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Land-Use Mapping from Skylab S-190B Photography

The accuracy of a land-use map produced from a Skylab S-190B color photograph was determined by comparing it with a field-checked land-use map made from high-altitude aircraft photography.

INTRODUCTION

THE PROSPECTS FOR producing accurate maps of land use from orbital altitudes at scales consistent with the needs of some local and State planners, i.e., 1:24,000 to 1:100,000, have been significantly increased with the acquisition of photography from the Skylab S-190B Earth Terrain Camera (Colvocoresses, 1972; Welch, 1974; Klemas *et al*., 1975). During the past five years, extensive analyses of land use mapping capabilities from photography acquired by high-altitude aircraft have been undertaken. Federal research projects, such as the Central Atlantic Regional Ecological Test Site (CARETS) Project (Alexander, 1973) and the Census Cities Experiment (Wray, 1973), have demonstrated the usefulness of airborne sensors for land-use mapping and change detection purposes. Land-use mapping capabilities using high-altitude aircraft photography have been expanded to similar mapping from satellite data.

Recently completed research has evaluated how effectively land-use maps can be made by using LANDSAT (formerly ERTS) data. Findings indicate that generalized land-use maps can be produced with percentages of accuracy ranging from 82.7 for commercial-industrial uses through 97.1 for irrigated open space (Ellefsen, 1973), and that the computer compatible tapes (CCTs) may permit detailed mapping at minimum mapping units approaching 0.4 hectares. The specific requirements for accurate mapping from LANDSAT-type data are complex in terms of spectral class for land-use class identification and assignment. This fact causes problems in the ability to interpret and map consistently from one scene to another. Considerably more research is needed on computer-assisted land-use classification with LANDSAT

ABSTRACT: *This article reports on research designed to analyze the suitability of S-190B Photography for land-use mapping. The research has been undertaken in an effort to analyze the reliability of such land-use data. A Level III land-use map of the city of Fairfax, Virginia, interpreted from a Skylab 3 S-190B "natural" color photograph was compared with a land-use map of the same area interpreted from a Wild RC-10 color-infrared photograph taken from a NASA U-2. The latter land-use map was field checked and corrected so that the relative accuracy of the Skylab map could be measured by direct comparison. Using the quotient of the number of points found to be the same, divided by the number of points examined, researchers found the Skylab map to have a relative accuracy of approximately 83 per cent.*

CCTs in order to bring this technique to operational use.

For land-use mapping at other than generalized levels of discrimination, greater spatial resolution would alleviate many problems. Skylab S-190B photography provides such greater resolution. This article reports on research designed to analyze the suitability of S-190B photography for land-use mapping. Portions of a previously developed detailed land-use classification were used in this study. The classification was based upon the remote-sensor oriented classification system presented in USGS Circular 671 (Anderson *et al.*, 1972). The Circular 671 classification grew out of the recommendations of the Interagency Steering Committee on Land-Use Information and Classification prior to the launch of LANDSAT-I. The recommendations postulated a Level I categorization most appropriately derivable from satellite sensors; a Level II Class appropriate for data from high-altitude aircraft; and third and fourth levels requiring low-altitude aircraft and ground sources.

The accuracy of a land-use map derived from remote sensor data is primarily a function of three variables, the data acquisition data processing system, the ability of the photo-image interpreter, and the land-use classification. This report addresses only data acquisition, specifically the S-190B sensor system. The author does, however, recognize the importance of the other variables in the total framework of accuracy determination.

An analysis of the value of a particular sensor to perform a given task should include not just a description of what the sensor detects, but also to what degree and how consistently it detects a particular phenomenon. Analysis of these points yields information dealing with a sensor's capabilities. For example, from enlarged LANDSAT multispectral scanner subsystem (MSS) color composites, urbanized areas can generally be delineated. However, it is often very difficult to determine which specific urban activity (commercial, industrial, residential, etc.) is present. This type of situation creates a need to quantify the results presented on the map by generating an "accuracy statement" or, more precisely, a reliability statement. This statement can then be considered the measure of a sensor's ability to perform a particular task.

Research Design

The following method was employed for measuring the accuracy of a land-use map covering an urban test site in the Virginia suburbs of Washington, D.C. The study began with the compilation of two land-use maps of the same area, one from S-190B photography and the other from high-altitude aircraft (U-2) RC-10 photography. The initial analytical step was the interpretation of photographic enlargements at a scale of 1:24,000 made from NASA-supplied color (SO-242) S-190B and Aerochrome Infrared (2443) RC-10 camera photographs, each covering the city of Fairfax, Virginia (Plate 1). The S-190B photo was taken August 5, 1973 and the RC-10 photo October 27, 1973.

By using categories derived from the hierarchical land-use classification system mentioned above, 1:24,000-scale land-use maps were compiled from the S-190B and RC-10 photographs (Figures 1 and 2). The land-use map produced from the RC-10 photography was field checked and corrected so that, for comparative purposes in this research, it is considered error free. This correction process facilitated the comparison of the map produced from S-190B photography to the map produced from RC-10 photography for accuracy determination.

The method of comparison was a systematic aligned sampling strategy, which compares two spatial data sets by using a corresponding point sample drawn from each map. (This technique is discussed by Berry and Baker, 1968). For example, consider two polygon maps, A and B, which cover exactly the same geographical area and use the same units of classification. Map A resulted from

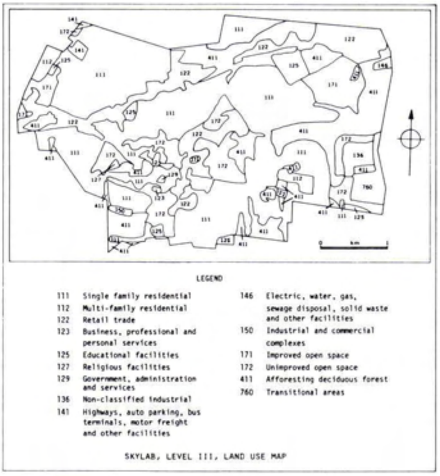

FIG. 1. Level III land-use map of the city of Fairfax, Virginia, generated from a Skylab-3, S-190B color photograph.

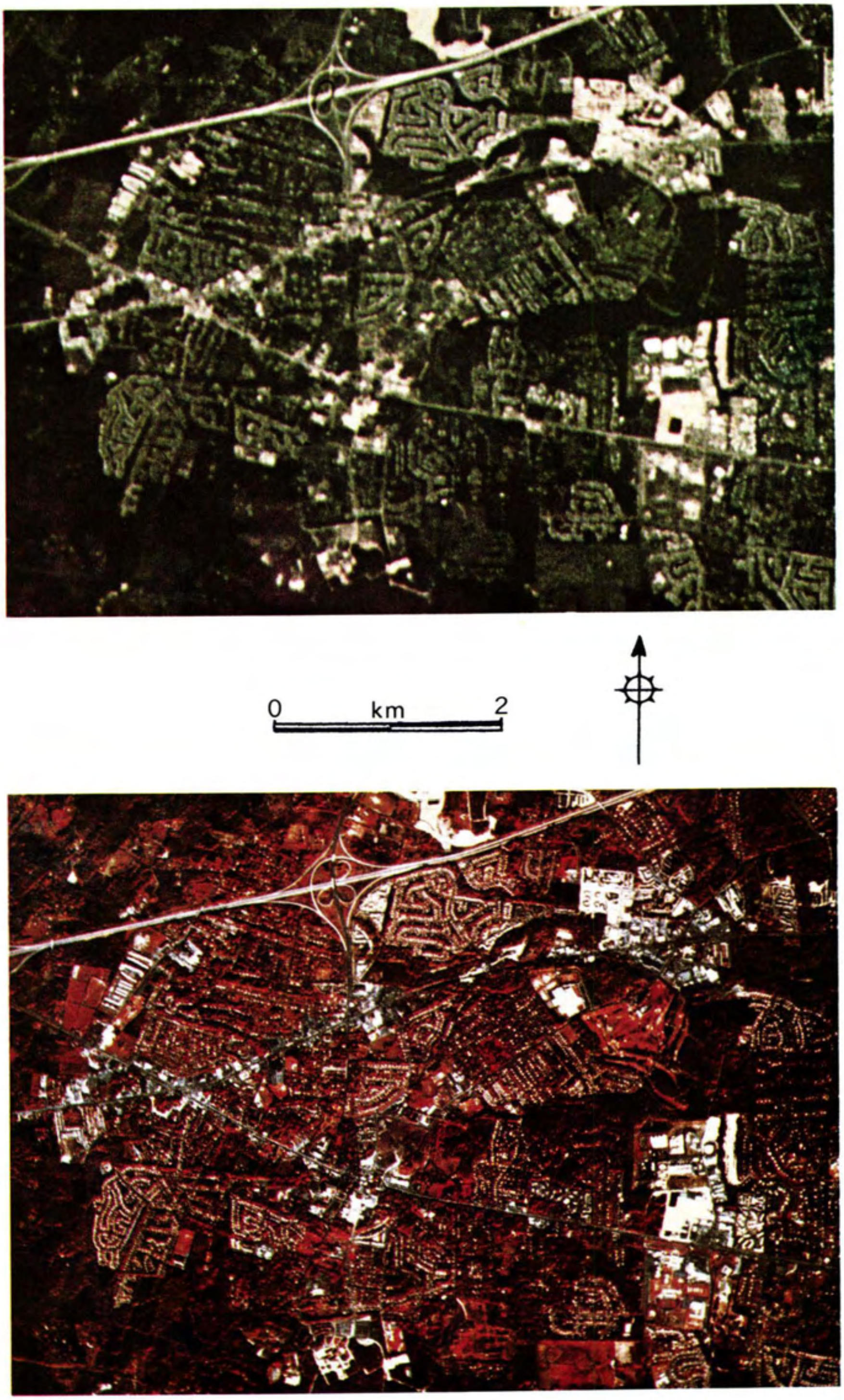

PLATE 1. (Upper) Color photograph of the city of Fairfax, Virginia, taken August 5, 1973, by the S-190B camera during the Skylab-3 mission, enlarged from a scale of 1:970,000. (Lower) Color infrared photograph of the same area taken October 27, 1973, with an RC-10 camera aboard a NASA U-2 aircraft, enlarged from a scale of 1:130,000.

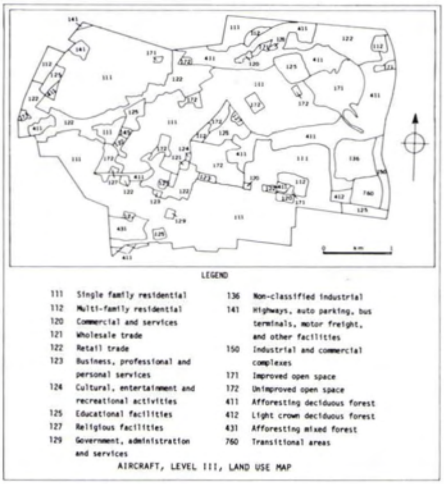

FIG. 2. Level III land-use map of the city of Fairfax, Virginia, generated from a RC-10, color infrared photograph.

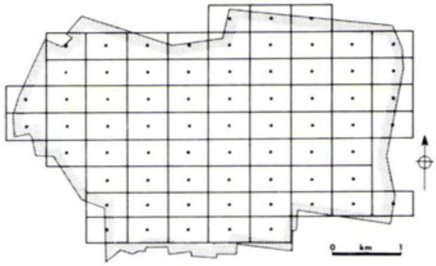

FIG. 3. The systematic aligned or "grid" sample used in this study to analyze the city of Fairfax, Virginia.

the interpretation of sensor X data and map B from analysis of sensor Y data. By observing points on one and then the other, one can determine which points, if any, have classification differences. Assuming further that map A, because of certain characteristics in sensor X combined with more detailed information from additional sources (other maps, field work, etc.), is accurate, and providing that the two maps are temporally similar, then any points on map B, different from those on map A, can be considered misinterpretations. The quotient of the number of points found to be the same on both maps divided by the total number of points examined thus can be considered a measure of accuracy.

The systematic aligned or grid sample was employed in this example because the mapped data did not contain any regularly repeated pattern or spatial periodicity. The geographical area analyzed was overlain by a grid of equal-sized cells, the center points of each serving as the observation point (Figure 3). The cell size was arbitrarily established based on the scale of the interpreted data. In this example, 69 sample points were examined for an area of 1600 hectares at a scale of 1:24,000.

A second technique employed was a comparison of the area measurements of land-use types. As an example, consider a classification system consisting of *n* land-use categories. For any given map using this classification, the sum of the areas of each category used will equal 100 per cent of the total area of the map. Consider further the case of three maps E, F, and G, of the same geographical area, which are produced by using the same classification system. Map E is generated from source R, map F from source S, and map G from source T. If map E, because of superior source information, is considered correct, they by comparing the percentage of area in each land use category in maps F and G to the percentage of their corresponding areas in map E, the relative accuracy of maps F and G by each land-use category can be determined. Suppose that a land-use classification with categories 1, 2, and 3 is employed and a hypothetical ground truth map is produced with 20 per cent of its area in category 1, 30 per cent in category 2, and 50 per cent in category 3. Another map has constituents of 21 per cent in 1, 31 per cent in 2, and 48 per cent in 3. Empirically the two are very similar. If, on the other hand, sizable discrepancies occur in the percentages, then a comprehensive look into the reasons for such differences will be in order. The actual physical determination of area was accomplished in this case by using a dot planimeter (Yuill, 1970).

RESULTS

The systematic aligned sample used in this study consisted of 69 points, 57 of which were found to be alike on both maps (Table 1). By using this particular method, the accuracy of the land-use map using Level III categories was computed to be approximately 83 per cent. Of the 12 points in disagreement, five occurred in cases where the S-190B data were misclassified as Unimproved Open Urban area. This appeared to be attributable to the spectral characteristics of the color film (SO-242) and the spatial resolution of the S-190B camera. The colorimetry was such that subtle vegetation differences were imperceptible, and the lack of detail in the data inhibited the observation of certain residential and commercial struc-

TABLE 1. MATRIX LISTING THE NUMBER OF OCCURRENCES OF S-190B INTERPRETED LAND USES IN RC-10 INTERPRETED (FIELD CHECKED) LAND USES FOR THE CITY OF FAIRFAX SAMPLE. DIAGONAL IS THE AXIS OF CORRECT S-190B INTERPRETATIONS. NOTE THAT CATEGORY CODES APPEAR IN FIGURES 1 AND 2.

AIRCRAFT RC-10	SKYLAB S-190B 111	112	122	125	126	150	171	172	411	412	760
111	34		1					1	2		
112			1								
122			7								
125				1				1			
136					1			1			
150											1
171			1				2				
172	1							3			
411								1	9		
412								1			
760											

tures. Positive identification of these features was difficult.

To analyze further the S-190B data of the Fairfax area, a comparison of area measurements by land-use categories was performed. Table 2 presents the Level III tabulations. The table indicates a sizable discrepancy in Residential Land area. Interpretation of S-190B photography resulted in the delineation of approximately 120 less hectares of Residential Land than did the analysis of aircraft photography. Both data sets were made by the same photointerpreter. Nearly all of the difference occurred in Single Family Residential areas, many of which are located in wooded or semi-wooded areas. In this situation, the spatial resolution of the S-190B Camera is not high enough to detect houses or other residential "keys" such as street patterns, sidewalks, etc.

TABLE 2. COMPARISON OF RC-10 AND S-190B MEASUREMENTS BY LEVEL III LAND-USE CATEGORIES FOR THE CITY OF FAIRFAX, VIRGINIA. NOTE THAT CATEGORY CODES APPEAR IN FIGURES 1 AND 2.

NOTE: AREA RECORDED IN HECTARES WITH ASSOCIATED PER CENT OF TOTAL AREA. EXAMPLE (AREA IN HECTARES/PER CENT OF TOTAL AREA).

	RC-10 Hectares	Per Cent	S-190B Hectares	Per Cent
111	780.4 /	50.22	657.3 /	42.30
112	32.2 /	2.07	26.4 /	1.70
120	7.4 /	0.48	— /	—
121	3.4 /	0.22	— /	—
122	166.3 /	10.70	166.4 /	10.71
123	3.6 /	0.23	1.4 /	0.09
124	0.8 /	0.05	— /	—
125	60.7 /	3.90	99.8 /	6.42
127	2.8 /	0.18	1.9 /	0.12
129	5.1 /	0.33	1.1 /	0.07
136	32.1 /	2.07	23.7 /	1.53
141	6.9 /	0.44	7.2 /	0.46
146	— /	—	4.8 /	0.51
150	12.1 /	0.78	4.5 /	0.29
171	54.4 /	3.50	39.6 /	2.55
172	128.2 /	8.25	152.9 /	9.84
411	215.2 /	13.85	339.5 /	21.84
412	5.6 /	0.36	— /	—
431	16.2 /	1.04	— /	—
760	20.6 /	1.33	27.5 /	1.77
	1554.0 /	100.0	1554.0 /	100.0

Areas of Commercial and Services land use were readily detectable by S-190B, especially retail trade areas. This appears to be due to the distinctive spectral and spatial characteristics of shopping areas. Two main types of commercialized areas are usually found: suburban shopping centers and urban commercial strips along major thoroughfares. Less Industrial area was interpreted from the S-190B data. This appears to be the result mainly of interpreter inability, in some cases, to detect differences between the Industrial and the Commercial and Services category when using S-190B photography.

A marked similarity was found between the two systems in discriminating the Urban-Open Ground category. Although the spatial discrimination was different, the spectral response to open ground was in many respects similar.

Forest Land interpretation, on the other hand, was less accurate with S-190B. The map generated from the S-190B photo had 58 per cent more area in forest than did the map generated from the RC-10 photo. This result was attributable mainly to the aforementioned tree-covered residential area where

120 hectares of Residential Land were misinterpreted as Forest Land from the S-190B data.

Conclusions

The high quality of the S-190B camera dramatizes a change in the early estimates of the technological capabilities of spaceborne sensors for land-use classification and mapping (Anderson *et al.*, 1972). The S-190B data permitted discrimination of certain Level III categories in urban area land-use analysis. This result suggests that the various hierarchical levels of land-use classification should not necessarily be determined by the altitude or type of vehicle employed as a sensor platform, but rather by the requirements of the users and the logic of the classification systems. As this example of the S-190B photography illustrates, it was possible to obtain relatively high-resolution orbital data having considerable value for land-use mapping in urban areas.

The capability of the S-190B data for interpreting ground features critical for land-use identification lies between the coarser-resolution LANDSAT MSS and the finer-resolution high-altitude RC-10 photography. It is, however, much closer to the RC-10 photography than to the LANDSAT. Experience with various remote-sensor data users indicates that photography of the caliber of S-190B would be of considerable value in the work of planning agencies at the State or regional level.

The availability of S-190B data has made possible the mapping of urban structural details from orbital altitudes. These include the location and extent of commercial and industrial areas, individual commercial and industrial structures, medium-duty and some light-duty roads, and considerable detail in the use patterns of surrounding non-urban land. Also detectable were most single-family residential areas. Residential developments lying under a heavy crown forest created interpretation problems. Better results could have been achieved if color infrared film with comparable photographic resolution had been used in the S-190B camera.

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