sections. This is another capability of the GIS, the information that is stored on section bases can be "joined" and displayed for larger areas.

LAND COVER

LANDSAT TM-July 29,1987





Sections 4,3,9,10; T28N,R5E
Miami Co., Indiana
NASA Applications Project

Scale: 1:27500

LARS/Purdue University

Figure 13

Figure 14. Digital land ownership map of Section 9, township 28N, range 5E displayed at at scale of 1:12,500. This map has been digitized from original maps provided by a private company, and incorporated into the spatial database after redrafting to 1:24,000 scale and registered to the base map.

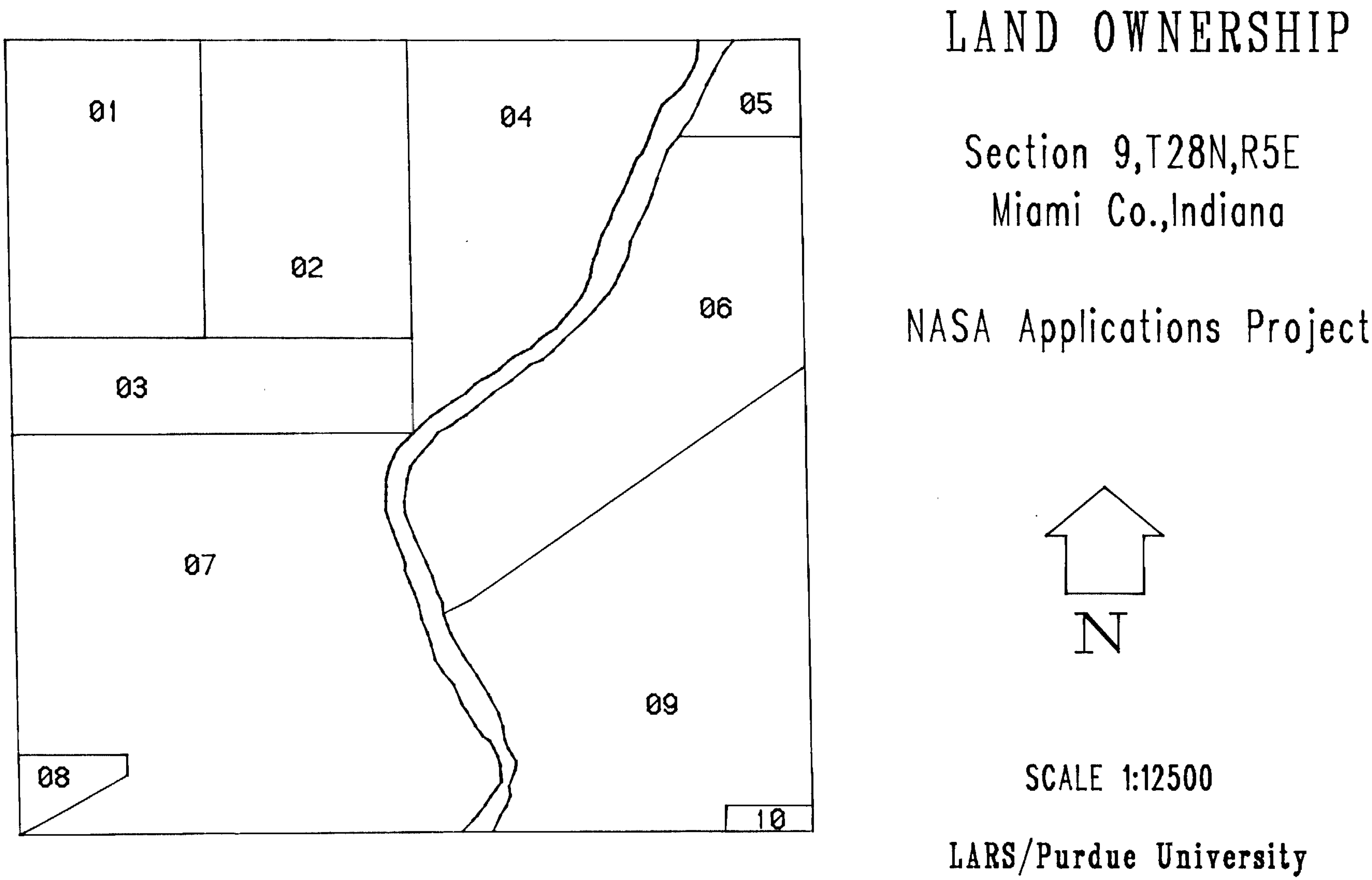
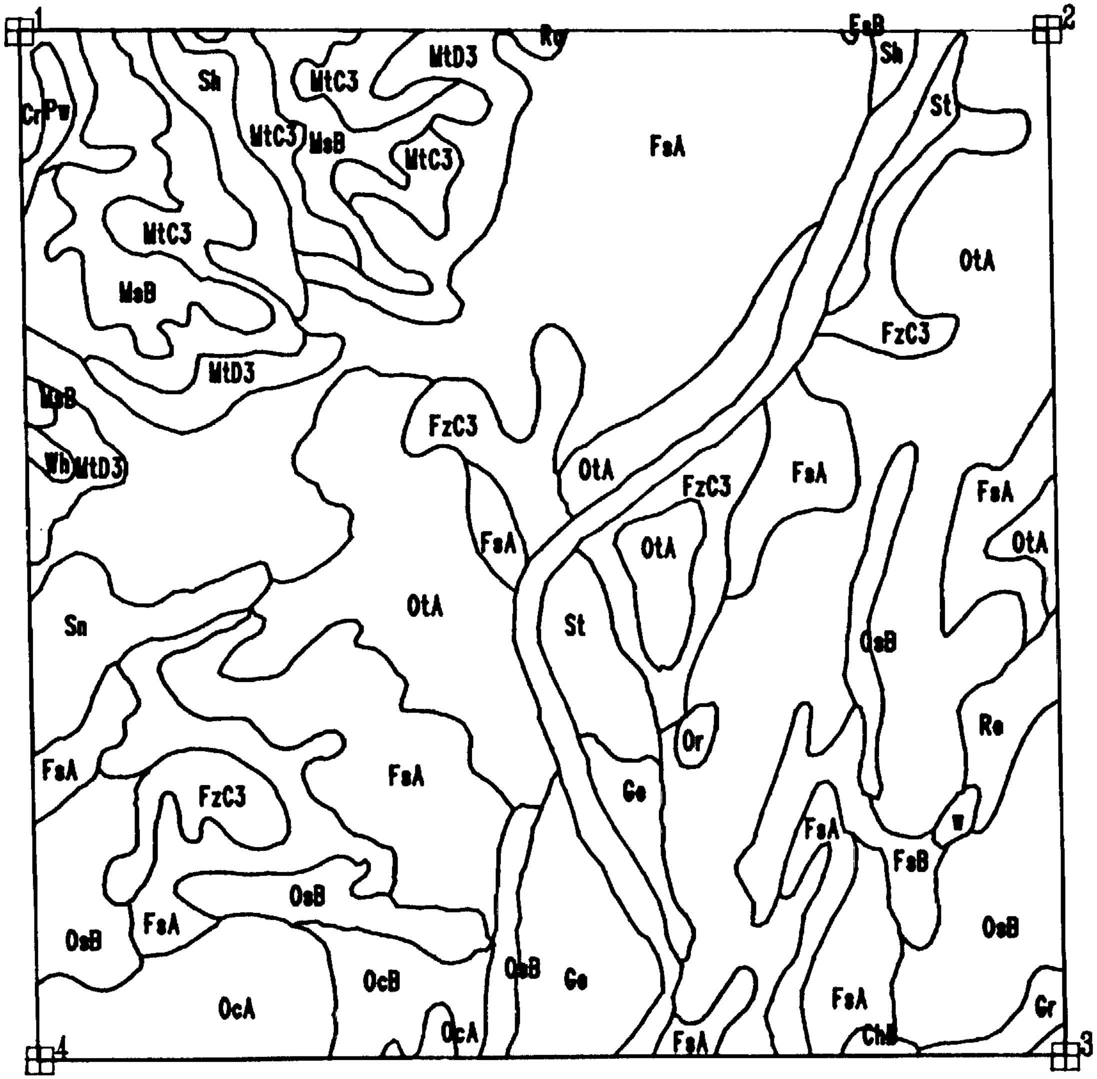

01
02
03
04
05
06
07
08
09
10
LAND OWNERSHIP
Section 9,T28N,R5E
Miami Co.,Indiana
NASA Applications Project
N
SCALE 1:12500
LARS/Purdue University

Figure 14

Figure 15. Digital soils map of Section 9, township 28N, range 5E. This map has been digitized from soil maps published in the Soil Survey Report for Miami County but registered to the reference base map.



SOILS MAP

Section 9,T28N,R5E

Miami Co., Indiana

NASA Applications Project

LARS/Purdue University

Figure 15

Figure 16. Road map of Section 9, township 28N, range 5E and digitized from USGS 7.5 minute quad maps (scale of 1:24,000). The location and type of roads is important so that proper credit can be given for calculating easements and reduction of taxes due to the easements.

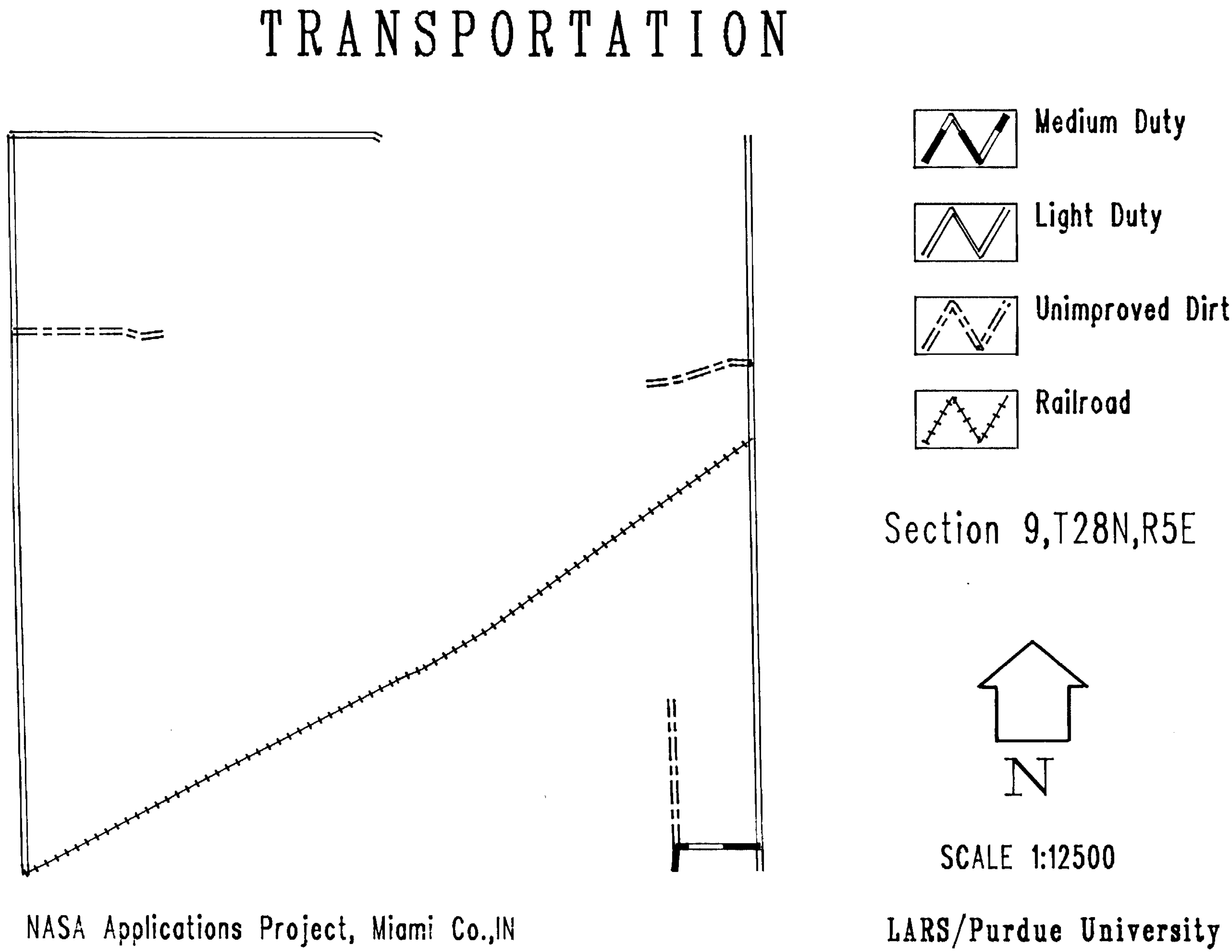

TRANSPORTATION
Medium Duty
Light Duty
Unimproved Dirt
Railroad
Section 9,T28N,R5E
N
SCALE 1:12500
NASA Applications Project, Miami Co.,IN
LARS/Purdue University

Figure 16

Figure 17. Surface hydrology including perennial, intermittent, and man-made ditches as derived from aerial photography, USGS 7.5 minute quad maps, and soil maps.

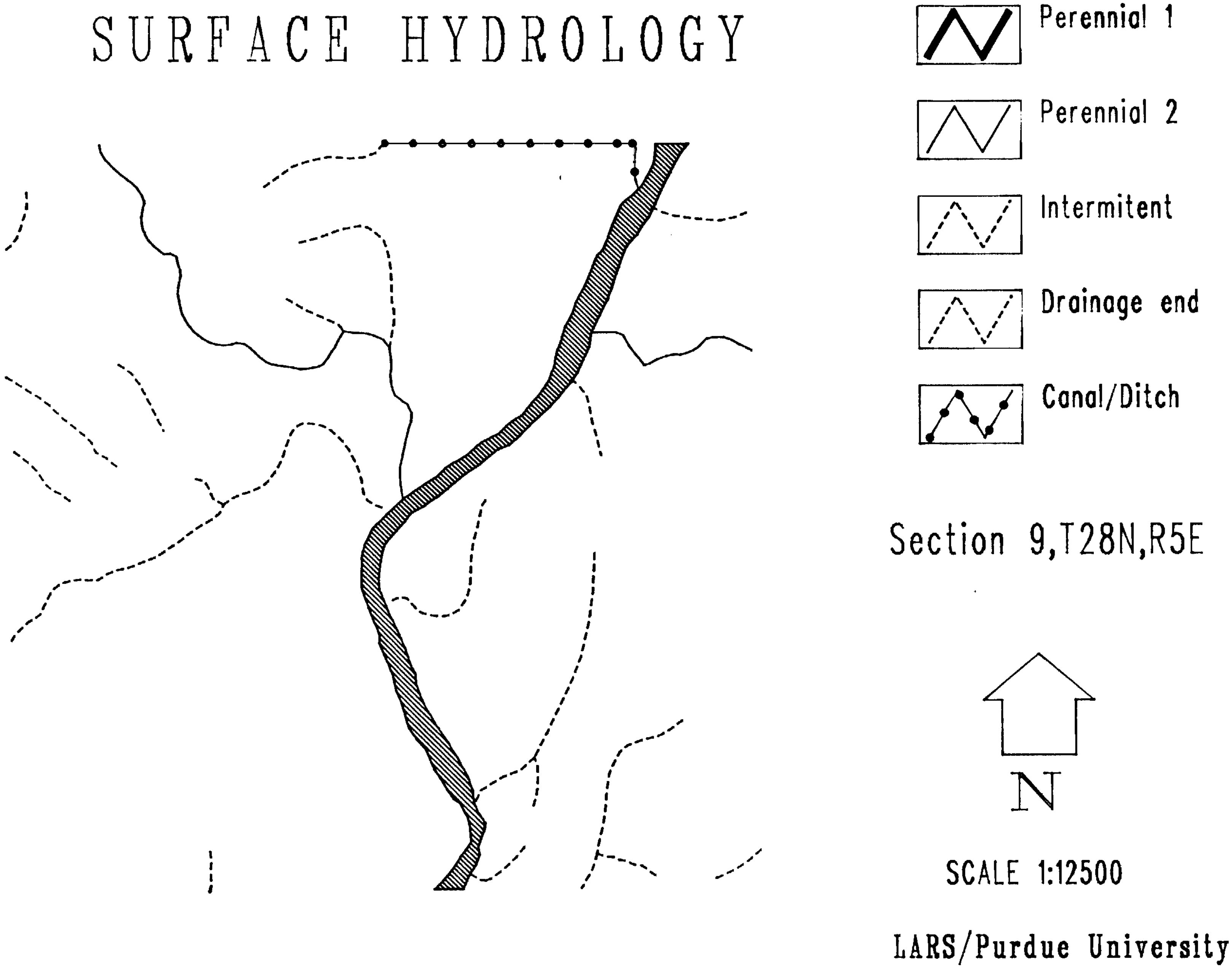
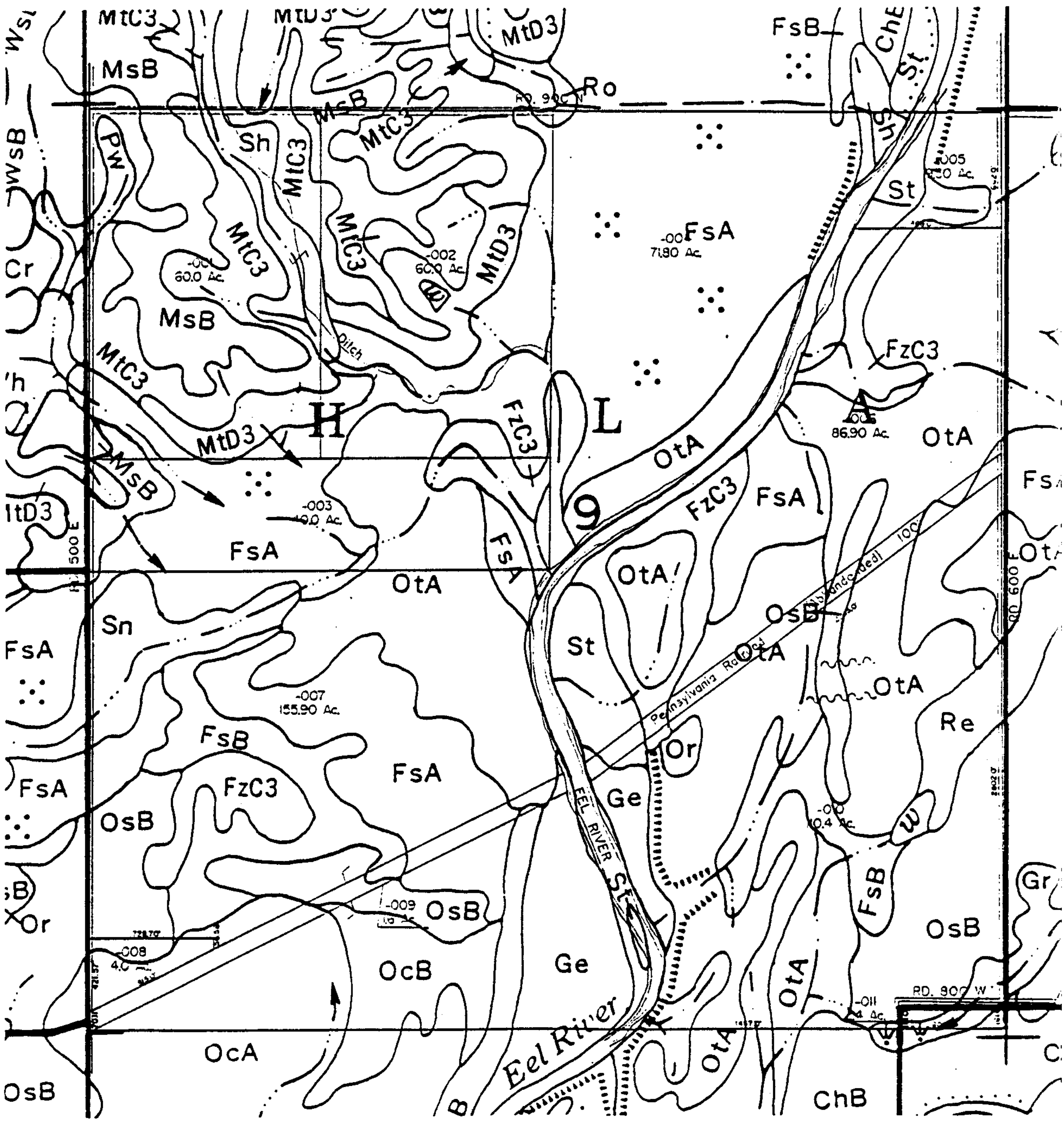

SURFACE HYDROLOGY
Perennial 1
Perennial 2
Intermitent
Drainage end
Canal/Ditch
Section 9,T28N,R5E
N
SCALE 1:12500
LARS/Purdue University

Figure 17

Figure 18. Overlay of land ownership, showing property boundaries, and soils which is an intermediate product of the current manual approach to agricultural reassessment. The soil map was enlarged from the originally published scale of 1:20,000 to 1:4,800. The distinctive features of this figure are the different mismatches between layers, such as the corner sections, mismatch of roads, and it is also very noticeable the the variation of the river boundaries. All these mismatches are a very important source of error to the final map. When the polygon areas are manually calculated using planimeters all of those differences are visually adjusted and the final map contains different kind of errors.



MsB
Ro
FsB
Sh
MtC3
MtD3
Pw
Cr
St
FsA
71.90 Ac.
60.0 Ac.
Ditch
FzC3
H
L
A
86.90 Ac.
OtA
9
FsA
Sn
155.90 Ac.
Pennsylvania Railroad
Or
Re
FsB
FzC3
OsB
Ge
EEL RIVER
OcB
OcA
Eel River
ChB
Gr
RD. 900 N
RD. 900 W
RD. 500 E
RD. 600 E

Figure 18

Figure 19. Soils map for four sections in T28N, R5E showing different productivity levels. This map was originally created and stored on a section basis. Using one of the standard functions of the GIS it is possible to join neighboring units and display them as a larger map. A query of the database was done to show soil productivity factors (SPF) larger than 1.1 and smaller than 0.6. These two values of soil productivity factors are an example of the query of the databases from the cartographic (spatial) database into the attribute database. SPF can be replaced by any other variable contained in the database.

SOIL PRODUCTIVITY FACTORS

SPF > 1.10

SPF < 0.60

Water

Sections 4,3,9,10; T28N,R5E
Miami Co., Indiana
NASA Applications Project

Scale: 1:24000

LARS/Purdue University

Figure 19

Figure 20. Steps followed during the database design process. First, the data requirements and processing are defined according to the user's needs. The second step (Phase 2) involves the conceptual design of the database. This design is generic and allows one to understand the structure of the data, as well as the interrelationships among all data. The third step involves the data model mapping which is a translation of the conceptual design model into the physical design. This translation is database management system dependent. The conceptual design is generic, and it can be translated into any of the three most common models such as network, hierarchical, or relational. In this research, we have chosen the relational database model to store and perform operations with the data. Phase 4 of the design is the physical design or the definition of the database structure. Finally the database is implemented in the geographic information system.

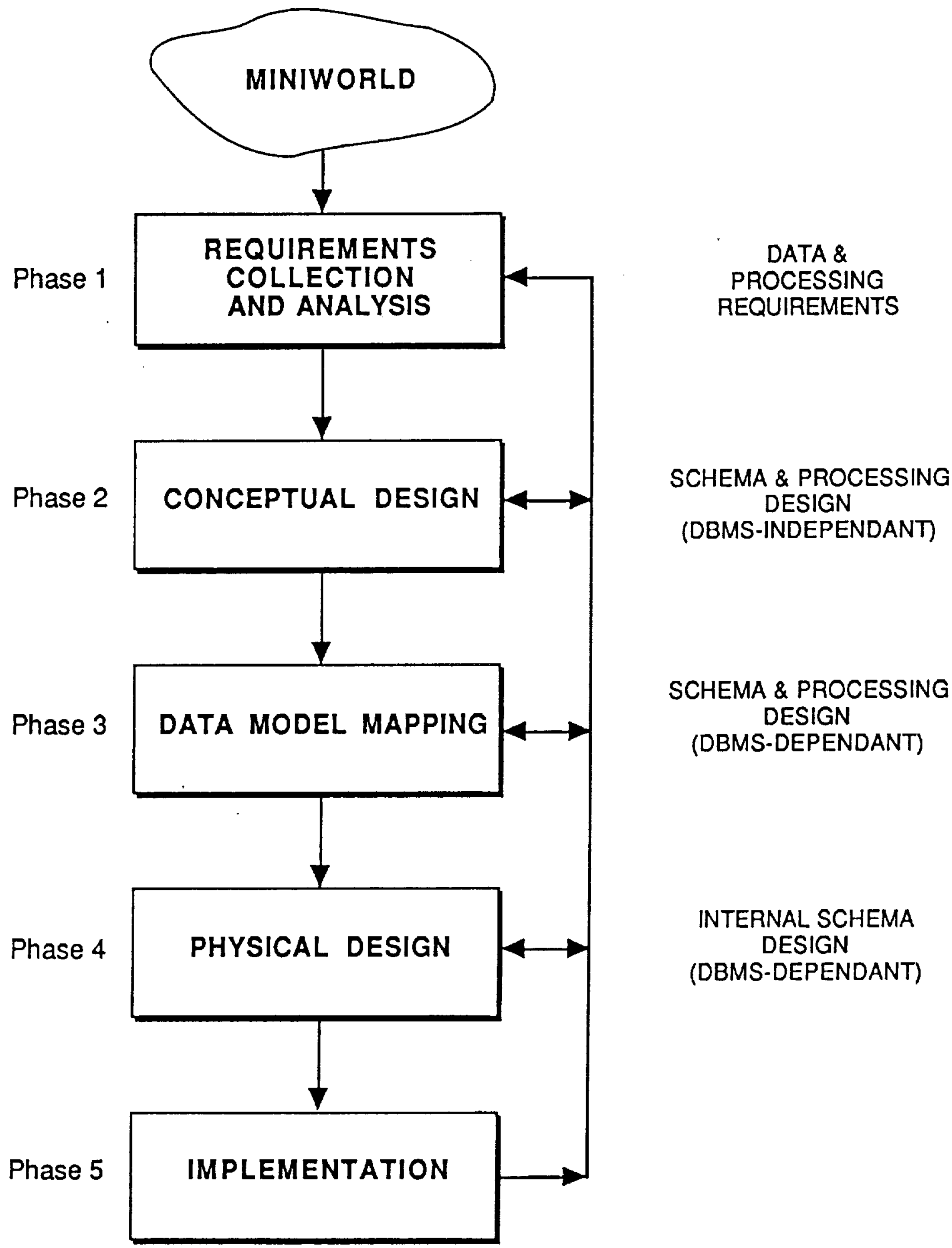

MINIWORLD
Phase 1
REQUIREMENTS COLLECTION AND ANALYSIS
DATA & PROCESSING REQUIREMENTS
Phase 2
CONCEPTUAL DESIGN
SCHEMA & PROCESSING DESIGN (DBMS-INDEPENDANT)
Phase 3
DATA MODEL MAPPING
SCHEMA & PROCESSING DESIGN (DBMS-DEPENDANT)
Phase 4
PHYSICAL DESIGN
INTERNAL SCHEMA DESIGN (DBMS-DEPENDANT)
Phase 5
IMPLEMENTATION

Figure 20

Figure 21. Definition of entity, relationships, and attributes; and their representations in the ER Diagram. Entitles are indicated with rectangles, relationships with diamonds, key attributes with black solid circles and underlines, and attributes with empty circles. In this illustration, we show that a parcel or property is owned by an owner which may be a person(s) or corporation.

THE ENTITY-RELATIONSHIP MODEL

Entity: is an object in the real world, with an independent existance.

Relationship: set of associations between entities.

Attributes: characteristics that describe entities or relationships.

THE EXTENDED ER DIAGRAM

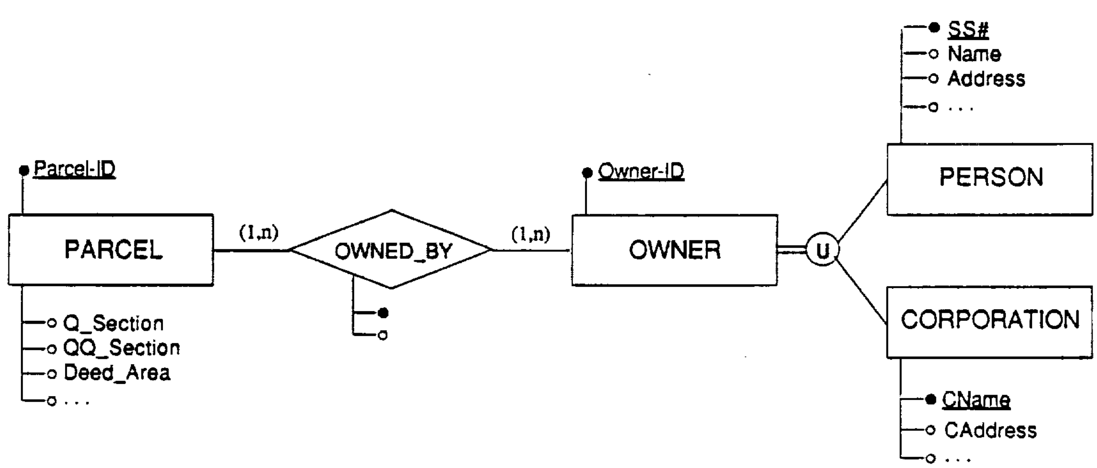


Figure 21

Figure 22. Conceptual schema of the land ownership database. This extended entity relationship (EER) diagram shows the interrelationship among data. Key attributes for each entity and relationship are indicated with a filled circle. The ER model is closer to the user's perception of the data, and it is independent of the system where the database will be implemented.

LAND OWNERSHIP DATABASE - EER DIAGRAM

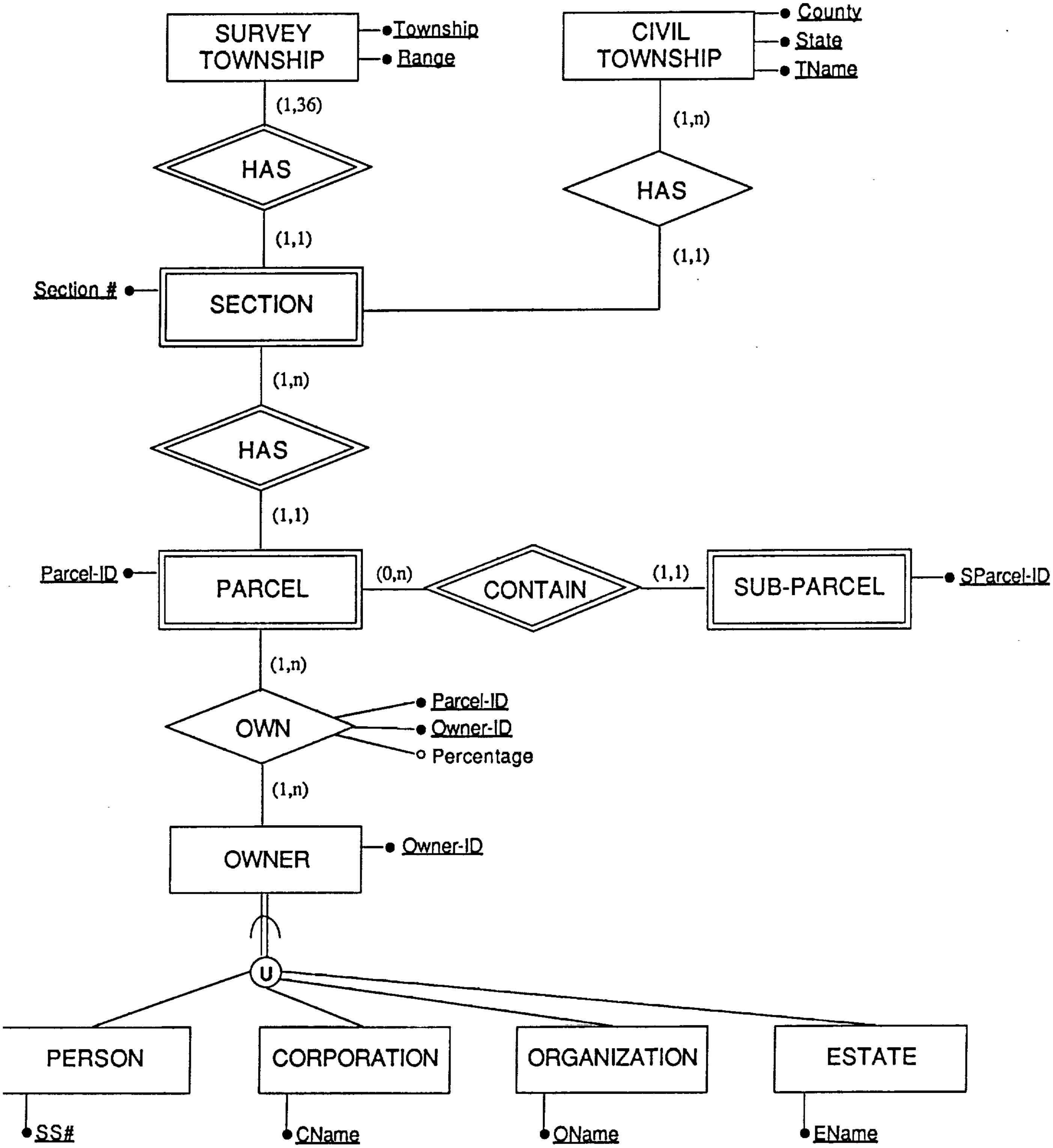


Figure 22

Figure 23. Polygon Attribute Table (PAT) showing a relational database schema for the land ownership database. The first two tables with the extension PAT are created by ARC, while the rest of the relations were developed using the INFO database management system. The arrows show the different links among relation's (tables). The links are established through common variables. This database allows to store data for legal description at parcel and sub-parcel level, information about sections and townships, names and addresses of owners, and types of ownership (corporations, organizations, etc.). It is also possible to store information about the percent that each owner has of one particular piece of land.

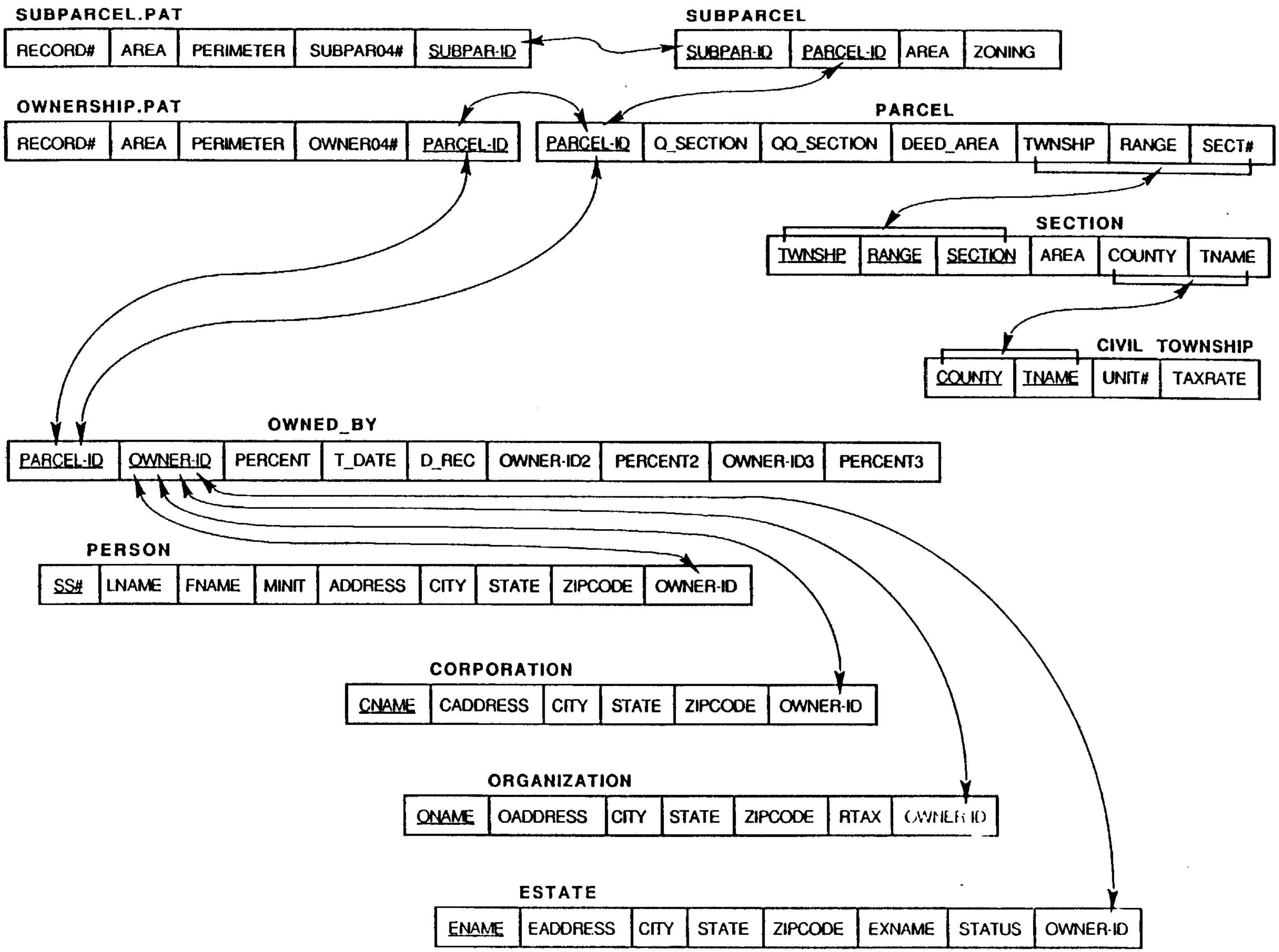

SUBPARCEL.PAT
RECORD# AREA PERIMETER SUBPAR04# SUBPAR-ID
SUBPARCEL
SUBPAR-ID PARCEL-ID AREA ZONING
OWNERSHIP.PAT
RECORD# AREA PERIMETER OWNER04# PARCEL-ID
PARCEL
PARCEL-ID Q_SECTION QQ_SECTION DEED_AREA TWNSHP RANGE SECT#
SECTION
TWNSHP RANGE SECTION AREA COUNTY TNAME
CIVIL TOWNSHIP
COUNTY TNAME UNIT# TAXRATE
OWNED_BY
PARCEL-ID OWNER-ID PERCENT T_DATE D_REC OWNER-ID2 PERCENT2 OWNER-ID3 PERCENT3
PERSON
SS# LNAME FNAME MINIT ADDRESS CITY STATE ZIPCODE OWNER-ID
CORPORATION
CNAME CADDRESS CITY STATE ZIPCODE OWNER-ID
ORGANIZATION
ONAME OADDRESS CITY STATE ZIPCODE RTAX OWNER-ID
ESTATE
ENAME EADDRESS CITY STATE ZIPCODE EXNAME STATUS OWNER-ID

Figure 23

Figure 24. Extended Entity Relationship (EER) diagram for the soils database. This database can contain data for each individual horizon, as well as for the map unit.

SOILS DATABASE - EER DIAGRAM

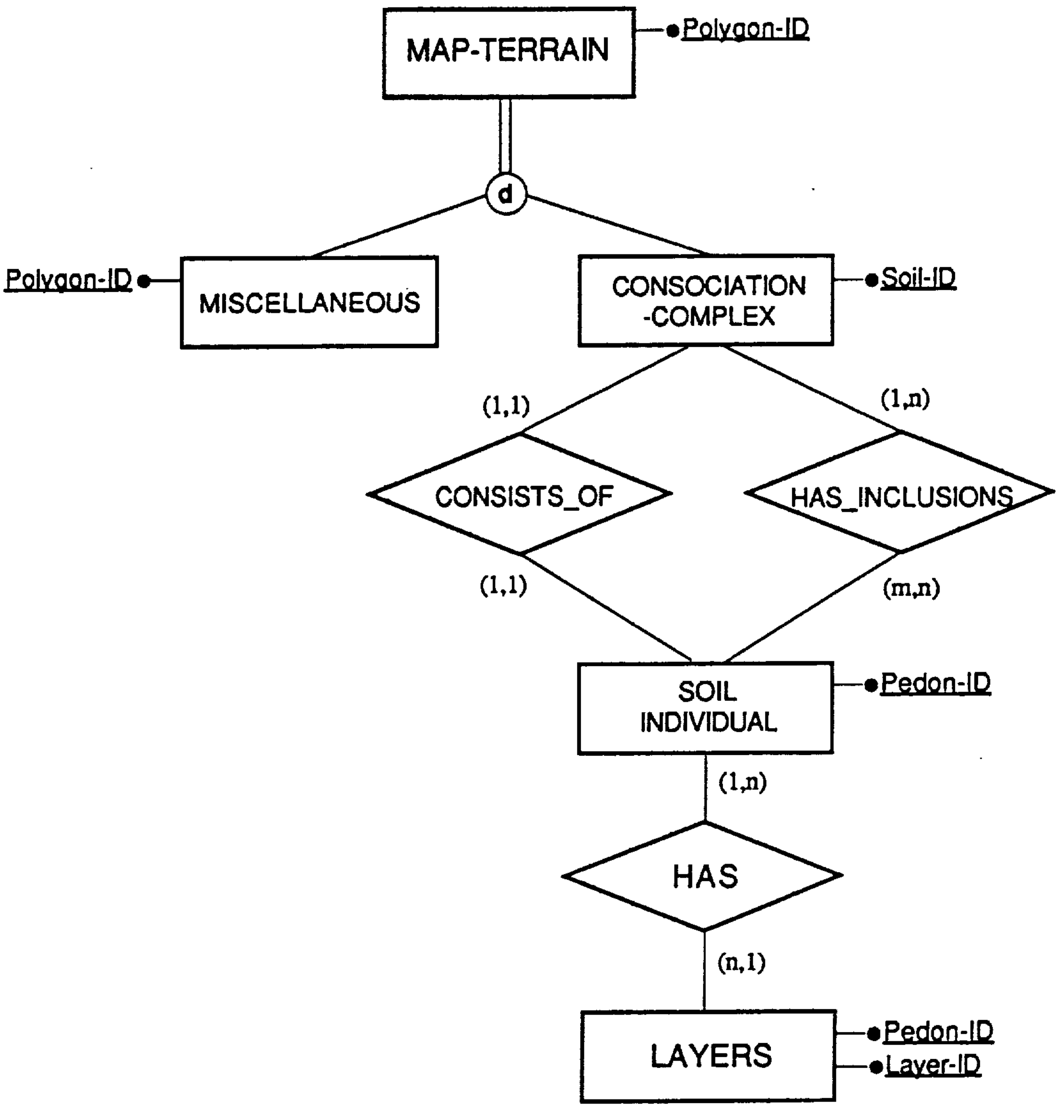


Figure 24

Figure 25. The databases have been implemented on a personal computer. This illustration shows the main menu with the different options for the ownership database. The database was implemented in INFO software. This first example allows to input data, update records, query the database for specified requests, or delete records. A "future applications" option was also included.

```
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                 MIAMI COUNTY PROJECT
------------------------------------------------------------------------------

          1 - DATA INPUT
          2 - RECORD UPDATE
          3 - DATABASE QUERY
          4 - RECORD DELETE
          5 - OTHER (FUTURE APPLICATIONS)
          0 - EXIT

               WHAT IS YOUR CHOICE? (NUMBER):
```

Figure 25

Figure 26. Map showing the parcels, and their ID numbers, owned by three persons within one section. This map was produced with the standard capabilities of ARC/INFO, and through the linking of three tables contained in the ownership database. The query was performed from the cartographic database into the attribute database; results can be displayed on the monitor screen or sent to a plotter. Similar queries can be performed for any variable that exists in the database.

QUERY OF PARCEL OWNERS

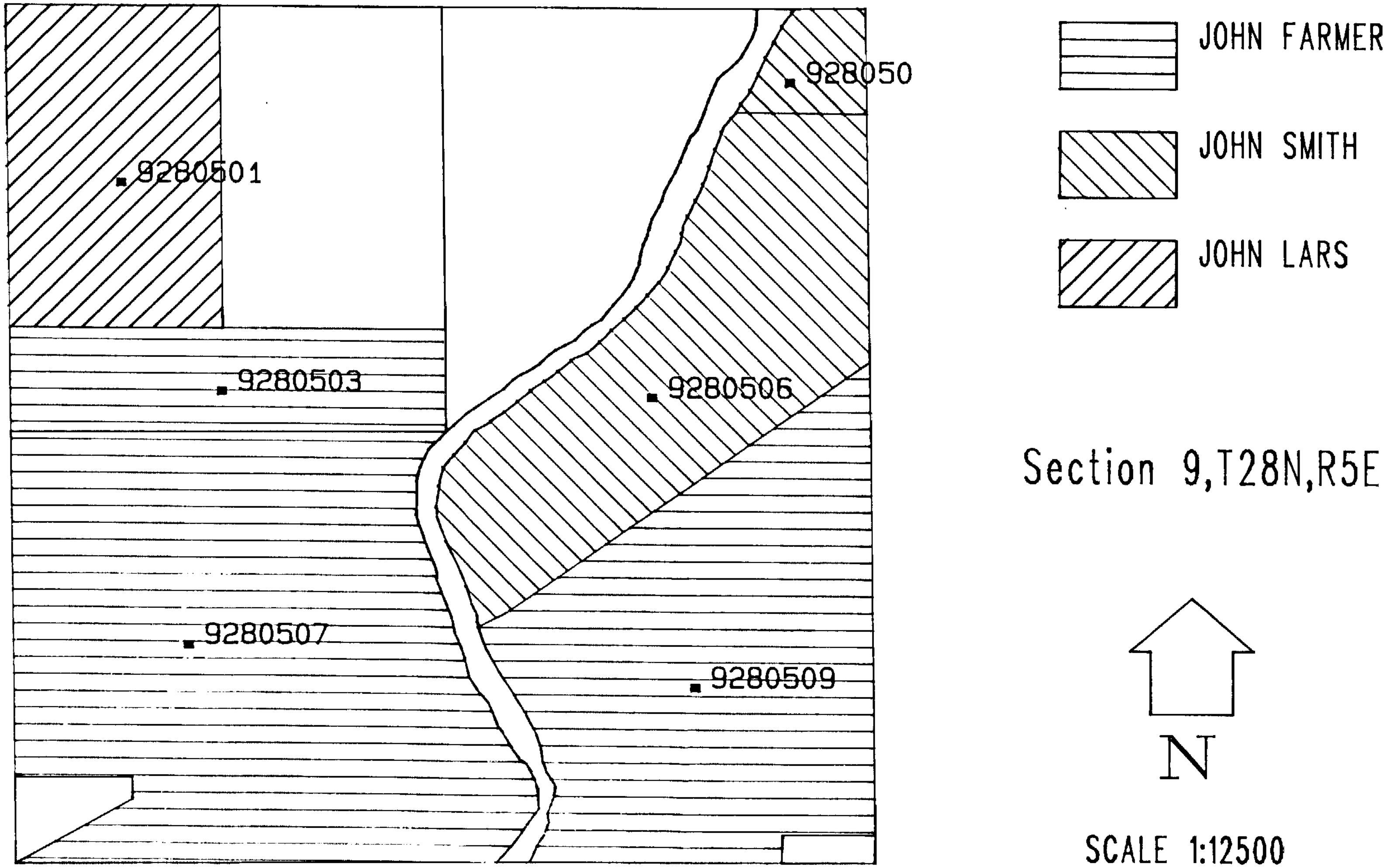

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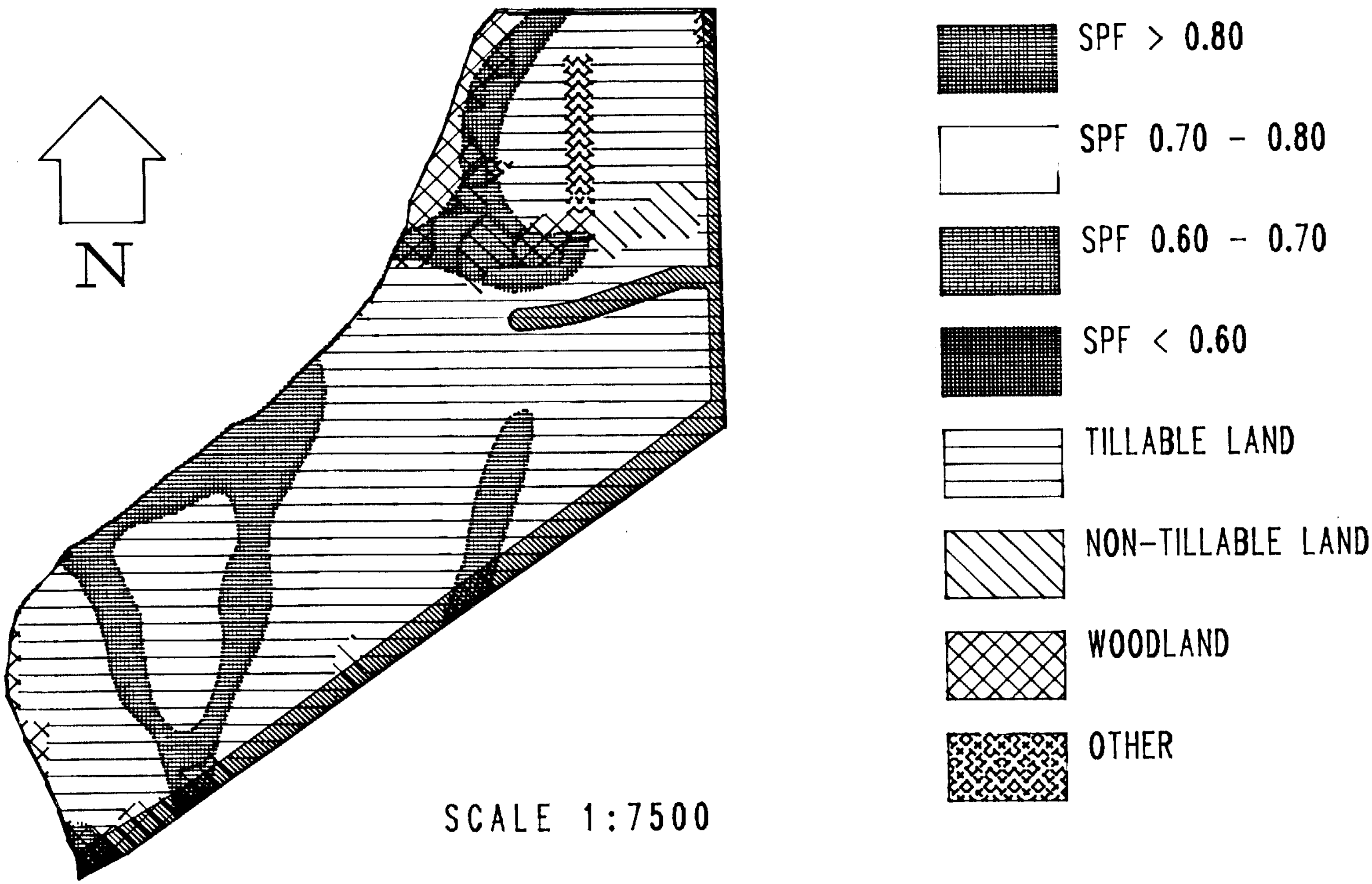
Figure 26

Figure 27. This map contains information about soil productivity factors (stored in the soils database) and land cover types (obtained from satellite data) as determined from the agricultural reassessment database. Easements and right-of-ways (obtained through proximity analysis of roads and drainage features) are also shown on the map. This kind of information is necessary to calculate land appraisal, and to complete the record cards.

SOIL PRODUCTIVITY AND LAND COVER

OWNER: John Farmer

LOCATION: Parcel 6,Sect 9,T28N,R5E



NASA Applications Project, Miami Co., IN

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Figure 27

Figure 28. Results of the GIS model for agricultural reassessment, in report format. This output reproduces the record card that is used to calculate agricultural land taxes. The model that was developed can automatically display land types, soils ID's, different acreage for each of the soil classes, productivity factors; and it can perform the rest of the calculations required to complete the tax assessment.

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PARCEL ID: 9280506
OWNER ID:

COUNTY: MIAMI COUNTY
SECTION: 9

LAND DATA AND COMPUTATIONS

LAND TYPE	SOIL ID	MEASURED ACREAGE	PROD FACTOR	BASE RATE	ADJUST. RATE	EXTENDED VALUE	INFLUENCE FACTOR	TRUE TAX VALUE
1	FsA	11.35	0.77	495	381	4,324	0.00	4,324
3	FsA	0.04	0.77	495	381	15	0.80	2
1	FzC3	13.43	0.60	495	297	3,988	0.00	3,988
2	FzC3	1.43	0.60	495	297	424	0.60	169
3	FzC3	1.77	0.60	495	297	525	0.80	104
7	FzC3	0.08	0.60	495	297	23	0.00	23
3	Ge	0.47	0.94	495	465	218	0.80	43
1	OsB	2.30	0.64	495	316	726	0.00	726
1	OtA	46.04	0.72	495	356	16390	0.00	16,390
2	OtA	2.12	0.72	495	356	754	0.60	301
3	OtA	0.51	0.72	495	356	181	0.80	36
7	OtA	1.61	0.72	495	356	573	0.00	573
1	St	7.38	0.77	495	381	2,811	0.00	2,811
3	St	3.23	0.77	495	381	1,230	0.80	245
9		1.00		3500		3,500		3,500

MEASURED ACREAGE 91.7 TRUE TAX VALUE 33,235

PARCEL ACREAGE :	86.90	
81 LEGAL DRAIN :	0.00	
82 PUBLIC ROADS:	0.00	
9 HOME SITES :	1.00	
TOTAL ACRES FARMLAND =>		85.90
TRUE TAX VALUE	33,235	
MEASURED ACREAGE:	91.7	
AVERAGE TRUE TAX VALUE/ACREAGE:		362.4
TRUE TAX VALUE OF FARMLAND:		31130.2

Figure 28