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LANDSAT FOREST AND RANGE INVENTORY OF SOUTHEAST TEXAS COUNTIES BY ADMINISTRATIVE BOUNDARIES*

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I. ABSTRACT

A computer-aided inventory of satellite data on forest and range land in southeast Texas counties (Walker, Montgomery, and San Jacinto) was conducted. Specifically, the study was designed to develop procedures to inventory these features to determine the acreage by administrative boundaries and to evaluate the classification results.

Two data sets (May and November 1973) were analyzed by means of an interactive computer process utilizing a training field classification approach.

The classification results were evaluated first against historical data and again using a technique which involved sample plot checks. For the May data set, aggregating the county acreages into a single acreage per class resulted in acreages which varied less than 10 percent from the historical data. For each individual county, the class acreage estimates varied more than for the aggregate results. The acreages produced from the November classification results were unacceptable. The classification accuracies were poor when the sample plot evaluation technique was used; however, the difficulties encountered in applying the evaluation technique to Land Satellite (Landsat) data interpretation suggest that the evaluation technique was at fault rather than the classification accuracies.

The study determined that pine, hardwood, and range could be inventoried by county boundaries in May. Mixed acreages could not be determined in either May or November. The forest classes and range were not spectrally separable on the November data.

It was found that the county signatures obtained for each class could be used to classify acreage in the other counties; therefore, the derived signatures for pine, hardwood, and range could extend a minimum of 0.617 million hectares (1.5 million acres, the area of the three counties).

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II. INTRODUCTION

In preparing for forest and range management, inventory-related information such as timber type and acreage by administrative boundaries was needed. The purpose of this study was to develop computer-aided remote sensing techniques for conducting inventories using satellite data. Specifically, the following objectives were pursued.

- Development of procedures to inventory forest and range acreage by administrative boundaries
- Evaluation of the classification results against U.S. Forest Service (USFS) survey figures
- Evaluation of the classification results using a sampling technique

Previous investigators have reported varying degrees of success in remote sensing applications using satellite or aircraft data. Using computer classification techniques on fall Landsat data, Heller[1] separated pine and hardwood with accuracies ranging from 42 to 81 percent. Erb[2] reported classifying summer Landsat data into pine and hardwood with 91-percent accuracy. Consequently, pine and hardwood seemed separable using Landsat data, but the the investigators wished to determine if mixed pine/hardwood and range could also be separated.

Although investigators have previously studied timber type separability and seasons for inventory, this study was designed to produce acreage estimates by administrative boundaries — specifically, county boundaries. To date no such information has been available in map form.

In the development of procedures for making forest inventories, information was extracted from areas verified through ground checks or ancillary information. These fields were used to train the computer for classification. The study was

designed to determine the number and distribution of training fields necessary to obtain each class signature. In addition, the lateral extension of each signature was to be investigated. Lastly, it was to be determined which of the two data sets (May or November) was better for performing inventories.

The study is part of the Forestry Applications Exploratory Studies Project[3] conducted by the Earth Observations Division at the Lyndon B. Johnson Space Center of the National Aeronautics and Space Administration and by the Southern Region of the USFS, U.S. Department of Agriculture.

III. STUDY SITE AND ANALYSIS

A. Study Site

Three southeast Texas counties (Walker, Montgomery, and San Jacinto) comprising 0.617 million hectares (1.5 million acres) were selected for study. This acreage, part of an area called the east Texas piney woods, lies in the physiographic province known as the Gulf Coastal Plains (figure 1). The topography is flat to gently rolling, with sandy soils over a heavy clay subsoil and clay outcrops.

Forest vegetation generally consists of shortleaf pine (*Pinus echinata*) on ridges and upper slopes and loblolly pine (*Pinus taeda*) and hardwoods on the lower slopes and in the bottoms. The hardwoods are primarily laurel oak (*Quercus laurifolia*), willow oak (*Quercus phellos*), sweetgum (*Liquidambar styraciflua*), and nuttal oak (*Quercus nuttallii*). On some high, dry sites, post oak (*Quercus stellata*) and black oak (*Quercus velutina*) predominate. Further descriptions of these timber types are available.[4]

B. Analysis Levels

The inventory was performed using a two-level hierarchy.

- Level I — Forest, range, and other land were differentiated.
- Level II — Forest was further divided into pine, hardwood, and mixed pine/hardwood (table 1).

Table 1. Hierarchy of Features Studied in Tri-County Pilot Study

Level I	Level II
Forest	Pine
	Hardwood
	Mixed pine/hardwood
Range	
Other land	

C. Features

Because parts of the standard definitions adopted by the Society of American Foresters,[5] the USFS survey,[6] and the U.S. Geological Survey[7] (USGS) do not lend themselves to the present remote sensing applications, the definitions have been modified for this study as follows:

1. *Forest.* Land of 0.4 hectare (1 acre) and larger in size supporting a stand of trees whose crowns cover more than 10 percent of the area.
2. *Range.* Land excluding forest that produces forage for animal grazing.
3. *Other land.* Nonforest land and nonrange land, implying agriculture, urban areas, water bodies, and miscellaneous.
4. *Pine.* Gymnosperm trees, generally having evergreen and needle foliage. A softwood stand is comprised of more than 50 percent pine in the overstory.
5. *Hardwood.* Angiosperm trees, generally having broad-leaved and deciduous foliage. A hardwood stand is comprised of less than 25 percent pine in the overstory.
6. *Mixed pine/hardwood.* A stand of mixed softwood/hardwood is comprised of 25 to 50 percent pine in the overstory.

IV. TECHNICAL APPROACH

A wall-to-wall, training field approach was used wherein every picture element (pixel) in the study site was classified. The approach consisted of (1) registering Landsat imagery to USGS topographic maps, (2) acquiring spectral signatures of features by locating training fields and computing their statistics, (3) conducting computer classification using a nonparametric classifier that assigns the upper and lower spectral limits of each class, and (4) evaluating classification results. Figure 2 shows a schematic processing flow.

The selected Landsat images (May and November 1973) were registered to USGS topographic maps.

Training fields were selected from simulated color infrared transparencies (1:150 000 scale) of the registered tapes. The line and pixel coordinates were recorded, and the same fields were used for both data sets.

A. Landsat Data

Two seasons were represented by the Landsat frames: fall (ID 1127-16253, November 27, 1973) and late spring (ID 1289-16254, May 8, 1973). The data set consisted of 2000 pixels by 2000 lines; however, only the area within the county boundaries (0.617 million hectares) was analyzed.

B. Signature Acquisition

To determine the number of training fields necessary to develop a signature that accounted for all class variations, two training sets were used. A total of 15 fields was arbitrarily selected in each county for each class. However, 45 fields for range and hardwood could not be located reliably. The fields were 6 by 6 pixels [12 hectares (29 acres)] or smaller, if necessary, because of narrow range or hardwood areas.

Spectral gray values for each class by county were tabulated (table 2). In some cases, pine and hardwood signatures overlapped, and it was necessary to decide to which class the overlapping spectral values belonged. This occurred in band 6 in the May data set and in band 5 in the November data set. These overlapping points were assigned to the class in which the majority of the points occurred. The mixed pine/hardwood signature overlapped both the hardwood and pine signatures. Based on the values obtained from the mixed area training fields, the signatures for pine and hardwood were truncated to provide a mixed signature.

V. ANALYSIS RESULTS

Composite signatures for the entire study area were based on 48 fields for pine, 45 for hardwood, 23 for range, and 11 for mixed. The composite signatures used in classification are shown in table 3.

Using the May data set, every pixel was classified as either pine, hardwood, range, or mixed pine/hardwood, and county classification maps were output (figures 3, 4, and 5). Acreages were computed, tabulated,[8] and the results produced by the General Electric IMAGE 100 (GE 100) computer were compared with the USFS and SCS figures (table 4). Using the November data set, pine, hardwood, and range were classified. Acreages per class are shown in table 5.

VI. EVALUATION OF RESULTS

Results were evaluated first against historical USFS and Soil Conservation Service (SCS) figures and again utilizing an evaluation technique that included aircraft photographs (1:120 000 scale).

For the May data set, the differences between historical data collected by the USFS and SCS and the classification results from Montgomery, Walker, and San Jacinto Counties varied 13.8, 17.9, and 22.7 percent by county for pine; 6.1, 1.2, and 10.9 percent by county for hardwood; and 12.9, 7.5, and 42.8 percent by county for range (table 4).

The percentage of errors in the USFS survey estimates is less over large areas. The error is approximately 3 to 5 percent for areas less than 0.202 million hectares (0.5 million acres) and approximately 1 percent for areas greater than 0.404 million hectares (1 million acres). Consequently, when the county figures were aggregated, the resulting differences were reduced to: pine, 5.2 percent; hardwood, 5.7 percent; and range, 8.5 percent (table 6).

In the November data set, historical data and classification results varied 9.1, 28, and 14.87 percent by county for pine; 170, 132, and 77 percent by county for hardwood; 24.8, 58.7, and 20.5 percent by county for range (table 5). The figures were aggregated resulting in errors of 10.1 percent, 126 percent, and 22.8 percent for pine, hardwood, and range, respectively (table 6).

Many difficulties arose in identifying mixed pine/hardwood. First, mixed stands were difficult to identify and locate on the USFS compartment maps, aircraft photographs, and Landsat imagery. In addition, the USFS figures include abandoned cropland that is being reforested. Although these areas contain some trees, the trees are very sparse, are not typical forest stands, and are extremely difficult to detect.

In an evaluation technique developed by the Forestry Applications Project (FAP), initially a 1-percent sample of the study site was checked using aircraft photography. One hundred 32-hectare (80-acre) plots were selected randomly throughout

the tri-county area for intensive evaluation. Each plot contained 100 pixels (10 by 10) and was located on computer classification maps and divided into nine equal subplots. Each subplot was evaluated independently. By examining the computer output, each subplot was assigned to the predominant class.

Once these 40-hectare (100-acre) random plots were located on classification maps, the Kargl reflecting projector was used to register these maps to the photographs. Recognizable features such as roads on both the classification maps and the photographs were used to locate the plots on the photographs. Each of the nine subplots was interpreted to be the class that comprised the majority of that subplot based on the photographs.

To check the probability of correct classification (PCC), the following formula[9] was used:

$$PCC = \frac{1}{2}\left[\left(\frac{p_1 + q_1}{N} + \frac{p_2 + q_2}{N} + \frac{p_3 + q_3}{N} + \frac{p_4 + q_4}{N} + \frac{p_5 + q_5}{N}\right) - (M - 2)\right]$$

where

N = Total number of samples

p = Pixels correctly classified as class i

q = Pixels other than class i correctly classified

M = Total number of classes

Determining the PCC with a 90-percent confidence interval is expressed by the formula:

$$PCC - 1.64\sqrt{\frac{PCC\ (1-PCC)}{N}},\ PCC + 1.64\sqrt{\frac{PCC\ (1-PCC)}{N}}$$

where PCC is calculated from the preceding formula and N equals the total samples. This formula gives the lower and upper probability bounds of correct classification. The results of the comparison of computer classification and aircraft photointerpretation are shown in tables 4 and 5.

The tabulated results for the May data set showed 87 percent pine, 40 percent hardwood, and 55 percent range correctly classified. For the November data set, 79 percent pine, 47 percent hardwood, and 69 percent range were correctly classified. For the May data set, the overall PCC (figure 6) included all four classes at a 90-percent confidence interval. The PCC ranged from 51 to 56 percent. The November overall PCC (figure 7) included pine, hardwood, and range at a 90-percent confidence interval and ranged from 56 to 61 percent.

VII. SUMMARY AND CONCLUSIONS

In the evaluation of May classification results, the aggregate of all counties by class correlated well with the historical data. Acreages obtained from classification with a wall-to-wall technique were compared to USFS and SCS figures. For the May data set, the results differed 13.8, 17.9, and 22.7 percent by county for pine; 6.1, 1.2, and 10.9 percent by county for hardwood; and 12.9, 7.5, and 42.8 percent by county for range (Montgomery, Walker, and San Jacinto counties, respectively). Presumably, the large range error for San Jacinto County was due to heavy rain preceding the Landsat overpass. All mixed figures were more than 100 percent in disagreement, caused in part by differences between USFS definitions and remote sensing definitions. In addition, USFS figures include cropland that has been abandoned since 1958 and is in the process of being reforested as mixed pine/hardwood. The aggregate of all counties produced errors of 5.2, 5.7, and 8.5 percent for pine, hardwood, and range, respectively.

For the November data set, the wall-to-wall classification results differed from historical data 9.1, 28, and 14.9 percent by county for pine; 170, 132, and 77 percent by county for hardwood; and 24.8, 58.7, and 20.5 percent by county for range. The aggregate figures differed 10.1, 126, and 22.8 percent for pine, hardwood, and range, respectively.

For the May sample plot evaluation, the classification accuracies were: pine, 87 percent; hardwood, 40 percent; mixed, 2.5 percent; range, 55 percent; and other, 30 percent. The overall PCC at a 90-percent confidence interval ranged from 51 to 56 percent.

Using the sample plot evaluation technique, the November classification accuracies were: pine, 79 percent; hardwood, 47 percent; range, 70 percent; and other, 16 percent. The overall PCC at a 90-percent confidence interval ranged from 56 to 61 percent.

The sample plot evaluation technique produced classification accuracies that were unacceptable. Since the results incorporated all procedural errors into the accuracy figures, the investigators felt that the technique should be redesigned.

In May, pine, hardwood, and range could be inventoried successfully by administrative boundaries. Mixed land could not

be mapped on either data set (May or November). The pine, hardwood, and range signatures were not separable on the November data.

The procedure for establishing class signatures from a minimum of training fields was successful. Pine and hardwood training fields could be selected from simulated color infrared Landsat imagery (1:150 000 scale).

The class signature derived from 15 training fields in any county could have been used to classify the entire study site adequately. Likewise, 15 training fields selected over the entire study area would have been sufficient to develop signatures. Thus, the signatures for pine, hardwood, and range extended over the area of the three counties (0.617 million hectares).

VIII. REFERENCES

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Table 2. Spectral Signatures Produced from Histograms of May and November Training Fields.

County	May data set			November data set		
	Channel			Channel		
	2	3	4	2	3	4
Pine						
Walker	6-8	16-23	18-28	4-6	7-12	9-13
Montgomery	6-8	15-22	17-26	4-6	9-12	9-13
San Jacinto	6-8	15-23	18-28	4-6	8-12	9-13
Hardwood						
Walker	6-8	24-29	28-36	5-7	8-12	10-14
Montgomery	6-8	23-30	27-37	5-7	9-12	9-13
San Jacinto	6-8	22-30	27-38	5-7	9-12	9-13
Range						
Walker	10-13	23-29	25-35	9-13	11-16	12-16
Montgomery	10-13	22-31	24-38	8-12	12-18	13-20
San Jacinto	10-14	22-31	23-35	8-13	11-17	12-21
Mixed						
San Jacinto	6-8	22-24	26-28	–	–	–

Table 3. Spectral Signatures Used for Classification of May and November Data Set.

[Resolution = 64]

Class	Channel		
	2	3	4
May data set			
Pine	6-8	16-23	18-27
Hardwood	6-8	24-30	27-38
Mixed	6-6	23-24	26-28
Range	10-13	23-30	25-35
November data set			
Pine	4-5	8-12	9-13
Hardwood	6-7	9-12	9-13
Mixed[a]	-	-	-
Range	8-13	11-18	12-21

[a]No mixed pine/hardwood was classified.

Table 4. Class Acreages for May Data Set as Determined by GE 100 Compared to USFS Forest and SCS Range Figures

Class	GE 100		USFS and SCS		Difference
	Hectares	Acres	Hectares	Acres	
Montgomery County					
Pine	121 935	301 820	105 220	260 000	13.85
Hardwood	33 432	82 754	31 566	78 000	6.1
Range	34 006	84 174	39 986	98 806	12.9
Mixed	2 655	6 572	66 896	[a]165 300	
Total area in county	282 181	697 269	282 237	697 408	0.0002
Walker County					
Pine	63 802	157 928	77 863	192 400	17.9
Hardwood	23 394	[a]57 906	23 149	57 200	1.2
Range	49 904	123 526	46 474	114 837	7.5
Mixed	610	1 511	29 462	[a]72 800	
Total area in county	206 665	510 670	204 562	505 472	1.0
San Jacinto County					
Pine	62 292	154 190	80 736	199 500	22.7
Hardwood	25 554	63 253	23 067	57 000	10.9
Range	15 495	[b]38 355	27 162	67 117	42.8
Mixed	1 936	4 793	13 840	[a]34 200	
Total area in county	168 320	415 921	161 619	399 360	4.1

[a]The USFS figures include abandoned cropland in the process of being reforested. These areas, in which tree growth is very sparse, are not typical forest stands.

[b]Heavy rain [4.8 cm (1.89 in.)] had flooded many areas presumed to be range and resulted in standing water. Range covered with water could not be detected.

Table 5. Class Acreages for November Data Set as Determined by GE 100 Compared to USFS Forest and SCS Range Figures

Class	GE 100		USFS and SCS		Difference
	Hectares	Acres	Hectares	Acres	
Montgomery County					
Pine	114 790	283 646	105 220	260 000	9.1
Hardwood	85 247	210 647	31 566	78 000	170
Range	50 866	125 691	39 177	96 806	24.8
Mixed			66 896	[a]165 300	
Total area in county	281 647	695 950	282 237	697 408	.0002
Walker County					
Pine	56 040	138 474	77 863	192 400	28.0
Hardwood	53 706	132 707	23 148	57 200	132
Range	73 794	182 346	46 474	114 837	58.7
Mixed			29 462	[a]72 800	
Total area in county	208 945	516 305	204 562	505 472	1.0
San Jacinto County					
Pine	68 732	169 838	80 736	199 500	14.87
Hardwood	40 853	100 948	23 068	57 000	77
Range	21 596	53 366	27 162	67 117	20.5
Mixed			13 840	[a]34 200	
Total area in county	165 275	408 394	161 619	399 360	4.1

[a]The USFS figures include abandoned cropland in the process of being reforested. These areas, in which tree growth is very sparse, are not typical forest stands.

Table 6. Acreage Obtained From May and November Classifications

Class	Wall-to-wall		Difference between historical and wall-to-wall, %
	Hectares	Acres	
May data set			
Pine	248 461	613 948	5.2
Hardwood	82 541	203 913	5.7
Range	99 600	246 110	8.5
Mixed	6 513	16 095	100
Other	220 070	543 793	100
November data set			
Pine	239 416	591 598	10.12
Hardwood	179 806	444 302	126
Range	146 258	361 403	22.8
Mixed[a]	-	-	-
Other	-	-	-

[a]No mixed signature was established.

Figure 1. Texas County Map Showing the Tri-County Pilot Study Area (Walker, Montgomery, and San Jacinto Counties).

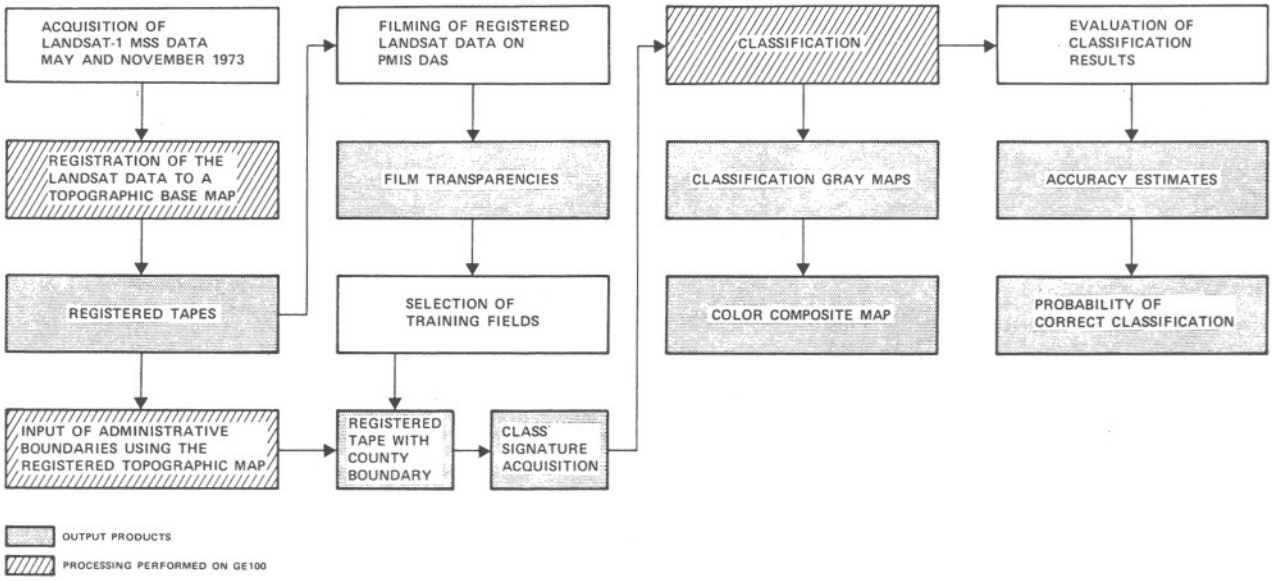

Figure 2. Schematic Processing Flow of the Wall-to-Wall, Training Field Classification Approach.

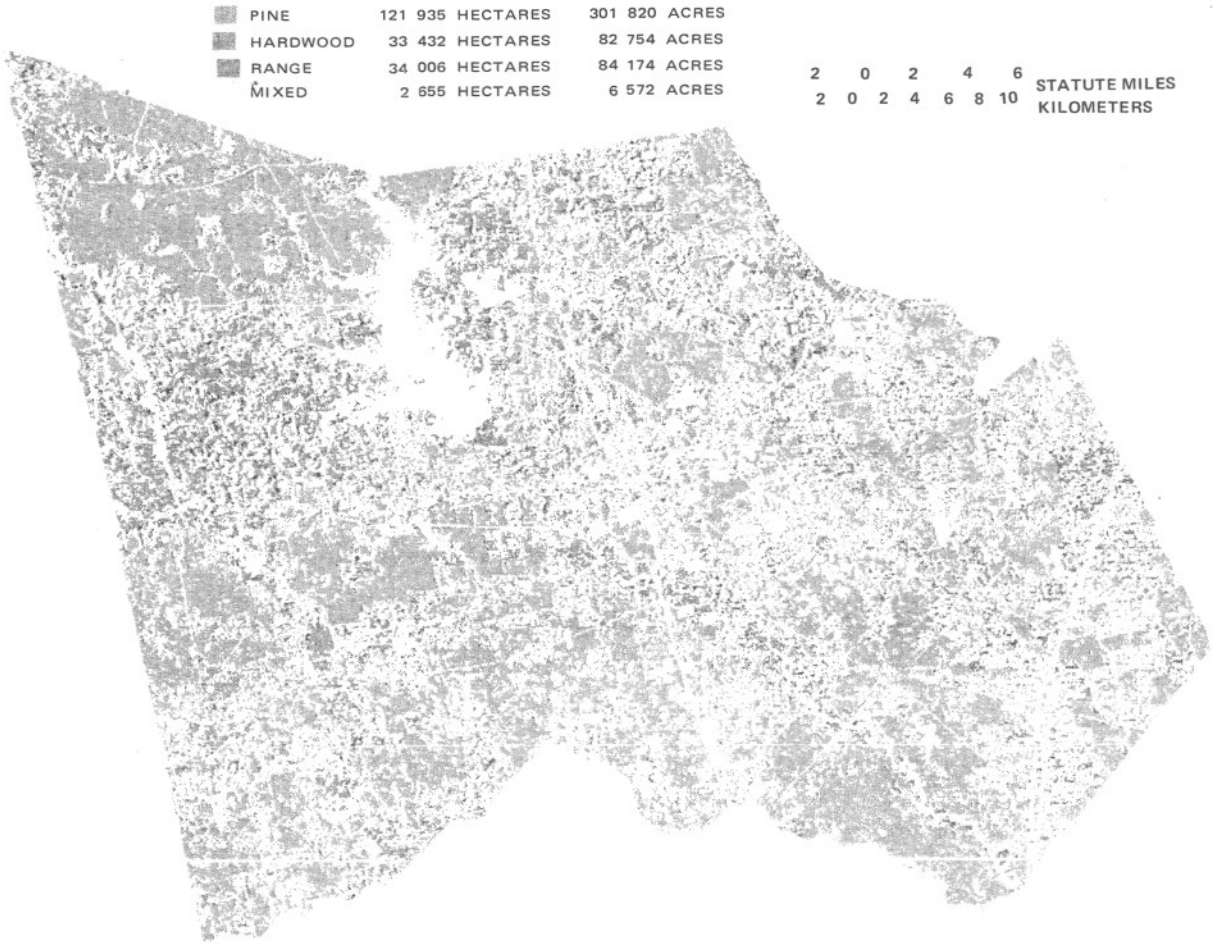

Figure 3. Classification Map of Montgomery County, Texas, From Forest and Range Inventory Using Landsat-1, May 1973.

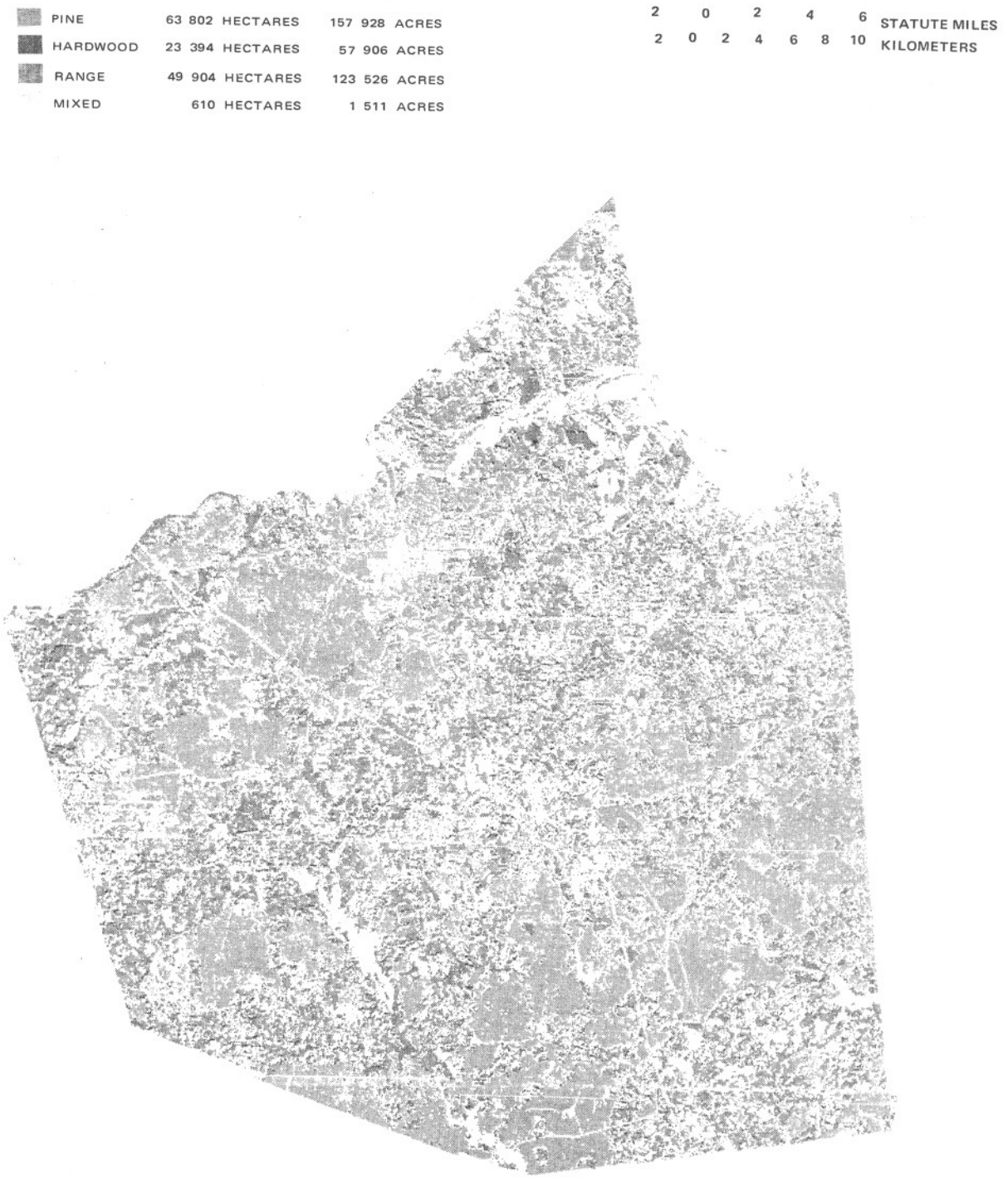

Figure 4. Classification Map of Walker County, Texas, From Forest and Range Inventory Using Landsat-1, May 1973.

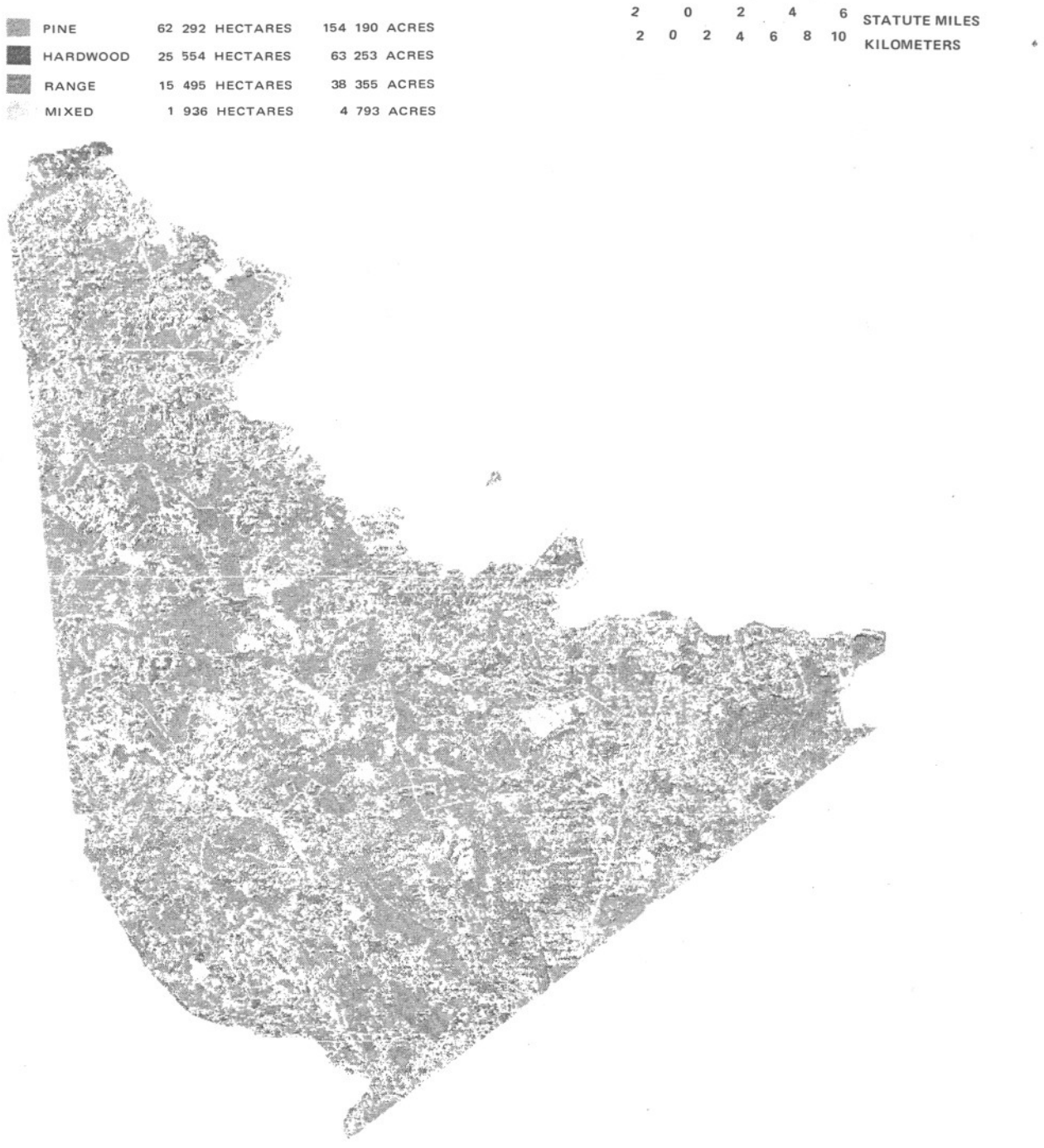

Figure 5. Classification Map of San Jacinto County, Texas, From Forest and Range Inventory Using Landsat-1, May 1973.

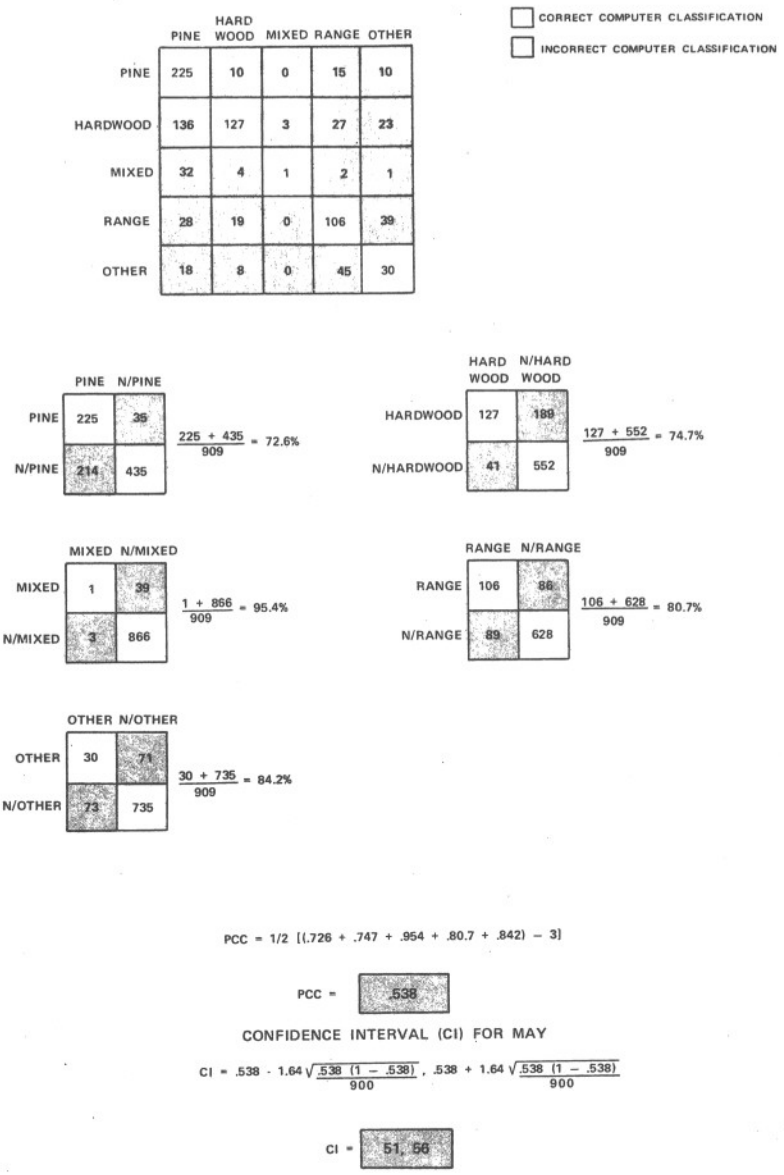

Figure 6. Overall PCC Results of May Evaluation and Two-Class PCC for May.

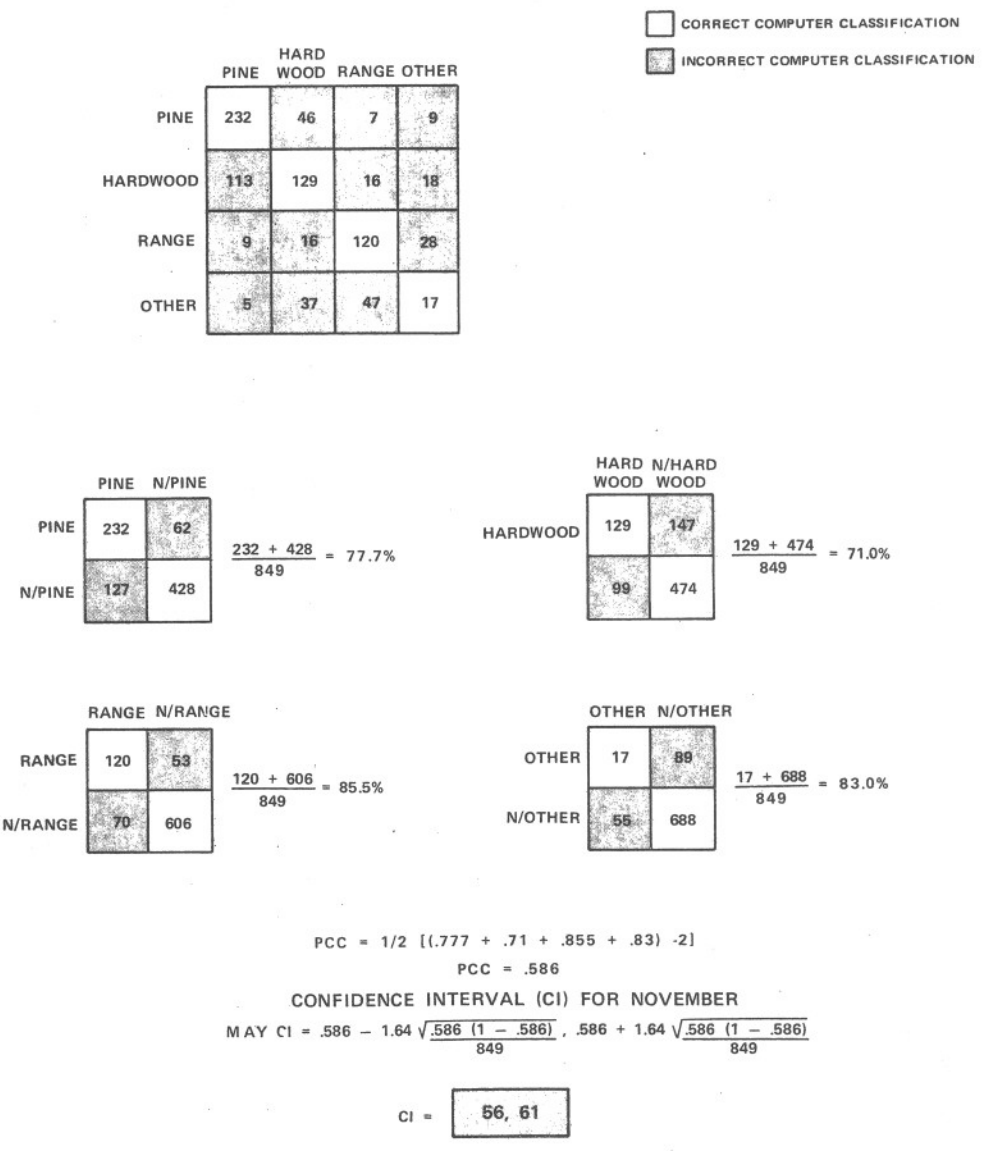

Figure 7. Overall PCC Results of November Evaluation and Two-Class PCC for November.