NATIONWIDE FORESTRY APPLICATIONS PROGRAM

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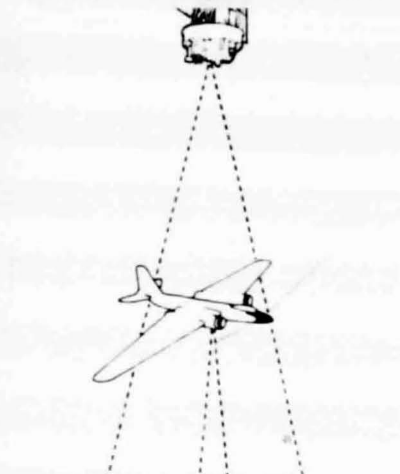

**TEN-ECOSYSTEM STUDY (TES)
SITE V REPORT, KERSHAW
COUNTY, SOUTH CAROLINA,
REPORT 4 OF 4**

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U.S. Department of Agriculture

NOTE: In 1976, the Nationwide Forestry Applications Program was expanded from a Regional project by cooperative agreement between the Forest Service, U. S. Department of Agriculture, and the National Aeronautics and Space Administration (NASA). The Program is designed to sponsor research and development on the application of remote sensing analysis techniques to problems arising from the need to inventory, monitor and manage forests and rangelands, including the assessment of impacts on forest stands from insect and disease damage.

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PREFACE

The Nationwide Forestry Applications Program was established in 1971 at the National Aeronautics and Space Administration, Lyndon B. Johnson Space Center to develop and demonstrate remote sensing technology in performing forestry resources inventories, with particular application to the U.S. Department of Agriculture, Forest Service. During the 1971-75 time period, many small and localized feasibility studies were conducted, and the technology was developed for automatic data processing of satellite and aircraft multispectral scanner data. Conventional methods of photointerpretation analysis were also studied. The studies were directed primarily toward specific applications within Region VIII of the Forest Service. The need for extending the technology to intermediate and large-sized applications was reflected in the passage of the Forest and Rangeland Renewable Resources Planning Act, Public Law 93-378. In response to some of the research requirements of these acts, the Ten-Ecosystem Study was initiated to investigate the feasibility for analysis of forest and grassland ecosystems on a national scale.

The Ten-Ecosystem Study is an automatic data processing feasibility study using Landsat data, supporting aircraft imagery, and ancillary information for inventorying forest, grassland, and water by administrative boundaries in 10 grossly categorized ecosystems of the United States. For each specific ecosystem, analysis success, problems, and failures are to be identified clearly and objectively. Also, recommendations are to be made which are directed toward future large area inventory analyses in each specific ecosystem. Based on the combined experience gained in each of the 10 ecosystem studies, recommendations on the definition and requirements of a preliminary integrated automatic data processing analysis system to inventory nationwide forest and rangeland renewable resources are to be made.

The primary objectives of the Ten-Ecosystem Study are as follows.

a. Investigate the feasibility of using automatic data processing of remotely sensed data to inventory forest, grassland, and inland water areas within administrative boundaries for specified ecosystems of the United States.

b. Identify automatic data processing analysis problems related to each site (ecosystem) and recommend solutions.

c. Define the requirements for an automatic data processing system to perform a nationwide forest and grassland inventory.

These objectives will be addressed in the Ten-Ecosystem Study final report, to be completed in October 1978, after the completion of the processing and analysis of the individual sites.

This report discusses the analysis of the Kershaw County, South Carolina, site which was selected to represent the Southeastern Pine Ecosystem and the Oak-Pine Ecosystem.

This report was prepared under Contract NAS 9-15200, Job Order 75-325, Action Document 63-1737-5325-33. It is the final of four reports covering the study conducted at the Kershaw County, South Carolina, study site. Distribution of this report has been approved by the supervisor of the Forestry Applications Section and the manager of the Earth Observations Exploratory Studies Department.

CONTENTS

TABLES

FIGURES

1. INTRODUCTION

This document is the final report on the work performed on a study site located in Kershaw County, South Carolina, as a part of the Ten-Ecosystem Study (TES). (References 1, 2, and 3 are the previous reports.) This site (Site V), the fifth of nine sites, encompasses two ecosystems, which accounts for 9 sites and 10 ecosystems. The Kershaw County, South Carolina, location was chosen to represent both the southeastern pine and oak-pine vegetation types (ref. 4).

Site V represents a county of 203 554 square hectometers (503 100 acres) located in central South Carolina. Eight Landsat transparencies were evaluated to determine the two best seasons to use in the automatic data processing (ADP) analysis. The data processing consisted of a separability study and a simulated inventory study. The separability study was designed to establish the level of classification detail which is possible to achieve using Landsat data, and the simulated inventory study was used to determine how far classification of features could successfully be extended using limited ground-truth data. Classification results, based on the inventory study, were evaluated statistically to determine the map classification and feature proportion accuracy. For each phase of the work, both man-hours and machine-hours were recorded in order to establish guidelines for future project planning.

Initially, the site was classified into Level II features (ref. 5); that is, softwood, hardwood, grassland, water, and other. Level II accuracies from the separability study were found to be greater than 90 percent for all features, with the exception of grassland which was 80 percent. A Level III classification of softwood was performed to identify loblolly and slash pines, but the results were inconclusive because of the small sample size.

2. PRELIMINARY ANALYSIS AND SITE FAMILIARIZATION

This section presents a summary of procedures used and the results of the preliminary analysis and site familiarization tasks of Site V. The preliminary analysis task was designed to establish the two Landsat dates to be used in the computer analysis; and the site familiarization task was to provide first-hand ground information and background data on site vegetation, soils, geology, and forest management practices.

2.1 OBJECTIVES

The objectives of the preliminary analysis were as follows.

a. To establish the best seasons for ADP analysis by examining Landsat color composite frames

b. To provide initial site familiarization, thereby providing a basis for selecting training fields and identifying anomalous areas to be ground checked

c. To provide information on characteristic vegetation changes throughout the year

The objectives of the site familiarization task included the following.

a. Collecting information on site soils, climate, vegetation, geology, and forest management practices

b. Contacting U.S. Department of Agriculture (USDA), Forest Service personnel at the site for first-hand information

c. Visiting prospective training field locations for analysis of the vegetation patterns

2.2 GENERAL SITE DESCRIPTION

Kershaw County, South Carolina, was selected jointly by the USDA, Forest Service and the Nationwide Forestry Applications Program

(NFAP) as being representative of both the Oak-Pine Ecosystem and the Southeastern Pine Ecosystem. The forestry inventory conducted by the Forest Service was completed in 1977, and their data will provide a good basis for comparison of results. The Forest Service inventory results will be available in late 1978.

Kershaw County is located in central South Carolina and contains three land resource regions: the Southern Coastal Plain, Carolina Sand Hills, and the Southern Piedmont. The Carolina Sand Hills generally provides a transition zone between the Oak-Pine (Piedmont) and Southeastern Pine (Southern Coastal Plain) Ecosystems.

The climate is mild and humid in both summer and winter. Soil moisture and topography are the main factors which influence the distribution of vegetation.

2.3 PROCEDURES

To accomplish the objectives of the preliminary analysis and the site familiarization tasks, the procedures described in reference 6 were followed and are outlined in the next two sections.

2.3.1 PRELIMINARY ANALYSIS

One frame of high-altitude color-infrared photography taken over the site was interpreted at a scale of 1:30 000. The features of softwood, hardwood, grassland, and water were delineated. This classification was used as a basis of comparison with an interpretation made from Landsat color composite images over the same ground area. Five different Landsat dates were evaluated, and the one with the highest probability of correct classification (PCC) was selected as the primary date for ADP analysis.

The PCC was calculated by using a systematic grid (121 points), constructed over both the Landsat and the photointerpretated data.

The total number of correctly identified points on the Landsat data (the photointerpretation data were used as the ground reference) divided by 121 (the total number of points) gave the PCC for the image.

The second date for ADP analysis was selected based on two factors: the date had a high PCC for the features of hardwood and grassland, and the date represented a major change in hardwood and grassland growth patterns from the first date selected.

The aerial photographs were also used as the basis in selecting potential training fields to be used for ADP analysis. The selected areas represented large homogeneous features or anomalous areas to be identified in the ground check. The number of training fields selected was proportional to the occurrence of the class in the scene. The ground check of the training fields also provided a means of evaluating the accuracy of the initial photointerpretation data.

2.3.2 SITE FAMILIARIZATION

The site familiarization consisted of evaluating all available and pertinent literature on geology, climate, vegetation, and forest management practices for the South Carolina area. Personal contact with forest personnel provided expanded, first-hand information on these topics.

The ground check task covered a 1-week period. The training fields were divided between two teams of scientists who visited the training field and recorded site characteristics. The recorded characteristics included major forest species which were present, cover percentage, tree size, soil color, and under story species.

2.4 RESULTS

2.4.1 PRELIMINARY ANALYSIS

Figure 2-1 presents a stereopair with interpretations. This type of photointerpretation was used to evaluate the Landsat interpretation. The aerial photography used in this study was collected on the National Aeronautics and Space Administration (NASA) aircraft Mission 76-110A (July 21, 1976).

The PCC of the Landsat interpretation is presented in table 2-1. The May 1973 and May 1975 dates provided the highest accuracy in tonal separation in comparison with the photographs. The February 1976 date was selected as the second best date, based on its high PCC for hardwood and grassland and its representation of the leaf-off condition for deciduous trees (fig. 2-2).

The May 1973 Landsat date was finally selected for ADP analysis because of the high PCC and the 3-year time difference from the February 1976 secondary date. This time period would allow the data to be used for a future study of major vegetation change detection and analysis.

A total of 70 training fields were selected throughout the site. Based on the ground check of these areas, the overall accuracy of the photointerpretation was 100 percent.

2.4.2 SITE FAMILIARIZATION

This section discusses the general site characteristics based on the research and field investigations. Topics discussed include climate, geology, soil, and vegetation (refs. 7, 8, 9, 10, respectively).

Kershaw County, South Carolina, was selected to be representative of both the Southeastern Pine and the Oak-Pine Ecosystems.

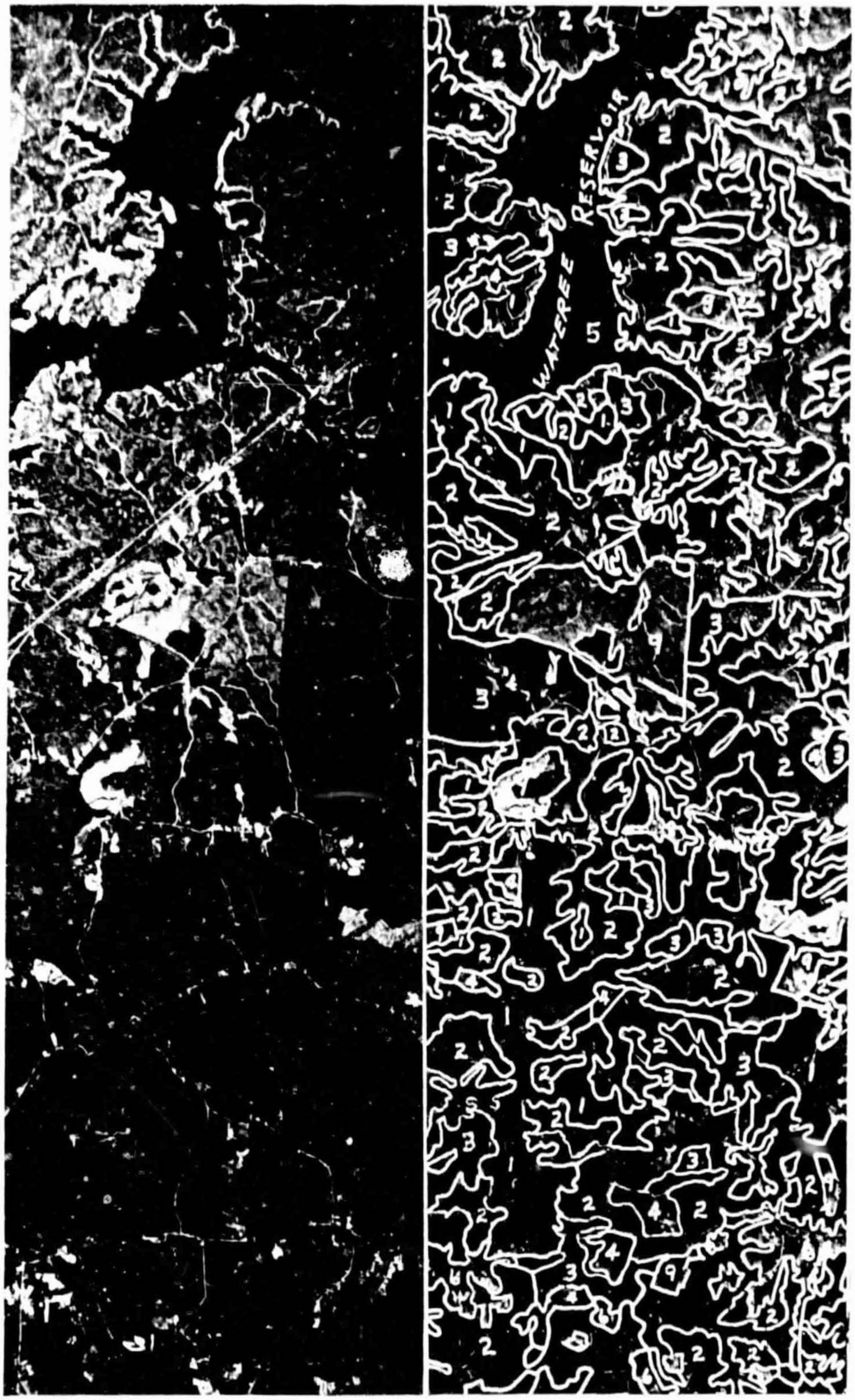
TABLE 2-1.– PCC FOR FIVE LANDSAT DATES[a]

ADP	Date	Frame number	PCC	PCC_{HG} (b)
I	May 24, 1975	5035-15054	60.33	78.50
	May 16, 1973	1297-15270	57.85	78.10
	Oct. 21, 1974[c]	1820-15205	50.41	78.92
II	Feb. 19, 1976	5306-14545	44.63	74.79
	Sept. 7, 1972	1046-15315	35.54	70.66

[a]High-altitude color-infrared photographs were used as ground reference.

[b]This is the PCC for hardwood and grassland.

[c]The frame did not cover the entire county.



LEGEND:

1. Hardwood
2. Softwood
3. Mixed
4. Grass
5. Water
6. Cultivated
7. Urban
8. Rock
9. Cutover

North

Figure 2-1.— Stereogram of a portion of the aerial photography used in imagery evaluation (1:120 000 scale). (Mission 76-110A, July 21, 1976.)

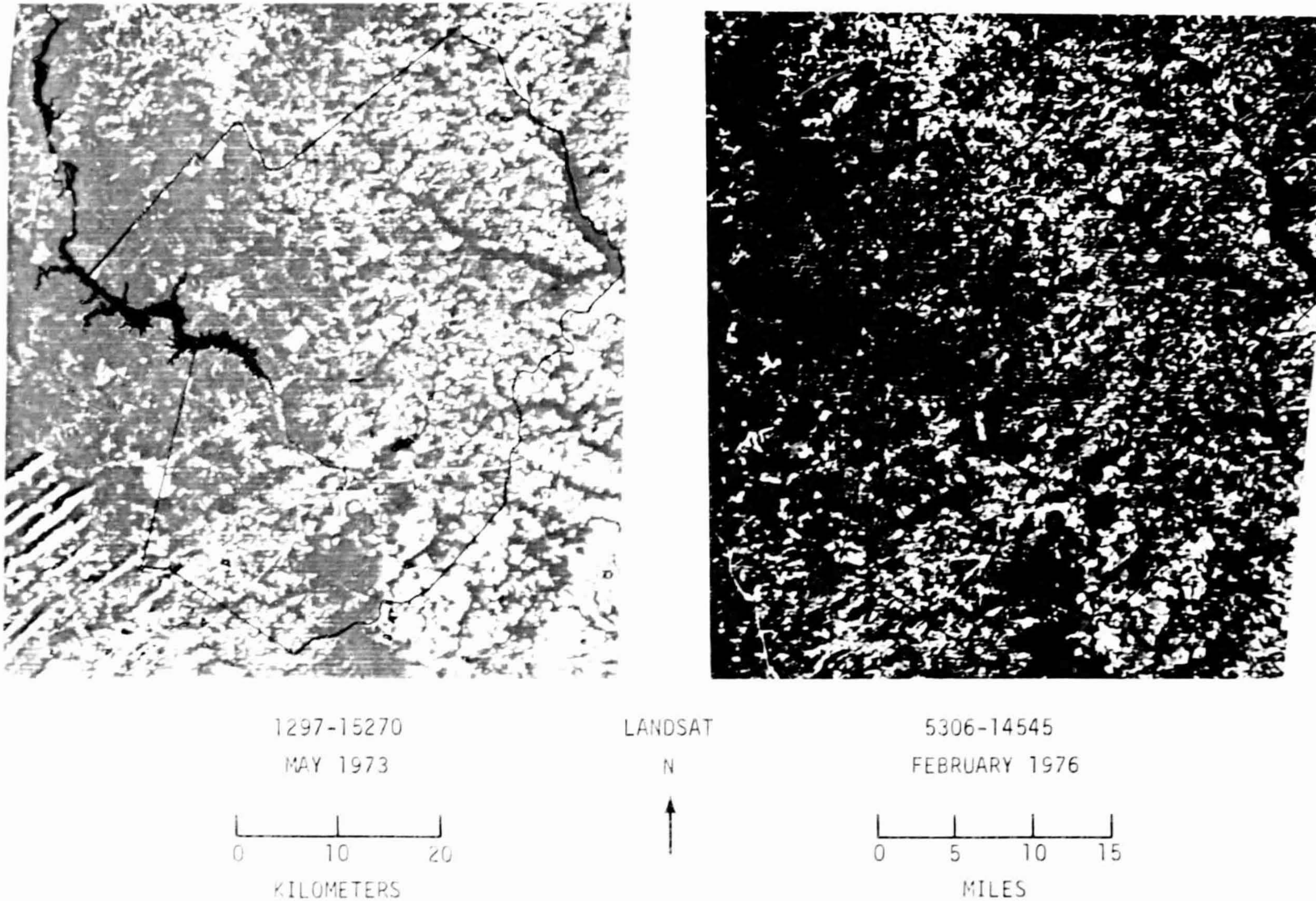


Figure 2-2.- Landsat images selected for automatic data processing.

The county is 203 554 square hectometers (503 100 acres) in size and is located in central South Carolina, latitude 34°17' north, longitude 80°36' west (fig. 2-3).

2.4.2.1 Climate

The climate is mild because of the modifying effect of the Gulf of Mexico and the Atlantic Ocean on easterly moving weather systems. The water bodies contribute to relatively mild and humid winters with average January temperatures of 7.2° C (45° F). The summer is uniformly warm and humid, with average July temperatures of 26.6° C (80° F). Occasionally, cold, dry polar or arctic air masses reach the area, bringing freezing and frost conditions. The mean annual temperature is 16.83° C (62.3° F).

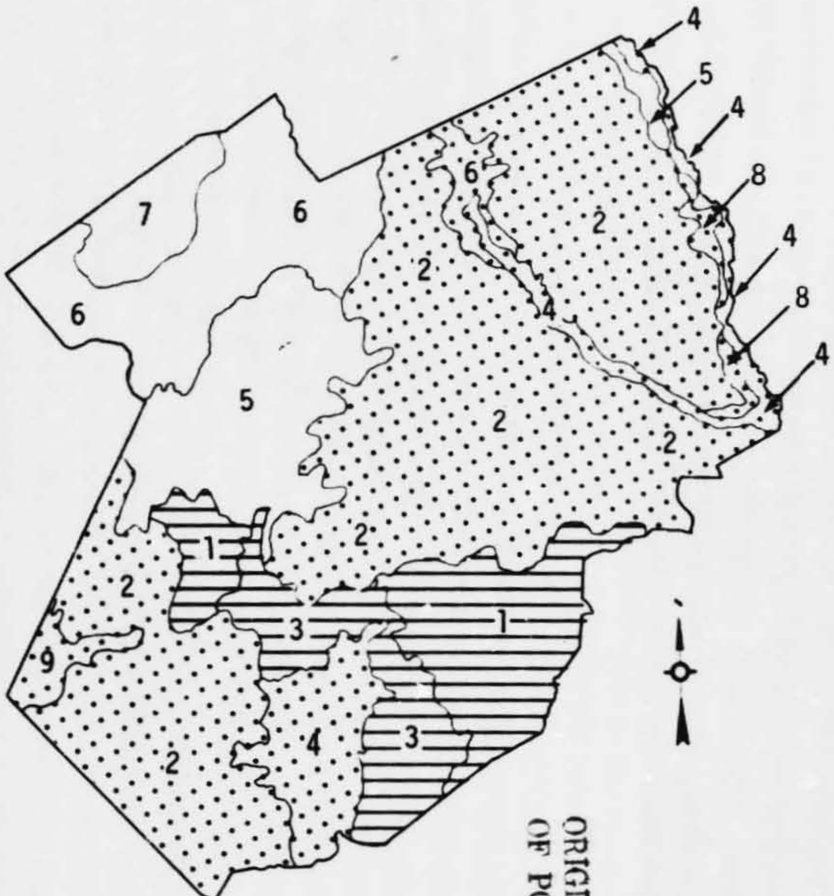
Southerly and easterly winds from the Atlantic provide most moisture and precipitation. The mean annual total precipitation is 113.79 centimeters (44.8 inches).

2.4.2.2 Geology and Soils

The greater part of the county is underlain by the Tuscaloosa formation with the Piedmont appearing in the northeast corner. The formation is 76.2 to 91.4 meters (250 to 300 feet) thick, consisting chiefly of buff sand on greasy sericite shist. However, in the southern or southeastern portion of the county, the formation contains more gravel and is highly ferruginous. The greater iron content, indicated by a reddish color, is probably caused by the sediments being derived from granitic rocks which are more ferruginous than those from the shist.

The formation gives rise to two of the three physiographic divisions of the county: the Sand Hills and the Coastal Plain. The third division is the Piedmont (fig. 2-4).

Figure 2-3.- Location of Kershaw County.



Soil Associations

LEGEND

1. Gilead-Vaucluse-Lakeland association: Well-drained, deep to moderately deep soils on gently sloping to steep areas.
2. Lakeland-Gilead-Vaucluse association: Well-drained, moderately deep and deep drouthy soils of the Sand Hills.
3. Wickham-Altavista-Roanoke association: Well-drained to poorly drained soils on the Wateree River terrace.
4. Wehadkee-Chewacla-Swamp association: Nearly level, very poorly drained soils on stream flood plains.
5. Goldston-Georgeville-Herndon association: Well-drained, shallow to deep soils of the Carolina Slate belt.
6. Louisburg-Lockhart-Cecil association: Well-drained soils of the Southern Piedmont upland with sandy loam or coarse sandy loam surface layers.
7. Appling, Louisburg Complex - Rough stony land association: Light-colored, coarse-textured, gently sloping soils and steep land with many rock outcrops.
8. Wahee-Izagora-Leaf association: Nearly level, moderately well drained to poorly drained soils on stream terraces.
9. Chesterfield-Bradley-Herndon association: Well-drained, gently sloping to sloping soils along the Fall Line from the Piedmont to the Coastal Plain.

Physiographic Divisions

- Piedmont (5, 6, 7)
- Coastal Plain (1, 3)
- Carolina Sand Hills (2, 4, 6, 8, 9)

Figure 2-4.– Physiographic divisions and corresponding soil associations for Kershaw County, South Carolina.

The Carolina Sand Hills in the northeastern and central portion of the county represents a transition zone between the Coastal Plain and the Piedmont. The elevation is 61 to 152 meters (200 to 500 feet), increasing from south to north. The area is a dissected, rolling to hilly upland with many stabilized dunes.

The second division, the Southern Coastal Plain, has elevations which gradually increase from 30 to 91 meters (100 to 300 feet) in the Piedmont. The gently to strongly sloping dissected plain is underlain with unconsolidated sands, silts, and clays. Upper valleys of streams are narrow, but the lower valleys are broad and have widely meandering stream channels.

The Piedmont division increases in elevation from 91 to 183 meters (300 to 600 feet). This dissected plateau is underlain mostly by shist, gneiss, granite, and by some basic crystalline rocks, sandstones, and slates. The topography is gently rolling to hilly, and the stream valleys are narrow.

The soils of the county may be defined broadly on the basis of the three physical divisions. Figure 2-4 shows the general soil categories associated with the physiographic divisions.

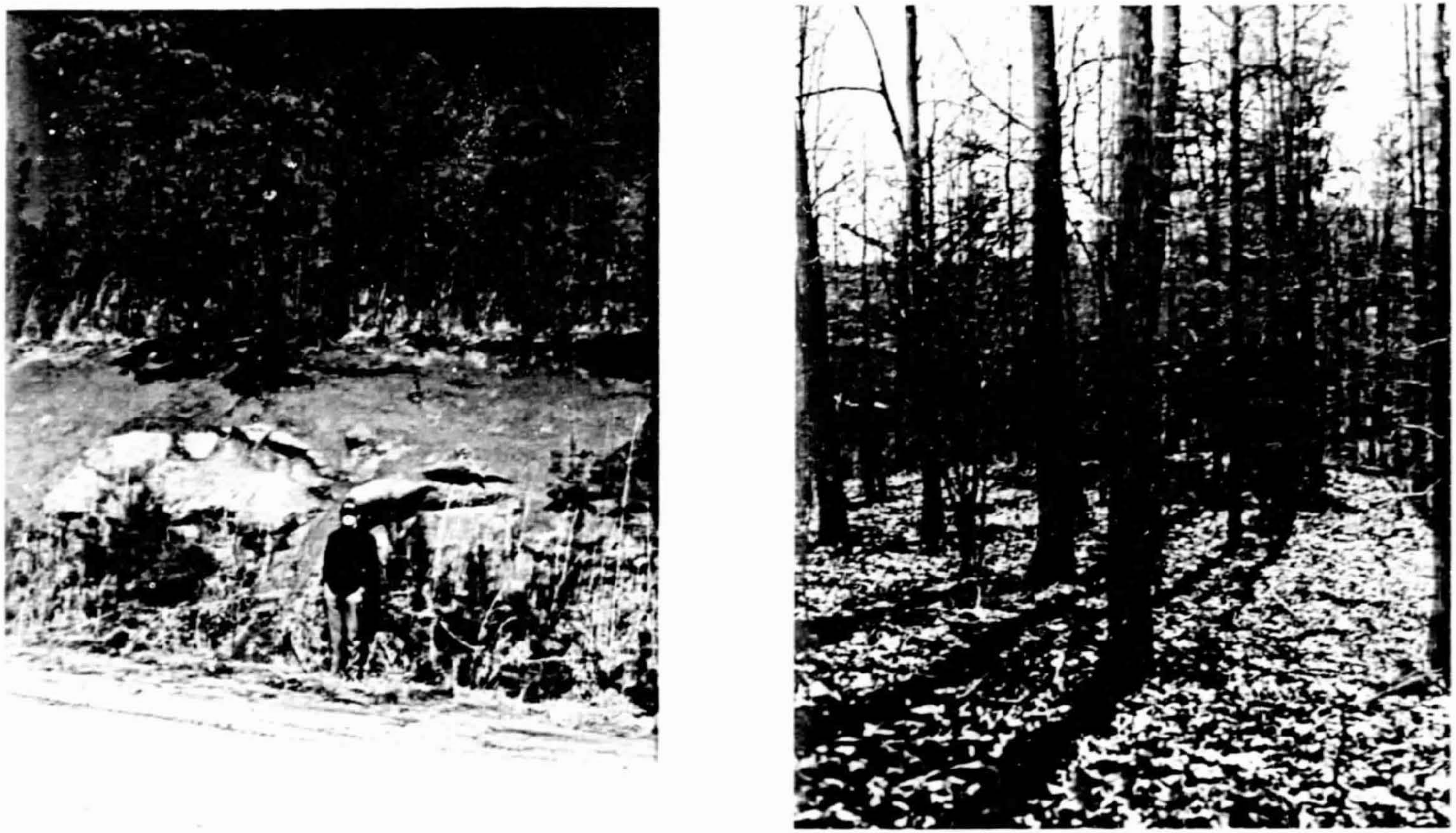
2.4.2.3 Vegetation

The Oak-Pine and Southeastern Pine Ecosystems correspond generally to the areas defined as the Piedmont and the Coastal Plain, respectively. The Carolina Sand Hills is a transition zone between the two ecosystems. The tree species growth and distribution are controlled mainly by soil type and moisture characteristics throughout the site. In general, hardwoods grow in the drains, and the pines grow on drier slopes and on ridgetops.

The Oak-Pine Ecosystem within the Piedmont is characterized by red and white oaks (*Quercus rubia, Quercus alba*) growing in the narrow, moist valley bottoms and pines, loblolly (*Pinus taeda)* and shortleaf (*Pinus echinata*), growing on the drier slopes and ridgetops (fig. 2-5).

The Southeastern Pine Ecosystem is characterized by pine growth on all dry sites (fig. 2-6). The pines include loblolly, shortleaf, and longleaf (*Pinus palustria*). Pines do not grow well in the broad river flood plains where hardwoods dominate. Typical hardwoods include water oak (*Quercus nigra*), river birch (*Betula nigra*), and yellow poplar (*Liriodendron tulipifera*). Agriculture fields and pasture occupy much of the land on the upland sites.

The pine species distribution is quite variable throughout the county. Reforestration efforts in the 1950's encouraged landowners to plant loblolly and shortleaf pines on abandoned cotton fields throughout the county. The Sand Hills division is mainly covered with agricultural fields and pine plantations of various species.



(a) Slash pine growing on Piedmont soil.

(b) Oak and hickory (foreground) and slash pine (background).

Figure 2-5.– Oak-pine area ground photographs.

(a) Loblolly pine plantations on sandy soils.

(b) Grassland (foreground) and loblolly and hardwood mix (background).

Figure 2-6.– Southeastern pine area ground photographs.

3. PREPROCESSING AND PROCESSING

The general objective of preprocessing was the preparation of the two Landsat data tapes for analysis on the Interactive Multispectral Image Analysis System, model 100 (Image-100), and scaling of the output data. Processing consisted of two tasks: (1) a separability study to determine the level of detail at which forest and grassland features can be differentiated and (2) an acreage inventory to determine how well limited ground-truth information from 10 percent of the site could be used to extend class signatures to the entire county.

3.1 OBJECTIVES

The objectives of the preprocessing task included the following.

a. Image-to-image registration of the two optimal Landsat data sets (i.e., May 1973, frame number 1297-15270, and February 1976, frame number 5306-14545)

b. Registration of the Landsat data to ground-control points

c. Calculation of scale factors to be applied to the data to produce a classification output with a 1-to-1 aspect ratio and calculation of Landsat picture element (pixel) size after scaling

d. Superimposing administrative boundaries on the Landsat data

e. Producing film transparencies of the resultant Landsat data

The objectives of the processing task, which consisted of a type separability study and an acreage inventory study, were as follows.

a. Determining the most effective radiometric resolution for data processing

b. Obtaining master signatures for the Level II classes of softwood, hardwood, grassland, and water

c. Determining training field accuracies at Level II

d. Determining the best Landsat date based on training field accuracies

e. Determining the Level III species classification training field accuracies

The acreage inventory was to develop signatures from a predesignated 10-percent area of the study site, to classify the entire site, and to produce acreage estimates and classification theme prints for analysis in the evaluation task (section 4).

3.2 PROCEDURES

Preprocessing and processing procedures are described in detail in reference 6. The following sections will present a brief description of the major preprocessing and processing steps which are diagrammed in figure 3-1.

3.2.1 PREPROCESSING

To accomplish the objectives of the preprocessing task, the February Landsat date was registered to the May date using the Earth Resources Interactive Processing System (ERIPS). This image-to-image registration produced an 8-channel temporal data tape which was 1000 pixels by 1000 lines in size.

The temporal data tape from ERIPS was used on the Image-100 to perform an image-to-ground registration. This registration used a least-squares analysis to calculate the coefficients to be used to convert image control points to the corresponding map control point. The coefficients were used to calculate a rotation factor which shifts data lines to the west in order to create the proper alinement of Landsat data with ground features.

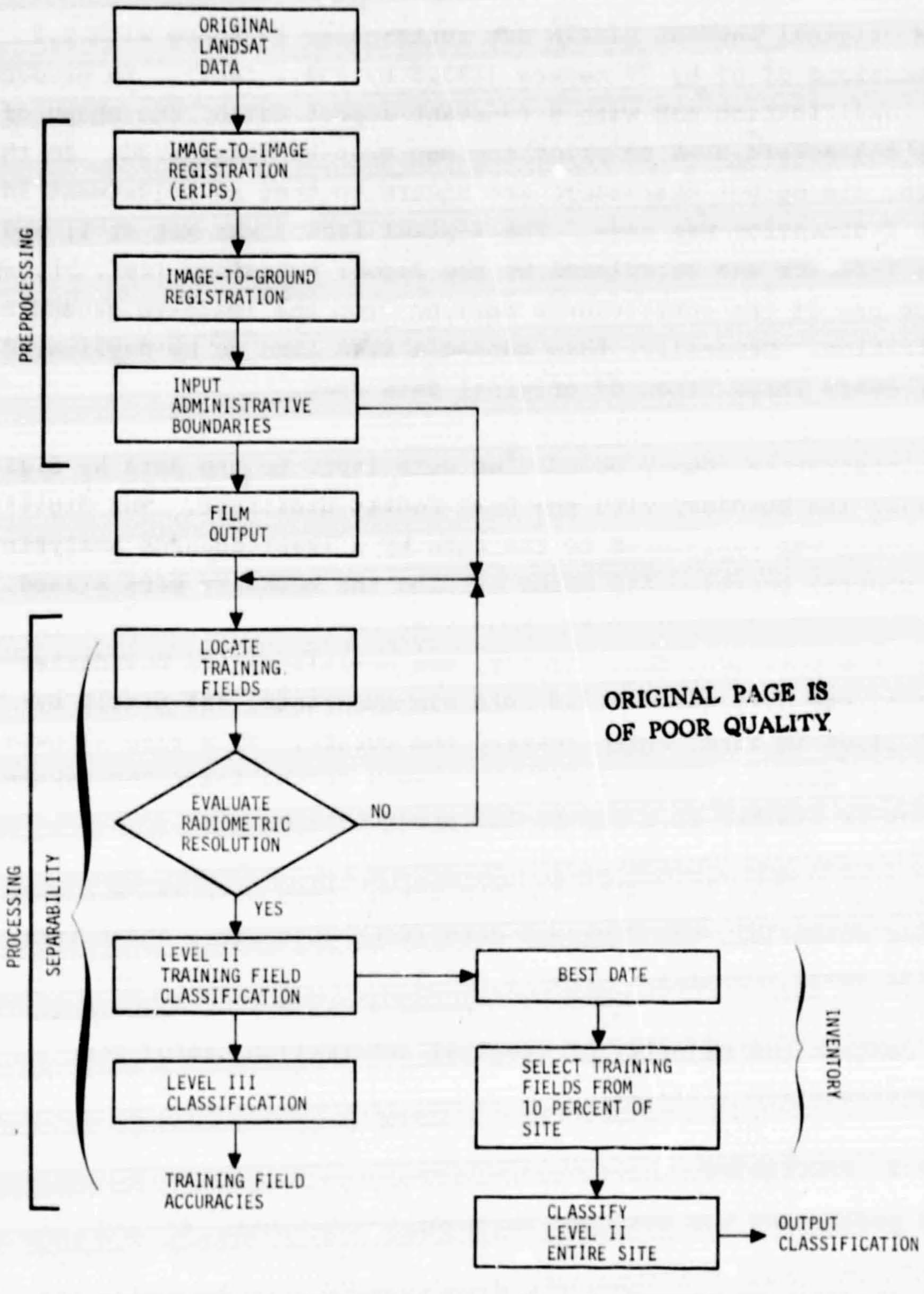


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Figure 3-1.– Preprocessing and processing data flow.

The original Landsat pixels are rectangular in shape with X,Y dimensions of 59 by 79 meters (193.5 by 259.1 feet). To produce a classification map with a constant aspect ratio, the shape of the characters used to print the map must be considered. In this case, the output characters are square so that an adjustment in the Y-dimension was made. The X-pixel factor was set at 1; and the Y-factor was calculated by the Jacobi transform (ref. 1), which made use of the coefficients derived from the image-to-ground registration. Generally, this caused a scan line to be duplicated for every three lines of original data read.

Administrative county boundaries were input to the data by digitizing the boundary with the Dell Foster digitizer. The digitized boundary was registered to the data by a least-squares analysis of 16 control points. All areas outside the boundary were erased.

With the rotation, scale factor, and administrative boundaries input, the site was divided into six quadrants, 485 pixels by 485 lines in size, which covered the county. This size allowed for the display of all lines and pixels on the Image-100 screen, which is limited to a 512-by-512 presentation.

Three data sets were made for the site. They were the May date (four channels), the February date (four channels), and a temporal image containing bands 2 and 4 of the February date and bands 2 and 4 of the May date. Bands 2 and 4 have been shown to contain the majority of spectral information useful for classification (ref. 11).

3.2.2 PROCESSING

The processing was designed to study two factors important to forestry remote sensing (i.e., type separability and acreage inventory). The type separability study was to determine the amount of detail obtainable from Landsat data in terms of features which could be classified by ADP techniques.

The acreage inventory study was designed to determine how successfully ADP technology can extend limited ground truth for large area inventories.

The TES investigated two levels of hierarchy (table 3-1). Level II features included softwood, hardwood, grassland, and water. The definitions of softwood and hardwood are the ones presently used in the Forest Service survey (ref. 12). Level III features defined for this site were loblolly and slash pines.

3.2.2.1 Separability Study

For the separability study, the training fields which were selected on the photography and visited in the field were located on the Landsat data. The training fields were scattered throughout the site and represented the Level II features. The signatures for the individual training fields were aggregated to produce a master signature for each feature. In order to obtain unique signatures for each feature, a maximum likelihood decision program, CLASS, was run. The program CLASS resolves the classification ambiguity, when a cell in spectral space has been classified as more than one feature, by assigning the cell to the feature which has the highest probability of occupancy in the cell. The master signature was then used to classify the original training fields and to compute training field accuracies.

An initial evaluation was performed with signatures from one quadrant to determine the radiometric resolution which produced a signature variance of less than 4.5 radiance values in each channel and qualitatively provided good scene classification. The resolutions selected were used for all subsequent processing.

TABLE 3-1.— LEVEL OF HIERARCHY CLASSIFIED IN KERSHAW COUNTY

Class	Definition
Softwood[a]	Coniferous trees, usually evergreen, include longleaf-slash pine, loblolly-shortleaf pine, and oak-pine mix where hardwoods comprise a plurality of the stocking and pines comprise 25 to 50 percent of the stocking. Level III features were loblolly and slash pines.
Hardwood[a]	Dicotyledonous trees, usually broad leaved and deciduous, including oak-hickory in upland areas and oak-gum-cypress mix in bottomland locations.
Grassland[a]	Includes both improved pasture, where some management practices (planting and fertilization) are used to produce a forage crop or to provide a grazing area, and rangeland, consisting principally of native grasses, forbs, or shrubs valuable for forage.
Water	Rivers and lakes, mainly the Wateree Reservoir and the Wateree, Lynches, and Little Lynches Rivers.

[a]Standard Forest Service survey definitions for the southeastern United States.

Master signatures and training field accuracies were calculated for each data set. The date which provided the highest overall PCC was selected as the optimal date and used in the area inventory study.

A Level III species separation was performed if the Level II training field accuracies were 90 percent or better for all softwood and hardwood and 80 percent or better for grassland. The major Level III species for which ground truth was available were loblolly and slash pines. Hardwoods occurred as mixes of various species, and a separation was not attempted.

3.2.2.2 Area Inventory

The best date selected from the separability study was used as the basis for the area inventory. An area representing 10 percent of the site, which had not been visited on the ground, was used to extract Level II training signatures. The training fields were selected from the interpretation of high-altitude color-infrared photographs at a scale of 1:120 000. The Level II signatures were then used to classify the remainder of the site. The classification output was then evaluated using procedures presented in section 4.2.2 to determine overall map accuracy, feature proportions, and errors in proportion.

3.3 RESULTS

3.3.1 PREPROCESSING

Table 3-2 summarizes the results of the image-to-image and image-to-ground registrations. Generally, the registration accuracies were 1.4 to 2.0 pixels.

The root-mean-square (rms) error may be slightly higher than the standard of 1.5 in two cases, but this was felt to be acceptable in order to have a good distribution of control points throughout

TABLE 3-2.— CONTROL POINTS AND RESULTING RMS ERROR OR TWO REGISTRATIONS

Registration method	Number of control points	RMS error
Image to image	51	2.0 pixels
Image to ground	28	1.748 pixels 1.416 lines

the site. The line stretch factor, calculated from the coefficients of the least-squares program, was 1.41. This represented 344 Landsat lines read into 485 image lines on the Image-100. Approximately every fourth line was duplicated for each data set. Each screen pixel size represented a square with an area of 0.322 square hectometers (0.795 acre).

3.3.2 PROCESSING

The radiometric resolution selected for classification of each date is presented in table 3-3. The average variance at the given resolution ranged from 0.29 to 1.39 data values. Also, based on a qualitative evaluation of the classification of segment 1, the resolutions in table 3-3 were judged to produce a classification similar to that available from aerial photography.

TABLE 3-3.— RADIOMETRIC CELL RESOLUTIONS WITH AVERAGE VARIANCE, ESTABLISHED FOR KERSHAW COUNTY CLASSIFICATION, WITH THREE DATA SETS

Date	Band			
	1	2	3	4
February	64 (0.87)	64 (0.29)	64 (0.51)	32 (0.44)
May	32 (1.39)	32 (.35)	32 (.52)	16 (.37)
Temporal	32 (.35)	16 (.37)	64 (.29)	32 (.44)

3.3.2.1 Separability

The Level II training field accuracies for each date are presented in table 3-4. The temporal data have the highest overall and individual class accuracies and, therefore, were used for the area inventory processing.

TABLE 3-4.— SUMMARY OF TRAINING FIELD CLASSIFICATION ACCURACIES FOR THE SEPARABILITY STUDY

Feature	February	May	Temporal
Softwood	99.2	97.6	99.2
Hardwood	92.0	95.4	100
Grassland	100	90.3	100
Water	100	99.4	100
Total	98.4	97.7	99.9

The Level II feature accuracies met the established limit, so two Level III classifications were performed. The first Level III separation involved the separation of the class mixed from softwood. Mixed, in this instance, was defined as areas of about 40 to 60 percent softwood and 40 to 60 percent hardwood. This definition differs from that used in the Forest Service survey, but it is more representative of the type of mix which can be identified by Landsat. The training field accuracies were highest for mixed areas in the temporal data when the other classes were also classified (table 3-5).

A Level III species separation was also performed using the training field information acquired during the site familiarization trip. Loblolly and slash pine separability was investigated using the temporal data. Table 3-6 presents the training field accuracies.

TABLE 3-5.– SUMMARY OF TRAINING FIELD CLASSIFICATION ACCURACY WITH MIXED AS A FEATURE

Feature	February	May	Temporal
Softwood	87.3	98.4	90.5
Mix	63.5	78.8	88.5
Hardwood	89.1	92.6	97.1
Grassland	100	93.1	100
Water	100	100	100
Total	94.4	96.8	97.6

TABLE 3-6.– TRAINING FIELD ACCURACIES FOR LEVEL III SPECIES CLASSIFICATION USING TEMPORAL DATA SET

Feature / Ground	Sample size pixels	Classification, %	
		Loblolly	Slash
Loblolly	76	89.4	10.6
Slash	28	10.6	89.4

3.3.2.2 Area Inventory

The feature proportions developed by the inventory classification of the entire county is presented in table 3-7. Only signatures developed from 10 percent of the county area were used in classifying the entire site. The county acreages from the 1967 Forest Service survey (ref. 12) are also presented for comparison.

The total county acreages differ from Forest Service acreages only about 2 percent, and the acreages for the individual classes differ by 23 to 52 percent. The range in spectral values may be reduced by lowering the radiometric resolution used for classification by a factor of 2 (i.e., 16, 8, 32, and 16 and 8, 4, 16, and 8). With the same training areas, the proportions for each feature are increased with the reduced radiometric resolution.

TABLE 3-7.– COMPARISON BETWEEN INVENTORY CLASSIFICATION AND FOREST SERVICE AND SOIL CONSERVATION SERVICE (SCS) ACREAGES FOR KERSHAW COUNTY, SOUTH CAROLINA[a]

Feature	ADP inventory proportions[b] (radiometric resolution), %			USDA, Forest Service and SCS proportions[b]
	32, 16, 64, 32	16, 8, 32, 16	8, 4, 16, 8	
Softwood	24.7	30.9	42.9	51.0
Hardwood	15.5	25.4	29.3	24.8
Grassland	2.7	11.4	16.2	3.6
Water	1.0	1.7	1.7	2.2
Other	54.2	28.8	7.9	18.4
Total	98.1	98.2	98.0	100.0

[a]Total county acreage equals 203 554 square hectometers (503 100 acres).

[b]Temporal image data were inventoried.

4. POSTPROCESSING AND EVALUATION

The inventory classification results were used in the postprocessing and evaluation tasks. Postprocessing produced classification maps for evaluation and produced classification maps with a minimum feature size. The evaluation used a statistical sampling technique of the classification to quantify overall map accuracy, proportion estimation, and error in proportion.

4.1 OBJECTIVES

Postprocessing requirements included the following.

a. Producing a film transparency of four merged segments, 970 by 970 pixels, after being processed through the GETMIX/CLEAN program

b. Producing a film transparency of original classification results

c. Producing classification maps at a scale of 1:126 000

d. Producing alphanumeric printouts of classification results for analysis during evaluation

The evaluation of the classification was designed to determine the following.

a. The overall map PCC

b. The confidence interval for the PCC

c. The proportion of each class

d. The proportion error for each class

e. An improvement in precision of class acreage estimates by the regression calculation

4.2 PROCEDURES

4.2.1 POSTPROCESSING

The area inventory classification was processed through the steps in figure 4-1 to produce the required output.

The Univac 1108 computer was used to merge the four classification segments into a single data tape. The data were then run through the program GETMIX/CLEAN. This program groups feature classes, which are less than a given size, into the larger, surrounding class. This process eliminates the salt-and-pepper effect caused by pixel-by-pixel classification. The final classification maps have a cleaner appearance and more closely approximate Forest Service stand maps. Ten acres is the normal minimum size area mapped and was used to execute the GETMIX/CLEAN program. Areas less than 16 square hectometers (40 acres) in size were eliminated in the case of water. This is one of the criteria established by the Forest Service for census versus noncensus water.

The output of this task and the results from the original inventory classification were filmed for documentation purposes. The classification results were also output on a line printer for use in the evaluation.

4.2.2 EVALUATION

The process used for evaluation is outlined in figure 4-2.

A total of 25 primary sampling unit (PSU) locations were chosen using a random number generator and were located on the alphanumeric printout. The PSU's were initially plotted on both aerial photographs and on the Landsat color composites. Where the PSU's fell on clouds or cloud shadows, on either the Landsat segments or the aerial photography, new PSU's were chosen so that a maximum of 25 PSU's could be evaluated.

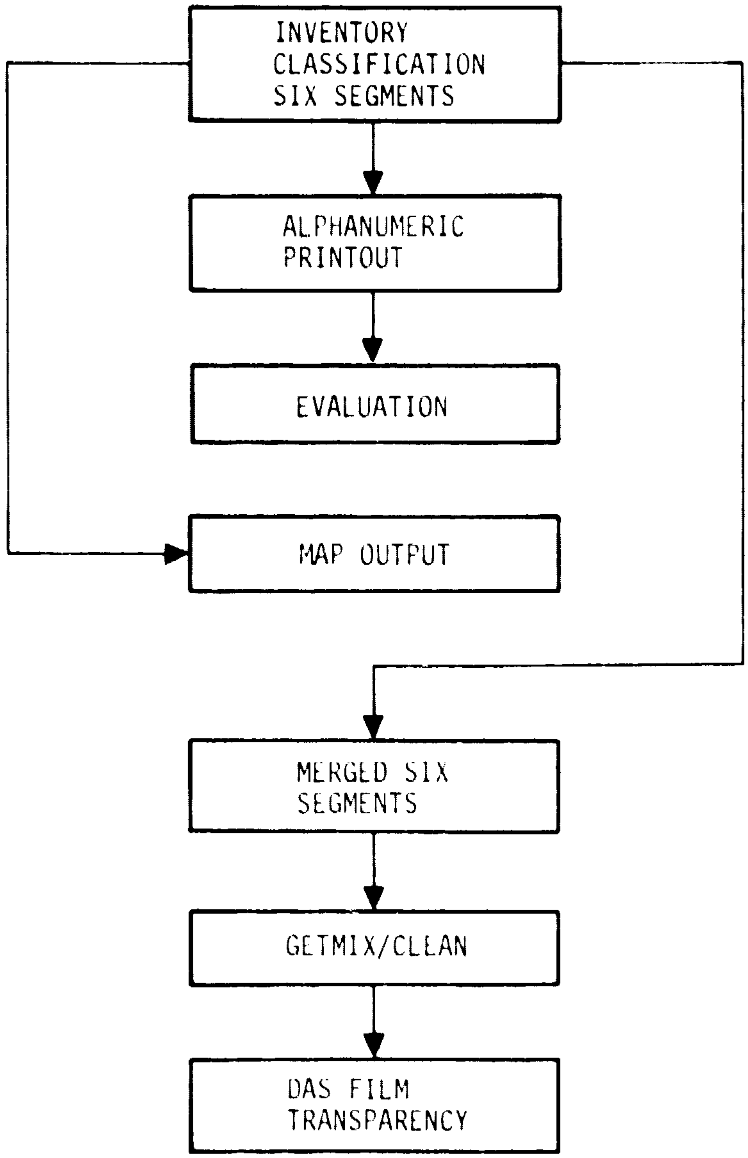


Figure 4-1.– Postprocessing flow diagram.

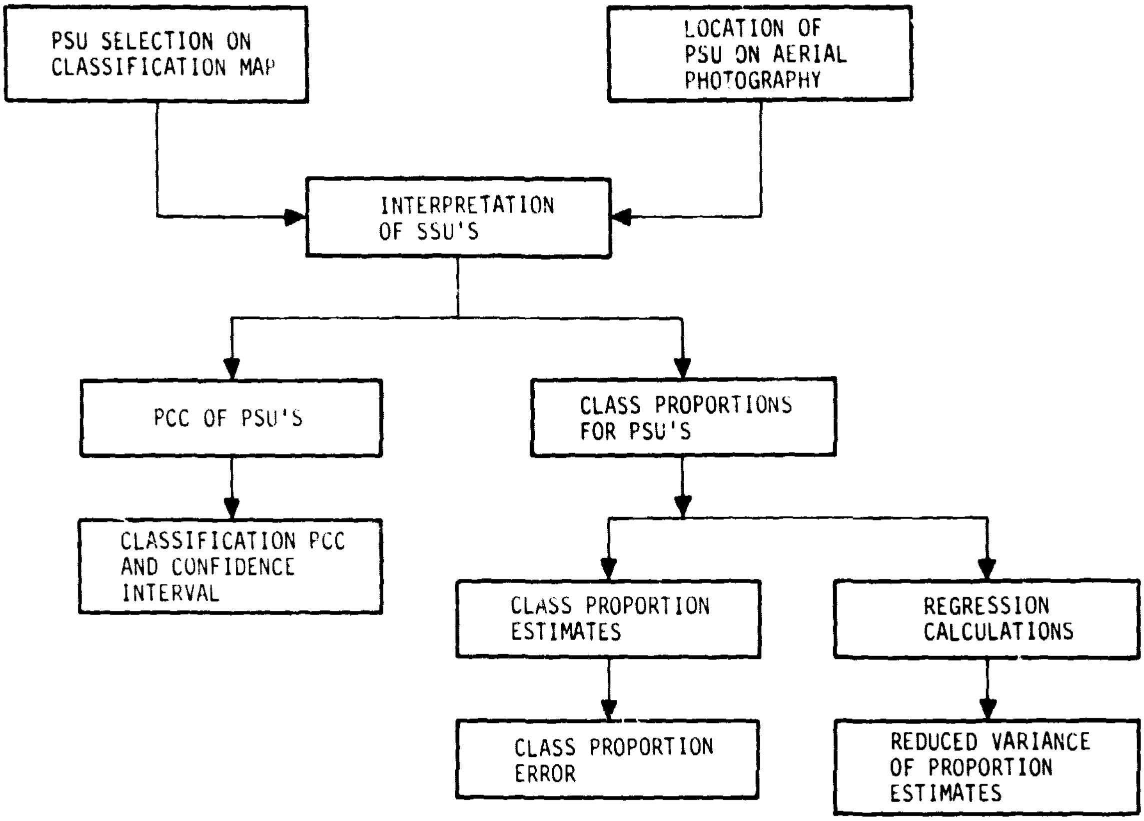


Figure 4-2.— Evaluation flow diagram.

A total of six control points in or outside each PSU were picked The control points consisted of easily identifiable ground features. The control point coordinates were digitized on the Landsat data and aerial photograph. They were then used in a least-squares-fit program on a programmable hand electronic calculator to determine the registration parameters (ref. 13). These parameters were used to calculate the exact location of the PSU on the aerial photograph.

Ten secondary sampling units (SSU's) were randomly located within each PSU. The classifications within each SSU (2 by 2 pixels in size) were compared with interpreted classification of the same area on aerial photography, using the zoom transfer scope. The SSU accuracies and proportions were combined to develop the PCC and class proportion for each PSU. The PSU statistics were then used to develop accuracies and proportions for the entire site. The classification results from only the inventory study were evaluated.

The TES procedures require a minimum of 10 PSU's, with a total of 100 SSU's being processed. Using these numbers, it was possible to determine the average PCC for the site by dividing the total number of SSU's into the total number of SSU's correctly classified. After the PCC for 10 PSU's had been computed, the confidence interval was determined at the 90-percent confidence level, and the half interval (Δ) was calculated. If Δ was greater than 5 percent, additional PSU's (up to a total of 25) were evaluated until Δ came within the required range (i.e., less than 5-percent PCC).

Estimated class proportions ($\hat{p}$) for each class were calculated by summing the PSU proportions from the computer classification and dividing by the number of PSU's [m in eq. (1)]. Aerial photographic class proportions (p) were calculated in a similar manner by using the photointerpreted proportions for each PSU.

$$\hat{p} = \frac{1}{m} \sum_{i=1}^{m} \hat{p}_i \tag{1}$$

where

m = number of PSU's

$\hat{p}$ = PSU class proportion from computer classification

i = PSU index

The mean error in class proportion, B, is calculated by summing the difference between the photographic class proportions (p_i) and the ADP class proportions for each PSU and dividing the result by the total number of PSU's [m in eq. (2)].

$$B = \frac{1}{m} \sum_{i=1} B_i = \frac{1}{m} \sum_{i=1} (p_i - \hat{p}_i) \tag{2}$$

4.3 RESULTS

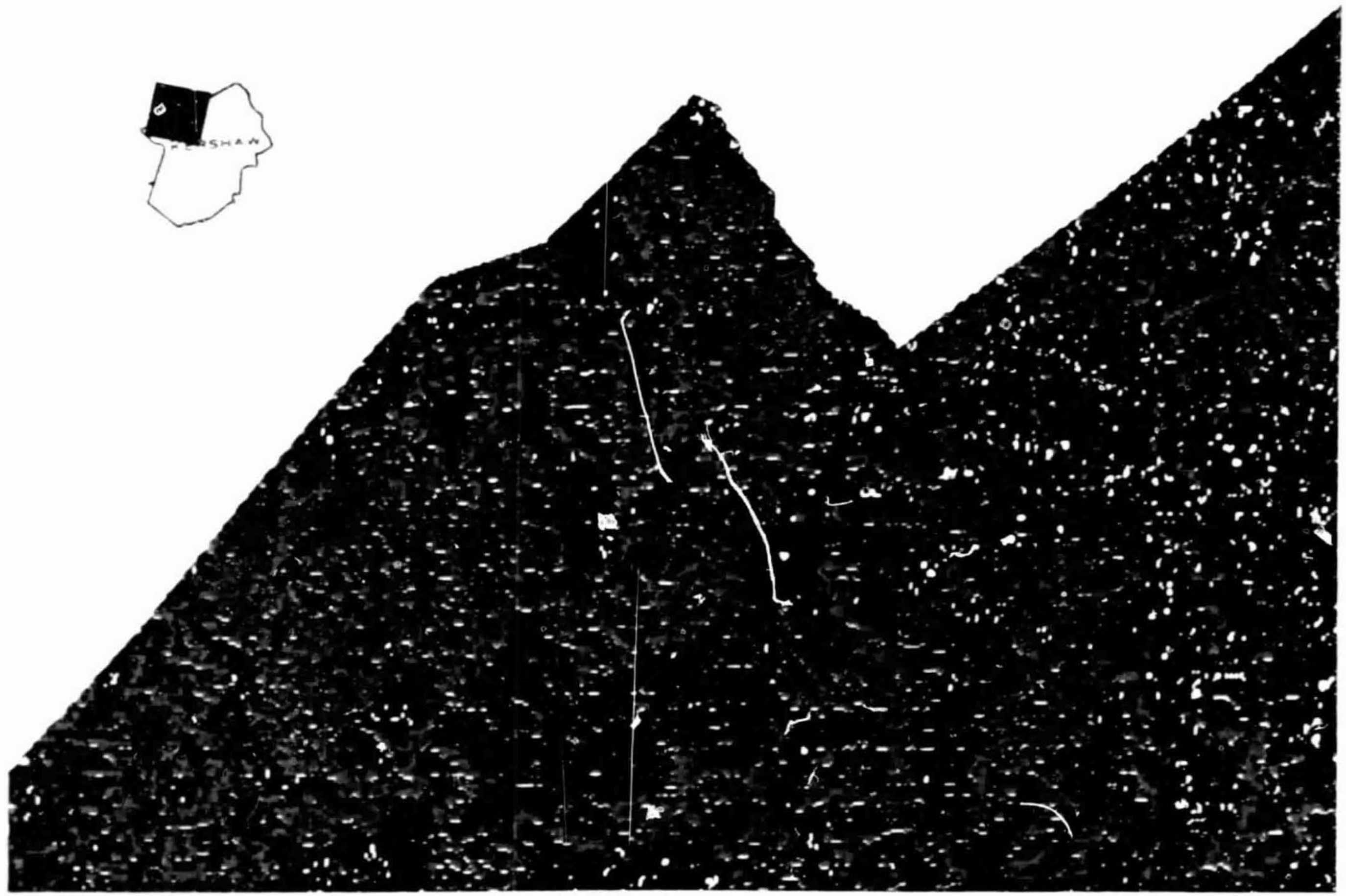
4.3.1 POSTPROCESSING

Figure 4-3 presents the original inventory classification for segment 1, with a radiometric cell resolution of 32, 16, 64, and 32.

Figure 4-4 is the same area after the GETMIX/CLEAN program has been applied. There are now more solid areas of classification.

Figure 4-5 presents the classification using the same inventory training fields with a reduced resolution of 8, 4, 16, and 8. There is more of the total site classified with larger, more continuous areas of classification.

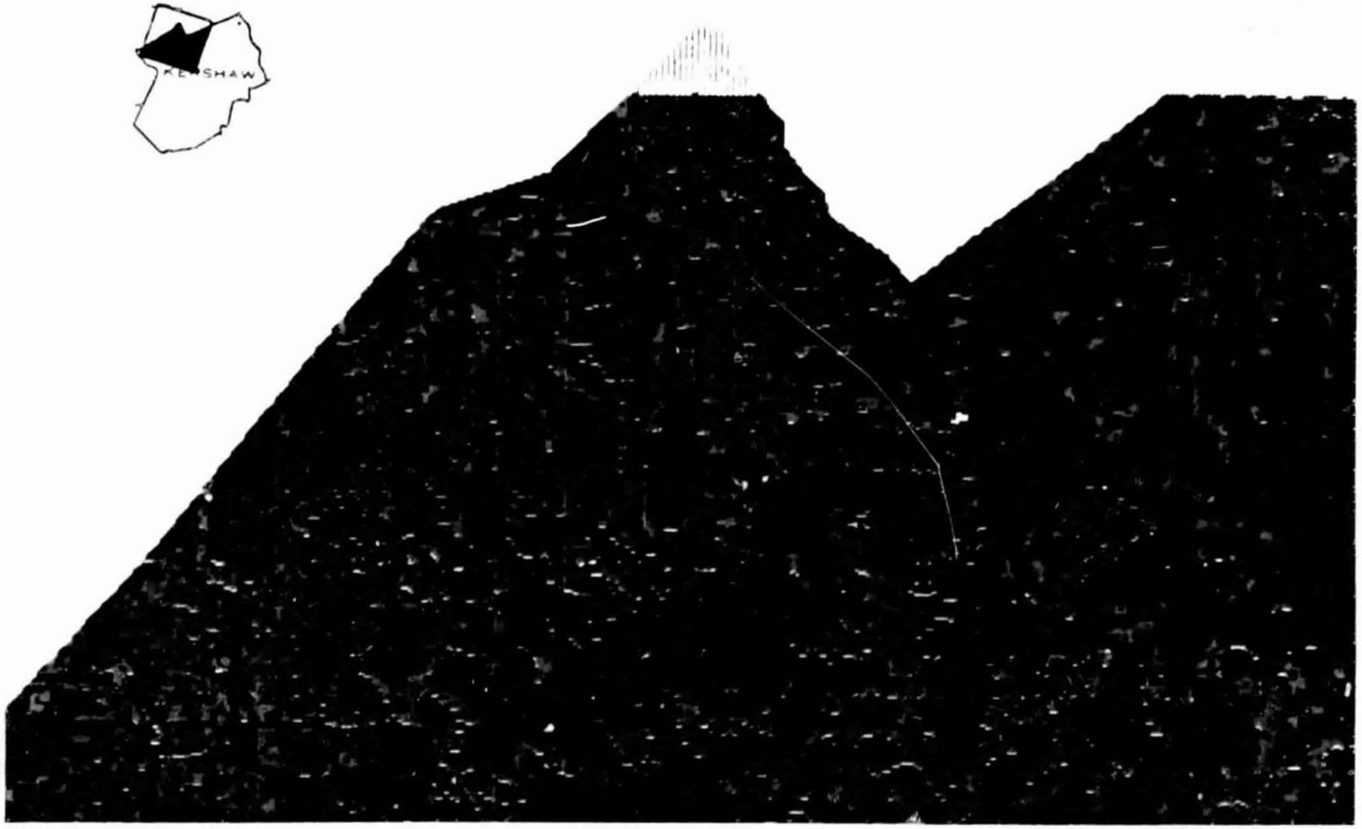
Figure 4-6 is the inventory classification map of the entire county, overlaid onto a black-and-white rendition of band 5 in the February data set.



LEGEND

Green – Softwood (loblolly, shortleaf pine)
Red – Hardwood (red oak, white oak, river birch)
Yellow – Grassland
Blue – Water
Black – Other

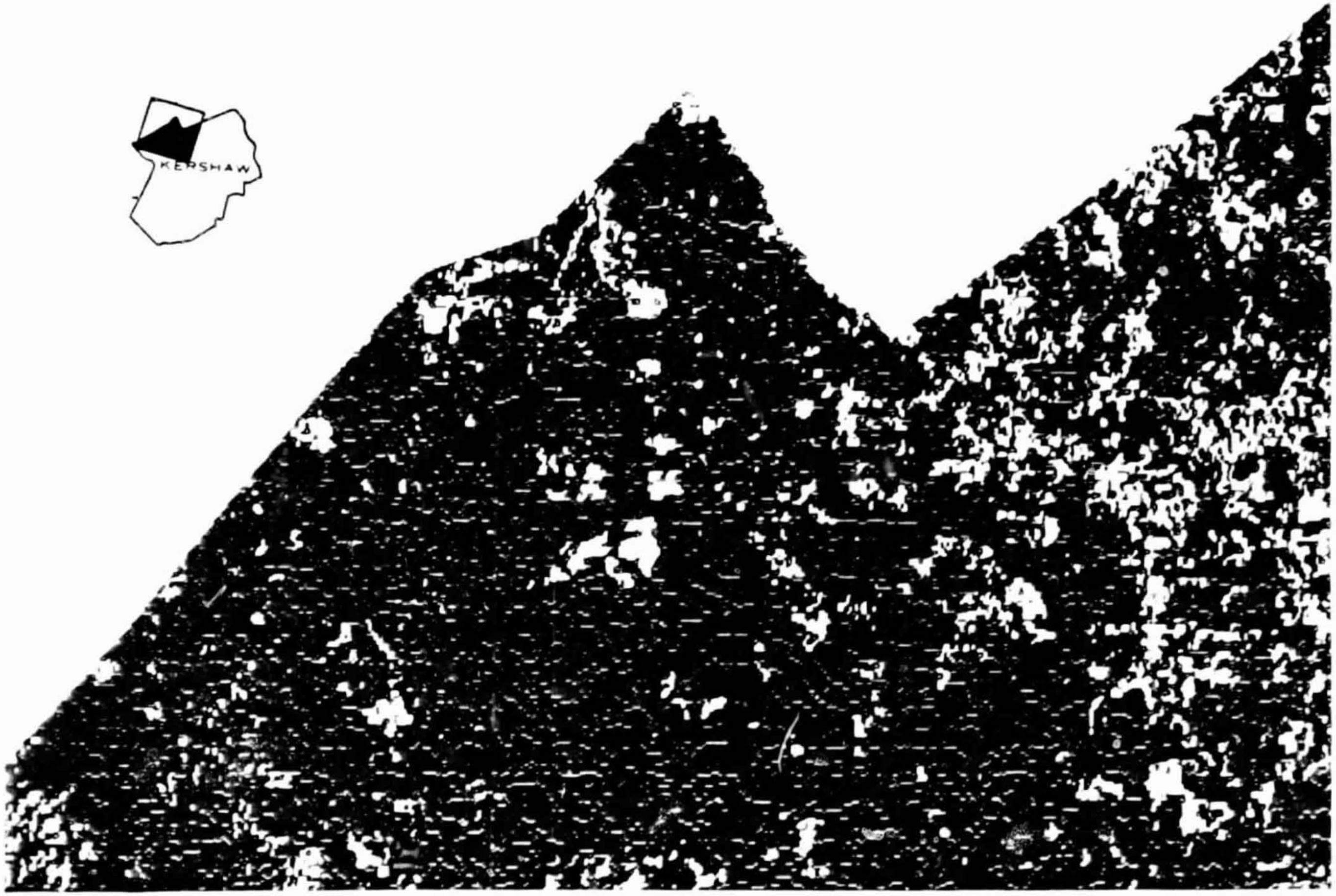
Figure 4-3.- Inventory classification of segment 1. (Temporal data; radiometric resolution 32, 16, 64, and 32.)



LEGEND:

Green — Softwood (loblolly, shortleaf pine)
Red — Hardwood (red oak, white oak, river birch)
Yellow — Grassland
Blue — Water
Black — Other

Figure 4-4.- Inventory classification of segment 1 after GETMIX/CLEAN. (Temporal data; radiometric resolution 32, 16, 64, and 32.)



LEGEND

Green — Softwood (loblolly, shortleaf pine)
Red — Hardwood (red oak, white oak, river birch)
Yellow — Grassland
Blue — Water
Black — Other

Figure 4-5.– Inventory classification of segment 1. (Temporal data; radiometric resolution 8, 4, 16, and 8.)

Presented on following page.

Figure 4-6.– Inventory classification of Kershaw County, South Carolina. (Temporal data; radiometric resolution 8, 4, 16, and 8.)

NATIONWIDE FORESTRY APPLICATIONS PROGRAM
TEN ECOSYSTEM STUDY

KERSHAW COUNTY, SOUTH CAROLINA

4.3.2 EVALUATION

Results obtained after calculating 18 PSU's, using the original locations on the alphanumeric output, produced a PCC of 60 percent with a delta of 0.058 (table 4-1). A check of six PSU locations indicated that they had not been located to within ±1 pixel as called for in the procedures. The PSU locations on the alphanumeric output were repositioned using the zoom transfer scope and using the prominent features on the aerial photography for alinement. Based on the best-fit locations and an additional six PSU's, the PCC was increased but the confidence interval remained about the same.

A one-way analysis of variance (ANOVA; ref. 13) indicated that there was not a statistical difference between the means when using the original and the best-fit locations.

TABLE 4-1.– PCC AND CONFIDENCE INTERVAL AT THE 90-PERCENT LEVEL FOR INVENTORY CLASSIFICATION

Inventory[a]	Number of PSU's	PCC	90-percent confidence interval	$\Delta.9$
Original PSU locations	18	60.0	(0.54, 0.66)	0.058
Best fit (local registration)	24	70.0	(.64, .76)	.057

[a]ANOVA: Calculated $F_{1,40}$ = 4.0336.
Tabulated F(0.05 significance) = 4.08.

Table 4-2 presents the calculated proportions of each class for the simulated inventory study using 24 PSU's. The class proportions were determined by evaluating the PSU's on the photography (p), the estimated proportion ($\hat{p}$) from the computer classification, the average error of the estimate (B), and the confidence interval of the average error at the 0.9-confidence level ($\Delta.9$).

TABLE 4-2.- PROPORTION ERRORS FOR THE INVENTORY STUDY AND BEST-FIT PSU LOCATIONS

Feature	Proportion error			
	Photographic class proportion, p	ADP class proportion, $\hat{p}$	Average error, B	90-percent confidence interval
Softwood	0.371	0.314	0.057	(0.021, 0.093)
Hardwood	.291	.222	.069	(.036, .108)
Grassland	.039	.042	-.003	(-.025, .019)
Water	.018	.015	.003	(-.005, .011)
Other	.278	.407	-.129	(-.167, .091)

Table 4-2 also presents the class proportion error estimates calculated for the study site. To reduce the variance of the estimates, a linear regression analysis was performed using the estimated class proportion ($\hat{p}_i$) versus the true class proportion (p_i).

The F-test was used to test the hypothesis that the true slope of the regression was 1 and the intercept was 0. This hypothesis was accepted for all classes at the 0.01-level of significance (ref. 14). This indicated that there was no significant bias in the proportion estimate between the photointerpreted results and the ADP classification.

Figures 4-7 and 4-8 present an illustration of the class proportions calculated by using different procedures throughout the TES. Softwood and hardwood proportions are presented for the wall-to-wall classification of the separability study for the three data sets and the Forest Service survey estimates. The data presented in ascending order are: line 1, wall-to-wall separability proportion estimates of the given class for the three dates and the ADP simulated inventory wall-to-wall estimate;

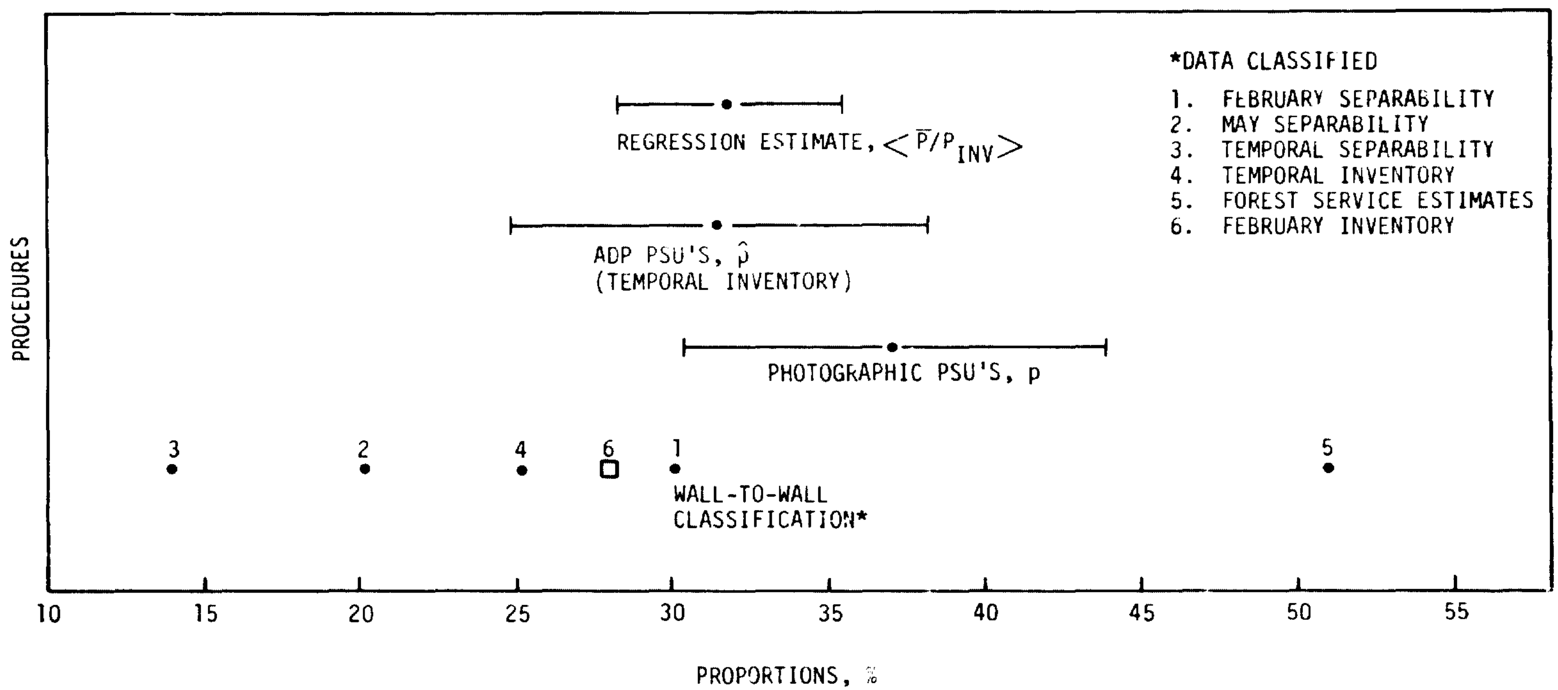


Figure 4-7.– Softwood proportions for Kershaw County, South Carolina, based on four procedures. (0.90 confidence limits.)

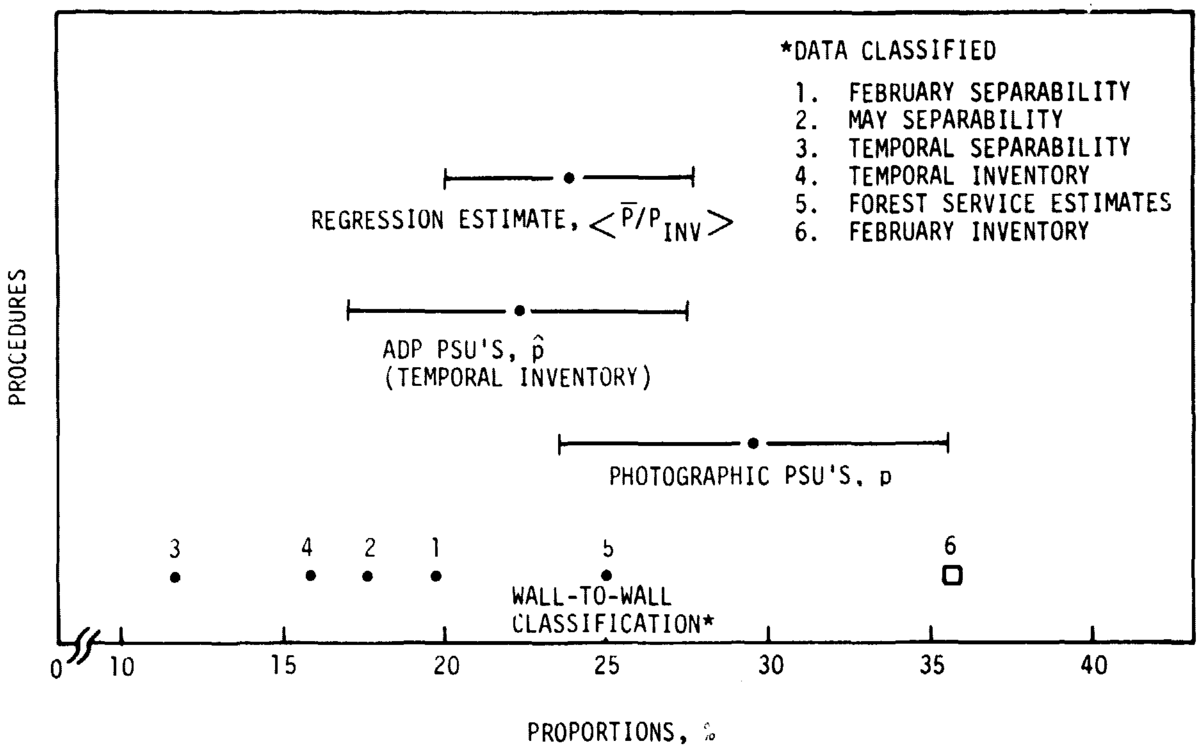


Figure 4-8.– Hardwood proportions for Kershaw County, South Carolina, based on four procedures. (0.90 confidence limits.)

line 2, the aerial photograph sample estimate and its 90-percent confidence interval; line 3, the ADP simulated inventory sample estimate and its 90-percent confidence interval; and line 4, the regression estimate, its 90-percent confidence interval, and the corresponding wall-to-wall separability estimate.

It was expected that the wall-to-wall separability proportions would be the best estimate of the class proportions because the training fields are selected from throughout the site and should be most representative of the class. This is not the case. The temporal inventory estimates provided a higher class proportion estimate than the separability result. The 90-percent confidence interval for the hardwood estimates includes the Forest Service estimate. The softwood estimates are between the Forest Service value and the ADP estimates.

Table 4-3 presents a further comparison of the different class proportion estimation procedures for Level I. The temporal separability estimate (0.257) is inconsistent with the single date separability estimates (0.378 and 0.409). The temporal inventory (0.410) is also inconsistent with the other sample estimates.

TABLE 4-3.— PROPORTIONS FOR KERSHAW COUNTY LEVEL I AND LEVEL II

Type estimate	Level II		Level I[a]			
	Softwood	Hardwood	Forest	Grassland	Water	Unclassified
February separability	0.301	0.198	0.409	0.019	0.010	0.472
May separability	.202	.176	.378	.064	.010	.578
Temporal separability	.140	.117	.257	.006	.009	.728
Temporal inventory	.252	.158	.410	.028	.010	.552
Inventory sample	.315	.222	.537	.042	.015	.407
Photographic sample	.371	.294	.665	.039	.018	.278
Regression estimate	.317	.237	.554	(b)	(b)	(b)

[a]Forest = softwood plus hardwood.

[b]Not calculated.

5. DIRECT RESOURCE UTILIZATION

The resources which were required for the study included (1) site data, such as the Landsat imagery, the aerial photographs, and ancillary information; (2) manpower; and (3) the machine and equipment time.

Through the period the study was in progress, strict hourly records were kept on man-hours and machine time. These are listed in table 5-1.

Certain costs are included as incidental in this report, such as the cost of eight color-composite Landsat frames, the Landsat scenes in the form of computer-compatible tapes, and the color-infrared aerial photographs from Mission 76-110A, flown in July 1976.

The costs of transportation, food, and lodging for four people who visited Site V are also included in this report. Costs for project planning, data review, administration, photointerpretation equipment, and office space were not included.

Table 5-2 shows the breakdown of the hourly costs for machine time, manpower, and incidental costs. Comparing the total costs with the total land area, the direct costs amount to 13 cents per square hectometer (5.6 cents per acre).

Future sites and work performed in a production mode would be considerably cheaper if the analysts were familiar with the site and the system characteristics. The cost analysis would still fluctuate because of the increased machine and labor costs resulting from inflation. This could be overcome on projecting cost estimates by applying a percentage factor to the basic costs.

TABLE 5-1.– RESOURCES UTILIZED FOR SITE PROCESSING

Task	Man-hours	Machine hours				
		ERIPS registration	Image-100 interactive analysis	PMIS/DAS image composition	Dell Foster digitization	UNIVAC GETMIX/CLEAN
Preliminary image analysis	104					
Site analysis	222					
Preprocessing	120	9	16	5	2	
Processing	300		55	6	3	
Postprocessing	92		12	6	16	1.9
Evaluation	190					
Reporting	[a]133, 80, 80, and 160					
Total	1483	9	83	17	21	1.9

[a]For reports 1, 2, 3 and 4, respectively.

TABLE 5-2.- DIRECT COSTS FOR MACHINE AND MAN-HOURS

System	Cost/hour, dollars	Hours	Total cost, dollars
Image-100	300	83	24 900
ERIPS	300	9	2 700
UNIVAC 1110	300	1.9	500
PMIS/DAS	100	17	1 700
Dell Foster	15	21	315
Total computer cost			30 185
Man-hours			
Salary	8.75	1483	12 976.25
Overhead	3.68	1483	5 457.44
Total man-hour cost			18 433.69
Total direct cost[a]			48 618.00

[a]An average cost of 13 cents/square hectometer (5.6 cents/acre) was estimated.

6. ANALYSIS OF RESULTS

The following sections analyze the results of the preliminary analysis, preprocessing, processing, evaluation, and post-processing for this site as they address the following questions: (1) What seasons provide the best separation of vegetation types; (2) what levels of mapping detail are possible; (3) are the accuracies of mapping acceptable; (4) how did the environmental and data processing factors interact to effect the final results; and (5) are the results unique or characteristic of this vegetative association?

These questions address the objectives to be satisfied for each site; the final report, which is an intersite comparison, will address the overall TES objectives.

The results presented here reflect the procedures detailed in reference 6, which were designed for implementation with the Image-100 data analysis system as of 1975. Since that time, many programs and system improvements, which should be included in future environmental analysis systems, have been made. The new procedures and techniques are also discussed in terms of how they can be used to improve and speed up site analysis.

6.1 OPTIMAL DATES

The May 1973 and February 1976 Landsat data were selected for ADP evaluation by using a visual interpretation and correlation procedure. These two dates were selected from eight possible scenes which covered the site and met all the selection criteria, one of which was less than 10 percent cloud cover.

The separability study (based on training field accuracies) indicated that both dates were similar in the separation of

Level II features. The temporal data set had the highest accuracies and was used for later processing in the area inventory study.

In the southeastern United States, these dates generally correspond to seasonal periods of early and late spring. It is during this time that the deciduous trees are budding and the new growth in grasses is beginning. The new vegetative growth is much brighter, spectrally, than the same vegetation later in the growing season.

The spectral contrast between grasses, softwoods, and deciduous trees is generally distinctive throughout the growing season but is most apparent in the spring.

Early and late spring Landsat data were selected as most useful for ADP vegetation classification for a site in east Texas (ref. 11), which is also in the Southeastern Pine Ecosystem.

The temporal data were expected to provide increased classification accuracy by using the characteristic spectral change in most vegetative features. The results of this study indicate that there was not a significant increase in accuracy or class proportion estimation when temporal data were used for classification versus a single date. The use of the temporal data for Level II classification does not produce better results from those results produced by using a single date.

The training field accuracies for the temporal data were 2 to 3 percent higher than the single dates. However, the class proportions from the separability study were the lowest when compared to the other data sets and the Forest Service survey estimate (figs. 4-7 and 4-8).

The reduced scene classification which results when temporal data are used may be caused by the increased variance of the class spectral signatures in the scene. In other words, the temporal signatures are specific for the training field, but the fields do not cover the increased class variance produced by the temporal data. Temporal data would require more training fields to cover the class diversity of variable classes such as deciduous trees, grasses, and agricultural fields.

The small increase in class separability and the increased scene variability for Level II features do not justify the increased processing time and the cost of temporal data sets. This may not be true when attempting to do a more detailed Level III species classification or when a total ecological resources evaluation is made. In these two cases, the temporal data may provide a meaningful differentiation of ecological classes and may document important change trends.

6.2 <u>LEVELS OF MAPPING DETAIL</u>

6.2.1 SEPARABILITY STUDY

Training field accuracies yield good separation in Level II features (softwood, hardwood, grassland, and water) when the February, May, and temporal data sets are used. None of the class accuracies differed more than 10 percent between data sets. The temporal data set showed the highest overall accuracies. When a mixed forest (50 percent softwood, 50 percent hardwood) was included, the training field accuracies remained high, with the May and temporal data sets showing the highest accuracies (tables 3-4 and 3-5). The Level III species separation of softwood (loblolly and slash pines) also showed high training field accuracies, about 85 percent (table 3-6).

The training field accuracies for the mixed forest and the loblolly and slash pines are the result of two factors: the small size of the training field sample (about 100 pixels) and the use of temporal data. These factors, more than a consistent signature for these classes throughout the site, contributed to the results. A more thorough investigation of the classification results should be made before the ability to map species is established. These detailed evaluations were not within the scope of TES because the only ground-truth information for the species was from the areas visited during the site familiarization trip.

6.2.2 AREA INVENTORY

The area inventory used signatures from a representative 10-percent area of the site to classify the remaining 90 percent of the site. The results of this study were evaluated and the results indicated that the overall map accuracy (PCC) was 70 percent (±5.7 percent at the 90-percent confidence level). The weighted average error in the ADP class proportion estimates was 3.3 percent compared to the photographic class proportion (table 4-2). The photographic class proportion was based on an interpretation of the aerial photographs.

The site familiarization task had previously indicated that the Level II photointerpretation was 100-percent correct when compared to the ground checks. Thus, the correlation between the Landsat classification proportions and proportions from the aerial photographs should be excellent.

The comparison of the classification softwood and hardwood acreages with the Forest Service acreages shows a discrepancy of as much as 50 percent. This inconsistency between the good proportion estimation when the photograph is used as ground truth and the poor comparison when the Forest Service figures are used may be caused by two factors; that is, evaluation techniques and the base figures used. This again points to the problems in comparing two different systems.

The evaluation techniques could be improved to refine the PCC measurement and proportion estimate for an improved statistical analysis. But the results of the evaluation should be more nearly comparable with the photographs than a strict comparison of Forest Service information. Intuitively, this seems true because the Landsat and the aerial photographs are similar systems using class spectral information for feature classification.

The Forest Service acreage figures, on the other hand, are statistically derived from extensive ground sampling to produce proportion estimates on a wide variety of defined forest features; that is, forest types, stand condition, stocking density, etc. It is only if these factors are correlated with unique spectral properties that they may be identified and classified on Landsat data.

Part of the problem in a one-to-one comparison of results is due to Forest Service definitions, such as "commercial forest land at least 16.7 percent stocked by forest trees of any size or formerly having had such tree cover, producing or capable of producing crops of industrial wood." This definition is based on past forest stocking and future capability, both of which are not related to spectral properties but are related to management and subjective analysis. For this reason, a one-to-one comparison of results is misleading, whether the comparison is favorable or not.

Perhaps a classification of the site into spectral classes and a correlation of the spectral classes with forest classes of ecological units would be a more meaningful and useful way to interpret Landsat data for use by the Forest Service.

6.3 ENVIRONMENTAL VERSUS SYSTEM RESULTS

The question to be discussed in this section, based on the study results, is: What aspects of the site classification results were due to environmental characteristics and which were due to characteristics of the Image-100 system?

The classification results are heavily influenced by the areal extent and distribution of the vegetative features, the use of temporal data, and the use of training fields for classification. This has been documented in reference 15, which presents the results of additional data processing performed for Kershaw County.

Environmentally, this site is characterized by small clumps or stringers of hardwood, softwood, and grassland areas which average 366 meters (1200 feet) in width. The classes are mixed together with no large contiguous areas of a single class. The land is generally flat with little topographic relief and shadowing caused by slope; aspect is not a problem. There is some problem in acquiring cloud-free imagery over South Carolina. Cloud-free days average six to eight per month from January to May.

Any site, regardless of the ecosystem to which it may be assigned, which is characterized by these same factors could have similar processing problems [i.e., St. Louis County, Minnesota (ref. 16)].

These environmental site characteristics create the problem which the computer classification system must be designed to handle. In the case of this site, the small size of the classes and their scattered positions created many transition or mixed areas. Two facts were apparent in classifying the site. The entire site variability could not be covered well in only a 10-percent sample area, and training fields could not reasonably be positioned to cover all the spectral variation within the 10-percent area. An unsupervised clustering algorithm used in the 10-percent area could provide better signatures for extension throughout the study site.

7. CONCLUSIONS AND RECOMMENDATIONS

This section presents the conclusions resulting from the analysis of Site V, an assessment of the technical procedures, and recommended changes for future processing systems. Recommendations for further studies are also provided.

7.1 CONCLUSIONS

The primary objectives of TES and the conclusions derived from the study of Site V are as follows.

Objective: Investigate the feasibility of using ADP remote sensing technology to inventory forest, rangeland, and water areas.

Conclusion: The Image-100 system can be used to classify Level II features, with an overall mapping accuracy of 70 percent ± 5.0 percent at the 90-percent confidence level. This area inventory classification used ground truth from only 10 percent of the site to establish signatures. Total direct analysis costs were 13 cents per square hectometer (5.6 cents per acre) and included the costs of the separability study, report writing, and other developmental studies. ADP remote sensing technology is usable for those projects which can use this level of detail and accuracy.

Objective: Identify processing problems and recommend solutions pertinent to specific sites.

Conclusion: Use of training fields for signature development in the area inventory did not adequately cover the class variability when a 10-percent area of the site was used for training. This means that the wall-to-wall class proportion estimates were considerably in error from the Forest Service values.

The use of an unsupervised clustering procedure, with ground truth being used to identify the clusters, may provide for a more efficient classification of the site. This would be especially true of complex sites with many small features scattered throughout, such as Kershaw County.

In order to produce correctly scaled output map products, data correction techniques should be separated from classification procedures. Scaled and geometrically correct data are not required for classification, and this type of correction could be done more efficiently on the final output data as opposed to correcting the Landsat data as is currently done. Administrative boundaries and training fields could be located on the original Landsat data by using existing registration techniques.

The use of the temporal data set does not sufficiently increase the training field accuracies over single-date accuracies to warrant the additional processing time and cost. In fact, for general levels of classification such as Level II, the temporal data reduce the overall classification by increasing the spectral variability throughout the site. This may not hold true for Level III features.

Objective: Define and recommend the requirements necessary for an integrated ADP system capable of supporting a large area forest and rangeland remote sensing project.

Conclusion: Based on the data processed for this site and on past TES procedures, the following outline of a system for a wide area inventory is proposed.

Initially, the following facts must be known.

a. What computer system or type will be used or is needed?

b. What is the objective of the survey; that is, acreage estimates or vegetation classification maps or both, change detection, or resources other than vegetated?

c. What level of detail is needed?

d. What is the size of the area to be surveyed?

If the following items are assumed, the procedures outlined in figure 7-1 would be appropriate.

a. The computer system must allow for user interaction and display of data.

b. The objectives are to calculate vegetation acreages and to produce maps of selected areas for incorporation into an overall resources inventory.

c. The levels classified would be as detailed as possible based on the meaningful spectral separability of the classes within the site.

d. A large area is to be surveyed.

Figure 7-1 outlines two data flows; one is for generating ground-registered classification maps of selected areas, and the other is for developing area vegetative proportions.

The secondary objectives of TES and the conclusions derived from the Site V study are as follows.

Objective: Determine the mapping accuracies of two levels of classification within the ecosystem.

Conclusion: The Level II training field classification accuracy was 99.9 percent for the temporal data set, with softwood at 99.2 percent and hardwood at 100 percent. The evaluation of the area inventory using the temporal data and training fields from 10 percent of the area showed mapping accuracies of 70 percent ± 5.7 percent at the 90-percent confidence level. A Level III species classification of slash and loblolly pines both showed

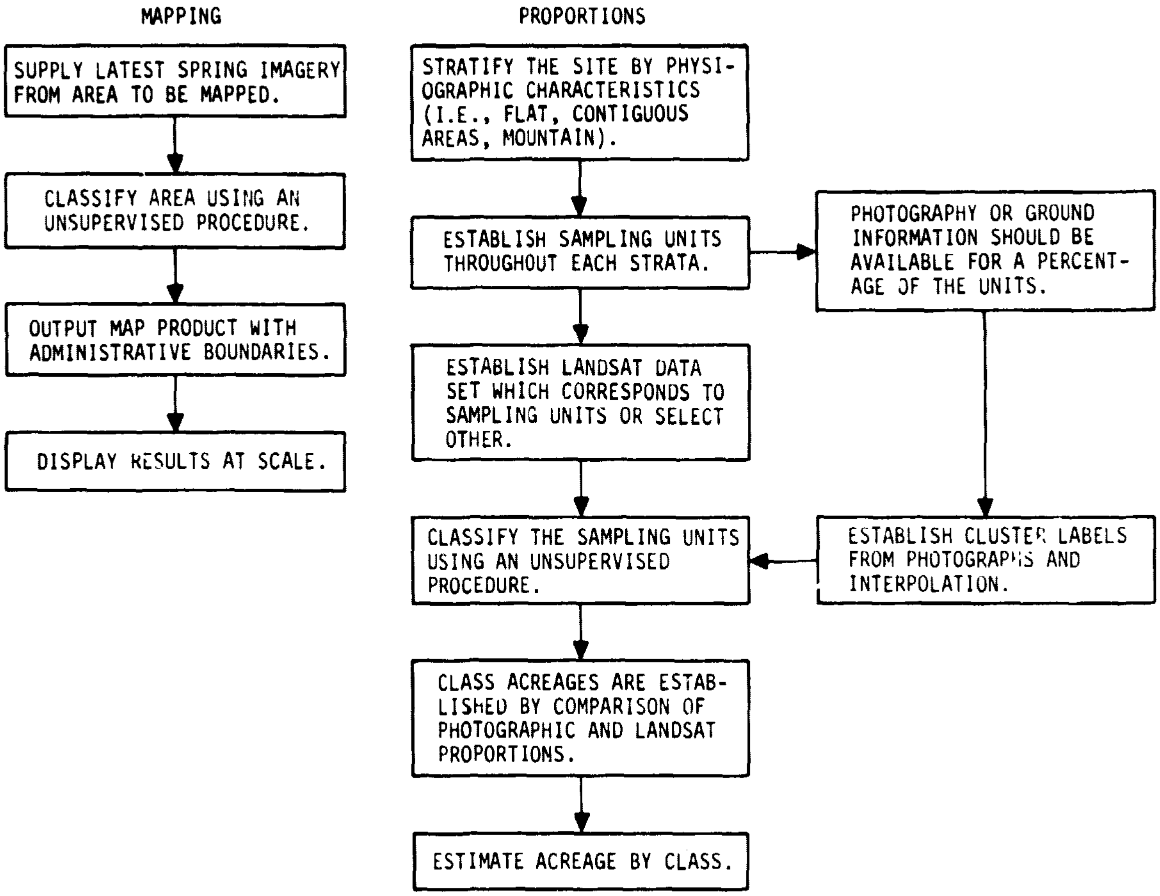


Figure 7-1.— System design for class proportion estimation and area mapping.

training field accuracies of 89 percent. This result may be due more to the small sample size than to the actual spectral differentiation.

<u>Objective</u>: Determine the season or seasons of the year that offer the best solution to type mapping within the ecosystem.

<u>Conclusion</u>: Early or late spring data (February or May) from the Coastal Plain area provide the highest vegetative contrast.

7.2 RECOMMENDATIONS

From the processing performed on this site and previous TES results, the following questions still require further study.

a. Does supervised or unsupervised processing provide the best results in terms of map classification accuracy?

b. How does the method used in evaluating the classification affect the results? Is one method best?

c. What data sampling techniques can be used to estimate class proportions most accurately as opposed to classification of each pixel in the site?

d. What is a proper basis for comparison of remote sensing classification and Forest Service data? If there is not a common base, how should the remote sensing information be presented for use by the Forest Service?

e. In evaluating the basis for comparing the results of the Forest Service timber data with remote sensing classification, how should a correlation between Landsat spectral values and Forest Service ground survey plots be made?