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Integration of Land-Use Data and Soil Survey Data

Remotely sensed land-use data were digitized and registered with digitized soil survey data to provide quantitative information for resource planning.

Introduction

Land-use and cover inventories provide basic data for the development of land-use plans. Remote sensing technology provides a vehicle for the rapid collection of current, detailed, land-use and cover inventories for a variety of planning and management purposes. Especially relevant is the spatial context of the data which provides the analyst with a knowledge of the distribution of resource categories, their areal extent, and proximal relationships. However, natural resource related phenomena are the result of complex interactions among many factors. Such relationships make it imperative that land managers take an interdisciplinary approach to problems and utilize the full potential of all available tools (Hitchcock, Baxter, and Cox, 1975).

Abstract: *Remote sensing technology provides a vehicle for the rapid collection of current, detailed land-use data for a variety of planning purposes. Especially relevant is the spatial context of the data which provides the analyst with a knowledge of the distribution of resources, their areal extent, and proximal relationships. However, the analytical phase can be enhanced by registering the data to a coordinate system which allows combination with other resource data (e.g., soils, topographic). Such an approach was used to increase the utility of remotely sensed interpretations and provide quantitative spatial analyses for a rapidly developing area adjacent to the Black Hills in western South Dakota. Land-use interpretations (Modified Level III, visually interpreted) from RB-57 photography were digitized (congressional township coordinates) using the dominant feature of a 2.5-acre cell. Unpublished soil survey data were similarly digitized and interpretive soils maps generated by means of a computer-assisted process with overlay capabilities. Resulting interpretations of soils data and land-use data were integrated and maps were computer-plotted at several scales to study land-use and soils relationships and temporal land-use changes. This series of analyses also was used in the development of zoning ordinances and maps for the area. The role of remote sensing in land analysis can be enhanced by integrating the data with other resource data through assignment to a coordinate system which is referenced to ground points.*

At present, the regional decision-maker typically lacks relatable basic information on the use, composition, character, and the temporal change of the region (Clapp *et al.*, 1973). The most basic forms of data, such as

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soil maps and land-use, have been traditionally unavailable in formats directly useable in the regional planning process. However, computer-assisted processing provides capabilities for including a variety of mapped data of different types and scales in land analysis. The analytical phase of resource planning can be improved by encoding remotely sensed interpretations into a ground-referenced cellular or polygon system (e.g., referenced to geodetic coordinates, congressional township coordinates, etc.) which allows combination with other spatial resource data, such as soils or topographic, which are similarly managed (Cox, Hitchcock, and Weber, 1975). These capabilities have been developed in a program called SPAN for Spatial Analysis (Cox and DeVries, 1977). The program assists in the analysis of spatially distributed remote sensor and/or other geographically distributed data.

A portion of a study area of 34,000 ha (84,000 acres) near the Black Hills in western South Dakota provides an example of the approach. Soils and land-use data were composited for utilization in planning and zoning activities along an interstate highway corridor. Land-use data (Modified Level III of Anderson, Hardy, and Roach, 1972) were visually interpreted from RB-57 photography to supply detailed information for planning and zoning in the study area adjacent to the Black Hills in western Meade County, South Dakota. The detailed land-use data were digitized as the dominant feature of a 1 ha (2.5 acre) cell for combination with soil interpretation data. The cellular grid (1 ha, 2.5 acre cells) used for digitizing the data was referenced to congressional township coordinates. Soil survey data (unpublished field mapping sheets) and eight interpretations pertinent to the study were obtained through the courtesy of the Soil Conservation Service. Soil data were digitized similarly to land-use and interpretive soil data, and maps were generated via the computer-assisted process which has compositing capabilities. Resulting interpretations of digital land-use and soil interpretation data were then merged and a series of maps were computer-drawn from the new data sets at several scales to study land-use and soil relationships. A "quick look" analysis of temporal land-use changes also was provided. This was accomplished by plotting the then current land-use data at the scale of seven-year-old photography indicative of previous land use and manually overlaying the two data sets for analysis. The objective of this paper is to discuss how the utility of remotely sensed interpretations can be increased through use of a computer-assisted process which provides capabilities for merging or compositing several types of data of varying formats. In this study the resulting maps and summary data were used for planning and zoning in a rapidly developing area (34,000 ha) adjacent to the Black Hills in western Meade County, South Dakota.

Procedure

Data Source

Detailed land-use information for the study area was visually interpreted from enlargements (1:24,000 scale) of high-altitude NASA color photography (RB-57, August 1974). A modification of the Level III classification of Anderson *et al.* (1972) was adopted to provide land-use categories compatible with user needs. Table 1 provides a description of the land-use levels used in the Black Hills study area. Study area descriptions and details of interpretation of the land-use and data collection have been reported (Byrnes, Frazee, and Cox, 1975).

Soil maps and interpretations for each mapping unit found in the study area were obtained from the Soil Conservation Service (SCS). Field mapping sheets (unpublished survey) with soils delineated and coded were provided at a scale of 1:15,840. The area was comprised of 57 different detailed soil mapping units. Soil interpretations provided by SCS were used to produce eight interpretive maps to be combined with the land-use data. This was accomplished by assigning the appropriate interpretations to the soils data and plotting the maps. The interpretations which accompanied the SCS map indicated soil limitations for

(1) Dwellings with basements,
(2) Septic tank absorption fields,
(3) Sewage lagoons,
(4) Shallow excavations,
(5) Area sanitary landfill,
(6) Trench sanitary landfill,
(7) Local roads and streets, and
(8) Suitability as a source of road fill.

The levels of limitations for the first seven soil interpretations were slight, moderate, moderate-to-severe, and severe and were indicated by numbers 1, 2, 3, and 4 respectively. Road fill was classed as good, fair, poor-to-fair, and poor. Numeric codes assigned to the land-use and interpretive soils data are in Table 2. The method for developing interpretive soil data sets from original digitized soil data is discussed later.

TABLE 1. LAND-USE CATEGORIES USED IN THE BLACK HILLS AREA

Level I[1]	Level II[2]	Level III[3]
Urban		
	Residential	
		Single family
		Multi-family
		Mobile home
		Mobile home park
	Commercial	
		General commercial
		Motel/Hotel
	Industrial	
		Light industrial
		Heavy industrial
	Transportation	
		Dual highway
		Primary road
		Secondary road
	Institutional	
		Schools
		Churches
		Cemeteries
		Hospitals
		Public buildings
	Parks/Recreational	
		Campgrounds
		Marinas
Agricultural land		
	Cropland	
	Hayland	
Rangeland		
Forest land		
Water		
Barren land		

[1] Level I land use is a classification system for identifying general uses of land in a given geographical area.
[2] Level II subdivides the general categories of Level I.
[3] Level III is a very detailed classification for Level II categories.

DATA DIGITIZATION

Land-use and soils data were digitized as the dominant feature of a 1 ha (2.5 acre) cell. The representative symbol (alphanumeric, alpha, or numeric) was recorded on ordinary 80-column data forms. Data were referenced to congressional township coordinates by subdividing the townships into cells. All data were manually digitized using grids which were computer-drawn to fit scales of 1:15,840 and 1:24,000 for the soil survey field sheets and the-land use data from RB-57 enlargements, respectively. Grids also can be drawn to fit geodetic, Universal Transverse Mercator, or other projections (R. C. Durfee, 1975). The change-point method of digitization was used. This method involves indicating the row and column reference numbers for the first data element in a row and then only the column numbers for successive data changes within the row. If more than one computer card (80 columns) is

TABLE 2. NUMERIC CODES FOR LAND-USE CATEGORIES AND SOIL INTERPRETATION CLASSES. NUMERIC CODES WERE ASSIGNED TO EACH MAPPING CATEGORY TO PROVIDE COMPATIBILITY WITH DIGITAL COMPUTERS.

Variables[a]	
Land Use	*Code*
Range	1
Forest	2
Agricultural	3
Residential	4
Commercial	5
Mobile Home	6
Urban	7
Soils Limitations	
Slight	1
Moderate	2
Moderate-to-severe	3
Severe	4

[a] Numeric codes for soils were assigned to the original soils data by an interpretation assignment step (see text for details). Each soil interpretive map was comprised of the four levels shown except road fill where the one, two, three, four assignment represented good, fair, fair-to-poor, and poor respectively.

required to enter a row (line) of data, the row number is repeated in columns one to three for all successive cards and the coding process continues by indicating the columns for successive data changes. Columns 73-80 are left blank for data identification purposes. The total study area was 34,000 ha and was analyzed as three data sets of 128 × 128 one hectare square cells (2.5 acres).

DATA HANDLING AND ANALYSIS

Data were analyzed (i.e., interpretive maps, compositing, area analysis, etc.) by SPAN, a *SP*atial *AN*alysis program for handling geographically distributed data (Cox and DeVries, 1977). Details of format for individual cards and steps for combining data can be found in the SPAN document. Therefore, they are not discussed but general information on the procedure and types of output products is given.

First, the data recorded on coding sheets are keypunched. Next, a series of parameter cards are set up to run SPAN. These parameter cards indicate the size of the data matrix, cell size and unit, number of data categories, data codes, etc. Also, codes for the digitized mapping units are assigned specific numeric values on parameter cards to provide computer compatible data.

A set of parameter cards is also required to formulate interpretive maps of three or four categories from a number of soil mapping codes. On these cards the soils with similar interpretive categories are simply listed in certain card columns followed by a numerical designation representing the interpretive class. For example, a 1 for slight, 2 for severe, and so on (Table 2). This results in the creation of a new interpretive data set with numeric codes (e.g., 1-4) representing interpretive levels. Details for the parameter cards set-ups are in Cox and DeVries (1977).

All data are processed for errors by an error checking step which lists row-column anomalies and high or low data values. The step lists data errors and their location by row and column. It also checks against a control list of original codes (e.g., soil and land-use codes) for unmatched entries. Numeric data with row and column references are passed to a plotter program for map compilation. The scale of the plotted map is specified by indicating the desired cell size in inches.

Frequency counts of data elements and the area of each mapped categories in appropriate units (acres, hectares) are provided along with the working map output in the form of plotter drawn maps. Several options are available for the final plotted map. Plotted categories can be identified by lines enclosing cells or polygons of data with numerical or symbolic identifiers within the lines, lines around symbols, or lines around shaded areas.

Two or more data sets can be combined by designating desired combinations of the categories of each variable on parameter cards. This is accomplished by designating the levels of each variable that are to be combined to create new levels or composite two or more types of data on a single map (Table 3). Area summaries and map output are similar to that described in the preceding paragraph.

A simple temporal analysis ("quick look") was implemented by plotting a map of current detailed land use data at the scale (1:7,920) of older data which had been recorded on black-and-white photos. The plots of current data were manually overlayed on the older photography for analysis.

Results

A portion of the modified Level III land use data for the study area is shown in Figure 1. Data are in seven classes for presentation purposes. These data encompass an area of approximately 83 square kilometers (8,300 ha or 20,500 acres). The photointerpreted land-use data were digitized and computer processed to produce the computer-drawn map shown in Figure 2, which shows a portion of the area. The map was originally plotted at a scale of 1:7,920 to be compatible with other base information (aerial photography) being used by the planners.

Computer maps of eight soil interpretations were produced for the same portion of the study area as the detailed land use data. Figure 3 shows an interpretive map for limitations to dwellings with basements. Area summaries showed extensive areas of severe limitations due to steep, shallow soils in many instances. The map also was produced at a scale of 1:7,920 for use with other resource information as well as land-use data.

Land-use and soils data were merged through computer processing to provide analyses of their proximal relationships and interactions. In Figure 4, residential, commercial, urban, and mobile homes were merged with soil interpretation data (e.g., limitations to dwellings with basements) and plotted on a single map. The categories for the map are described in the legend of Figure 4.

A "quick look" temporal analysis was provided by overlaying a scaled computer-

Table 3. General Format for Combining Land-Use and Soil Interpretations.

Variable		New Levels[a]							
Source Number[b] (1-3)[c]		1 (4-6)	2 (7-8)	3 (9-10)	4 (11-12)	5 (13-14)	6 (15-16)	7 (17-18)	8 (19-20)
Land-Use	010	4	5	6	7	1	1	1	1
Land-Use	010	—	—	—	—	2	2	2	2
Land-Use	010	—	—	—	—	3	3	3	3
Soils	020	1	1	1	1	1	2	3	4
Soils	020	2	2	2	2				
Soils	020	3	3	3	3				
Soils	020	4	4	4	4				

[a] New Levels are constructed from combinations of codes (Table 2) designating levels of variables in each column. New levels (1-8) are described in the legend of Figure 4.
[b] Data sets for each of the variables are automatically numbered (10, 20 etc.) in the order they are written on a file for overlay and analysis.
[c] Designates fields for parameter cards.

drawn map of current land use data (similar to that in Figure 2) over seven-year-old land-use data that had been recorded on old black-and-white photography of the area taken in 1968. A semi-quantitative visual assessment resulted with notes on major land-use changes and their spatial locations.

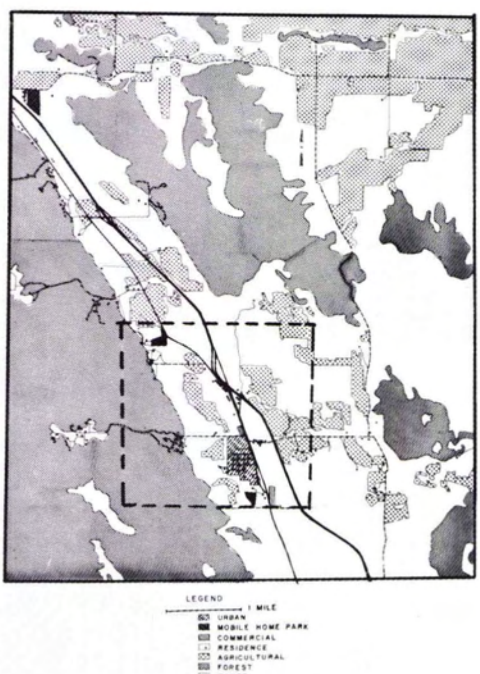

Fig. 1. Detailed land-use interpretation of the Blackhawk region of the Black Hills strip area in Meade County. The map was prepared from RB-57 photography (August 1974) enlarged from 1:120,000 to 1:24,000 scale. Blackhawk is the urban area in the middle, lower third of the map. This area was chosen because it is relatively undeveloped and provides a good data set for presentation.

Discussion

The utility of remotely sensed data was increased by entering it into a cellular data base for computer processing and integration with other similarly processed data, soils interpretations in this case. Digitizing the remotely sensed land-use interpretation in reference to ground points and computer processing the data provided several rapidly available products not conventional with manual preparation of interpretations. Data were initially used to prepare a single working land-use map which was computer drawn to a desired scale and the categorical data analyzed to provide areal estimates.

Fig. 2. A plotter map of land use for the portion of the area in Figure 1 within the dashed lines. Data were input at 2.5 acres (1 ha) and were plotted at a scale of 1:7,920 (8 inches = 1 mile).

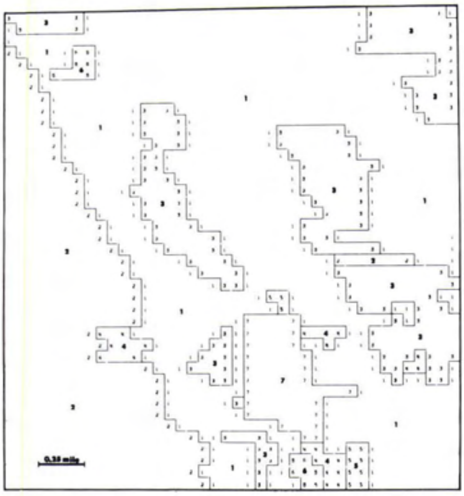

FIG. 3. A soil interpretive map of limitations to dwellings with basements for the same area as in Figure 2. Soil mapping units were digitized at the 2.5 acre (1 ha) cell level and originally plotted at 1:7,920 (8 inches = 1 mile). Soils in level three are complexes in which one of the soils has moderate limitations and the other severe. These should be field-checked for the location of each component during the ground surveys.

FIG. 4. Land-use and soils relationships for the area in Figures 2 and 3. These are spatially expressed by computer analysis of digital data and plotter mapping. Note the proximity of various land uses and soil limitations. Data were originally plotted at a scale of 1:7,920 (8 inches = 1 mile) for comparison with older photo-based data.

Therefore, the advantages of computer processing at this point were that (1) the digital data were registered to coordinates and stored in an easily accessible form for overlay or monitoring; (2) the manual planimetering task was accomplished by computer analysis; and (3) the spatial display was provided at the requested scale by means of the computer plotter. Plotting of maps to scale reduces commonly required cartographic or photolab renditions. The advantage of processing soil data and mapping interpretations (Figure 3) by these techniques is that the original map symbol data are recorded and stored and can be called to provide any of a number of interpretations. First, this deletes the need to go through the original maps to assign numeric codes to each of the mapping units before digitizing or making manual interpretation. Second, it permits the use of field sheets for unpublished surveys or published surveys, whichever are available, because scale is no problem with computer-drawn grids.

Land-use maps provide needed data for assessing spatial relations and proportions of land in various classes. But, land planning and zoning requires that other information, such as soils, be integrated with land-use information to establish a number of important relationships. For example, the integration of land-use and interpretive soils data (Figure 4) by overlay provided a perspective not viewed when either variable was analyzed separately (Figures 2 and 3). In combination, the data show the spatial relations of selected land-use classes to soil characteristics. In addition, the acreage summaries for the soils in land areas which had not been developed (that occupied by range, agricultural, and forest uses) provided quantitative evidence that much of the remainder of the study area was not suitable for basement-type dwellings. For the entire study area (34,000 ha or 84,000 acres), about 70 percent had severe limitations while 26 percent had slight-to-moderate limitations. Only 8 percent of the area had slight limitations. In several analyses, two or more soil limitations were overlayed to produce a single interpretive map showing only the more severe limitations. These data were then overlayed with land-use information. This decreased the number of individual analyses required. These are the types of data that provide a quantitative basis for planning and zoning. The detailed land-use data were overlayed with other soil interpretations to provide a more comprehensive data package for land analysis and planning.

The change in land-use over time also is an important aspect of land analysis. Monitoring land-use change provides data for making future predictions of land use by evaluating where land-use changes have taken place. The "quick look" approach consisted of plotting current land-use data at the scale of older land-use data which had been recorded on black-and-white photos. Apparent land-use change for a seven-year period indicated that development has rapidly increased in the more environmentally sensitive areas. The more apparent land-use changes were growth along the interstate highway in the forested region of the county, where the physical restraints of steep and unstable slopes, shallow soils, and flood plains present a variety of problems in providing sewage disposal, fire protection, road construction and maintenance, and other public services. Several of these residential developments are shown as pockets within the steeply sloping, forested regions occupying the western (left) portion of Figures 1 and 2. This technique provides a rapid assessment of temporal change and can be used where the digitization of historical data is not desirable or feasible. Although quantitative values are not presented here, the type and direction of land-use changes were apparent from this approach which compared current land-use data to seven-year-old data. Cox *et al.* (1975) discussed machine processing of remotely sensed data for temporal analysis of land-use changes in forested areas. The advantage of machine processing is that all data (i.e., historical and current) are stored for easy retrieval and the approach is more quantitative with areal summaries. Both approaches have merits and one should be chosen to fit user needs.

Summary

Remote sensing technology provides a vehicle for rapid collection of current, detailed land-use data for a variety of planning purposes. Its role in land analysis can be improved by integrating the interpretive data with other resource data through assignment to a cellular grid system referenced to ground coordinates. This type of processing permits input of data from various sources and scales and provides spatial analysis through plotted maps at various scales with quantitative summary information in tabular form. It also negates many of the necessary steps (i.e., enlarging, reducing, preparing clear overlays manually, etc.) usually required when integrating data from remote sensing with data from other sources of different scales. Data can be utilized in the original form, whether numeric or mixed codes.

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