AUTOMATIC CATEGORIZATION OF LAND-WATER COVER TYPES OF THE GREEN SWAMP, FLORIDA, USING SKYLAB MULTISPECTRAL SCANNER (S-192) DATA

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ABSTRACT

The Green Swamp, the fountainhead of five major rivers, a broad flat wetland comprising 2,253 square kilometers (870 square miles) of the central highlands of the Florida peninsula was chosen as a Skylab Earth Resources Experiment Package (EREP) test site. This report summarizes the techniques used and the results achieved in the successful application of Skylab Multispectral Scanner (EREP S-192) high-density digital tape data for the automatic categorizing and mapping of land-water cover types in the Green Swamp. Data was provided from NASA Skylab pass number 10 on 13 June 1973. Significant results achieved included the automatic mapping of a nine-category and a three-category land-water cover map of the Green Swamp. The land-water cover map was used to make interpretations of a hydro-logic condition in the Green Swamp. This type of use marks a significant breakthrough in the processing and utilization of EREP S-192 data.

INTRODUCTION

There are encroaching pressures of urban and industrial development in the environmentally sensitive area of the Green Swamp. This area, essential to water resources and the ecological stability of major drainage systems, is a complex of swamps, creeks, rivers, lakes, prairies, pine flatwoods, and sand hills. The water, land, and vegetation are undergoing rapid changes caused by logging, reforestation, alteration of natural drainage by canalization and ponding, burning and clearing for sod farming, improved pasture, citrus

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farming, and urban and industrial development. There is an urgent need for environmental appraisals in this area to develop a rational basis for planning and controlled development. Conventional techniques, based primarily on the use of photography and field studies, have not been entirely satisfactory for this timely appraisal because of the large size and complexity of the area. In response to these deficiencies, this study objective is to use the Green Swamp and its environs as a laboratory to evaluate Skylab multispectral scanner data for automatic mapping of the needed environmental categories for interpretation and assessments.* A timely use of remote sensing data resulting from this study has already been demonstrated by the Green Swamp settlement (Ref 1).

LOCATION AND DESCRIPTION OF THE GREEN SWAMP TEST SITE

The Green Swamp is in the central part of the Florida Peninsula, as shown in Figure 1. The swamp is an extensive area of swampy flatlands and sandy ridges. The elevation of the land surface varies from about 60 meters (200 feet) above mean sea level in the eastern part to about 23 meters (75 feet) in the western part. Five major drainage systems originate in or near the Green Swamp area, as shown in Figure 2. The Withlacoochee River drains two-thirds of the area. The little Withlacoocnee River, the headwaters of the Oklawaha River, the Hillsborough River, the headwaters of the Kissimee River, and the headwaters of the Peace River drain the remaining area.

The Green Swamp was described by Pride (Ref 2) to include the southern parts of Lake and Sumpter Counties, the northern part of Polk County, and the eastern parts of Pasco and Hernando Counties, as shown in Figure 2. The eastern boundary is U.S. Highway 27, from Clermont south-southeastward to Haines City. The southern boundaries generally coincide with divides separating drainage northward to the Withlacoochee River basin from drainage southward to the Peace and Hillsborough River basins. The western

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boundary is U.S. Highway 301, northward from Dade City to St. Catherine. The northern boundary extends from St. Catherine eastward to, and along, State Highway 50 eastward to Clermont. The boundaries described enclose an area of approximately 2,253 square kilometers (870 square miles).

The Green Swamp is not a continuous expanse of swamp but a composite of many swamps that are distributed fairly uniformly within the area. Interspersed among the swamps are low ridges, hills, and flatlands. Several large and many small lakes of sinkhole origin rim the southeastern and northeastern parts of the area. Prominent topographic features affecting the drainage of the eastern part of the area are the alternating low ridges and swales. These features trend generally north-northwestward and are parallel to the major axis of the Florida peninsula. In the western part of the area, the main land-surface features are large swamps, flatlands, and rolling hills. Most of the swamps support good growths of cypress trees. In the flatlands and uplands, pine and scrub oak trees grow abundantly. The largest continuous expanse of swampland lies within the valley of the Withlacoochee River.

The Green Swamp area has a warm humid climate. The average summer temperature is 27°C (81°F) and the average winter temperature is 16°C (61°F). About 75% of the 135 centimeters (53 inches) of rainfall per year that reaches the land surface in the Green Swamp area is lost to evapotranspiration. The remaining 25% recharges the underlying aquifers and replenishes swamps, streams, lakes and ponds. Because of the gradual slope of the land and the dense vegetative cover, the river basin systems drain surface waters from the Green Swamp area very slowly. As a result of this slow drainage process, surface waters remain within the area for extended periods following the rainy season.

The surface is mantled with a varying thickness of sand and clay which comprises the nonartesian aquifer. Underlying this mantle is an intermediate unit of sandy clays and interbedded limestone layers that, where present, may form a semi-confining layer above porous marine limestones that underlie and drain the subsurface.

The vegetative associations and soil types in the Green Swamp area can best be organized into three major categories; wetlands, flatwoods, and uplands.

Wetland plants and soils occur in low wet areas which may be inundated for varying portions of the year and, in the past, have rarely, if ever, been burned by forest fires. The soils in these areas are usually poorly drained and high in organic matter and often have clayey subsoils. The wetland vegetative associations within the Green Swamp area are river and creek floodplains, cypress heads, bayheads, sloughs, and freshwater marshes.

The flatwoods vegetative associations occur on low nearly-level areas with sandy strongly-acid soils and a high water table. Periodic inundation and saturation during the wet season and the occurrence of fire during certain dry seasons have molded vegetative associations which are adapted to these stresses. These associations, known as pine flatwoods, have three species of pine as the predominant overstory; longleaf pine, slash pine, and pond pine. The agricultural modifications range in intensity from rangeland, where much of the pine overstory and palmetto understory remain, to improved pasture.

The majority of the upland soils are well-drained to excessively-drained deep sandy soils that are low in organic matter, strongly acid, and low in fertility. The natural vegetative associations found on these soils are the sandhill communities, with longleaf pine and various scrub oak species, and hammocks, with live oak and laurel oak. Much of these areas in the eastern and southeastern portions of the Green Swamp have been developed as citrus groves.

Because of the abundance of natural food, water, and shelter, a wide variety of wildlife populations are found within the Green Swamp. The swamp also serves as a wintering ground and migratory stop-over for many birds that breed elsewhere in North America. Endangered or threatened species within the area include the American alligator, bald eagle, osprey, and Florida panther.

PROBLEM

The Green Swamp area is undergoing rapid change caused by logging, reforestation; alteration of natural drainage by canalization and ponding; burning and clearing for sod farming, improved pasture, citrus farming, and urban and industrial development. Citrus production and related industrial processing occurs in adjacent Polk County, the sixth largest producer of citrus products in the world. There are some sand-mining operations scattered throughout the Green Swamp. Phosphate mining in nearby Polk County produces 24 percent of the world's phosphate supply.

The pressure for further development in the Green Swamp is mounting daily as a result of its location between three of the fastest-growing areas in the state. The 1980 population estimate for the Orlando tri-county area is 740,100 and for the Tampa-Hillsborough area is 629,500, a population increase of 63 to 28 percent, respectively, for the ten-year period from 1970 to 1980.

The establishment of the Disneyworld complex, located on 111 square kilometers (27,443 acres) about 8 kilometers (five miles) east of the Green Swamp, has had the greatest impact on the alteration of land use, economy, and population growth in central Florida. Since 1967, there has been more than 300 square kilometers (75,000 acres) of agriculture and open land purchased for development in the Disney area between Orlando and the Green Swamp. These developments are primarily tourist and residential-oriented. Major tourists attractions recently completed include Sea World and Circus World. The largest residential development underway is Poinciana, a 194 square kilometer (48,000 acre) development with a projected population of 250,000.

National, state, and local government agencies, as well as conservationists, environmentalists, and private citizens, are becoming increasingly alarmed over the potential loss of the Green Swamp to urbanization. It is now realized that improper planning and construction of new industrial and residential areas in the Green Swamp can have a disastrous effect on this environmentally-sensitive area. In this area, there is an urgent need for environmental appraisals to develop a rational basis for planning and controlled development. The timely acquisition and production of maps and data needed for this appraisal; based on the use of conventional aerial photography, photometric mapmaking, and field studies; has not been satisfactory because of the large size and complexity of the Green Swamp.

OBJECTIVES

In response to the need for a timely and economical means of acquiring the information needed for the environmental appraisal of the Green Swamp, this investigation is to evaluate the suitability of using Skylab S-192 data as a basis for acquiring the needed environmental information. To accomplish this program objective, the Green Swamp was used as a laboratory, representative of many similar environmentally sensitive areas throughout the world. Intermediate goals that were accomplished in achieving this objective included:

- Developing techniques for processing and analyzing Skylab S-192 high-density digital tapes.
- Evaluating relative spectral contributions of S-192 bands and comparing with ERTS band to delineate land-water cover categories in the Green Swamp.
- Evaluating application of automatically-categorized imagery for use in the environmental analysis of the Green Swamp.

Achieving these objectives would not only contribute to the much-needed environmental survey of the Green Swamp, but would provide the tools and techniques needed to perform similar surveys worldwide.

DATA PROCESSING

The objectives of this investigation were achieved through development and application of computer processing techniques for automatic categorization of land-water cover types from S-192 data.

Figure 3 shows the elements of the Bendix Earth Resources Data Center used to transform the high density digital tapes (HDDT) into computer compatible tapes (CCTs) and image products. The elements of this center include a Digital Equipment Corporation PDP-11/15 computer with 32 K-words of core memory, two 1.5 M-word disk packs, two nine-track 800-bit-per-inch tape transports, a high-speed processor, a linc printer, a card reader, and the teletypewriter unit. Other units are the color moving-window computer-refreshed display, operator console, a glow-modulator film recorder, and a Gerber plotter.

The steps used in the processing and analysis of the S-192 data are shown in Figure 4. The steps, as noted in the figure, are grouped into three phases; pre-processing, analysis, and processing. The pre-processing phase includes those works necessary to transform the S-192 HDDT into a noise-filtered linearized tape, recorded in a standard computer-tape format. This phase also includes the generation of single-band and false-color imagery to support the analysis of S-192 noise and the location and selection of land-water category training areas.

The analysis phase includes locating training areas representative of each land-water category and the development and evaluation of the spectral characteristics and computer processing coefficients for each category. This phase is repeated until an acceptable categorization accuracy is achieved. The output of the analysis phase is the processing coefficients which are then used by the computer to generate nine and three-category color-coded land-water cover maps of the test site.

The implementation of the processing phases and the results achieved are briefly summarized in the following paragraphs.

Pre-Processing Phase

Generate raw data. The 13 bands of S-192 data were provided by NASA as a bi-phase modulated digital signal on fourteen-track magnetic tape with a 10,000 bit-per-inch (bpi) packing density. Two bands are multiplexed onto one track of the tape.

The first processing objectives were to locate the HDDT coordinates of the data acquired on the Green Swamp test site and to transform this data to a standard CCT format. Coordinate location was established by viewing the HDDT data on the TV monitor, as shown in Figure 3, and by generating and analyzing 70-mm film of the taped data.

This imagery, although badly distorted geometrically because of the conical scan pattern, permitted the start and stop scan lines bracketing the test site to be determined. The desired S-192 data were then transformed from the HDDT to a standard CCT format having nine tracks with 800-bpi records in ASCII code.

Generate linearized CCT. - Imagery produced from this raw data CCT and the HDDT contains the conical-line scan-pattern used by the S-192. During the early phases of the study, an attempt was made to locate known targets, using the TV monitor and gray-scale printouts where the data contained the conical pattern. Identification of most targets was found to be extremely difficult when the pattern was present. To improve the geometric fidelity of the S-192 data, a CCT whose data is "linearized" was generated from the raw data tape. On this tape, the data were recorded as if the S-192 scans were normal to the direction of spacecraft motion. For this approach, a straight line, normal to the spacecraft heading, was assumed. A nearest-neighbor processing algorithm was used to locate and record on the linearized CCT the picture elements or pixels that best correspond to this line. A total of 265 conical scan lines contributed pixels to the 916-pixel normal or linearized line. Each pixel on the linearized line represents a ground coverage of approximately 79 by 79 meters (260 by 260 ft or 1.676 acres). The line length or swath width covers 72.4 kilometers (39.1 n. miles). Although the data resulting from this processing step are geometrically very good, some residual distortions remain, such as one resulting from earth rotation effects. To date, the removal of residual errors from the data has not been considered by this study.

Generate linearized imagery. - Imagery was produced from the linearized CCTs to support studies of noise in the S-192 bands and to aid in locating known ground truth areas. The production of film imagery at this intermediate stage was not an essential task, but a supportive one, since all bands and combinations of bands could also be viewed on the color TV monitor.

Figure 5 shows a 72.4 by 100 kilometer (39.1 by 54.0 n. mile) area of Florida in each of the 13 S-192 bands. Atmospheric parameters and noise factors degrade the quality of the imagery to some degree. A study of these factors has revealed the following information:

Atmospheric effects: In Band 1, low atmospheric transmission and backscatter of the sunlight from the atmosphere (path radiance) reduce the contrast of the scene.

Detector noise: A very low frequency (f) 1/f noise is very apparent in thermal Band 13.

Cooler piston noise: This noise is most noticeable in Band 5. The noise has a fundamental frequency in the range of 16 to 18 Hz (a period of about six scan lines).

Power inverter noise: This noise produces a herringbone pattern, has a fundamental frequency of 22.413 kHz, and is most noticeable in Band 4. The noise is also observed in Bands 1, 2, 3, 5, 7, and 8.

Sync drop-outs: This noise is most noted near the center of the image in Bands 11 and 12. Poor signal-to-noise ratio on the HDDT sync signal causes CCT generation to skip the video areas. This is most easily observed in Bands 11 and 12.

Fast Fourier transform (FFT) techniques are being used to determine exact noise frequencies. Digital simulation of notch filters and other techniques are being developed and applied to data to filter some noise frequencies.

Figure 6 shows a side-by-side comparison of false color composite images using three S-192 bands. The image on the right side in the figure was produced using S-192 Bands 4, 5, and 8. As noted in Table I, these bands correspond approximately to LANDSAT MSS Bands 4, 5, and 7. The false color image on the left side of the figure was generated from S-192 Bands 3, 6, and 11. It is significant to note that this spectral combination produced imagery of the test site which was far superior to that available with the ERTS bands. Band 11, as will be noted later, contributed more than any other band to the automatic categorization of the Green Swamp land-water cover types.

Analysis

Land-water cover types that represent environment categories for the interpretation and appraisal of environmental conditions in the Green Swamp were established on the basis of combining field studies with analysis of S-192 data. The initial objective was to automate the categorization of wetland, pine flatwood, and uplands with a categorization accuracy which would, as a minimum, satisfy Anderson's first criterion (Ref 3) of 90 percent or more.

Locate training areas. - The first task was to locate and designate to the computer a number of S-192 picture elements or pixels that best typified the land-water categories of interest, the "training areas". These areas of known characteristics were established from aerial photographs and ground survey data and were located on the S-192 CCTs by viewing the taped data on the TV monitor. The coordinates of the training areas were designated to the computer by placing a rectangular cursor over the desired area and assigning a training area designation, category code, and color code. Several training areas were picked for each category. The color code is used in later playback of the tapes when the computer-categorized data is displayed in the designated colors.

Develop processing coefficients. - The S-192 spectral measurements within the training area boundaries were edited by the computer from the CCT and processed to obtain a numerical descriptor to represent the "spectral characteristics" (computer processing coefficients) of each land-water category. The descriptors included the mean signal and standard deviation for each S-192 band and the covariance matrix taken above the origin. These descriptors were then used to generate a set of "canonical coefficients". This program, previously reported by Dye (Ref 4), derives, for each category, a set of canonical coefficients. In the automatic categorization processing, these coefficients are used by the computer to form a linear combination of the S-192 measurements to produce a "canonical variable" whose amplitude is associated with the probability of the unknown measurement being from the target sought.

In categorization processing, the probability of an S-192 pixel arising from each one of the different land-water categories of interest is computed for each pixel and a decision, based on these computations, is reached. If all probabilities are below a threshold level specified by the operator, the computer is permitted to decide that the category viewed is unknown, "uncategorized".

Evaluate selection of training areas and processing coefficients. - Before producing categorized data on a large amount of S-192 data, a number of tests were applied to evaluate the computer's capability of performing the desired interpretation. The tests include generating categorization accuracy tables similar to those shown in Table II and viewing the processed results on the TV monitor.

Selection of training areas, generation of accuracy tables, and evaluation of processing results using computer printouts and the TV monitor were iterative operations. To obtain accurate categorization of wetlands, pine flatwoods, and uplands, nine subcategories with corresponding training areas were established and then merged in the computer to define the three major categories. As noted in the accuracy table, Table II, the wetland category is composed of subcategories; cypress, water, fresh water marsh, bayheads, and mixed wetlands. The pine flatwoods category is composed of improved pasture, mixed palmetto, and pine. The upland category is composed of citrus. A number of training areas were picked for each subcategory to obtain a representative spectral representation for the composite.

The computer categorization accuracy achieved on the subcategories were established by analysis of the accuracy tables and by viewing the computer decisions which were displayed as color codes on the TV monitor. Table II indicates that all categories were correctly categorized over 86 percent of the time. It is also noted in the table that a small percentage of wetlands will be categorized as pine flatwoods but not visa versa. It is also observed that there is no confusion between pine flatwoods and uplands. The computer decisions were also displayed on the TV monitor, verified with ground-truth data, and found to be truly representative of land-cover conditions in the Green Swamp area.

Good ground truth was found to be essential for locating training areas and verifying categorization accuracy. We used LANDSAT-1 imagery, Skylab and U-2 photography, imagery from light aircraft and helicopters, and data from field-trips by jeep. The best ground truth data were found to be photographically acquired by Skylab, U-2, and helicopter surveys.

Band Contribution Factors. - One of the by-products of the canonical analysis program (Ref 5) is a figure of merit that specifies the relative importance of each S-192 band, i. e., its contribution, to separating each category from all other categories. Figure 7 shows, graphically, the importance of each band for all land-water categories considered in the Green Swamp study. Band 11 contributed most in categorizing all cover types in the Green Swamp except pine. In categorizing pine, Band 8 was most significant. Band 8 was the second most important band, when considered over all categories, with Bands 13 and 7 sharing the role of third most important band.

Processing

When satisfaction with the categorization accuracy was achieved on the nine subcategories, the processing coefficients were placed into the computer disk file and used to process that portion of the CCT covering the Green Swamp, approximately 1,562 scan lines. This first step in the categorization processing resulted in new or categorized CCTs, where each S-192 pixel is represented by a code designating one of the nine subcategories. This tape was later used to generate three and nine-category imagery, and as a medium to store the interpreted information on the study areas. Computer-generated area measurement tables were also edited from this tape to determine the areal extent of each category.

Area Measurement Table - The area measurement table, Table III, is the first real data product useful to land-use planning. This table provides a quantitative measure of the amount of land that falls within a particular category in terms of square kilometers, acres, and percent of the total area processed.

A review of the area printout shows that the wetlands category covers 29.76 percent (2,398.2 square kilometers) of the Green Swamp test area. The remainder of the area is approximately equally divided between pine flatwoods and uplands. The single most dominant subcategories are citrus (2,158.9 square kilometers), mixed palmetto (1,824.6 square kilometers), and cypress heads (1,318.6 square kilometers).

Obtaining similar area coverage tables from additional overflights on the test area would permit the environmental changes of the land to be determined.

Categorized Imagery - The categorized tape was also used to generate three-category and nine-category color-coded imagery of the Green Swamp, in which a color denotes a specific land-water category.

The categories and corresponding colors used in the nine-category imagery follows. The code following the color relates the category to those defined by USGS Circular 671 (Ref 6).

WETLANDS 05, 06

- BLUE, 05-01, 02, 03. Water, lakes, ponds, and streams.
- LIGHT BLUE, 06-01, 02. Fresh water marshes and bogs.
- TURQUOISE, 06-01, 02. Bayheads, marshes, and bogs.
- LIGHT GREEN, 06-01; 05-01. Cypress heads and sloughs.
- PURPLE, 06-01. Mixed wetlands, bayheads, bogs, and creek flood plains with mixed hardwoods and palms.

PINE FLATWOODS 03, 02

- GREEN, 03-01, 02; 02-01. Mixed palmetto, and natural rangeland.
- DARK GREEN, 02-01; 03-01, 02. Improved pasture, managed rangeland, and sod farms.
- YELLOW, 04-02. Pine, managed and reforested.

UPLANDS 02, 07, 01, (02, 03, 05, 06)

- ORANGE, 02-01, 02; 07-03; 01-01, 04, 05. Citrus, sandhills, extractive earth (gravel pits, construction sites, and other areas of disturbed or bare earth) residential, and transportation.

UNCLASSIFIED

- BLACK. This category includes all targets that do not exceed the probability thresholds established by the investigator.

Figure 8 shows the nine-category image together with ground-truth photographs of typical training areas representative of the wetlands, pine flatwood, and uplands. The central portion of the Green Swamp is observed in the categorized image to be comprised mainly by the colors blue, light blue, turquoise, light green, purple, green, and dark green, representing the wetlands and pine flatwood categories. The borders are predominantly orange. To the north and west, the north-northwestern trending ridges are observed as strips of orange, alternating with blues and greens to the east.

From analysis of the categorized imagery, the Green Swamp is a wetlands and pine flatwood basin, bordered at the northwest and west by uplands. The southwestern boundary is mainly a mixture of uplands and pine flatwoods that grades into a series of alternating north-northwestward-trending upland ridges and pine flatwoods, and wetland swales to the east that are disected by river drainage valleys of the Withlacoochee and Hillsborough Rivers.

To produce the three-category image of wetlands, pine flatwoods, and uplands, as shown in Figure 9, the subcategories are merged in the computer and imaged in the three colors; blue denoting wetlands, green denoting pine flatwoods, and red denoting uplands. Black, in the nine and the three-category image, represents uncategorized land cover.

The categories and corresponding colors used in the three category imagery follow:

WETLANDS

<u>BLUE</u>. Composite of water, fresh water marshes, bayheads, cypress heads, mixed marshes, and other wetland categories. Mostly wet.

PINK FLATWOODS

<u>GREEN</u>. Composite of natural to managed rangeland, improved pasture, and reforested areas. Mostly wet to poorly drained.

UPLANDS

<u>RED</u>. Composite of sandhills, citrus groves, extractive earth, and other areas of residential, disturbed, or bare earth. Mostly well drained.

UNCATEGORIZED

<u>BLACK</u>. This category includes all targets that do not exceed the probability thresholds established by the investigator.

Because of the edge effect in the photographic processing of the composites of separates of black and white negatives assigned to represent the computer-generated pine flatlands and uplands categories, a yellow bloom was developed. The yellow bloom border actually shows where approximately equal portions of pine flatwoods and uplands should occur. This edge effect also causes a light blue bloom where pine flatwood and wetland categories are mixed. The light blue areas are mainly gradational downslope from pine flatwood areas to wetlands and are, consequently, wetter and more subject to frequent flooding than the green color-coded pine flatwood category.

The three-category image demonstrates the poorly-drained basin characteristics of the Green Swamp. A basin of wetland and pine flatwood categories; color-coded blue and green, respectively; are bordered mainly by well-drained uplands, coded red. Consequently, the Green Swamp is a large, broad, and relatively flat swamp, composed mainly of wet to poorly-drained wetlands to the north and poorly-drained to moderately-drained pine flatwoods to the south.

CONCLUSION

Because the Green Swamp basin is predominantly wetlands and pine flatwoods and since these categories are wet to poorly-drained, planners and developers will encounter periodic flooding and drainage problems in the central portion of the Green Swamp. Development for optimum drainage is somewhat limited to the upland categories around the borders of the Green Swamp which occur as sandhills and ridges, with intermittent sinkhole lakes, and swampy areas.

Skylab S-192 data provide a useful tool for synoptic appraisal of land-cover types and environmental analysis that could provide developers and planners with an overview of development problems that they may encounter in large and complex areas such as the Green Swamp.

Primarily because of the addition of bands at longer wavelengths, the S-192 data appear to be more useful for delineating categories in the Green Swamp than LANDSAT-1 data.

Those Skylab S-192 bands that are most useful for delineating land-water cover categories in the Green Swamp area are as follows: Band 11 most significant, Band 8 second-most significant, and Bands 7 and 13 are third-most and similar.

Because of the additional spectral resolution available in the S-192 data, it is possible to categorize complex areas, such as the Green Swamp, with great accuracy, provided the investigator has the adequate ground truth needed to establish the many subcategories and to merge them into logical composites.

RECOMMENDATIONS

Categorization accuracy tables and imagery should be generated from noise-filtered S-192 data using the training areas defined by this study. Comparisons should then be made with the non-filtered data to establish the value of noise filtering.

To have transfer value, the techniques and knowledge developed by this investigation should be applied to other areas of the world where Skylab S-192 data are available. There should be included in this selection of additional test sites another wetlands area, an arid environment site, and possibly a glacial site.

The spatial resolution of the S-192 data should be investigated further to establish needs for wetlands categorization and mapping.

Those bands that contribute most significantly to categorizing land-cover types in the Green Swamp test site should be selectively used to determine the value of selecting fewer bands for automatic processing. This should be particularly important to guiding the selection of bands for future space instruments.

The geometric quality of the categorized imagery should be further evaluated. One procedure for accomplishing this would be to generate categorized map overlays (Ref 7) and to compare the overlay data to base maps and aerial photographs.

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Table I

SKYLAB S-192 AND LANDSAT-1 MSS BANDS

S-192		LANDSAT-1	
Band No.	Band (Microns)	Band No.	Band (Microns)
1	0.41 - 0.46		
2	0.46 - 0.51		
3	0.52 - 0.56		
4	0.56 - 0.61	4	0.5 - 0.6
5	0.62 - 0.67	5	0.6 - 0.7
6	0.68 - 0.76	6	0.7 - 0.8
7	0.78 - 0.88		
8	0.98 - 1.08	7	0.8 - 1.1
9	1.09 - 1.19		
10	1.20 - 1.30		
11	1.55 - 1.75		
12	2.10 - 2.35		
13	10.2 - 12.5		

Table II

CATEGORIZATION ACCURACY TABLE USED TO EVALUATE SELECTION OF TRAINING AREA

Category	Subcategory	Category Number								
		1	2	3	4	5	6	7	8	9
Wetlands	1. Cypress	86	0	1.3	0	4.5	0	0.6	7.6	0
	2. Water	0	100	0	0	0	0	0	0	0
	3. Fresh Water Marsh	0	0	100	0	0	0	0	0	0
	4. Bayhead	0	0	0	99	0	0	1	0	0
	5. Mixed Wetlands	11.5	0	0	0	88.5	0	0	0	0
Pine Flatwoods	6. Improved Pasture	0	0	0	0	0	98	2	0	0
	7. Mixed Palmetto	0	0	0	0	0	0	94	6	0
	8. Pine	0	0	0	0	0	0	0	100	0
Uplands	9. Citrus	0	0	0	0	0	0	0	0	100

Table III

AUTOMATIC TABULATION OF CATEGORY AREAS

Major Category	Subcategory	Percent of Total Area	Square Kilometers	Acres
Wetlands	Cypress Heads	16.36	1,318.6	325,852
	Water	3.83	308.9	76,327
	Fresh Water Marsh	4.43	356.8	88,167
	Bayheads	2.06	165.8	40,977
	Mixed Wetlands	3.08	248.1	61,306
	Wetlands Summary	29.76	2,398.2	592,629
Pine Flat-woods	Improved Pasture	5.08	408.7	100,984
	Mixed Palmetto	22.64	1,824.6	450,894
	Pine	5.17	416.6	102,958
	Flatwoods Summary	32.89	2,649.9	654,836
Uplands	Citrus	26.79	2,158.9	533,486
Uncategorized		10.56	850.7	210,222
Total		100.00	8,057.7	1,991,173

Note: One S-192 pixel = 1.676 acres.

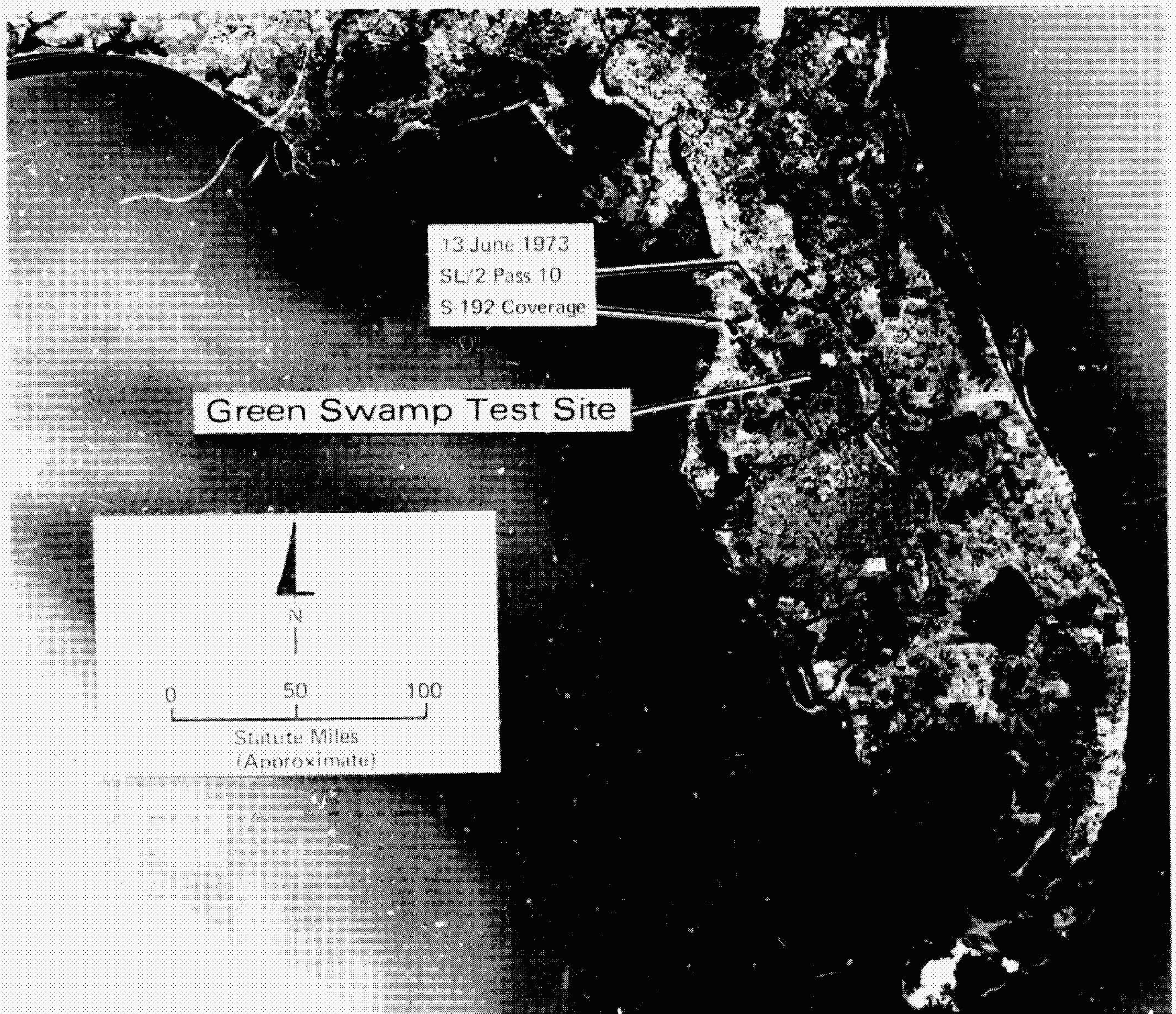

Figure 1 Location of the Green Swamp Test Site, Florida

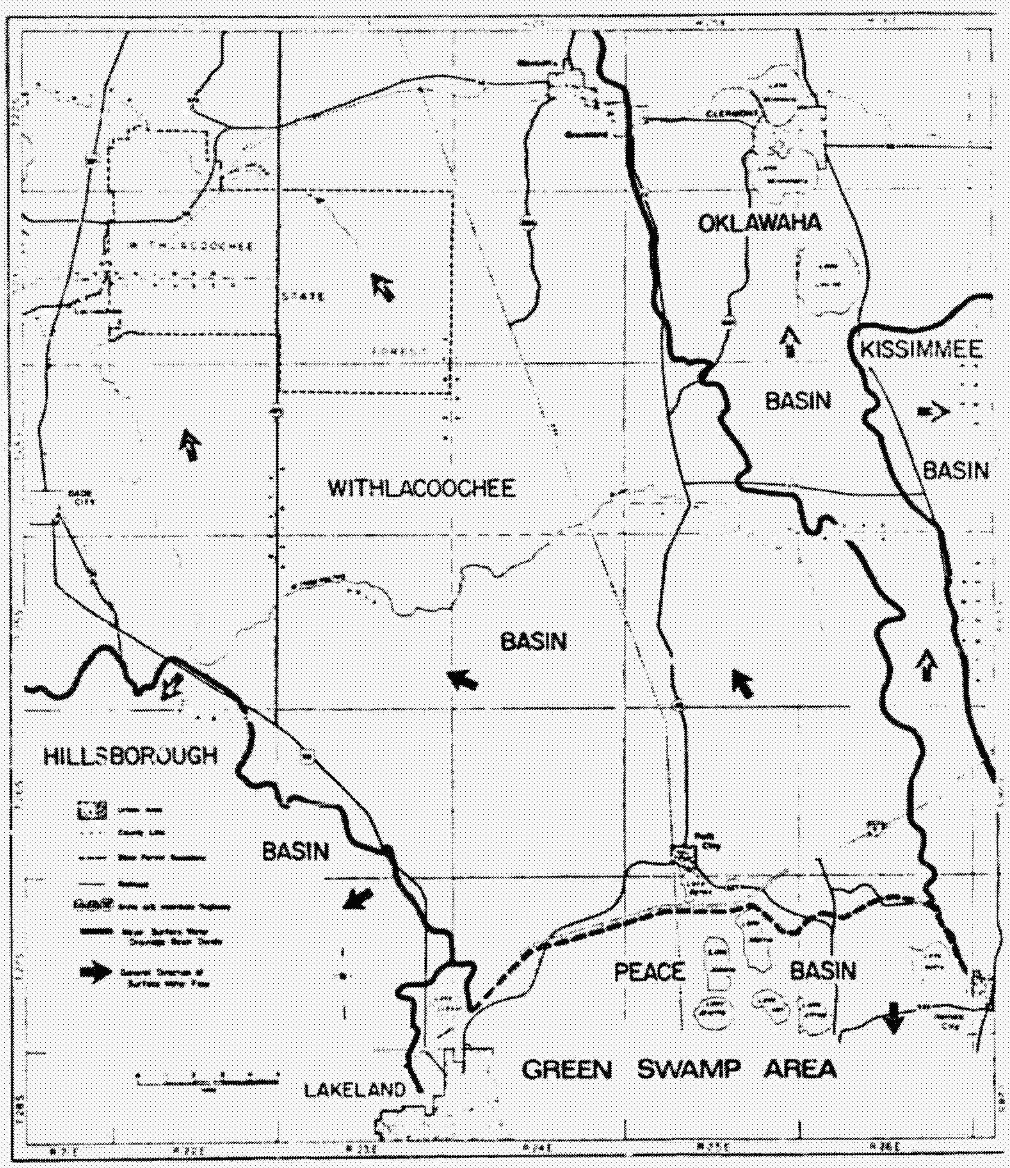

Figure 2 Green Swamp Test Site, Showing Major Surface Water Drainage Basins and General Direction of Surface Water Flow

Figure 3 Machine processing of Skylab EREP S-192 data

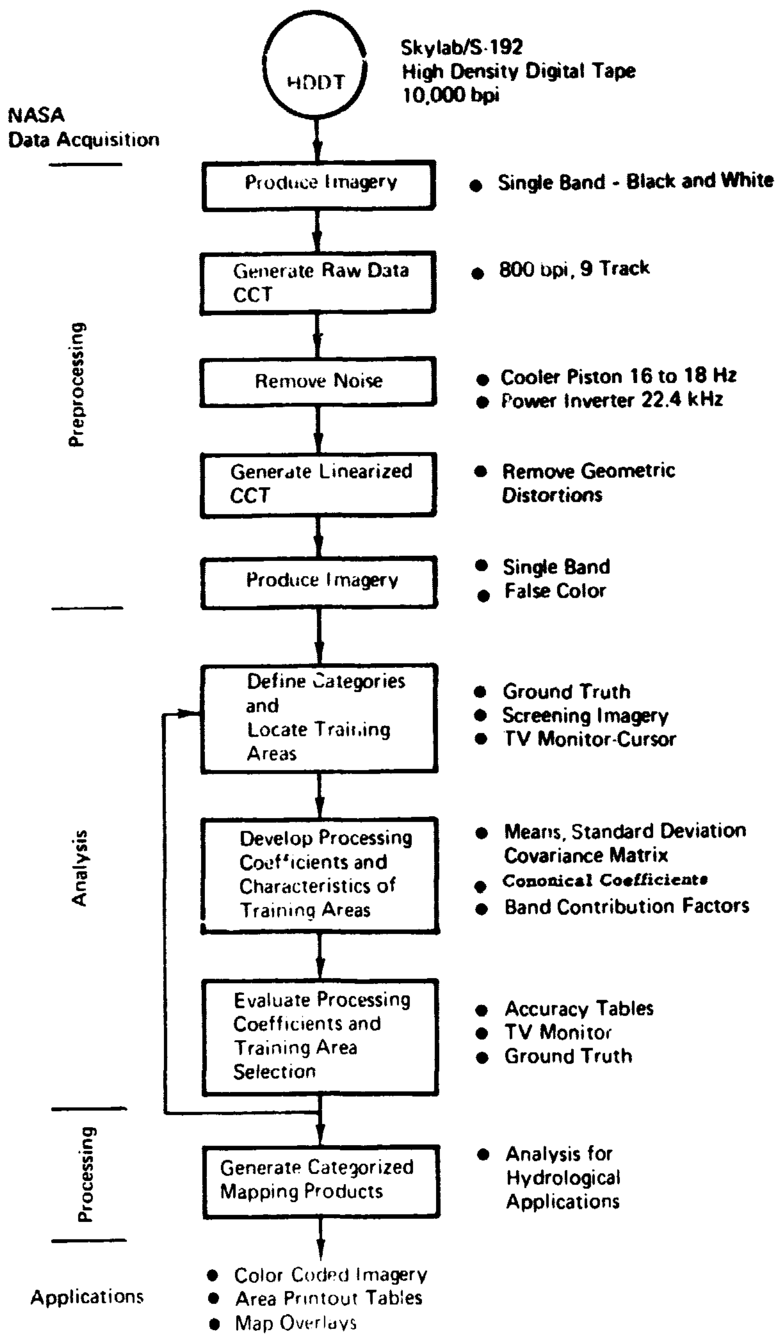

Figure 4 Processing and Analysis of Skylab S-192 High Density Digital Tapes

SKYLAB S192 IMAGERY OF THE FLORIDA GREEN SWAMP

SL/2 T-6 PASS 10, JUNE 13, 1973

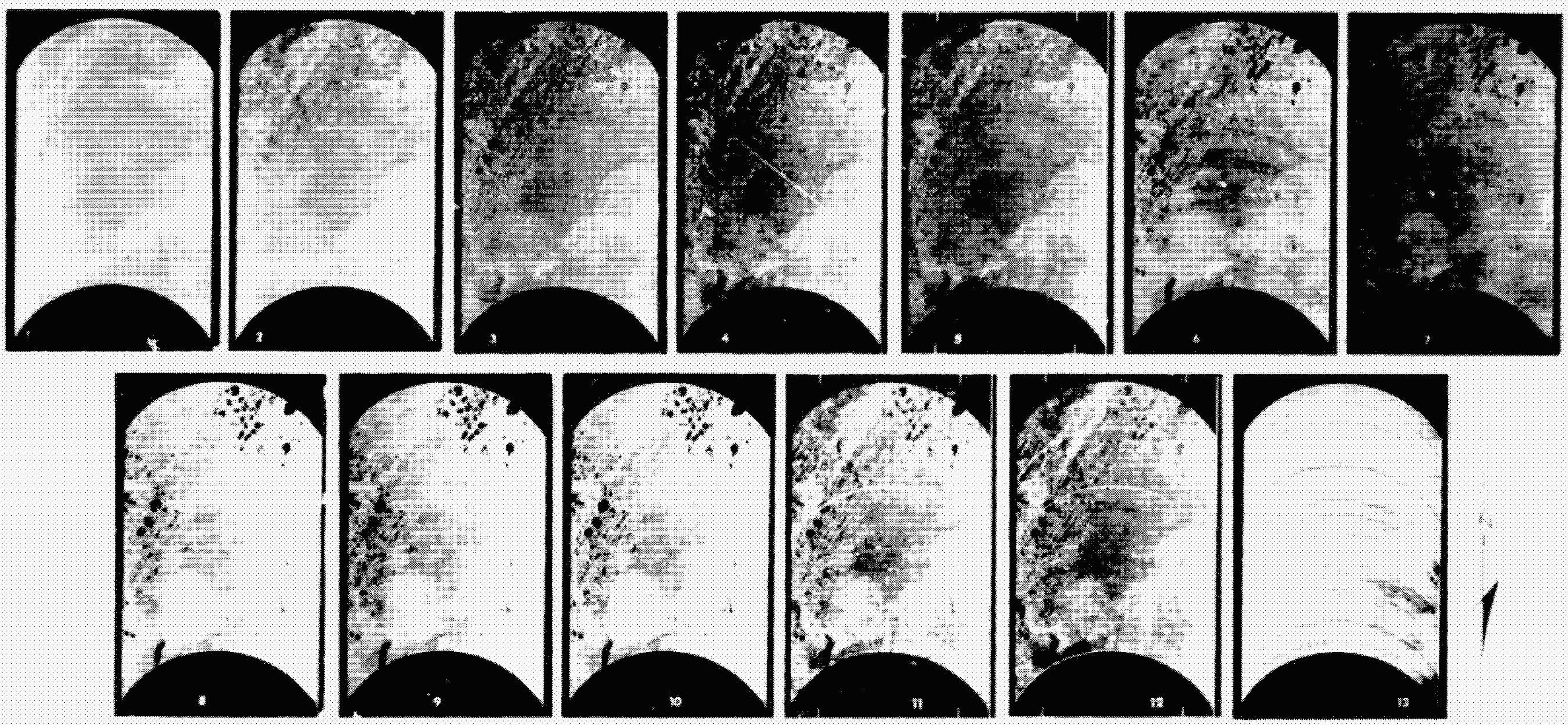

Figure 5 Skylab S-192 Imagery of the Florida Green Swamp;
SL/2 T-6 Pass 10, 13 June 1973

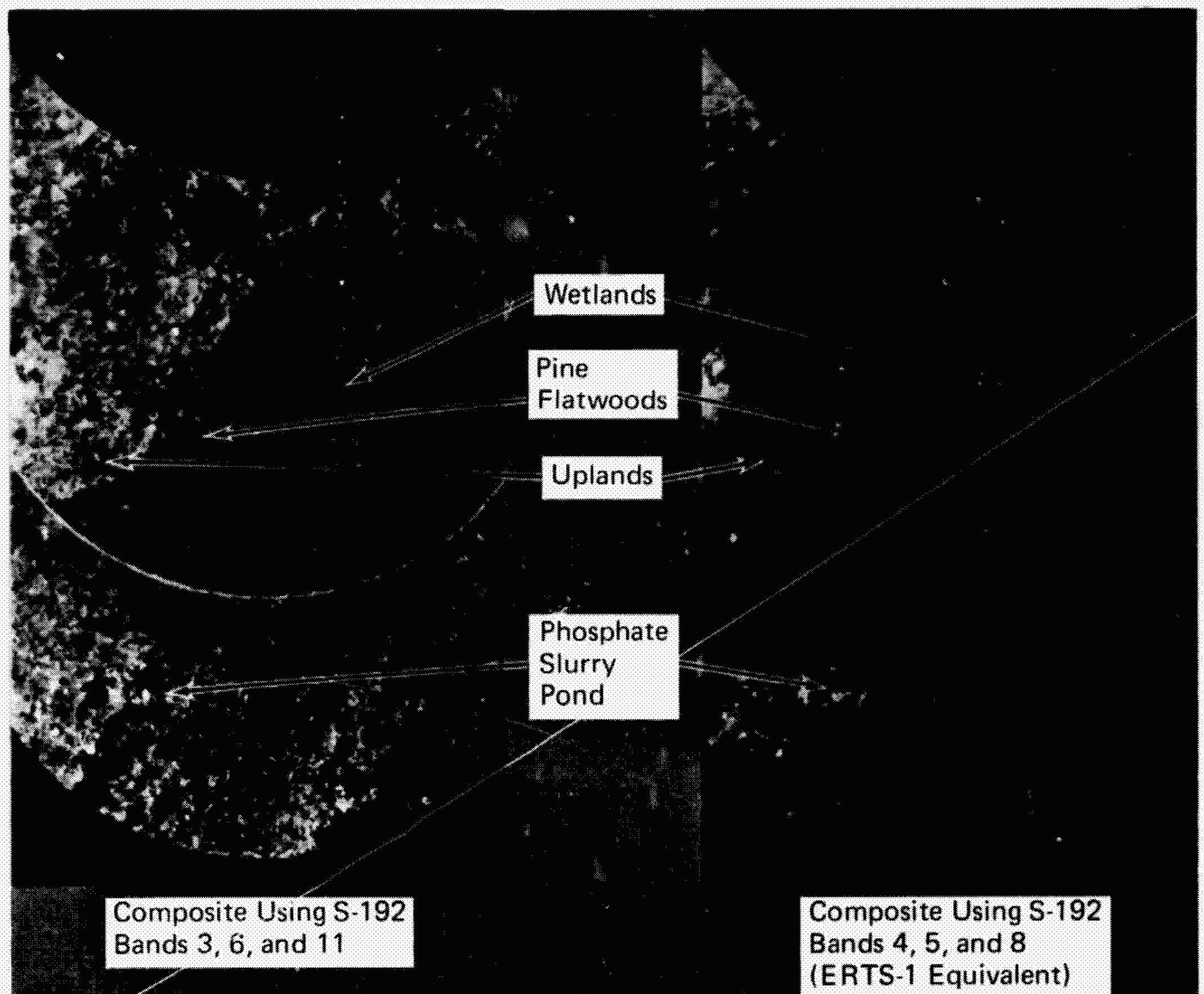

Figure 6 Color Composite Images of Skylab SL/2, S-192 Bands Showing Advantages of Using Spectral Combinations Differing from LANDSAT-1 Bands

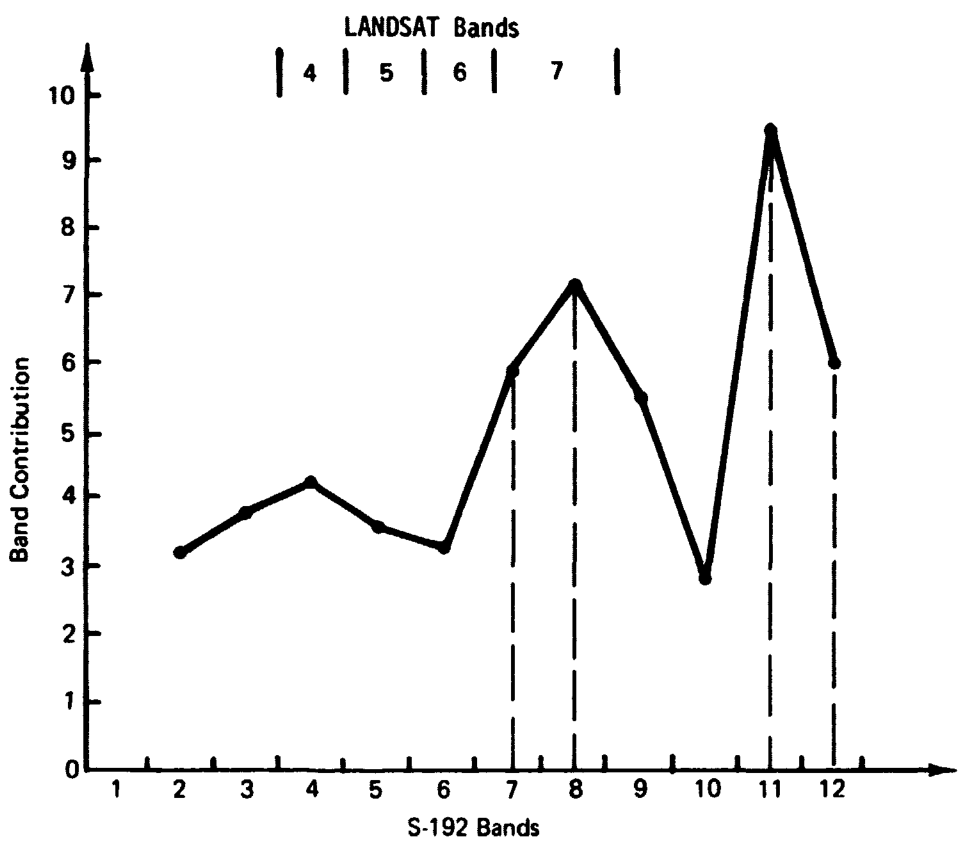

Figure 7 Relative Band Contribution of Skylab S-192 Bands for Automatic Categorization of Land-Water Cover Types of the Green Swamp, Florida

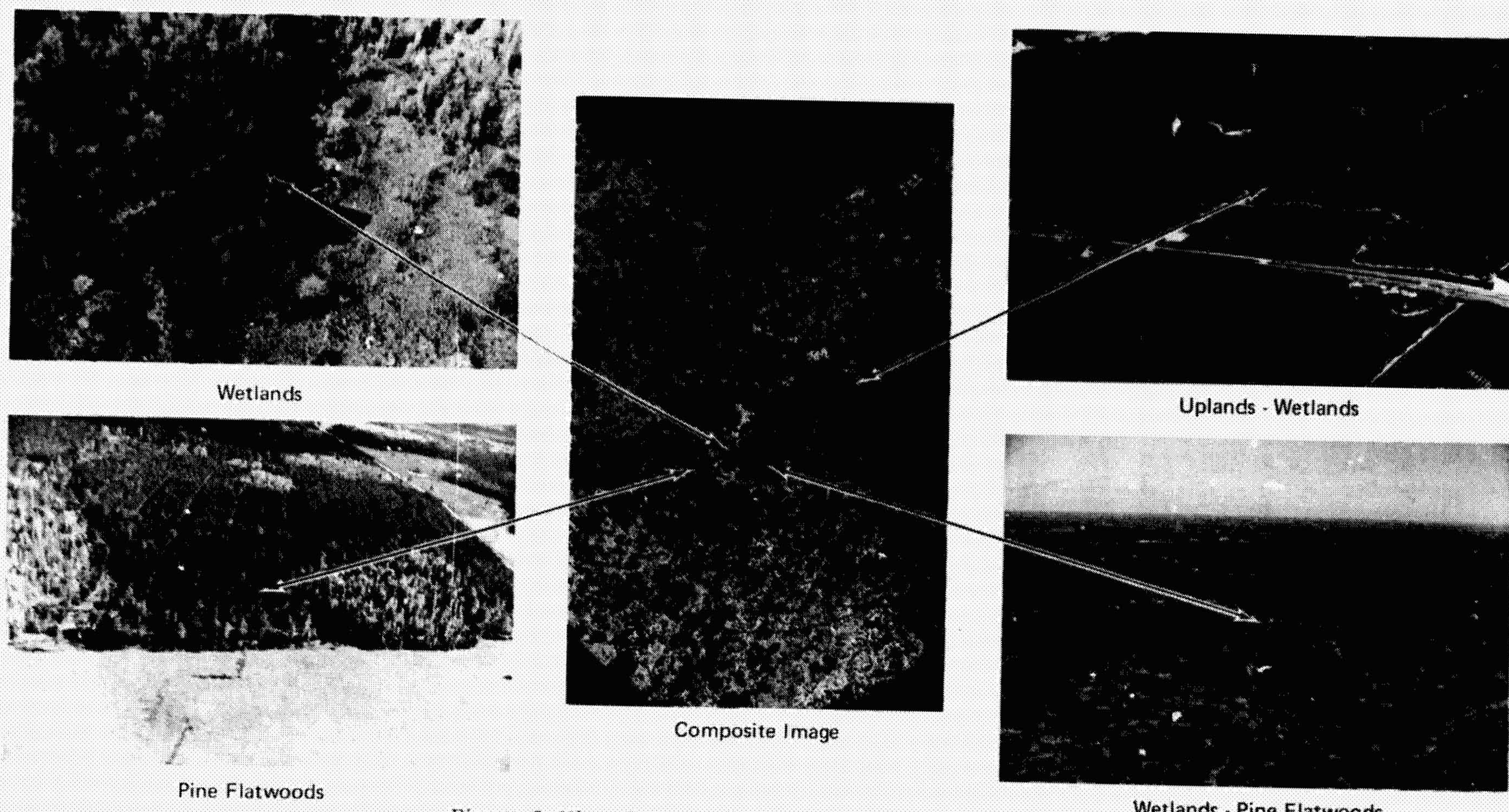

Figure 8 Nine-Category Image from Skylab S-192 Data and Examples of Ground Truth Areas

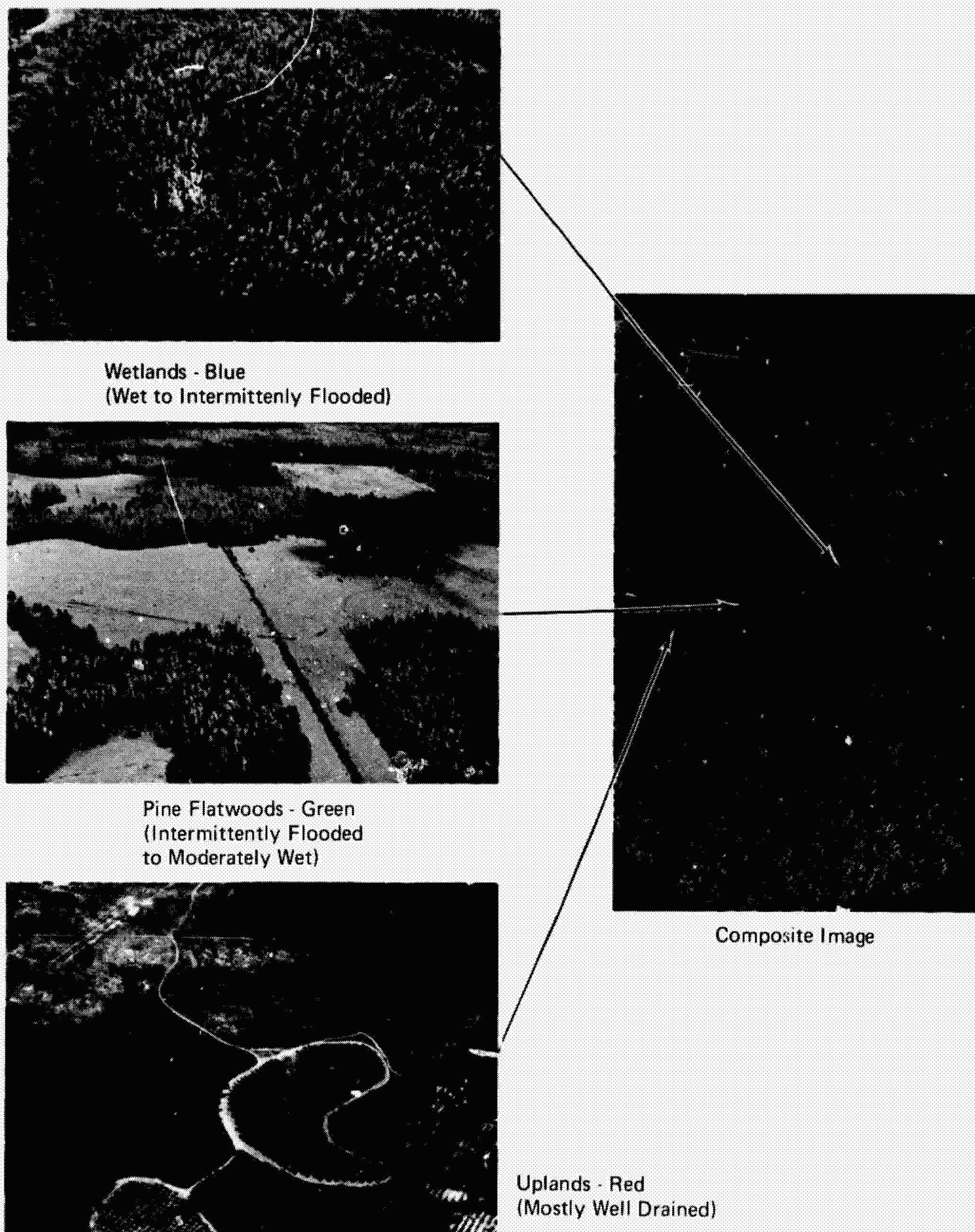

Figure 9 Three-Category image from Skylab S-192 data showing wetlands, pine flatwoods and uplands.