Douglas A. Stow
John E. Estes
Geography Remote Sensing Unit
University of California, Santa Barbara
Santa Barbara, CA 93106

Landsat and Digital Terrain Data for County-Level Resource Management

A methodology for analyzing error within a geographic information systems context is described.

Abstract: *The ability to quantify the source and magnitude of errors associated with a given methodology for portraying landscape parameters is important. The goal of the research presented herein has been to derive a quantifiable measure of data representation accuracy for thematically classified Landsat and digital terrain tape data within the context of the needs of the county level resource manager in Ventura County, California. A case study, which assesses the ability of Landsat to provide spatially accurate thematically classified land-cover information and digital terrain tapes to provide elevation, is presented. In addition, the digital terrain tapes can also be processed to supply other terrain information, such as slope angle and aspect, for input to a county-level resource management information system.*

Analytic procedures developed in connection with this study differ from similar previous studies in that they have been specifically designed around a digital, fixed-grid geographic information system. System attributes were oriented toward county-level resource management usage. Landsat derived, thematically classified data correctly represented land cover in 234 of 320 (73 percent, or 68 to 78 percent at the 95 percent confidence limits) randomly sampled grid cells, but only 202 (63 percent) of the 320 sampled digital terrain tape elevation values were within one-half of the contour interval (30.5 metres) when compared to 1:24,000-scale topographic map data.

Results of this study indicate that (1) thematically classified Landsat data can be suitable as a first stage sample of land cover for county-level resource management assessments, and (2) digital terrain tape data produced by digitizing 1:250,000-scale Army Mapping Service topographic maps appear to be unsuitable for portraying elevations for county-level needs. Digital terrain tape data, however, may be effective in supplying derived graphic or terrain data products, as well as in supplying additional channels of data for county-level land-cover classification procedures.

Introduction

The expanding information requirements of planning and resource management agencies at all levels of the political/administrative hierarchy have provided considerable impetus to the development of geographic information systems (GIS). Agencies at the federal, state, regional, county, and local levels rely on environmental data as input into their decision-making process. Although many types of data are employed in this decision process, two existing data sources which offer potentially valuable information are Landsat multispectral scanner (MSS) computer compatible tapes (CCT's), and digital terrain tapes (Stow, 1978).

The main objectives of the research reported herein have been to

- Examine the potential of the National Aeronautics and Space Administration developed Landsat

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and the National Cartographic Information Center's (NCIC) digital terrain tape data as inputs into a county-level resource information system; and
- Develop a methodology which specifically analyzes the magnitude and source of error involved in the incorporation of Landsat/MSS derived land-cover classification and digital terrain tape data into a geographic information system.

Using computer-assisted image processing procedures, it is possible to inventory land-cover categories by processing Landsat digital data. In addition to the elevation data recorded on the digital terrain tapes, slope gradient and aspect data can be calculated from the tapes by computer processing. Such calculations are difficult and cannot be derived efficiently from standard topographic maps. Each of these data types alone—thematically classified land-cover data from Landsat, and elevation, slope angle, and aspect from digital terrain information, in a usable format—would supply important information to resource managers. However, by combining these data sets within the context of a geographic information system, the resulting synergism offers additional and potentially more powerful information to the user.

An empirical approach has been chosen so that an assessment of data set accuracy in representing specific environmental phenomena could be determined. Although a theoretical understanding of factors affecting data accuracy is also important, potential geographic information system users are typically more interested in, and responsive to, accuracy figures derived from a well designed systematic sampling procedure (Eastwood *et al.*, 1976).

Background

The study area for the analysis of the potential of Landsat and digital terrain data sets within a GIS context is represented by the Matilija 7.5-minute, 1:24,000-scale topographic quadrangle in Ventura County, California (Figure 1). The area contains a diversity of land-use and land-cover types associated with the biophysical and cultural setting of the region. This diversity, combined with the presence of significant topographic variation, makes the quadrangle an excellent area for verifying the accuracy of the Landsat derived land-cover classification and topographic data in a geographic information system framework.

Geographic information systems evolved as a means of assembling, storing, and analyzing diverse data pertaining to specific geographic areas, with spatial locations of the data serving as the basis for the information systems (Tomlinson, 1976; Calkins and Tomlinson, 1977). Geographic information system structure has evolved around locational identifiers and the methods used to encode data for input storage and manipulation.

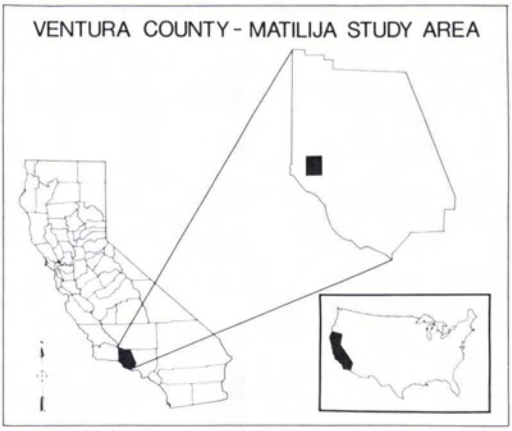

FIG. 1. Map showing Matilija 7.5-minute quadrangle study site in Ventura County, California.

Many systems have been developed, primarily for land use planning and resources management at the urban, regional, state, and national levels of government. Most of these systems rely on data from existing maps or on data that can be mapped readily to supply the locational information required by the systems. Remote sensing data usually have been interpreted visually or manually, converted to thematic map form, and then digitized for input into a GIS (Shelton and Estes, 1979).

To date, there has been only limited theoretical discussion of remote sensing as a source of data for geographic information systems. Even less discussion has occurred concerning the techniques and advantages of direct linkage between geographic information systems and the new computer-based remote sensing systems for automated and machine-assisted image analysis. Yet, geographic information systems are becoming important tools in public decision-making and have significant potential to facilitate the use of remotely sensed data. This potential has only recently begun to be explored and developed. For example, recent developments in satellite remote sensing have established pixels as locational identifiers, produced large volumes of data in digital format, and created new types and frequencies of data for analysis of the human environment. These data can routinely and directly be used as input to geographic information systems. However, there is a lack of understanding of (1) the data input problems of GIS systems, (2) the monitoring capabilities of remote sensing systems, and (3) the improved modeling and timely synoptic analysis of environmental conditions and processes based on the utilization of (a) the monitoring capabilities of remote sensing and (b) the analytical capabilities of computer-based information systems (Shelton and Estes, in review).

Many county-level resource managers have only

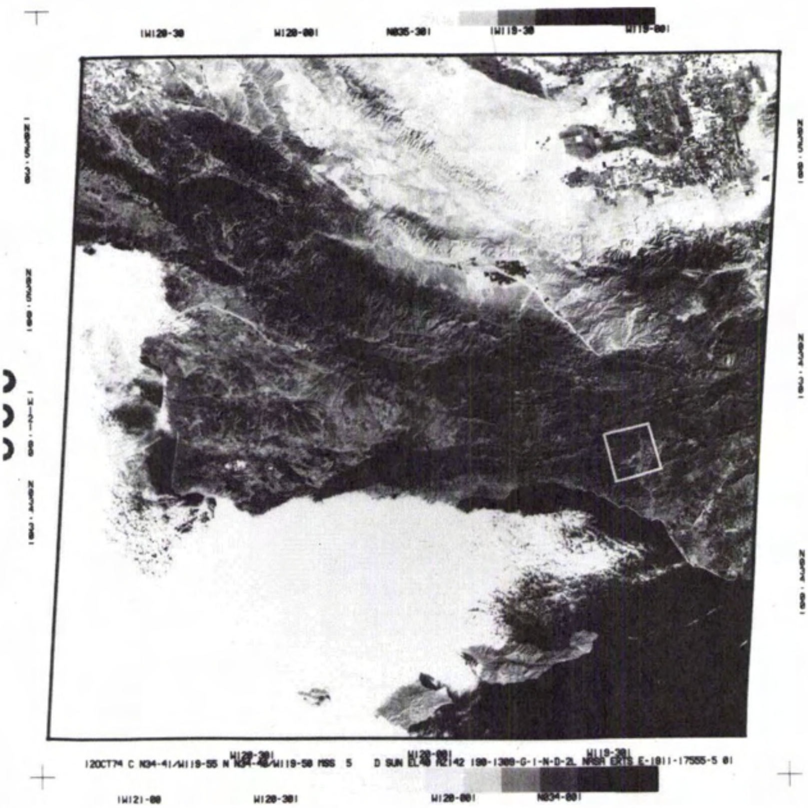

FIG. 2. 12 October 1974 Landsat Band 5 image illustrating the multispectral scanner data for which thematic land-cover data were derived. The white quadrangle outlines the Matilija study site which was thematically classified.

recently begun to realize the efficiencies inherent in computerized geographic information systems technology (Lockhard and Singer, 1980). A wide variety of resource management activities stand to benefit from the use of such systems for storing, organizing, manipulating, and retrieving resource data.

Some of the county-level resource management activities which stand to benefit from application of geographic information system technology include

- Environmental impact assessments;
- U.S. Environmental Protection Agency (EPA) local 208 water quality planning elements;
- Watershed runoff and other hydrologic modeling; and
- Fire and fuel management modeling;

to name but a few.

Among the benefits that can be realized by resource managers is the ease with which spatially-referenced resource data may be retrieved and manipulated by a wide variety of users with diverse management responsibilities. Quite often, data sets and duplication of data collection efforts by agencies within a given administrative unit may not be realized until an information system is well established and properly maintained.

Land-cover and topographic data are two of the major information inputs required for resource management information systems at all levels of jurisdiction. In simple terms these two spatial data types describe both the cover and relative variations of the surface terrain, which are essential to the modeling and managing of most Earth resource phenomena. County-level resource managers who have either developed or already utilize a geographic information system should look closely at Landsat MSS and NCIC digital terrain tape data for supplying these important data which can produce basic inputs to a large number of the models they employ. In the discussion that follows, we address some of the problems and potentials that county-level resource managers should consider prior to adopting Landsat and digital terrain data types as information sources. Emphasis is placed on data accuracy and, more specifically, the documentation of a methodology for assessing the accuracy of these data.To accomplish this analysis, the study employs a geographic information system to provide the

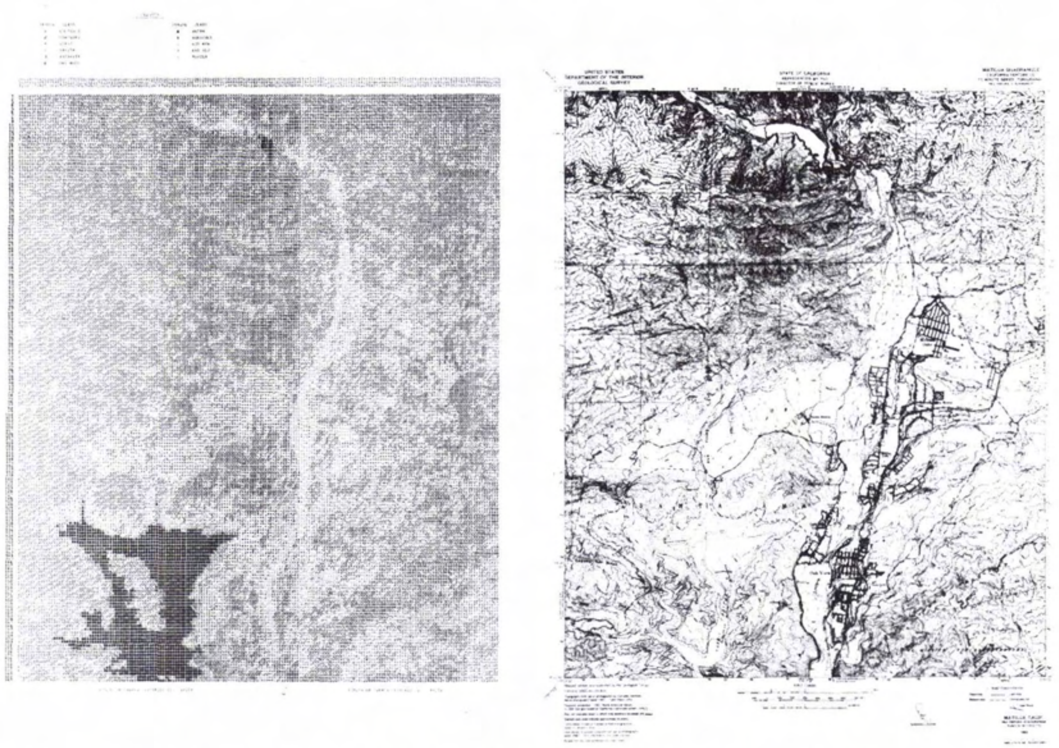

FIG. 3. (a) Lineprinter map of Landsat-derived land-cover data for the Matilija quad study site. The original multispectral scanner data have been geometrically corrected and are comparable to (although referenced to a different map projection) (b), the reduced version of a USGS 1:24,000-scale topographic quadrangle map of the area.

framework within which the analysis of Landsat and digital terrain data accuracy characteristics within the context of county-level resource management decision needs is accomplished. The information system employed would be generically referred to as a grid system, because data are stored in fixed-interval square grid cells.

Digital data recorded by the Landsat multispectral scanner (MSS) have been used to categorize land cover for imaged areas. Land-cover classification from Landsat/MSS data can be viewed as a statistical determination of characteristic spectral signatures associated with land-cover types. Once a representative sample of spectral signatures are associated spatially with specific land-cover categories, large areas (up to several Landsat scenes) can be classified simultaneously (depending upon the geographic homogeneity of categories and their spectral responses within the scene). Because the Landsat covers most areas on the Earth at least once every 18 days (more often at high latitudes to 81° North and 81° South latitudes, and/or if more than one Landsat is operational at a given time), land-cover classifications may be updated at intervals which satisfy many of the needs of land resources managers involved in the planning and management decision processes. For these applications, some type of image format map is the typical form on which the final classification product is presented. Critical for geographic information systems, though, are digital data files where a particular thematic class is coded in a single byte of date, and rows and columns of these data bytes represent the gridded spatial orientation of the data.

Elevation data stored in digital form on the digital terrain tapes appear to be a convenient and cost-effective means of acquiring terrain data for input into a geographic information system. Originally produced by the Army Map Service (now the Defense Mapping Agency (DMA)) for military defense purposes, the terrain tapes have recently been released through the United States Geological Survey's National Cartographic Information Center (NCIC) for public use at a cost which is considerably less than the time and materials costs. Digital terrain tapes were produced by digitizing the Army Map Service (AMS) 1:250,000-scale topographic series maps. A fixed-grid of elevation values resulted from digitization of the map contours and interpolation of non-digitized grid points, which were then recorded on magnetic

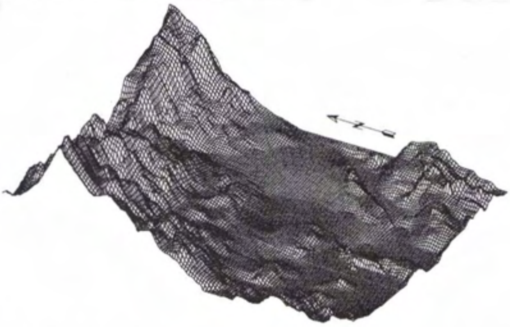

FIG. 4. Three-dimensional terrain perspective plot generated from NCIC digital terrain tape data of the Matilija quadrangle area.

tape. This data array may be processed to yield various map scales and projections by computer cartographic techniques (Figure 4). Other terrain information, such as slope gradient, length, aspect, and convexity, can also be calculated from the data contained on the tape, through the use of common computer processing techniques (Evans, 1972; Dole, 1978).

The terrain data have also been shown useful in the classification and inventory of certain land-cover categories (Krebs *et al.*, 1976; Strahler *et al.*, 1979). When incorporated with Landsat multispectral data in a compatible form (similar to their storage form in the geographic information system of this study), the addition of the terrain information has been shown to improve classification accuracies of categories that exhibit unique terrain dependencies, specifically, natural vegetation categories (Fleming and Hoffler, 1979; Strahler, 1978).

METHODOLOGY

Both Landsat/MSS and digital terrain tape data were digitally processed to facilitate their incorporation into the geographic information system used in this study. This grid-based system employs a one-acre fixed grid storage cell, 63.6 metres per side, and used the Universal Transverse Mercator (UTM) projection. In other words, data in columns of the data storage array follow Northings and rows follow Eastings of the UTM-projection coordinate system.

Landsat/MSS data were processed digitally to perform image rectification/georeferencing and classification. NASA/Goddard's Digital Image Rectification System (DIRS) was used to perform the rectification/georeferencing processing (Van Wie, 1976). Such processing allows the raw Landsat data to be geometrically corrected and transformed to the informations system UTM projection. Using DIRS, the following functions were performed:

- Resampling/regridding to square one-acre pixels;
- Systematic and non-systematic geometric corrections;
- "Rubber sheet" georeferencing to the UTM grid system; and,
- Extraction of data for 7.5-minute quadrangle area (see Figure 3).

Purdue/LARS' LARSYS 3 image processing package was used to perform a conventional supervised automated land-cover classification (Phillips, 1973). Ten land-cover categories similar to a United States Geological Survey (USGS) Level II classification (Anderson *et al.*, 1976) were derived using the four spectral bands of a 12 October 1974 Landsat scene (Figure 2). This scene was chosen as a base date (when the information system was established), because of its exceptional image quality and an intuitive knowledge of optimal seasonal spectral signature characteristics between land-cover categories of interest. Land-cover reflectance statistics were generated from training sites that were selected with the aid of supporting 9 in. by 9 in. low-altitude color aerial photography and 1:24,000-scale vegetation map data. These derived statistics were used to generate a pixel by pixel classification of land cover based on maximum likelihood decision rule criteria. The final output was a digital, land cover classification map compatible with the storage attributes of the geographic information system (Figure 3).

NCIC digital terrain tape data were also processed into a form suitable for its incorporation into the geographic information system. The 63.5-metre fixed-grid form of the raw data was resampled, regridded, and matrix-transposed to conform with the information system's grid specifications (Junkin, 1979).* These operations adjust both the orientation of the data array and the size of the storage grid cell for data set compatibility.

DATA ANALYSIS

In order to derive accuracy information, a verification procedure based upon a systematic random sampling scheme was applied to the digitally processed classified Landsat and terrain data sets. Percentages of correct land-cover and elevation representation were determined by verification checks of random grid cells against conventional, large-scale data. The procedure does not attempt to examine accuracies for particular land-cover and elevation categories, but instead assesses the total representation accuracy of each data set. Therefore, both positional (*x-y* component) and attribute (*z* component) accuracy will influence the final representation accuracy that is assessed.

*Software allowing for data reformatting, subscene extraction, and regridding was developed by Jeff Dozier of the Geography Department, University of California at Santa Barbara.

Articles describing methodologies for the measurement of accuracy for nominal-scale land-use/land-cover data are justifiably numerous (Hord and Brooner, 1976; Fitzpatrick-Lins, 1978; Hay, 1979; Ginevan, 1979). Many of them are concerned with the statistical reliability of sample design, but do not deal with the design of measurement and assessment criteria for evaluating the "correctness" of thematic categorizations. Most treatises that do define methodologies for actually comparing thematic land-use/land-cover data with "ground truth" observations have been involved with polygonal representations of the thematic data in analog (map) form (Hord and Brooner, 1976); Fitzpatrick-Lins, 1978).

Many attempts have been made to assess the accuracy of digital thematic Landsat data (grid representation). Few, though, have documented a methodology that systematically takes into consideration the positional accuracy of the data, as well as whether sampled data cells are randomly distributed. The tendency in past accuracy assessments of thematic Landsat data has been to check the accuracy of classifying contiguous blocks of data cells known as "test sites." In some instances, accuracy figures are mistakenly determined by checking how accurately the grid cells originally used for deriving training sites in the supervised classification mode are categorized. In both cases it is questionable that effects of either positional or random distribution are adequately considered.

In this study, sampled grid cells were located by calculating Easting and Northing coordinates of grid center points. A random number generator produced x and y coordinates for numbers between one and the dimensions of the data array under study (182 by 219). Using the sample design criterion of Fitzpatrick-Lins (1978), 320 samples were sequentially chosen from a larger number of randomly generated coordinate pairs. After plotting the position of sample points, it was decided that the distribution was indeed evenly and randomly distributed. Coordinate pairs were then converted to Eastings and Northings. A UTM grid transparency designed for overlaying on 1:24,000-scale, 7.5 quadrangles facilitated the location of sample grid-center points on the verification data sets.

Landsat-derived land-cover categories for sample cells were verified against a 1:24,000-scale orthophotoquad, while the actual land-cover verification was judged from the interpreter's 9 in. by 9 in. low altitude color aerial photography. A problem arose in the verification procedure in that the color aerial photography was imaged two years after the image date of the Landsat data. To minimize the impact of this time differential, areas that might have changed during this two year period were identified by comparing NASA high altitude color infrared photographs acquired near the time of the low-altitude aerial photography and Landsat data acquisitions.

A comparative analysis of land cover was based on an interpretation of the low-altitude aerial photography for an area surrounding the grid-cell center, similar to that of the geographic information system (one-acre). Derived accuracy figures were influenced by more than the performance of the multispectral classification. Accuracy was also influenced by the ability to correctly rectify/georeference the processed Landsat data using the DIRS software.

NCIC digital terrain tape data were checked against the USGS 1:24,000-scale "Matilija" topographic quadrangle map by measuring along UTM coordinates and locating sample positions. An accuracy criteria similar to that of USGS topographic map accuracy checks (i.e., ± one-half of the original mapping contour interval or 30.5 metres), was used to set up the arbitrary limits of correct elevation representation. The elevation value on, or interpolated between, the contours nearest the sample grid-center point was considered the "real" value. An either/or "correctness" measure was then derived from the percentage of digital values that were within 30.5 metres elevation of the "real" (topographic map) value.

Results

Using the techniques described above, data representation accuracy as analyzed for Landsat land cover and digital terrain tape data was found to be as follows:

- Landsat derived data correctly represented land cover in 234 of 320 randomly shaped grid cells as verified against low-altitude photography. This resulted in an overall accuracy of 73 percent (68 percent-78 percent at a 95 percent confidence interval) (Figure 5); and,
- Only 202 (63 percent) of the 320 sampled digital terrain tape elevation values were within one-half of the contour interval (30.5 metres), as compared against 1:24,000-scale topographic map data.

The 73 percent accuracy figure for Landsat land-cover representation here should be compared prudently with figures arrived at by previous Landsat classification accuracy assessments. Most of these assessments analyze only how well a statistical-based classifier operated when applied to Landsat data to determine land-cover classes from spectral signatures, rather than whether the final output product of the Landsat classification accurately represents spatially distributed *in situ* land-cover conditions. By also accounting for the ability to accurately rectify/georeference the Landsat data to the projection scheme of the geographic information system, the accuracy figure derived in this study was expected to be somewhat

Photo Verified Class	Information System Representative Class										
	Chaparral	Oak Woodland	Coastal Sage Scrub	Grassland	Riparian	Barren	Water	Agriculture	Urban Residential	Mobile	Total
Chaparral	97	•	4	1	•	•	•	14	5	•	121
Oak Woodland	9	33	•	1	•	•	1	•	•	•	44
Coastal Sage Scrub	•	•	9	4	1	•	•	•	•	•	14
Grassland	•	•	8	28	•	2	•	•	10	•	48
Riparian	1	•	1	•	4	•	•	•	3	•	9
Barren	•	•	•	•	1	14	•	•	2	3	20
Water	•	•	•	•	•	•	15	•	•	•	15
Agriculture	6	•	•	1	•	•	•	6	•	•	13
Urban Residential	3	•	•	2	1	•	•	•	24	•	30
Mobile	•	•	•	•	2	•	•	•	•	4	6
Total	116	33	22	37	9	16	16	20	44	7	234

correct representation - 73%

68 - 78% at 95%

total number of samples = 320

FIG. 5. Contingency table depicting accuracy verification of thematic Landsat derived land-cover data. The figure compares accuracies obtained from the analysis of the Landsat information (as represented within the geographic information system) versus the analysis of the "ground truth" data derived from a USGS orthophoto quad and low altitude color photography.

lower; (that is, lower than studies in the past that have not considered positional accuracy and random sampling in their methodology). Whether or not the accuracy level of representing individual data is sufficient depends on the particular information needs of individual resource managers.

Considering the USGS' accuracy standard of 90 percent of all sampled points falling within one-half of the contour interval, the 63 percent accuracy for the digital terrain tape data derived here is considered disappointing within the context of the objectives of this study. However, this figure too must be carefully extrapolated when employed for areas and utilities outside the scope of the study. Data representation errors appeared to be more a function of vertical inaccuracy than of horizontal displacements. Upon briefly assessing the location and magnitude of "error" samples, most of them were located in the mountainous portions of the test site. In most cases, none of the adjacent data elements were within the acceptable accuracy criteria either. The topographic form of terrain features was portrayed well in a generalized way, but the elevation values themselves, in a given area, often were significantly beyond the allowable accuracy criteria.

Although exact elevation values are not accurate in all cases, the portrayal of generalized topographic surface from point to point may in fact be adequate for many county-level resource management purposes. That is, the secondarily-derived slope, aspect, and convexity data, which are often more important to resource managers, have been found in other studies to be acceptably accurate (Dozier and Outcalt, 1978; Strahler, 1978). Even these data accuracies, though, are questionable for areas of irregular terrain. For irregular terrain the high degree of "smoothing" of the digital terrain tape data often over-generalizes the true surface expression of terrain (i.e., fails to portray smaller terrain features such as canyons and knolls).

CONCLUSIONS

The major findings specific to the data set, study area, and framework for analysis of this research are

- Single date Landsat/MSS derived land-cover classification data appear to be a source of marginally accurate data for meeting county-level resource management information requirements, as incorporated into a digital geographic information system. The derived 73 percent classification accuracy (68-78 percent at the 95 percent confidence level) is significantly below the 85 percent accuracy standard of the USGS land-cover mapping program. Its readily incorporated digital form and frequency of coverage, however, make it an appealing first stage land-cover base, which may be easily edited through other image processing and geographic information system techniques. Thematic Landsat data's greatest potential appears, in this context, to be in a "change detection" mode for updating more detailed and accurate classifications.
- Based on an analysis of the data employed in this project, NCIC digital terrain tape data information of value to resource managers, within the context of a geographic information system, appears to be unsuitable for many resource management assessments, due to its failure to accurately represent elevation values. At present, it is not possible to correctly and efficiently edit this data source to a point of acceptable accuracy. The digital terrain tape data are, though, an inexpensive, readily available source suitable for producing automated cartographic outputs and secondary data such as slope, aspect, and convexity. It has also been shown useful for incorporation into digital land-cover classification as a means of improving classification accuracies for terrain-dependent categories.

In concluding this research effort, a recommendation is offered with regards to further related research of Landsat derived land-cover and digital terrain tape data, and their incorporation into geographic information systems. Other processing systems and analysis techniques (including multi-date analysis) must also be examined. Attributes such as cost and utility must continue to be researched in an objective, unbiased manner. Results and findings must be well documented so as to influence the considerations of the resource management user community. Of particular importance is the necessity to continue to empirically derive and demonstrate standardized quantitative accuracy measurements for a wide variety of methodologies in differing geographic environments.

Acknowledgments

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References

Anderson, J. R., *et al.*, 1976. *A Land-use and land-cover classification system for use with remote sensor data,* USGS Professional Paper, 964.

Calkins, H. W., and R. F. Tomlinson, 1977. *Geographic information systems, methods, and equipment for land use planning,* Resources and Land Investigations (RAL) Program, USGS, Reston, Va.

Doyle, F. J., 1978. Digital terrain model: An overview, *Photogrammetric Engineering and Remote Sensing,* Volume 44, No. 12, pp. 1481-1485.

Dozier, J., and S. Outcalt, 1978. An approach toward energy balance simulation over rugged terrain, *Geographical Analysis,* 11:65-85.

Eastwood, L., *et al.*, 1976. *Program on earth observation data management system (EODMS),* Final report, Center for Development of Technology, Washington University.

Evans, I. S., 1972. *Spatial analysis in geomorphology,* Edited by Richard J. Chorley, New York, Harper and Row.

Fitzpatrick-Lins, K., 1978. Accuracy of selected land use and land cover maps in the greater Atlanta region, Georgia, *Journal Research U.S. Geological Survey,* Volume 6, No. 2, pp. 169-172.

Fleming, M. D., and R. M. Hoffer, 1979. Machine processing of Landsat MSS and DMA topographic data for forest cover type mapping, *Machine Processing of Remotely Sensed Data, Symposium Proceedings,* Purdue University, Lab for Apps. of Remote Sensing, West Lafayette, Ind., pp. 377-390.

Ginevan, M. E., 1979. Testing land-use map accuracy criteria, *Photogrammetric Engineering and Remote Sensing,* Volume 45, No. 10, pp. 1371-1377.

Hay, C. M., 1979. Sample designs to test land-use map accuracy, *Photogrammetric Engineering and Remote Sensing,* Volume 45, No. 4, pp. 529-533.

Hord, R. M., and W. Brooner, 1976. Land-use map accuracy criteria, *Photogrammetric Engineering and Remote Sensing,* Volume 42, No. 5, pp. 671-677.

Junkin, B. G., 1979. *A method for the processing and analysis of digital terrain elevation data,* NASA/ERL Technical Report No. 177.

Krebs, P. V., *et al.*, 1976. *Multiple resource evaluation of Region 2 U.S. Forest Service Land, utilizing Landsat/MSS data,* Goddard Space Flight Center, NASA Contract No. 5-70948.

Lockard, W. M., J. Singer, and H. Rickard, 1980. *Ventura County user information study,* Executive Summary to California State Assembly Bill 2560-Imbrecht, Ventura Co. Flood Control and Water Resources Department.

Phillips, T. L., 1973. *LARSYS Version 3 User's Manual,* Purdue Research Foundation.

Shelton, R. L., and J. E. Estes, 1979. Integration of remote sensing and geographic information systems, *Proceedings, Thirteenth International Symposium on Remote Sensing of Environment,* Environmental Research Institute of Michigan, Ann Arbor, Michigan, Volume I, pp. 463-483.

Shelton, R. L., and J. E. Estes, (In Review), Remote Sensing and Geographic Information Systems: An Unrealized Potential, Requested for submission by Editor of *Geoprocessing*.

Stow, D. A., 1978. *An Analysis of Landsat and Digital Terrain Tape Data in a Geobase Information System Context: Ventura Court Cases Study,* MA Thesis, Geography Dept., University of California, Santa Barbara.

Strahler, A. H., 1978. Improving forest cover classification accuracy from Landsat by incorporating topographic information, *12th International Symposium on Remote Sensing of Environment,* Manila, Phillippines, pp. 927-942.

Strahler, A. H., T. L. Logan, and C. E. Woodcock, 1979. Forest classification and inventory system using Landsat, digital terrain and ground sample data, *Proceedings, Thirteenth International Symposium on Remote Sensing of Environment,* Environmental Research Institute of Michigan, Ann Arbor, Michigan, Volume III, pp. 1541-1557.

Tomlinson, R. F., *et al.*, 1976. *Computer handling of geographical data,* UNESCO Press.

Van Wie, Peter, and Maurice Stein, 1976. A Landsat digital image and rectification system, *Machine Processing of Remotely Sensed Data,* Purdue: LARS Symposium Proceedings.

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