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ANALYZING ACCURACY ATTRIBUTES OF LANDSAT AND DIGITAL TERRAIN TAPE DATA IN THE CONTEXT OF A DIGITAL GEOBASE INFORMATION SYSTEM

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ABSTRACT

The major conclusions reached in this research effort are: 1) Landsat derived land cover classification data are, at present, a marginally accurate data source for county-level resource management requirements; and 2) the accuracy of standard product National Cartographic Information Center (NCIC) Digital Terrain Tape data appear to be questionable, again with respect to the information requirements of county level resource managers.

Data representation accuracy has been analyzed for Landsat/MSS land cover and NCIC Digital Terrain Tape data. Landsat derived data correctly represented land cover in 71.5% of 200 randomly sampled grid cells verified against low-altitude photography. Only 61% of the sampled Digital Terrain Tape elevation values were within one-half of the contour interval (30.5 meters) on a 1:24,000 scale topographic map.

The analysis here has been specifically designed around a digital, fixed-grid geobase information system. System attributes were oriented towards county level resource management usage. Results from this study indicate that for the geographic area and objectives of this research: 1) Landsat classification data are suitable as a first stage sample of land cover for county level resource management assessments; and 2) Digital Terrain tape data are inaccurate in portraying absolute elevations, but may be effective in supplying derived graphic or terrain data products, as well as in supplying additional channels of data for the land cover classification procedure.

I. INTRODUCTION

The main objectives of the research reported herein have been to:

- Examine the potential of Landsat and National Cartographic Information Center (NCIC) Digital Terrain Tape data as inputs into a county level decision-oriented resource information system; and to,
- Specifically analyze the magnitude and source of error involved in the incorporation of Landsat/MSS derived land cover classification and Digital Terrain Tape data into a conceptual geobase information system.

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. 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.

Landsat MSS data allow the making of automated or semi-automated land cover classifications of a given scene. Besides the elevation data recorded on the Digital Terrain Tapes, simple computer calculations make the tapes a source of slope gradient and aspect data. These data alone, in a usable format, would significantly benefit the information needs of resource managers. However, by combining

these data sets in the context of a geobase information system, the resulting synergism offers additional and potentially more powerful information to the user.

It has been the goal of this research to derive some quantifiable measure of geobase information system representation accuracy to test the incorporation of Landsat and Digital Terrain Tape data, in a specific location, for a given task. A site in Ventura County, California (see Figure 1) was chosen as the study area. The task was to provide information on environmental conditions of interest to resource managers as they attempt to assess the environmental impacts of public works projects. Such an empirical approach was chosen so that the true accuracy of the data sets in representing specific environmental phenomena could be determined. Although a theoretical understanding of factors affecting data accuracy is important, potential geobase information system users are most interested in, and responsive to, accuracy figures derived usually from a systematic sampling procedure, (Eastwood, 1976⁵).

II. BACKGROUND

The study area for the analysis of the Landsat and digital terrain data sets is the area 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 cover types associated with the biophysical and cultural setting of the region. This diversity, combined with the presence of significant topographic variation, makes Ventura County an excellent area for analyzing the land cover classification and topographic data in a geobase information system framework.

A geobase information system is a method of acquiring, storing, and retrieving geographic data (Tomlinson, 1976¹²; Calkins and Tomlinson, 1977²). It varies from other information systems in that data are representative of and stored according to its geographical location. A conceptual geobase information system has been developed here to provide the framework for analyzing Landsat and digital terrain data accuracy characteristics, which could then be extrapolated with minimum variation to those attained by an actual operational system.

Digital data recorded by the Multi-spectral Scanner (MSS) of the Landsat Earth Resources Technology Satellite may be used to determine the type of land

cover of imaged areas (Figure 2). Land cover classification from Landsat/MSS data can be viewed as a statistical determination of characteristic spectral signatures associated with land cover types. Once determined, these signatures can be used to classify fairly large areas at a given time. Because the Landsat satellite covers most areas on the earth once every eighteen days or greater if more than one Landsat is operational, land cover classifications may be conveniently updated at intervals required by most land resources planning and management functions. For these applications, some type of image format map is the typical form on which the final classification product is presented.

At first glance 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 geobase information system. Originally produced by the Defense Mapping Agency (DMA) for military defense purposes, the terrain tapes have recently been released through the National Cartographic Information Center (NCIC) for public use. Digital Terrain Tapes are produced by digitizing the Army Mapping Service (AMS) 1:250,000-scale topographic series maps. A fixed grid of elevation values results from digitization of the map contours and interpolation of non-digitized grid points, which are then recorded on magnetic tape. The grid may also be processed to yield various map scales and projections by computer cartographic techniques. Other terrain information, such as slope gradient, length, aspect, and convexity can also be calculated from the data contained in the tape, through the use of relatively straight forward computer processing techniques (Evans, 1972⁶; Doyle, 1978³).

III. METHODOLOGY

Both Landsat/MSS and Digital Terrain Tape data were subjected to conventional digital processing techniques to facilitate their incorporation into a geobase information system. The conceptual system created for the purpose of this study is based on a one-acre fixed-grid storage cell, 63.615 meters per side, and uses a UTM referencing system. The system is considered conceptual as it was designed only to provide the framework for the analysis and has not as yet been adopted for operational usage by either the Geography Remote Sensing Unit, University of California, Santa Barbara or Ventura

County.

Landsat/MSS data were digitally processed 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, 1976¹³). Using DIRS the following functions were performed:

1. Resampling/regridding to square one-acre pixels;
2. Systematic and non-systematic geometric corrections;
3. Rubber sheeting georeferencing to UTM grid system;
4. Extraction of data for 7.5 minute quadrangle area.

Purdue/LARS' LARSYS 3 image processing package was used to perform a conventional, supervised, automated land cover classification (Phillips, 1973¹⁰). Ten land cover class categories similar to a United States Geological Survey (USGS) Level II classification were classified using the four spectral bands of an October 12, 1974 Landsat scene (Anderson, 1976¹). Classification statistics were generated from training sites that were selected with the aid of collateral 9 in. x 9 in. low-altitude photography and 1:24,000-scale vegetation map data. The final output was a digital, land cover classification map compatible with the specifications of the conceptual geobase information system (Figure 3).

NCIC Digital Terrain Tape data were also processed into a form suitable for its incorporation into the conceptual information system. The 63.5 meter fixed-grid form of the raw data was resampled, re-gridded and matrix transposed to conform with the conceptual system's grid specifications, (Junkin, 1979⁸). This, as well as the ability to extract the appropriate quadrangle area were achieved using software developed by Dr. Jeff Dozier of the Department of Geography, University of California, Santa Barbara.

IV. DATA ANALYSIS

In order to derive accuracy information a verification procedure based on a 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 classes, but instead assesses the total representation accuracy of each data set. Individual class and elevation accuracy information could be obtained through the application of a stratified random sampling procedure, however, this was not attempted at this time in this limited study area.

Sampled grid cells were located by calculating the UTM easting and northing coordinate of grid-center points. A random number generator selected X and Y coordinates from all numbers between zero and the dimensions of the system's digital matrix grid. Two-hundred of these numbers were then converted to eastings and northings. A UTM grid transparency designed for overlaying on 1:24,000-scale 7.5 minute quadrangles facilitated the location of sample grid-center points on the verification data sets.

Landsat-derived land cover classes for sample cells were verified against 1:24,000-scale orthophoto quadrangle and complimentary 1:12,000-scale, low-altitude aerial photography. Although grid-center points were initially located on the orthophoto quad, the actual land cover verification was judged from the interpreter's 9 in. x 9 in. low-altitude aerial photography. This judgement was based on an analysis of the area surrounding the grid-cell center, comparable to that of the conceptual information system (one acre). Accuracy verification, then was more than just a function of the multi-spectral classification. Accuracy was also a function of the ability to correctly rectify/georeference the processed Landsat data.

Digital Terrain Tape data was checked against a USGS 1:24,000-scale topographic quad map in the same manner, by measuring along UTM coordinates. An accuracy criteria similar to that of USGS topographic map accuracy checks, $\pm$ one-half of the original mapping contour interval or 30.5 meters, was used to set the arbitrary limits of correct elevation representation. The elevation value on or interpolated between the contour line nearest the sample grid-center point was considered the "map-truth" value. A "correctness" measure was then derived from the percentage of digital values that were within 30.5 meters of the "map-truth" value.

V. 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:

1. Landsat derived data correctly represented land cover in 143 of 200 randomly sampled grid cells verified against low-altitude photography (Figure 4); and
2. Only 122 of the 200 sampled Digital Terrain Tape elevation values were within one-half of the contour interval (30.5 meters), as compared against 1:24,000-scale topographic map data.

The 71.5% accuracy figure for Landsat land cover representation is somewhat deceptive and cannot directly be compared with most of the figures arrived at by previous Landsat classification accuracy studies. Most of these studies have analyzed only how well a statistical-based classifier can determine land cover classes from spectral signatures, rather than whether the final data product accurately represents in situ land cover conditions (Hord and Brooner, 1976⁷). By also accounting for the ability to accurately rectify/georeference the Landsat data to the projection scheme of the geobase information system, the derived accuracy figure is likely to be somewhat lower. Whether or not exact data representation is critical depends on the particular information needs of individual resource managers.

Considering the USGS' accuracy standard of 90% of all sampled points falling within one-half of the contour interval, the 61% 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 may be somewhat deceptive when employed outside the methodology employed in this study. Although the exact elevation values may be inaccurate, the true topographic surface from point to point may in fact be correctly portrayed. 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 somewhat more accurate (Dozier and Outcalt, 1978⁴; Strahler, 1978¹¹). Even these data may be questionable in representing areas of irregular terrain, as influenced by the degree of "smoothing" of the Digital Terrain Tape data.

VI. CONCLUSIONS

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

- 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 geobase information system. Its readily incorporated digital form and frequency of update make it an appealing first cut land cover base, which may be reasonably accurate in portraying land cover after information system editing.
- NCIC Digital Terrain Tape data information of value to resource managers, within the context of a geobase information system, appear to be unsuitable for many resource management assessments, due to its failure to accurately represent elevation values. Although, 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 an inexpensive, readily available source suitable for producing automated cartographic outputs and secondary data such as slope, aspect and convexity (Figure 5). The data have also been shown useful when incorporated with Landsat multispectral data as additional channels of information for improving classification accuracies (Figure 6) (Strahler, 1978¹¹; Krebs et al., 1976⁹).

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 geobase information systems. Other processing and analysis techniques must 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 and environments.

REFERENCES

1. Anderson, James R., 1976. "A Land-use and Land-cover Classification System for Use With Remote Sensor Data," USGS Professional Paper 964.
2. Calkins, H.W., and Tomlinson, R.F., 1977. "Geographic Information Systems, Methods, and Equipment for Land Use Planning," Resources and Land Investigations (RACI) Program, USGS, Reston, Va.
3. Doyle, F.S., 1978. "Digital Terrain Models: An Overview," Photogrammetric Engineering and Remote Sensing, Vol. 44, No. 12, pp. 1481-1485.
4. Dozier, J., and Outcalt, S., 1978. "An Approach Toward Energy Balance Simulation Over Rugged Terrain," Submitted to Geographic Analysis.
5. Eastwood, et al., 1976. "Program on Earth Observation Data Management System (EODMS)," Final Report, Center For Development of Technology, Washington University.
6. Evans, Ian S., 1972. "Spatial Analysis in Geomorphology," Edited by Richard J. Chorley, New York, Harper and Row.
7. Hord, R.M., and Brooner, W., 1976. "Land-Use Map Accuracy Criteria," Photogrammetric Engineering and Remote Sensing, XLII.
8. Junkin, Bobby G., 1979. "A Method for the Processing and Analysis of Digital Terrain Elevation Data," NASA/ERL Technical Report No. 177.
9. Krebs, Paul 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. NAS 5-70948.
10. Phillips, T.L., 1973. "LARSYS Version 3 User's Manual," Purdue Research Foundation.
11. Strahler, Alan H., 1978. "Improving Forest Cover Classification Accuracy From Landsat By Incorporating," Symposium on Remote Sensing of the Environment, Manila, Phillipines.
12. Tomlinson, R.F., et al., 1976. "Computer Handling of Geographical Data." UNESCO press.
13. Van Wie, Peter, and Stein, Maurice, 1976. "A Landsat Digital Image Rectification System," Machine Processing of Remotely Sensed Data, Purdue: LARS Symposium Proceedings.

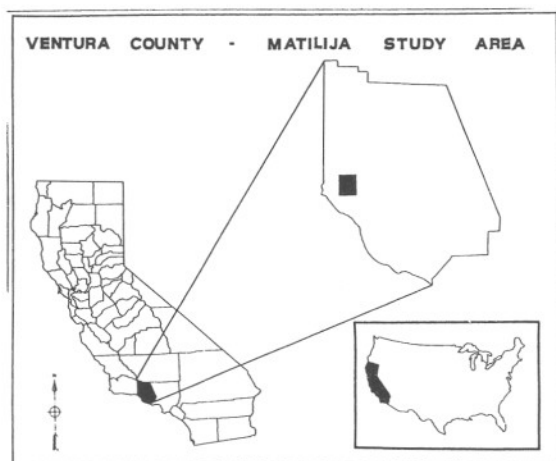


Figure 1. Matilija Quad Study Area. Study area is portrayed in its geographical context in Ventura County, California.



Figure 2. Landsat/MSS Imagery. Landsat scene 1811-17555. Matilija study area is shown outlined on this October 12, 1974 Landsat image. The image portrays the raw digital Landsat data from which this study's land cover classification has been derived.

Photo Verified Class	Information System Representative Class										Total
	Chaparral	Oak Woodland	Coastal Sage Scrub	Grassland	Riparian	Barren	Water	Agriculture	Urban Residential	Mobile	
Chaparral	59	*	2	*	*	*	*	11	4	*	76
Oak Woodland	6	22	*	1	*	*	*	*	*	*	29
Coastal Sage Scrub	*	*	5	2	*	*	*	*	*	*	7
Grassland	1	*	4	17	*	2	*	*	7	*	31
Riparian	1	*	*	*	3	*	*	*	2	*	6
Barren	*	*	*	*	1	8	*	*	2	1	12
Water	*	*	*	*	*	*	10	*	*	*	10
Agriculture	4	*	*	1	*	*	*	3	*	*	8
Urban Residential	2	*	*	1	1	*	*	*	14	*	18
Mobile	*	*	*	*	2	*	*	*	*	2	4
Total	73	22	11	22	7	10	10	14	29	3	143

correct representation - 71%

Figure 4. Landsat Land Cover Representation Accuracy. Results of 200 randomly sampled grids verified against low altitude photography.

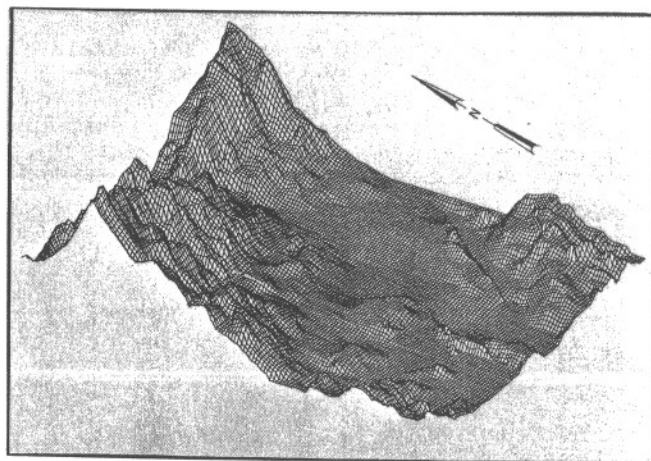
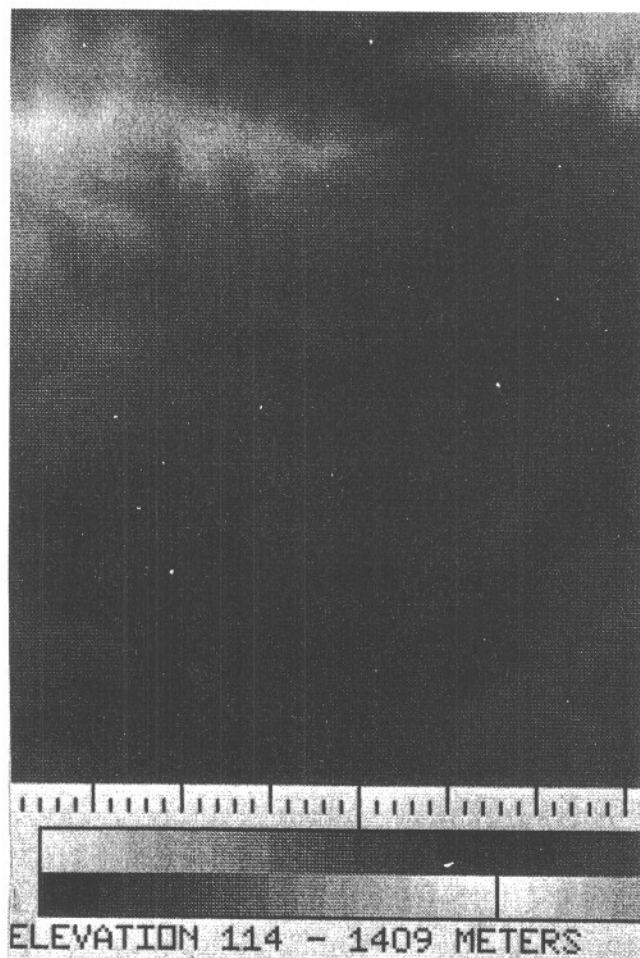


Figure 5. 3-Dimensional Perspective Plot of Matilija Quad Study Area. This is an example of computer/plotter generated graphics that may be derived from NCIC Digital Terrain Tape data.

Figure 6. Elevation Image From Digital Terrain Tape Elevation Values. Digital elevation values for the Matilija area have been converted to digital grey numbers (min. elevation 114 m = 0 DN, max. elevation 1409 m = 255 DN). Film writer has produced an "elevation image" where bright values represent areas of highest elevation. Elevation data in this form can then be added as an additional channel of information in an automated land cover classification. Classification may be improved when land cover classes are distinctly correlated to elevation in a given area.

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