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# EVALUATION OF REMOTE SENSING TECHNIQUES ON SELECTED FOREST SITES IN FLORIDA



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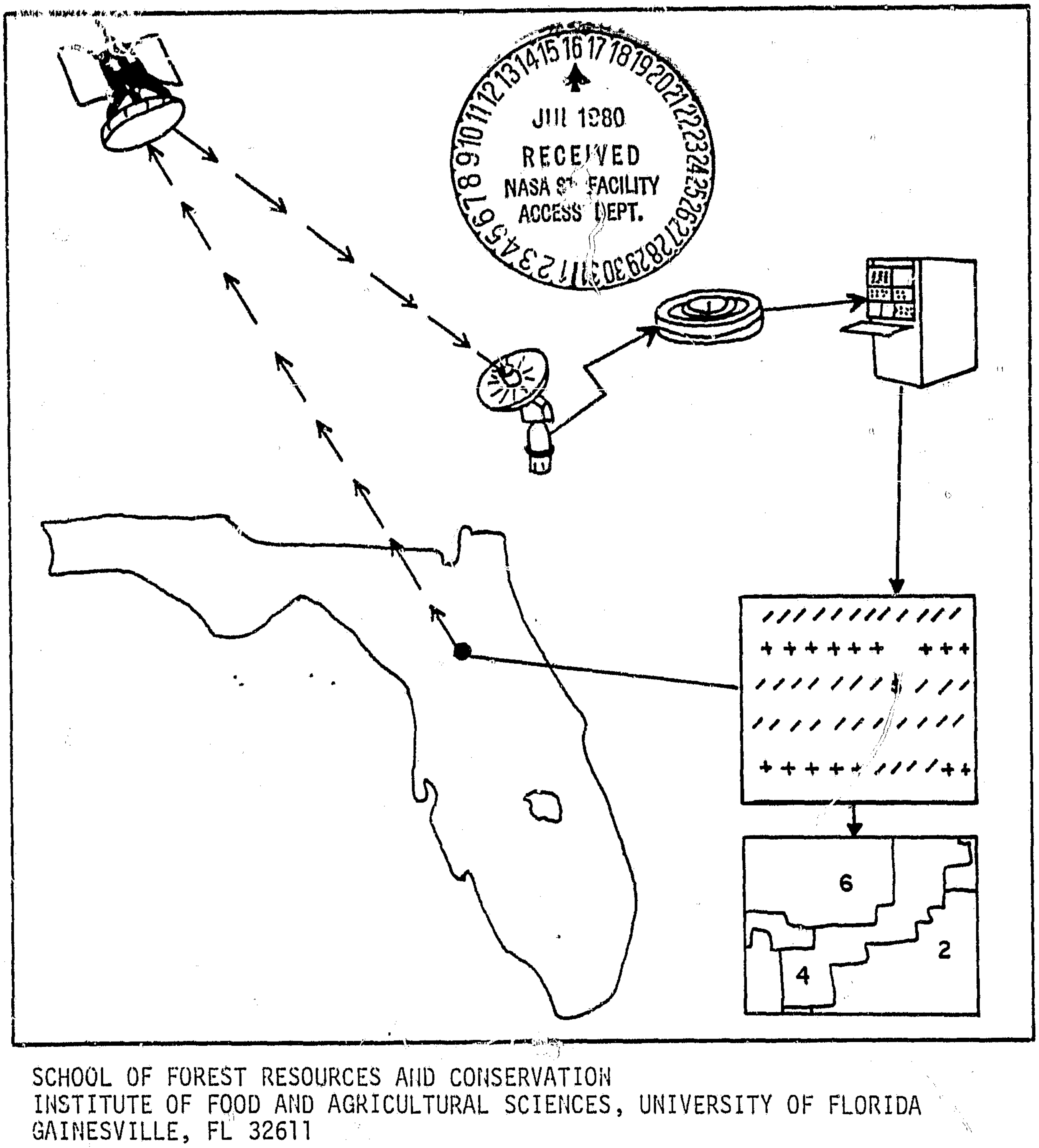


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# Evaluation of Remote Sensing Techniques

National Aeronautics and
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# EVALUATION OF REMOTE SENSING TECHNIQUES

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EROS Data Center

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## ABSTRACT

This report presents the results of a project supported jointly by NASA - Kennedy Space Center and the University of Florida in Gainesville. The main objective of the study was to evaluate the proximity of computer-generated character maps from satellite input data to actual ground cover conditions on two test sites in Florida. Two Landsat analyses techniques of those employed by the Science, Technology and Applications Branch at the Kennedy Space Center have been evaluated: the unsupervised clustering algorithm, called Landsat Signature Development Program (LSDP), and the interactive one based on the Multispectral Image Analyzer (Image 100). Both the potential and the limitations of the resulting maps are discussed, and suggestions are presented for future research. As part of the project, the LSDP family of computer programs has been converted to run on the Northeast Regional Data Center which serves the University of Florida. The programs may thus be accessed by other data centers of the State University System Computer Network.

## ACKNOWLEDGEMENTS

We are grateful to the National Aeronautics and Space Administration/ John F. Kennedy Space Center for funding the project and making whatever technical facilities were needed available to us. Roy A. Bland, Principal Technical Representative, has been very instrumental as a liaison between our team at the University of Florida and the J. F. Kennedy Space Center. Royce Hall, Computer Sciences Corporation at Kennedy Space Center has provided valuable computer programming assistance. The support of Reed Barnett, Chief, Science Technology and Applications Branch at Kennedy Space Center, is gratefully acknowledged. We wish to thank Diane Muscato for her diligent work in typing and arranging the material for this report. The cover page and most of the drawings were done by our talented illustrator, Joyce Lottinville. Expert editorial assistance has been provided by Sandra Buby.

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## INTRODUCTION

Developing and updating ground cover maps is of paramount importance to a wide array of users. Rational management of land resources in particular requires an accurate assessment of existing resource profile at given points in time, and respective changes over time. As conflicting uses of land and fresh water are intensified, the need to establish compatible regional, national, and international land use/land cover information systems is underlined by planning agencies of the public and nonpublic sectors alike.

Much progress has been made during the past three decades in supplementing planimetric and topographic maps with ground cover details obtained from aerial photographs. However, human photointerpretation is very tedious, time consuming, and thus, a costly process. At best it reflects relevant abilities as well as qualitative judgements of individual photo interpreters. Because of the time and cost involved, the updating of land use/land cover maps at frequent time intervals when needed is not always feasible.

The availability of satellite data, and the advantages offered by automatic machine processing of raw satellite data, have opened up new and exciting possibilities for developing ground cover maps. Several approaches have already been employed in machine recognition of spatial patterns and automatic display of ground features with minimal human intervention.

It was the main purpose of this limited study, which was supported jointly by NASA-Kennedy Space Center and the School of Forest Resources and Conservation at the University of Florida, to evaluate a small number of computer-generated ground cover maps from satellite input tapes.

## OBJECTIVES

The objectives of this study as specified by the contract were:

To familiarize a remote sensing working group of the School of Forest Resources and Conservation at the University of Florida with the Multispectral Image Analyzer (Image 100) and other remote sensing analyses techniques typical of those available at the Kennedy Space Center, and;

To test the applicability and operational feasibility of computer-generated character maps of Landsat satellite scenes of selected forest sites in Florida.

To make the LSDP program available to a wider audience at the University of Florida.

## STUDY PROCEDURE

The methodology adopted in this study has involved the following steps:

. Selection Criteria for the Study Area

. Test Sites

. Landsat Input Data

Fort Myers Test Site

Gainesville Test Site

. Satellite Data Processing System

. Interactive Image 100 Processing System

. General Purpose Computer Generated Maps

. Selection of Aerial Photographs

. Preliminary Evaluation of Computer Maps

. Test for Areal Correspondence

. Preparation of Overlays from Aerial Photographs

. Reference Data

. Area Estimation by Ground Cover Categories on Aerial Photo Overlays

. Preparation of Overlays and Acreage Estimation of Land Cover Types on the LANDSAT Computer Maps

. Analysis, Evaluation, and Discussion of the Results

. Conversion of the Landsat Analyses Computer Programs to Florida's State University System

SELECTION CRITERIA FOR THE STUDY AREAS

The following criteria have been used in selecting the study areas:

.Budget and time constraints

.Diversity of ground cover conditions

.Advance knowledge of the study areas

.Availability of Landsat input data

.Availability of recent aerial photography

## TEST SITES

On the basis of the above criteria, two test sites were selected. One test site is located in Alacnua, Bradford, and Union counties of north central Florida and covers an area of about 21 x 21 miles (Fig. 1). An imaginary north-south transect along the center of this test site begins just north of Gainesville at 29° 42' N latitude and 82° 15' W longitude. The transect ends at 32° 30' N latitude and 82° 15' W longitude. In terms of ground cover conditions, this test site is characterized among others by deciduous and non-deciduous hardwood forests, mixed softwoods-hardwoods, natural pine stands, pine plantations of various ages, grazing lands, cultivated fields, rivers, lakes, small towns, and scattered residential areas.

The other test site is located in southwestern Florida near the city of Fort Myers and covers part of Lee County (Fig.2). This test site is approximately 20 miles along the east-west direction (longitude 81° 40' W to 82° 00' W) and 23 miles along the north-south direction (latitude 26° 21' N to 26° 41' N). The main ground cover features of this test site include mixed hardwood and softwood forests, cultivated and open uncultivated fields, residential areas, part of the city of Fort Myers, mining pits (some filled with water), and a section of the Caloosahatchee River.

The topography of both test sites is relatively flat. A list of predominant tree and shrub species by site is included in Appendix B, while the main soil types are listed in Appendix C.

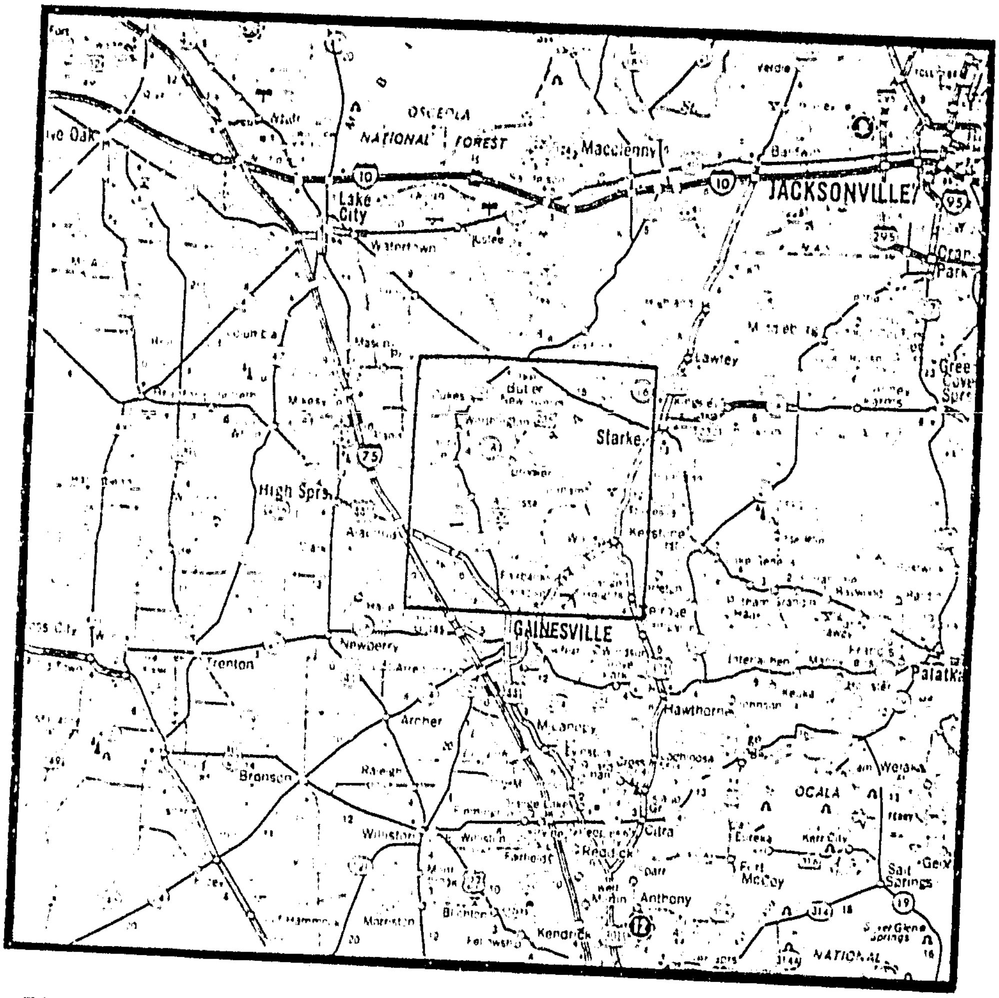


Fig. 1. Gainesville test site.

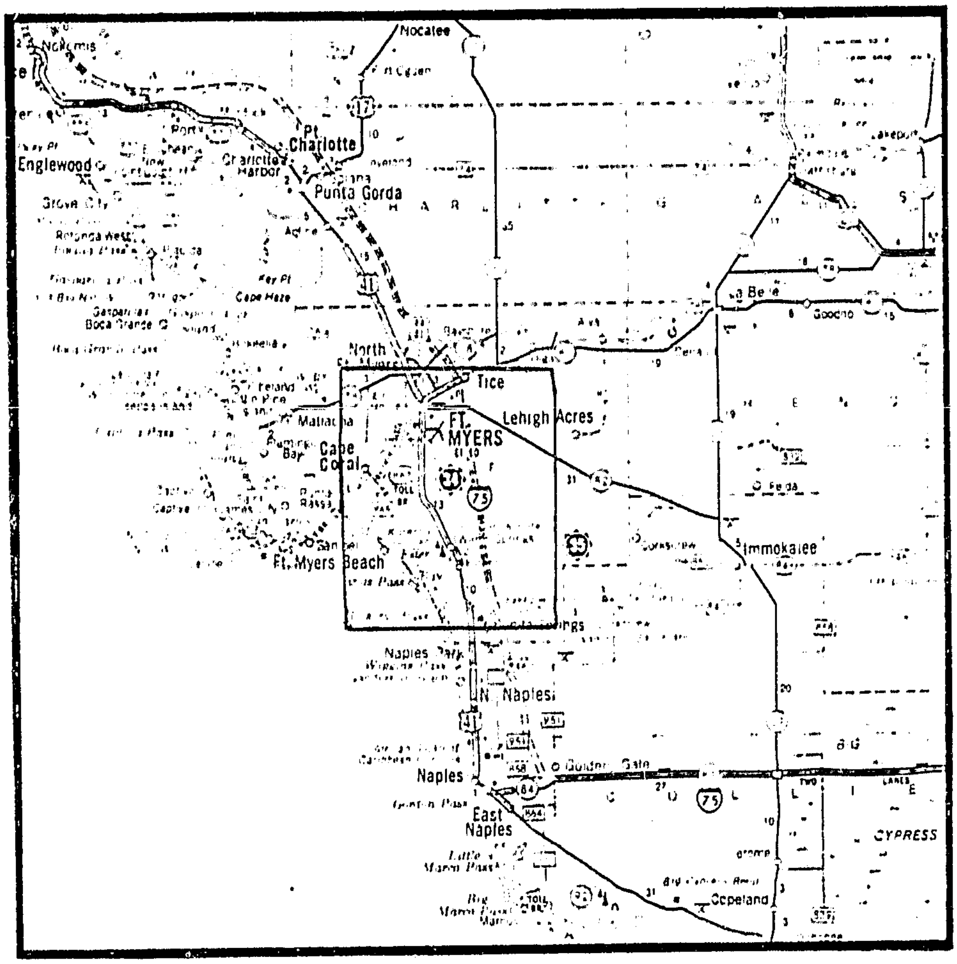


Fig. 2. Fort Myers test site.



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## LANDSAT INPUT DATA

For this study, the following satellite input data was used:

### Fort Myers Test Site

March 4, 1975 - Landsat Scene Identification No. 2041-15174

February 21, 1977 - Landsat Scene Identification No. 20761-15023.

### Gainesville Test Site

April 17, 1977 - Landsat Scene Identification No. 20816-15024

October 14, 1977 - Landsat Scene Identification No. 20996-14544.

The selected dates were partially dictated by the availability of raw data and the need to evaluate possible changes over a short time interval (1975 to 1977), as well as within-year seasonal variation (April vs. October, 1977).

## SATELLITE DATA PROCESSING SYSTEM

Presently users of the satellite data at the Kennedy Space Center (KSC) Applications Projects Branch employ several Landsat analyses techniques, two of which have been evaluated in this study: the unsupervised clustering algorithm, called Landsat Signature Development Program (LSDP), and the interactive one based on the Multispectral Image Analyzer (Image 100). The LSDP and three companion programs written in FORTRAN V, namely, the Landsat Geometric Correction Program (LGCP), the Landsat Signature Comparison Program (LSCP), and the Landsat Classification and Mapping Program (LCMP) are briefly described in Appendix A.

## INTERACTIVE IMAGE 100 PROCESSING SYSTEM

The Image 100 (Fig. 3) is designed to accommodate data in the format received from the Landsat input tapes. It enables users to interact with the data on a real-time basis.

By training on small samples of known characteristics, all other areas of a given Landsat scene with a similar signature can be displayed on a color CRT within seconds. Up to eight themes of the same scene can be displayed simultaneously. Through a suitably scaled Gould line printer, character maps can be subsequently produced to closely approximate the 1:24000 scale of the US Geological Survey (USGS) quadrangle sheets used in this study.

## GENERAL PURPOSE COMPUTER-GENERATED MAPS

LSDP 1:24,0000 computer maps of the four Landsat scenes were produced by the KSC Honeywell 635 computers. These were run at several chi-square confidence levels which control the number of resultant clusters. That is, the cluster statistics cannot change more than the selected chi square value will allow. A confidence level of 95 percent would produce more clusters than the more demanding confidence level of 99 percent. It was concluded that 98- and 99 percent confidence levels produced the most useful number of classes, and these were the only maps considered. Each of the character maps covers an area of 520 x 520 pixels (465 square miles). For an area of about 130 x 130 pixels (29 square miles), LSDP maps were also produced at the 98 percent level of confidence for both sites and

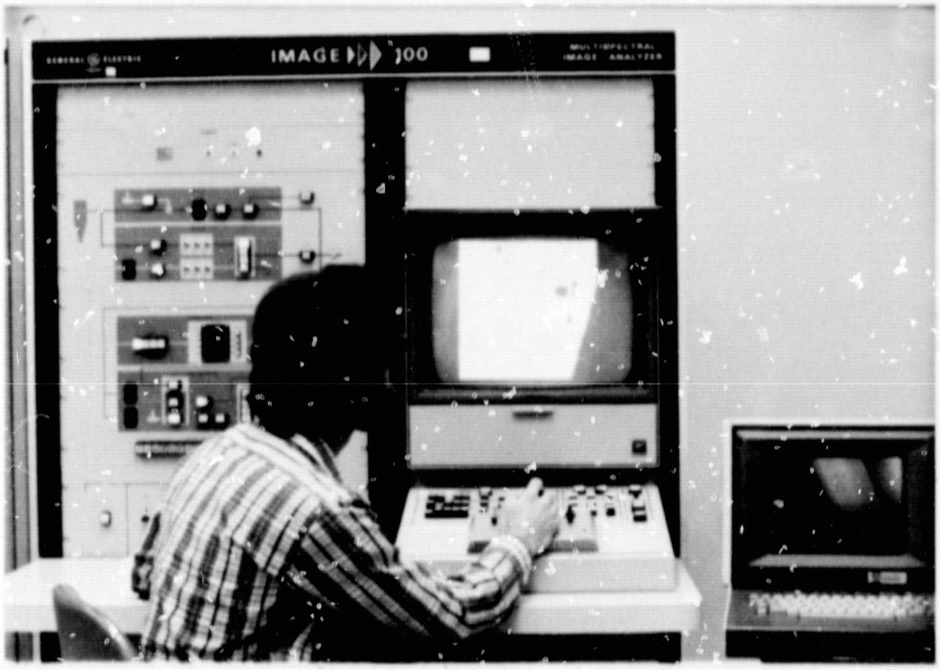


Figure 3. Image 100 at NASA-Kennedy Space Center.

dates. The purpose was to find out whether computer-generated maps of smaller areas provide a better proximity to actual ground conditions -- due to smaller variations in spectral reflectance -- than those covering relatively larger areas.

LCMP 1:24,000 maps were also produced at confidence levels corresponding to LSDP maps, but only those at the 98% confidence level were used in this study. LCMP receives its input from LSDP generated data and can improve the cluster statistics before final mapping, usually producing a somewhat more accurate map, leaving less areas unclassified than do the LSDP maps. KSC personnel anticipate removing LCMP as a separate program with the merger of its more vigorous statistical routines into the LSDP algorithm.

SELECTION OF AERIAL PHOTOGRAPHS

The most promising computer maps for both test sites were subsequently compared against corresponding USGS maps and aerial vertical photographs of the same 1:24000 scale. Although some recent aerial photos were available, it was decided to use Mark Hurd's black and white panchromatic ones taken in 1973. There are certain small segments of the Fort Myers test site where appreciable changes have taken place since 1973, especially around the city. But the largest portions of both test sites have more stable ground cover conditions, such as forests, agricultural lands, rivers, other water bodies, etc. Based on firsthand knowledge of the test sites, it was determined that the Mark Hurd photos provided a good and uniform basis for comparison, especially since they were of the same scale as the computer-generated maps.

PRELIMINARY EVALUATION OF COMPUTER MAPS

As an initial step, the LSDP, LCMP, and the Gould maps for both sites were overlaid on 1:24000 USGS quadrangle maps (1966 Edition). Characteristic ground features such as lakes, rivers, highways, roads, and coast lines from the USGS maps were used to establish reference points on the computer-generated maps.

The Austin Cary Forest (ACF) and the Beef Research Unit (BRU) of the University of Florida in the Gainesville test site were selected for the preliminary evaluation of the computer maps. The ACF includes natural and planted pine stands, bottomland hardwoods, cypress, and recently logged-planted areas. The BRU has mainly grazing lands and cultivated fields (light and dark tone). Some tree islands and cypress domes are also present. Vertical 1:10000 black and white aerial panchromatic photos taken on 10/5/77 were available for preliminary field and laboratory work.

In the Ft. Myers test site, a sample area was selected within another intensive remote sensing study (Arvanitis, 1978). As a reference base, we have used black and white 1:24000 aerial photographs as well as color infrared transparencies taken in 1978. This sample area includes forest areas, open cultivated or uncultivated fields, a river, small ponds, and scattered houses.

As a first step, the ACF, BRU, and the Ft. Myers sample areas were located on the computer maps. Major ground features delineated on aerial photos were identified on the Landsat maps, and a list was made of the computer symbols representing those features. It was observed from the beginning that in several locations more than one symbol was used by the computer maps to denote the same ground cover condition. Also, the same symbol was sometimes used to represent more than one ground cover classification.

In comparing the computer-generated maps to the aerial photos attention was given to determining whether the maps could depict specific ground features. Such features include forests (hardwoods, softwoods, mixed), cultivated fields, grazing lands, uncultivated open fields, recently logged and/or planted parcels, large bodies of fresh and salt water, rivers, as well as residential/industrial areas.

The next step was to use the selected preliminary classifications to identify similar areas on the computer maps. It was observed that the LSDP machine-processed maps at the 98 and 99 percent confidence levels and the corresponding LCMP maps produced the best results. Subsequently, all other maps at 95, 96, 97 and 99.8 percent confidence levels were eliminated from further consideration since they were not consistent in depicting ground cover conditions of the test sites.

## TEST FOR AREAL CORRESPONDENCE

Geographers have been using a procedure called areal correspondence to quantify the degree of agreement between two map overlays depicting various categories of the same ground area but developed from two different sources, say, aerial photographs and computer-generated maps.

For this study, two sample areas, representing a wide range of ground cover classifications, and covering approximately 4,200 acres each, were selected in the Gainesville test site. The objective was to evaluate the one-to-one areal correspondence of major ground cover categories, as outlined on the Mark Hurd aerial photographs, and the computer-generated map (Figs. 4 to 7). A grid of 1,050 square plots -- each covering 4.02 acres -- was superimposed on each of the four overlays developed from the aerial photographs and the respective computer-generated maps.

A simple random sample of 100 square plots was selected without replacement to estimate the one-to-one areal correspondence between aerial photographs and the machine processed maps.

From the results of this comparison it became obvious that features covering small ground areas, such as roads, narrow rivers, clusters of houses, ponds, and the like, are obscured by the edge effect of the surrounding dissimilar areas. The resolution of computer-generated maps diminishes beyond a certain point. However, overall we were convinced that comparing acreages by categories, as depicted by the various computer-generated maps and those delineated on the Mark Hurd aerial photographs, for the same scene may provide an insight into the capabilities and limitations of the Landsat maps.[1/]

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[1/] In a recent article, Ginevan (1979) suggested use of acceptance sampling in evaluating the accuracy of computer-processed land cover maps. Basically, this approach deals with the determination of the "optimal" number of ground truth samples and the "allowable" number of misclassifications of these samples.

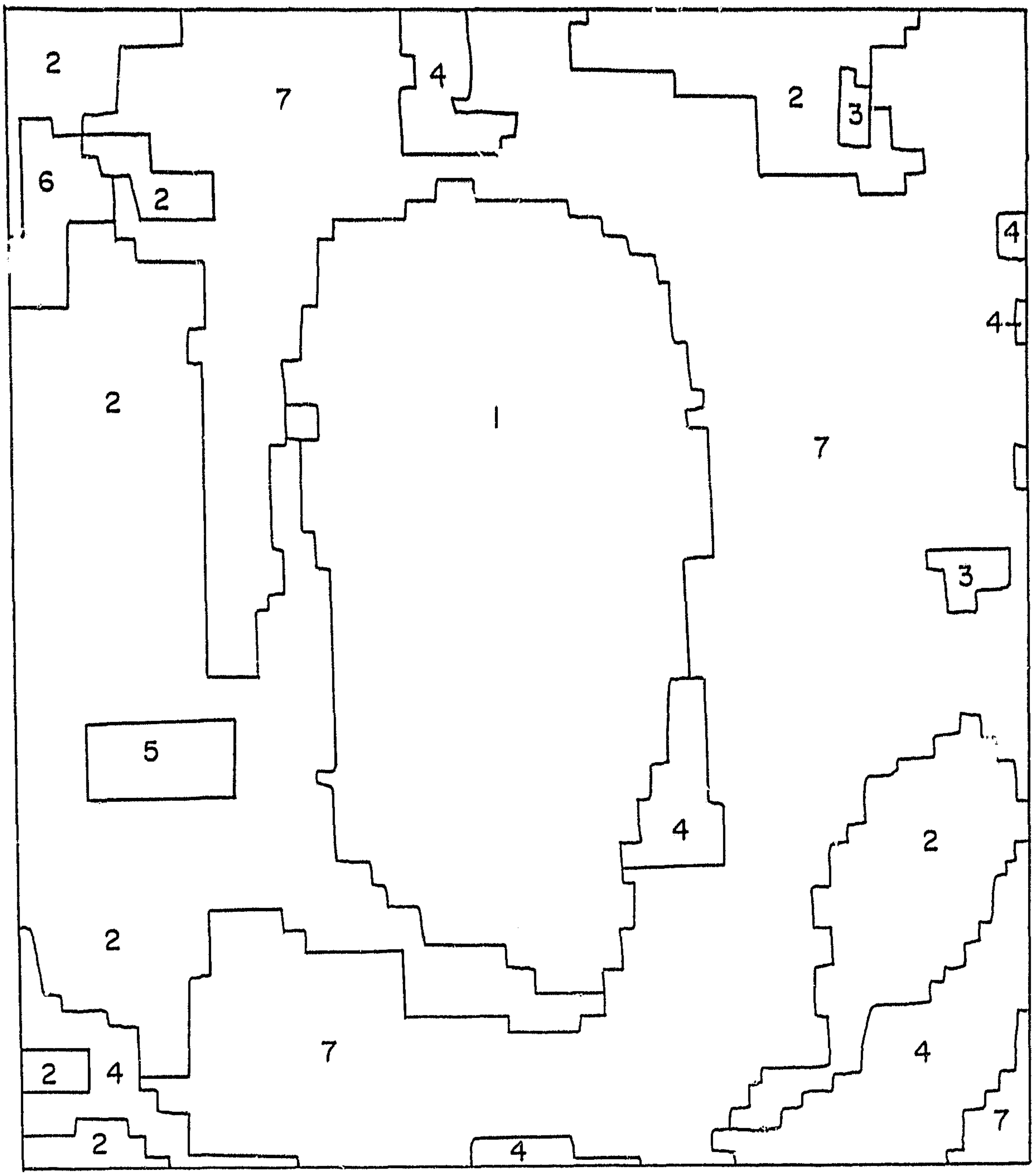



Fig. 4. A section of the April 17, 1977, LCMP computer map showing Hampton Lake. The numbers refer to the ground classification of the Gainesville test site.

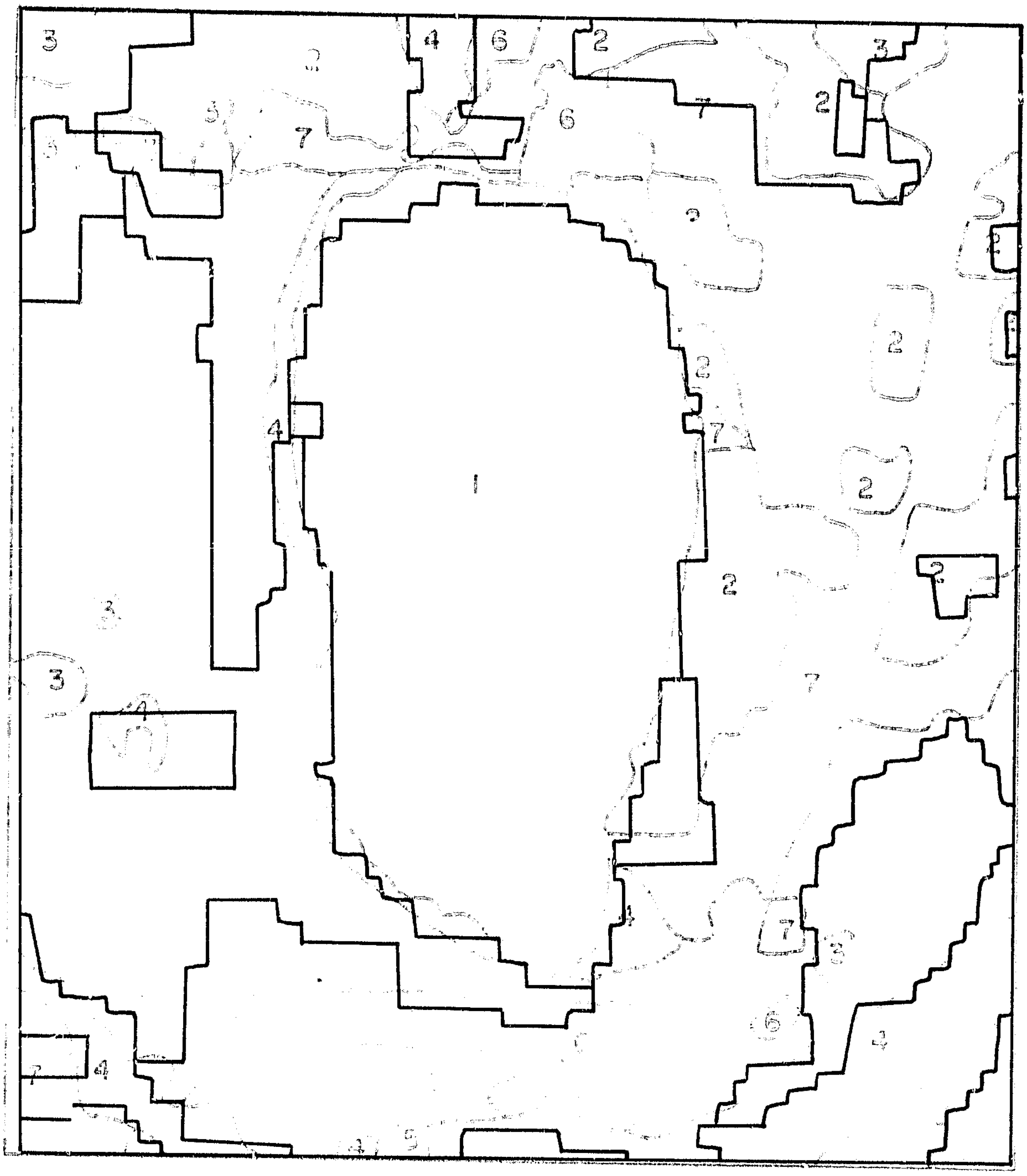


Fig. 5. A section of a Mark Hurd aerial photograph showing Hampton Lake. The numbers refer to the ground classification of the Gainesville test site.

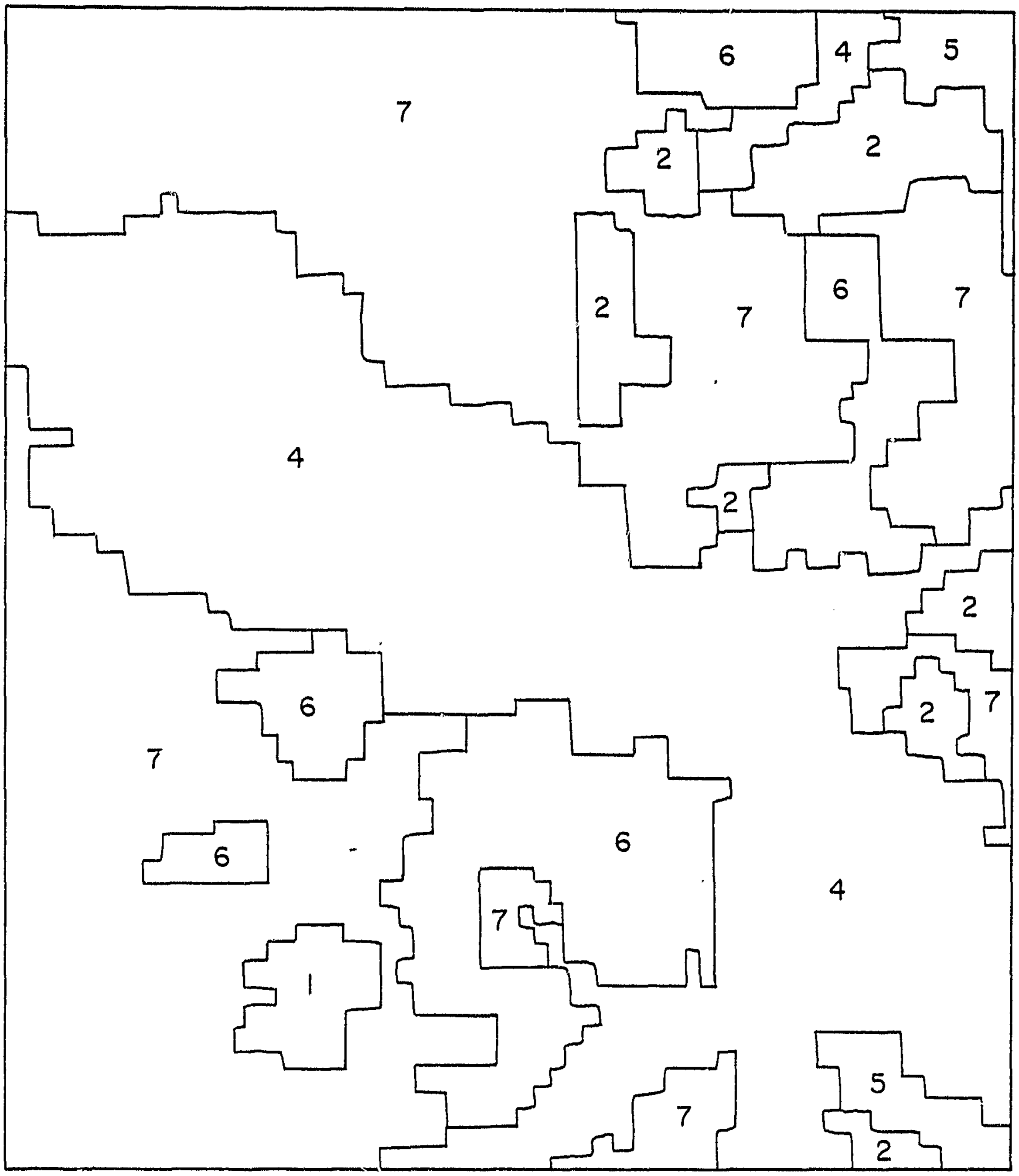



Fig. 6. A section of the April 17, 1977, LCMP computer map showing the Santa Fe River. The numbers refer to the ground classification of the Gainesville test site.

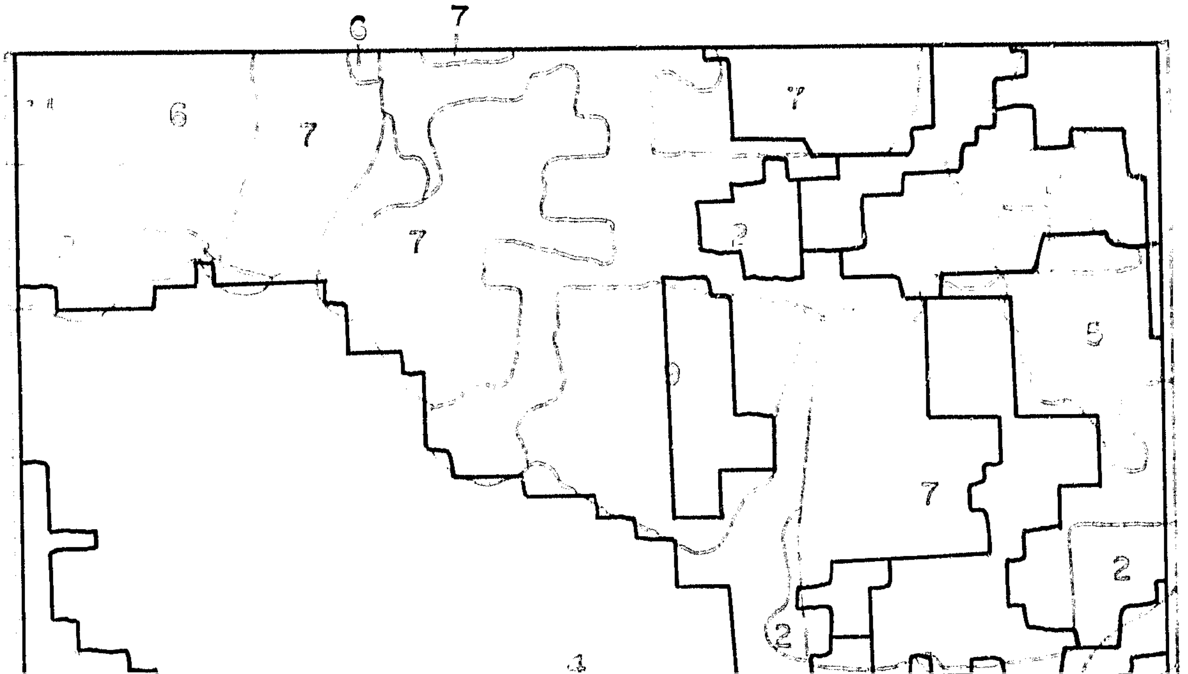



Fig. 7. A section of a Mark Hurd aerial photograph showing the Santa Fe River. The numbers refer to the ground classification of the Gainesville test site.

Also, from this part of the study the following ranking scale for boundary delineation of the various cover types on the computer-generated maps and the Mark Hurd aerial photographs has been developed:

| Rank | Description |
|---|---|
| 1 | Boundary lines are clearly defined. |
| 2 | Edge effect and diffusion introduce some difficulties in the delineation. |
| 3 | Increasing uncertainties on exact boundary line location. |
| 4 | Less than 30 percent of the various ground cover categories may be correctly delineated. |

PREPARATION OF OVERLAYS FROM AERIAL PHOTOGRAPHS

For the set of selected computer maps of both test sites and dates, overlays have been prepared on frosted acetate.

One larger area and a smaller one were selected for detailed acreage estimation. The objective was to determine whether the size of an area affects the overall acreage estimation by categories. Because of budget constraints, the Image 100 maps were evaluated only for the smaller size areas. For the Gainesville test site, the two areas selected for a detailed evaluation were about 95,000 acres and 23,000 acres, respectively. For the Fort Myers test site, the areas were approximately 68,000 and 25,000 acres, respectively.

REFERENCE DATA

A sampling scheme was employed to collect reference data from the aerial photographs that would enable us to identify the major ground cover types on the Landsat computer maps. A grid of 3,380 plots -- 1 square inch in size, each representing 88 acres -- was superimposed on the aerial photos and the selected Landsat computer maps. A 10 percent sample, or 338 plots, were systematically selected for evaluation. On each of the 338 plots on the aerial photos, ground cover types were recorded along with the corresponding character elements on the computer maps. This information was then used to identify the major ground cover types on the Landsat computer maps.

During this evaluation process those sections of the computer-processed maps which appeared to deviate considerably from the photo-interpretation results were marked and verified in the field. Subsequently 34 plots -- 12 in the Gainesville test site and 22 in the Ft. Myers test site -- were identified for field verification of the actual ground features. When applicable, data were collected on tree size, soil color (light or dark tone), and understory species.

In the Gainesville test site the major changes that have occurred since 1973 were due to logging operations of forest areas. In Ft. Myers interim changes were attributed primarily to the expansion of the industrial, commercial, and residential areas.

AREA ESTIMATION BY GROUND COVER CATEGORIES ON AERIAL PHOTO OVERLAYS

Acreages on the photo overlays for various strata were determined as follows:

First, the average photo scale was determined by measuring photo and corresponding ground or map distances.

Then, the appropriate photo scale conversion factor was used in the LASICO Rolling Disk Electronic Planimeter, which was programmed to measure acreage in acres.

The various strata on each overlay were planimetered three times, and the average of the three readings was used in the analysis.

## PREPARATION OF OVERLAYS AND ACREAGE ESTIMATION OF LAND COVER TYPES ON THE LANDSAT COMPUTER MAPS

Overlays were also prepared for the individual Landsat computer maps based on the key developed previously from the reference data. Delineation of boundary lines and preparation of overlays for the Gould maps were made by the same person who themed the various ground cover categories.

Acreages for each classification on the computer map overlays were estimated by counting the number of pixels for each ground cover category (1 pixel x 1.1 acres).

## ANALYSIS OF THE RESULTS

In general, the acreage estimation by land cover categories indicates that as the number of classifications decreases below four, or increases above twenty-four, the agreement between the computer maps and the actual ground conditions is weakened. Within this range, the overall correspondence tends to increase inversely proportionally to the number of classifications.

The Florida Division of State Planning distinguishes seven major land classifications on conventional vertical aerial photographs (Appendix D):

| | |
|---|---|
| Urban or Built-up Lands | Water |
| Agricultural Lands | Wetlands |
| Rangelands | Barren Lands |
| Forest Lands | |

Tables 6 and 18 include the breakdown of major classifications identified in the Ft. Myers (8 classes) and the Gainesville (9 classes) test sites. No reliable distinction between agricultural and rangelands was possible on the computer maps. Therefore, they were combined to form one or two major classifications depending on tonal contrasts (light or dark fields) of each test site.

There was some speculation that the smaller size maps (130 x 130 pixels) may provide a better representation of ground cover categories than the larger ones (520 x 520 pixels). Comparative results for both sites indicate that there was no significant improvement in the outcome. On this basis, the smaller computer maps were eliminated from further consideration.

The LCMP maps were selected in three out of four cases as more promising than the corresponding LSDP maps. For the Gainesville test site, the 10/14/77 LSDP map was selected as being more accurate than the corresponding LCMP one.

The following are more detailed results pertaining to both test sites.

FORT MYERS TEST SITE

A careful evaluation of all LSDP and LCMP computer-generated maps has revealed that for both dates of input data, namely 3/4/75 and 2/21/77, the best maps were the LCMP ones. In addition, two Gould printer maps -- one for each date -- were also produced from theme development in the Image 100.

The LCMP and Image 100 maps depict water, urban areas (residential, industrial and commercial), cultivated fields as well as forested and/or small, natural open fields at a satisfactory level of accuracy (69 to 89 percent).

The number of character elements used by LCMP and Image 100 maps were different for each of the two dates (Table 1).

Table 1. Number of character elements of LCMP and Image 100 maps for an area 520 x 520 pixels. Fort Myers test site.

| Input Data | Computer Map | No. of Character Elements |
|---|---|---|
| March 4, 1975 | LCMP | 24 |
| | Image 100 | 8 |
| February 21, 1977 | LCMP | 18 |
| | Image 100 | 10 |

The LCMP computer maps employed different character elements to denote a specific ground or water category. More than one character element was used for a particular ground classification, and more than one ground classification were depicted by the same character element (see Appendix E). Tables 2 through 5 provide details of the various ground features identified on each of the LCMP and Image 100 maps along with their boundary delineation scale as previously described.

Table 2. Ground features identified on the LCMP computer map with boundary delineation scales. Input data 3/4/75. Fort Myers test site.

LCMP 3/4/75 — 24 Character Elements

| Classification Index No. | Boundary Delineation Scale | Ground Feature |
|---|---|---|
| 1 | 1 | Water |
| 2 | 4 | Mangroves |
| 3 | 2 | Forest areas and/or small, open uncultivated fields |
| 4 | 2 | Cultivated fields |
| 5 | 4 | Residential, commercial, and industrial areas |

Table 3. Ground features identified on the LCMP computer map with boundary delineation scales. Input data 2/21/77. Fort Myers test site.

LCMP 2/21/77 — 18 Character Elements

| Classification Index No. | Boundary Delineation Scale | Ground Feature |
|---|---|---|
| 1 | 1 | Fresh water |
| 2 | 1 | Salt water |
| 3 | 4 | Forest areas and/or small, open uncultivated fields |
| 4 | 3 | Cultivated fields |
| 5 | 4 | Residential, commercial, and industrial areas |

Table 4. Ground features identified on the Image 100 map with boundary delineation scales. Input data 3/4/75. Fort Myers test site.

Image 100 3/4/75 — 8 Character Elements

| Classification Index No. | Boundary Delineation Scale | Ground Feature |
|---|---|---|
| 1 | 1 | Water |
| 2 | 3 | Mangroves |
| 3 | 2 | Forest areas and/or small, open uncultivated fields |
| 4 | 4 | Cultivated fields |
| 5 | 3 | Residential, commercial, and industrial areas |

Table 5. Ground features identified on the Image 100 map with boundary delineation scales. Input data 2/21/77. Fort Myers test site.

Image 100 2/21/77 — 10 Character Elements

| Classification Index No. | Boundary Delineation Scale | Ground Feature |
|---|---|---|
| 1 | 2 | Water |
| 2 | 1 | Forested areas and/or small, open uncultivated fields |
| 3 | 3 | Cultivated fields |
| 4 | 4 | Residential, commercial, and industrial areas |

On the February 21, 1977, LCMP map it was possible to differentiate fresh from salt water. This may have been a coincidence, since we were unable to make a similar distinction on the March 4, 1975, LCMP map and on the Image 100 maps for both dates.

Mangroves were depicted only on the March 4, 1975, LCMP and the Image 100 maps. One explanation may be that during the elapsed period of time increasing urbanization of the coastal regions disturbed the mangrove boundaries which could not be accurately identified on the February 21, 1977, maps.

Reference data were based on vertical panchromatic aerial photographs supplemented by field observations. The following ground classifications were delineated on aerial photos:

Table 6. Ground features identified on the Mark Hurd aerial photographs -- 1973 and boundary delineation scales. Fort Myers test site.

Aerial Photographs - 1973

| Classification Index No. | Boundary Delineation Scale | Ground Feature |
|---|---|---|
| 1 | 1 | Fresh water |
| 2 | 1 | Salt water |
| 3 | 2 | Mangroves |
| 4 | 2 | Dense forest areas |
| 5 | 2 | Natural open fields and grazing areas with scattered trees |
| 6 | 2 | Light tone (sandy) cultivated fields |
| 7 | 3 | Dark tone cultivated fields |
| 8 | 1 | Residential, commercial, and industrial areas |

Not all ground features identified on the aerial photos were depicted by the LCMP and Image 100 maps. For both dates, dense forest areas (class 4), and small (less than 20 acres), uncultivated fields (class 5) were combined. We were unable to delineate uncultivated fields because of their sporadic occurrence and small size.

Light tone and dark tone cultivated fields (class 6 and 7, respectively) were combined since it was not possible to detect differences in tonal contrasts.

For the March 4, 1975, LCMP map and both Image 100 maps, fresh and salt water were combined. Also, mangroves were not separated from the forested areas on the February 21, 1977, maps.

As one may anticipate from the available Landsat resolutions, there was no reliable way of identifying small, individual ground features with any degree of assurance on the computer-produced maps. Only in an abandoned residential area was it possible to relate individual character elements to ground features such as dirt roads and small clumps of pine trees. As explained in a previous section, all comparisons of distinguishable strata delineated on aerial photos and the various computer-generated maps were made on an acreage basis.

LCMP: March 4, 1975.

The results are summarized in Table 7. In this and all subsequent similar tables some minor discrepancies in the total acreage between aerial photos and computer generated maps may be noticed. Such small discrepancies are attributed to rounding errors among the various ground cover categories.

Table 7. LCMP map area estimation by ground cover categories. Input data 3/4/75. Tract size about 68,000 acres. Fort Myers test site.

| Ground Cover Classification | Area, Acres Aerial Photos | LCMP | Percent | Accuracy, Percent |
|---|---|---|---|---|
| Water | 14489 | 15647 | .231 | 92.0 |
| Mangroves | 8954 | 6511 | .096 | 72.7 |
| Forest areas and/or small open uncultivated fields | 28345 | 27255 | .402 | 96.2 |
| Cultivated fields | 10328 | 10612 | .156 | 97.2 |
| Residential, commercial and industrial areas | 5573 | 7835 | .115 | 59.4 |
| Totals | 67689 | 67860 | 1.000 | |
| Weighted mean accuracy | | | | 88.9 ± 12.6 |

With the exceptions of mangroves and residential/industrial areas, the other three categories were reasonably well classified.

Mangroves occur mostly in narrow strips along the shoreline. Other scattered small mangrove islands one to eight acres in size were not differentiated from their immediate surroundings, and as a result their total area was underestimated.

Scattered residential, industrial, or commercial areas constitute a relatively small portion of the total mapped area. In the majority of cases they were depicted as cultivated fields, which usually surround cites, and were overestimated.

Relatively large bodies of water were properly classified by the LCMP map with a 92% accuracy. However, this was not the case with small ponds and creeks, where there is a considerable edge effect. Also, there was no differentiation between fresh and salt water.

Cultivated fields were mapped correctly within 2.8%. Forest areas do not form a continuum in this test site. Small parcels are intermixed with uncultivated fields, grazing, or burned areas. Thus, forests were not depicted as such by LCMP. When combined with open uncultivated fields, the result was within 3.8% of the actual ground conditions.

The mean accuracy x for each computer generated map was calculated by the following formula:

$$x = \sum_i x_i \; p_i$$

where $x_i$ is the percent of agreement of the ith ground cover category between a computer-generated map and the corresponding one, which represents the actual ground cover. The latter type of maps were developed from aerial photographs, USGS maps, and field observations.

$p_i$ is the percent of the ith ground cover category on a given computer-generated map.

The variance of x is given by:

$$Var(x) = (\Sigma_i x_i^2 \; p_i - x^2) \quad ,$$

and the standard deviation s by the square root of the Var (x).

In this case, the overall weighted mean accuracy of 88.9% with a standard deviation of ± 12.6% is considered to be satisfactory.

For the smaller size area of about 25,000 acres, the results are summarized in Table 8.

Table 8. LCMP map area estimation by ground cover categories. Input data 3/4/75. Tract size about 25,000 acres. Fort Myers test site.

| Ground Cover Classification | Area, Acres Aerial Photos | Area, Acres LCMP | Percent | Accuracy, Percent |
|---|---|---|---|---|
| Water | 6856 | 7231 | .294 | 94.5 |
| Mangroves | 4942 | 3153 | .128 | 63.8 |
| Forest areas and/or small, open. uncultivated fields | 7291 | 7312 | .298 | 99.7 |
| Cultivated fields | 3862 | 3346 | .136 | 86.6 |
| Residential, commercial, and industrial areas | 1625 | 3532 | .144 | -17.3 |
| Totals | 24576 | 24574 | 1.000 | |
| Weighted mean accuracy | | | | 74.9 ± 39.1 |

The best results were related to water and forest/open uncultivated fields. Residential and industrial areas were not well depicted by this LCMP map. Mangroves were again underestimated, as in the larger tract size, by about 36%.

The overall weighted mean accuracy was 74.9%, but the standard deviation is largely due to the poor results of the residential and industrial areas.

LCMP: February 21, 1977.

The results are summarized in Table 9.

Table 9. LCMP map area estimation by ground cover categories. Input data 2/21/77. Tract size about 68,000 acres. Fort Myers test site.

| Ground Cover Classification | Area, Acres: Aerial Photos | Area, Acres: LCMP | Percent | Accuracy, Percent |
|---|---|---|---|---|
| Fresh Water | 2062 | 2087 | .031 | 98.8 |
| Salt Water | 12504 | 12000 | .177 | 96.0 |
| Forest areas and/or small, open, uncultivated fields | 37390 | 29309 | .432 | 78.5 |
| Cultivated fields | 10328 | 17042 | .251 | 35.0 |
| Residential, commercial, and industrial areas | 5506 | 7402 | .109 | 65.6 |
| Totals | 67790 | 67858 | 1.000 | |
| Weighted mean accuracy | | | | 70.0 $\pm$ 21.6 |

Overall, water was correctly classified within 2.6 percent. In addition, this LCMP map classified fresh water from salt separately, something that was not done in the LCMP map of 3/4/75. Estimation of areas covered by fresh water was much better in the larger size map of about 68,000 acres than on the smaller 25,000 acre one. However, for the salt water, the difference between the two maps was small.

The results for the other three categories (cultivated fields, forest, and/or open uncultivated fields, and residential/industrial areas) were not very satisfactory. Also mangroves were not depicted as such by this map whose weighted mean accuracy was 70 ± 21.6%.

For the smaller tract of about 25,000 acres, the LCMP results are summarized in Table 10.

Table 10. LCMP map area estimation by ground cover categories. Input data 2/21/77. Tract size about 25,000 acres. Fort Myers test site.

| Ground Cover Classifications | Area, Acres: Aerial Photos | Area, Acres: LCMP | Percent | Accuracy, Percent |
|---|---|---|---|---|
| Fresh water | 520 | 413 | .017 | 79.4 |
| Salt water | 6336 | 5871 | .239 | 92.7 |
| Forest areas and/or small, open, uncultivated fields | 12233 | 10699 | .435 | 87.5 |
| Cultivated fields | 3862 | 5202 | .212 | 65.3 |
| Residential, commercial, and industrial areas | 1625 | 2390 | .097 | 52.9 |
| Totals | 24576 | 24575 | 1.000 | |
| Weighted mean accuracy | | | | 80.5 ± 15.2 |

In this map, the area covered with salt water was better estimated than any of the other four categories.

The weighted mean accuracy of this map was good (80 ± 15.2%).

Image 100: March 4, 1975.

The results are summarized in Table 11.

Table 11. Image 100 map area estimation by ground cover categories. Input data 3/4/75. Tract size about 25,000 acres. Fort Myers test site.

| Ground Cover Classification | Area, Acres: Aerial Photos | Area, Acres: Gould Map | Percent | Accuracy, Percent |
|---|---|---|---|---|
| Water | 6856 | 6423 | .261 | 93.7 |
| Mangroves | 4942 | 3219 | .131 | 65.1 |
| Forest areas and/or small, open, uncultivated fields | 7292 | 6320 | .257 | 86.7 |
| Cultivated fields | 3962 | 6551 | .267 | 34.6 |
| Residential, commercial, and industrial areas | 1625 | 2061 | .084 | 73.2 |
| Totals | 24577 | 24574 | 1.000 | |
| Weighted mean accuracy | | | | 70.6 ± 23.8 |

Water bodies were depicted reasonably well within 6.3% of their actual surface area. No distinction between fresh and salt water was possible in this case. The next best classification was related to forest and/or open, uncultivated fields. The results become progressively worse as one moves to residential areas, cultivated fields, and mangroves.

The weighted mean accuracy of this map was 70.6 ± 23.8%. The relatively large standard deviation is mainly attributed to the underestimation of cultivated fields and, to a lesser extent, to that of mangroves.

Image 100: February 21, 1977.

The results are summarized in Table 12.

Table 12. Image 100 map area estimation by ground cover categories. Input data 2/21/77. Tract size about 25,000 acres. Fort Myers test site.

| Ground Cover Classification | Area, Acres Aerial Photos | Gould Map | Percent | Accuracy, Percent |
|---|---|---|---|---|
| Water | 6857 | 5585 | .227 | 81.4 |
| Forest areas and/or small, open, uncultivated fields | 12233 | 11755 | .478 | 96.1 |
| Cultivated fields | 3862 | 3307 | .135 | 85.6 |
| Residential, commercial, and industrial areas | 1625 | 3928 | .160 | -41.7 |
| Totals | 24576 | 24575 | 1.000 | |
| Weighted mean accuracy | | | | 69.3 ± 48.8 |

In this map, the best result within 3.9% of the actual ground cover is related to forest and/or open fields. Areas covered with water were not as close to the actual ones as they have been on previous maps of the Fort Myers test site.

Mangroves were not classified separately by this map, and residential/industrial areas were poorly depicted. As a result, the weighted mean accuracy of the map was 69.3% with a large standard deviation of ± 48.8%.

GAINESVILLE TEST SITE

For the Gainesville test site, the following computer-generated maps, based on the input data of 10/14/77 and covering a 520 x 520 pixel area, were selected as the most promising among all others examined:

-LSDP at the 98% confidence level

-LSDP at the 99% confidence level

-LCMP.

The 130 x 130 pixel maps for this test site and date have not produced satisfactory results. Out of the three maps mentioned above, the LSDP at the 98% confidence level was finally selected as better representing ground conditions than the other two.

For the input data of 4/17/77 and the 520 x 520 pixel area, the following three computer maps were promising:

-LSDP at 98% confidence level

-LSDP at 99% confidence level

-LCMP.

Following preliminary field evaluations of the selected computer maps, it was decided to finally use the LCMP for the 520 x 520 pixel area, since the LSDP map at the 98% confidence level for the 130 x 130 pixel area was almost identical to that of LCMP for the larger area.

In addition to the LSDP maps, two machine-processed maps, one for each input date, have been generated by themeing scenes of the site in the Image 100.

Each one of the computer generated maps has employed different character elements to depict the same ground features.

Table 13. Number of character elements for the LCMP, LSDP and Image 100 maps for an area 520 x 520 pixels. Gainesville test site.

| Input data | Computer Map | No. of character elements |
| --- | --- | --- |
| October 14, 1977 | LSDP | 5 |
| | Image 100 | 3 |
| April 17, 1977 | LCMP | 4 |
| | Image 100 | 4 |

The following are details of the various classifications of the selected computer maps:

Table 14. Ground features identified on the LCMP computer map with boundary delineation scales. Input data 4/17/77. Gainesville test site.

LCMP: 4/17/77 — 4 Character Elements

| Classification Index No. | Boundary Delineation Scale | Ground Feature |
|---|---|---|
| 1 | 1 | Water (Lakes) |
| 2 | 1 | Evergreen forests: mature pine - dense crown closure - hardwood or palmetto understory. |
| 3 | 2 | Cypress with scattered pines and hardwoods. |
| 4 | 1 | Mixed deciduous and non-deciduous hardwoods, cypress, and scattered pines. |
| 5 | 3 | Open fields (light or dark tone) of grasses, palmetto and scattered dense patches of trees, young pine plantations, residential areas, or cropfields. |

Table 15. Ground features identified on the LSDP computer map with boundary delineation scales. Input data 10/14/77. Gainesville test site.

| LSDP: 10/14/77 | | 5 Character Elements |
|---|---|---|
| Classification Index No. | Boundary Delineation Scale | Ground Feature |
| 1 | 1 | Water (Lakes) |
| 2 | 1 | Forests (deciduous and evergreen). |
| 3 | 2 | Light tone open fields (plowed, cropland, light grasses), or residential areas. |
| 4 | 2 | Dark tone open fields, (natural or uncultivated), scattered patches of trees, residential areas, young pine plantations, or recently logged areas. |

Table 16. Ground features identified on the Image 100 map with boundary delineation scales. Input data 4/17/77. Gainesville test site.

| Image 100: 4/17/77 | | 4 Character Elements |
|---|---|---|
| Classification Index No. | Boundary Delineation Scale | Ground Feature |
| 1 | 1 | Water (lakes). |
| 2 | 2 | Forest areas - deciduous and non-deciduous hardwoods, cypress, and evergreen forest. |
| 3 | 2 | Cultivated fields. |
| 4 | 4 | Uncultivated fields. |

Table 17. Ground features identified on the Image 100 map with boundary delineation scales. Input data 10/14/77. Gainesville test site.

Gould: 10/14/77 — 3 Character Elements

| Classification Index No. | Boundary Delineation Scale | Ground Feature |
|---|---|---|
| 1 | 1 | Water (lakes) |
| 2 | 2 | Forested areas |
| 3 | 2 | Open fields (uncultivated or cultivated) or recently logged areas |

Reference data on ground cover conditions for the Gainesville test were also based on the Mark Hurd vertical black and white aerial photographs, supplemented by recent field observations. The following strata were delineated on the aerial photos:

Table 18. Ground features identified on the Mark Hurd aerial photographs - 1973, and boundary delineation scales. Gainesville test site.

Aerial Photographs (1973).

| Classification Index No. | Boundary Delineation Scale | Ground Features |
|---|---|---|
| 1 | 1 | Water (lakes) |
| 2 | 1 | Evergreen forests |
| 3 | 1 | Cypress stands |
| 4 | 2 | Mixed deciduous and non-deciduous hardwoods |
| 5 | 2 | Dark tone uncultivated fields |
| 6 | 1 | Dark tone cultivated fields (plowed, grazing lands) |
| 7 | 1 | Light tone cultivated fields |
| 8 | 2 | Residential, commercial or industrial areas |
| 9 | 1 | Young pine plantations |

As it was the case with the Fort Myers test site, the evaluation of the computer-generated maps was based on acreage estimation by ground cover categories. One larger area of about 95,000 acres and one smaller one of 23,000 acres were selected for this purpose.
The following are specific details.

LCMP: April 17, 1977

The results are summarized in Tables 19 and 20.

Table 19. LCMP area estimation by ground cover categories. Input data 4/17/77. Tract size about 95,000 acres. Gainesville test site.

| Ground Cover Classification | Area, Acres: Aerial Photos | Area, Acres: LCMP | Percent | Accuracy, Percent |
|---|---|---|---|---|
| Water (lakes) | 4127 | 4439 | .047 | 92.4 |
| Evergreen forests | 32532 | 25423 | .268 | 78.1 |
| Cypress | 2539 | 2409 | .025 | 94.9 |
| Mixed forests | 18415 | 13155 | .139 | 71.4 |
| Open fields | 37206 | 49460 | .521 | 71.4 |
| Totals | 94819 | 94886 | 1.000 | |
| Weight mean accuracy | | | | 74.8 ± 5.5 |

In this map cypress domes were classified within 5.1% accuracy. Water surfaces (lakes) were also depicted on the map with an accuracy of 92.4%. However, open fields were overestimated by 28.6

percent, while mixed forest stands were underestimated by a similar amount. As a result, the overall weighted mean accuracy for this map was 74.8 ± 5.5%.

For the smaller tract, the results were not very satisfactory (Table 20).

Table 20. LCMP area estimation by ground cover categories. Input data 4/17/77. Tract size about 23,000 acres. Gainesville test site.

| Ground Cover Classification | Area, Acres: Aerial Photos | Area, Acres: LCMP | Percent | Accuracy, percent |
|---|---|---|---|---|
| Water (lakes) | 1056 | 1315 | .058 | 75.5 |
| Evergreen forests | 7808 | 3926 | .171 | 50.3 |
| Cypress | 124 | 89 | .004 | 71.8 |
| Mixed forests | 4463 | 3649 | .159 | 81.7 |
| Open fields | 9432 | 13937 | .608 | 52.2 |
| Totals | 22883 | 22916 | 1.000 | |
| Weighted mean accuracy | | | | 57.9 ± 12.2 |

In all five categories the discrepancies between the LCMP maps and the actual ground conditions were large. As a result, the overall weighted mean accuracy of this map was 57.9 ± 12.2%, the lowest for all twelve computer-generated maps evaluated in this study.

LSDP: October 14, 1977.

Tables 21 and 22 summarize the results.

Table 21. LSDP area estimation by ground cover categories. Input data 10/14/77. Tract size about 95,000 acres. Gainesville test site.

| Ground Cover Classification | Area, Acres: Aerial Photos | Area, Acres: LSDP | Percent | Accuracy, percent |
|---|---|---|---|---|
| Water (lakes) | 4127 | 4147 | .044 | 99.5 |
| Forest areas | 53486 | 60989 | .643 | 86.0 |
| Light tone fields | 20714 | 19527 | .206 | 94.3 |
| Dark tone fields | 16492 | 10223 | .108 | 62.0 |
| Totals | 94719 | 94886 | 1.000 | |
| Weighted mean accuracy | | | | 85.7 ± 9.3 |

In this map the delineation of fresh water lakes was almost perfect. Light tone fields and forested areas were also very well depicted by this LSDP map. However, large discrepancies in the estimation of dark fields have lowered the overall weighted mean accuracy to 85.7 ± 9.3%.

Table 22. LSDP area estimation by ground cover categories. Input data 10/14/77. Tract size about 23,000 acres. Gainesville test site.

| Ground Cover Classification | Area, Acres: Aerial Photos | Area, Acres: LSDP | Percent | Accuracy, percent |
|---|---|---|---|---|
| Water (lakes) | 1056 | 916 | .040 | 86.7 |
| Forest areas | 12395 | 13018 | .575 | 95.0 |
| Light tone fields | 6435 | 5779 | .255 | 89.8 |
| Dark tone fields | 2968 | 2938 | .130 | 99.0 |
| Totals | 22854 | 22651 | 1.000 | |
| Weight mean accuracy | | | | 93.8 ± 4.5 |

The overall results of the smaller tract size LSDP map were very good. The weighted accuracy for the four depicted categories ranges from 86.7% to 99.0%, with an average of 93.8 ± 4.5%, the second best among the twelve maps examined.

Image 100: April 17, 1977.

Table 23 summarized the results.

Table 23. Area estimation based on Image 100 map. Input data 4/17/77. Tract size about 23,000 acres. Gainesville test site.

| Ground Cover Classification | Area, Acres Aerial Photos | Area, Acres Gould | Percent | Accuracy, percent |
|---|---|---|---|---|
| Water (lakes) | 1056 | 998 | .044 | 94.5 |
| Forest areas | 12386 | 10897 | .475 | 88.0 |
| Cultivated fields | 8317 | 9102 | .397 | 90.6 |
| Uncultivated fields | 1148 | 1940 | .085 | 31.0 |
| Totals | 22907 | 22917 | 1.000 | |
| Weighted mean accuracy | | | | 84.5 ± 16.5 |

The Image 100 4/17/77 map provided good acreage estimation for water (lakes), forest areas, and cultivated fields. Although open uncultivated fields were overestimated by 69%, the overall weighted mean accuracy of this map was 84.5 ± 16.5%.

<u>Image 100: October 14, 1977</u>.

The results are summarized in Table 24.

Table 24. Area estimation based on Image 100 map. Input data 10/14/77. Tract size about 23,000 acres. Gainesville test site.

| Ground Cover Classification | Area, Acres Aerial Photos | Gould | Percent | Accuracy, percent |
|---|---|---|---|---|
| Water (lakes) | 1056 | 984 | .043 | 93.2 |
| Forest areas | 12386 | 11966 | .522 | 96.6 |
| Open cultivated or non-cultivated fields | 9466 | 9966 | .435 | 94.7 |
| Totals | 22908 | 22916 | 1.000 | |
| Weighted mean accuracy | | | | 95.6 $\pm$ 2.6 |

This map produced good results only for three categories: lakes, forest areas, and open fields. It was not possible in this case to separate cultivated from uncultivated fields. With only three ground cover categories, the weighted mean accuracy of the 10/14/77 Gould map was 95.6 $\pm$ 2.6%, the best result among all the maps evaluated in this study.

## EVALUATION OF THE RESULTS

This has been a limited study, both in scope and availability of resources. It would thus be preposterous to extrapolate the findings. We do feel, however, that some of our observations, listed below, deserve consideration for further study.

Several ground cover categories of the computer-generated maps (LSDP, LCMP, Image 100) evaluated in this study provided highly accurate results which could be used effectively on a large scale basis.

With one exception, results from the Gainesville test site were more satisfactory than those of the Fort Myers test site. This outcome may be attributed to the highly diversified ecological conditions, and thus, to the wider range of spectral response patterns of the Fort Myers test site as compared to those of the Gainesville site.

For the Fort Myers test site the 2/21/77 LCMP maps provided a separate classification for salt water. This rather rare coincidence may be attributed to the wave motion at that particular time, and/or to the turbidity of the merging water from Caloosahatchee River. It is known that suspended organic and inorganic materials in water bodies cause scattering and absorption of incident energy, thus affecting the spectral reflectance which is detected by Landsat (Fig. 8).

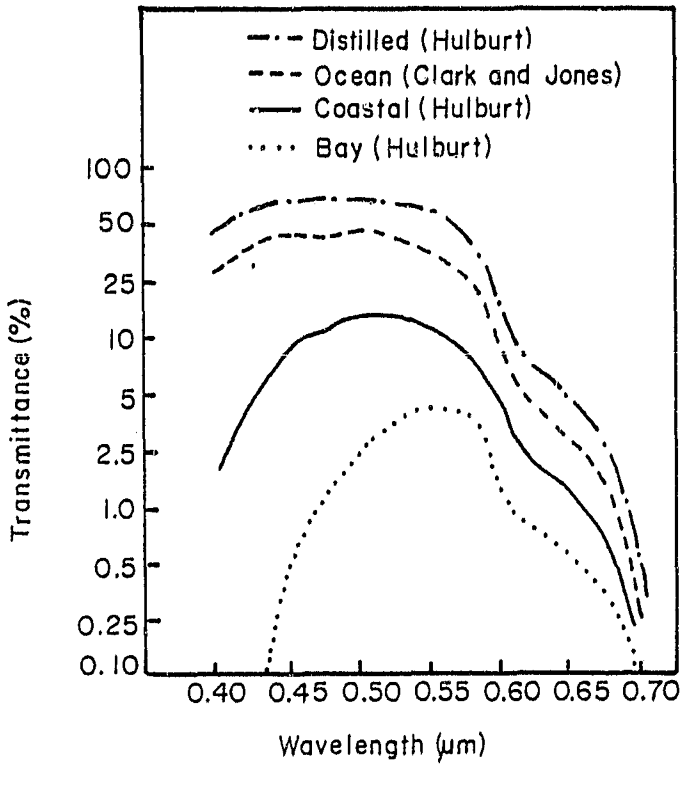



Figure 8. Spectral transmittance through ten meters of water of various types. (After Sprecht et al. Copyright © 1973, American Society of Photogrammetry. Used with permission.)

It was not possible to detect any appreciable difference due to the elapsed period of time between 1975 and 1977 in the Fort Myers site. In the process of evaluating the various LSDP, LCMP, and Image 100 maps, difficulties were encountered in superimposing the computer-generated maps onto vertical aerial photographs and the U.S. Geological Survey's 7-1/2 min. quadrangle sheets. Although the LSDP, LCMP, and Image 100 maps are supposed to be of the same scale as the USGS ones (1:24000), there are differences in the north-south direction due mainly to line printing and the size of individual character elements. These differences introduce problems in field orientation, and area estimation by ground cover categories, which must be properly corrected. It is our understanding that a better procedure has now been developed at the KSC-Applications Projects Branch which allows corrections with ground reference data. This procedure, which was not available at the time this study was conducted, produces improved LCMP classifications.

The exact location of specific ground features, such as small residential areas, roads, small rivers, and lakes, cannot be determined from any of the evaluated computer-generated maps in this study. Due to edge effect, such features are classified in one of the surrounding cover categories.

The field use of the LSDP, LCMP, and Image 100 maps is not very easy. The inability to precisely locate reference points on the maps and the bulk of computer output presented operational field difficulties, especially during adverse weather and ground conditions.

While the available Mark Hurd aerial photographs overall were adequate for this study, there was a very important need to have corresponding images between conventional aerial photography and satellite input data. This was particularly the case in areas characterized by rapidly changing ground cover conditions.

Overall, computer-generated maps for relatively small areas, such as 130 x 130 pixels, have not produced better results in this study than maps covering larger areas (520 x 520 pixels).

Along transition zones of such ground features as shorelines, lakes, and ponds, the areas are usually left unclassified in the computer-generated maps due to noise or edge effect. As a result, locating the exact boundary lines on the maps becomes a very difficult task.

Although specific pixel character elements of the computer-generated maps represent in some cases certain ground features such as forests, cultivated fields, open uncultivated fields, and the like, the overall use of the same symbol is not consistent in a given map. The spatial pattern of the specific ground cover mosaic and the reflectance from surrounding areas seem to affect the use of alternative mapping characters to denote the same ground surface features.

Successful themeing of Landsat scenes on the Image 100 depends heavily on firsthand knowledge of ground cover conditions and the ability to locate specific features on Landsat input tapes as displayed on the console screen. Usually, areas with smaller ecological diversities can be more easily themed on the interactive Image 100 than those characterized by heterogeneous conditions.

In all computer maps, sites, and dates examined, the best results were achieved when the classification was limited to only land and water. Even with three cover categories (water, forests, open fields) the 10/14/77 Image 100 map was 95.6% accurate.

Residential areas in many cases were falsely depicted by the LSDP, LCMP, and the Image 100 maps as cultivated fields.

Forest areas were usually underestimated by the various computer maps, while the open uncultivated fields were overestimated. The discrepancies were most likely caused by the season of the year, but other factors include the landscape pattern, the size of ground areas covered by these two categories, the interchanging schemes on the ground (spatial patterns), and tree species.

The color of the map characters appeared to affect the ease of interpreting various classifications. Between the black and blue character outputs examined, maps with black characters appeared to be easier to work with than those printed in blue.

In assigning character elements to represent various reflectance values it would be preferable for the LSDP and LCMP programs to use distinct map characters in a sequential order to avoid misinterpretation of the computer maps. This is particularly important when mixed character elements are present on a small section of the maps. One should examine the possibility of modifying the programs to allow overlapping of character elements as it is done, for example, by SYMAP (see Appendix F).

The elimination of computer dropouts (blanks) in some of the maps reduces the possibility of identifying ground features, such as residential areas, or cultivated and/or uncultivated fields which may be depicted as blanks.

The number of classifications on the maps is inversely proportional to the level of significance. For example, in the Fort Myers test site the February 21, 1977, LSDP computer outputs at 95%, 96%, 97%, 98%, and 99% confidence levels have resulted in 37, 28, 26, 16, and 11 classifications, respectively. Therefore, computer-generated maps with higher levels of confidence are easier to interpret since they have relatively smaller numbers of classifications than maps with lower confidence levels.

As one may anticipate, the results obtained from computer-generated maps are better when they refer to major ground cover types such as forest areas, lakes, large agricultural and/or uncultivated fields. Residential areas, unless large (such as Fort Myers proper), and small fields cannot be delineated with adequate accuracy. Small towns like Waldo and Starke in the Gainesville test site are confused with cultivated fields.

The Image 100 allows only for eight different themes at one time for the same scene. In highly diversified sites, where more than eight ground cover categories may be present, one ends up with a relatively large number of "unclassified" and overlapping areas.

If one wishes to have a specific symbol assigned to a given ground cover category by the LSDP and LCMP programs, it is necessary to run the programs first in order to find out which character element represents the classification in question. In subsequent runs one may indicate in one of the control input cards the desired symbol which will replace that of the initial run. Similar results may be achieved interactively with the Image 100 and the Gould printer.

## DISCUSSION

In reviewing the results of this limited study it should be realized that in an unsupervised, computer-aided pattern recognition method such as the one employed by the LSDP and LCMP maps, good results may be expected only when the features of interest have distinct spectral signatures. In the real world of renewable natural resources such desirable states are not abundant. Data analysts and resource specialists are confronted with highly variable and often overlapping spectral patterns even when they are dealing with a seemingly simple resource such as bare soil or forest cover (Fig. 9 and 10).

It is not sufficient to know the specific spectral characteristics of a single resource, such as a given tree species, but also spatial and temporal variations, along with the dynamic factors influencing such variations. Therefore, to make effective use of Landsat data, and the available processing methods, there is a need to develop reference data banks from the same areas at different times of the year and over a period of years.

Powerful interactive devices, such as the Image 100, depends heavily on man/machine interface. If knowledge of dynamic spectral characteristics for the study areas is available, one would expect to produce reliable results.

In sensing ground cover conditions, Landsat depicts the broader scene. As a result, the presence of an earth feature may be obscured by another one. Such cases were found, for example, in the test sites where relatively open forest stands were classified as uncultivated fields. Apparently, strong reflectance from the understory overshadows that of an open overstory. Thus land cover computer maps derived from Landsat data may not always be closely related to the actual use of a given piece of land.

In the middle portion of the spectrum, the soil reflects more than the vegetation. The reverse is true in the near infrared portion of the spectrum (0.7 - 1.3 $\mu$m). Thus differentiation between the two becomes rather difficult. Also dark tone soils may not be separated from vegetation in the visible or middle infrared wave lengths (Fig. 11 and 12).

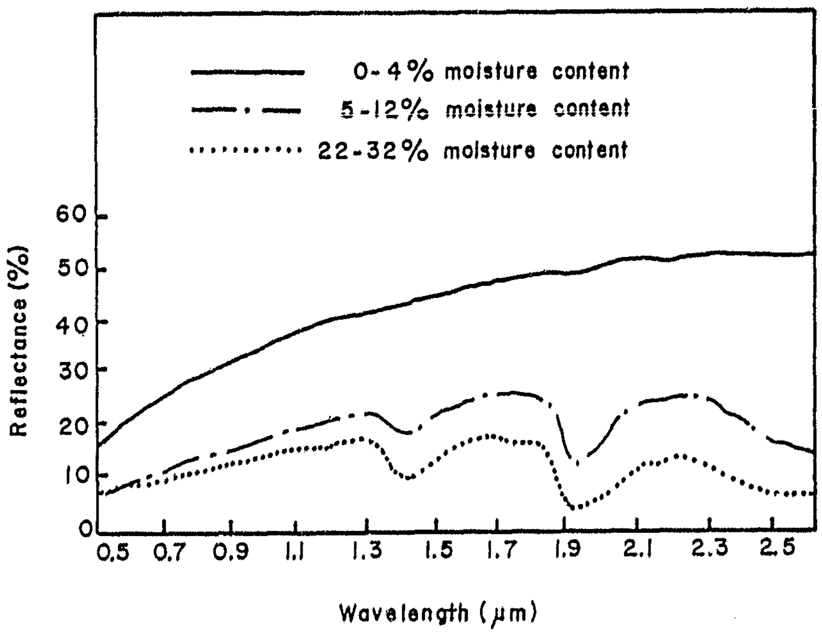
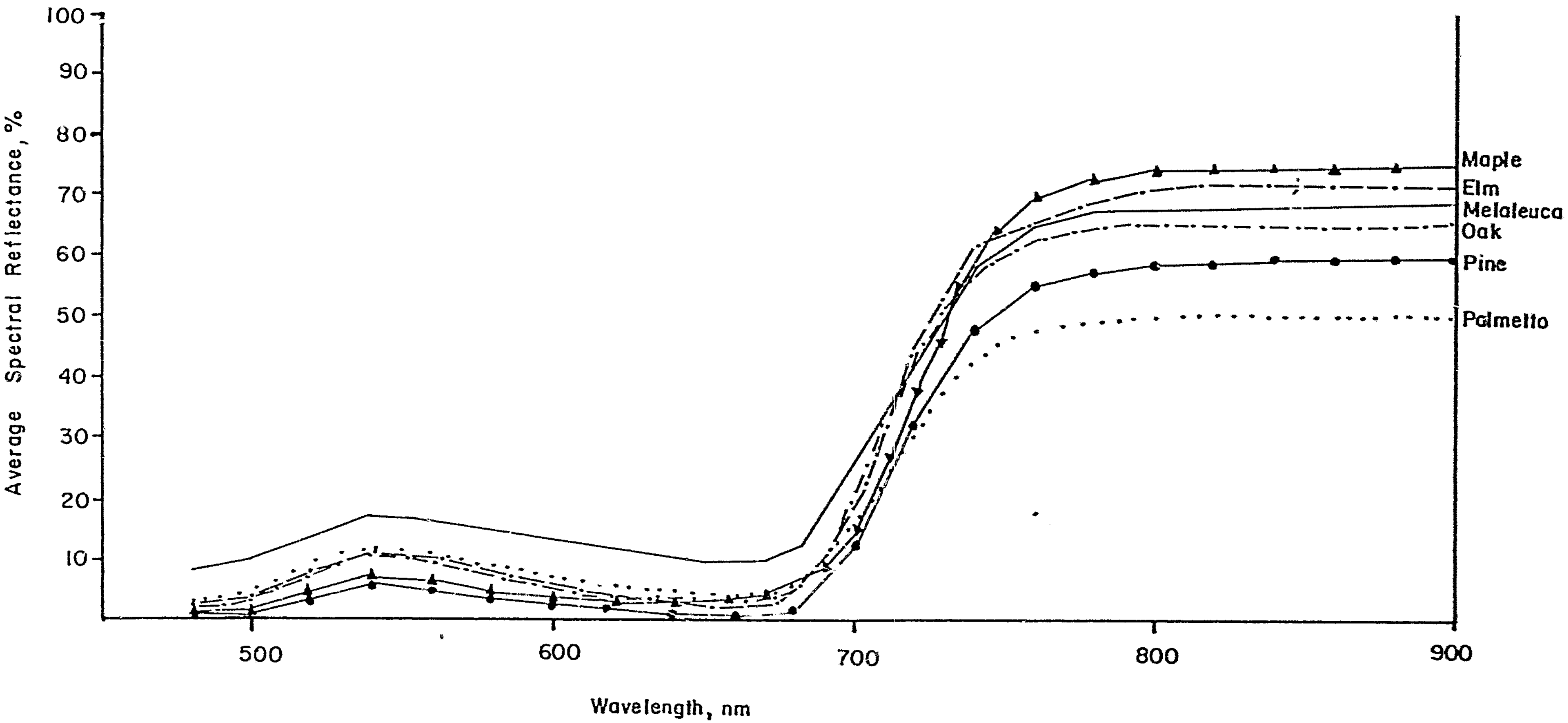



Figure 9. Spectral reflectance curves for Chelsea sand in three moisture-content groupings. After Hoffer and Johannsen in: Remote Sensing. The Quantitative Approach, Ed. by P. H. Swain and S. M. Davis. Copyright © 1978 McGraw-Hill, Inc. used with permission of McGraw-Hill Book Company.

Fig. 10. Average spectral reflectance curves for six different species from ground measurements (Arvanitis, 1978).



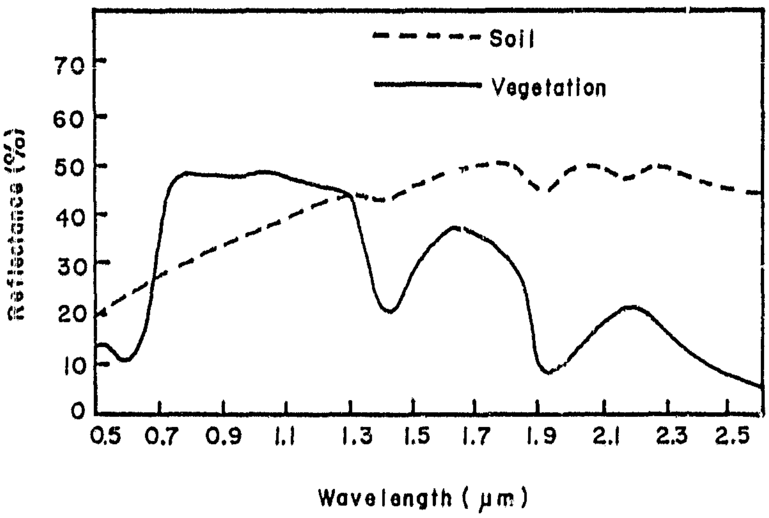



Figure 11. Spectral reflectance curves for healthy green vegetation and air-dried soils. These curves represent averages of 240 spectra from vegetation and 154 spectra from air-dried soils. The relative differences in reflectance in the visible (0.4 to 0.7 μm), near-infrared (0.7 to 1.3 μm), and middle-infrared (1.3 to 3.0 μm) portions of the spectrum are clearly shown by this data. After Hoffer in: Remote Sensing. The Quantitative Approach, Ed. by P. H. Swain and S. M. Davis. Copyright ©1978 McGraw-Hill, Inc. used with permission of McGraw-Hill Book Company.

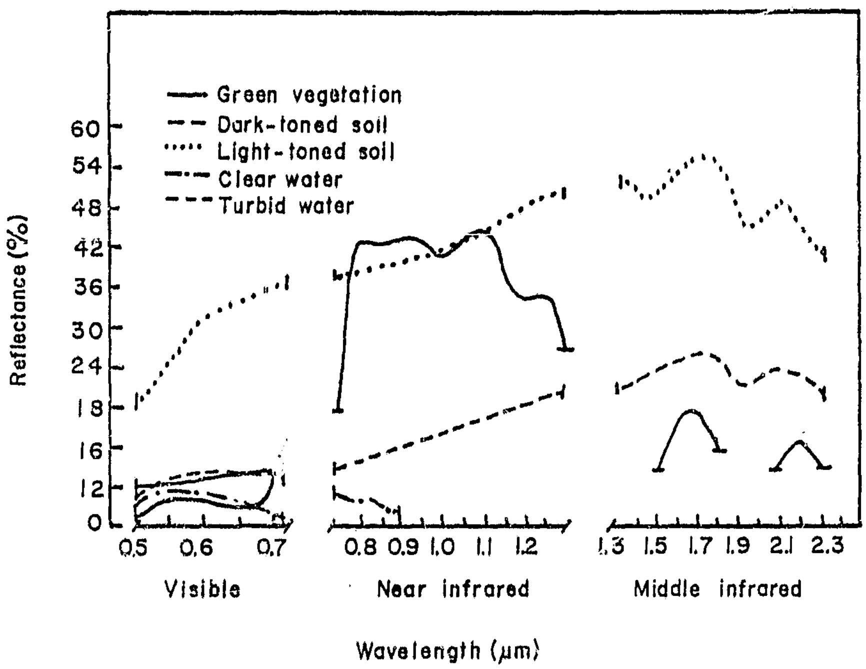



Figure 12. Spectral reflectance curves for green vegetation, light and dark soils, and clear and turbid water. After Hoffer in: Remote Sensing. The Quantitative Approach, Ed. by P. H. Swain and S. M. Davis. 

Swain and Davis (1978) argue that a good portion of the variation in spectral reflectance associated with vegetative cover may often be eliminated through proper consideration of the conditions under which the remote sensor data are collected. They list the following four possibilities:

1. Collect data, if possible, at the times during the growing season when the cover type or feature of interest has a spectral response pattern that is significantly different from any other cover type (e.g., when wheat is a mature, golden-yellow color and all other crops are various tones of green).
2. Obtain remote sensor data when the variations for a given species of interest are at a minimum (e.g., the middle of the growing season for corn or soybeans, after the crop has reached maximum canopy coverage but before senescence has started for any variety of that crop).
3. Collect data at intervals throughout the growing season, since no single time period will be optimal for all species or physiognomic groups.
4. Collect data under restricted environmental conditions, such as at a minimum specified sun angle, with less than 10 percent cloud cover, or after a certain number of days since the last rainfall.

GENERAL USAGE OF LSDP/LCMP LANDSAT ANALYSIS PROGRAMS

The ease of converting a version of the LSDP family of Landsat Analyses programs to the University of Florida comp. ing systems (Amdahl 470 V/G-11) during the course of this study suggests that the KSC programs have the potential to become readily available to a wide range of potential users. This Landsat analysis tool can run on any available general purpose computer system that accepts FORTRAN IV and has an associated tape reader and a display device. The novel feature of this technique is that it is very simple to utilize. Once the programs are operational, all a user need specify is the center of the scene to be analyzed and the level of confidence desired. Although these programs could be most effectively employed by a sophisticated remote sensing analyst who could store and refine signatures via the LSCP ancillary program, the technique's widest appeal would be for an individual user who is neither a computer nor a remote sensing expert. This feature makes these programs especially suitable for training students in the rudiments of remote sensing by satellite.

## CONCLUDING REMARKS

There is every indication to suggest that digital multispectral image processing systems based on Landsat input data will play an increasingly important role in pattern recognition and mapping land cover in the years to come. Repeatability and versatility are but two of the attractive features of this approach. Qualified answers to ever present questions of renewable natural resources and respective changes through time may be provided by rapid processing of Landsat data.

To make such an approach a cost-effective one on an operational basis there is a need for close cooperation between resource analysts and those thoroughly familiar with multispectral processing systems similar to the one investigated in this study. There are some suggestions from recent studies (Harding and Scott, 1978) that the minimum area for which this approach may become cost-effective is between one and two million acres.

Computer-produced maps from Landsat data provide a synoptic appraisal of terrain features. The ease of their frequent update may greatly assist rational planning, especially in areas characterized by rapid changes of land and water use due to human activities.

In this study, the overall proximity of the evaluated maps to the actual ground conditions is considered to be satisfactory. The findings are in line with reported work which has been conducted under comparable conditions.

Finally, the findings of this limited study should be interpreted in the proper context. More research is needed to refine the whole approach from the machine-processing of Landsat input data to the ground feature extraction. The study was convincing enough that computer classification of digital Landsat multispectral data, supplemented with auxiliary information, such as vegetation species, soil types, and microclimate, may soon become a valuable, indispensable tool in the hands of skillful analysts of renewable natural resources. Simulated parallax to produce stereoscopic Landsat scenes would further enhance the use of this powerful technique, especially with the future availability of the advanced multispectral scanner (thematic mapper) of the forthcoming Landsat.

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APPENDIX A

# BASIC FEATURES OF THE LSDP FAMILY OF COMPUTER PROGRAMS AND THE IMAGE 100 SYSTEM

## LSDP Family of Computer Programs

In early 1975, the need became apparent in the user community for a tool to analyze Landsat data which did not require remote sensing or multispectral scanner analyses expertise. The need was also apparent for this tool to be transferrable and relatively easy to operate by a small staff or even an individual user. With these ground rules a small group at KSC on a part-time basis developed four computer programs written in FORTRAN V for the analyses of Landsat scenes (Hall, McGuire, and Bland, 1976). These four programs are:

Landsat Geometric Correction Program - LGCP

Landsat Signature Development Program - LSDP

Landsat Signature Comparison Program - LSCP

Landsat Classification and Mapping Program - LCMP

## Landsat Geometric Correction Program (LGCP)

A Landsat scene is contained on magnetic tape and represents a 100 x 100 nautical mile area. The raw Landsat data contains geometric distortions due principally to the rotation of the earth under the Landsat satellites. For most applications this distortion must be corrected and reconstructed to an appropriate scale. Most users prefer a 1:24,000 scale.

The LGCP was developed at KSC to essentially remove geometric errors in the raw Landsat data. A method developed by LARS at Purdue University, which basically consists of resampling the data by means of a 2 x 2 transformation matrix, was used to accomplish this correction. This correction scene was first developed for a 130 x 130 pixel area. Later work permitted the LGCP to correct a 520 x 520 pixel area. The arrangement of the pixels within the corrected image are such that the pixels represented by characters on an output device at a specified aspect ratio will provide a representation of the original Landsat scene. This representation corresponds very closely in scale and alignment with U.S. Geodetic Survey 1:24,000 scale maps. A geometric correction scheme based on ground control points has been recently added to the KSC analysis software, but was not completed in time for the analyses work done in the report.

The LGCP method of correcting Landsat data is independent of the other three programs described below. Software developed at KSC has permitted LGCP tapes containing a scene of 20 x 20 pixels to be utilized on the Image 100. The new ground control point program corrects a scene of 910 x 910 pixels.

Landsat Signature Development Program (LSDP)

LSDP, an unsupervised clustering algorithm, was first developed to automatically classify an LGCP scene of 130 x 130 pixels. By late 1977, when the LGCP correction was expanded to a 520 x 520 pixel scene, the LSDP was modified to analyze this size scene. In a more recent development, the program extends the analysis scene to one of 920 x 920 pixels. This results in a 4-1/2 x 5-1/2 foot character map representing an area of about 24 x 30 miles. To utilize LSDP the user need specify only one of five available confidence levels and the center point latitude and longitude coordinates of the scene to be analyzed.

There is an inherent clustering tendency in Landsat multispectral scanner data. LSDP will generate a character map that, by identifying each of the general classes of surface features extracted from the scene data with a specified line printer symbol, indicated the location and distribution of these general classes within the scene. Also provided with the character map are a number of self-explanatory tables, each of which describes some aspect of the spectral properties of the resultant classes, some interclass relationships, the incident of picture elements assigned to the various classes in the character map classification of the scene, or some significant intermediate stage in the development of the final classes.

A principal assumption made concerning the data is that the coordinate system can be realigned, via a rotation matrix compared with the matrix of eigenvectors, in order to improve the overall effectiveness of a band-by-band classification approach. Once transformed, the covariant terms are assumed not to be significant and therefore treated as zero. This concession was made primarily because it does not seem to preclude the accuracy sought in the classification. The transformed data is reduced before rotation by not considering pixels which did not occur at least four times in the scene. This again was a trade-off of classification effectiveness versus computer impact.

The spatial organization of the rotated data is not retained, only the unique transformed pixel values and their frequency of occurrence. This data set is then reduced to a set of clusters defined by a near frequency, and a mean and variance in each band. Each cluster is formed by collecting all pixels in the set within a fixed distance about a seed pixel and then accepting only pixels in the set that do not change the variance by more than the chi-square statistic would permit at a selected level, and that is not more than the associated standard deviations from the mean.

The first seed pixel is the most frequent in the data set, and the next seed is the most frequent in the set remaining after forming the first cluster. All non-seed pixels are checked for acceptance to each subsequent cluster formed provided their frequency is less than the seed frequency. The fixed distance about the seed is two maximum projections of the original scale intervals on the rotated axis. This distance is used to compute an initial mean and variance for each cluster before letting them adapt with the chi-square and standard deviation test.

Clusters are next subjected to a merge test. Cluster pairs with mean separation within a certain hyperellisoidal region are merged. The merge region is a function of the clusters mean, variances and mean frequencies, and the object of the merge is to insure a significant resultant set of clusters. When all clusters are stable, i.e., do not pass the merge test, they are next inspected for overlap at the three standard deviation ranges. All overlaps are resolved by the maximum likelihood rule, using the mean frequencies as the "a priori" factors.

This results in a set of non-overlapping regions in the data space. Pixels which fall in these regions are assigned unique characters, then mapped by reading again the data set. Pixels which do not fall in this region which are assigned a blank character and consequently their position on the character map is left blank. The means and covariance matrix of the pixels that fall within these cluster regions constitute the signatures associated with the character map, and these signatures are included in the associated tables that are printed after the LSDP analysis.

### Landsat Signature Comparison Program (LSCP)

A further modification of LSDP in 1978 allowed an option to place the LSDP generated signatures on a separate tape. LSCP was designed to test a given set of these LSDP signatures and pool those signatures which are not significantly different in the statistical sense. For each pair-wise combination of signatures, a weighted mean covariance matrix and associated transformation matrix are computed. The transformation matrix is then used to realign the coordinate system of the signature pairs and a divergence test is applied. Those signature pairs failing the test are pooled, starting with the pair with the lowest value of the test statistic.

After a pair of signatures has been pooled, the divergence test is reapplied to the pooled signature against the other remaining signatures, and the process is started all over again. The process is continued until all pairs of signature combinations pass the divergence test. The resultant set of signatures is then written on magnetic tape and also printed.

### Landsat Classification and Mapping Program (LCMP)

LCMP was designed to accept inputs from the LSCP outputs, or by any other process that can define a class mean vector and a class covariance matrix. It is possible to associate with each input class a probability density function (p.d.f.) to the multivariate normal type. The maximum likelihood decision rule will then assign each pixel vector x from the Landsat scene to that class for which the value of the p.d.f. at x is greater than the value at x of the p.d.f. of any other class.

If the pixel vector x is within the .998 confidence region for the class to which it was assigned by the max-like rule, then x will be accepted as a member of this class and will be represented on the character map by the symbol associated with this class. Otherwise, x is taken to be unclassified, as in an LSDP character map, and will be represented by the blank symbol on the character map. Thus, the LCMP should be, in most cases, somewhat more significantly accurate than a single LSDP run.

Image 100

The Image 100 (Figure 3) was designed to accommodate data in the format received from the Landsat satellites which is in four bands ranging from .38 to 1.1 microns. Since the Image 100 system has been known for several years in the analysis of Landsat data, books listed in the references of this paper should be consulted for details on the many sophisticated functions this system can perform.

Only the parallelepiped, one-dimensional histogram mode was used in this study. This parallelepiped mode is the initial step to the other more sophisticated modes. Here, training areas, ranging in size from one pixel to N pixels, are first established with the cursor on the video picture of a Landsat scene. This results in four one-dimensional histograms. From these histograms, the upper and lower limits of the spectral distributions in each channel can be determined. These limits can then be modified when misclassifications are evident. Then the entire Landsat scene is classified with these training site signatures (themes).

Further software work at KSC enables a user to read an LGCP tape directly into the Image 100 system. An on-line Gould printer, suitably scaled, will produce a 1:24,000 scale charactered map. Each Image 100 produced theme is represented by a single character. This output allows ready comparisons to LSDP and LCMP character maps, as well as 1:24,000 scale ground truth maps. These comparisons form the basis for this report.

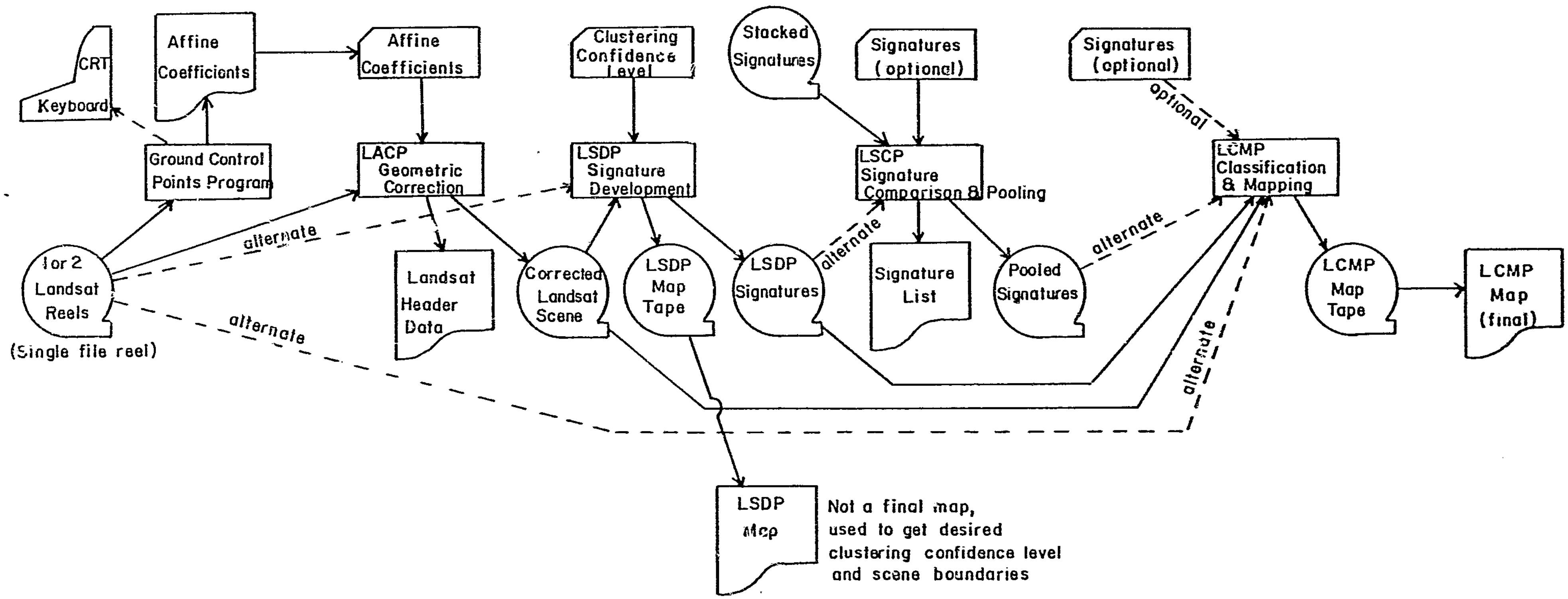


Figure 13. **LANDSAT DATA PROCESSING FLOW**

APPENDIX B

# TREE SPECIES OF THE TEST SITES

Fort Myers Test Site (Lee County)

A. Hardwoods

Avicennia germinans (L.) L., black-mangrove

Casuarina equisetifolia L., australian pine

Casuarina glauca F. vM., australian pine

Celtis laevigata Wild., sugarberry

Conocarpus erectas L. button-mangrove

Fraxinus caroliniana Mill., Carollina ash.

Magnolia virginiana L., sweetbay

Melaleuca quinquenervia L., cajeput

Nyssa sylvatica Marsh., black tupelo

Quercus laevis Walt., turkey oak

Quercus laurifolia Michx., laurel oak

Quercus nigra L., water oak

Quercus virginiana Mill., live oak

Schinus terebinthifolius, brazilian pepper, Florida holly

B. Softwoods

Pinus elliottii var. densa - slash pine

Taxodium distichum (L.) Rich., bald cypress

Taxodium distichum var. nutan (Ait.), Sweet, pond cypress

Gainesville Test Site (Alachua, Bradford and Union County)

A. Bottomland Hardwoods

Acer rubrum L., red maple

Carpinus caroliniana Walt., American hornbeam

Celtis laevigata Willd., sugarberry

Fagus grandifolia Ehrh., American beech

Fraxinus caroliniana Mill., Carolina ash

Liquidambar styracifluar L., sweetgum

Liriodendron tulipifera L., yellow-polar

Magnolia grandiflora L., southern magnolia

Magnolia virginiana L., sweetbay

Nyssa aquatica L., water tupelo

Nyssa sylvatica Marsh., black tupelo

Nyssa sylvatica var. biflora (Walt.) Sarg., blackgum

Quercus michauxii Nutt., swamp chestnut oak

Quercus nigra L., water oak

B. Upland Hardwoods

Carya glabra (Mill.) Sweet, pignut hickory

Prunus serotina Ehrh., black cherry

Quercus laevis Walt., turkey oak

Quercus laurifolia Michx., laurel oak

Quercus virginiana Mill., live oak

C. <u>Softwoods</u>

*Pinus elliottii* Engelm. var. *elliottii*, slash pine

*Pinus palustris* Mill., longleaf pine

*Pinus taeda* L., loblolly pine

*Taxodium distichum* (L.) Rich., bald cypress

*Taxodium distichum* var. *nutans* (Ait.) sweet, pond cypress

# APPENDIX C

## MAJOR SOIL CLASSIFICATIONS OF THE TEST SITES

I. Gainesville Test Site (Alachua, Bradford and Union County)

A. Well-drained to moderately well-drained soils

1. Alpin-Blanton association - excessively drained soil
2. Arrendondo var., Alaga-Kenney association - well-drained soil
3. Arrendondo-Zuber association - well-drained soil
4. Candler-Apopka association - excessively drained soil
5. Chipley-Albany-Rutlege association - moderately well-drained soil
6. Chipley-Leon-Osier association - moderately well-drained soil
7. Hernando-Archer-Chiefland association - moderately well-drained soil
8. Jonesville-Chiefland-Archer association - excessively drained soil
9. Kendrick-Hague-Zuber association - well-drained soil
10. Stilson-Pelham-Mascotte association - moderately well-drained soil
11. Tavares-Myakka-Basinger association - moderately well-drained soil

B. Poorly drained soils

12. Blichton-Flemington-Kawgoha association - poorly drained soil
13. Eureka-Paisley-Eaton association - poorly drained soil
14. Fellowship var., Hague var., Blichton var., association - poorly drained soil

15. Kanopha-Chipley-Sevanton association - poorly drained soil
16. Lynne-Pomona-Pompano association - poorly drained soil
17. Mascotte-Leon-Surrency association - poorly drained soil
18. Megget var., Wauchula-Chobee association - poorly drained soil
19. Myakka-Wauchula-Placid association - poorly drained soil
20. Phihan-Plummer-Rutlege association - poorly drained soil
21. Plummer var., Rutlege var., association - poorly drained soil
22. Scranton-Basinger-Myakka association - somewhat poorly drained soil
23. Sparr-Lochloosa-Tavares association - somewhat poorly drained soil

C. Very poorly drained soils

24. Brighton association - very poorly drained soil
25. Freshwater swamp association - very poorly drained soil
26. Martel-Placid association - very poorly drained soil
27. Okeechobee-Terra-Ceia-Tomoka association - very poorly drained soil
28. Osier-Rutlege-Leon association - poorly to very poorly drained soil
29. Portsmouth-Rains association - very poorly drained soil

II. Fort Myers Test Site (Lee County)

A. Well-drained soils

1. Pomello association - well-drained soil

B. <u>Poorly drained soils</u>

2. Adamsville-Pompano association - somewhat poorly drained soil

3. Immakalee-Myakka-Pompano association - poorly drained soil

4. Keri-Ft. Drum-Hallandale association - poorly drained soil

5. Pompano-Charlotte association - poorly drained soil

# APPENDIX D

# CLASSIFICATION SYSTEM USED IN THE 1976 FLORIDA LAND USE INVENTORY PREPARED BY USGS IN COOPERATION WITH THE DIVISION OF STATE PLANNING

The classification system outlined below as "A. Basic Classification System" is similar to, but does not duplicate, the Florida system. Since the USGS funded a major portion of the project and prepared most of the technical work, the system used had to reflect nationwide needs and current technical capabilities. However, because of Florida's unique data needs, USGS agreed to develop additional information, noted below as "B. Supplementary Land Use Data To Be Shown In Separate Map Overlays." With this additional information it is possible to provide most of the Level II information defined in Section II of this report.

A. Basic Classification System

| Level I | Level II |
|---|---|
| 1 Urban and Built-up Land | 11 Residential |
| | 12 Commercial and Services |
| | 13 Industrial |
| | 14 Transportation, Communications and Utilities |
| | 15 Industrial and Commercial Complexes |
| | 16 Mixed |
| | 17 Other |
| 2 Agricultural Land | 21 Cropland and Pasture |
| | 22 Orchards, Groves, Vineyards, Nurseries, and Ornamental Horticultural Areas |
| | 23 Confined Feeding Operations |
| | 24 Other |

| Level I | Level II |
| --- | --- |
| 3 Rangeland | 31 Herbaceous Range<br>32 Shrub-Brushland Range<br>33 Mixed |
| 4 Forest Land | 41 Deciduous<br>42 Evergreen<br>43 Mixed |
| 5 Water | 51 Streams and Canals<br>52 Lakes<br>53 Reservoirs<br>54 Bays and Estuaries<br>55 Other |
| 6 Wetland | 61 Forested<br>62 Non-forested |
| 7 Barren Land | 71 Salt Flats<br>72 Beaches<br>73 Sandy Areas Other than Beaches<br>74 Bare Exposed Rock<br>75 Strip Mines, Quarries, and Gravel Pits<br>76 Transitional Areas<br>77 Mixed |

B. Supplementary Land Use Data To Be Shown in Separate Map Overlays

1 Institutional Uses
2 Citrus Groves
3 Transportation Canals and Waterways
4 Wetland Forest, Deciduous, Evergreen, Mixed
5 Mangroves
6 Cypress
7 Planted Pine
8 Non-forested Wetlands
   A Vegetated
   B Bare

APPENDIX E

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CLASS - 1 FRESH WATER. LCMP computer map.
Input data 2/21/77. Fort Myers test site.



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BBMMMMMMMMMMB;MMMMMMMMMM%  MM;;BMMMMB%;BM
MBBMBBBMM;MMMMMMM;MMBBM;.MBMMMBMMB;%%%%B
WBBBMMMMMBMMBBMBMMMMM;M;.M;;M;;MMMM;B;BB
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CLASS - 2 MANGROVES. LCMP Computer Map.
Input data 3/4/75. Fort Myers test site.

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E>>>>>EEE+EEE++++++++++E+EE+E+++++++++++
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EEE+++>EE+FE++++++++++++++++EE+EEE++++++
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CLASS – 3 SALT WATER. LCMP computer map. Input data 2/21/77. Fort Myers test site.

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CLASS – 4 FCREST AREAS AND/ OR OPEN UNCULTIVATED FIELDS. LCMP computer map. Input data 2/21/77. Fort Myers test site.

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CLASS – 5 OPEN CULTIVATED FIELDS. LCMP computer map. Input data 2/21/77. Fort Myers test site.

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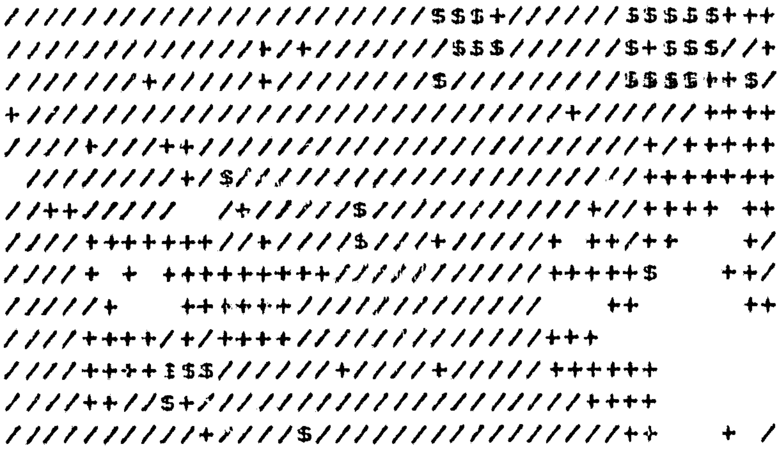
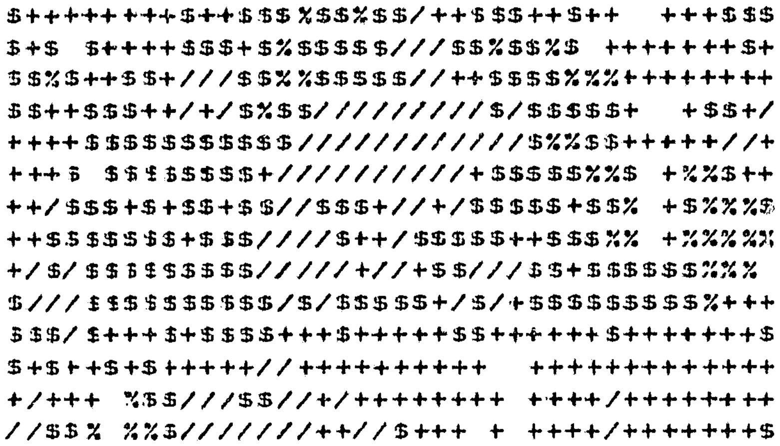
CLASS – 6 RESIDENTIAL, COMMERCIAL, AND INDUSTRIAL AREAS. LCMP computer map. Input data 2/21/77. Fort Myers test site.



CLASS – 1 EVERGREEN FORESTS: MATURE PINE – DENSE CROWN CLOSURE – OAK, PALMETTO OR CYPRESS UNDERSTORY. LCMP computer map. Input data 4/17/77. Gainesville test site.



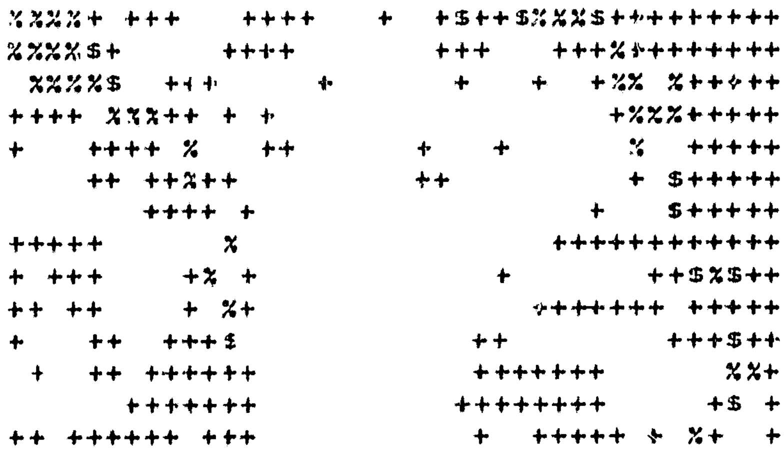
CLASS – 2 CYPRESS MIXED WITH PINE AND HARDWOODS. LCMP computer map. Input data 4/17/77. Gainesville test site.

```
++$///++     +  +//+++%%$$%$ +%%++++
////$+       ++ +++$$%%%%%%$$++$ +
/$+   +++++++  ++++%++%% %%$$+++++
+++    + + +++ ++++%%+%%$%%$$++  +++
+++  +++++   +++++++$%%%$%%%%$++    +
++++/+++    +++++$%%%%%%%%%%%+    ++
     +++    + +++$%%%%%$%%+          ++++
    + +     + +++%%%$%%$%++          +  +
    ++          +%%%$%$$% ++      +    +++
$%      + + ++%%%%%%%$%%%+ +  ++      +++
%%%     + + ++%%%%%%%%%%$+ +++$$+++++$%%
%%%%        ++%%%%%%%%%%$$$ +  $$%$$%%%%
%$%%% %++ ++++%%%%%%%%%$++++    ++%%++%%
$$$$$%%$+++++%%%%%%%%%%+       ++ ++++++
```

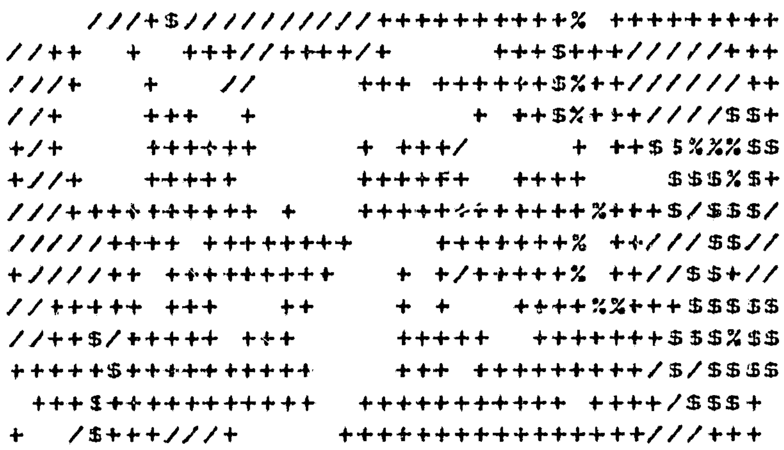
CLASS - 3 MIXED DECIDUOUS AND NON-
DECIDUOUS HARDWOODS, CYPRESS
AND SCATTERED EVERGREEN.
LCMP computer map. Input data
4/17/77. Gainesville test site.

```
//$/++++/+++++++++      // /++++++++++++++
///////++++++++++++++/+++    ++ +++++++++
/////////+++++++++///////$++++++++/+$+/+//
///+$$///+++++++++///////$++++//++/$$$$$+
/////////++++/++++++++/++//+++/$$$$$$$++
++//////++++++++/+++++++//+++//++++++++++/
+++/////+//+++++++++++++++++++$//++++++++++
++///////+/++//++++++++++++++$/////++++++$
////+///+/+++/++/+/+/+++++/$//////+/+++//
////$///////++/////+$$/+++++/$+++++++/++///
////+///+++/++//////$$$++++$++//+++/+//++
///////////+++///+/$$$+/++$//$/++++//+//
////////++//+   /+++/$$///++//++++++///+//
+////////+//++++/////+///   ++++///+ +/////
```

CLASS - 4 OPEN UNCULTIVATED FIELDS(NATURAL
GRASSES, PALMETTO, SCATTERED DENSE
PATCHES OF TREES) OR YOUNG PINE
PLANTATIONS. LSDP computer map.
Input data 10/14/77. Gainesville
test site.

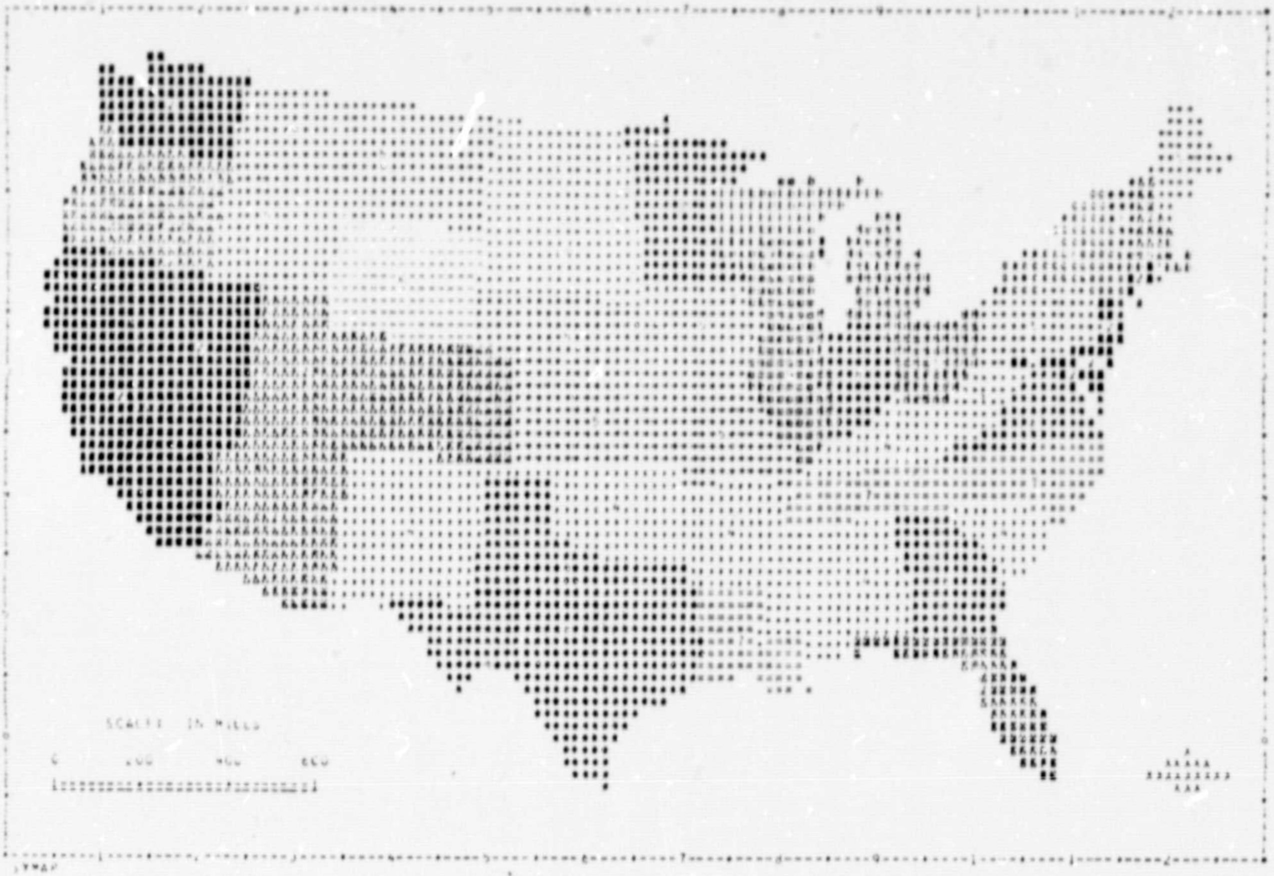


CLASS – 5 LIGHT TONE OPEN FIELDS(PLOWED OR BARREN WITH SPARSE GRASSES) OR MAN STRUCTURES. LSDP computer map. Input data 10/14/77. Gainesville test site.



CLASS – 6 DARK TONE OPEN FIELDS, NATURAL OR NON-CULTIVATED FIELDS, SCATTERED PATCHES OF TREES, MAN STRUCTURES, OR YOUNG PINE PLANTATIONS. LSDP computer map. Input data 10/14/77. Gainesville test site.

APPENDIX F




SYMAP

0.0:0523 MINUTES FOR MAP

4 X 3 CROSSTABULATION BETWEEN PERCENT POPULATION CHANGE FROM 1960-1970
AND MEDIAN FAMILY INCOME IN 1969
FOR THE CONTERMINOUS UNITED STATES BY STATE

DATA VALUE EXTREMES ARE 1.00 12.00

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MINIMUM | BELOW | 1.50 | 2.50 | 3.50 | 4.50 | 5.50 | 6.50 | 7.50 | 8.50 | 9.50 | 10.50 | ABOVE |
| MAXIMUM | 1.50 | 2.50 | 3.50 | 4.50 | 5.50 | 6.50 | 7.50 | 8.50 | 9.50 | 10.50 | 11.50 | 11.50 |

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 10.00 | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 |

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

| LEVEL | L | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | H |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FREQ. | 4 | 1 | 0 | 6 | 9 | 1 | 3 | 6 | 5 | 0 | 6 | 7 |

APPENDIX G

# DOCUMENTATION OF THE LANDSAT SIGNATURE DEVELOPMENT PROGRAM AT THE UNIVERSITY OF FLORIDA

The LSDP-2 version of the Landsat Analysis family programs developed at KSC to analyze digital satellite imagery has been adapted to the Amdahl 470 V/6-11 of the Northeast Regional Data Center (NERDC) which serves the University of Florida in Gainesville. The Amdahl 470 is operated under a Multi-Virtual Storage (MVS) Operating System and JESZ/NJE system control programs.

NERDC is directly connected through JES/NJE communication with the Florida State University (Tallahassee) Computing Center, as well as the Central Florida, Southeast, and Northwest Regional Data Centers (Fig. 14). Potential users within the State University System (SUS) may access the LSDP-2 via the SUS Computer Network.

NERDC has initiated a Landsat data tape library that is available to prospective users within the SUS. This library consists of 9-track magnetic tapes (1600 bpi) with an EBCDIC character set. Landsat scenes are identified by the center point, the latitude and longitude coordinates of the scene, and the date of the scene.

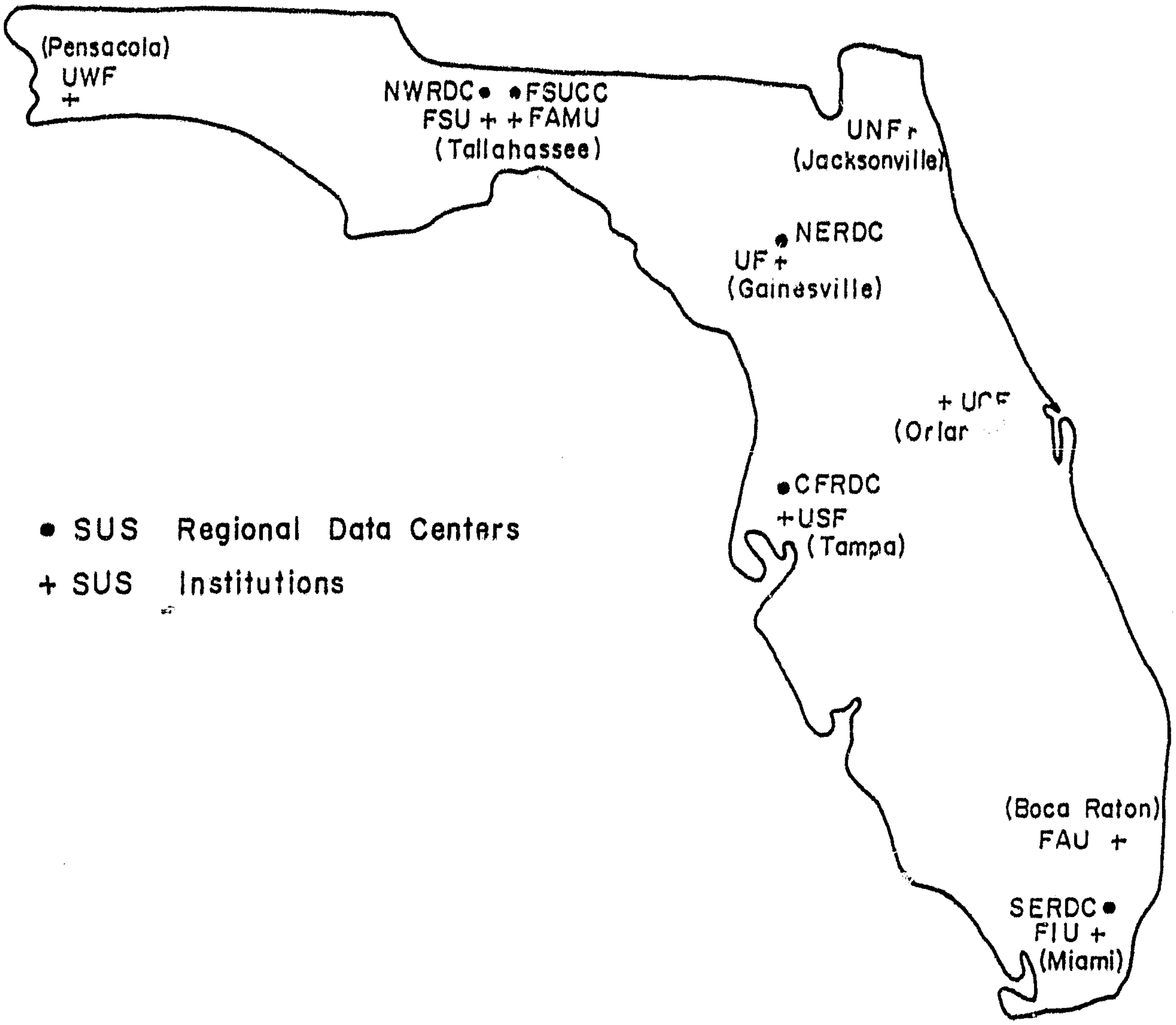
The job control language required to access the LSDP-2 is as follows:

```
//jobname  JOB  (___,___,30,50,0,___0),'yourname',  CLASS=2
/*  PASSWORD  Sequence number,password
//  EXEC LSDP2  INSITE='dgname of cct',file=
//LAND.SYSIN  DD  *
Input Site Card describing the specific area.
/*
```

Format for the Input Site Card:

| Columns | Contents |
|---|---|
| 1-10 | LX1, the starting element (No default; range is from 1 to 815, depending on satellite collecting data) |
| 11-20 | LX2, the ending element (No default; range is from 2 to 816, depending on satellite collecting data) |
| 21-30 | LY1, the starting scanline (No default; range is from 1 to 2339) |
| 31-40 | LY2, the ending scanline (No default; range is from 2 to 2340) |
| 41-50 | LDX, the element increment for classification<br>1 = use every element between LX1 and LX2<br>2 = use every other element between LX1 and LX2<br>Default is 1 |
| 51-60 | LDY, the scanline increment for classification<br>1 = use every element between LY1 and LY2<br>2 = use every other element between LY1 and LY2<br>Default is 1 |
| 65 | MAP, the mapping control<br>0 = full sized character map<br>1 = character map is scaled by LDX and LDY<br>Default is 0 |
| 70 | FMT, the input data format<br>1 = tape supplied is a raw data tape (CCT)<br>2 = tape supplied is a geometrically corrected tape<br>No default |
| 71-80 | CCL, the class confidence limit for clustering (punch the decimal point)<br>Choices are 95.0, 96.0, 97.0, 98.0, 99.0, 99.8<br>Default is 98.0 |

Fig. 11. Florida's State University System SUS Computer Network



The LSDP output consists of a character map which displays the location and distribution of the general classes within the scene. Also provided with the character map are a number of self-explanatory tables describing some aspects of the spectral properties of the resultant classes. A plot of class signatures using Band 5 (Red band) and Band 7 (Near infrared band) may be constructed from the output. Figure 15 used by the Geography Department at the University of Florida indicates a tentative guide to identify major ground cover types. Hopefully, this will become a useful aid to the novice user as well as to the more sophisticated remote sensing analysts.

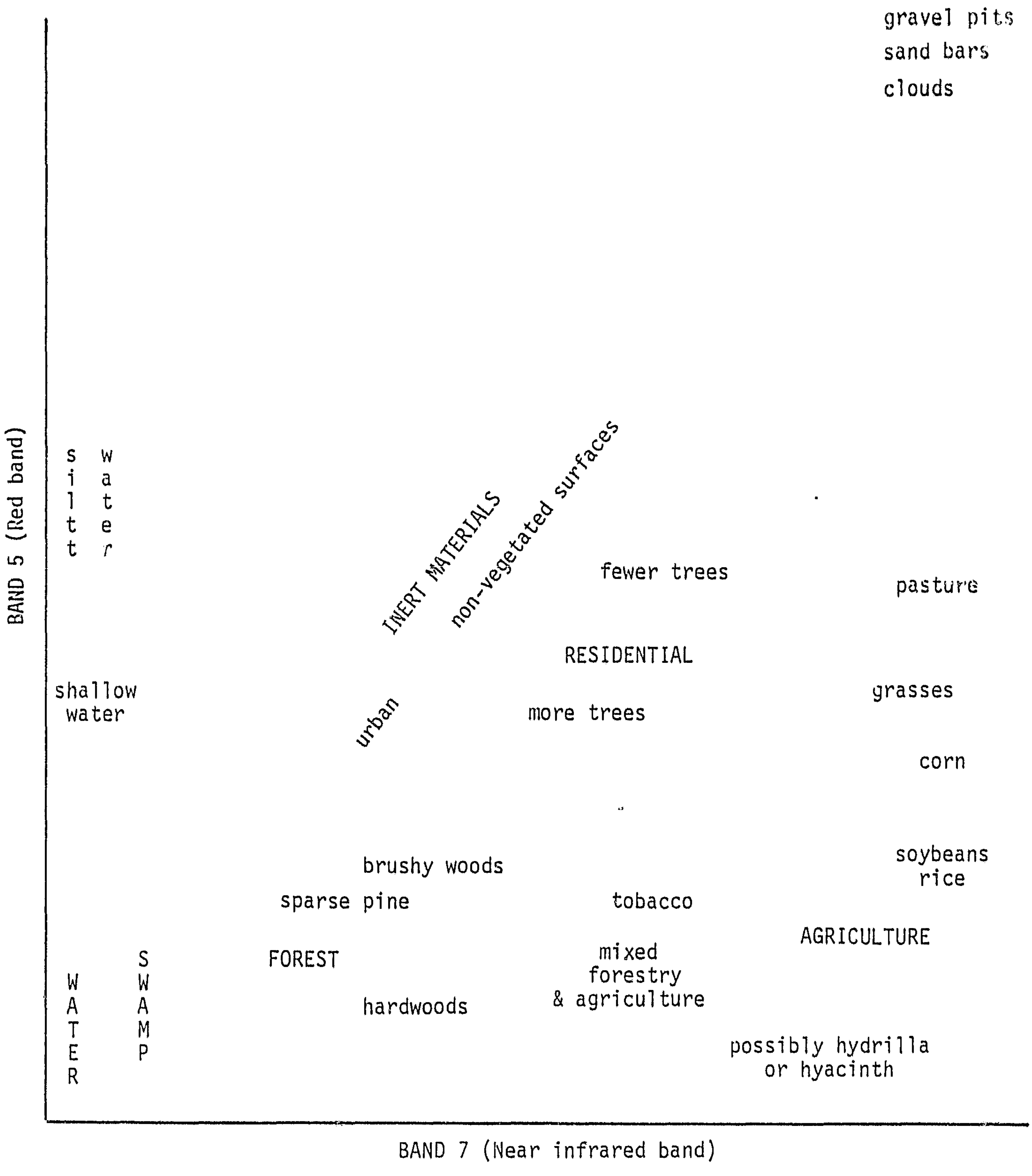



Fig. 15. Tentative guide for class signature identification (Hetrick, 1979).

The category labelled RESIDENTIAL may well be very much mixed with other types of areas depending on the types of land cover in non-residential areas. In addition, the scales of the two axes are neither absolute nor equal. They are scaled according to the data values for the particular scene with which one is working (Hetrick, 1979).

Work now in progress at the University of Florida is aimed at adapting the Landsat Geometric Correction Program (LGCP) as well as the LSDP-3.

APPENDIX H

Fig. 16. Caloosahatchee River. Fort Myers test site.

Fig. 17. Mangroves along Fort Myers beach. Fort Myers test site.

Fig. 18. Mangrove island. Fort Myers test site.

Fig. 19. Evergreen forest with a palmetto understory adjacent to a cypress stand. Fort Myers test site.

Fig. 20. Natural open field with scattered pines. Fort Myers test site.

Fig. 21. Improved pasture. Fort Myers test site.

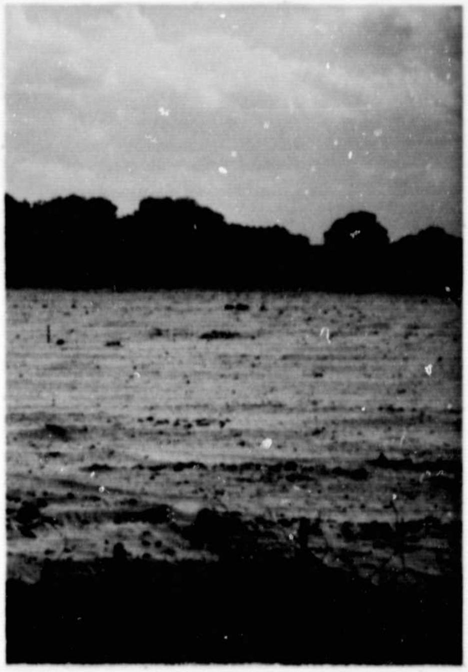


Fig. 22. Light tone cultivated field. Fort Myers test site.

Fig. 23. Dark tone cultivated field. Fort Myers test site.

Fig. 24. Dark tone cultivated field. Gainesville test site.

Fig. 25. Light tone cultivated field. Gainesville test site.

Fig. 26. Residential area. Gainesville test site.

Fig. 27. Lake. Gainesville test site.

Fig. 28. Evergreen forest with palmetto and grass understory. Gainesville test site.

Fig. 29. Mixed deciduous hardwood stand. Gainesville test site.

Fig. 30. Improved pasture. Gainesville test site.

Fig. 31. Natural open field that has been recently planted with pine. Gainesville test site.

APPENDIX I

## DIFFERENTIATION OF COLORS ON LANDSAT COMPOSITE PRINTS

Major ground features on the Landsat color composites from the Image 100 for both test sites were identified according to the ISCC-NBS centroid color system.

This system was developed by the Inter-Society Color Council and National Bureau of Standards, and is widely used in the fields of color measurement and designation. The method is a purely descriptive one; it divides the color solid into 267 parts. Each part of the color solid is described by a hue name and modifiers appropriate for its lightness and saturation, e.g., deep purplish red (Table 25). The color name is determined from a series of charts dimensioned according to the Munsell scales of hue, value, and chroma. These charts are published by the National Bureau of Standards in NBS Circular 553 (see Literature Cited).

Tables 26 and 27 include the ISCC-NBS number and color designation, the appropriate Munsell renotation and ground features for the Gainesville and Fort Myers test site, respectfully.

Table 25. Abbreviations for the hue names and modifiers used to identify the lightness and saturation of the colors on the Landsat composites.

| Hue Name (Adjective) | Abbreviation | Modifier | Abbreviation |
|---|---|---|---|
| Red (reddish) | R (r) | dark | d. |
| (yellowish) | (y) | light | l. |
| Green (greenish) | G (g) | moderate | m. |
| Blue (bluish) | B (b) | pale | p. |
| Pink | Pk | strong | s. |
| Brown (brownish) | Br (br) | very dark | v.d. |
| Grey (greyish) | Gy (gy) | | |

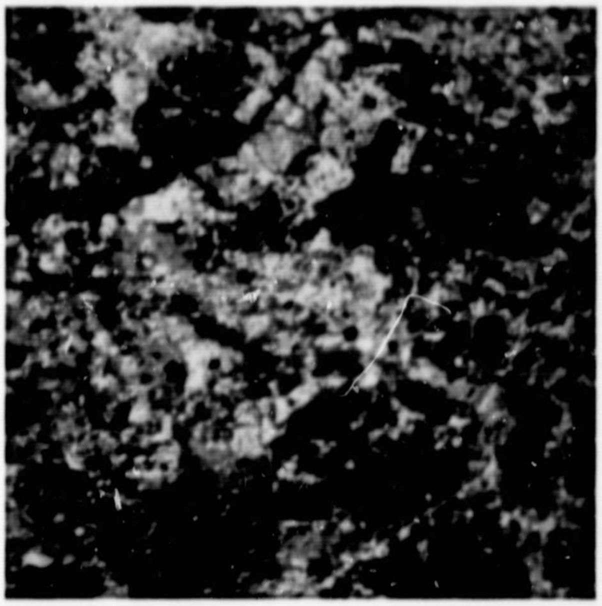


Figure 32. Color composite of Landsat imagery as displayed by the Image 100. Gainesville test site.

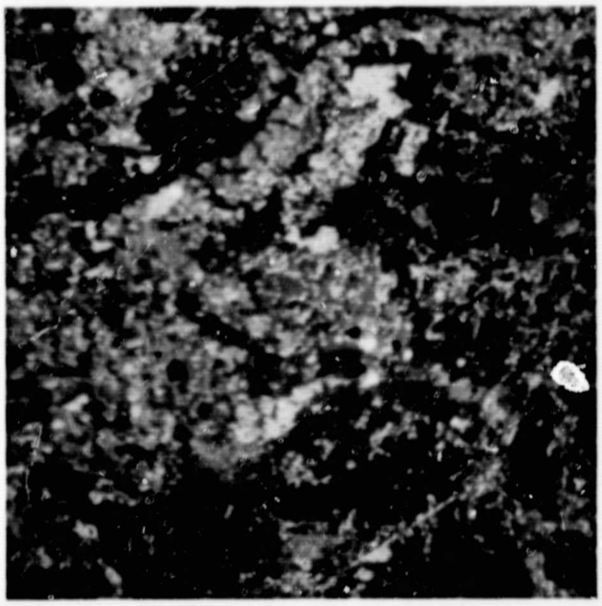




Figure 33. Color composite of Landsat imagery showing uncultivated fields and major roads (themed yellow) as displayed by the Image 100. Gainesville test site.

Table 26. ISCC-NBS and Munsell Color Classification of the Landsat Color Composites from the Image 100. Gainesville Test Site.

| ISCC-NBS | | | |
|---|---|---|---|
| No | Designation (abbreviated) | Munsell Renotations | Ground Feature |
| 31 | p.yPk | 4.2YR 8.6/2.2 | Uncultivated fields and roads |
| 150 | gy.G | 8.8G 4.5/1.8 | Forested areas |
| 154 | l.gGy | 3.0G 7.5/0.9 | Cultivated fields |
| 175 | v.d. gB | 5.0B 1.5/3.6 | Water (Lakes) |

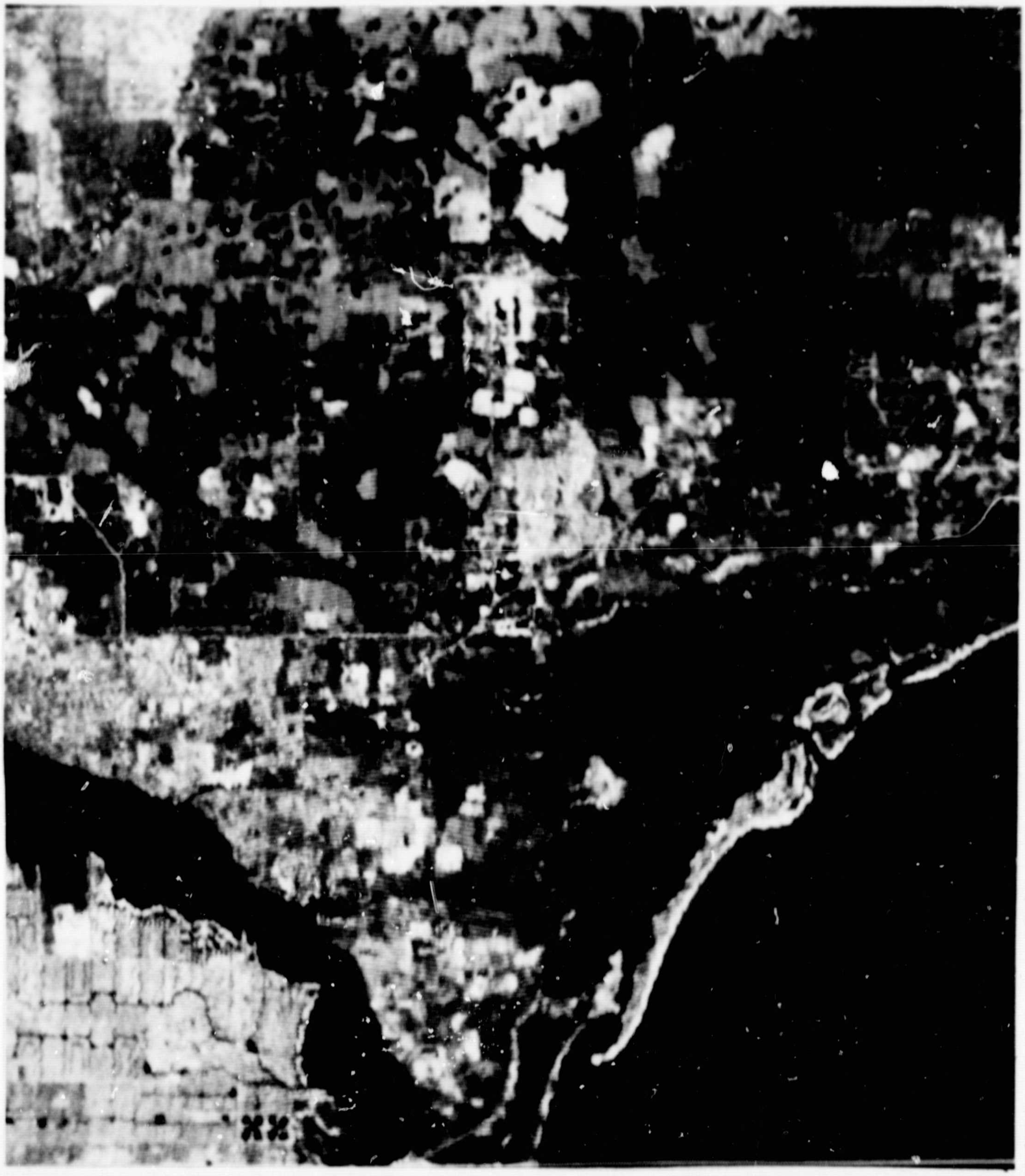


Figure 34. Color composite of Landsat imagery as displayed by the Image 100. Fort Myers test site.

Figure 35. Color composite of Landsat imagery showing mangroves and evergreen forests (themed yellow) as displayed by the Image 100. Fort Myers test site.

Table 27. ISCC-NBS and Munsell Color Classification of the Landsat Color Composites from the Image 100. Fort Myers Test Site.

| ISCC-NBS | | | |
|---|---|---|---|
| No. | Designation (Abbreviated) | Munsell Renotations | Ground Feature |
| 20-21 | d. [illegible] R- blackish R | 2.9 R 2.7/2.1 - 3.9 R 0.8/1.7 | Marshland (sawgrass with scattered pines) inundated with water part of the year |
| 33 | br. Pk | 7.0 YR 7.1/2.3 | Cultivated fields |
| 40 | s. rBr | 0.3 YR 3.1/9.9 | Melaleuca and other hardwoods stands |
| 43 | m. rBr | 9.0 R 3.4/5.2 | Mangroves and ever-green stands |
| 178 | s. B | 2.9 PB 4.1/10.4 | Salt water |
| 183 | d. B | 2.2 PB 1.7/5.5 | Fresh and salt water |
| 190 | l. bGy | 8.2 B 7.5/1.0 | Residential, commercial, and industrial areas |
| 193 | b Black | 9.6 B 1.1/0.8 | Small ponds |
| 263 | white | 2.5 PB 9.5/0.2 | Beaches, uncultivated fields, residential, commercial, and industrial areas |