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PROCEDURE 1 APPLICABILITY TO RANGELAND
CLASSIFICATION: FINAL REPORT

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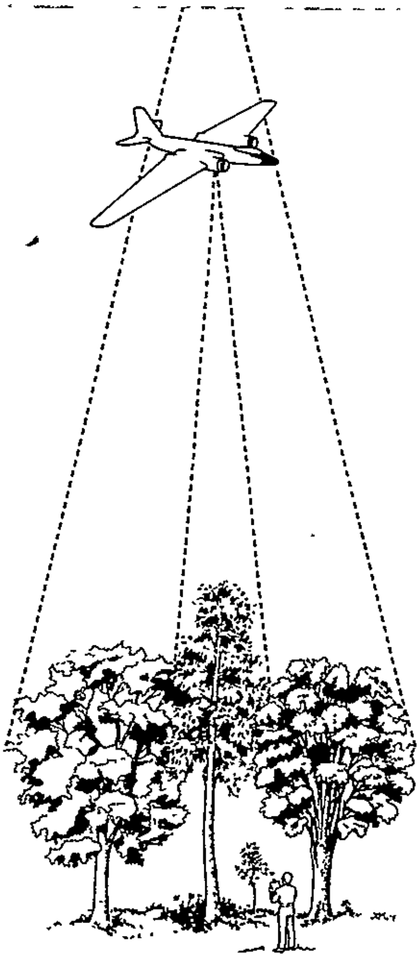

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16. Abstract

Procedure 1, a computer-aided processing technique, was developed in the Large Area Crop Inventory Experiment to optimize automated data processing and to minimize analyst processing time. To determine how effectively and accurately rangeland proportions can be estimated using Procedure 1, the procedure was applied to a test site in Weld County, Colorado. Rangeland proportions were accurately estimated, rangeland and nonrangeland were separated and mapped.

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PREFACE

The purpose of this technology assessment task was to investigate the features of existing automated data processing systems and, specifically, to investigate analysis techniques and identify methodology that could be useful in forest and rangeland inventories. Investigations of the Large Area Crop Inventory Experiment techniques were of first priority for the technology assessment task. (The Large Area Crop Inventory Experiment is a joint project of the U.S. Department of Agriculture, National Aeronautics and Space Administration, and National Oceanic and Atmospheric Administration.) Procedure 1, a classification system which was developed in the Large Area Crop Inventory Experiment, was tested on a rangeland site in Weld County, Colorado; this report presents the results.

The specific objectives of Phase 1 of this technology assessment task were to

a. Identify and test portions of Procedure 1 to determine applicability to forest and rangeland automated data processing for classification

b. Develop detailed guidelines for using Procedure 1 in forest and rangeland classification

c. Identify other Large Area Crop Inventory Experiment analysis techniques and systems which may have features applicable to forest and rangeland classification

This final report documents the procedures, results, and conclusions of this task. The report was prepared under Contract NAS 9-15200, Job Order 75-335. It has been approved by the supervisor of the Forestry Applications Section for limited distribution to persons directly associated with the Nationwide Forestry Applications Program.

The author wishes to acknowledge the support and consultation of the LACIE Development and Evaluation Department. Appreciation is extended to David Register, Ruth Minter, Elizabeth Delgado, Kathy Abotteen, Dick Hinkle, Jim Prill, and Harold Almond. Additionally, the author wishes to thank all individuals who reviewed and commented upon various drafts of this document for their suggestions and constructive criticisms.

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ACRONYMS

ADP	automated data processing
CAMS	Classification and Mensuration Subsystem
CAS	Crop Assessment Subsystem
CCIT	CAMS/CAS interface tape
ERIPS	Earth Resources Interactive Processing System
Image 100	Interactive Multispectral Image Analysis System, model 100
JSC	Lyndon B. Johnson Space Center
LACIE	Large Area Crop Inventory Experiment
Landsat	name given to three satellites which were formerly called Earth Resources Technology Satellites — referred to as Landsat-1, Landsat-2, and Landsat-3.
MSS	multispectral scanner
NASA	National Aeronautics and Space Administration
PCC	probability of correct classification
PFC	production film converter
pixel	picture element
RT&E	research, test, and evaluation
TES	Ten-Ecosystem Study

1. INTRODUCTION

Effective rangeland and forest management decisions require inventory information such as species composition, environmental relationships, grass conditions, vegetation productivity, and timber density and volume. Remote sensing is potentially a useful tool for gathering multiresource inventory information. Classification schemes are frequently used to reduce remote sensing data to a form which can be used to support multiresource inventories. One such classification scheme which was developed to facilitate analysis of Landsat multispectral scanner (MSS) data is called Procedure 1.

Procedure 1 was developed to solve classification problems encountered in the Large Area Crop Inventory Experiment (LACIE). The procedure is a processing technique and, as such, it is a remote sensing analysis tool designed to optimize automated data processing (ADP) and to minimize analyst processing time. The procedure can be implemented on any computer and used with any data set. However, at the National Aeronautics and Space Administration/Lyndon B. Johnson Space Center (NASA/JSC), Procedure 1 is used to process LACIE Landsat segments. Each segment is a 117-line by 196-picture-element (pixel) image area of Landsat digital data; this is the maximum size used. (Detailed information on Procedure 1 can be found in reference 1.)

For this technology assessment task, Procedure 1 was selected as the classification scheme to evaluate for application to forest and rangeland inventories.

1.1 SCOPE

The scope of this task was to determine how effectively and accurately rangeland and forest proportions can be estimated using the current LACIE Procedure 1.

1.2 APPROACH

To address this task, Procedure 1 was applied to Level I features (forest, rangeland, and water) and Level II features (rangeland, hardwood, and softwood). Level I and Level II features were separated and mapped, and proportions were estimated with specified levels of confidence. The classification results were statistically evaluated, and the accuracy and precision were measured.

2. METHODOLOGY

Two general assumptions were made.

a. Rangeland, nonrangeland, forest, nonforest, and water could be differentiated on aircraft photographs with no significant error.

b. Short prairie grass, salt grass, hardwood, and softwood could be differentiated on aircraft photographs with no significant error.

If features could not be differentiated on aircraft photographs, the analyst could not identify the feature because supporting field information was not collected. Additionally, the aircraft photographs were used with Landsat digital data to establish probability of correct classification (PCC) and to evaluate the classification results.

2.1 OVERVIEW

The investigation consisted of task I.1, plan preparation; task I.2, procedure preparation; task I.3, site selection; task I.4, data selection; task I.5, data processing; task I.6, evaluation; and task I.7, documentation. Figure 2-1 shows the procedure flow for tasks I.3 through I.6.

In tasks I.1 and I.2, a plan and the preliminary procedures, respectively, were prepared (ref. 2).

In task I.3 (site selection), the scientists screened all existing LACIE Landsat segments to select a site. Criteria for site selection were the availability of aircraft coverage and the location within a Ten-Ecosystem Study (TES) site. (The TES sites are Grand County, Colorado; Warren County, Pennsylvania; St. Louis County, Minnesota; Sandoval County, New Mexico; Kershaw

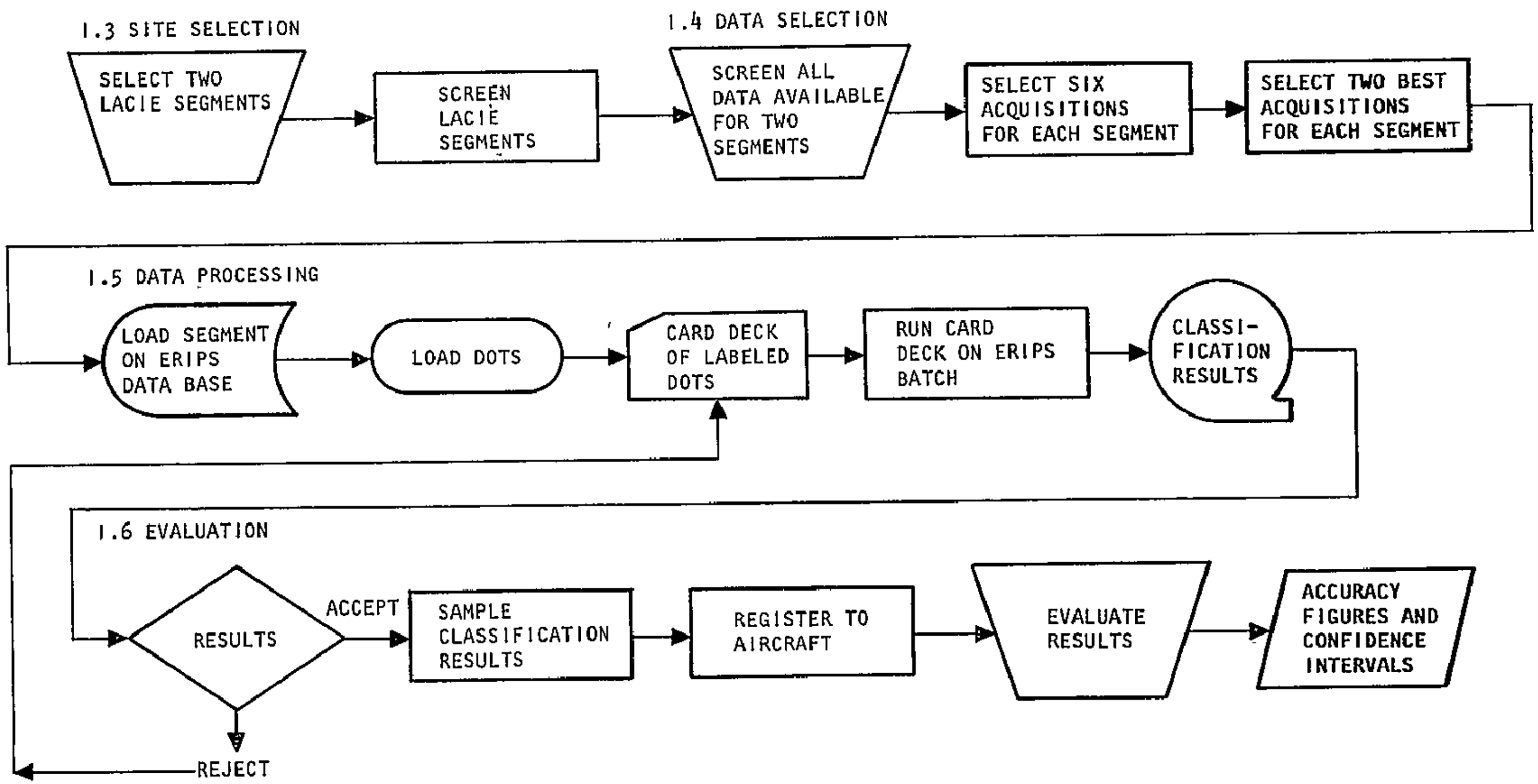


Figure 2-1.— Analysis flow.

County, South Carolina; Ft. Yukon, Alaska; Weld County, Colorado; Grays Harbor County, Washington; and Washington County, Missouri.)

In task I.4 (data selection), all LACIE acquisitions of Landsat data for each segment were screened to select six dates. These dates were distributed through the available 1976 and 1977 data. The two best dates were selected for processing on the basis of the PCC. The PCC was calculated by identifying 50 dots on the LACIE segment and comparing the data with the corresponding dots on the aircraft photographs.

$$PCC = \frac{\text{Number of correctly classified dots}}{\text{Total number of dots}} \times 100$$

The interpretation was performed independently by two interpreters. The interpretation of the aircraft photographs was considered correct.

In task I.5 (data processing), two levels of classification (table 2-1) were investigated using Procedure 1.

TABLE 2-1.— ANALYSIS LEVELS

Level I	Level II
Forest	Softwood
	Hardwood
Rangeland	Rangeland
Other	Other
Water	Water

Task I.6 (evaluation) included determining acreage proportion estimates and accompanying statistical qualifiers. Task I.7 (documentation) included three reports. Report 1 (ref. 2) is the task plan which describes the task objectives, scope, data requirements, and resources requirements. Report 2 (ref. 3), the interim report, documents the progress and interim results; and report 3, the final report, documents the detailed procedures, findings, conclusions, and recommendations.

2.2 SITE AND DATA SELECTIONS

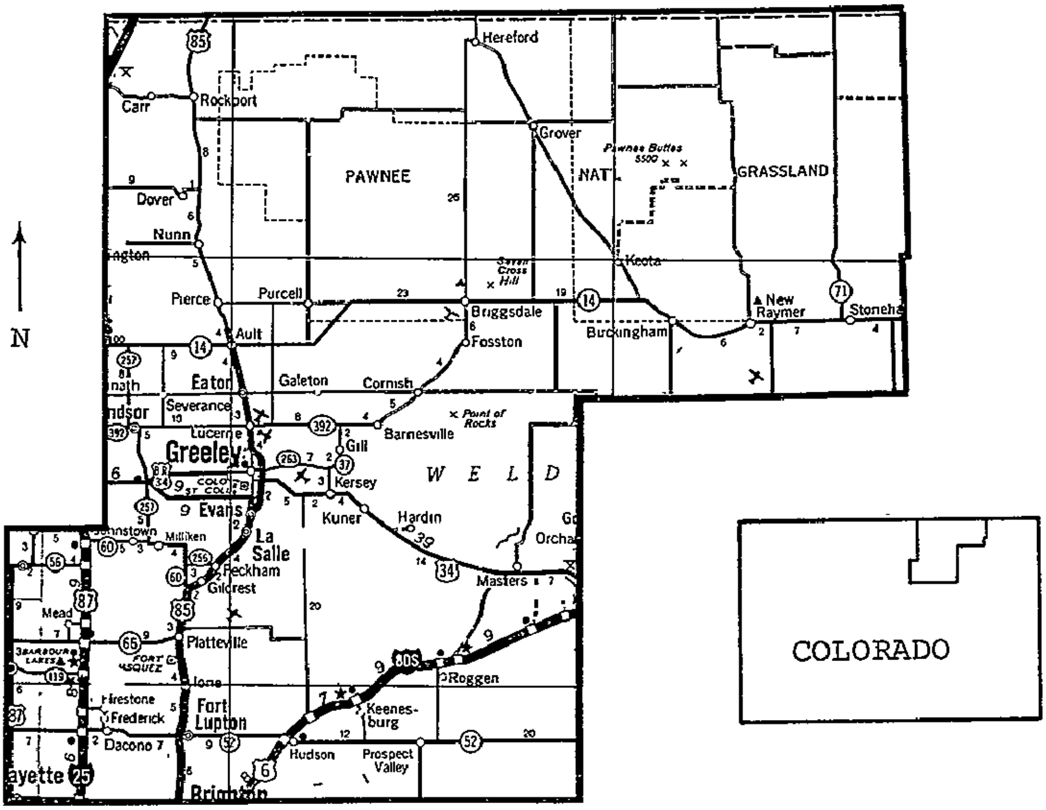
Tasks I.3 and I.4 are interdependent and will be discussed as such. After the site has been selected, the data which must be selected include digital and film transparencies of Landsat data, aircraft photographs, and ancillary information.

2.2.1 SELECTION AND DESCRIPTION OF THE GEOGRAPHIC AREA

Two constraints influenced the choice of the area to be investigated: LACIE Landsat segments must be available, and the area must be one of the nine sites selected for study in the TES. Using LACIE segments minimizes data receipt and data handling time. Selecting a site from the TES allows utilization of existing aerial photographs and ground truth.

The LACIE segment index was consulted and several LACIE segments were found in Colorado. No LACIE segments were found in the other states represented in the TES. The Colorado segments were screened and several segments were found in Weld County. As a result, Weld County, Colorado, was selected as the study site (fig. 2-2).

Weld County, in northeastern Colorado, is part of the U.S. Great Plains physiographic region. Topography can be described as rolling plains with a general slope to the north and east.



Scale: 1 inch equals approximately
29 kilometers (18 miles)

Figure 2-2.— Weld County orientation map.

Elevation ranges from 1524 to 1830 meters (5000 to 6000 feet). The climate is continental with dry, cold winters and warm, dry summers (ref. 4).

The site contains both agricultural land and rangeland. Approximately 35 percent of the county is agricultural; less than 1 percent is woodland and woodland pasture; 40 percent is rangeland; and the remaining 19 percent includes such areas as urban, water, and bare soil (ref. 5).

The dominant range vegetation consists of the prairie short grasses, principally grama grass and buffalo grass (*Bouteloua gracilis* and *Buchloe dactyloides*). Secondary species include salt grass (*Distichlis stricta*), four-winged saltbrush (*Atriplex*), soapweed (*Yucca glauca*), and prickly pear (*Opuntia* spp.). The primary agricultural crops are wheat, corn, and sugar beets (refs. 5,6).

2.2.2 LANDSAT DATA

In the technology assessment task, Landsat MSS data were used as the source data in the Procedure 1 evaluation. From the available 1976 and 1977 Landsat data, six dates were selected that contain LACIE segments. Each segment was approximately 9280 square hectometers (22 932 acres). A color-infrared transparency of each LACIE segment was produced on a production film converter (PFC).

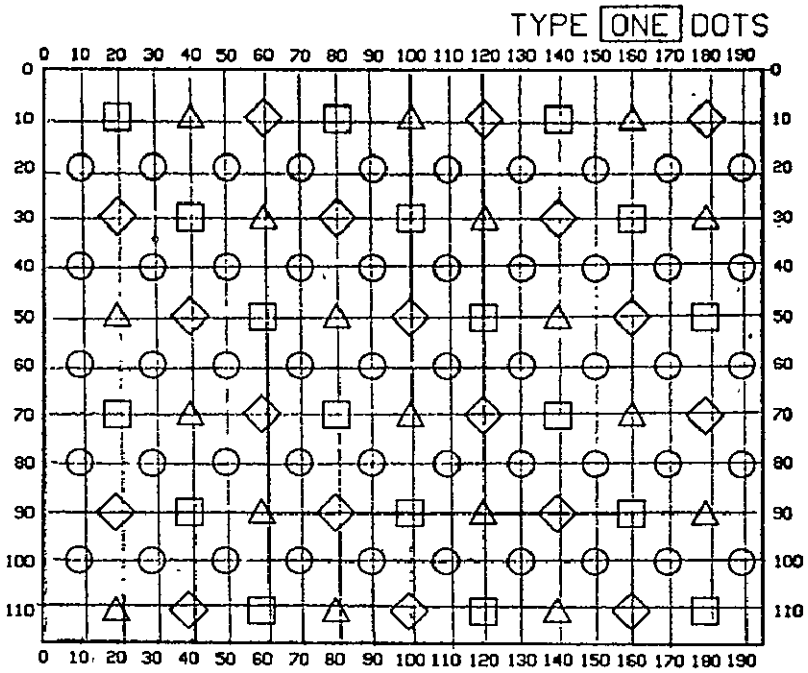
2.2.3 AIRCRAFT AND ANCILLARY DATA

Color-infrared photographs, obtained by NASA aircraft in 1972 (Mission 211, scale 1:120 000), were utilized as the basic source of surface feature information. Ancillary data such as crop calendars and topographic maps were also used.

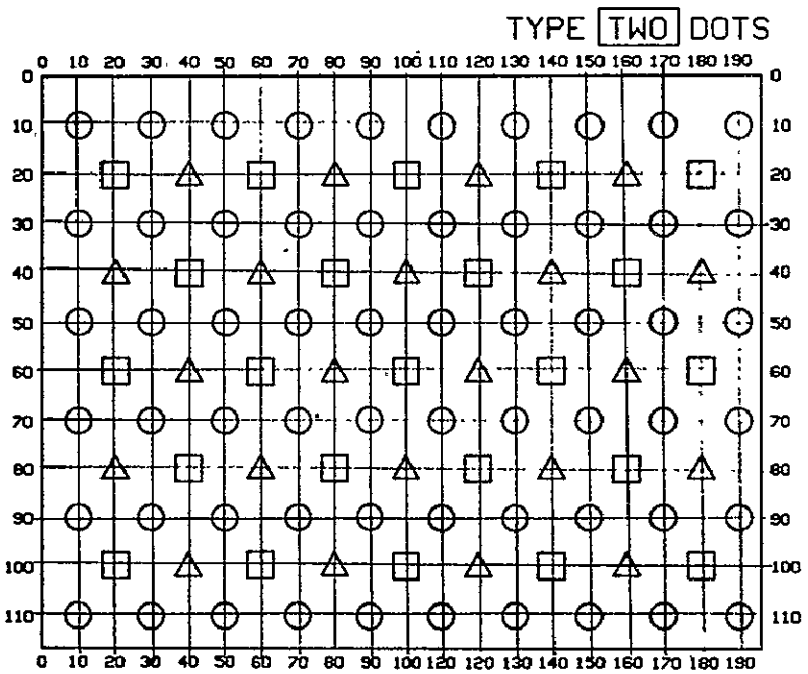
2.3 PROCESSING PROCEDURE

Initially, a systematic sample of individual pixels are identified as wheat or nonwheat. In the labeling procedure, a 10-pixel by 10-line grid is overlaid on the Landsat data segment. A dot overlay (fig. 2-3) is a part of the computer program and is overlaid on the grid. Using the grid, the analyst identifies individual pixels across the segment. For example, the pixels under the circles are identified as wheat or nonwheat; then the pixels under the squares, triangles, and diamonds are identified. A maximum of 209 dots can be labeled. A minimum of 70 dots must be labeled (ref. 1).

Two kinds of dots, type 1 and type 2, are labeled. The type 1 grid is overlaid on the segment [fig. 2-3(a)] and at least 30 dots are labeled. Next, the type 2 grid is overlaid [fig. 2-3(b)] and at least 40 dots are labeled. The type 2 grid has the same symbols as type 1; however, the pattern of the symbols is different. For example, for the type 2 grid, the circles are at alternate, odd, 10-line intervals. The circles for type 1 are at alternate, even, 10-line intervals. A computer-selected portion of the type 1 dots (for example, 10) are used as starting values for clusters. (The procedure has been modified since the completion of this study; however, this report describes the procedure which was in effect at the time.) For example, the spectral values of 6, 8, 16, and 4 in channels 4, 5, 6, and 7, respectively, are the spectral values associated with the beginning vector for one cluster. (The data for the entire segment are clustered.) Next, each cluster is identified as wheat or nonwheat. The basis for the identification is the spectral value for the cluster. The cluster's spectral value is compared with the spectral value



(a) Type 1 dots.



(b) Type 2 dots.

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Figure 2-3.– Dot grid overlays.

of each dot. When the spectral values match, the cluster will be labeled the same as the dot. For example, if cluster 25 corresponds to dot 1 and dot 1 is wheat, cluster 25 will be identified as wheat. The cluster statistics are used to classify the segments as wheat or nonwheat.

Type 2 dots are labeled and used to correct the initial classification for bias. The analyst's dot labels are compared with the classifier's dot labels. The difference between these labels is the classifier bias. For example, a table is constructed (table 2-2) in which the analyst labeled 12 dots as wheat and the classifier labeled 10 of the dots as wheat and 2 as nonwheat. The classifier bias for the wheat is 3/13. For nonwheat, the analyst labeled 13 dots. The classifier labeled 10 dots as nonwheat and 3 as wheat. The classifier bias for nonwheat is 2/12 (ref. 7).

TABLE 2-2.— ALPHA TABLE FOR TYPE 2 DOTS

	Wheat	Nonwheat	Total
Wheat	10	3	13
Nonwheat	2	10	12
Total	12	13	25

If the classifier wheat proportion is 0.50, the bias-corrected proportion is calculated as follows:

$$\text{Bias corrected} = 0.50(10/13) + 0.50(2/12)$$
$$= 0.47$$

By using a bias correction, an assumption is made that the original classification estimate is incorrect and must be modified by using a correction factor.

Procedure 1 was implemented on the Earth Resources Interactive Processing System (ERIPS); clustering and classification are also performed on this system.

2.4 EVALUATION PROCEDURES

Task I.6, evaluation (see fig. 2-1), included determining acreage proportion estimates and accompanying statistical qualifiers.

Before an analyst can place confidence in the classification map produced by using the processing procedures, it is necessary to evaluate the classification accuracy of the map. Because the cost of checking the map 100 percent on the ground would be prohibitive even if it were possible, an efficient evaluation method is required.

The photographic class proportion (p), the computer-estimated proportion (q), and the 90-percent confidence interval of each proportion were calculated. The class proportion was obtained by manual interpretation of the designated sample on aerial photographs. The estimated proportion was obtained from the computer classification.

A confidence interval is the range which would contain the true value of the estimated quantity at a prescribed percentage of the time. For Procedure 1 a 90-percent confidence level was selected. For example, if a 90-percent confidence interval of 83 to 93 percent were obtained for a proportion estimate, the analyst would be confident that 90 percent of a similar proportion estimate would be between 83 and 90 percent.

A paired t-test (ref. 8) was used to determine if the difference between the proportions calculated from the manual interpretation and from the computer classification was significant. The null hypothesis tested was that the difference was insignificant; that is, $\bar{p} - \bar{q} = 0$, where $\bar{p}$ is the estimator of p (proportion derived from interpretation of aerial photographs) and $\bar{q}$ is the estimator of q (proportion derived from computer classification). A level of significance ($\alpha = 0.10$) was selected.

Based on the number of degrees of freedom (number of samples - 1) and the level of significance, a t-value was calculated. (For details on calculating t-values, see reference 8.) For example, with 22 degrees of freedom and $\alpha = 0.10$, the t-value equals 1.717.

The calculated t-value was compared to a table of cumulative t-values. If the calculated value was greater than the table value, the difference between the proportion derived from aerial photographs and the proportion derived from computer classification was significant at $\alpha = 0.10$. If the value was less, the difference was insignificant and can be said to be attributed to chance.

Initially, 23 systematically selected samples were evaluated. The samples were selected from the classification map and located on the corresponding aerial photographs. A Zoom Transfer Scope was used to determine the sample location on the photographs. Beginning at line 10, pixel 10 on the LACIE segment, a sample was taken at every 20 pixels. A square cluster of eight pixels was evaluated at the sample point, and the proportion of the sample was recorded. The procedure was followed for lines 30, 50, 70, 90, and 110.

The half-range confidence interval delta was used to calculate the range of the confidence interval symmetric to the proportion. For example, if the proportion equals 87.5 percent and the delta is 0.049, the confidence interval is (87.5 - 4.9, 87.5 + 4.9). (For details on calculating the delta, see reference 8.) A delta of 0.05 for the classification map was acceptable.

2.5 RESOURCE REQUIREMENTS

The total hours used in Phase 1 of this technology assessment task was 650. Approximately 4 months were spent in data processing; 1 month was spent in evaluating the results; and 4 weeks were devoted to documentation. The scheduled analysis flow is shown in table 2-3. Resource expenditures are shown in table 2-4.

TABLE 2-3.— TECHNOLOGY ASSESSMENT TASK LEVEL II SCHEDULE

Task	Fiscal year 1978							
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
Project plan								
Site selection (2 weeks)		Site selected						
Data set selection (2 weeks)		Data received						
Processing (4 months)				Interim report		Processing complete		
Evaluation (1 month)								
Documentation (4 weeks)							Final report	

TABLE 2-4.– RESOURCE EXPENDITURES

Task	Personnel	Man-hours	Equipment hours
Experiment design and project plan	1 site scientist 1 clerk typist 2 reviewers	69 6 10	
Site selection	1 site scientist	22	
Data selection	1 site scientist 1 analysis interpreter	31 7	
Processing	1 site scientist	61	14 ERIPS batch runs
Evaluation	1 site scientist 1 scientist	67 2	
Documentation	1 site scientist 1 editor 1 typist 1 illustrator	178 17 28 17	
Administration	Administrative Clerical	124 11	

3. RESULTS

3.1 SITE SELECTION

After screening LACIE segments, the only TES site represented by these segments was Weld County, Colorado. Aircraft photographs taken over the site and ancillary information were available. Consequently, Weld County was selected for analysis. Of the segments in Weld County, only two (segments 9928 and 9929) were covered by aerial photographs. These segments were selected for analysis.

3.2 DATA SELECTION

Of the available data sets, six sets were selected for each segment. Table 3-1 lists the calendar and Julian date for each acquisition. (The data are stored in the data base by Julian date.) Of the six acquisitions, the two dates with the highest PCC were selected for each segment. For segment 9928, 7/16 and 5/22 (PCC's = 82 percent) were selected. For segment 9929, 6/28 and 5/5 (PCC's = 84 percent) were selected (table 3-2).

TABLE 3-1.— SEGMENT ACQUISITION

Segment 9928		Segment 9929	
Julian date	Calendar date	Julian date	Calendar date
77197	7/16/77	77178	6/28/77
77142	5/22/77	77125	5/05/77
77215	8/03/77	77143	5/23/77
77161	6/10/77	77098	3/30/77
76310	1/15/76	76347	12/12/76
76274	10/01/76	77251	9/08/76

TABLE 3-2.– SEGMENT PCC

Segment 9928		Segment 9929	
PCC	Calendar date	PCC	Calendar date
82	7/16/77	84	6/28/77
82	5/22/77	84	5/05/77
78	8/03/77	78	5/23/77
78	6/10/77	78	12/12/76
76	11/05/76	78	3/30/77
76	10/01/76	78	9/08/77

3.3 DATA PROCESSING

3.3.1 DOT LABELING

No hardwood or softwood was identified in the segments. Rangeland, brush, and other lands were labeled on segment 9929. Only rangeland and other lands were identified on segment 9928. Level III labeling (short prairie grass and salt grass) was not accomplished because these grasses could not be identified on the aerial photographs. Although portions of Weld County were ground checked in another study, the area in this study was not checked. The photointerpreter was not familiar with prairie and salt grass locations; consequently, the analyst could not distinguish between the two on the photographs.

3.3.2 PCC

The PCC was calculated for type 1 and type 2 dots, rangeland type 1 dots, and rangeland type 2 dots. The PCC was calculated by the computer, which compared the analyst-classified dot labels with the computer-classified dot labels. Using the previous example (table 2-2), the analyst labeled 25 dots, 12 wheat and 13 nonwheat; and the computer labeled 13 dots wheat and 12 nonwheat. The analyst is assumed to be correct.

For example:

$$PCC = 0.50(10/13) + 0.50(10/12)$$
$$= 0.80$$

The number of dots used for each calculation varied (table 3-3). For rangeland type 1 dots, the PCC was calculated for brush and rangeland as one category, excluding nonrangeland.

TABLE 3-3.— CLASSIFICATION PCC

Segment	Type of dot	Number of dots	PCC, all type 1 dots	PCC, all type 1 range dots	PCC, all type 2 dots	PCC, all type 2 range dots
9929	1	45	100	100		
	2	49			93	93
9928	1	46	97.8	99.8		
	2	44			96.7	96.7

LACIE established standards of 80 percent PCC. If this criterion was met, the results were considered satisfactory. By this standard, the results in table 3-3 are satisfactory.

3.3.3 CLASSIFICATION PERCENTAGES

The computer-calculated percentage of rangeland for segment 9928 varied from 77 to 80 percent with a 5-percent variance of the bias-corrected estimate. Rangeland estimates for segment 9929 varied from 76 to 81 percent with a 13-percent variance. Table 3-4 presents these proportion estimates.

TABLE 3-4.— PROPORTION ESTIMATES

[Values are given in percentages.]

	Segment 9928		Segment 9929			Total range
	Range	Nonrange	Range	Brush	Nonrange	
Classification	0.80	0.20	0.79	0.02	0.19	0.81
Corrected classification	.77	.23	.72	0	.23	.76
Variance	.05	.05	.13	0	.13	.13
Random sample	.79	.21	.81	0	.19	.81

3.4 EVALUATION RESULTS

3.4.1 SYSTEMATIC SAMPLING EVALUATION RESULTS

Although the PCC and the variance of the segments (table 3-4) met the LACIE-specified criteria of 80 percent PCC and 27 percent variance, an additional evaluation was performed using an initial sample size of 23 clusters on the computer interpretation and the photointerpretation. The resulting proportions and confidence intervals are summarized in table 3-5.

TABLE 3-5.— EVALUATION RESULTS BASED ON 23 CLUSTER SAMPLES

	Segment 9928		Segment 9929	
	Range	Nonrange	Range	Nonrange
Estimated class proportion, $\overline{p}$	1.00	—	0.808	0.192
Confidence interval, $\Delta 0.9$	—	—	±.0809	±.0809
Estimated class proportion, $\overline{q}$	.956	0.044	.895	.105
Confidence interval, $\Delta 0.9$	±.104	±.04	±.0811	±.054

Because the delta of the confidence interval was greater than 0.05, the sample size was increased to 50. Results of the 50 samples are shown in table 3-6.

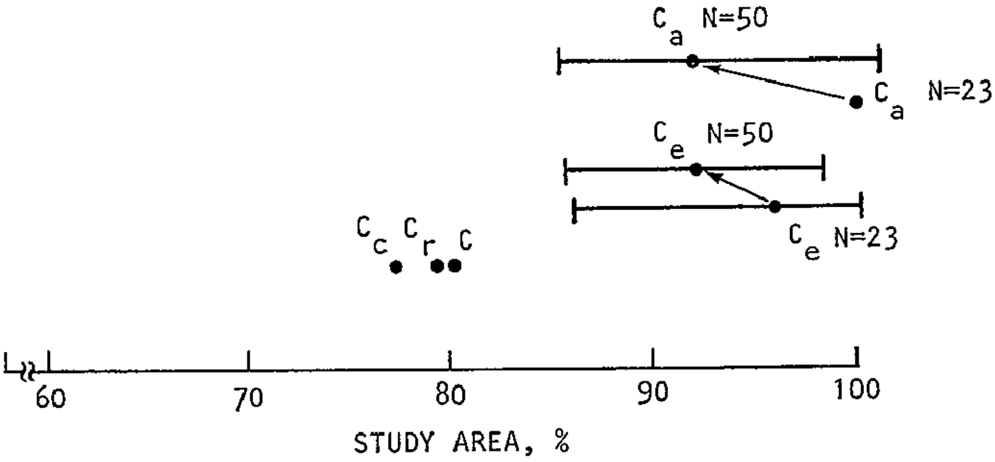
With the increased sample size, the variance decreased and the proportion derived from the evaluation shifted toward the proportion derived from wall-to-wall classification. In segment 9928, the photointerpretation (C_a) for rangeland shifted from 1.0 (table 3-5) to 0.92 (table 3-6) toward an initial classification (C) of 0.80, a bias-corrected classification (C_c) of 0.77, and a random sample (C_r) of 0.79. For the same segment, the initial computer interpretation (C_e) moved from 0.956 to 0.92, which is also toward the C, C_c, and C_r proportions. Because the C_a proportion from 23 samples was 1.0, the delta was not calculated. The C_e delta was ±0.104.

The C_a proportion from 50 samples had a delta of ±0.060. The C_e delta was reduced from ±0.104 to ±0.064. The trends exhibited in segment 9928 were also apparent in segment 9929. For example, the C_a shifted from 0.808 (table 3-5) to 0.782 (table 3-6) toward a C of 0.81, a C_r of 0.79, and a C_c of 0.77 (fig. 3-1). Likewise, the initial C_e of 0.895 decreased to 0.847. The C_a delta was reduced from ±0.080 to ±0.068. The C_e delta was reduced from ±0.081 to ±0.057.

To determine the significance of the difference between aircraft and computer proportions, a student's t-test was applied to the results. The hypothesis that there was no significant difference between the computer estimate and the photointerpreted estimate: H: $\overline{p} - \overline{q} = 0$ was tested. For $\alpha = 0.10$ and 50 samples, there was no significant difference between the proportions derived either manually from photointerpretation or from ADP.

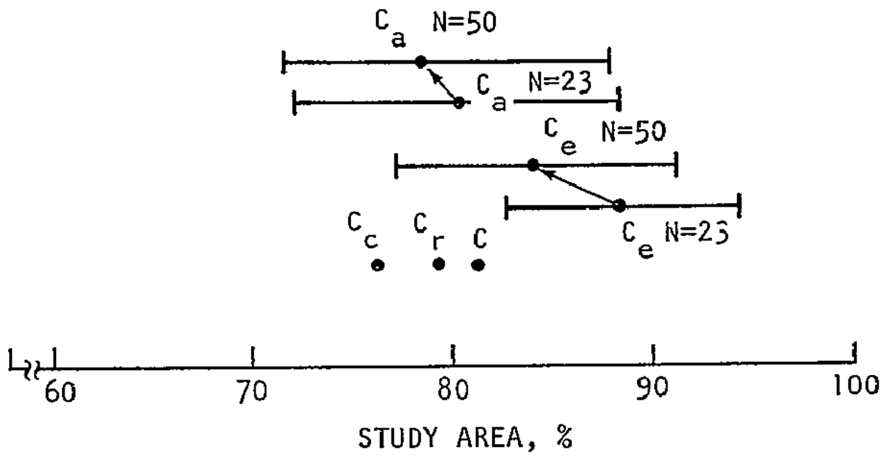
TABLE 3-6.— SUMMARY OF CLASS PROPORTION BASED ON 50 SAMPLES

	Estimated class proportion, $\bar{p}$	Confidence interval, $\Delta 0.9$	Estimated class proportion, $\bar{q}$	Confidence interval, $\Delta 0.9$	Significance, $\bar{p} - \bar{q}$
Segment 9928 range	0.920	±0.060	0.920	±0.064	None
Segment 9928 nonrange	.080	±.072	.080	±.059	None
Segment 9929 range	.782	±.096	.847	±.058	None
Segment 9929 nonrange	.218	±.095	.153	±.058	None



(a) Segment 9928.

9929



(b) Segment 9929.

LEGEND

N = number of samples

C = initial classification

C_c = bias-corrected classification

C_r = random sample

C_e = initial computer classification

C_a = photointerpretation

├─┤ = confidence interval

← = shift in proportiohs

Figure 3-1.– Proportion estimates of rangeland for segments 9928 and 9929 in Weld County, Colorado.

Rangeland proportions derived from C, C_c, C_r, C_e, and C_a are shown in figure 3-1. It is interesting to note that the classifications of C_c and C_a are very similar. In fact, proportion results from a t-test verified that the difference between them was insignificant. Also note that the rangeland proportion in segment 9928 was greater than any of the wall-to-wall classification results (C_c, C_r, or C).

4. DISCUSSION OF RESULTS

The use of Procedure 1 as a processing technique for rangeland inventories looks promising. The PCC's are high (93 to 100 percent); the proportion estimates between classification, the bias-corrected classification, and the random sample are similar (80, 77, and 79 percent, respectively, for segment 9928; and 81, 76, and 81 percent for segment 9929).

Because of the small variance between the initial classification and bias-corrected classification, the assumption can be made that the bias is small and that the computer classifier and analyst agree.

The similarity between the rangeland bias classification proportion (0.81 and 0.79 for segments 9929 and 9928, respectively) and the random sample (0.81 for both segments) leads to the postulation that estimates can be calculated equally well using either systematic or random sampling. To verify that this result is not the result of the homogeneity of the area, it is recommended that the hypothesis be tested on a heterogeneous area.

Testing the evaluation of 23 systematic clusters showed that, statistically speaking, the differences between the proportion estimate ($\hat{p}$) from aircraft photographs and the proportion estimate ($\hat{q}$) from the computer classification were insignificant. Therefore, it can be assumed that the inventory classification is accurate 90 percent of the time. Because the delta of the confidence interval for each estimate was greater than 0.05, the sample site was increased.

It is expected that the delta decreases with an increase in sample size. This means that the confidence interval is more narrow and implies that the data are grouped more closely around the mean of the interval. For all classes, the proportion estimates from the larger sample more closely approximate the proportion from the wall-to-wall estimates. The implication is that the larger sample is more representative of the population.

For segment 9929, the rangeland proportion from sampling (0.92 ± 0.064) is larger than that derived from wall-to-wall (0.81) classification. Although the wall-to-wall classification is barely within the confidence interval for the sample, the mean of the interval is 8 percent larger. Examination of the segment showed the nonrangeland areas to be concentrated in only a few locations on the scene. Only four samples contained nonrangeland. Consequently, the rangeland proportion is high. To ensure sampling in the nonrangeland area, a stratified sampling design, which designates that a percentage of the samples be taken in the nonrangeland area, should be used.

Although Procedure 1 appears suitable for rangeland classification, some problem areas in dot location were noted. Misclassifications were noted on the map. When the misclassifications do not fall on a specified dot, it is difficult to train the classifier to classify the pixels. The misclassified pixels cannot be correctly labeled, but the cluster containing the pixels can be relabeled. However, because all pixels in the cluster are relabeled, additional misclassifications are produced if the cluster contains both rangeland and nonrangeland pixels. It must be noted that these misclassifications are obvious because field patterns are obvious. Rangeland pixels within a field or nonrangeland pixels in a range area are more conspicuous than in a truly heterogeneous area.

All range signatures may not be represented on a fixed grid because the rangeland signature is diverse. For example, preliminary analysis of segment 9928 shows rangeland cluster mean values range from 34 to 69 in channel 5 and 20 to 30 in channel 7. Because rangeland is not homogeneous or found in uniform patterns, it is difficult to account for all rangeland signatures using the current fixed grid.

However, the grid density could be increased from 209 dots to 1000 to 2000 dots. Increased dots could account for the diversity within a signature. Another alternative is a nonfixed-dot pattern where the dot could be located anywhere on the scene. Although a more complete signature could be obtained, systematic sampling would be lost. A combination of a systematic grid plus a movable dot would be ideal. The dots on the grid could be labeled and any features off the grid could be included with the movable dot.

5. CONCLUSIONS AND RECOMMENDATIONS

The assessment of LACIE Procedure 1 as an improved method for rangeland classification using Landsat data was addressed with three objectives.

a. LACIE Procedure 1 was applied to a rangeland test site, and the procedure produced accurate rangeland classification (section 3.4.1).

b. Detailed procedures have been developed and were presented for applying LACIE Procedure 1 to a renewable resource classification problem.

c. An additional LACIE technique (Procedure 2) has been identified as possibly applicable to forest and rangeland classification.

Additionally, the following were verified.

a. Level I features (rangeland and nonrangeland) were separated and mapped, and proportions were estimated with accompanying confidence statements. Other Level II features (agriculture and urban) were considered as other land. In the site, no forest was present.

b. Level II feature (rangeland) was differentiated and mapped, and proportions were estimated with accompanying confidence statements.

An assumption that short prairie grass and salt grass could be differentiated on aircraft photographs was inaccurate for the Weld County site. However, rangeland could be differentiated.

An additional conclusion for the Weld County site was that estimates derived from either random or systematic sampling are satisfactory.

The following recommendations are made.

a. Procedure 1 should be applied to a forest site in order to verify its applicability for forest inventory.

b. Procedure 1 should be tested in a heterogeneous area containing several forest and rangeland features such as softwood, hardwood, mixed softwood/hardwood, grass, brush, and water.

Additionally, it is recommended that the Procedure 1 grid be modified because the rangeland signatures tested were diverse and all signatures may not be represented on a fixed grid. This could be done either by increasing the grid density or allowing for a movable dot. For inventory purposes, a combination of a systematic grid and a movable dot is recommended.

A further recommendation is that Procedure 2 be investigated to determine its applicability to forest and rangeland inventory.

6. REFERENCES

1. CAMS Requirements Document. LACIE C00200 (JSC-11330), vol. II, rev. D, July 1977.

2. Reeves, C. A.: Technology Assessment Task: Preliminary Experiment Design of Procedure 1 Applicability to Forest and Range Inventory. Lockheed Electronics Co., Inc. (Houston, Texas), LEC-11412, November 1977.

3. Reeves, C. A.: Technology Assessment Task: Interim Report on the Application of LACIE Procedure 1 to a Rangeland Test Site. Lockheed Electronics Co., Inc. (Houston, Texas), LEC-11874, February 1978.

4. Hunt, C. B.: Physiography of the United States. W. H. Freeman and Company (San Francisco, California), 1972.

5. LACIE packet.

6. Personnal communication with Gerald Arp.

7. Personal communication with D. Register, R. Minter, L. Delgado, K. Abotteen, D. Hinkle, and M. Goldberg.

8. Ostle, B.; and Mensing, R. W.: Statistics in Research. Iowa State University Press (Ames, Iowa), 1975.

APPENDIX

DETAILED PROCEDURES

APPENDIX

DETAILED PROCEDURES

A.1 SITE SELECTION

1. Determine which LACIE segments are contained in the TES sites by consulting an index of LACIE segments.
2. The LACIE index identifies the county containing the segment. Eliminate all segments not in a TES county.
3. Plot the LACIE segment on a 9- by 9-inch Landsat transparency.
4. Conduct a search to determine which of the remaining segments have aircraft coverage.
5. Eliminate all segments without coverage.
6. From the remaining segments, select two for processing. Check out the LACIE packet which contains geographic and crop information on the site.
7. Using the LACIE index, determine the acquisitions available for processing. Segments must be on one existing data base. Segments cannot be cross-loaded from two data bases.
8. Select six acquisitions representing the seasonal changes. For example, select a date for fall, winter, spring, and summer. Select the remaining two dates which best differentiate the features of interest. To determine these dates, consult the crop calendar and the LACIE analysts who worked the segment.
9. Order a color-infrared film transparency for each date. The Information Storage, Retrieval, and Reformatting Subsystem handles these orders.
10. Upon receipt of the film determine the PCC for each date.

A.2 PCC DETERMINATION TO SELECT BEST DATES

1. Register corners of LACIE segment to aircraft photograph using the Zoom Transfer Scope.
2. Construct a grid for the portion of the photograph corresponding to the segment. The grid represents 10 pixels by 10 lines.
3. Construct the symbol overlays to correspond with the dot grid overlays (figs. A-1 and A-2).
4. Identify the area under the upper left portion of all circles on the grid; 50 circles will be labeled. Aircraft interpretation is considered correct.
5. Place the type 1 dot grid over the segment and identify the upper left portion of the 50 circles.
6. Calculate the PCC:

$$PCC = \frac{\text{Number of correctly classified dots}}{\text{Total number of dots}} \times 100$$

7. Tabulate the results.

A.3 DATA PROCESSING

1. Request segments be loaded on the research, test, and evaluation (RT&E) data base on the ERIPS and on the Image 100 Hybrid system.
2. Overlay the type 1 dot grid on the segment and identify the area under the upper left portion of each circle. This procedure is known as dot labeling. Label each circle, totaling 50 dots. (This step should have been completed during PCC determination.)
3. Overlay the type 2 dot grid and label a minimum of 40 dots. Circles, squares, triangles, and diamonds are labeled.
4. Prepare a dot deck, a field deck, and a deck (figs. A-3, A-4, and A-5).

5. Prepare a LACIE Data Product Request form (figs. A-6 and A-7).

   a. Attach the dot deck and field deck (figs. A-3 and A-4) to the completed form (fig A-6).

   b. Attach the deck (fig. A-5) to the completed form (fig. A-7).

   c. Submit both decks to LACIE Physical Data Library.

6. Obtain a black-and-white classification map, one color cluster map, a Classification and Mensuration Subsystem (CAMS) delog, and a CAMS/Crop Assessment Subsystem (CAS) interface tape (CCIT) report. The CCIT report contains computer-calculated PCC's and proportion estimates.

7. Check the PCC's and variances on the CCIT report. If the PCC is greater than 0.80 and the threshold is less than 3 percent, the classification is satisfactory. If the PCC is greater than 0.7, check the variance of the bias. If the variance is less than 0.0027, the classification is satisfactory.

8. If the classification is unsatisfactory, check the dot labels and relabel incorrect dots. Return to step 3.

A.4 EVALUATION OF RESULTS

1. Overlay the dot grid on the classification map.

2. Identify the pixels under the upper left corner of each square. For the first pass, the sample size is 23. Identify the proportion of each class.

3. Overlay the corresponding dot grid on the aerial photograph.

4. Label the area under the square as in step 2.

5. Estimate $\bar{p}$ for each class on the aerial photograph as follows:

$$\hat{p} = \bar{p} = \frac{1}{n}\Sigma p_i$$

where $\bar{p}$ is the estimator of p, and $\hat{p}$ is the estimate.

6. Estimate the standard deviation s_p^2 for each class:

$$s_p^2 = \frac{1}{n - 1}\Sigma(p_i - \bar{p})^2$$

7. Compute $s_{\bar{p}}$ (standard deviation of the mean estimate for each class):

$$s_{\bar{p}} = \sqrt{\frac{s_p^2}{n}}$$

8. Compute the confidence interval for p ($\alpha = 0.10$):

$$\hat{p} = \bar{p} \pm \Delta_{(1-\alpha)(n-1)}$$

$$\Delta_{(1-\alpha)(n-1)} = t_{(1-\alpha/2)(n-1)} s_{\bar{p}}$$

If calculated Δ is greater than 0.05, increase the sample size to 50.

9. Calculate the individual statistic (steps 5 through 8) for $\bar{q}$ of each class of the computer classification.

10. Test the hypothesis that there is no significant difference between the computer estimate and the photointerpretation estimate: H: $\bar{p} - \bar{q} = 0$

$$d_i = (p_i - q_i)$$

$$\bar{d} = \frac{1}{n}\Sigma d_i = \frac{1}{n}\Sigma(p_i - q_i) = \bar{p} - \bar{q}$$

$$s_d^2 = \frac{1}{n - 1}\Sigma(d_i - \bar{d})^2$$

$$s_{\bar{d}} = \sqrt{\frac{s_d^2}{n}}$$

$$t = \frac{\bar{d}}{s_{\bar{d}}}$$

11. Compare the calculated t-value with the book t-value:

$$t_{(1-\alpha/2)(n-1)}$$

12. If $t_{(1-\alpha/2)(n-1)} < t$, accept the hypothesis;
    if $t_{(1-\alpha/2)(n-1)} > t$, reject the hypothesis.

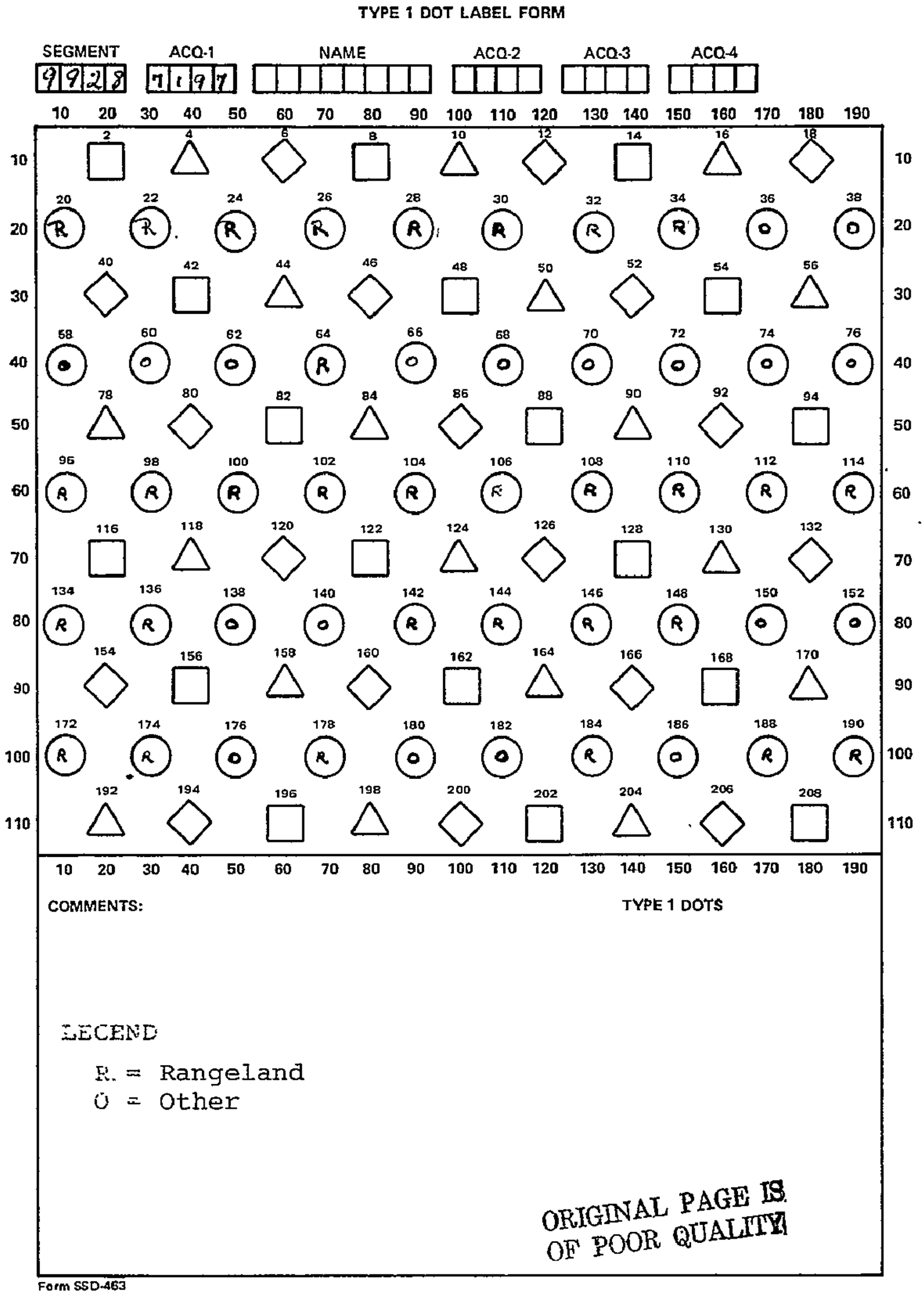
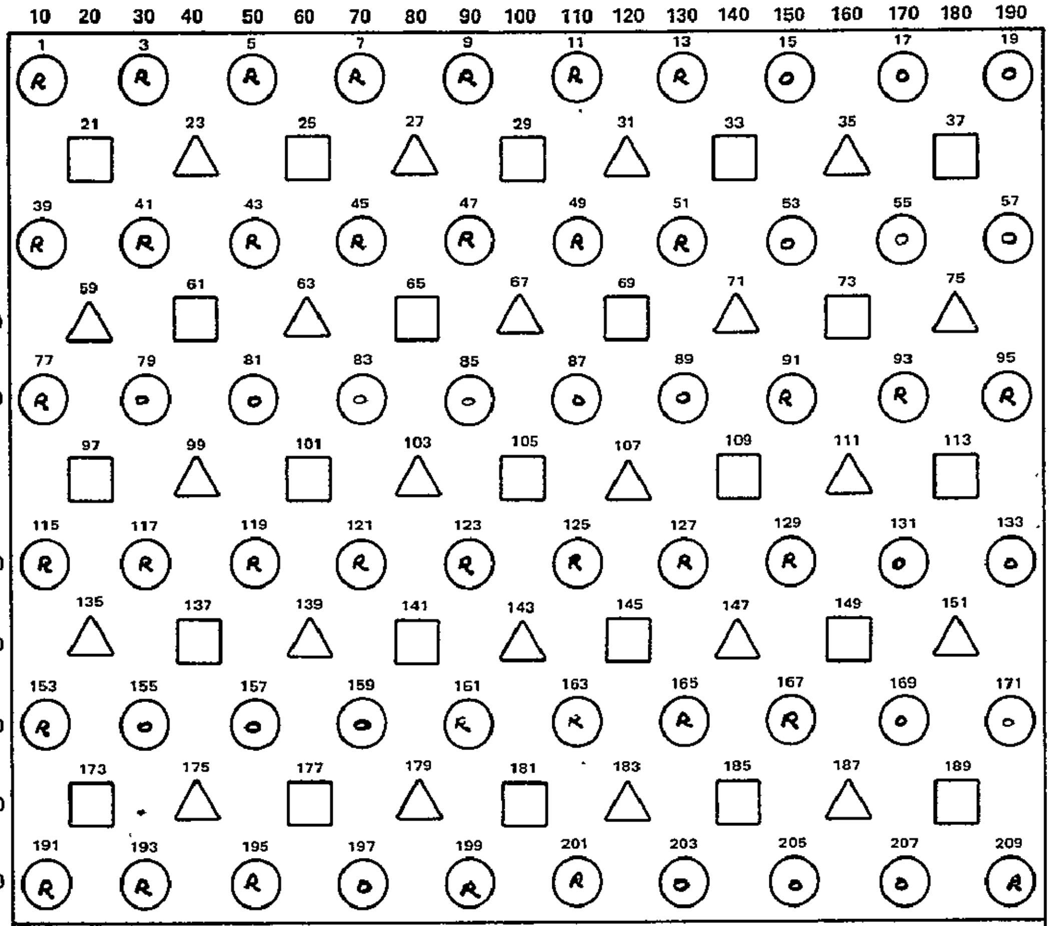


Figure A-1.— Type 1 dot form.



TYPE 2 DOT LABEL FORM

SEGMENT 9928 | ACQ-1 7197 | NAME | ACQ-2 | ACQ-3 | ACQ-4

	10	20	30	40	50	60	70	80	90	100
10	1 R	3 R	5 R	7 R	9 R	11 R	13 R	15 O	17 O	19 O
20	21	23	25	27	29	31	33	35	37	
30	39 R	41 R	43 R	45 R	47 R	49 R	51 R	53 O	55 O	57 O
40	59	61	63	65	67	69	71	73	75	
50	77 R	79 O	81 O	83 O	85 O	87 O	89 O	91 R	93 R	95 R
60	97	99	101	103	105	107	109	111	113	
70	115 R	117 R	119 R	121 R	123 R	125 R	127 R	129 R	131 O	133 O
80	135	137	139	141	143	145	147	149	151	
90	153 R	155 O	157 O	159 O	161 R	163 R	165 R	167 R	169 O	171 O
100	173	175	177	179	181	183	185	187	189	
110	191 R	193 R	195 R	197 O	199 R	201 R	203 O	205 O	207 O	209 R

COMMENTS:

LEGEND

R = Rangeland
O = Other

TYPE 2 DOTS

m_1 = W/W = ____

n_1 = /W = ____

m_2 = O/O = ____

n_2 = /O = ____

W_C = ALL PIXELS CLASSIFIED WHEAT = ____

N_C = ALL PIXELS CLASSIFIED NONWHEAT = ____

BASE = 22 932 – DU – THRESHOLD – X = ____

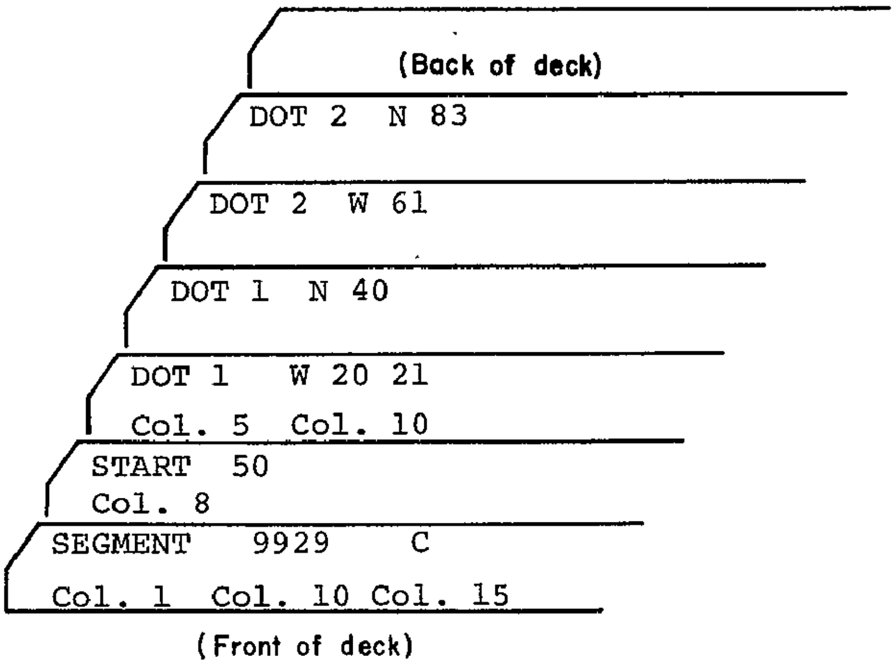
$\alpha_1 = \frac{m_1}{n_1} =$ ____ $\alpha_2 = \frac{m_2}{n_2} =$ ____

$$W_{BC} = (\alpha_1)\left(\frac{W_C}{BASE} \times 100\right) + (1-\alpha_2)\left(\frac{N_C}{BASE} \times 100\right)$$

( )( ) + ( )( ) =

Form SSD-464

Figure A-2.– Type 2 dot form.



Card 1 — 9929 is the number assigned to the segment on the data base; C means complete update of dot labels.

Card 2 — Number of dots for starting vectors.

Card 3 — Dot card, 1 means a type 1 dot; W designates all dots on the card as wheat; 20 is the dot number on the type 1 dot label form (fig. A-1).

Card 4 — Dot card for type 1 nonwheat dots.

Card 5 — Dot card for type 2 wheat dots. The dot number is from the type 2 dot label form (fig. A-2).

Card 6 — Dot card for type 2 nonwheat dots.

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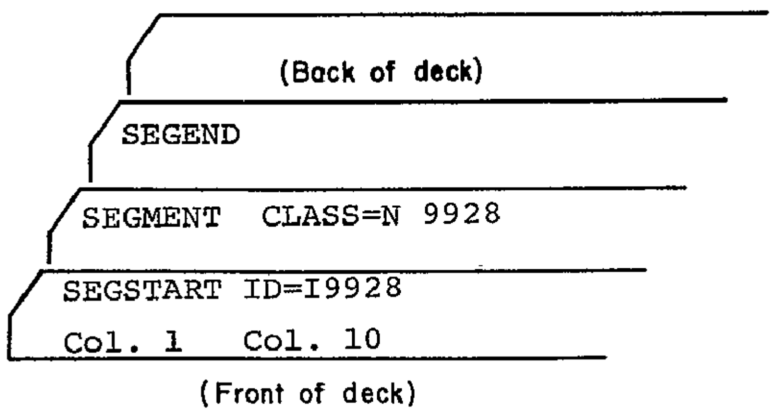
OF POOR QUALITY

Figure A-3.— Dot deck.

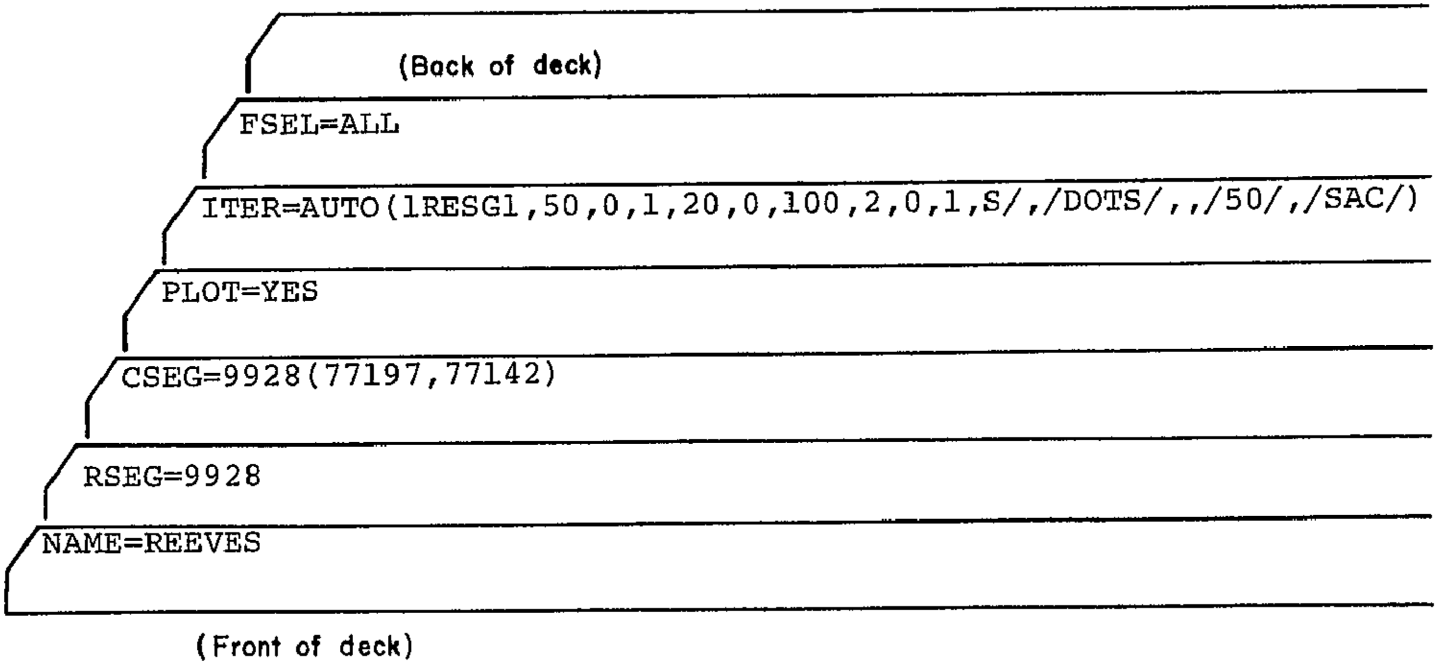


Card 1 – Identification card used to retrieve image.

Card 2 – Class card which identifies field.

Card 3 – End card.

Figure A-4.– Field deck.



Card 1 — Your name.

Card 2 — Segment number.

Card 3 — Segment number and acquisitions to be processed.

Card 4 — Produces spectral plots.

Card 5 — Iterative clustering; automatically label; parameters identify nearest neighbor clustering as defined in CAMS; type 1 dots as starting vectors; and Sun angle correction.

Card 6 — Feature selection. (In this case, use all channels for classification.)

Figure A-5.— Deck.

RT&E

C 3 4 F A D - 1 3 5 3 - C A R - 2 4 -

LACIE DATA PRODUCT REQUEST

NAME C. A. Reeves PHONE 333-6314

KEYPUNCH & LIST ______ NON-LACIE

DATA BASE UNLOAD ______

DATA BASE UPDATE X HIST ______ Dots X FIELDS X PRO CONT ______ VIA CARDS X TAPE ______

DATA BASE QUERY ______ HIST ______ FIELDS ______

BATCH PRODUCTION ______

PFC FILM REQUEST ______

INTERACTIVE JOB ______ SCHEDULE TIME FROM ______ TO ______ DATE ______

INPUT TAPE NO.	FILE NO		SAMPLE SEGMENTS TO BE PROCESSED				
	OR						
	OR						
	OR						
	OR						
	OR						
	OR						

COMMENTS

EOD DATA MANAGER/DATE

PFC PRODUCTS		COM PRODUCTS	OTHER
CODE NAME	8. COLOR ALL 4 CHANNELS ______	1. CAMS REPORT ______	1. CARD LISTING ______
1. COLOR IR ______	9. B&W CLASS MAP ______	2. CAMS DELOG ______	2 TRANSACTION REPORT X
2 ENHANCED COLOR ______	10 COLOR CLUSTER ______	3 INDEXED DATA REPORT ______	3. JSC INTF TAPE ______
3. TEMPORAL COLOR COMPOSITE ______	11. LINEAR COMB B&W ______	4 CLASS CHAR MAP ______	4. FLDS DEF TAPE ______
4. B&W, ALL 4 CHANNELS ______	12. LINEAR COMB COLOR ______	5 CLASS CLUS MAP ______	
5. SINGLE B&W SCREENING ______	13 B&W FB OVERLAY ______		
6 COLOR CLASS IMAGE ______			
7. ENGINEERING IMAGE ______			

DPCA SPECIAL INSTRUCTIONS: DPCA APPROVAL: ______

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LACIE OPS SUPV.

TO PFC		TO DDC		ACC NOS.
NO. ______	DATE ______	FICHE	______	______
NO ______		TAB	______	______
		TAPE	______	______
		FILM	______	______

TO COMF

NO. ______ DATE ______

NO ______

COMPLETE EOD D/M ______ DATE ______

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Figure A-6.— Form to be attached to the dot and field decks.

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RT&E

C 3 4 E A P - 7 3 5 3 - C A R - 0 7 -

LACIE DATA PRODUCT REQUEST

NAME C.A Reeves PHONE 333-6314

KEYPUNCH & LIST ______ ☒ NON-LACIE

DATA BASE UNLOAD ______
DATA BASE UPDATE X HIST ______ FIELDS X PRO CONT X VIA CARDS X TAPE ______
DATA BASE QUERY ______ HIST ______ FIELDS ______
BATCH PRODUCTION ______
PFC FILM REQUEST ______
INTERACTIVE JOB ______ SCHEDULE TIME. FROM ______ TO ______ DATE ______

INPUT TAPE NO.	FILE NO.		SAMPLE SEGMENTS TO BE PROCESSED				
	OR						
	OR						
	OR						
	OR						
	OR						
	OR						

COMMENTS:

EOD DATA MANAGER/DATE

PFC PRODUCTS

CODE NAME
1. COLOR IR ______
2. ENHANCED COLOR ______
3. TEMPORAL COLOR COMPOSITE ______
4. B&W, ALL 4 CHANNELS ______
5. SINGLE B&W SCREENING ______
6. COLOR CLASS IMAGE ______
7. ENGINEERING IMAGE ______
8. COLOR ALL 4 CHANNELS ______
9. B&W CLASS MAP X
10. COLOR CLUSTER X
11. LINEAR COMB B&W ______
12. LINEAR COMB COLOR ______
13. B&W FB OVERLAY ______

COM PRODUCTS

1. CAMS REPORT ______
2. CAMS DELOG X
3. INDEXED DATA REPORT ______
4. CLASS CHAR MAP ______
5. CLASS CLUS MAP ______

OTHER

1. CARD LISTING ______
2. TRANSACTION REPORT X
3. JSC INTF TAPE ______
4. FLDS DEF TAPE ______
5 spectral aids X
6 CCT X

DPCA SPECIAL INSTRUCTIONS: DPCA APPROVAL: ______

send DTERM tape, CAMSIANS tape to Bldg. 17

LACIE OPS SUPV.

TO PFC
NO. ______ DATE ______
NO. ______

TO DDC
FICHE ______
TAB ______
TAPE ______
FILM ______

ACC NOS.

TO COMF
NO. ______ DATE ______
NO. ______

COMPLETE EOD D/M ______ DATE ______

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Figure A-7.— Form to be attached to the deck.