"OHIO'S STATEWIDE LAND USE INVENTORY: AN OPERATIONAL APPROACH FOR APPLYING LANDSAT DATA TO STATE, REGIONAL AND LOCAL PLANNING PROGRAMS"

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ABSTRACT

The purpose of this paper is to provide a brief description of the programmatic, technical, user application and cost factors associated with the development of an operational, statewide land use inventory from LANDSAT data.

The expanding scope of State planning in Ohio has necessitated the development of a comprehensive statewide land use inventory. Three State of Ohio Departments have cooperatively undertaken the development of such an inventory through the processing of LANDSAT data. LANDSAT MSS data are subjected to geometrical and categorical processing to produce map files for each of the 200 fifteen (15) minute quads covering Ohio. LANDSAT computer compatible tapes will be rescanned to produce inventory tapes which identify eight (8) Level I land use categories and a variety of Level II categories. The inventory tapes will then be processed through a series of ten (10) software programs developed by the State of Ohio. The net result will be a computerized inventory which can be displayed in map or tabular form for various geographic units, at a variety of scales and for selected categories of usage. The computerized inventory data files will be applied to technical programs developed by the various state agencies. The output of these programs will be used in State, regional and local planning programs. The entire project will be completed at a lower cost than previous statewide inventories.

INTRODUCTION

The most recent statewide, comprehensive inventory of Ohio's land uses was prepared in 1965. This first statewide land use inventory was developed from the United States Geological Survey 7 1/2 minute quad sheets prepared for Ohio between 1958 and 1964. This 15 year old inventory is in fact a "generalized" summary of Ohio land uses as they existed in 1960.

The inventory was compiled county by county using manual measurement and inventory techniques. The inventory was performed by overlaying a one acre grid template on a United States Geological Survey 7 1/2 minute quad sheet. The individual county analysis would allocate the various land uses shown on the 7 1/2 minute quad sheet into 25 categories which were later aggregated into 12. All land was divided into two broad categories; urban or nonurban.

"Urban Land" was defined as land within the boundaries of municipal corporations having a population of 2,500 or more. All land outside of these municipalities was considered "nonurban". Nonurban land was allocated among eleven (11) categories. These include: manufacturing, mining and extraction, commercial, wetlands, forest woodland and agriculture, more than ten (10) residential structures per 20 acres and 5-10 residential structures per 20 acres. The first three of these "nonurban" categories were only counted if they exceeded ten (10) acres in size. Institutional, recreation, inland water bodies and wetlands had to exceed 40 acres in size before being categorized. Nonurban residential uses had to exceed a 20 acre threshold before being categorized. All uses not fitting any of these twelve (12) categories were classified by default into a large category called "cropland, pastureland and other".

The entire inventory project took nearly two (2) years to reach completion. The twelve (12) categories were displayed for the entire state on a map sheet at a scale of approximately 1:500,000. Since data had been inventoried on the basis of county boundaries, nine (9) regional maps displaying the twelve (12) categories for groups of counties were prepared at a scale of 1:250,000. In addition, a report entitled "Use of Land In Ohio" which analyzed the data and disaggregated the twelve categories into the original 25 was published as an extension of the maps.

While detailed accuracy figures are not available for the entire inventory, spot checks for specific counties have been made. A number of inaccuracies were revealed in these spot checks. County boundaries do not coincide directly with 7 1/2 minute quad sheets. Through the course of an inventory, urban uses would be accidently allocated to adjacent counties. Forest lands, wetlands, etc., appear to unnaturally follow county boundaries in certain areas of the state. Finally, the inventory portrays uses as of 1960 while in fact, input data covered a six year time frame. Thus, differences in acreage occurred for urban areas when compared with the 1960 census.

The generalized 1960 Ohio Land Use Inventory represented a major state undertaking using one of the first HUD 701 planning grants provided to the state. The motivation for this project came from a general desire for an overall picture of the state. In effect, the project was research oriented with the small scale maps representing the primary objective and product.

The expanding scope of state planning as reflected in a wide variety of new planning programs, has generated the need for an accurate, up-to-date comprehensive Ohio land use inventory. The expanding scope of state planning in Ohio is briefly illustrated by the following examples.

- The Coastal Zone Management Act which requires coastal states (including the Great Lakes) to prepare detailed management strategies for shoreland areas.

- The expanded land use requirements of the HUD 701 program which now mandate the preparation of statewide land use programs.

- The 208 Water Quality planning process which requires significant amounts of land use data as input into the determination of quality and quantity of storm water runoff and nutrient flow into water ways.

- The technical planning assistance role of state government in Ohio has focused upon the dissemination of basic planning data such as a land use inventory.

- The reclamation of strip mined lands is mandated by Ohio 1972 Strip Mine Legislation. The development of an overall strategy for reclamation of some 346,000 acres requires the availability of detailed land use data. This program will be carried out using a portion of the excise tax on the severance of Ohio minerals.

- The development of statewide land use and growth policies require a land use inventory as a framework for decision making. Pending legislation in Ohio would focus considerable attention on the revamping of Ohio's land use planning law.

- Public concern over the preservation of agricultural land, the haphazard expansion of urban areas and the misuse of Ohio's land resources have begun to generate increasing pressure for meaningful land use plans which accurately portray present and future patterns of use.

In addition to generating the need for an up-to-date statewide inventory, the changing scope of state planning in Ohio has simultaneously provided a unique motivation for its preparation. This motivation emphasizes application requirements. The inventory is primarily viewed as a necessary input to a wide variety of on-going state planning programs, current public policy decisions and land resource issues. This emphasis upon applications requires that the inventory be completed in a flexible geographic format, at a variety of scales, with detailed as well as broad categories, and in a machine processing system which permits high speed, special purpose access to a variety of users.

These somewhat harsh constraints on the characteristics of the inventory, combined with the wide variety of potential applications have brought together the financial and technical resources of three State of Ohio Departments: the Department of Economic and Community Development, the Ohio Environmental Protection Agency and the Ohio Department of Natural Resources. These three Departments, in conjunction with NASA and Bendix Aerospace Division are cooperatively undertaking the processing of LANDSAT imagery into the required statewide land use inventory. Joint sponsorship of the inventory project represents an economical approach which eliminates duplication of effort and establishes a consistent, uniform data base utilized by the planning programs within the respective agencies.

GENERATION OF DIGITAL LAND-USE MAP FILES FROM LANDSAT DATA

The Ohio Land Use Inventory is being developed through the computer processing of 12 LANDSAT scenes. LANDSAT data, provided in the form of computer compatible tapes (CCTs), are transformed into digitally coded inventory files with each file representing the land-use within an area covered by a 15 minute quad map. A data sample, the smallest element within the file, has a north-south grid orientation, covers a ground area of 50 meters, and is coded to identify the land-use within the sample. Over 200 files based on the 15 minute quads, are being established to cover the States 44,222 square mile area.

The LANDSAT Multi Spectral Scanner (MSS) data are subjected to geometrical and categorical processing to produce the desired map files. Geometrical processing (1) establishes an earth to LANDSAT coordinate transformation, (2) develops a LANDSAT data file of a specified map area, (3) rotates the orientation of the data to north-south, (4) removes the skew in the data due to earth's rotation, and (5) resamples the data to a desired size. Categorical processing transforms the LANDSAT data samples into digital codes which identify the land-use within the sample.

The geometrical and categorical processing steps are carried out at the Bendix Data Center. The major elements of this system include: a Bendix Datagrid Digitizer System 100 for digitizing graphical data and a Bendix Multispectral-Data Analysis System (M-DAS) for the analysis of LANDSAT "computer-compatible tapes" (CCTs). M-DAS is the result of an evolutionary program initiated by Bendix in 1967 and is dedicated to the processing of remote sensing data (Johnson, 1974).

The nucleus of M-DAS is a Digital Equipment Corporation PDP-11/35 computer with 28K words of core memory, a 1.5M-word disc pack, two nine-track 800 bit-per-inch (bpi) tape transports, and a DECwriter unit. Other units are an Ampex FR-2000 14-track tape recorder, a bit synchronizer and tape deskew drawers which can reproduce up to 13 tape channels of multispectral data from high-density tape recordings, a high-speed hardwired special-purpose computer for processing multispectral data, a 9 1/2 in. drum recorder for recording imagery on film, and a color moving-window computer-refreshed display.

The geometrical processing of LANDSAT data usually precedes the categorical processing so that processing algorithms that improve both the spatial and radiometric (spectral) resolution may be used. Additonally, displaying geometrically corrected LANDSAT data on M-DAS in the north-south orientation facilitates location and identification of training areas needed for categorization.

LANDSAT data corresponding to a specific base map is edited from the LANDSAT CCTs, and rescanned to produce data samples of a specified orientation. An earth to LANDSAT coordinate transformation is used to locate the desired area to be mapped within the LANDSAT data, and to establish the location and direction of the vector (line) used to rescan the data. The first step in developing this transformation is to digitize carefully selected ground control points (GCPs) from a map. The criteria for selecting these GCPs is that they can be easily and accurately identified on LANDSAT imagery. The second step consists of coverting the latitude and longitude of these GCPs to LANDSAT coordinates by using a theoretical transformation derived from known and assumed spacecraft parameters including: heading, scan rate, altitude, and a knowledge of earth rotation parameters. The LANDSAT coordinates and transformation matrices thus obtained are approximate, based on the use of the nominal spacecraft parameters. This transformation matrix is used on M-DAS to produce the approximate LANDSAT coordinates and to display the area on the TV monitor. Positional errors of the GCPs identified by the operator are noted and designated by a cursor to the computer, which uses the error measurement to derive an improved set of coefficients for the transformation matrix. This procedure is repeated on additional GCPs until the desired geometric accuracy is achieved. This rapid interactive procedure is essential for producing a transformation matrix that provides an accurate transformation of earth to LANDSAT coordinates.

Once the earth to LANDSAT transformation is developed, LANDSAT data corresponding to a specific base map is edited and scanned in a west to east direction. While the data is being scanned it is resampled to produce the desired cell size. For the Ohio inventory a cell of 50 by 50 meters is being produced. The resampling methods available at Bendix range from the nearest neighbor to various popular interpolation rules such as bilinear, cubic spline and four point LaGrangian. Bendix has recently developed a discrete two dimensional deconvolution procedure which significantly improves both the radiometric and spatial resolution of LANDSAT data.

LANDSAT MSS data in either the geometrically corrected or raw data form is transformed into the interpreted land-use files by categorical processing. These categorization techniques (Dye, 1974, 1975; Rogers 1975) have been under continuous development at Bendix for the past 8 to 10 years, primarily using aircraft multispectral scanner data. More recently, LANDSAT MSS and Skylab/EREP-S192 data have been used.

The first step in categorical processing is to locate and designate to the computer a number of LANDSAT picture elements or "pixels" that best typify the land-water categories of interest, termed the "training areas". These areas of known characteristics are being established from aerial photographs and ground survey data, and are located on the LANDSAT CCTs by viewing the taped data on the M-DAS TV monitor. The coordinates of the training areas are designated to the computer by placing a cursor over the desired areas and assigning a training area designation, category code, and color code. Several training areas, typically 20 to 50 pixels in size, are picked for each category. On the raw data tapes a pixel corresponds to a ground coverage of 57 x 79 m. On the rescanned tape this becomes 50 x 50 m. The color code assigned to the training areas is later used in playback of the tapes when the computer-categorized data are displayed in the designated colors.

The LANDSAT spectral measurements within the training area boundaries are edited by the computer from the CCT and processed to obtain a numerical descriptor (computer-processing coefficients) to represent the spectral characteristics of each target category. The descriptors (Dye, 1974) include the mean signal and standard deviation for each LANDSAT band and the covariance matrix taken about the mean. The descriptors are used to generate a set of processing coefficients for each category. In automatic-category processing, the coefficients are used by the computer to form a linear combination of the LANDSAT measurements to produce a variable whose amplitude is associated with the probability of the unknown measurement being from the target sought. In category processing, the probability of a LANDSAT pixel arising from each one of the different target categories of interest is computed for each pixel and a decision, based on these computations, is reached. If all the probabilities are below a threshold level specified by the operator, the computer will decide that the category viewed is unknown (uncategorized).

Before producing categorized data for large areas, a number of tests are applied to evaluate the computer's ability to perform the desired interpretation. These tests include generating categorization-accuracy tables and viewing the processed imagery on the M-DAS TV monitor. Selection of training areas, generation of accuracy tables, and evaluation of processing results are iterative operations displayed through the use of computer printouts and the TV monitor.

The eight Level I land-use categories underlined below will be established for each of the LANDSAT scenes. Additional Level II categories will be established whenever possible. Experience has shown that; water can usually be subdivided into deep clear, shallow, and turbid; cropland into specific crop types; forest land into density related categories; barren land into sand, bare exposed rock, strip mines, etc. These additional categories will be established to the degree possible within each LANDSAT scene.

Ohio Land Use Inventory Categories

- Urban. Most dense industrial and commerical areas, major roadways, and high density residential areas. Vegetation coverage 0 to 35%.

- Suburban. Second most dense industrial and commercial areas. Includes medium to low density residential, public services, and isolated shopping centers. Vegetation coverage 30 to 80%.

- Agricultural Land. Cropland, pastureland, orchards, groves, vineyards, nurseries, and ornamental horticultural areas.

- Rangeland (Untended grass). Herbaceous range, shrub-brushland range, and mixed.

- Forest Land. Deciduous, evergreen, and mixed.

- Water. Streams, canals, lakes, reservoirs, bays, and estuaries.

- Wetland. Forest and nonforested.

- Barren Land. Beaches, strip mines, quarries, bare exposed rock, and gravel pits.

These categories correspond with the United States Geological Survey Land Use and Land Cover Classification System for Use with Remote Sensor Data. When satisfied with the categorization accuracy achieved on the land-water categories, the processing coefficients are placed into the computer disk file and used to process that portion of the LANDSAT CCTs covering the area of interest. This step in the categorization process results in new or categorized CCTs, where each LANDSAT pixel is represented by a code designating the land-water categories.

CONVERSION OF RESCANNED LANDSAT TAPES INTO AN OPERATIONAL INVENTORY STORAGE AND MANIPULATION SYSTEM

The complete set of rescanned inventoried tapes produced by Bendix will be reformated to conform to the automated georeferencing system (OCAP) developed by the Ohio Department of Natural Resources. OCAP is a set of eleven (11) programs written in PL/1 (Optimizer). The program library resides in the Ohio State Data Center which uses two IBM 370/158's with VS2 operating under ASP Version 3. Each IBM 370/158 has 2 megabytes of real storage. The OCAP programs require a minimum of 128K of virtual storage and operate typically in the range of 192-320K (virtual) depending on the size of the geographical area under study. The largest study areas to date have been complete counties (approximately 350,000 acres) with the analysis done at a resolution of approximately 1 acre. The rescanned inventory tapes are organized as a grid system where each grid represents a geographical area of fixed size. To conserve storage, the OCAP file structure records only changes in geographical information along strips of land of given width. Once the rescanned inventory tapes are in the OCAP format they can be used in any of the functions described below.

1. extensive file editing
2. file updating
3. scaling of geographical areas
4. merging of study areas
5. extraction of study areas
6. mapping of geographical variables
7. capability analysis (weighted linear model of geographical variables)
8. map overlays
9. searching of geographical attributes
10. miscellaneous file manipulation

For the purpose of the Ohio Land Use Inventory data files will be set up by OCAP, for the following geographic regions:

- State of Ohio
- 807 7 1/2 minute USGS quadrangles covering the state
- 88 counties at a scale of 1:620,500
- townships within each county
- selected municipalities

The OCAP software provides the State with a great deal of flexibility in using the inventory data. Base maps at a variety of scales can be easily established. Various geographic areas such as, groups of counties or townships and watersheds can be pulled out of the inventory files. Further, selected categories of land use may be extracted for special purpose study. This last capability makes it possible for the user to select and combine the level I and II categories generated for each LANDSAT scene. Thus, when examining the southwest portion of Ohio (Cincinnati, Dayton, etc.) it may be desirable to view three urban levels based upon density. For the northwest area of the state, the user may wish to examine only the cropland and rangeland levels. The ability to extract various combinations of land use categories has made it possible for the State to avoid establishing a fixed list of categories and in fact different categories will be established for different LANDSAT scenes.

The inventory can be presented in either tabular or computer line printer map form. Tabular data indicates a breakdown of acreage and its relative percentage, by land use category, in a selected geographic area. The tabular data will be compiled in a State Land Use Directory which will be distributed to state, regional and local planners in Ohio.

A MARK IV file management system is being generated to maintain an organized framework for the several hundred files that will be produced. The MARK IV file will be used to efficiently process requests for computer maps and/or tabular summaries for any geographical area in Ohio. Each of the state agencies can access the inventory directly from the State Data Center.

USER APPLICATIONS

In addition to investing considerable state financial resources (approximately $100,000) into the preparation of the land use inventory Ohio has moved to develop related technical programs which can directly harness and manipulate the inventory data for a wide range of state, regional and local planning needs.

Chief among these is the Ohio Department of Natural Resources's OCAP which in addition to the software package described above assembles various mapped inventories of an area's natural resources, such as soils, ground water, and bedrock, into a computerized mapping and analysis system that aids local officials in their planning activities. In it, the implications each of the resources has for future land use development are determined. These are then used to program the OCAP system to consider the ability of the area to undergo development in light of the support or limitations presented by the resource base. Land use inventory data can be directly used by the OCAP system in such analyses. Not only will the information indicate where intensive development has already taken place and where there is open land suitable for future expansion, but it will also make possible the determination of special areas, such as prime agricultural land and productive wildlife habitat, and the calculation of certain environmental measures, such as erosion potential.

Land capability analysis makes use of the best available scientific inventories in order to produce an end product that is understandable to the nonscientist. Much of the resource information necessary for analyses around the state has already been gathered, but its technical nature often prevents its use by decision makers. The OCAP system has been designed to make the translation to the everyday language used by local officials and planners. Experience has shown that most often it is the type of information being assembled in the land use inventory that is lacking and which must be gathered by the time consuming processes of aerial photo interpretation and field surveys.

The first countywide land capability analysis was performed for Lake County, where development pressures from nearby Cleveland have made it one of Ohio's fastest growing areas. Maps of the county's soils, slope, geology, vegetation, land use, watersheds, surface water, and elevation were computerized for use in the analysis. The OCAP system was programmed to produce maps showing where difficulties would be encountered during development activities, such as clearing and grading, excavation, and foundation building. It also analyzed all the resource data to indicate the best areas for various uses such as residential, commercial, agricultural, and recreational.

The computerized data base allows subsequent development of analyses for other applications as the need arises. For example the identification of areas suitable for land disposal of solid waste was developed on request after the Lake County base had been completed.

Projects are underway to use land capability analysis as an aid in virtually all of the new planning programs in the state, such as 208 water quality planning, the Coastal Zone Management Program and agricultural land preservation. The land use inventory data will be a major resource input to accomplishing these programs in a timely and effective fashion.

The Ohio Department of Economic and Community Development, in cooperation with Battelle Memorial Institute, is developing a Growth Allocation Model which will use the inventory data as a basic input for simulating the spatial, economic and environmental impacts associated with growth and development decisions. This allocation model will have several interesting attributes.

- It will utilize the land use inventory as a basic data file which provides the foundation for allocating new land uses.
- It will incorporate proven demographic, economic and environmental impact models which have been developed as components of the Department's planning program.
- The allocation model will be user oriented and can be applied to State and local planning programs throughout Ohio.

The Ohio Growth Allocation Model (OGAM), presently in the early stages of development will consist of two major components. The impact assessment component is a powerful simulation tool that may be used to identify the economic, demographic and environmental impacts resulting from growth and development decisions. The spatial allocation component describes the land use attributes of selected geographic areas and can be used to simulate spatial conditions at particular points in time as well as their change over time.

The spatial allocation component of OGAM uses a montecarlo probability surface for allocating additional population resulting from growth and development decisions. The probability surface is based upon the land use inventory for surface features, on the impact assessment component for economic and demographic features and on additional data files for physical features. OGAM will be primarily used to define the spatial location of land uses resulting from growth and development decisions. The spatial allocation procedure includes; the definition of policies which are constraints to development, an analysis of economic, environmental and social characteristics of the geographic area and criteria for analyzing the compatibility between adjacent land uses.

The compatability analysis describes the way in which adjacent land uses reinforce desired economic, environmental and social qualities of the natural and man-made environment. The purpose of the analysis is to assess the interrelationships among combinations of land uses. The analysis is done in three parts; economic compatibility is based upon the change in land values resulting from the spatial impacts, social compatibility is based upon acess to community services, and environmental compatibility is based upon the externalities resulting from the spatial pattern.

The land use inventory serves as a basic data input to OGAM. Inventory data provides the initial basis for developing the probability surface used to allocate the spatial impacts of growth and development decisions. Further, inventory data provides the beginning input for the compatibility analysis. While more detailed land use information is required to successfully complete the analysis, the inventory data can be used as a framework for adding detail.

Without the comprehensive statewide inventory developed from LANDSAT data, the spatial allocation model could only be calibrated on the basis of manual surveys conducted at great cost. With the completion of OGAM, the State will have a powerful planning tool which can be used to simulate and analyze the spatial impacts of key growth and development decisions.

The need for up-to-date information on land use, by watershed is crucial to the implementation of many water quality programs of the Ohio Environmental Protection Agency, especially as it relates to the question of non-point source pollution.

While many factors influence water quality, a dominating one is the use of land adjacent to surrounding lakes, rivers and drainage areas. During periods of rain or thaw, these areas discharge sediment and nutrients directly to the water bodies by means of surface runoff or storm drainage. Each land use category has its own special characteristic (EPA-1430, 1973) which is important in the calculation of the quantity and quality of storm-water runoff. For example, fertilized lawns (tended grass) and paved streets discharge more nutrients, especially phosphorus, than do rangeland (untended grass) and forested land. Cropland is often tilled in the spring when rainfall is heaviest and absorbs much of the water, but erosion in the form of sediments, which includes pesticides and fertilizer, are washed into nearby streams. This differs from what happens in a center city area where virtually all of the ground is covered by pavement and buildings and little or none of the water is absorbed into the earth. Instead, the water flows rapidly into storm sewers, carrying with it dirt from streets and buildings. To establish sediment and nutrient flows from the drainage areas into the waterways, accurate information on drainage area land use is essential.

Land use information presently available to planning agencies is not adequate for water quality planning purposes. The OEPA intends to use the output of the Ohio Land Use Inventory in two (2) ways. For those water quality programs presently being undertaken by regional agencies (Section 208 Waste Treatment Management Planning) the OEPA will provide uniform information on land use in a format useable for these projects. In addition, the State's overall role in water quality planning will be enhanced by the availability of the uniform data base which will be applied in phase II processing of Section 303 basin plans and in facility planning areas and environmental evaluation assessments within Section 201 construction grants.

COST COMPARISON

Completion of the entire inventory is a 9-12 month project. It's total cost is approximately $171,000. The generalized 1960 inventory cost $191,000 in 1965. The $191,000 cost is roughly equivalent to $310,000 in 1975 dollars.

CONCLUSION

The Ohio land use inventory is a beginning step. As it is completed, it will undergo accuracy and verification tests. Test sites will be randomly selected from the inventory and compared with available ground truth information. Further, the inventory will undergo continuous and varied user evaluations as it is applied to state, regional and local planning programs. The combination of random accuracy tests and user assessments will be used as input into inventory update projects.

The availability of an up-to-date, flexible statewide inventory of Ohio land uses will have significant benefits to state, regional and local planners in Ohio. These benefits include:

- The provision of a consistent data base used simultaneously by various levels of planning.
- The provision of basic data input into a number of planning programs requiring land use information.
- Encouraging the development of more sophisticated planning analysis tools which will improve the quality of public policy decisions.
- The provision of a basic planning tool - a land use inventory - which can be routinely updated at reasonable cost.

The inventory can be updated for any selected geographical configuration. For example, an update of the five county region surrounding the Cincinnati SMSA could be performed for approximately $10-20,000. On this basis, those regions of the State experiencing rapid change could be updated as frequently as necessary. More stable regions could be delayed until necessary. The timing for the update depends upon a number of factors, including data availability, funds and user needs. It is tentatively planned to request update funds in the next biennial budget cycle which begins in July of 1977 and ends in July of 1979. As the technology improves, it will be possible to periodically update and improve the coverage, accuracy and usefulness of the inventory.

These benefits represent substantial steps forward in improving the quality of planning programs in Ohio. The cost of the inventory, spread over the budgets of three state agencies is far outstripped by these benefits and the resulting improvements in Ohio's planning quality.

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