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TIMBER TYPE SEPARABILITY IN SOUTHEASTERN UNITED STATES ON LANDSAT-1 MSS DATA*

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ABSTRACT

A quantitative, computer-aided study was made on the spectral separability of timber types and condition classes in the Southeastern United States, using LANDSAT-1 multispectral scanner data. Conclusions were obtained on accuracies at different levels of mapping detail and the choice of parameters affecting mapping accuracies, such as spectral bands, number of bands, and seasons of data.

It was concluded that LANDSAT-1 could be used effectively to discriminate the gross forest features of softwood, hardwood, and regeneration. The only significant detectable age difference would be between an established forest versus a young (or denuded) forest, i.e., regeneration. The red or near infrared bands would be better for discrimination; phenological early and late spring data would be better than winter (summer and autumn data were not available for analysis). And a temporal analysis would be superior to single-season analysis. Lastly, two spectral bands would be most cost effective for computer analysis.

The study site, Sam Houston National Forest of East Texas, is a typical forest in the Flatwoods Zone, Southern Region, U. S. Forest Service. The widely accepted computer scheme of training-field, maximum likelihood-classifier was employed, while cross-classification accuracies and divergence measures were computed to evaluate timber type separability.

1.0 INTRODUCTION

This study was undertaken to determine the feasibility of mapping timber types and condition classes in the Southeastern United States using Land Satellite (LANDSAT-1, formerly Earth Resources Technology Satellite, ERTS-1) multispectral scanner (MSS) data via computer-aided analysis. Timber types refer to stand composition by dominant species, and condition classes refer to age, size, health, and adequacy of stocking. To this end, three objectives were pursued:

- To quantitatively determine the spectral separability between timber types and condition classes, and additionally between the general classes of merchantable timber which consist of sawtimber, poletimber, and regeneration softwood stands.

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- To determine the optimal spectral bands and seasons of MSS data for maximum separability between timber types and condition classes

- To determine the effects on classification accuracies because of variations in the number of spectral bands

Such a study is essential to computer-aided remote sensing applications on timber resource inventories concerned with mapping and volume estimation. The mapping accuracy, mapping levels, sensor spectral band coverages, seasons of data acquisition, and number of bands used in analysis are important design criteria in these inventories. An optimally designed timber resource inventory using remote sensing data, from satellites and aircraft, in conjunction with ground surveys would provide a most efficient, timely, accurate, and economical solution to many forest management problems. For example, studies by Aldrich (1971) and Colwell (1973) have proved the efficient use of a multistage sampling scheme to estimate timber volume on a forest-wide basis.

The present study determined whether or not satellite MSS data such as that of LANDSAT-1 could be used at or beyond the mapping level of softwood, hardwood, mixed softwood-hardwood, and regeneration, the four categories constituting forest land. (See hierarchy levels in section 2.2.) Also, this study established the feasibility of discriminating merchantability age classes by LANDSAT-1, i.e., discrimination between sawtimber, poletimber, and regeneration stands of softwood. These conclusions were derived from analyzing a typical forest in the Southeastern United States, as represented by the Sam Houston National Forest of East Texas.

A number of past studies have been carried out on similar subjects, but not to the same extent of details in mapping and not to the same amount of quantification of separability. In the report by Heller et al. (1974), investigators reported on the use of October LANDSAT-1 MSS data and computer classification techniques in mapping level II land use classes in Georgia. Level II included pine and hardwood classes and were identified with accuracies ranging from 42 to 81 percent. Erb (1974) reported the analysis of August 1972 LANDSAT-1 data on the Sam Houston National Forest of Texas, breaking forest land down into hardwood versus pine with accuracies as high as 91 percent. Aircraft MSS data have also been analyzed with the purpose of identifying forest land use classes. Weber (1972) reported processing a November data set over Atlanta, Georgia, and found that spectral bands very similar to band 7 (0.8-1.1 micron) and band 5 (0.6-0.7 micron) of LANDSAT-1 were the third and fourth best channels after the infrared band (1.5-1.8 micron) and thermal band (9.3-11.5 micron) for separability of forest classes. Accuracies for classification of pine and hardwoods ranged from 20 to 80 percent.

The present study is part of the Forestry Applications Exploratory Studies Project, which is 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 Forest Service, U. S. Department of Agriculture. Project details can be found in Anon. (1974).

2.0 STUDY SITE AND FEATURES

2.1 Site Description

The study site is the Conroe Unit, Raven District of Sam Houston National Forest, located 90 kilometers north of Houston, Texas (figure 1). This forest is in the "East Texas Piney Woods" or "Flatwoods," which is the heavily forested portion of East Texas. The Conroe Unit is within the southern Gulf Coastal Plain, and the overall area slopes to the southeast at 1.5 meters per kilometer. Slopes are generally between 3 and 7 percent; elevation differences between stream bottoms and ridge tops are usually no more than 25 meters.

The 28,500 hectares of the Conroe Unit consist of approximately 10 percent shortleaf pine (*Pinus echinata* Mill.) on the ridges and upper slopes, 75 percent loblolly pine (*Pinus taeda* L.) and hardwoods on the lower slopes, 10 percent hardwoods in the drainage ways, and 4 percent regeneration areas. The remaining 1 percent is made up of openings such as pipelines or oil well sites. The most common hardwood types are mixed oaks – laurel oak (*Quercus laurifolia* Michx.) and willow oak (*Quercus phellos* L.), and gums and oaks – sweetgum (*Liquidambar styraciflua* L.), nuttal oak (*Quercus nutalli* Palmer), and willow oak.

2.2 Analysis Levels

A five-level hierarchy of land features was used for this study (table I). The terminology and structure of the hierarchy resulted from modifications of those from the Society of American Foresters (Ford-Robertson, 1971; Anon., 1974), The Forest Survey (Sternitzke, 1967), and the Geological Survey (Anderson et al., 1972). The definitions of levels I and II features are adopted as follows:

Forestland -	land of 0.4 hectares or more in size supporting a stand of trees whose crowns cover more than 10 percent of the area
Softwood -	gymnosperms, generally having evergreen and needle foliage; a softwood stand consists of more than 50 percent pine in the overstory.
Hardwood -	angiosperms, generally having broadleaved and deciduous foliage; a hardwood stand consists of less than 25 percent pine in the overstory
Mixed softwood-hardwood -	a stand of mixed softwood-hardwood consisting of 25 to 50 percent pine and the rest hardwood
Regeneration area -	cutover, burned, or otherwise denuded forestland in process of being reclaimed by a young forest.

The class "regeneration" in level II was considered appropriate in this computer-aided remote sensing application, since regeneration has spectral characteristics known to be distinct from established forest stands. Also, it was considered impossible to discriminate among shortleaf regeneration, loblolly regeneration, and hardwood regeneration. The breakdown under regeneration into seedling-sapling or nonstocked is at level V.

Levels III, IV, and V are traditional breakdown and represent levels of detail usually mapped by ground survey or photointerpretation. The special level "general age class" was created to study the condition classes of softwoods collectively, i.e., sawtimber, poletimber, and regeneration areas. The identification of these general classes, as opposed to the more detailed level IV classes, has mercantile and management import. The limited amount of hardwood sites in the study area did not allow this study to analyze hardwood sawtimber, poletimber, and regeneration separability.

3.0 TECHNICAL APPROACH

The overall approach taken in this study is the "training-field classification/analysis" process used in computer systems such as LARSYS (Phillips, 1973), RECOG (Ells et al., 1972), and ERIPS (Anon., 1973). This approach essentially consists of (1) the acquisition of spectral signatures of land features by locating "training fields" of these features on MSS data and computation of their statistics; (2) searching for optimal set of channels for classification through calculation of some mathematical distances, e.g., divergence (Marill and Green, 1963) or probability of correct classification (PCC) (Anderson, 1958); and (3) computer classification, e.g., using a maximum likelihood classifier which assigns to an unknown data pixel (picture element in MSS data) a most likely class association from all the possible training classes. A training class means land feature on which training field statistics are available. Through this process, timber type separability information will be obtained via the two mathematical measures of divergence and PCC. (See section 3.2 for details.)

Figure 2 is a schematic flow diagram of the analysis procedures followed in this study. Three LANDSAT-1 data sets were checked for data quality before they were registered and composed to form one 11-channel data set. The registration was performed image-to-image and to the corresponding longitude and latitude locations. Since each individual-date data set has four MSS channels, the composition of data sets resulted in a 12-channel data set with the ordering of the channels and their spectral coverages tabulated in table II; however, the last channel of the May data set was too noisy, and thus omitted from analysis, hence an 11-channel data set.

Random training fields of the level V forest features (table I) were selected and their coordinates recorded on the MSS data. The same locations applied to all three dates because the three data sets had been registered to one another. By straightforward aggregation, training fields for all hierarchy levels were compiled. At each level, divergence calculations were made, compiled, tabulated, and analyzed. Also class pairs were classified, a pair at a time, producing pairwise correct classification accuracies. The average of these were then calculated, tabulated, and analyzed. Additionally, all class statistics were used simultaneously to classify all the selected random test fields, producing overall classification accuracies. (See section 4.0 for examples.)

3.1 LANDSAT-1 Data

The LANDSAT-1 frames over the study site were used for analysis and covered three distinctive phenological dates in the Southeastern United States. These dates covered winter (I.D. 1127-16253, November 27, 1973), early spring (I.D. 1217-16254, February 25, 1973), and late spring (I.D. 1289-16254, May 8, 1973). Summer and autumn data were not available for analysis. These three data sets were registered and composed to form an 11-channel (12 less 1 because of poor quality) temporal data set of a size roughly 500 scan lines and 600 pixels per line. The ordering and spectral coverages of these temporal channels are listed in table II. A black-and-white rendition of channel 6 (February band 2) is shown in figure 3.

Because of the small spatial resolution of LANDSAT-1 MSS data (at 80×80 meters per pixel after registration), the sizes of training fields and test fields were constrained to be no more than 5×5 pixels. Hardwood features usually called for narrower and smaller fields. In this study, the number of training fields and test fields had been chosen roughly proportional to their occurrence in the study site. These fields constituted roughly 1 percent of the study site.

3.2 Separability Measures: Divergence and PCC

Two mathematical measures were used to quantify the spectral separability between timber types: (1) the divergence measure, J and (2) the probability of correct classification, PCC. (Marill and Green, 1963; Anderson, 1958; and Chang, 1971)

The divergence measure is an approximate measure for separability, while the PCC measure is truly the separability measure. However, PCC is difficult, if not impossible to calculate except by straightforward estimation via computer classification which provides classification accuracy measures. On the other hand, the divergence measure can be algorithmically computed based on the usual statistical assumption of normality. In this study, the divergence measure and the classification accuracy measure were jointly calculated where an increase in values of either measure was construed as an increase in separability

The definitions of the divergence $J(C_1,C_2)$ and the pairwise correct classification accuracy $PCCA(C_1,C_2)$ between the two statistical classes C_1 and C_2 are as follows:

$$J(C_1,C_2) = \tfrac{1}{2}\mathrm{tr}\Big[\big[S_1 - S_2\big]\big[S_2^{-1} - S_1^{-1}\big]\Big] + \tfrac{1}{2}\big[M_1 - M_2\big]^T \big[S_1^{-1} + S_2^{-1}\big]\big[M_1 - M_2\big]$$

where M_1, S_1 are the mean vector and covariance matrix of C_1, and M_2, S_2 are those for C_2, tr stands for the trace operation on matrices, and T stands for the transpose operation on matrices.

$$PCCA(C_1,C_2) = \tfrac{1}{2}PCC(C_1) + \tfrac{1}{2}PCC(C_2)$$

where $PCC(C_1)$ and $PCC(C_2)$ are obtained by a two-class classification between C_1 and C_2, and where

$$PCC(C_1) = \text{(number of pixels of } C_1 \text{ correctly classified as from } C_1) \div \text{(number of pixels of } C_1)$$

and $PCC(C_2)$ is defined similarly.

When more than two classes are involved in classification, the overall average pairwise correct classification can be calculated as the average of the n(n-1)/2 pairwise measures, obtained from n(n-1)/2 possible pairs from the n classes (n>2).

4.0 ANALYSIS OF DATA PROCESSING RESULTS

All the data processing was performed at the Johnson Space Center, NASA, and on the Earth Resources Interactive Processing System (ERIPS) which is an interactive computer system developed at the center for remote sensing applications. This system has the capability of training field classification analysis as described in section 3.0. However, in this application on ERIPS, the transformed divergence J' was used instead of the divergence J defined in section 3.2, where J'=999 (1-exp(-J/16)). J' and J are equivalent (Swain, 1973); any conclusion drawn from J' computations applies to J computations and vice versa. Without further complication, the following sections will abuse the notation, using J to denote the transformed divergence and using divergence to mean transformed divergence.

4.1 Spectral Signature Plots

Before presenting the quantitative separability results in the next three sections, a most effective qualitative analysis could be made by plotting the spectral signatures of all the forest features. A spectral signature plot means the graph of the statistical mean data values versus spectral channel. The mean values were obtained from analyzing training fields.

Figure 4 is such a plot for all the 10 level V (the most detailed level) forest features. Four groups of features seem readily distinguishable and are thus presented in the figure: (1) regeneration, nonstocked; (2) regeneration, seedling and sapling; (3) hardwood, immature sawtimber; and (4) softwood and mixed softwood-hardwood, comprising loblolly and shortleaf, sawtimber and poletimber, mature and immature (table I).

In qualitative terms, then, only level II forest features can be distinguished from one another, except for the mixed softwood-hardwood feature in this level. The more detailed detection levels in levels III, IV, and V seem too much to ask of the LANDSAT-1 MSS sensor. Additionally, temporal channels 6 and 11 show widest spread of data values in the above mentioned four groups of signatures, indicating that these two channels would likely be the best two channels for discrimination of level II forest features (except for the mixed feature). Determination of the truly best channels involves consideration of the spread of data values about the mean value of all the features. Figure 4 does not indicate this kind of statistical variation, and only an analysis as in section 4.3 will give the most definitive answers.

These signatures were analyzed from a total of 25 training fields of the 10 level V forest features.

4.2 Pairwise Separability of Forest Features

The 25 level V training fields selected earlier were aggregated into 10 level V training classes, seven level IV training classes, five level III training classes, and four level II training classes. Each "training class" at any hierarchy level is taken as representative of the forest feature regarding spectral characteristics. Pairs of classes at all levels were classified one pair at one time, to obtain the pairwise correct classification accuracies (PCCA).

Figure 5 shows in bar-charts the PCCA versus feature pairs for level II, III, and the special level of general age classes displayed in sets of four bars: (1) best two channels of temporal data, (2) best two channels of November data, (3) best two channels of February data, and (4) best two channels of May data. The best channel sets were taken from results of section 4.3. Levels IV and V PCCA's are not presented in this paper but are available from Dillman and Kan (1975). PCCA between the softwood features of levels IV and V are generally between 50 and 60 percent, and those plots do not offer additional conclusions on the separability between those features. Plots of PCCA's for other channel set sizes are also available from Dillman and Kan (1975), and they show similar trends as in figure 5.

Level II PCCA's are high (from 87 to 99 percent) for all feature pairs at the best choice of data set (i.e., seasons or combinations of seasons) for channel set size of 2, except that softwood can only be separated from mixed softwood-hardwood with less than 80 percent. The lower PCCA between softwood and mixed softwood-hardwood is construed to be due to the definition of the two features (cf. section 2.2). Level III PCCA's are basically as high as level II PCCA's for softwood versus hardwood versus regeneration. Within the softwood and between softwood and mixed softwood-hardwood, PCCA's are as low as 61 percent.

The plot of figure 5(b) for the special level of general (softwood) age classes shows that separation between sawtimber and poletimber is poor (from 56 to 71 percent) where sawtimber versus regeneration or poletimber versus regeneration has PCCA above 95 percent. In other words, using LANDSAT-1 MSS sensor, the only significantly detectable age difference is between an established forest versus a young (or denuded) forest, i.e., regeneration.

The general trend of best season or combination of seasons is also discernible in figure 5; however, such conclusions are deferred to section 4.3, where additional divergence calculations and analysis are made.

4.3 Best Spectral Bands and Seasons

Using the training class statistics, the best channels from the temporal data set and the three individual season data sets were found for channel set sizes of 1, 2, 3, and 4. The prioritizing of channels was performed by ordering the magnitude of average divergence values between the training classes and was done for all levels of hierarchy. Table III tabulates that information.

From table III, it is apparent that the temporal data set (winter, early and late spring) offers the biggest overall average separability between all forest features at all hierarchy levels and at all channel set sizes (from 1 to 4 channels). The rating for individual seasons shows that February (phenological early spring) and May (phenological late spring) are better months than November (phenologically winter) for remotely sensing forest features in the Southeastern U.S. In particular, the red and near infrared channels of February and May data are good channels – channels 6 and 10 (sometimes 11 instead of 10) of the temporal data set.

Also, the average separability is shown to be lower at higher hierarchy levels, i.e., at higher details.

4.4 Classification Accuracy Versus Channel Set Size

Overall classification accuracies were also obtained when all classes were classified at the same time (in contrast with the pairwise cross-class classification described in section 4.2). Accuracies were obtained for all hierarchy levels, data sets, training fields, and a total of 24 test fields which were randomly distributed in the study site (Dillman and Kan, 1975). Only the test field overall classification accuracies are displayed in figure 6 versus the channel set sizes of 1, 2, 3, and 4 for the temporal and February data sets. Curves for May and November data sets are similar and lower than the February curves.

Increase in channel set size normally improves classification accuracy but it was found that the two best channels performed almost as well as three or four best channels. Thus the temporal data set proved superior to the other season data sets in classification accuracy and separability.

Apart from the above quantitative results, the entire study site was also classified and displayed in figure 7 for visual comparison with the unclassified MSS imagery of figure 3. The classification was performed on the temporal data set, using the best four channels (6, 8, 10, and 11) with the four level II forest features.

5.0 CONCLUSION

This computer-aided study has investigated quantitatively the spectral separability of timber types in Sam Houston National Forest of Texas, which is a typical forest in Southeastern United States, using LANDSAT-1 multispectral scanner data. Five hierarchy levels of mapping detail plus one level of general (softwood) age class were studied of three sets of data at winter, early and late spring. Also the temporal composite of those three data sets was studied. Seven conclusions are summarized as follows:

- The LANDSAT multispectral scanner sensor could be effectively used to separate the forest features of softwood, hardwood, and regeneration. Pairwise correct classification of training sets ranges from 87 to 99 percent and average correct classification for test fields ranges from 70 to 79 percent.

- The only significantly detectable age difference was between an established forest versus a young (or denuded) forest, i.e., regeneration. This conclusion was drawn from experience on softwood forests.

- The red (band 2: 0.6-0.7 micron) and one near infrared channel (band 3: 0.7-0.8 micron or band 4: 0.8-1.1 microns) of any of the three seasons (winter, early and late spring) would be better for discrimination.

- Phenological early and late spring could be equally good seasons for discrimination and would be better than the winter season. (Summer and autumn data were not available for analysis.)

- A temporal analysis using early and late spring LANDSAT data could improve classification accuracy up to 11 percent over single-season analysis.

- Analysis using the two best channels would perform almost as well as the four best channels for single-season or temporal analysis; hence, a two-channel analysis could be more cost-effective.

- It would be difficult to discriminate the forest features of mixed softwood-hardwood from the softwood feature by virtue of the definition of the two features: (1) softwood stand contains more than 50 percent softwood and (2) a mixed softwood-hardwood stand contains between 25 and 50 percent softwood.

It is observed that the capability of LANDSAT-1 is limited by many factors, including altitude, sensor design, and spatial data resolution. The last factor, in particular, will influence the level of mapping detail. A comprehensive study on forest classification and modeling has been reported by Kan et al. (1975).

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TABLE I

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FOREST HIERARCHY USED FOR CLASSIFICATION OF CONROE UNIT OF SAM HOUSTON FOREST

LEVEL I	LEVEL II	LEVEL III	LEVEL IV	LEVEL V	GENERAL AGE CLASSES	
FOREST LAND	SOFTWOOD	LOBLOLLY PINE	SAWTIMBER	MATURE, IMMATURE	SOFTWOOD	SAWTIMBER
			POLETIMBER	IMMATURE		
		SHORTLEAF PINE	SAWTIMBER	MATURE, IMMATURE		POLETIMBER
			POLETIMBER	IMMATURE		REGENERATION
	MIXED (SOFTWOOD, HARDWOOD)	LOBLOLLY/OAK/GUM	SAWTIMBER	IMMATURE		
	HARDWOOD	OAK, GUM	SAWTIMBER	IMMATURE		
	REGENERATION	—	—	SEEDLING/SAPLING, NON-STOCKED		

TABLE II

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SPECTRAL CHANNEL COVERAGE OF TEMPORAL DATA FOR ANALYSIS OF THE CONROE UNIT OF SAM HOUSTON NATIONAL FOREST

TEMPORAL CHANNEL * NUMBER	DATE	LANDSAT BAND	WAVELENGTH (MICRON)
1	NOVEMBER	1	.5 TO .6
2		2	.6 TO .7
3		3	.7 TO .8
4		4	.8 TO .1.1
5	FEBRUARY	1	.5 TO .6
6		2	.6 TO .7
7		3	.7 TO .8
8		4	.8 TO .1.1
9	MAY	1	.5 TO .6
10		2	.6 TO .7
11		3	.7 TO .8
12 **		4	.8 TO .1.1

* NOMENCLATURE USED THROUGH OUT THIS PAPER

** NOT USED FOR ANALYSIS DUE TO EXCESSIVE NOISE

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TABLE III

OPTIMUM CHANNELS AND CORRESPONDING AVERAGE PAIRWISE DIVERGENCE FOR FIVE LEVELS OF CLASSIFICATION: SAM HOUSTON NATIONAL FOREST

DATA SET	CHANNEL SET SIZE	LEVEL II		LEVEL III		LEVEL IV		LEVEL V		GENERAL AGE CLASSES	
		CHANNELS	AVERAGE DIVERGENCE	CHANNELS	AVERAGE DIVERGENCE	CHANNELS	AVERAGE DIVERGENCE	CHANNELS	AVERAGE DIVERGENCE	CHANNELS	AVERAGE DIVERGENCE
TEMPORAL DATA 11 CHANNEL*	4	6, 8, 10, 11	930	6 9 10 11	779	6, 8, 10, 11	769	3, 6, 8, 11	754	6, 8 10, 11	840
	3	6, 8, 10	897	6 10 11	740	6 8 11	728	6, 8, 11	704	6, 10, 11	799
	2	6, 10	842	6 10	682	6 11	675	6,11	653	6, 10	754
	1	6	699	6	613	6	589	6	566	6	674
NOVEMBER	4	1, 2, 3, 4	666	1 2 3 4	570	1 2 3 4	610	1, 2, 3, 4	616	1 2 3 4	630
	3	1, 2, 4	658	1 2 4	556	1 2 4	575	1 2 3	574	1 2 4	615
	2	2 4	629	2 4	520	1 2	524	1 2	528	1 2	574
	1	2	586	2	476	2	481	2	498	2	516
FEBRUARY	4	5, 6, 7, 8	810	5 6 7 8	714	5 6 7 8	692	5, 6, 7, 8	667	5, 6, 7, 8	758
	3	5 6 8	798	5 6 8	704	5 6 6	673	5, 6, 8	649	5, 6, 8	750
	2	6 8	775	6, 8	676	6 8	638	6, 8	617	6, 8	727
	1	6	699	6	613	6	589	6	566	6	674
MAY	*4										
	3	9, 10, 11	808	9, 10, 11	671	9, 10, 11	674	9, 10, 11	663	9, 10, 11	707
	2	10, 11	800	10, 11	649	10, 11	638	10, 11	631	10, 11	699
	1	10	539	11	487	11	519	11	502	11	484

* CHANNEL 12 NOT USED DUE TO EXCESSIVE NOISE, HENCE NO CHANNEL ORDERING FOR MAY DATA AT SET SIZE OF 4.

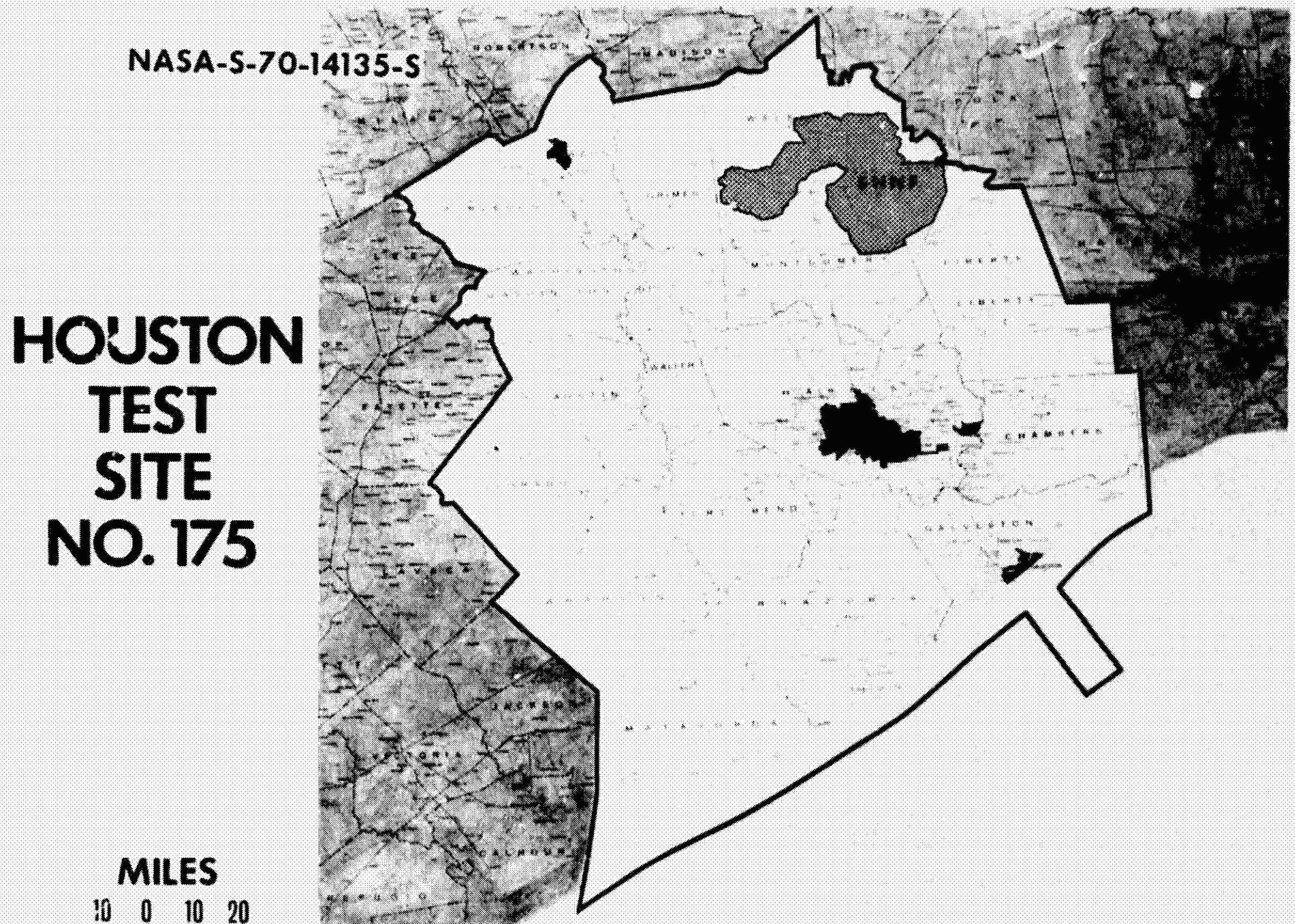

Figure 1. — Location of Sam Houston National Forest (shaded area).

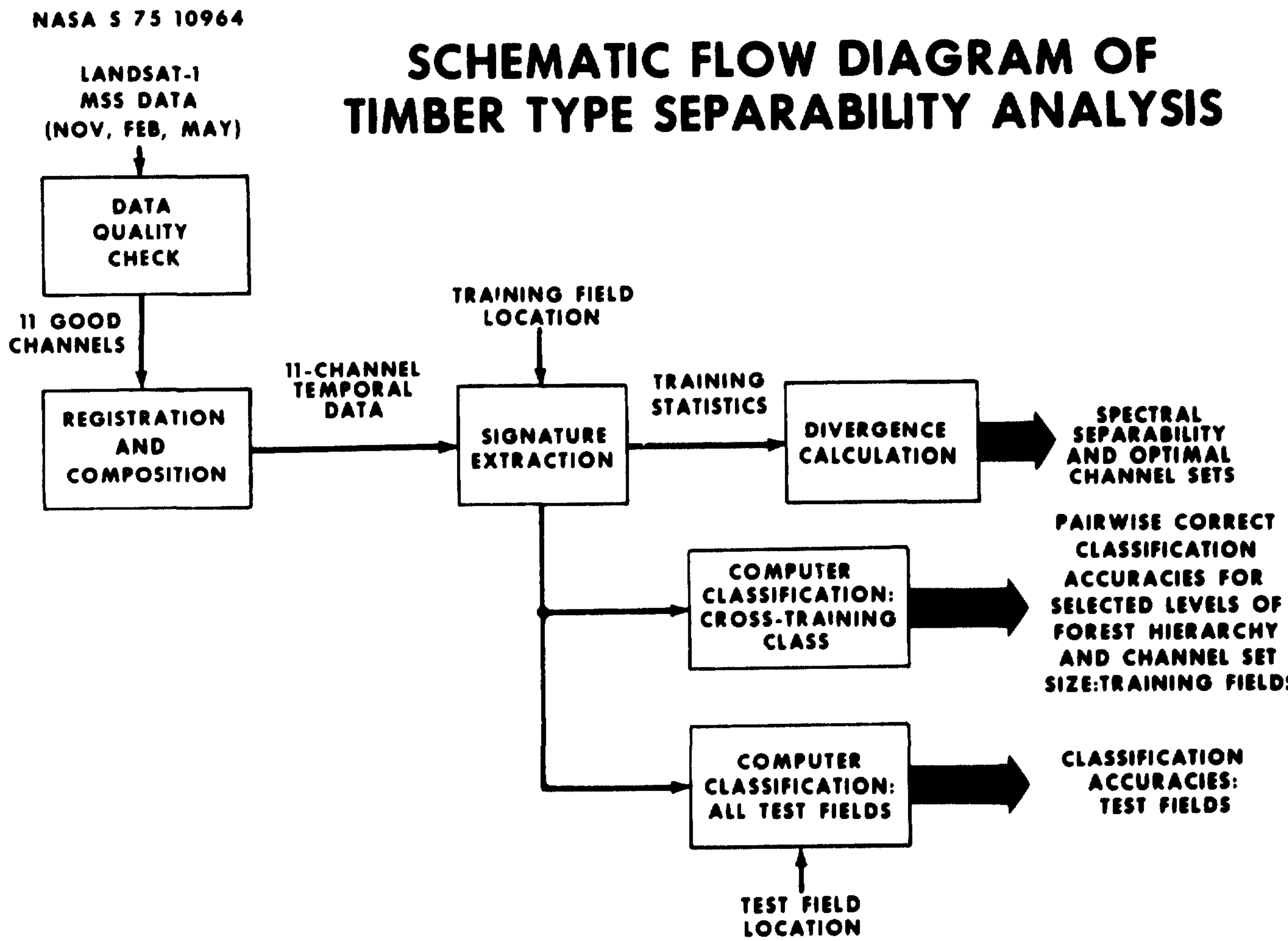
NASA S 75 10964
SCHEMATIC FLOW DIAGRAM OF TIMBER TYPE SEPARABILITY ANALYSIS
LANDSAT-1 MSS DATA (NOV, FEB, MAY)
DATA QUALITY CHECK
11 GOOD CHANNELS
REGISTRATION AND COMPOSITION
11-CHANNEL TEMPORAL DATA
TRAINING FIELD LOCATION
SIGNATURE EXTRACTION
TRAINING STATISTICS
DIVERGENCE CALCULATION
SPECTRAL SEPARABILITY AND OPTIMAL CHANNEL SETS
COMPUTER CLASSIFICATION: CROSS-TRAINING CLASS
PAIRWISE CORRECT CLASSIFICATION ACCURACIES FOR SELECTED LEVELS OF FOREST HIERARCHY AND CHANNEL SET SIZE:TRAINING FIELDS
COMPUTER CLASSIFICATION: ALL TEST FIELDS
CLASSIFICATION ACCURACIES: TEST FIELDS
TEST FIELD LOCATION

Figure 2

NASA S 75 10961

RAVEN DISTRICT OF SAM HOUSTON NATIONAL FOREST, LANDSAT - 1 IMAGE BAND 2, .6 - .7 μm, FEBRUARY 25, 1973 (CONROE UNIT, STUDY SITE OUTLINED)

Figure 3

NASA S 75 10968

LANDSAT, SPECTRAL SIGNATURE MEAN PLOT FOR LEVEL V TRAINING FIELDS

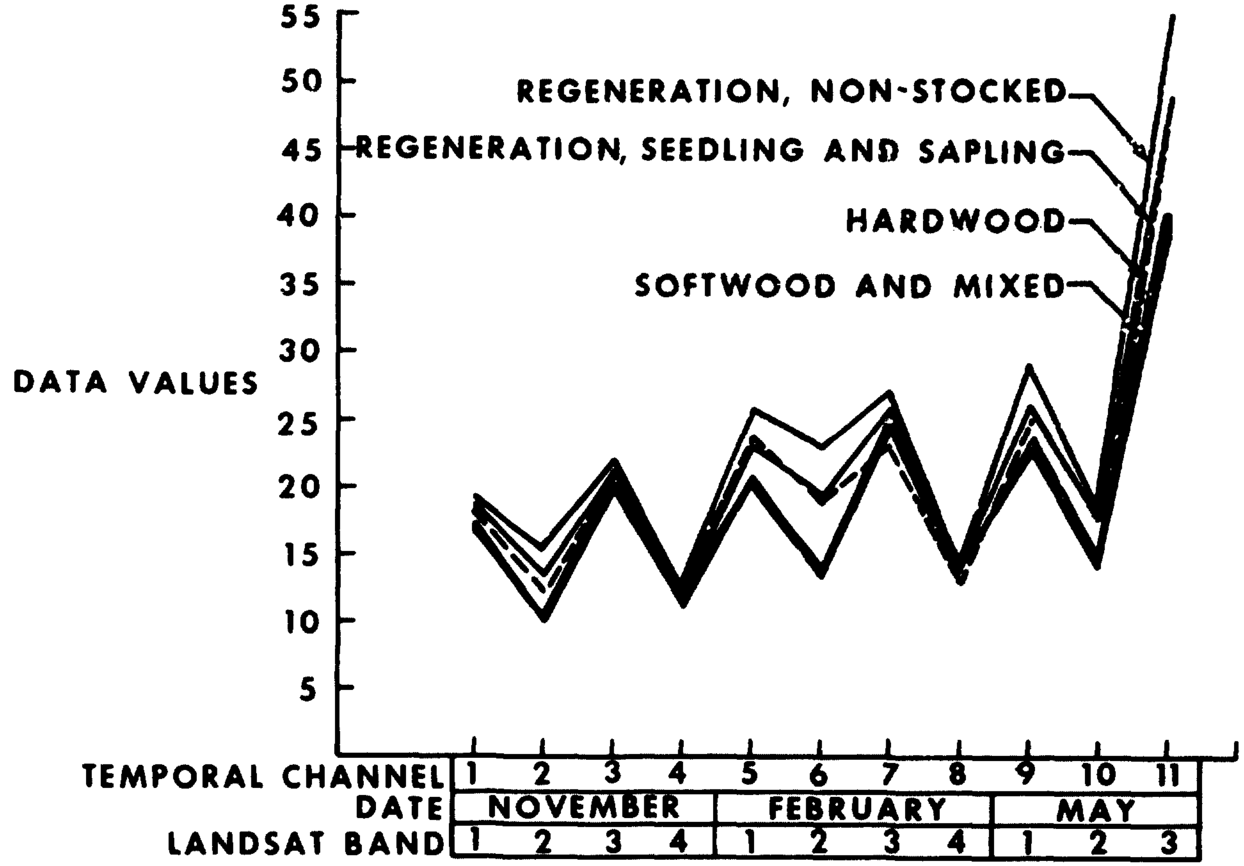

Figure 4

NASA S 75 10970

AVERAGE PAIRWISE CORRECT CLASSIFICATION ACCURACIES OF SAM HOUSTON NATIONAL FOREST TRAINING FIELDS FOR THREE LEVELS OF HIERARCHY, USING BEST 2 CHANNELS FOR 4 DATA SETS: (a) LEVEL II

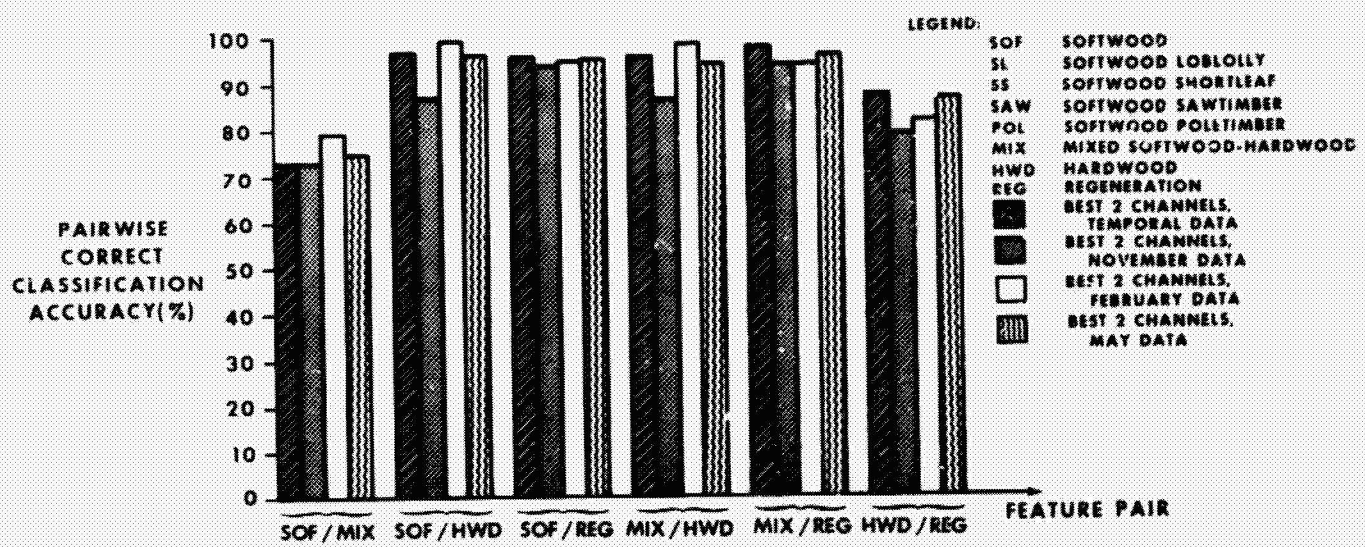

Figure 5(a)

NASA S 75 10971

AVERAGE PAIRWISE CORRECT CLASSIFICATION ACCURACIES OF SAM HOUSTON NATIONAL FOREST TRAINING FIELDS FOR THREE LEVELS OF HIERARCHY, USING BEST 2 CHANNELS FOR 4 DATA SETS: (b) LEVEL OF GENERAL AGE CLASSES

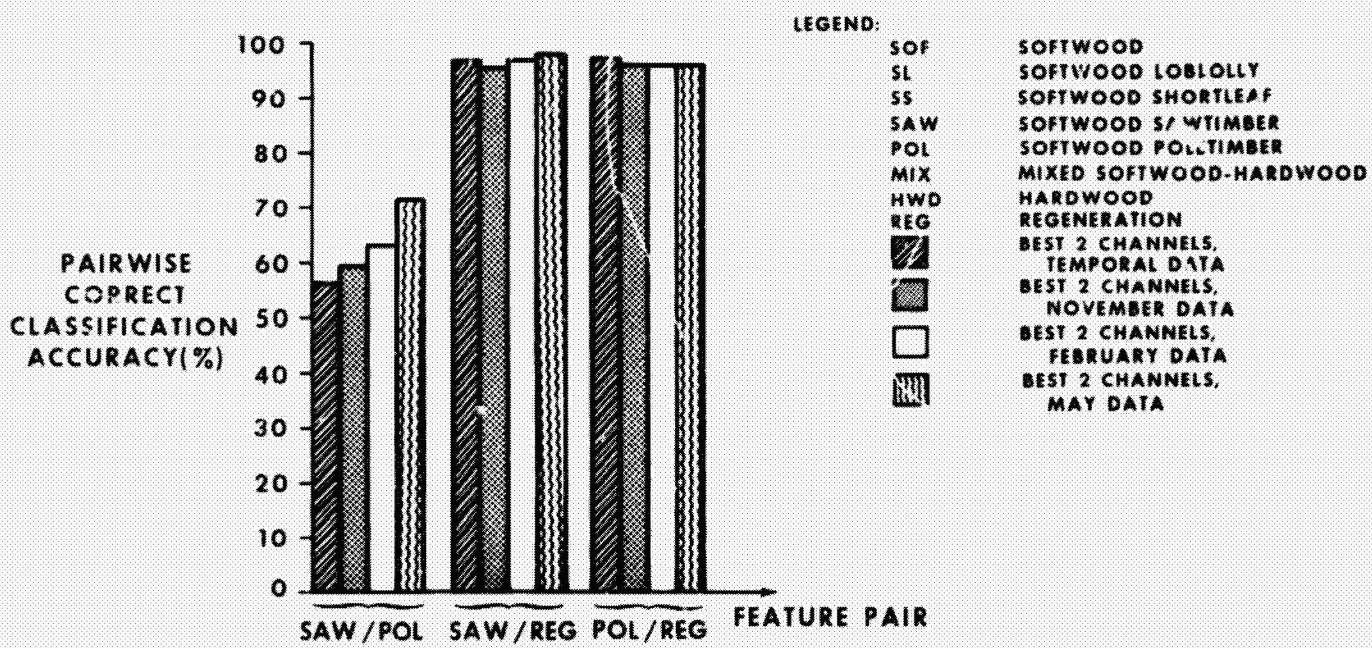

Figure 5(b)

NASA S 75 10972

AVERAGE PAIRWISE CORRECT CLASSIFICATION ACCURACIES OF SAM HOUSTON NATIONAL FOREST TRAINING FIELDS FOR THREE LEVELS OF HIERARCHY, USING BEST 2 CHANNELS FOR 4 DATA SETS: (c) LEVEL III

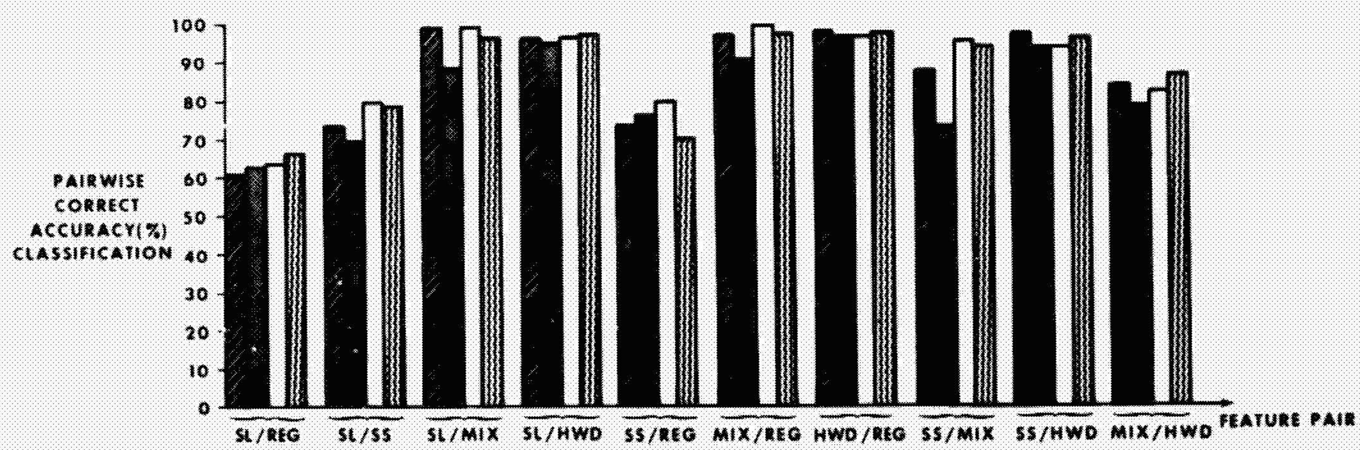

Figure 5(c)

NASA S 75 10969

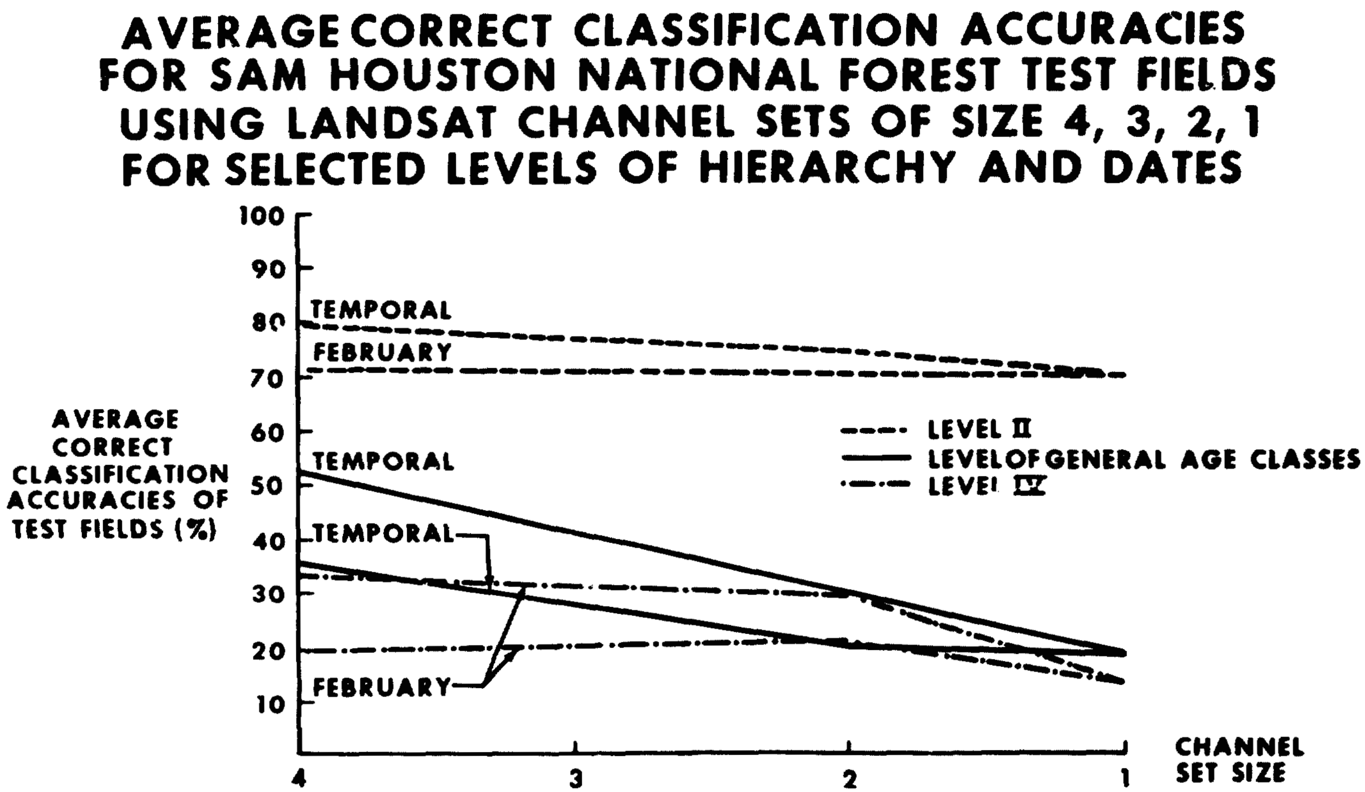

Figure 6

NASA S 75 10962

LEVEL II CLASSIFICATION OF CONROE STUDY SITE USING FOUR CHANNELS 6, 8, 10, 11 TEMPORAL DATA

	WHITE	SOFTWOOD
GRAY	LIGHT	REGENERATION
	MED	MIXED SOFTWOOD/ HARDWOOD
	DARK	HARDWOOD
	BLACK	UNCLASSIFIED

N ↑

Figure 7