Title: **INTEGRATION OF REMOTE SENSING AND GEOGRAPHICAL INFORMATION SYSTEMS FOR AGRICULTURAL REASSESSMENT[1]**

Authors: *R. Norberto Fernández, D. Fabián Lozano-García, and Chris J. Johannsen.*

Laboratory for Applications of Remote Sensing (LARS), Purdue University, West Lafayette, Indiana 47907.

Submitted to: *Photogrammetric Engineering & Remote Sensing.*

[1] Contribution from the Agronomy Dep., Purdue Univ. Agric. Exp. Stn., West Lafayette, IN 47907. Journal paper no. ______.

INTRODUCTION

In 1971, the General Assembly of the State of Indiana mandated that the assessment of agricultural lands should be based on the true cash agricultural production value of the lands (productive potential). A 1973 ammendment (House Enrolled Act Nº 1174) indicated the availability of soil survey data (meaning soil productivity factors) to be used by the counties in determinig the value of farmlands. Since detailed soil maps were not widely available at that time in the state of Indiana, nearly twenty five counties (out of ninety two) first used this procedure during the 1976 reassessment.

In 1983, a second ammendment (House Enrolled Act Nº 1430) clearly established the reassessment of farmlands in Indiana by productive potential rather than current market value. This procedure requires the use of detailed soil maps to determine the capability of the land to produce crops, land cover maps to categorize the different uses of the land, and property maps to identify indivual farms. Current legislation calls for land appraisal for reassessment, every four years.

As a way to integrate information needed for farmland reassessment, Santini *et al.* (1989) developed a "Soil Maps an Interpretation System" intended to assist individuals in Indiana counties, with the rapid recall and interpretation of detailed soil surveys. This system, which was first developed in 1983 and has been implemented in approximately thirty counties, contains county soil survey data, agricultural land ownership maps, land use maps, several soil attributes, and other variables, stored in database files. Selected macros allow to produce printouts of interpretive maps and reports (Santini *et al.*, 1989).

Although this system is able to produce different outputs (such as interpretive soil maps, land ownership maps and tables, land use maps and tables, and farmland valuation tables), technical limitations influenced the original design, thereafter, restricting its potential expansion, the posibility of integrating data from different sources for modeling, and the link to other systems.

Geographic information systems are useful tools to integrate different data for local land planning (Niemann *et al.*, 1987; Ventura, 1988), and natural resources management (Walsh, 1985). Remote sensing is also a valuable tool for mapping, monitoring and modeling agricultural and other natural resources (Bauer *et al.*, 1978; Estes, 1985). Recent developments in commercial technology allows to process and exchange data between remote sensing analysis and geographic information systems, at acceptable cost (Ehlers *et al.*, 1990). This functional integration, which is also available for microcomputer-based systems, opens the possibility to local agencies of integrating data and automating many cartographic tasks in an efficient and timely way. The Laboratory for Applications of Remote Sensing (LARS) at Purdue University is assissting Miami county officials in the use of these tecnologies for farmland reassessment, soil erosion mapping, and soil management.

The objective of this study was to utilize remote sensing and geographic information system technologies to develop a model for agricultural land appraisal in Miami county, Indiana. The model had to: *1)* comply with state and county laws; *2)* be accurate at the 90% level; *3)* be efficient in terms of data storage and data handling; and *4)* be flexible in presenting results, i.e. the model should be able to show results on county, section, and individual farm basis, and it should be able to display results in map and tabular format. Additionally, all operations and processing had to be performed on microcomputers. The results obtained from this model will be used by the Miami County officials in the agricultural reassessment.

BACKGROUND

The underlying idea of the Indiana farmland reassessment is that land should be valued according to its productive potential rather than its market value. Productive potential takes into account, first, the capacity of the soil to produce crops (soil productivity); second, the land cover type; and third, possible reductions in cropland productivity caused by river or stream flooding.

Each soil map unit is given a soil productivity factor (SPF) for use in the farmland reassessment. SPFs, which refer to the capacity of the soil to produce crops, are calculated based on soil properties such as slope, water holding capacity, natural drainage, organic matter content, etc.; and corn yield estimates over a 10 or 15 year period. In Indiana, corn yields estimates are the most reliable yield estimates available for all types of soils.

The land types defined for the farmland reassessment are: *tillable land*, land used for cropland or pasture with no impediments to routine tillage; *non-tillable land*, land with brush or scattered trees with less than 50% canopy cover or impediments for crop production; *woodland*, timber with 50% or more canopy cover; *other farmland*, farm buildings, farm ponds or running water; *agricultural support land*, public ditches and roads; *homesite*, land area for residential homesite. More productive land is rated higher than less productive land and thus, will have a higher assessed value (State Board of Tax Commissioners, 1986).

MATERIALS AND METHODS

HARDWARE AND SOFTWARE

The model for land appraisal was developed on microcomputer-based systems. The GIS was developed on a PC-ARC/INFO[1], and the analysis of satellite data was performed on a PC-ERDAS[2]. The ARC/INFO software was used to convert files from raster to vector format.

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[1]ARC/INFO is a trademark of Environmental Systems Research Institute, Inc. (ESRI), Redlands, California.

[2]Earth Resources Data Analysis System, Atlanta, Ga.

DATA INPUT AND CARTOGRAPHIC BASE

Several maps were used to build the spatial database (Table 1); they were redrafted on stable base (MYLAR®) and manually digitized using a GTCO[3] Digipad 2436A digitizing tablet, configured to encode coordinates in ASCII format with an accuracy of +/- 0.01 inch.

The cartographic reference layer of this GIS are stable-based USGS 7.5 minute series topographic maps (scale 1:24000). Details on accuracy of registration and geodetic reference can be found in Fernández *et al.* (1991). Locations of all features were expressed in terms of the Indiana State Plane Coordinate System (Curtis, 1974). The model was evaluated on sections 3, 4, 9, and 10, T28N, R5E, Miami county, Indiana.

REGISTRATION AND ANALYSIS OF SATELLITE DATA

Land cover maps were derived from digital analysis of satellite data. Several Landsat TM and SPOT scenes obtained at diferent dates throughout the growing season were used for temporal analysis. Each image was geometrically corrected using 220-250 control points for the entire County, and registered to the common base with sub-pixel accuracy (RMS = 0.25 pixel; 7.5 m). The analysis procedure included: development of training statistics using the supervised and unsupervised methods, refinement of training statistics, classification of test areas, correlation between spectral

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[3]GTCO Corporation, 1055 First Street, Rockville, MD 20850.

and informational classes, and the evaluation of classification results (Bauer *et al.*, 1978). After the classification was accepted, the final classes were recoded for the reassessment, polygons smaller than 0.4 ha (1 acre) were eliminated, and the map was transformed from raster to vector format using the ARC/INFO's software. The final map was then incorporated into the GIS spatial database (Fig.1).

DATABASE DESIGN

The database design process can be stated as follows:

> "Design the logical and physical structure of one or more databases to accomodate the information needs of the users in an organization for a defined set of applications" (Elmasri and Navathe, 1989).

The success in delivering information to satisfy those user's needs depends, in part, on the quality and availability of the data that reside in the system. To accomplish this, using ARC/INFO, it is necessary to design the cartographic layers, the feature attribute tables, lookup tables, and the map library (Chambers, 1989). In this paper, we will refer to the digital cartographic layers (with topology built in them) as the *spatial database*, and to the feature attribute tables as the *attribute database*.

For the spatial database, rural parcel and soil maps were digitized as polygon layers; while roads were digitized as line layers. Streams were digitized as line and polygon layers: at the scale of 1:24000, the main river in the area can be represented as a polygon (Fig. 1). Coverages (layers) were organized on Section basis, as required by the County officials. Each Section is 2.6 km^2 (1 sq.mile), and covers 259 ha (640 acres), approximately.

Attribute databases were designed to store descriptive information related to each map. A high-level conceptual model (the Extended Entity-Relationship model) was applied to create a schema, which reflects the semantics and constrains of the databases (Elmasri and Navathe, 1989; Chen, 1976). These conceptual models were then mapped into the relational data model and implemented in the INFO database management system.

Thematic data and attribute data are related through polygon identifiers; therefore, queries can be performed interactively from the spatial database or within the relational database (Morehouse, 1985).

RESULTS AND DISCUSSION

THE MANUAL APPROACH TO LAND APPRAISAL

The current approach to the appraisal of agricultural land for property tax purposes in most Indiana counties, involves several steps (Fig. 2). Land ownership maps showing rural property boundaries, on section basis, are manually drawn at the scale of 1:4800 from information contained in the deeds. Roads and ditches are also included in these maps. Soil maps published at the approximate scale of 1:20000 (Deal, 1979) are photomechanically enlarged to match the 1:4800 scale. Black and white aerial photographs taken at the approximate scale of 1:24000 are enlarged and rectified to 1:4800 scale. The error of this rectification is 0.05 cm. Maps showing different land cover types are then created by visually interpreting these photographs. Once these three basic layers of information are obtained, the next step is to manually overlay them to create a new map showing the combination of rural property boundaries, soils, and land cover types. The areas of the different polygons are then manually measured with a planimeter and reported, for each parcel, in the Indiana Agricultural Property Record Card (IAPRC; Fig.2). The rest of the land ownership information needed to complete the IAPCR is obtained from an automated attribute database implemented in a microcomputer. Soil productivity factors are directly inputted into the IAPRC for each map unit.

Several problems were identified with this approach. The cartographic procedure lacks adequate quality control. This was more noticeable in the rural property maps where numerous inconsistences were observed; among them, the number of parcels shown on maps did not always agree with the number of parcels stored in the attribute database; some parcel perimeters and areas shown on maps were different from the ones reported in the deeds (this problem was more noticiable for parcels that have natural features as boundaries); the areas of some sections did not correspond with the areas reported in the cadastre.

This manual approach requires that the original maps be subjected to a series of enlargements and scale changes; consequently, the final maps and the information derived from them contain different errors. There is a noticeable mismatch among similar features of the three layers, such as corner sections, roads, and rivers (Fig. 3). When soil maps are enlarged from their original scale to 1:4800 scale (approximately 5X), the lines that represent soil boundaries, in the resulting maps, have a width of approximately 1 mm, which at the scale of 1:4800 translates into 4.8 m (15.75 ft). Area measurements derived from these maps will contain errors associated to that line width. Furthermore, all discrepancies among features in the final maps are visually adjusted; this results in additional error and lack of consistency during the calculation of polygon areas. The final outcome are maps that contain a mixture of errors from different sources, which in many cases lack the accuracy required by the Assessor's office (≥90%).

Several problems were also identified in the ownership attribute database, such as redundant information, empty records, unnecessary data, and inefficient storage and retrieval of data due to a lack of design. Because this database is not integrated with the rest of the appraisal procedure, attribute information can only be reported in tabular format and independently from the cartographic representation of the information. Furthermore, the current approach does not allow to integrate data from other sources that could be used for analysis and modeling of rural resources.

THE GEOGRAPHIC INFORMATION SYSTEM APPROACH TO LAND APPRAISAL

In order to avoid the problems originated with the current manual approach, and to enhance the appraisal of agricultural lands, we have developed an automated procedure based on the geo-relational model (Fig. 4). Within this model, locational data can be represented with the topological model, while thematic data processing can be done with the relational model (Morehouse, 1985).

For the spatial database (Fig. 1), all layers of information were registered to stable-based USGS 7.5 minute series maps. Land cover maps were obtained from satellite data, as described in **MATERIALS AND METHODS**, transformed from raster to vector format, and incorporated into the spatial database. Because of the innacuracies that were detected in some of the original property maps, they were re-drafted on stable base at the scale of 1:24000, and then digitized. Soil maps, published at 1:20000 scale on uncontrolled aerial photography, were also re-drafted on stable base at 1:24000 scale, and digitized. During this scale conversion, minor adjustments were done to some of the soil delineations to match the topography. Roads and railroads were digitized directly from the USGS 7.5' Quad maps. The drainage network was obtained from different sources (USGS Quad maps, aerial photographs, soil maps, and property maps), drafted on stable base at 1:24000 scale, and then digitized.

These digital layers were then used as input for the land appraisal model, and to generate different maps using the software standard functions. State statutes mandate that a strip of land of 22.85 m (75 ft) each side of a legal drain (ditch) be used for maintenance of the drain; and, therefore, are not taxable to the affected landowner. These "easements" can be substracted during the calculations for the tax assessment. Also, 6.10 m (20 ft) each side of a road are used for maintenance (right of way). Proximity analyses were performed on roads and drainage maps in order to calculate easements and right of ways. The resulting maps were combined with the overlay of property boundaries, soils, and land cover to show the combination of these variables on section and individual farm basis (Fig. 4).

The attribute databases were redesigned and/or enhanced to accomodate more information. The rural *land ownership* database contains information about owners (persons, corporations, organizations, and estates), as well as legal descriptions of parcels. We have also designed a new database for *soils*, which contains information about the fifty soil mapping units present in Miami county. This information describes soil surface conditions, soil pedons, pedon sites, and soil horizons. Data were coded for input, and lookup tables were defined for display of the data. The soil database was loaded with data provided by the USDA Soil Conservation Service (Forms 5 and 6) in Indianapolis, Indiana. SCS files were reformatted to INFO format, and adapted to the new design. Similar soil information can be found in published soil survey reports (Deal, 1979). Soil productivity factors were also included in this database. The resulting databases are free from update anomalies, while preserving all dependencies among attributes. Since these databases are part of the GIS, they can be accesed from the spatial database through software routines, or from the DBMS independently. Details on the design and implementation of these databases can be found in (Fernández and Rusinkiewicz, 1991; Fernández *et al.*, 1991 a and b).

Some advantages of this GIS approach, as compared to the current manual approach, can be readily observed. The registration of all layers to a base map provides an accurate and efficient positioning of spatial features; therefore, allowing compatibility for the resulting products. Common features, such as rivers, roads, and corner sections, can be digitized only once in a template, and copied to subsequent layers when needed. This eliminates the problem of mismatches among layers.

All area measurements are done automatically by the system, eliminating the problem of line thickness and visual adjustments. The final results can be shown in map and tabular format; and, they can be incorporated into the IAPRC for further calculation of farm taxes (Fig. 5 and 6).

FALTA ACCURACY OF RESULTS!!

CONCLUSIONS

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