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An Analysis and Comparison of Landsat-1, Skylab (S-192) and Aircraft Data for Delineation of Land-Water Cover Types of the Green Swamp, Florida

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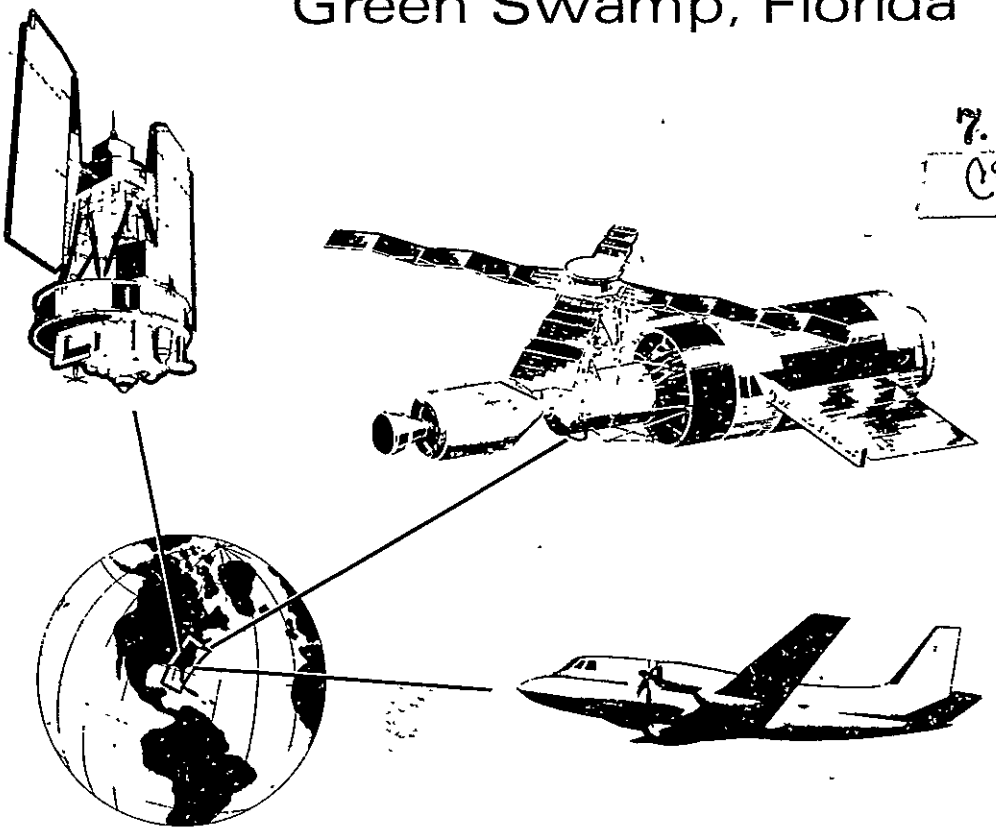

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16. Abstract

Landsat-1 and Skylab (S-192) data from the Green Swamp area of central Florida were categorized into five classes: water, cypress, other wetlands, pine, and pasture. These categories were compared with similar categories on a detailed vegetative map made using low altitude aerial photography. Agreement of Landsat and Skylab categorized data with the vegetation map were 87 percent and 83 percent respectively. The Green Swamp vegetative categories may be widespread but often consist of numerous small isolated areas, because Landsat has a greater resolution than Skylab it is more favorable for mapping the small vegetative categories. However with the additional spectral resolution available in the S-192 data it is possible to categorize complex areas, such as the Green Swamp, provided the investigator has adequate ground truth to establish the subcategories and to merge them into logical composites.

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ABSTRACT

Landsat-1 and Skylab (S-192) data from the Green Swamp area of central Florida were categorized into five classes: water, cypress, other wetlands, pine, and pasture. These categories were compared with similar categories on a detailed vegetative map made from low altitude aerial photography. Agreement of Landsat and Skylab categorized data with the vegetation map were 87 percent and 83 percent respectively. The Green Swamp vegetative categories may be widespread but often consist of numerous small isolated areas, because Landsat has a greater resolution than Skylab it is more favorable for mapping the small vegetative categories. However with the additional spectral resolution available in the S-192 data it is possible to categorize complex areas, such as the Green Swamp, provided the investigator has adequate ground truth to establish the subcategories and to merge them into logical composites.

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PREFACE

This investigation was performed for the National Aeronautics and Space Administration to evaluate and compare digital data from the Skylab S-192 and Landsat-1 Multispectral Scanners (MSS) and aircraft data for the determination of land-water cover types in the Green Swamp, Florida. The report summarizes the techniques used and results achieved in the successful application of Skylab S-192 and Landsat-1 data for automatic categorization and mapping of this test site. Data were provided from NASA Skylab S/L-2 pass number 10 of 13 June 1973 and Landsat-1 scene E1261-15285 of 10 April 1973. This investigation has concentrated on land-water cover types in the Clay Sink Quadrangle, part of the Green Swamp, Florida. The application of Skylab and Landsat data can be a useful contribution to environmental studies of the entire Green Swamp. The test site is representative of many similar environmentally sensitive areas throughout the world and, therefore, the results, techniques, and tools of this investigation provide a basis for surveys in similar environments elsewhere.

INTRODUCTION

This report provides a comparative assessment and evaluation of Skylab S-192 and Landsat data. Development of techniques required to process Skylab S-192 and Landsat data is described. Comparison of the data relative to: (a) training set requirements, (b) band contribution effectiveness and (c) classification accuracy are discussed. To perform this investigation the same interpretative procedure was applied to both S-192 and Landsat data and processing analysis results were used for comparison. Thematic images were produced for comparison of differences between the processed digital data and land-water cover maps derived from low level photography and supplemental ground truth. Differences due to spatial resolution, spectral discrimination and atmospheric effects are discussed. Level of classification and useful data output products are considered and the results useful for future operational systems are identified.

BACKGROUND

There is urban and industrial development encroaching on the environmentally sensitive 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 land, vegetation and the characteristics of the water resources 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 farming, and urban and industrial development.

National, State, and local governmental 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 context, there is an urgent need for land-water cover maps to be used for environmental appraisals to develop a rational basis for planning and controlled development. Although production of maps and data, based on the use of conventional aerial photography, photogrammetric mapmaking, and field studies have contributed considerably to describing this environment, a more rapid method of determining conditions over an area, is needed. The objective of this study is to use the Green Swamp and its environs as a laboratory to evaluate and compare Skylab and Landsat multispectral scanner data for rapid interpretation, assessment and automatic mapping of environmental categories.

Location and Description of the Green Swamp and the Test Sites

The Green Swamp is predominantly a broad flat wetland comprising 2,253 square kilometres (870 square miles) in the central highlands of the Florida peninsula (fig. 1).

A 172-square kilometre (66-square mile) area in the Green Swamp of central Florida was chosen as a Skylab Earth Resources Experiment Package and Landsat-1 test site. This area corresponds to the Clay Sink 1:24,000 topographic quadrangle map in the northwest part of the swamp. Within the test site a smaller sub test site of 32.4 square kilometres (12.5 square miles) was selected for the direct comparison of data; results were then extrapolated to the entire Clay Sink quadrangle.

The swamp is an extensive area of swampy flatlands and sandy ridges. The altitude of the land surface ranges from about 60 metres (200 feet) in the eastern part to about 18 metres (60 feet) in the western part. Five major drainage systems originate in or near the Green Swamp area. The Withlacoochee River drains two-thirds of the area. The Little Withlacoochee River, the headwaters of the Oklawaha River, the Hillsborough River, the headwaters of the Kissimmee River, and the headwaters of the Peace River drain the remaining area.

The Green Swamp was described by Pride (Ref 1) 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. The eastern boundary is U.S. Highway 27, from Clermont south-southeastward to Haines City. The southern boundaries generally coincide with the divides that separate drainage northward to the Withlacoochee River basin from drainage southward to the Peace and Hillsborough River basins. The western 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 to Clermont. The Green Swamp is not a continuous expanse of swamp but a composite of many swamps that are distributed 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

References, tables and illustrations are shown in that order, at the end of this report.

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-northwest 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 63 percent of the 1350 millimetres (53 inches) of rainfall per year that reaches the land surface in the Green Swamp area is lost to evaportranspiration.

Because of the gradual slope of the land and the dense vegetative cover, surface water drains from the Green Swamp area very slowly. As a result of this slow drainage, surface waters remain within the area for extended periods after the rainy season.

The surface is mantled with a layer of sand and clay, of varying thickness which comprises the nonartesian aquifier. Underlying this mantle is an intermediate unit of sandy clay 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 be organized into three major categories: wetlands, flatwoods and uplands.
(1) Wetland plants and soils are inundated for varying periods of time during the year. The soils are usually poorly drained, organic, and often have clayey subsoils. The wetland vegetative associations are river and creek floodplains, forests, cypress heads, bayheads, sloughs, and freshwater marshes.

(2) Flatwoods plants and soils are also periodically inundated, but usually not as deeply or as long as the wetlands. Flatwoods occur on low nearly-level areas with sandy, strongly-acid soils and a high water-table. Flatwood plants are adapted to occasional flooding and fire. Pine is the dominant large tree. Of the three species longleaf pine, slash pine, and pond pine; slash pine is most abundant.

Agricultural modifications of the flatwoods range in intensity from rangeland, where some of the pine overstory and most understory plants remain, to improved pasture, where pine and understory plants have been removed and grazing "grasses" planted.

(3) The upland vegetative associations are on well drained sandy soil. They are characterized by longleaf pine, various species of scrub oak, live oak, and laurel oak. Most of the natural upland vegetation has been cleared and planted in citrus, and to a lesser extent for improved pasture. Upland vegetative associations were categorized in a previous investigation using Skylab S-192 data (Ref 2) and were not included in the categorization of the Clay Sink quadrangle test site of this report as these associations are virtually absent from this quadrangle.

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 Landsat and Skylab S-192 data.

Figure 2 shows the elements of the Bendix Earth Resources Data Center where Landsat and Skylab data are processed. Here Skylab S-192 HDDT (high density digital tapes) were transformed into CCT's (computer compatible tapes) and image products. The elements of this Center include a Digital Equipment Corporation PDP-11/35 computer with 72K 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 line printer, a card reader, and a teletype unit. Other units are the color-moving window computer-refreshed display, operator console, an Optronics film recorder, and Gerber plotter.

The steps used in the processing and analyzing both the S-192 and Landsat data are shown in Figure 3. As noted in the flow diagram, the steps are in three groups; pre-processing, analysis, and final processing. The Skylab pre-processing phase includes those works necessary to transform the S-192 HDDT into noise-filtered linearized data, 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 the operator/interpreter is satisfied that the ground truth locations are categorized to agree with each selected category. The output of the analysis phase is the processing coefficients which were then used by the computer to generate categorized color-coded land-water coverage images and map overlays of the test site. The implementation of the processing phases and the results achieved are briefly summarized in the following paragraphs.

Pre-Processing Phase

The pre-processing phase consisted of selecting and locating coordinates within the Skylab S-192 HDDT data acquired over the Green Swamp test site. The selected data were then reformatted into a standard CCT format.

Generation of Raw Data - The 13 bands of Skylab S-192 data were provided by NASA as bi-phase modulated digital data on a 14 track magnetic tape with a 10,000 bpi (bit-per-inch) packing density. Two bands are multiplexed onto one track of the tape. Single band black and white 70-millimetre (2.8-inch) film of all bands was produced from the HDDT. The S-192 imagery, although geometrically distorted because of the conical scan pattern, permitted the extraction of data from the HDDT for the test site area and the selection of spectral bands to be used in processing the data. The desired S-192 data were then transformed from the HDDT to a standard raw data CCT format having 9 tracks with 800 bpi records.

Analysis and Filtering of Noise - The second pre-processing step was to develop digital filtering techniques to filter noise from the S-192 raw data. Fast Fourier transforms (Ref 3) were used to identify noise frequencies and determination of the filtering requirements were made from an analysis of the initial transform application and NASA information (Ref 4). Digital notch filters were developed and the raw data were pre-processed to suppress high and low frequency noise both across and along the scanner track.

Generation of Linearized CCT and Imagery - The images produced from this raw CCT data contains the conical-line scan-pattern used by the S-192 scanner. Identification and location of most targets was found to be difficult on this imagery. To improve the geometric fidelity of the S-192 data, a CCT, whose data are "linearized", was generated from the raw data CCT. On the linearized tape, 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 and 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 metres (260 by 260 feet or 1.55 acres). The line length or swath width covers 72.4 kilometres (39.1 nautical miles). 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. Although the imagery generated from this data is geometrically adequate, some residual distortions remain, such as one resulting from the effects of earth rotation. The removal of residual errors from the data is not considered in this study.

Figure 4 shows linearized imagery of the entire test site 72.5 by 100 kilometres (39.1 by 54.0 nautical mile) of Florida for each of the 13 S-192 bands. Atmospheric conditions and scanner noise factors degrade the quality of the imagery. An analysis of these factors and reference to the band wavelength shown in Table 1, reveal that the following conditions degrade the S-192 data information content.

Atmospheric Effects: Low atmospheric transmission and backscatter of the sunlight from the atmosphere (path radiance) reduce the contrast most markedly in band 1.

Detector Noise: A very low frequency (f), 1/f noise, completely degrades the quality of band 13.

Cooler Piston Noise: Although apparent in all 13 bands, this noise is most noticeable in band 5. This noise has a fundamental frequency of 16 to 18 Hz (a period of about six scan lines).

Power Inverter Noise: This noise causes a herringbone pattern within the imagery that markedly degrades band 4. The noise also occurs in bands 1, 2, 3, 5, 7, and 8.

Sync Drop-Outs: Poor signal-to-noise ratio on the HDDT sync signal causes a skip in some video areas when a CCT is generated. This noise is most noticeable near the center of the imagery in bands 11 and 12.

The Landsat CCTs were pre-processed for subsequent image production. Proper image alignment with vegetation overlay maps was obtained by an earth to Landsat coordinate transformation developed from ground control points digitized on a base map. The coordinate transformation is an interactive process where the ground control points are displayed on the TV monitor as a one pixel cursor point at the digitized map location in the scene. Further adjustments are made by the operator until the ground control points are located within an accuracy of one acre. The categorized image will then be properly aligned with the vegetation map.

Analysis Phase

Land-water cover types were selected to represent environmental conditions in the Green Swamp by analysis of aerial photography in combination with field studies of land-water cover and hydrologic investigations. This ground truth was used interactively with the Multispectral Data Analysis System (MDAS) for analysis of the test site.

Figure 5 shows the location of the Clay Sink Quadrangle with respect to the Landsat and S-192 coverage of Florida. The primary data inputs used for machine processing of the Green Swamp were established in this quadrangle were identified by the use of relevant ground truth information and extracted for machine processing.

Location of Training Areas - The data from Landsat or S-192 CCTs were displayed on a TV monitor as picture elements, called pixels. The first task was to locate and designate to the computer a number of pixels that best represent the land water category of interest. This group of pixels, called a training set,

represent areas whose land-water cover characteristics were established from the ground truth information. The coordinates of the training areas were then designated to the computer by placing a cursor over the desired area, followed by assignment of a training set number, category number and color code for each respective training set. Several training sets were selected for each category to establish analysis coefficients. Table II shows the categories which were defined in the analysis and illustrates the respective size of several Skylab S-192 and Landsat training sets.

Development of Processing Coefficients - The spectral measurements within the training area boundaries, edited by the computer from the Landsat and Skylab S-192 CCTs, were processed to obtain a numerical descriptor which represents the "spectral characteristics" (computer processing coefficients) for each land-water category. The numerical descriptors included the mean signal and standard deviation for each band and the covariance matrix taken about the mean. These descriptors were then used in a program, previously reported by Dye (Ref 5), to generate a set of categorical coefficients for each category. In automatic categorization processing these coefficients are used by the computer to form a linear combination of the 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 a 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".

Evaluation and Selection of Training Areas and Processing Coefficients - Before producing categorized data over a large area, analytical tests were applied to evaluate the computer's capability to perform the desired categorization for processing the entire area. These tests are: (a) generation of categorization accuracy tables (which show the performance of the analysis when applied to the training set data), (b) examination of categorical analysis factors (such as mean, standard deviation and eigenvalues) and (c) comparison of the categorized data, as viewed on the monitor, with specific ground truth areas.

The analysis of the categorization tables for all four Landsat bands (4, 5, 6, 7 - See Table I) and the eleven usable S-192 bands (2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 - See Table I) were used to refine the processing for the categories listed in Table II. The categorization tables indicate the percentage of each training set which is categorized into a target group sought and indicate the contribution of the training set toward defining the desired category,

Results of the analysis were viewed on the TV monitor where the computer analysis factors (such as standard deviations and matrix eigenvalues) were displayed for each category and relative evaluation pertaining to target separation (in the n-space analysis) can be performed.

The digital data was redisplayed on the TV monitor as categorized data where computer decisions were made for each pixel of data and displayed on the monitor as a color representing the corresponding category. As the categorized data was displayed, a cursory scan of the entire test site was performed. The size, shape, and classification of specific areas were simultaneously compared with the vegetation map and particular areas ranging in size from 1 to 50 acres were visually selected at random and compared to the vegetation map and aerial photography for verification of correct categorization performance. In both instances, categorized Landsat and Skylab S-192 data were found to be representative of land-water cover conditions in the Green Swamp area.

The selection of training areas, generation of categorization tables and evaluation of processing results were all iterative operations using computer printouts and the TV monitor. The categorization of a selected test site required between one and four training area selections to obtain optimum category target separation for each category selected.

Reliable ground-truth information and data were found to be essential for location of meaningful training areas and verification of the categorization accuracy. Landsat-1 imagery, photography from Skylab S-192, U-2, light aircraft and helicopters, vegetation maps (McPherson unpublished) and field data were used for verifying the accuracy of categorizations. The most useful ground truth data were photographs acquired by Skylab, aircraft, and helicopter surveys, vegetation maps, and field reports.

The vegetation overlay map of the Clay Sink Quadrangle, Florida, shown in Figure 6 is a precise compilation of ground truth sources and a good example of useful ground truth information. Areas of specified land-water cover types, indicated on the map, were used for training area selection when processing the Landsat and S-192 data. This smaller area was used to evaluate the categorization accuracy of the processed data. The image, vegetation overlay map, and other data were useful as a basis for comparing reported land-water cover types with the categorized Landsat and S-192 data.

Final Processing Phase

Production of Categorized Tape - When the operator/interpreter confirmed that the categorized locations agreed with the ground truth data, the processing coefficients were recorded on the computer disk file for processing of the entire Green Swamp and its environs. The processed area (encompassing 1562 and 2340

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scan lines for Skylab and Landsat respectively) was recorded on a Categorized CCT where each pixel within a specific land-water area is coded by the previously selected category number. This tape was later used to generate categorized imagery of the Clay Sink Quadrangle and served as a medium to store the interpreted information for the study area. Computer-generated area measurement tables were also edited from this tape to determine the actual extent of each category.

Area Measurement Table - The area measurement table is a data product that may be useful for land-use planning purposes. This table provides a quantitative tabulation of the amount of area that exists for each particular category and may be represented in units such as square kilometers, acres or percent of total area processed. An area measurement table of the test site (as shown in Figure 6) is illustrated in Figure 7. This area measurement data was generated from processed Landsat data and may be expanded, for purposes of analyses and planning, to other areas within the Landsat scene. Furthermore, similar coverage tables may be generated from data obtained by additional Landsat overpasses to permit a continuing assessment of environmental changes within the test area.

Location of the boundaries for area measurement tables, such as shown in Figure 7, were determined by digitized ground control points (GCP's) and application of an earth to Landsat coordinate transpormation as discussed in the preprocessing section. Similar software could be developed for an earth to Skylab transformation and the GCP's applied to generate a comparable area measurement table for S-192 data. Due to the complexity of the S-192 data, development of these programs was considered too expensive at this time. If the S-192 data were used on a regular basis, as Landsat data, software development could be accomplished.

Categorized Imagery - The categorized tape may be used to generate color-coded categorized imagery of the Green Swamp, in which a color denotes a specific land-water category. The categories and corresponding colors used in the categorized images are:

Category Type	Color	
	S-192	Landsat-1
Wetlands	Blue	Blue
Water	Blue	Blue
Cypress	Dark Brown	Red
Pine Flatwoods	Light Brown	Orange

Pasture	Green	Green
Uplands	Category not present in study area	
Unclassified (Targets that do not exceed probability thresholds established by the investigator)	Black	Black

COMPARISON OF SKYLAB S-192, LANDSAT-1 AND AIRCRAFT DATA

Multivariate categorical processing of Skylab S-192 and Landsat data illustrated the primary tradeoff of spatial resolution and spectral discrimination. The Bendix classification algorithm does not eliminate bands in the analysis, therefore additional spectral information, as from S-192 data, contributes to the feature extraction. In addition, the algorithm requires a sufficient number of training set measurements to properly establish categorical coefficients used in the classification processing and the number of measurements required is a function of the number of bands used in the processing.

The degree of detection and classification were both influenced by the spatial resolution and spectral discrimination of the multispectral scanner systems. The Skylab and Landsat parameters are:

Parameter	Skylab S-192	Landsat-1
spatial resolution (pixel size-acres)	1.55	1.1
spectral discrimination (range-microns) (see Table IO	13 bands (11 bands usable) (0.4-2.4) & (10.2-12.5)	4 bands (0.5-1.1)

During the processing it was generally noted that multispectral data and imagery were helpful in separating coniferous and decidous vegetation. Infrared photographs were also helpful in making the training area identifications.

Although images from the S-190A Multispectral Photograph Camera and the S-190B Earth Terrain Camera were used for training area identification, the high resolution color film, as also observed by Colvocoresses (Ref 6), was generally badly degraded for comparison with the S-192 and Landsat-1 MSS data. Since the images were not representative of S-190A and S-190B, evaluation and comparison was not pursued.

Inspection of Landsat-1 and Skylab S-192 categorized data provides a comprehensive comparison of categorization performance. Figure 8 shows two categorized images of approximately the same area of the Green Swamp as displayed on the TV monitor. Under this display the difference between the linear and linearized conical scan patterns can be noted. Comparison of the images shows the relative distinction of boundaries of large cover type areas and illustrates the comparative difference in spatial resolution of the data. The landing strip, road, water, and fish hatchery areas are well defined and indicate categorization agreement for these land-water cover types in both images of the categorized data.

Training Set Requirements - During the initial phases of Skylab S-192 processing, previously determined Landsat training sets were applied to the Skylab data. Examination of the ensuing algorithm results indicated that the training sets had larger classification errors than the comparable previous Landsat processing. Consequently, processing of the Skylab data required the selection of new training areas that were larger in order to obtain classification results comparable to the Landsat processed data. As previously discussed, optimum categorization is a result of refining the spatial and spectral parameters of the data to obtain categorization of the data which agrees with selected ground truth locations. This iterative procedure includes selection of training sets, evaluation of analysis results, generation of categorization tables and visual comparison of the categorized and ground truth data.

Comparison of Skylab S-192 to Landsat-1 processing indicated that larger training areas were needed for analysis of S-192 data for two reasons. The seven additional spectral bands of S-192 (11 (Skylab) - 4 (Landsat)) required more pixel measurement data (i.e., a greater number of pixels) and the larger S-192 spatial resolution of 1.55 acre per pixel compared to a 1.1 acre pixel for Landsat consequently made the overall S-192 training areas larger.

This is best illustrated by comparison of training set inputs for processing S-192 and Landsat data as shown in Table II. The columns in Table II indicate the total number of pixels contained in the training set(s) for each category (NOB) and the size (expressed in acres) which was computed by multiplying the total number of pixels contained in the training set(s) by the spatial resolution of 1.55 acre and 1.1 acre for the S-192 and Landsat data respectively.

Classification of pasture and other land cover types required a larger number of pixel measurements from the S-192 data and a correspondingly larger total training area. The training area sizes for pasture were 49.6 acres for S-192 and 18.7 acres for Landsat in order to obtain categorization.

Because limited homogeneous water areas (lakes, rivers, and borrow pits) were available in the test site, categorization from the S-192 data required selection of three smaller training set areas. The training sets provided 1, 4 and 4 pixel measurements from the eleven usable S-192 bands of data. The 1.1 acre spatial resolution (pixel size) of the Landsat data allowed the selection of one 15 pixel (16.5 acre) training set. Categorization and target separation of water from all other land cover types was accomplished with nearly equal training set sizes for S-192 and Landsat processing because the signatures obtained for water were more homogeneous and distinguishable than the land cover categories.

Band Contribution Coefficients - One of the by-products of the categorical analysis program (Ref 5) is a figure of merit that specifies the relative importance of each band in the analysis, that is, its contribution in separating each category from all other categories. Figure 9 shows, graphically, the relative contribution of each band toward identification of several land-water categories in the test site. Band contribution coefficients for S-192 and Landsat are shown on the same graph is their relative wavelength position for simultaneous comparison of coefficients used in each analysis. Since the S-192 and Landsat data were each processed separately, comparison of the contribution coefficient amplitudes between S-192 and Landsat is not appropriate. The contribution coefficients are derived from the number of analysis variables, the eigenvalues, and the category standard deviation in each band. Typical numerical values of 1.0 indicate reasonable band contribution toward categorization in the n-space analysis.

Figure 9 shows that the S-192 bands, which are outside of the Landsat band range, contributed significantly to the categorization of cypress and water. In fact, S-192 bands 8, 9, 10 or 11 (see Table I for wavelengths) contributed significantly to the classification of each of the categories. Skylab S-192 bands 8 and 11 respectively contributed most to the categorization of pine and cypress and band 8 was most significant in distinguishing the two types of trees.

Examination of the Landsat and Skylab contribution coefficients for all bands (Figure 9) for water indicates that they have a higher magnitude than the coefficients of other categories. This one reason why categorization of water did not require comparably larger Skylab training set areas. In addition the Landsat and S-192 band contributions exhibit a symmetrical conformance.

Figure 10 shows the cumulative average of the contribution coefficients for the five similar Landsat and Skylab S-192 categories. As previously described, band 1 exhibited significant atmospheric effects and band 13 was very noisy and they were both rejected from this analysis. The six S-192 bands which provide the contribution to the categorization of the Green Swamp are, in order of preference, bands 11, 6, 2, 10, 5, and 8. The four available Landsat bands, ranked in order of preference and contribution are bands 7, 5, 6 and 4.

Further inspection of Figure 10 indicates that the S-192 band contribution coefficients exhibited larger relative amplitude differences than the Landsat coefficients. This indicates that better category separation was obtained in the n-space analysis of S-192 data. Finally, from Figure 10, the best general combination of bands which would provide the most useful information are S-192 band numbers 2, 6, 8, 10 and 11. The thermal band (10.2 - 12.5 microns band 13) would also be very useful (Ref 7), but in the case of S-192 data, band 13 was too noisy.

Categorization Performance - The categorization performance of the Landsat-1 and Skylab S-192 data were evaluated by comparison of the respective categorized data to the vegetation overlay map shown in Figure 6. The vegetation map was produced from low altitude aerial photography and ground truth information.

Two sample areas for each major category were visually selected in the S-192 categorized data and the corresponding area was located in the Landsat categorized data. Figure 8 shows 32.4-square kilometre (approximately 8,000-acre) section of the vegetation map and corresponding Landsat and S-192 categorized data of a part of the Clay Sink Quadrangle where the sample areas were selected. These sample areas were compared to the vegetation map where each pixel was determined to agree or disagree with the corresponding area defined by the land cover boundaries of the vegetation map. In each case the total area compared was approximately four hundred acres.

The section of the vegetation map shown in Figure 6 was manually categorized and percent of total area occupied by each category was calculated. A cumulative agreement factor for all of the categories was obtained by weighting the agreement percentages by both the ratio of area occupied by each category with respect to the test site and by the sample area size, which can be calculated by the expression;

$$A = \frac{\sum_{i=1}^{5} P_i \, (S_i + C_i)}{\sum_{i=1}^{5} S_i + C_i}$$

where A is the weighted agreement factor, P_i is the category agreement percentage, S_i is the sample size, C_i is the area occupied by each category and "i" is the category number. The calculation for Landsat-1 is;

$$A = \frac{76.3\ (37 + 13.2) + 88.6\ (2730 + 74) + 91.2\ (539 + 105.5)}{37 + 13.2 + 2730 + 74 + 539 + 105.5}$$

$$\frac{85.5\ (4263 + 86.5) + 90.9\ (395 + 83.5)}{5263 + 86.5 + 395 + 83.5}$$

The calculation results indicate that the agreement of Landsat and S-192 categorized data with the vegetation map were 87.2 percent and 82.8 percent respectively.

Weighted Agreement Percentage

Category	Landsat	S-192	Percent of Total Area of Vegetation Map Section (in percent)
1. Water	76.3	69.7	0.5
2. Cypress	88.6	75.9	34.2
3. Wetlands*	91.2	80.2	6.7
4. Pine	85.5	87.8	53.4
5. Pasture	90.9	82.2	4.9
	87.2	82.8	

*Includes River Bottom, Mixed Swamp, and Marshes.

Categorization Capability - Categories which may be defined from the data are related to the spatial resolution or spectral discrimination of the Landsat-1 and Skylab S-192 system respectively. Processing Landsat data may provide selection of more wetland and pine flatwood type categories due to the spatial resolution of the scanner. Whereas, analysis of Skylab S-192 data may allow additional subdivision of a limited number of categories if large training areas are available. Presently, Landsat may relate more to user requirements, primarily because the resolution probably allows more useful selection of major categories.

SUMMARY AND CONCLUSIONS

In response to the need for rapid and economical means of acquiring environmental information to appraise (Ref 11) the Green Swamp, this investigation evaluated Landsat and Skylab S-192 data as a source for this information.

The Green Swamp vegetative categories (cypress, pine, etc.) may be widespread but often consist of numerous small isolated areas. Because Landsat has a greater spatial resolution (1.1 acre) than Skylab S-192 (1.55 acre), it is more favorable for categorizing the small vegetative areas of the Green Swamp.

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On the other hand Skylab S-192 band numbers 9, 10 and 11 (which are outside the Landsat spectral range) contributed considerably in the Skylab classification of the Green Swamp vegetation types. Because of the additional spectral resolution available in the S-192 data, it is possible to categorize complex areas, such as the Green Swamp, provided the investigator has adequate ground truth to establish the many subcategories and to merge them into logical composites (Ref 6).

Categorization agreement of the Landsat data, S-192 data and the vegetation map was affected by the different spatial resolution, geometric distortion, and scan pattern present in each of the three categorized data displays.

This initial categorization of scanner data to a detailed land cover map provides incentive for further comparative investigations employing more advanced data processing and comparison techniques. Correction of geometric and radiometric distortions can be performed by special software to rescan and resample the digital scanner data. The resulting data would be reformatted into 50-metre grid cells which are north-south oriented. In a similar manner, land water cover maps could be digitized on the same 50-metre grid and the results recorded on magnetic computer tape. Through techniques employing ground control points digital scanner data and map information could be aligned to a best fit basis within the 50-metre cell.

The use of these techniques enables the direct comparison of Landsat and Skylab S-192 digital data with detailed maps prepared from aerial photography and ground truth information. Direct cell by cell comparison of this data could be accomplished on a computer system over relatively large areas such as an entire quadrangle or Landsat scene. Output products used for the comparison could be comparison statistics and categorized image and overlay maps.

Although the S-192 conical scanner has some fundamental geometric advantages over the Landsat line scanner, the disadvantages related to the S-192 data are the current lack of equipment and experience for processing conical scan data, the linear nature of present processing systems and the availability of data (Ref 6).

Landsat processing was more favorable than Skylab for this particular application, primarily because of Landsat's better spatial resolution. For the categories chosen, the Bendix feature extraction algorithm provided comparable classification accuracy using only the four Landsat bands. Certainly the best system for classification of the Green Swamp should include the Landsat spatial resolution and the Skylab spectral discrimination although this combination is not required to achieve the accuracies obtained in this study.

Significant results and conclusions resulting from this study are:

- Techniques have been developed for pre-processing Skylab S-192 data into a format similar to Landsat data. The S-192 data requires more pre-processing steps (as shown in Figure 3) than available Landsat data.

- Multivariate categorical processing of the Skylab S-192 data required larger training areas than those used for Landsat because, (a) the greater number of bands required more pixel measurement data and (b) the larger pixel size represents a correspondingly larger area.

- Landsat data were easier to process because the comparatively better spatial resolution allows more training set data (signatures in each band) to be extracted from a small homogeneous area of land-water cover.

- Categorization performance of the digital scanner data as evaluated by comparison with a detailed vegetation map indicated a nearly similar agreement of Landsat-1 and Skylab S-192 categorized data with the vegetation map of 87 percent and 83 percent respectively.

- Skylab S-192 data bands 8, 9, 10 and 11 which are beyond the Landsat band range, were useful in detection and categorization of cover types in the Green Swamp.

- Skylab S-192 data with the additional longer wavelength bands than are available from Landsat-1 is better able to identify marshes and cypress within the major wetlands classification.

ACKNOWLEDGMENTS

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- The U. S. Geological Survey: Benjamin McPherson (for the Clay Sink vegetation map and other ground truth data).

- The Goddard Space Flight Center (for data and technical support).

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APPENDIX A

VEGETATION MAP*

Aerial photographs of the major vegetation categories in the Green Swamp are shown in Figures 11 and 12. Descriptions of vegetative categories used in preparation of the vegetation map follows:

CYPRESS FORESTS: Generally rounded "heads" or elongate "strands", with Cypress Trees (Taxodium sp.) as dominant overstory. Understory variable. In the southwest bay trees (Gordonia lasianthus; Magnolia virginiana; Persea palustris and P. borbonia) are common and may dominate cypress in some heads and strands. Common understudy plants include wax myrtle (Myrica cerifera), St. Johns Wort (Hypericum sp.), slash pine (Pinus elliotti), red maple (Acer rubrum), dahoon (Ilex cassine), blackgum (Nyssa biflora), and swamp fern (Blechnum serrulatum). Forest floods for variable periods during the year depending on rainfall and local drainage activities. Typically the forests are flooded for months during and following the rainy season, June through October.

RIVER BOTTOM SWAMP: Swamps bordering rivers and creeks. Typically deep-water swamps dominated by cypress, blackgum, and pop ash (Fraxinus caroliniana). Other common trees include rep maple, sweetgum (Liquidambar styraciflua), elm (Ulnus floridana), willow (Salix caroliniana), and laurel oak (Quercus laurifolia). On slightly higher land bordering rivers and creeks large oaks and bay trees are often common. RIVER BOTTOM SWAMP reaches its greatest size along the Withlacoochee River north of Rock Ridge.

MIXED SWAMP FOREST: Swamp trees other than cypress dominant. Where bay trees dominate, the forest is called a bay head. Bay heads are common in the east and southeast parts of the swamp. Other common trees include red maple, sweetgum, elm, laurel oak, wax myrtle, slash pine, cypress, and black gum.

MESIC HAMMOCK FOREST: Dense forests of trees, shrubs, vines, ferns, and epiphytes. Largest stands occur along the Withlacoochee River where they merge with the RIVER BOTTOM SWAMP or border the river. Common plants include laurel oak, live oak (Quercus virginiana), red bay, cabbage palm (Sabel palmetto), dahoon, white bay (Magnolia virginiana), wild coffee (Psychotria undata), and slash pine. Soil is often damp and the forest may flood periodically during heavy rainfall.

MARSHES: Wetlands in which herbaceous vegetation dominates over shrubs and trees. Common plants include saw grass (Cladium jamaicensis), arrowhead (Sagittaria latifolia; Sagittaria sp.), pickerelweek (Pontederia lanceolata), maindencane (Panicum hemitomon), bulrush, (Scirpus sp.), Ludwigia sp., cattail, (Typha sp.), white water lily, Nymphaea odorata, and hat pins (Eriocaulon sp.). Sometimes small trees and shrubs such as buttonbush (Cephalanthus occidentalis) willow, and primrose willow (Ludwigia peruviana) are mixed with the herbaceous plants.

*Comments: Benjamin McPherson, 1975.

PINE FLATWOODS: Relatively open forests of slash pine (Pinus elliottii) or long leaf pine (P. palustris). Common understory plants include saw palmetto (Serenoa repens), gallbery (Ilex glabra), wire grass (Aristida stricta), wax myrtle (Myrica cerifera), lyonia (Lyonia lucida), broomsedge (Andropogon virginicus) and blackberry (Rubus trivialis). Live oak and laurel oak are sometimes understory trees. In places pines have been planted so densely that understory plants are largely absent.

RANGELAND; Original PINE FLATWOODS that have been partly cleared so that tree crown cover is less than 10 percent. Plants are similar to those of the FLATWOODS.

PASTURE: Land largely cleared of its native plants. Originally PINE FLATWOODS.

UPLAND PASTURE: Land largely cleared of its native plants except for large live oaks (Q. virginiana) which serve as shade trees for cattle.

SANDHILL UPLANDS: Relatively open forests of turkey oak (Quercus laevis), and longleaf pine with an understory of broomsedge, wire grass, and a variety of other grasses, composites, scrub oaks, and other low growing plants. In places small oaks such as the bluejack oak (Q. incana), Chapman's oak (Q. chapmanii), myrtle oak (Q. myrtifolia) and sand live oak (Q. virginiana var. geminata) may dominate and form a dense scrub forest. The uplands are sandy, well-drained areas and are of prime aquifer recharge potential.

LIVEOAK STANDS: Usually areas of relatively small size in which large live oak trees have been left standing. Stands are common in UPLAND PASTURE, and on higher land surrounding lakes.

CITRUS GROVES: Citrus trees planted in rows primarily on the SANDHILL UPLANDS. Groves are on well-drained land that is important in aquifer recharge.

STRIPPED LAND: Land in which vegetation is largely removed and bare earth is exposed or in which the earth has been recently colonized by "weeds". Includes land drained and cleared for residential development, or land stripped for mining or other activities.

BUILT UP LAND: Land used for residential and commercial purposes where structures exceed 4 per cent over 10 acres.

METHODS AND MATERIALS
(For Preparation of the Vegetative Map)

The map was made with the aid of aerial photography in conjunction with ground surveys. The basic photography used was color infrared taken in February and March 1975 at 3,000 metres (10,000 feet). Higher altitude (12,000 metres or 40,000 feet) color infrared taken in December 1972 and 1974 was used to supplement the low altitude photography. The high altitude photography, because it was taken in early winter, was of special benefit in separating decidous forest from evergreen forest. It also provided a better overview of large features. The low altitude photography was useful because of its great resolution.

U. S. Geological Survey 1:24,000 quadrangle maps were used as control for the features drawn on the map. Roads, trails, and structures were taken directly from the quadrangle maps.

Ground surveys were made in October, 1973, January 1975 and July 1975. Most of the swamp was flown by helicopter for field inspection in July 1975.

APPENDIX B

ATMOSPHERIC PARAMETERS

Atmospheric Parameters - Desired reflectance information is difficult to obtain directly from the Landsat or S-192 sensor radiance measurements because these measurements are a function of unknown solar and atmospheric parameters caused by the intervening atmosphere, and these parameters vary significantly. The radiance, L, sensed by the spacecraft sensor from a given target, depends not only upon the reflectance, ρ, of the target, but also upon the target irradiance, H, and upon the spectral absorption and scattering of the atmosphere between the target and the spacecraft. The atmosphere attenuates the radiance reflected from the target to the spacecraft and adds to the foreground radiance by back-scatter of sunlight from the atmosphere, L_A. The composite radiance, L, recorded within an MSS band for a spacecraft looking vertically is, therefore, related to the desired target reflectance, ρ, and to the solar and atmospheric parameters; H, τ, and L_A; by:

$$L = \frac{\rho}{\pi} H \tau + L_A \tag{1}$$

where τ is the beam transmittance for one air mass.

The target irradiance, H, has two components; one caused by the direct sun, denoted $H_{SUN} \cos Z$ (in which H_{SUN} is the irradiance on a surface normal to the sun's rays and Z is the solar zenith angle) and a component caused by the sky, denoted H_{SKY}. Expanding of H of Equation 1 in terms of the direct sun and sky components and solving the equation τ^m results in

$$\rho = \frac{(L - L_A) \cdot \pi}{\tau (H_{SUN} \cos Z + H_{SKY})} \tag{2}$$

For a remote sensing system looking vertically downward, τ is the atmospheric transmission of one air mass. If m is the number of air masses referenced to the zenith air mass (for which m = 1), the atmospheric transmission through some other value of m is given by τ^m. The direct sun component of target irradiance, H_{SUN}, in Equation 2 can be subdivided ad

$$H_{SUN} = H_o \tau^m, \tag{3}$$

in terms of the solar irradiance normal to the sun's rays outside the atmosphere, H_o. Combining Equations 2 and 3, the desired target reflectance, ρ, in terms of MSS radiance, L, measurements is

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$$\rho = \frac{(L - L_A) \cdot \pi}{\tau\,(H_o\,\tau^m \cos Z + H_{SKY})} \tag{4}$$

where L_A, τ, H_o, m, cos Z, and H_{SKY} are the solar and atmospheric parameters that must be known to accurately compute target reflectance.

In the machine processing of computer compatible tapes (CCTs), the parameters L, H_o, m and Z of Equation 4 are easily and quickly determined. Target counts, c_i, recorded on the CCTs are transformed to the target radiance, L of Equation 4 by

$$L_i = c_i\ K_i\ \text{mw/cm}^2 - \text{sr}, \tag{5}$$

where i indicates MSS band number and constants K_i are determined as described on Page G-14 of the ERTS Data User Handbook (Ref 8); (K_4 = 0.0195, K_5 = 0.0157, K_6 - 0.0138, K_7 - 0.0730). The sun zenith angle, Z, is computer from $Z = 90 - \theta_E$, in which the sun elevation angle, θ_E, is also extracted from the CCT.

Beam transmittance, τ , and solar irradiance outside the atmosphere, H_o, can be determined by making a series of H_{sun} measurements and then plotting an "extinction" curve. The beam transmittance per unit air mass, τ , is then computed from

$$\tau = \left(\frac{H_{SUN}\,(m_1)}{H_{SUN}\,(m_2)} \right)^{\frac{1}{m_1 - m_2}} \tag{6}$$

where

H_{sun} (m_1) = direct beam solar irradiance at air mass m_1.

H_{sun} (m_2) = direct beam solar irradiance at another air mass, m_2.

It can be shown that the slope of the extinction curve is log τ, and Equation 6 follows directly.

The value of H_o (i.e., H_{sun} at m = 0), once determined for each RPMI band, may be used to test and/or recalibrate the RPMI, using the Sun as a source, at any location in the world.

Beam transmittance, τ , derived from 10 sets of field measurements covering the period January through June of 1973 shows this parameter to range from 70 to 85 percent in Band 4, from 77 to 90 percent in Band 5, from 81 to 94 percent in Band 6, and from 84 to 97 percent in Band 7 as shown below:

Beam Transmittance,

LANDSAT MSS Band	Average	Minimum	Maximum	Standard Deviation
4	0.799	0.697	0.856	0.051
5	0.852	0.770	0.901	0.048
6	0.885	0.812	0.940	0.051
7	0.899	0.843	0.975	0.052

The solar irradiance, H_0, outside the earth's atmosphere is well known and changes less than 6 percent over a 12-month period. H_0 can be determined from NASA-published data (Thekaekara, Ref 9) or derived from Radiant Power Measuring Instrument measurements. Values obtained from RPMI and Dr. Thekaekara's published data for a mean earth-sun distance of 1 astronomical unit (AU), are;

Landsat MSS Band	RPMI mW/cm^2	Thekaekara mW/cm^2
4	18.65	17.7
5	15.11	15.15
6	12.33	12.37
7	25.17	14.88

The remaining solar and atmospheric parameters needed for Equation 4; L_A, and H_{SKY}; depend on the specific atmosphere within the scene and must be determined by the Principal Investigator at the time of MSS overflight.

The only remaining atmospheric parameter needed to transform MSS radiance into reflectance is the radiance, L_A, reaching the spacecraft from Rayleigh and aerosol scattering by the atmosphere. As path radiance cannot be measured directly, it must be derived from ground-based sky radiance measurements of the backscatter. The simplest technique is to use the RPMI to measure the sky radiance, L_{MEAS} (ϕ), scattered at angle ϕ, such that ϕ is identical to ϕ'; the angle through which radiation is scattered to the spacecraft, and then to correct this measurement for the difference in air masses between the direction of observation and the direction of the spacecraft. This technique provides a straightforward measurement procedure when $Z > 45^o$. When L_{MEAS} is recorded at an angle equal to the scattering angle to the MSS, the path radiance, L_A, seen by the MSS is

$$L_A = L_{MEAS} \left(\frac{1 - \tau}{1 - \tau^{m_o}} \right) , \qquad (7)$$

in which m_o is the air mass in the direction of observation (in this case $m_o = 1/\cos\beta$) and T, as previously defined, is the atmospheric transmission per unit air mass. The validity of this formula has been demonstrated by Rogers and Peacock (Ref 4). Equation 7 is used when the atmospheric measurements are made concurrent with the MSS, overflight; (i.e., at a sun angle close to the one at the time of the MSS flyover).

However, if $Z < 45^o$, it is easy to see that $\beta > 90^o$ and a simple determination of L_A is not possible. During the summer months, this is frequently the condition at the time of the Landsat overpass. It becomes necessary to make the sky radiance measurements at a time when $Z > 45^o$ and to correct for the greater attenuation of the incident sunlight. Based on this analysis a simple technique was established to determine energy scattered to Landsat by the atmosphere using ground based measurements of sky radiance.

For 27 March this atmospheric radiance was found to be equivalent to that produced by a surface area having a reflectance of 11 percent in Band 4, 5 percent in Band 5, 3 percent in Band 6, and 1 percent in Band 7. Furthermore, analysis of ground-measured data acquired during the January through June 1973 time period shows that this atmospheric radiance, which is a function of sun angle (scattering angle), will vary over a one year period by 28 percent or more at the Landsat sun angles existing at Florida latitudes.

In summary, computer processing of Landsat CCT's and atmospheric parameters have established the feasibility of using these techniques for obtaining and applying atmospheric parameters in the transformation of Landsat and Skylab S-192 measurements into absolute reflectance signatures of land water cover types.

TABLE I

Skylab S-192 and Landsat-1 MSS Bands

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

Categories and Training Set Total Size Comparison for Landsat-1 and Skylab S-192 Processing

		LANDSAT-1		S-192	
Name of Category	Color	NOB[1] (Pixels)	Size[2] (Acres	NOB (Pixels)	Size[2] (Acres)
Pasture	Purple	17	18.7	32	49.6
Pine	Orange	12	13.2	32	49.6
Cypress	Green	9	9.9	18	27.9
Composite (Cypress & Other Cover)	Yellow	9	9.9	( )[3]	
Mixed Wet-lands	Red	21	23.1	( )[3]	
River Swamp	Cyan	16	17.6	27	41.9
Water	Blue	16.5	15.2	9	14.0

NOTES:

(1) NOB - Number of Observations; total number of picture elements (pixels) within the training sets to define the categories for this investigation.

(2) Size- Number of acres within the training sets (Landsat NOB x 1.1 acre Skylab: NOB x 1.55 acre)

(3) For this specific test site numerical descriptors (Ref. 5) could not be sufficiently defined to obtain the desired categorization accuracy. These categories were deleted from the S-192 band contribution comparison.

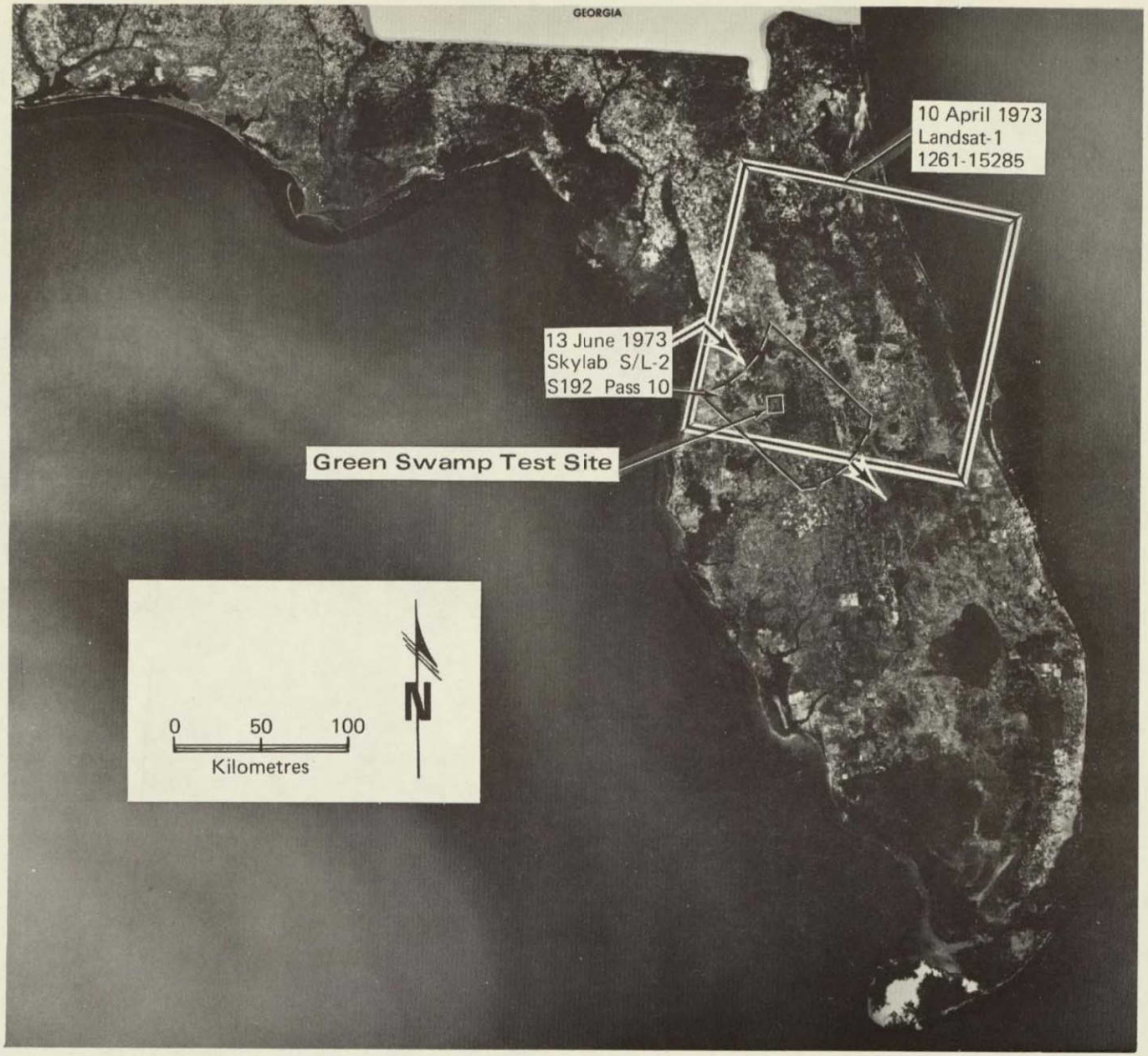

Figure 1 Location of the Green Swamp Test Site, Florida: Landsat color composite.

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Datagrid Digitizer

Preprocessing

Develop Earth to Satellite Coordinate Transformation

- Digitize Ground Control Points
- Designate Location of Training Areas
- Digitize Boundaries of Areas for which Area Printout Tables are Required; Watersheds, Counties, Townships and Other Boundaries

Multispectral-Data Analysis System (M-DAS)

Processing and Analysis

Produce Categorized Tapes

- Define Land-Water Categories and Locate Corresponding Training Areas within Data Tapes
- Compute Category Characteristics
- Evaluate Training Area Selection
- Transform Data Tapes into New Set of Tapes where Each Pixel is Coded to Correspond to Interpreted Land-Water Categories

Cal Comp Plotter

Final Processing

Generate Data and Map Products from Categorized Tapes

- Produce Transparent Color-Codes Overlay for Each Category; Typical Scales of 1:24,000, 1:62,500, and 1:250,000.
- Generate Color-Coded Imagery Where Color is Used as a Code to Designate Categories.
- Produce Tabular Computer Printouts Listing Area Covered by Land-Water Categories within Specified Political and Geographic Boundaries in Percent Coverage per Category, Acres, and Square Kilometers.

Figure 2 Elements of Bendix Earth Resources Data Center used in transformation and processing of data tapes.

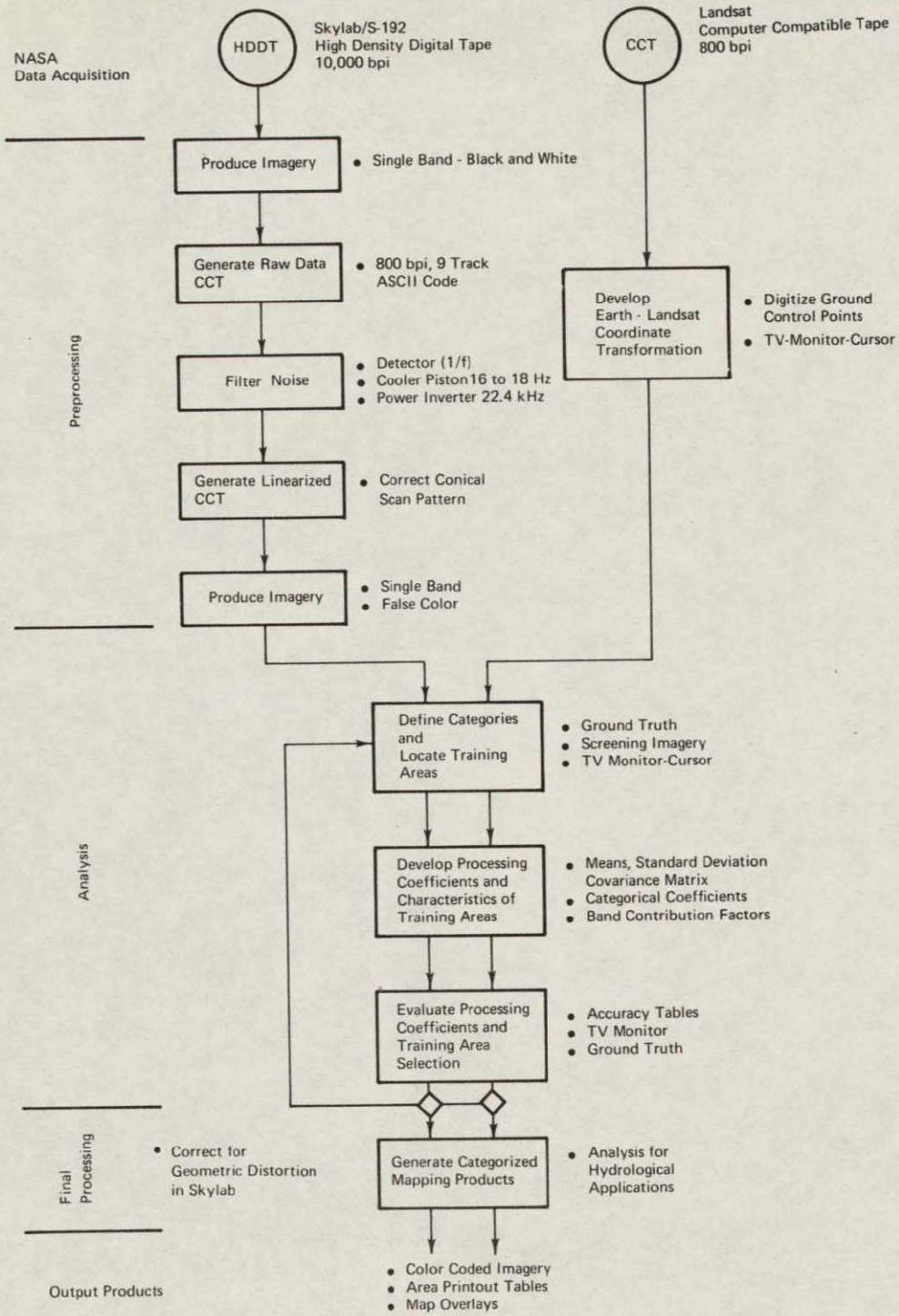

Figure 3 Flow diagram showing processing and analysis of Skylab S-192 and Landsat data.

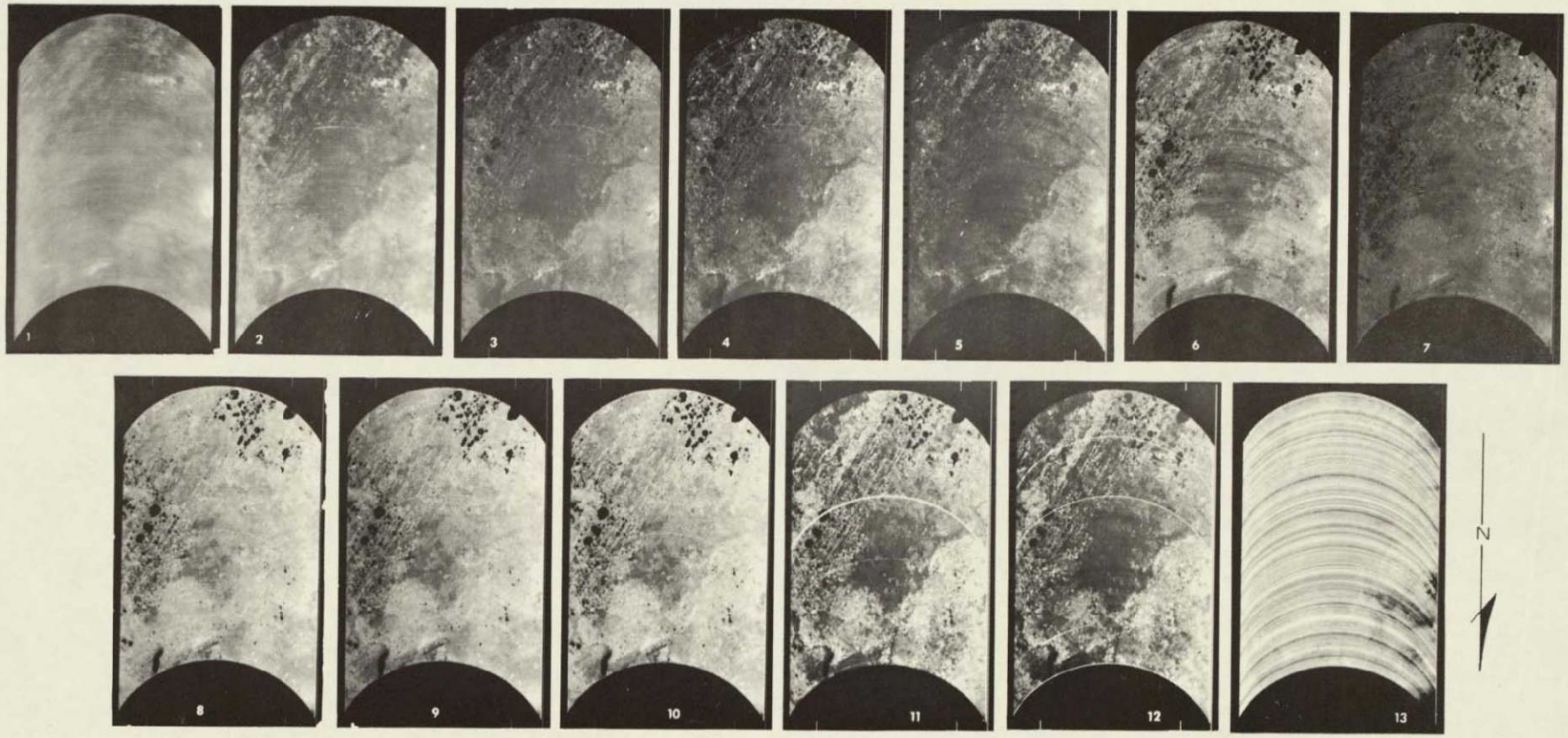

Figure 4. Skylab S-192 Imagery, Spectral Bands 1 through 13, of the Florida Green Swamp; S/L2 T-6 Pass 10, 13 June 1973

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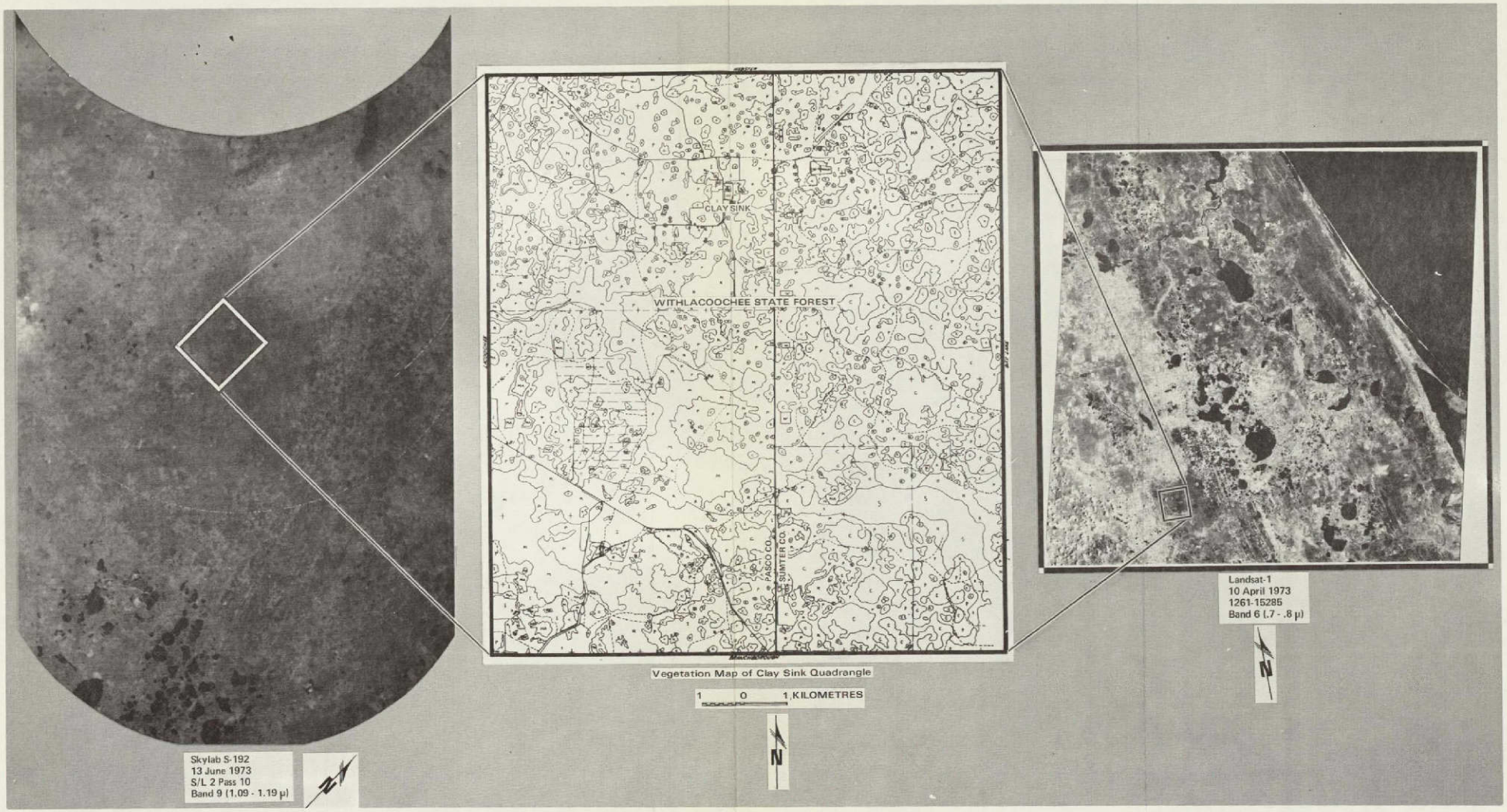

Figure 5 Location of Test Site with respect to Landsat-1 and Skylab S-192 coverage over Green Swamp, Florida.

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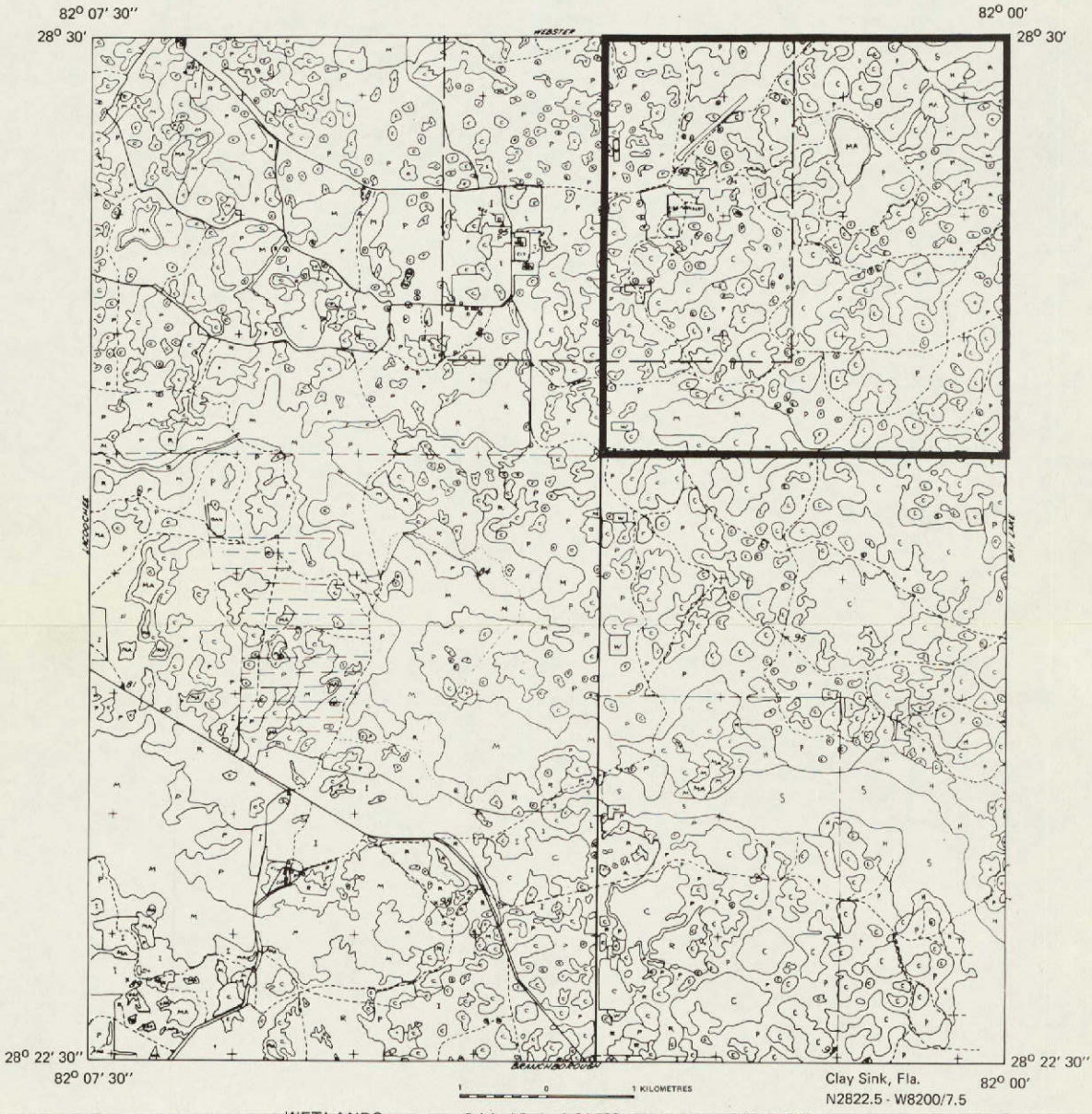
FOLDOUT FRAME 1



Original Scale 1:24,000

N

WETLANDS		PINE FLATWOODS		UPLANDS	
C	Cypress			P+	Pasture - Uplands
M	Mixed Swamp			OAK	Natural Uplands (Oaks)
S	River Bottom Swamp			CIT	Citrus
H	Mesic Hammock	P	Pine Flatwoods	I-F	Farm Lands
MA	Marshes	R	Rangeland	RES	Residential
W	Lakes, Borrow Pits	I	Improved Pasture	D	Disturbed Land

FOLDOUT FRAME 2

Figure 6 Vegetation map of Clay Sink Quadrangle, Florida used for ground truth identification in selection of training sets. Blocked in area is the test validation area between vegetative map categories and computer derived categories from Landsat-1 and Skylab data.

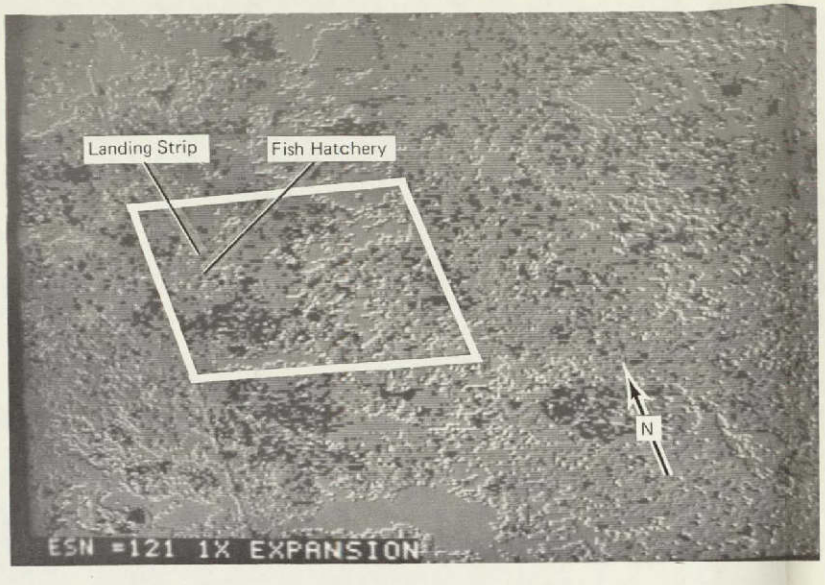
Category	Percent of Total	Acres	Square Kilometers
Uncategorized	25.88	4011.42	19.47
Water	0.73	135.27	0.55
Cypress	15.69	2926.59	11.80
Wetlands*	7.77	1444.32	5.84
Pine	38.97	7134.41	28.87
Pasture	11.58	2150.83	8.71
Totals	100.00	18592.83	75.24

* River Bottom Swamp, Mixed Swamp and Marshes

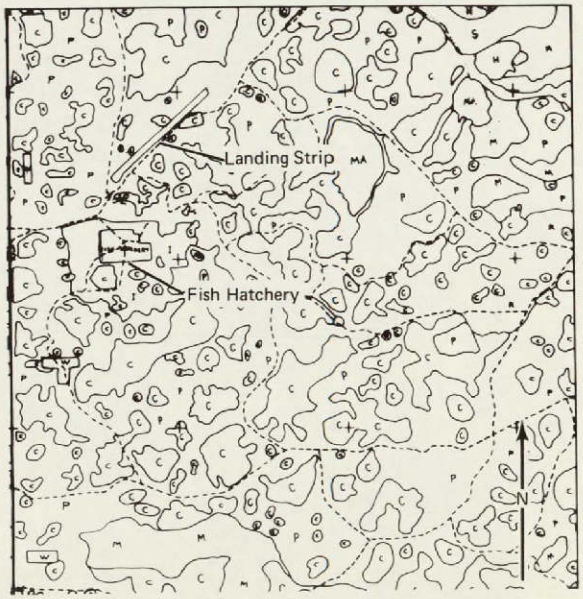
Figure 7 Area tabulation derived from Landsat data of sub-test site area a portion of which is shown in top center of figure 6.

FOLDOUT FRAME 1

Landsat-1 Categorized Data



Not to Scale



Approximately 8,000 acre section
of vegetation map of Clay Sink Quadrangle.

Explanation

Category	Map Code	Color: Landsat	Color: Skylab
Pine Flatwoods	P	Orange	Light Brown
Cypress	C	Red	Dark Brown
Pasture	I	Green	Green
Wetlands	W, M, S	Blue	Blue
Uncategorized	---	Black	Black

1 km

FOLDOUT FRAME 2

Skylab S192 Categorized Data

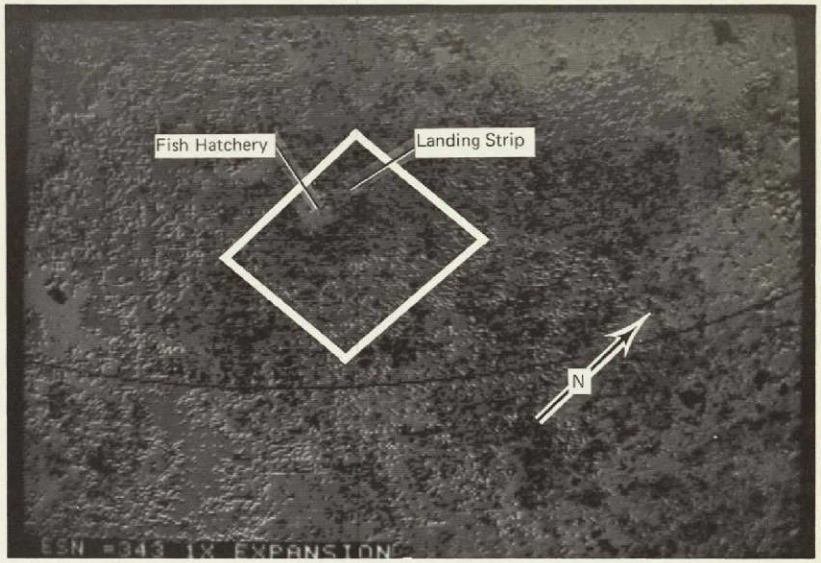


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Figure 8 Categorization performance for Landsat-1 and Skylab S-192 processed data and a vegetation map of approximately the same area.

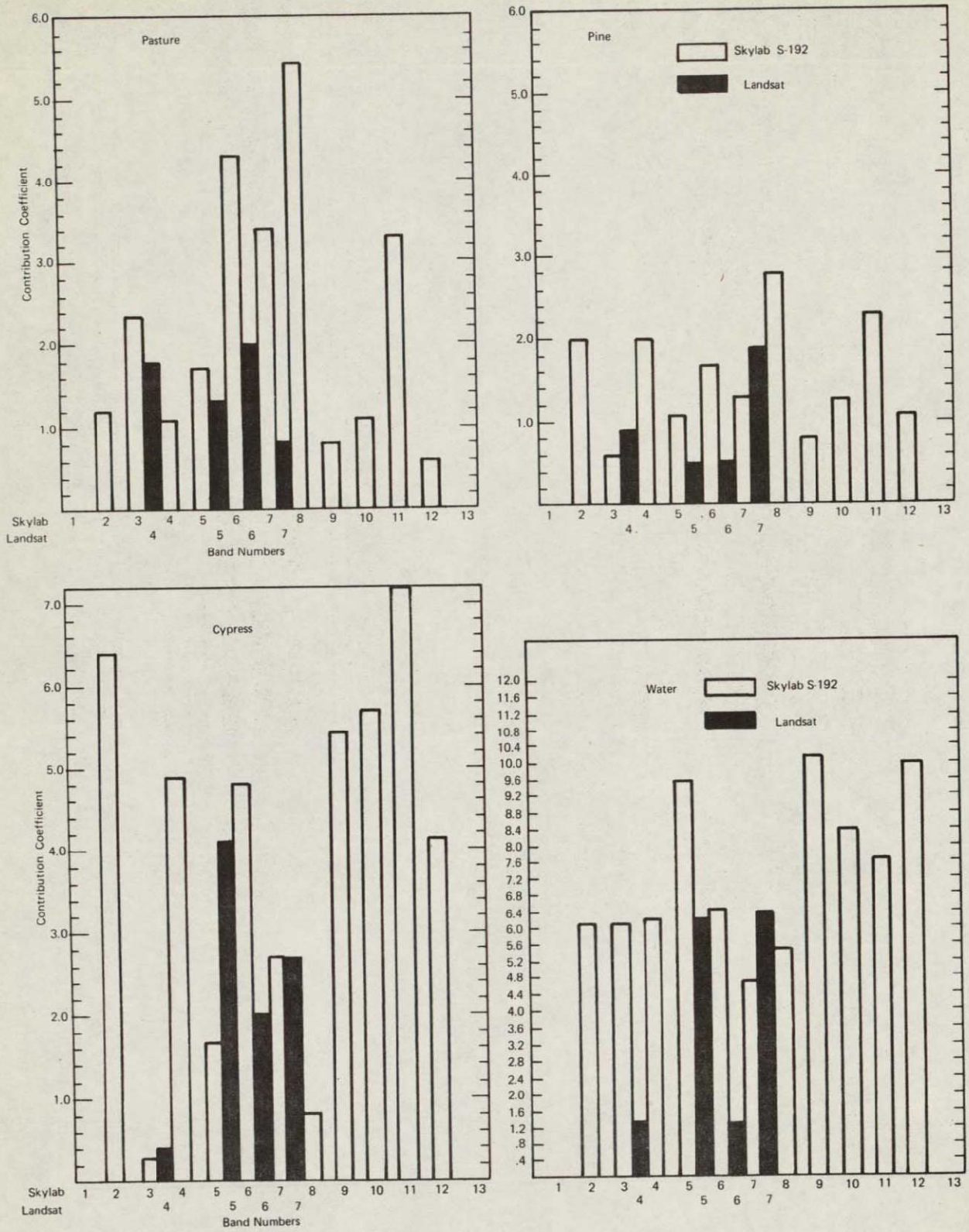

Figure 9 Band contribution coefficients for selected categories, derived from processing and analysis of Landsat and Skylab S-192 data.

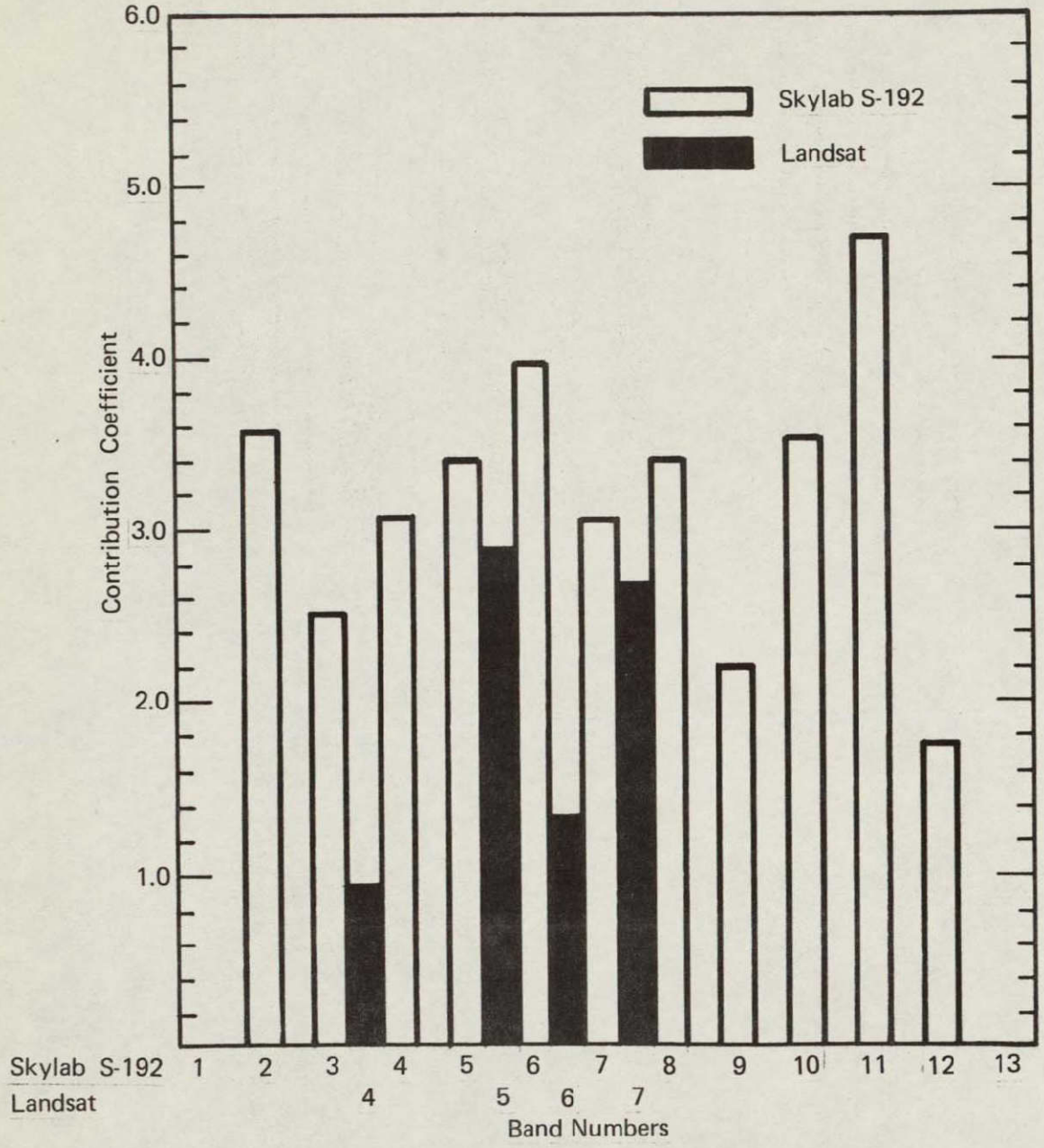

Figure 10 Band contribution coefficients for all categories, derived from processing and analysis of Landsat and Skylab S-192 data. Included in the categorical processing were seven Landsat categories and five S-192 categories.

Pasture, Pine, Cypress

Cypress

Figure 11. Aerial photographs showing vegetative categories in the Green Swamp, Florida.

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Mixed swamp

River bottom swamp

Figure 12. Aerial photographs showing wetland categories in the Green Swamp, Florida.

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@abs The author has identified the following significant results. Landsat 1 and Skylab (S192) data from the Green Swamp area of central Florida were categorized into five classes: water, cypress, other wetlands, pine, and pasture. These categories were compared with similar categories on a detailed vegetative map made using low altitude aerial photography. Agreement of Landsat and Skylab categoriezed data with the vegetation map were 87 percent and 83 percent respectively. The Green Swamp vegetative categories may be widespread but often consist of numerous small isolated areas, because Landsat has a greater resolution than Skylab, it is more favorable for mapping the small vegetative categories.