National Mapping Program

An Evaluation of Landsat 3 Return Beam Vidicon Imagery for Land Cover Mapping and Change Detection

Open-File Report 83-886

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U.S. GEOLOGICAL SURVEY

AN EVALUATION OF LANDSAT 3 RETURN BEAM VIDICON IMAGERY FOR LAND COVER MAPPING AND CHANGE DETECTION

By Valerie A. Milazzo

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Reston, Virginia
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CONVERSION TABLE

Length

Multiply	By	To Obtain
feet (ft)	0.3048	meters (m)
mile, statute (mi)	1.6093	kilometers (km)

Area

Multiply	By	To Obtain
feet^2 (ft^2)	0.092903	meters^2 (m^2)
acre	0.4047	hectàres
miles^2 statute (mi^2)	2.5900	kilometers^2 (km^2)

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ABSTRACT

Up-to-date land use and land cover maps and data are necessary for understanding how the United States presently uses its land resources and for proper planning and effective management of these resources. To meet this need, research is being conducted on methods to update U.S. Geological Survey (USGS) land use and land cover maps. As part of a revision program, a procedure is needed to compare maps periodically with more current remotely sensed data to identify those maps having sufficient change to warrant revision. Such quick-look inspection requires use of a remote sensing source that is easily available, inexpensive to acquire, and simple to use in terms of data processing and handling. The spatial resolution of imagery from the return beam vidicon (RBV) camera aboard the Landsat 3 satellite suggested that such data might prove useful in inspecting land use and land cover maps. In this study, a 1972 land use and land cover map derived from aerial photographs was compared with a 1978 Landsat RBV image to delineate areas of change. These changes were then evaluated against a control set of change data, derived from aerial photographs. Findings indicate that RBV imagery is useful in establishing the fact of change and in identifying gross category changes. However, a limited role is seen for Landsat 3 RBV imagery in the overall land use and land cover map inspection process.

I. INTRODUCTION

Up-to-date land use and land cover maps and data are necessary for understanding how the United States presently uses its land resources and for proper planning and effective management of these resources. In response to this need, research is underway on methods to update existing USGS land use and land cover data in a timely and uniform manner (Milazzo, 1980). As part of a revision program, a procedure is needed whereby existing land use and land cover maps can be compared periodically with more current remotely sensed data to identify those maps in which enough change has occurred to warrant revision. Such a quick-look inspection requires use of a remotely sensed source that is easily and readily available, inexpensive to acquire and process, and simple to use in terms of data processing and data handling requirements.

The positional accuracy and improved resolution and quality of imagery from the return beam vidicon (RBV) camera system aboard the National Aeronautics and Space Administration (NASA) Landsat 3 (as compared with earlier Landsat RBV and MSS imagery) suggests that such data may be useful in a USGS land use and land cover map inspection program.

II. STUDY OBJECTIVES AND GENERAL METHODOLOGY

The primary objectives of this study are to: (1) Evaluate the utility of Landsat 3 RBV imagery as a photo source for detecting, identifying, and mapping changes in land use and land cover, and (2) provide recommendations concerning the role of Landsat RBV imagery (or other sources having comparable data characteristics such as Landsat 4 Thematic Mapper data) in an operational USGS land use and land cover map inspection program and suggest areas for further research.

The study employs two general research methodologies and techniques. First, both conventional photointerpretation techniques and standard cartographic procedures are utilized for data extraction and mapping. A 1972 land use and land cover map derived from aerial photographs is visually compared with 1978 Landsat RBV imagery of the same area to identify and delineate areas of change. Second, the polygons of change derived from Landsat data are then evaluated against a control set of change data, derived in the same way, but from aerial photographs of roughly the same time period. Areas of change are calculated, and standard statistical and geographic data analysis methods are utilized to evaluate research results.

III. BACKGROUND

A. Previous Investigations

Since the late 1960's, the USGS has been actively involved in remote sensing research. This research has often dealt with evaluating the usefulness of new or alternative remotely sensed data sources for the extraction of basic thematic data and for developing new or improved mapping procedures and products. The Office of Geographic and Cartographic Research, National Mapping Division, has undertaken numerous studies in the use of remotely sensed data from earth resources satellites for applications to land use and land cover mapping and change detection.

Early research by Wray (1973) and Alexander (1973), for example, investigated the use of imagery from the Landsat multispectral scanner (MSS) for identifying and mapping land use and land cover in urban and regional environments. In research by Milazzo (1974), the applications of earth resources photography aboard NASA's Skylab satellite were documented for metropolitan area land use analysis. Further studies by Gaydos and others (1977) and Gaydos and Newland (1978) presented results of computer classification of Landsat MSS digital data in mapping multiple land use and land cover categories. Applications to single theme land use data extraction were addressed by Thelin and others (1981). Other research by Place (1976)' and Milazzo (1980) focused on the use of Landsat MSS imagery and digital data (Milazzo and others, 1977) in land use change detection.

Related to this research have been studies investigating the role of Landsat imagery in updating standard map products. Fleming (1980), Moore and Gregory (1979), and Moore and others (1980) reported on work conducted by the Government of Canada in utilizing Landsat MSS imagery to revise topographic maps.

Research completed by Falcone (1979) described the use of imagery from the redesigned RBV camera system aboard Landsat 3 for inspecting/revising USGS topographic maps, and Lewis and Shore (1980) reported on the successful use of RBV imagery in updating State forestry maps in Oregon. The potential role of RBV imagery in detecting land use change and in inspecting/revising USGS land use and land cover maps was described in a report by Milazzo (1981); however, to date, no research has been completed that fully evaluates RBV imagery specifically for this purpose.

B. Study Area

The site chosen for this study covers a 2,100 mi^2 area located in south-central Florida, approximately centered on the city of Kissimmee, and includes portions of five Florida counties (fig. 1).

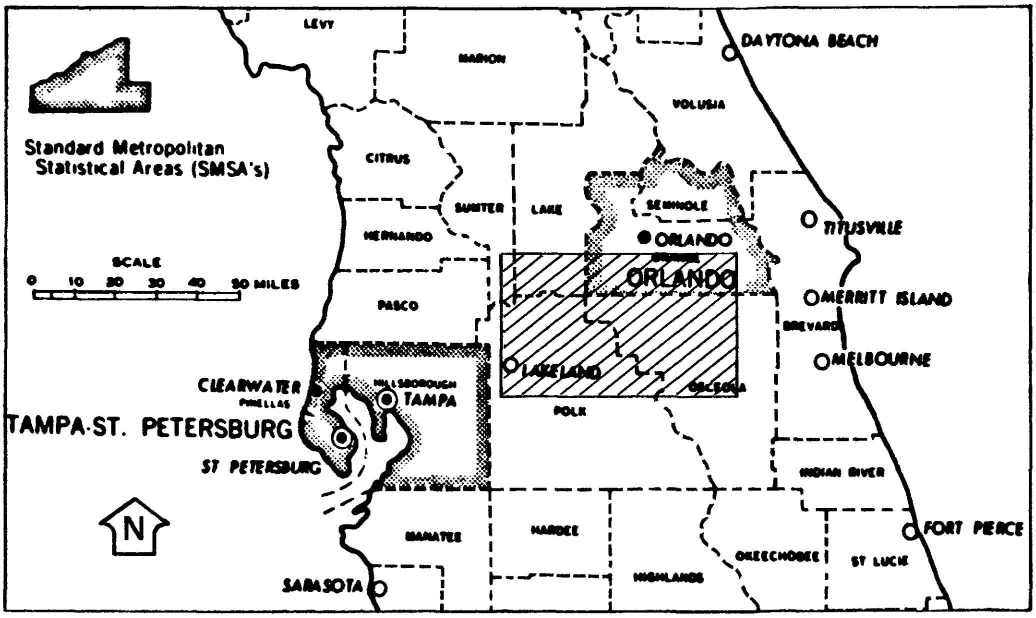

Figure 1.--Location of study site in south-central Florida.

The configuration of the study area corresponds to the southwest quarter section of the Orlando 1:250,000-scale land use and land cover map (an area of 1° longitude by 30' latitude). The study site includes the southern one-third of the Orlando Standard Metropolitan Statistical Area (SMSA) and extends southwestward to the city of Lakeland. The area is crisscrossed by a network of primary roadways and has experienced marked urban growth and development during most of the 1970's, a development trend that continues to the present time (table 1). This growth has been particularly evident in the area southwest of Orlando as a result of the construction and subsequent development of the Walt Disney World theme park complex and a host of surrounding associated retail and service establishments and facilities. While this urban growth has been confined in both its spatial and areal dimensions to either the fringes of existing urban centers or along major automobile arterials, its impact has nevertheless been felt strongly throughout this predominantly rural region. A more subtle yet pervasive (at least in terms of land acreage) alteration of the landscape has also taken place within the area. This change concerns the steady expansion of agricultural activity, primarily cropland and pasture, into surrounding wetland and palmetto prairie rangeland environments. Still, agricultural land, wetland, and rangeland remain fairly evenly divided, and together constitute the dominant cover types, with an 80 percent share of the study area's 1.3 million acres.

C. Landsat 3 RBV Sensor System

The Landsat 3 RBV sensor system utilizes a vidicon tube (television) camera to collect and record remotely sensed data (Clark and Meyer, 1982). In this system the ground-area image is stored on the photosensitive surface of the camera tube which, after shuttering, is electronically scanned to produce a video signal output. The Landsat 3 RBV configuration consists of two vidicon cameras, arranged side-by-side so that both cameras can be shuttered sequentially, twice each, in about the same time it takes to acquire one MSS image. This results in four RBV "subscenes," designated A, B, C, D, for every MSS scene acquired (fig. 2).

Both RBV cameras sense data in a single broad spectral band width, between 0.51 and 0.75 micrometers, which roughly extends from the blue-green to the beginning near-infrared part of the electromagnetic spectrum. Each RBV subscene covers a ground area of approximately 99 km x 99 km, with approximately 17 km sidelap. The effective ground resolution is slightly less than 30 m (27-30 m). Each RBV scene is processed originally at a nominal scale of 1:500,000. Landsat 3 RBV data are available from the EROS Data Center, Sioux Falls, South Dakota, in the same photographic product formats (except for scale) as the single-band MSS data.

In acquiring RBV image coverage for the study, the specific geographic coordinates of the area were provided to the National Cartographic Information Center (NCIC), U.S. Geological Survey, Reston, Virginia. A geographic computer search was then conducted to locate and identify

Table 1.--1972 and 1977 land use and land cover polygon and acreage totals, by category, for Florida study area

Land Use and Land Cover Category		1972				1977			
		# of Polygons	%	Acres	%	# of Polygons	%	Acres	%
1 Urban or Built-Up Land	11	196	6.2	57971	4.3	266	8.2	60748	4.5
	12	152	4.8	12680	0.9	175	5.4	13256	1.0
	13	32	1.0	3223	0.2	36	1.1	3435	0.3
	14	26	0.8	11037	0.8	30	0.9	11707	0.8
	15	2	0.1	678	0.1	7	0.2	678	0.1
	17	39	1.2	4658	0.3	43	1.3	5420	0.4
		447	14.1	90247	6.6	557	17.1	95244	7.1
2 Agricultural Land	21	388	12.3	289996	21.6	392	12.1	306533	22.8
	22	282	9.0	159211	11.8	254	7.6	158865	11.8
	23	17	0.5	289	0.0	18	0.6	289	0.0
	24	10	0.3	214	0.0	10	0.3	186	0.0
		697	22.1	449710	33.4	674	20.6	465873	34.6
3 Rangeland	31	266	8.4	290164	21.6	254	7.6	267662	19.9
	32	1	0.0	963	0.1	1	0.0	963	0.1
		267	8.4	291127	21.7	255	7.6	268625	20.0
4 Forest Land	41	1	0.0	106	0.0	1	0.0	106	0.0
	42	184	5.8	46313	3.4	151	4.7	41382	3.1
		185	5.8	46419	3.4	152	4.7	41488	3.1
5 Water	52	425	13.5	104368	7.8	419	13.0	103333	7.7
	53	107	3.4	10205	0.8	112	3.5	5937	0.4
		532	16.9	114573	8.6	531	16.5	109270	8.1
6 Wetland	61	710	22.6	283421	21.1	688	21.3	282991	21.1
	62	201	6.4	46384	3.5	198	6.1	49525	3.7
		911	29.0	329805	24.6	886	27.4	332516	24.8
7 Barren Land	75	34	1.1	5960	0.4	42	1.3	9168	0.7
	76	75	2.4	15839	1.2	134	4.2	21496	1.6
		109	3.5	21799	1.6	176	5.5	30664	2.3
TOTAL		3148		1343680		3231		1343680	

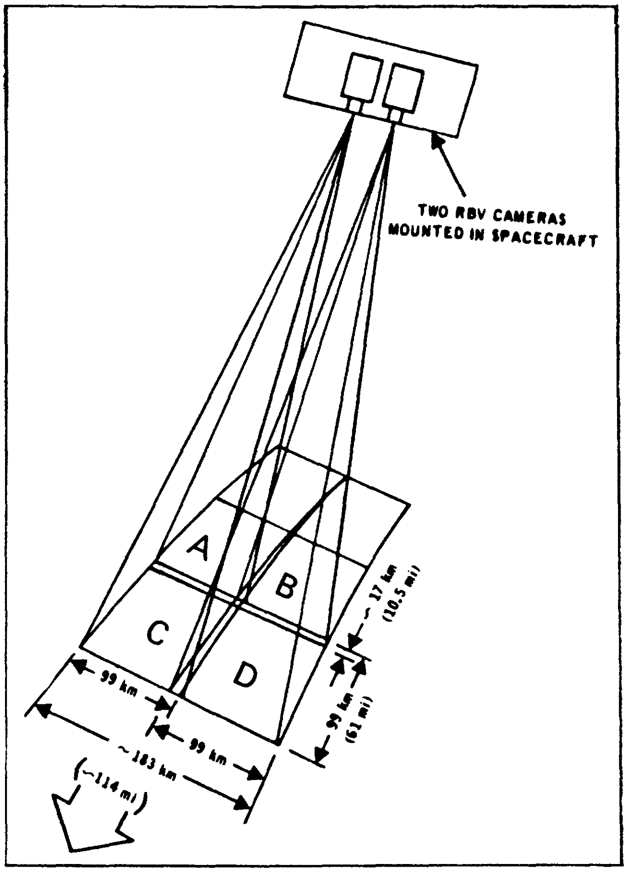

Figure 2.--Approximate scanning configuration and coverage of the Landsat 3 RBV cameras.

appropriate RBV subscenes covering the study area and also meeting other user-specified parameters.[1] From the computer printout a preliminary selection of subscenes that best met the required time of year and image quality parameters was made from among the 28 subscenes listed. These images were then previewed on microfiche cassettes contained in the NCIC browse facility. Parts of two Landsat 3 RBV subscenes, acquired on November 4, 1978, were needed to cover the study area (fig. 3). Black-and-white 1:500,000-scale film positives were subsequently ordered from the EROS Data Center.

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[1] A listing of all RBV subscenes covering the area that met a minimum image quality standard of 7 (on a scale of 1 to 8) and had a maximum cloud coverage of 10 percent was requested.

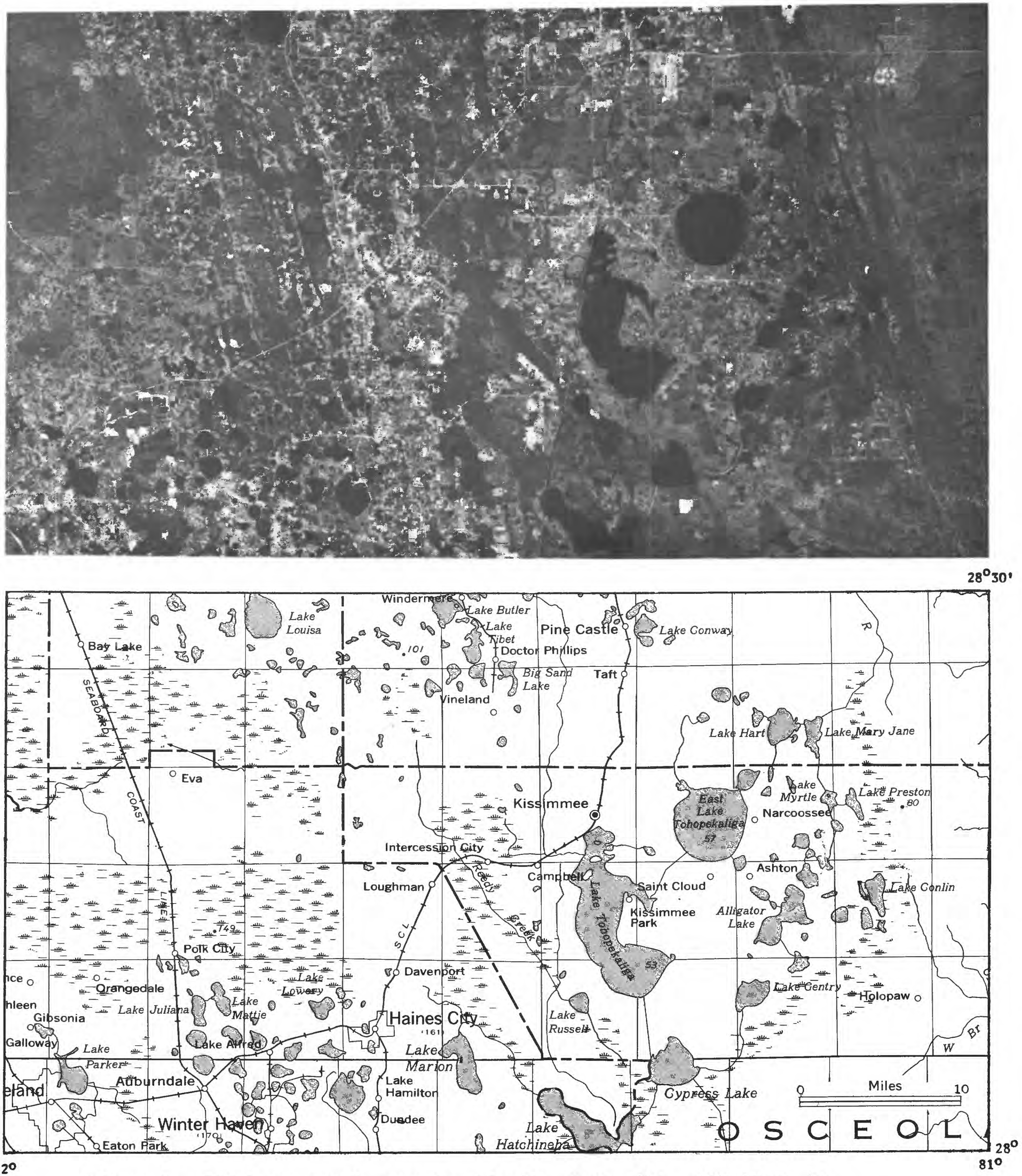

Figure 3.--RBV image mosaic covering Florida study site. RBV image is mosaic of parts of subscenes C and D of image number 30244-15175, taken on November 4, 1978. Map is part of USGS 1:500,000-scale Florida State base map.

IV. APPROACH

A. Change-Mapping Procedure

Land use and land cover changes for the area under study had previously been mapped from portions of 25 1:80,000-scale high resolution black-and-white aerial photographs acquired during November 1977. These change data served as the control data against which to evaluate the changes mapped using the RBV imagery.[2/] Land use and land cover changes were derived from the aerial photographs and RBV images using the same mapping technique (fig. 4). A film positive of the southwest quarter of the original 1:250,000-scale 1972 land use and land cover map was enlarged to a compilation scale of 1:100,000. This transparency was superimposed on the remotely sensed source film (either the aerial photographs or RBV images) which had also been photographically brought to the same scale as the base map. Each land use and land cover polygon on the map was then visually compared with the corresponding land use and land cover feature appearing on the new image source. Valid sequential land use and land cover category differences between the mapped polygons and corresponding areas on the image were delineated as polygons of change on a stable-base drafting film overlay which was punch-registered to the land use map. Only the actual areas of change were mapped and were represented as complete polygons. Each change polygon had to meet established minimum mapping size criteria of 10 or 40 acres, depending on the category, in order to be shown. Each polygon of change was labeled by a four-digit "from-to" code identifying both the old Level II land use and land cover category that was shown on the map and the new Level II category as derived from the new image source (see table 2 and also Anderson and others, 1976, for description of categories). A separate polygon of change was delineated for every change in boundary or category that occurred. The time required to map changes using the aerial photographs was 20.25 hours. The change mapping using RBV images was completed in 3.25 hours.

B. Change-Area Statistics

To better evaluate and compare the RBV image and aerial photograph change-mapping results, the area of each individual change polygon mapped was independently measured using an electronic polar planimeter. The entire change map made from the aerial photographs and the RBV images was traversed four separate times, so that independent replicated measurements were available. These sets of replicated measurements were

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[2/] The change mapping conducted using the aerial photographs was part of another study that was completed several months before the RBV image interpretation was undertaken. Given the time lapse between the two sets of interpretations, it is felt that the RBV mapping effort was negligibly influenced or biased by the control data.

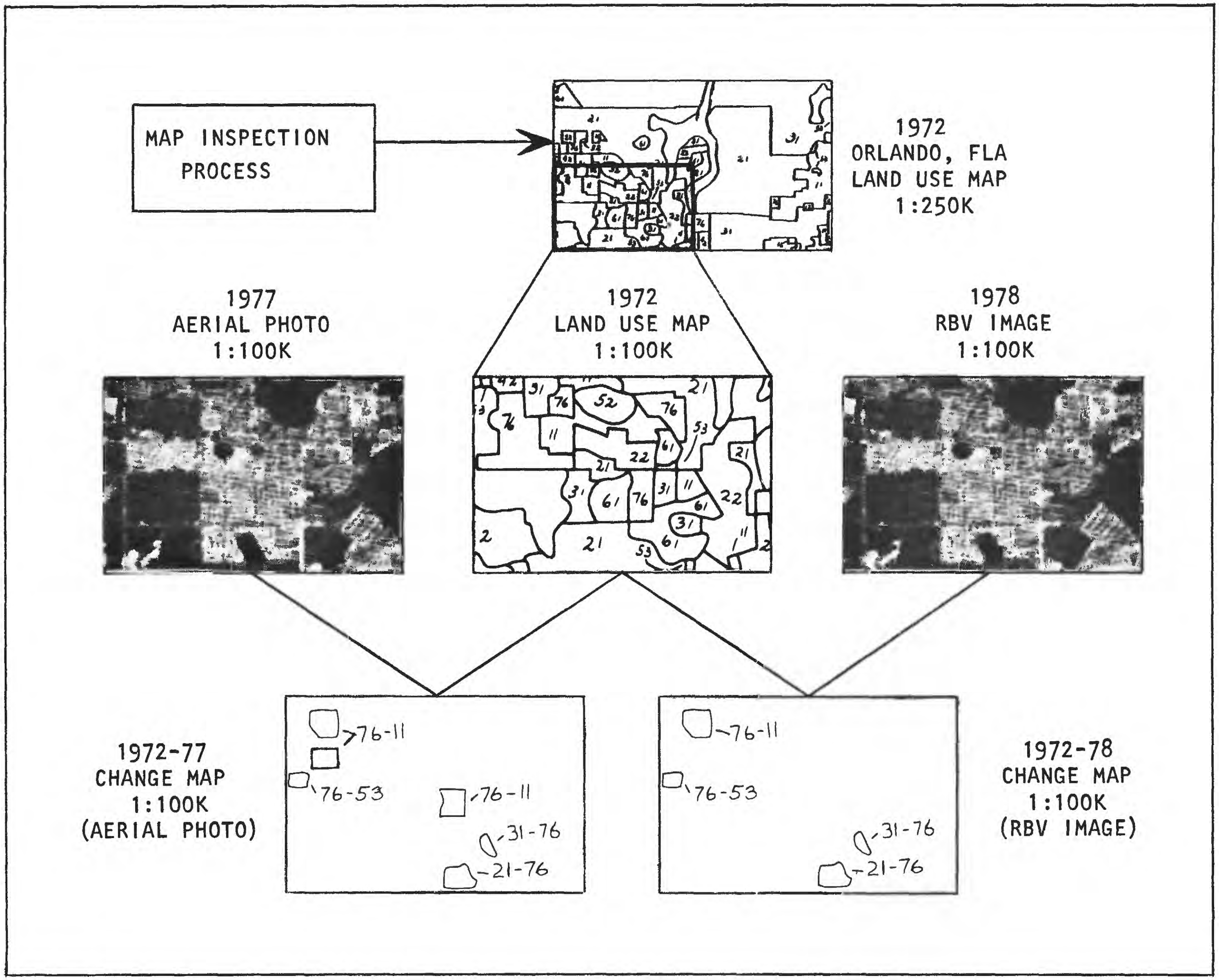

Figure 4.--Diagram of map inspection procedure used in study. (Maps and photographs do not represent the actual study area.)

Table 2.--U.S. Geological Survey land use and land cover classification system for use with remote sensor data [From Anderson and others, 1976]

LEVEL I		LEVEL II	
1	Urban or Built-up Land	11	Residential
		12	Commercial and Services
		13	Industrial
		14	Transportation, Communications, and Utilities
		15	Industrial and Commercial Complexes
		16	Mixed Urban or Built-up Land
		17	Other Urban or Built-up Land
2	Agricultural Land	21	Cropland and Pasture
		22	Orchards, Groves, Vineyards, Nurseries, and Ornamental Horticultural Areas
		23	Confined Feeding Operations
		24	Other Agricultural Land
3	Rangeland	31	Herbaceous Rangeland
		32	Shrub-Brushland Rangeland
		33	Mixed Rangeland
4	Forest Land	41	Deciduous Forest Land
		42	Evergreen Forest Land
		43	Mixed Forest Land
5	Water	51	Streams and Canals
		52	Lakes
		53	Reservoirs
		54	Bays and Estuaries
6	Wetland	61	Forested Wetland
		62	Nonforested Wetlands
7	Barren Land	71	Dry Salt Flats
		72	Beaches
		73	Sandy Areas Other than Beaches
		74	Bare Exposed Rock
		75	Strip Mines, Quarries, and Gravel Pits
		76	Transitional Areas
		77	Mixed Barren Land
8	Tundra	81	Shrub and Brush Tundra
		82	Herbaceous Tundra
		83	Bare Ground Tundra
		84	Wet Tundra
		85	Mixed Tundra
9	Perennial Snow or Ice	91	Perennial Snowfields
		92	Glaciers

rearranged in the form of repetitive measurements of the area for each change polygon. The repetitive readings were then entered into the computer and run through a computerized editing procedure (Grubbs, 1950) from which the mean and standard deviation were computed. In addition, the grand standard deviation for all measurements on the land use change maps was computed. This grand standard deviation represents the precision of the ability to make an area measurement for the equipment-image-observer combination. The mean values for the area data by polygon for each change category were then printed out in tabular form. In addition the area data were presented in the form of change matrices listing individual and cumulative areas of change by category as well as the number of change polygons by category.

V. RESULTS

Analysis of the change polygon and area measurement data derived from the aerial photographs shows that about 53,000 acres, or 4 percent of the area's 1.3 million acres, underwent a change in use or cover type between 1972 and November 1977 (tables 3 and 4).

Table 3.--Aerial photograph and RBV image land use and land cover change polygon totals

Land Use and Land Cover

Change Polygons

LEVEL 1 CLASS / SOURCE	(1) Urban or Built-up Land	(2) Agricultural Land	(3) Rangeland	(4) Forest Land	(5) Water	(6) Wetland	(7) Barren Land	TOTAL
AERIAL PHOTOGRAPHS	110	91	9	1	13	26	121	371
RBV IMAGES	102	59	6	0	0	2	172	341

Table 4.--Aerial photograph and RBV image land use and land cover change acreage totals

Land Use and Land Cover

Change Acreage

LEVEL 1 CLASS / SOURCE	(1) Urban or Built-up Land	(2) Agricultural Land	(3) Rangeland	(4) Forest Land	(5) Water	(6) Wetland	(7) Barren Land	TOTAL
AERIAL PHOTOGRAPHS	5248	23803	2719	49	409	5853	14857	52938
RBV IMAGES	6414	14988	4287	-	-	5984	19360	51033

This amount was represented by a total of 371 individual change polygons, which accounted for 12 percent of all polygons mapped in 1972. The dominant changes involved conversion of palmetto prairie to new agricultural activity, namely, cropland and pasture, while existing cropland and pasture changed to transitional areas and to residential land use categories. The distribution of these changes by polygon size and new land use or land cover category is shown in table 5.

Table 5.--Change polygons interpreted from aerial photographs, by size and category

LEVEL I CLASS / POLYGON SIZE	(1) Urban or Built-Up Land	(2) Agricultural Land	(3) Rangeland	(4) Forest Land	(5) Water	(6) Wetland	(7) Barren Land		TOTAL	% OF TOTAL BY SIZE
< 40 ACRES	68	-	-	-	9	-	60		137	37%
40-80 ACRES	28	37	1	1	4	8	23		102	27%
> 80 ACRES	14	54	8	-	-	18	38		132	36%
TOTAL	110	91	9	1	13	26	121		371	
% OF TOTAL BY CATEGORY	30%	25%	2%	-	4%	7%	33%			

Results of the RBV image change mapping show that approximately 51,000 acres, or 3.8 percent of the study area's total acreage, were identified as having changed between 1972 and November 1978 (table 4). This amount, in turn, was represented by a total of 341 individual polygons of change, with the dominant conversions again being the same as that observed on the aerial photographs (table 3). If we compare only these total change acreages and change polygon results with the aerial photograph change data, it would appear that the change map derived from the RBV image source was 96 and 92 percent correct in identifying both the areal extent and the number of occurrences, respectively, of land use and land cover change. However, closer examination of the data reveals that the true accuracy levels were considerably less than those indicated by the total figures alone. In order to determine the true accuracy level, each change polygon mapped from the RBV image was compared with each change polygon mapped from the aerial photographs (fig. 5). Polygons mapped from the RBV data were identified as falling into one of five groups of changes: (1) Change detected and correctly mapped at Level II category, (2) change detected and correcty mapped at Level I category only, (3) change detected but misclassified, (4) change not detected, and (5) change detected on RBV image only.

The results of the polygon-by-polygon comparison of the aerial photograph and the RBV image change data showed that of the 371 change polygons identified in the aerial photograph control set, only 184 were correctly

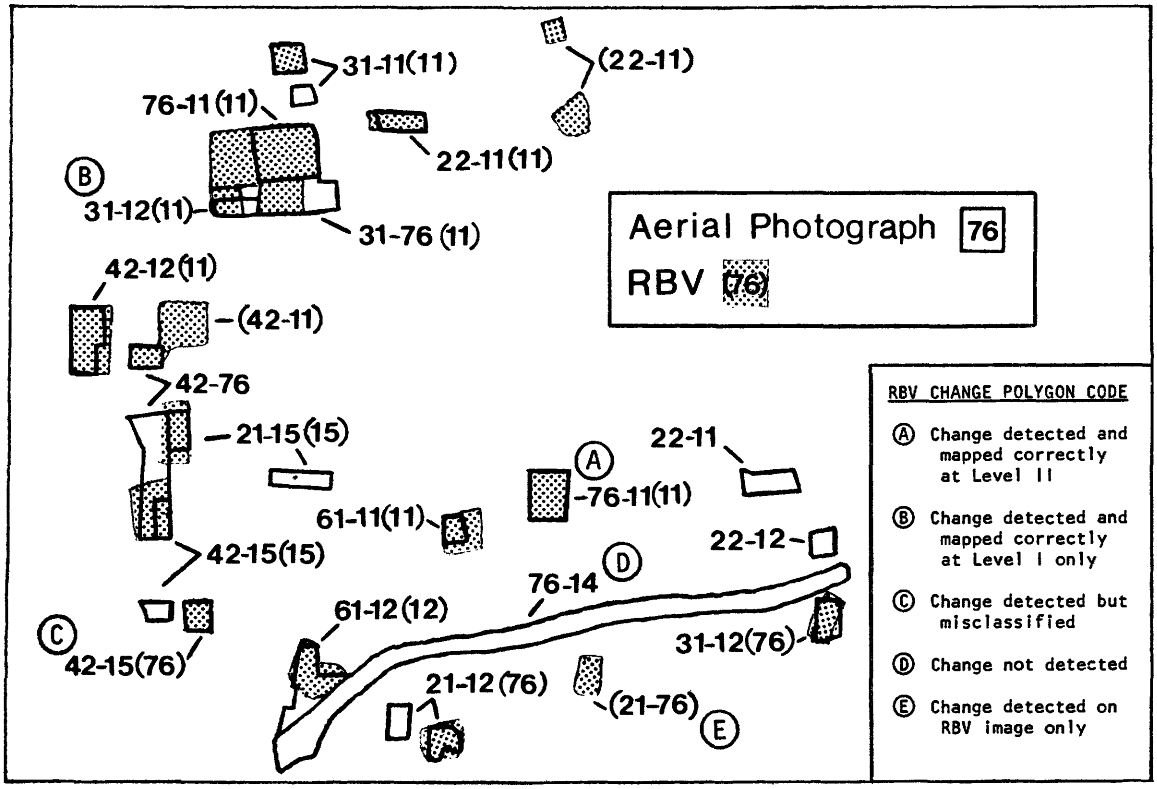

Figure 5.--Portion of land use and land cover change map showing change polygons and identifiers derived from aerial photographs. RBV image-derived change polygons (stipled areas) are superimposed.

identified as changes (regardless of category) on the RBV imagery (table 6). The remaining 187 polygons of change identified on the aerial photographs were not shown as changes on the RBV images. Given these data, a true polygon accuracy level of about 50 percent emerges for the RBV image-derived change map. The earlier higher accuracy percentage based on 341 occurrences of change mapped from the RBV data was due to the fact that in addition to the 184 correctly identified change polygons, another 157 polygons (representing 46 percent of the RBV polygons mapped) were interpreted as changes which did not appear as changes in the control data set. In terms of area values, somewhat better results were achieved in that 63 percent of the total land acreage identified as change on the aerial photographs was captured (table 7). The 157 additional change polygons that were not mapped from the aerial photographs represented 35 percent of the total area identified as change from the RBV data. In order to better assess the strengths and weaknesses of the RBV data in identifying specific categories of change, a further analysis was made of the changes that occurred within each of the Level I land use and land cover categories.

Table 6.--Aerial photograph and RBV image change polygon matrix

Level I Land Use and Land Cover Class		RBV								Aerial Photo Changes Identified by RBV	Aerial Photo Changes Missed by RBV	Total Aerial Photo Change Polygons	Percent Aerial Photo Changes Identified by RBV
		1	2	3	4	5	6	7					
Aerial Photograph	1	32						20		52	58	110	47%
	2		47	1						48	43	91	53%
	3			1						1	8	9	11%
	4									-	1	1	0%
	5							2		2	11	13	15%
	6						2			2	24	26	8%
	7	17						62		79	42	121	65%
										184	187	371	50%
Additional Changes Identified by RBV		53	12	4	-	-	-	88	157				
Total Changes Identified by RBV		102	59	6	-	-	2	172	341				
Percent Additional Changes to Total RBV Changes in Category		52%	20%	67%	-	-	0%	51%	46%				

Land Use and Land Cover

Change

Polygons

Table 6.

Table 7.--Aerial photograph and RBV image change acreage matrix

Level I Land Use and Land Cover Class		RBV								Aerial Photo Change Areas Identified by RBV	Aerial Photo Change Areas Missed by RBV	Total Aerial Photo Change Areas	Percent Aerial Photo Change Areas Identified by RBV
		1	2	3	4	5	6	7					
Aerial Photograph	1	1235						1264		2499	2749	5248	48%
	2		13578	1588						15136	8667	23803	64%
	3			404						404	2315	2719	15%
	4									-	49	49	0%
	5							88		88	321	409	22%
	6						3088			3088	2765	5853	53%
	7	1482						10507		11989	2868	14857	81%
										33204	19734	52938	63%
Additional Change Area Identified by RBV		3697	1410	2325	-	-	2896	7501	17829				
Total Change Area Identified by RBV		6414	14988	4287	-	-	5984	19360	51033				
Percent Additional Change Area to Total RBV Change Area in Category		58%	9%	54%	-	-	48%	39%	35%				

Land Use and Land Cover

Change

Areas

(Acres)

Table 7.

A. Urban or Built-Up Land

About 47 percent of the polygons mapped from the aerial photographs as changes to the Urban or Built-Up class were identified on the RBV data. There was relatively good correspondence in both the size distribution and shapes of change polygons delineated from the aerial photographs for the Urban or Built-Up class and those polygons that were identified as changes on the RBV images (table 8).

Table 8.--Change polygons interpreted from aerial photographs also identified on RBV images, by size and category

LEVEL 1 CLASS / POLYGON SIZE	(1) Urban or Built-Up Land	(2) Agricultural Land	(3) Rangeland	(4) Forest Land	(5) Water	(6) Wetland	(7) Barren Land		TOTAL	% OF TOTAL BY SIZE
< 40 ACRES	31	-	-	-	1	-	34		66	36%
40-80 ACRES	14	12	-	-	1	-	16		43	23%
> 80 ACRES	7	36	1	-	-	2	29		75	41%
TOTAL	52	48	1	-	2	2	79		184	
% OF TOTAL BY CATEGORY	28%	26%	1%	-	1%	1%	43%			

About 62 percent of the change polygons mapped were correctly identified to the Levels I and II categories. The most success was achieved in identifying changes from Agricultural Land (category 21) and Rangeland (category 31) to the Urban or Built-Up class. The remaining 38 percent of the polygons changing to this class were correctly picked up from the RBV imagery, but were misclassified as Transitional Areas (category 76). In terms of area, the extent of change to Urban or Built-Up Land was also underestimated, with only 48 percent of the actual change area being identified from the RBV images.

The remaining 53 and 52 percent of the polygons and area, respectively, that changed to the Urban or Built-Up class were not picked up as changes from the RBV image. A look at the data reveals two observations. One, most of the missed changes were very small polygons, with many of them well below 40 acres in size (table 9).

Two, the majority of the missed changes involved conversions of land from Transitional Areas (category 76) to Urban or Built-Up Land (categories 11-16). On the RBV image the spectral response for land in transition (usually land under construction) and that of most Urban or Built-Up categories is very similar, that is, highly reflective, owing to the absence of established vegetative cover. As a result many small polygon occurrences of these changes appeared merely as bright spots on the image.

Table 9.--Change polygons interpreted from aerial photographs not identified on RBV images, by size and category

LEVEL 1 CLASS POLYGON SIZE	(1) Urban or Built-Up Land	(2) Agricultural Land	(3) Rangeland	(4) Forest Land	(5) Water	(6) Wetland	(7) Barren Land		TOTAL	% OF TOTAL BY SIZE
< 40 ACRES	38	-	-	-	8	-	27		73	39%
40-80 ACRES	14	24	1	1	3	8	6		57	30%
> 80 ACRES	6	19	7	-	-	16	9		57	30%
TOTAL	58	43	8	1	11	24	42		187	
% OF TOTAL BY CATEGORY										

Because they were not large enough to permit the discernment of actual developmental patterns, given the resolution level of the RBV data, they were therefore assumed to be unchanged and left in the Transitional Areas category. A case in point is the completion of portions of the BeeLine Expressway. In 1972 the roadway was present, but some sections were unpaved. These unpaved sections were therefore categorized on the land use and land cover map as transitional land (category 76). By 1977 some of these sections had been paved over and opened to traffic, now appropriately placing them in Urban or Built-Up Land, category 14. Since they appear no different spectrally on the RBV image from the unpaved portions, they were left in Transitional Areas, category 76 (fig. 6).

In addition to valid instances of change to the Urban or Built-Up class, a large number of unconfirmed changes were interpreted from the RBV imagery (table 6). About as many polygons of additional and possibly false change were identified as were valid changes. These additional changes were responsible for an overall overestimate in the RBV data in the amount of land going into the Urban or Built-Up class. Approximately 52 percent of the polygons interpreted from the RBV imagery as Urban or Built-Up Land were not identified as any type of change in the aerial photo data set. Over half of these unconfirmed change polygons involved changes that were below 40 acres in size (table 10).

Again the highly reflective return from these small-area polygons on the RBV image (together with inferences drawn from their spatial locations and surrounding cover types) gave them the appearance of a change to an Urban or Built-Up Land use or cover category. Unfortunately, in the absence of supplementary source materials confirming these as legitimate changes, it remains unknown how many of these small-area spectral differences represent legitimate categorical changes that occurred after the date of the aerial photography, or to what extent they represent temporal spectral differences that occurred within a single land use or land cover category.

Table 10.--Additional change polygons interpreted from RBV image, by size and category

LEVEL 1 CLASS / POLYGON SIZE	(1) Urban or Built-Up Land	(2) Agricultural Land	(3) Rangeland	(4) Forest Land	(5) Water	(6) Wetland	(7) Barren Land		TOTAL	% OF TOTAL BY SIZE
< 40 ACRES	31	-	-	-	-	-	49		80	51%
40-80 ACRES	13	8	1	-	-	-	19		41	26%
> 80 ACRES	9	4	3	-	-	-	20		36	23%
TOTAL	53	12	4	-	-	-	88		157	
% OF TOTAL BY CATEGORY	16%	4%	1%	-	-	-	26%			

B. Agricultural Land, Rangeland, and Forest Land

Slightly over half of the polygons that went into new agricultural activity during this period were identified on the RBV imagery. These polygons accounted for 64 percent of the total acreage involved in change to the Agricultural Land class. Changes to this class were successfully identified at the Level II categorization in 90 percent of the cases. Unlike the Urban or Built-Up class, total acreage in this category was significantly underestimated. Again, a considerable number of change polygons to Agricultural Land were simply not identified from the RBV data. The missed polygons involved mostly small to medium parcels of land between 40 and 80 acres that changed from palmetto prairie grassland (category 31) to cropland and pasture (category 21)--a category change that does not always yield a visually discernible spectral change. Additionally, of the change polygons correctly interpreted from the RBV imagery, most tended to be delineated smaller than actually occurred. Far fewer false change polygons were identified for this category than for the Urban or Built-Up class.

Of the nine polygon changes to the Rangeland category mapped from the aerial photographs, only one was identified from the RBV imagery. Many of the changes involved fairly large parcels of land (parcels larger than 80 acres), so polygon size was not a factor in their omission by the RBV. Most changes came from cropland and pasture land that had been abandoned and left to revert to natural vegetative cover. Again, the difficulty in separating palmetto prairie from fallow or abandoned cropland and pasture was probably the reason for not identifying more of the changes that occurred between these two land cover categories.

Aerial Photograph

Figure 6.--Comparison of portions of aerial photograph and RBV image at 1:100,000 change compilation scale. Bee-Line Expressway is shown going east-west at center of images. Image overlays are portions of 1977 and 1978 aerial photograph and RBV derived change polygon maps, respectively.

RBV Image

Only one 49-acre parcel of land was interpreted from the aerial photographs as a change to the Forest Land category. This polygon was not detected as a change on the RBV imagery, nor were any additional change polygons identified for this category.

C. Water and Wetland

Poor results were achieved in using the RBV data to identify polygons that changed to the Water and Wetland classes. Only 2 of the 13 polygons that changed to the Reservoirs category were identified from the RBV, and in both cases, they were misclassified as changes to Transitional Areas, category 76.

In the Wetland category, only 2 of the 26 change polygons were identified on the RBV images. While this constitutes only 8 percent of the total polygon changes to this class, it represents a 53 percent share of the total acreage that changed to Wetland in this time period. No additional change polygons were identified in either the Level I Water or Wetland classes.

D. Barren Land

The Barren Land class in this area consists of two categories--Strip Mines, Quarries, and Gravel Pits (category 75) and Transitional Areas (category 76). The dynamic nature of this area is attested to by the amount of change going both into and out of the Transitional Areas category. From the aerial photographs, 43 polygons were identified as going from transitional land during the 1972-1977 period to other categories of land use and land cover, chiefly into residential land. At the same time, 121 polygons were identified as going into additional transitional land, primarily coming from the Agricultural Land and Rangeland categories. Monitoring of such transitional areas may provide clues as to the level and direction of continued future growth and development likely to occur within the area. The acreage statistics tell a similar story. Transitional Areas represent the single largest acreage change in terms of land gained during this time period, comprising about 28 percent of all acreage conversions.

For the combined Barren Land categories, 79 polygons, or 65 percent of the polygons identified on the aerial photographs, were also identified as changes on the RBV images. This constitutes 81 percent of all the land acreage identified on the aerial photographs as change to the Barren Land class. Thus, the RBV was used successfully in capturing a major portion of the acreage changes in this class. Over two-thirds of these changes were correctly interpreted at the Level II categorization. A total of 42 polygons went undetected as any type of change on the RBV. Of these missed change polygons, about two-thirds were under 40 acres.

An additional 22 change polygons that were mapped from the aerial photographs as changes to other categories were mislabeled on the RBV image change map as changes to the Barren Land class. As mentioned previously, there was some difficulty in using the RBV image to separate those changes going into Transitional Areas from those changes to the Urban or Built-Up class. The data show that a preponderance of the changes misidentified as going into the Transitional Areas category were in fact changes to Urban or Built-Up categories. This points up a general tendancy to lump changes under the Transitional Area category when a change was detected between the land use map and the RBV image, but the type of change could not be determined.

As with the Urban or Built-Up Land class, a large number of change polygons to the Transitional Areas category, that did not exist as any type of change on the aerial photograph change map, were identified from the RBV data. These polygons comprised about 39 percent of the total acreage shown as change to this category on the RBV image change map. Over half of these additional unconfirmed changes involved polygons of below 40 acres. As with the Urban or Built-Up Land class, it is not known how many of these changes are false changes (that is, they identify within-category spectral changes) picked up on the RBV data, or to what extent they represent additional valid sequential changes to the Barren Land class that took place since the time of the aerial photography.

VI. DISCUSSION

Map inspection and change mapping using 1978 RBV data were completed in about one-sixth of the time and at a fraction of the cost (including source acquisition and processing) required to inspect and map changes from the aerial photographs (table 11). In this quick-look inspection, the RBV image identified 50 percent and 63 percent of the land use and land cover change polygons and acreage, respectively, that were identified as changes between the 1972 land use map and the 1977 aerial photographs. Thus the RBV images were used successfully to detect a majority of the change occurrences.

Overall, the RBV imagery was considered more accurate in detecting the fact that a change had occurred, than in identifying what type of change it was. Generally, the inability to identify specific types of change from the RBV imagery, particularly among certain categories such as Urban or Built-Up Land, is considered a drawback to the full use of RBV imagery in the map inspection process, since the decision to update a map often takes into account the types of change that have occurred, not only the amounts. Reasonable success was achieved, however, in using the RBV imagery to identify large acreage changes among certain broad land use and land cover classes, namely Rangeland to Agricultural Land, and Rangeland, Agricultural Land, and Forest Land to Barren Land and Urban or Built-Up Land. It was particularly effective in detecting both the polygons and acreages that converted to Transitional Areas during this time, one of the

Table 11.--Time/cost comparison for map inspection using aerial photographs and RBV images

	PHASE	AERIAL PHOTOGRAPHS ($)	RBV IMAGES ($)
1.	REMOTE SENSING SOURCE ACQUISITION (25, 1:80,000 B-W AERIAL PHOTOGRAPHS) (2, 1:500,000 B-W RBV IMAGES)	250	20
2.	PHOTOGRAPHIC PROCESSING (SCALED TRANSPARENCIES AT 1:100,000)	225	103
3.	PREPARATION OF MAP COMPILATION MATERIALS (1:250,000 → 1:100,000)	42	42
4.	MAP INSPECTION/CHANGE MAPPING (20.25 HRS - AERIAL PHOTOGRAPHS) (3.25 HRS - RBV IMAGES)	218	35
	TOTAL COST =	735	200

changes that is considered fairly important to detect and identify. The RBV imagery was not useful, however, for identifying nearly all changes to both the Level I Water and Wetland classes, except for a very few large acreage changes to the latter. The spectral channel of the single RBV band was the primary contributing factor in the inability to identify changes that occurred in both the Water and Wetland classes. Poor results were also achieved in identifying many of the changes that went from Transitional Areas to Urban or Built-Up Land. Resolution limitations of the RBV sensor precluded accurate identification of many small polygons of change involving these two classes. This is particularly unfortunate because many of the changes considered important from a map updating standpoint often involve this very type of land conversion.

Although the change data derived from the RBV imagery resulted in an underestimate of both the actual number and amount of true polygon changes that occurred in all Level I classes, many additional instances of unconfirmed and possibly false change were identified, particularly in the Barren Land and Urban or Built-Up classes, that did not appear on the aerial photographs. These changes, when combined with the identified true changes, resulted in an overall overestimate of the change that occurred in these two classes. Total additional unconfirmed polygon and acreage changes for all classes amounted to 46 percent and 35 percent, respectively, of all the changes mapped from the RBV data.

The number of additional changes mapped from the RBV images that did not appear on the aerial photographs is certainly cause for concern regarding the reliable use of RBV data for land use map inspection in this area.

The one-year difference in coverage between the aerial photographs and RBV images can perhaps explain some of these additional changes (that is, they are real changes that occurred during the one-year interval). However, the nature and level of past changes within the study area, together with the known resolution/interpretation limitations of the RBV sensor, suggest that a larger percentage of additional changes (particularly within the 10-40 acre size range) are bogus change polygons. It is considered coincidental that in this study the amount of true change identified using the RBV images, together with the additional changes detected, resulted in a better than 90 percent correct estimate of the actual change that occurred.

VII. CONCLUSIONS

The results of the study showed that the RBV imagery was useful in identifying a major portion of the changes that occurred in the study area. In the absence of better alternative source materials, the RBV data can be recommended, albeit advisedly, for use in providing a rough estimate of change in some environments. It is suggested that in some areas (for example, western/southwestern U.S.) RBV imagery can be used with acceptable reliability for estimating certain gross category changes (such as were described in this study) as well as for identifying certain land use and land cover feature data. However, there exist two main drawbacks to the use of RBV imagery that preclude its application in the across-the-board land use map inspection process. These are: (1) The inability to derive more consistent and specific identification of the types of changes, particularly to certain critical land use and land cover categories such as Urban or Built-Up Land, Water, and Wetland, and (2) the amount of additional and possibly false changes detected from the RBV imagery which may result in inaccurate estimates concerning the overall type and level of change that has occurred and, hence, the need for map updating. These drawbacks are linked primarily to inherent limitations in both the spectral domain (only a single channel of panchromatic spectral information is available) and in spatial (ground) resolution of the RBV image product. Wider application of RBV imagery in the map inspection process may be possible, however, by altering the map inspection/change detection parameters used in this study. Raising the minimum change polygon size, for example, from 10 acres to 40 acres for urban, water, and transitional categories and from 40 to 80 acres for most rural categories would increase detection accuracy and eliminate much of the additional false-change data, or "noise," picked up from the RBV imagery--most of which was shown in the statistics to occur below these levels. Although this larger minimum size would result in a lower sensitivity to real change, the corresponding reduction in the amount of "noise" would thereby increase the overall reliability of the data that were mapped. These data might then serve as input to models or guidelines to estimate the total amount of change and to aid map-revision decisions.

VIII. RECOMMENDATIONS

While the positional accuracy of the RBV data may make it an appealing source for certain base mapping applications, its limited spectral information and spatial definition make it less than fully satisfactory for extracting the kinds and levels of categorical thematic data presently required in the land use and land cover map inspection and revision process. This study has nonetheless helped to further sharpen and refine our requirements concerning the attributes sought in a remotely sensed image source that can be used in map inspection and in thematic land cover mapping. Encouragingly, the recently acquired Landsat 4 Thematic Mapper (TM) imagery overcomes both the spectral and, in a sense, the spatial shortcomings of the RBV data. As such, it will likely provide a better alternative to Landsat 3 RBV imagery for accomplishing some of these tasks. It is recommended that further investigation be undertaken to evaluate TM imagery for use in inspecting/revising land use and land cover maps.

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