E7.4-10506
CR 134246

SKYLAB S192 DATA EVALUATION:

COMPARISONS WITH ERTS-1 RESULTS

(E74-10506) SKYLAB S192 DATA EVALUATION: COMPARISONS WITH ERTS-1 RESULTS (Lockheed Electronics Co.) 58 p HC $6.00 CSCL 05B

N74-22953

Unclas
G3/13 00506

Job Order 77-523

Prepared By

Lockheed Electronics Company, Inc.
Aerospace Systems Division
Houston, Texas

Contract NAS 9-12200

For

EARTH OBSERVATIONS DIVISION

National Aeronautics and Space Administration
LYNDON B. JOHNSON SPACE CENTER
Houston, Texas

January 1974

LEC-1711

SKYLAB S192 DATA EVALUATION: COMPARISONS WITH ERTS-1 RESULTS

Job Order 77-523

PREPARED BY

C. Y. Chang

C. Y. Chang, Scientific Programming Specialist
Data Applications Section

APPROVED BY

C. E. Clouse

C. E. Clouse, Supervisor
Data Applications Section

D. N. Brandt for

J. E. Davis, Manager
Data Applications and Physics Department

Prepared By

Lockheed Electronics Company, Inc.

For

Earth Observations Division

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER
HOUSTON, TEXAS

January 1974

LEC-1711

CONTENTS

TABLES

FIGURES

ACKNOWLEDGEMENTS

The author expresses his appreciation for the contributions of Mr. S. B. Chism and Dr. S. S. Yao of Lockheed Electronics Company. Mr. Chism participated in the initial phase of the study, and Dr. Yao performed the registration of S192 and ERTS-1 data.

SUMMARY

The Skylab S192 data was evaluated by (1) comparing the classification results using S192 and ERTS-1 data over the Holt County agricultural study area, and (2) investigating the impact of signal-to-noise ratio on classification accuracies using registered S192 and ERTS-1 data. The pairwise divergence of classes and the classification accuracies for various band subsets were obtained and analyzed.

The preceding studies indicate the following.

(1) The classification accuracy obtained on S192 data using its best subset of four bands can be expected to be as high as that on ERTS-1 data.

(2) When a subset of four S192 bands that are spectrally similar to the ERTS-1 bands was used for classification, an obvious deterioration in the classification accuracy was observed with respect to the ERTS-1 results. Possible factors causing this deterioration are believed to be:

   (a) the poorer inherent separability of these S192 bands which have narrower spectral coverages than their corresponding ERTS-1 bands

   (b) the lower signal-to-noise ratio for most of these S192 bands.

(3) The thermal bands 13 and 14 (both λ:10.01 ∿ 12.63 μm) as well as the near IR bands 11 (λ:1.56 ∿ 1.73 μm) and 12 (λ:2.10 ∿ 2.35 μm) were found to be relatively important in the classification of

agricultural data. Although bands 11 and 12 were highly correlated, both were invariably included in the best subsets of band sizes, four and beyond, according to the divergence criterion.

(4) The differentiation of corn from popcorn was rather difficult on both S192 and ERTS-1 data acquired at an early summer date.

(5) The results on both sets of data indicate that it was relatively easy to differentiate grass from any other class.

It is recommended that

(1) a segment of straightened and calibrated S192 data at a later stage of crop growth be acquired for a further evaluation; and

(2) the S192 noise problems be resolved to improve the data quality, and thus enhance the classification performance of S192 data.

1.0 INTRODUCTION

The primary objective of this study was to evaluate S192 data for utility in Earth Observations Division (EOD) applications.

Two task plans had been established in order to accomplish this objective:

(1) Task 1 was to compare classification results using S192 and ERTS-1 data over Holt County, Nebraska.

(2) Task 2 was to investigate the impact of signal-to-noise ratio on classification accuracies using registered S192 and ERTS-1 data.

To carry out Task 1, a subset of S192 bands which are equivalent to the ERTS-1 bands were first identified. Various subsets were then determined thereof based on the divergence criterion. Finally maximum likelihood classifications were performed on a segment of the Holt County agriculture data using the previously selected subsets of S192 bands as well as the entire ERTS-1 bands.

The registration of S192 imagery with the corresponding ERTS-1 imagery was a prerequisite to Task 2. Subsequent procedures in Task 2 involved various substitutions of appropriate S192 bands for the equivalent ERTS-1 bands, and vice versa, in classifying the registered data. The classification results were then used in the evaluation of signal-to-noise ratio problems.

The major analysis facility was the Earth Resources Interactive Processing System (ERIPS), although existing capabilities on the UNIVAC 1108 system were also utilized. Among those performed on the UNIVAC 1108 computer were the SCERTS* runs and the registration of S192 and ERTS-1 data.

*SCERTS is a computer program designed to draw gray maps and histograms of multispectral data in either LARSYS I or II format.

2.0 DATA DESCRIPTIONS

The data under consideration included:

(1) Skylab S192 data acquired during the EREP pass 6 on June 8, 1973 over Holt County, Nebraska (see SCERTS results figure 1 and 2); and

(2) ERTS-1 data acquired on May 31, 1973 over the same area as above (see SCERTS results figures 3 and 4). The data analyzed were all in the LARSYS II format.

There were 14 bands with S192 and 4 bands with ERTS-1. The equivalence of S192 to ERTS-1 bands was obtained by inspection of respective spectral coverages (see figure 5)*. Table I summaries this result.

TABLE I.– EQUIVALENCE BETWEEN S192 AND ERTS-1 BANDS

ERTS-1 Band	S192 Band
1	3, 4
2	5
3	6
4	7, 8

The equivalence shown in table I is by no means an absolute one. In fact, S192 band 6 corresponded very much with ERTS-1 band 2, so did S192 band 9 with ERTS-1 band 4. Also S192 band 7 partially fell into the spectral range of ERTS-1 band 3. Nevertheless, the result shown in table I is sufficient for the purpose of this study.

*This figure was provided by S. B. Chism.

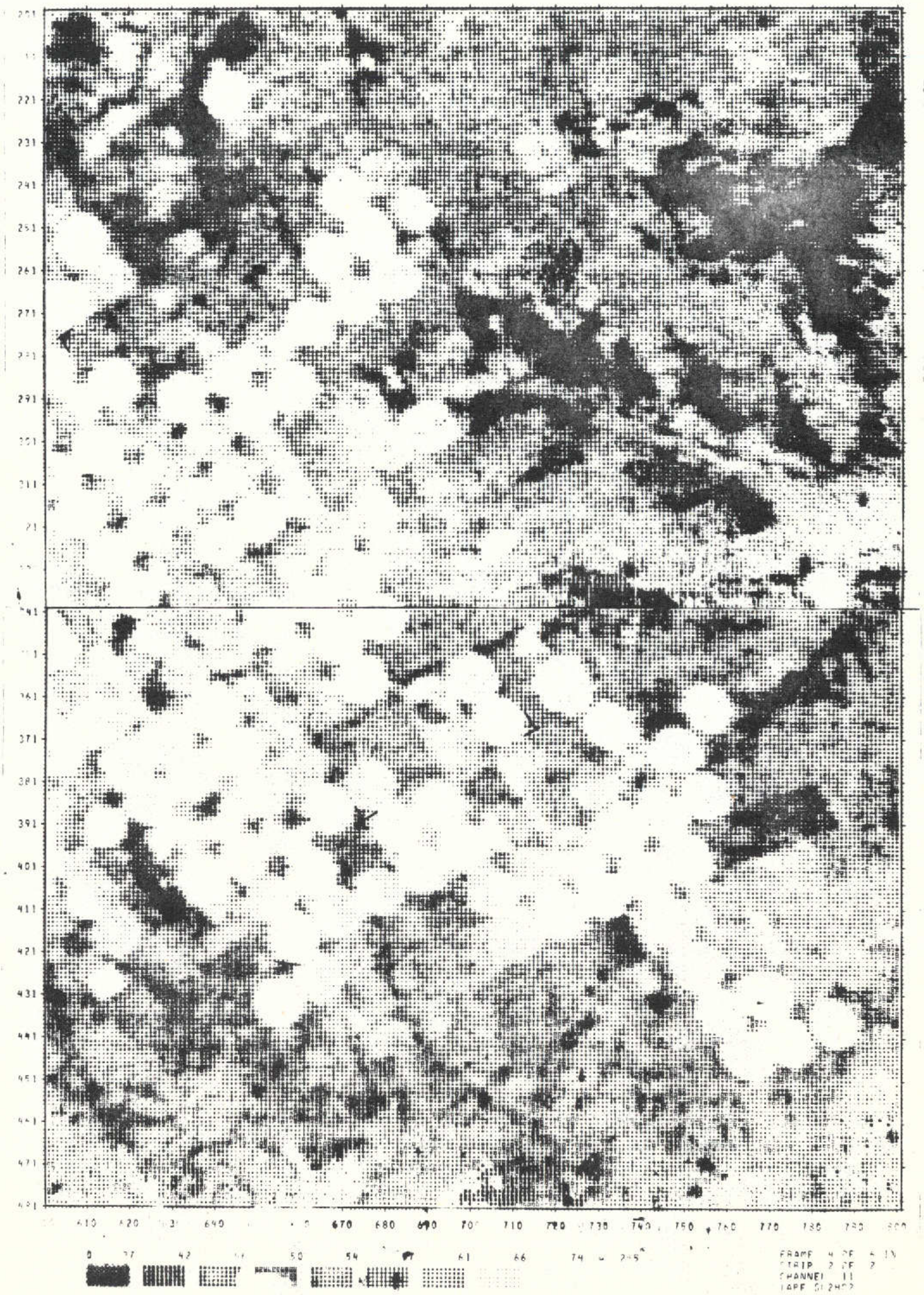


Figure 1. — Holt County, Nebraska agricultural study area
(S192, band 11).

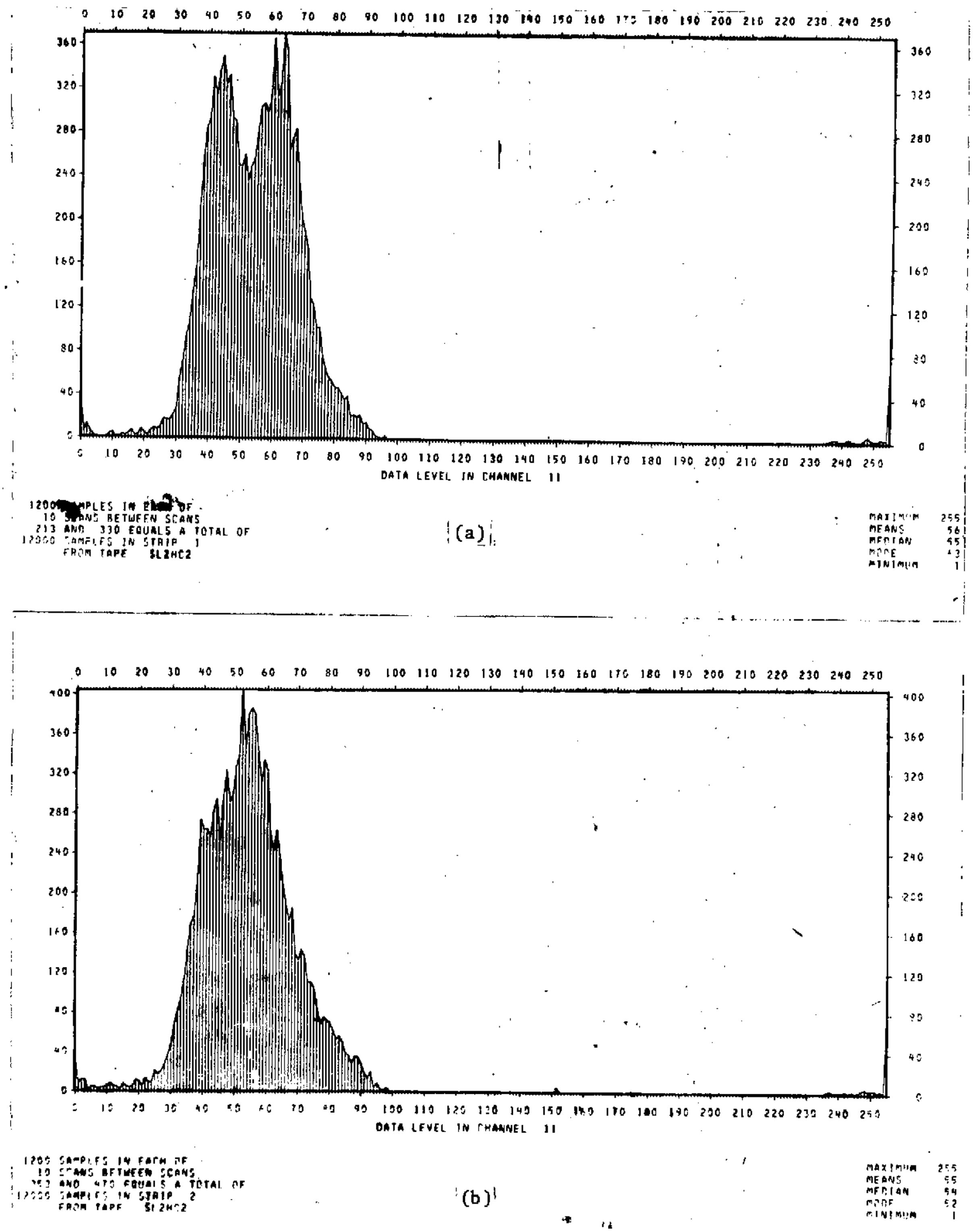


Figure 2. — Histograms for Holt County S192 data.

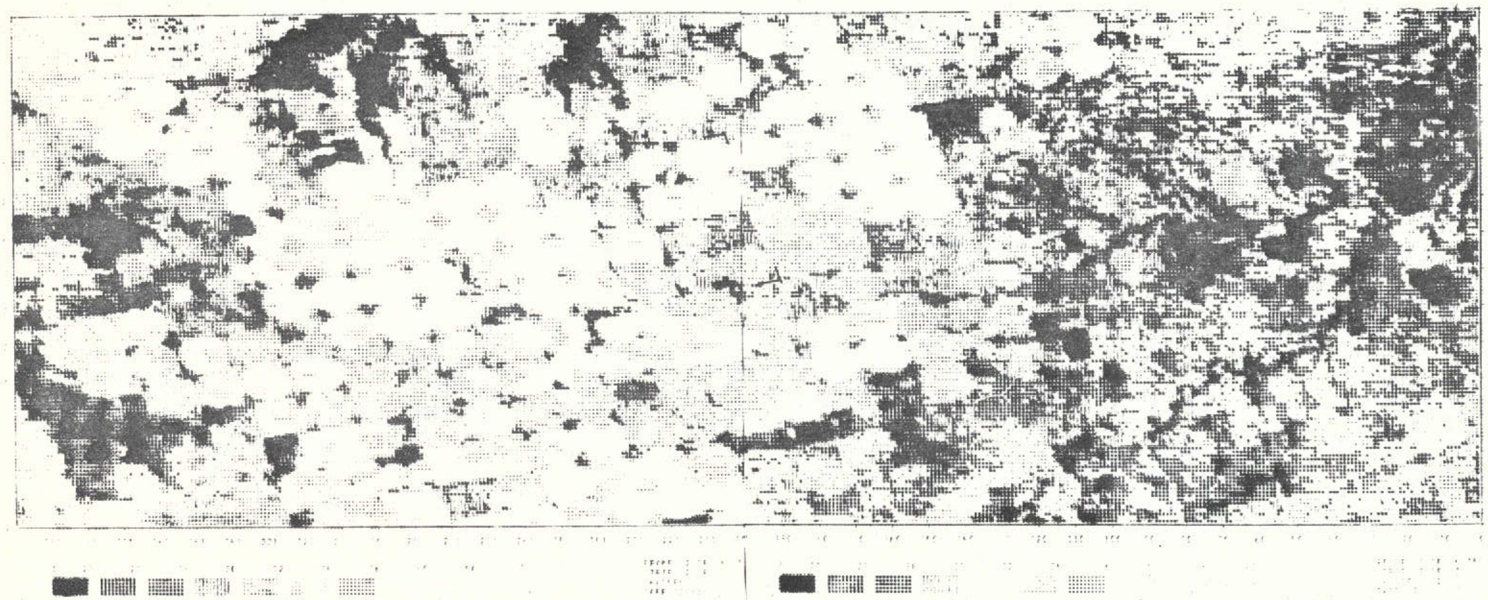


Figure 3. – Holt County, Nebraska agricultural study area
(ERTS-1, band 2).

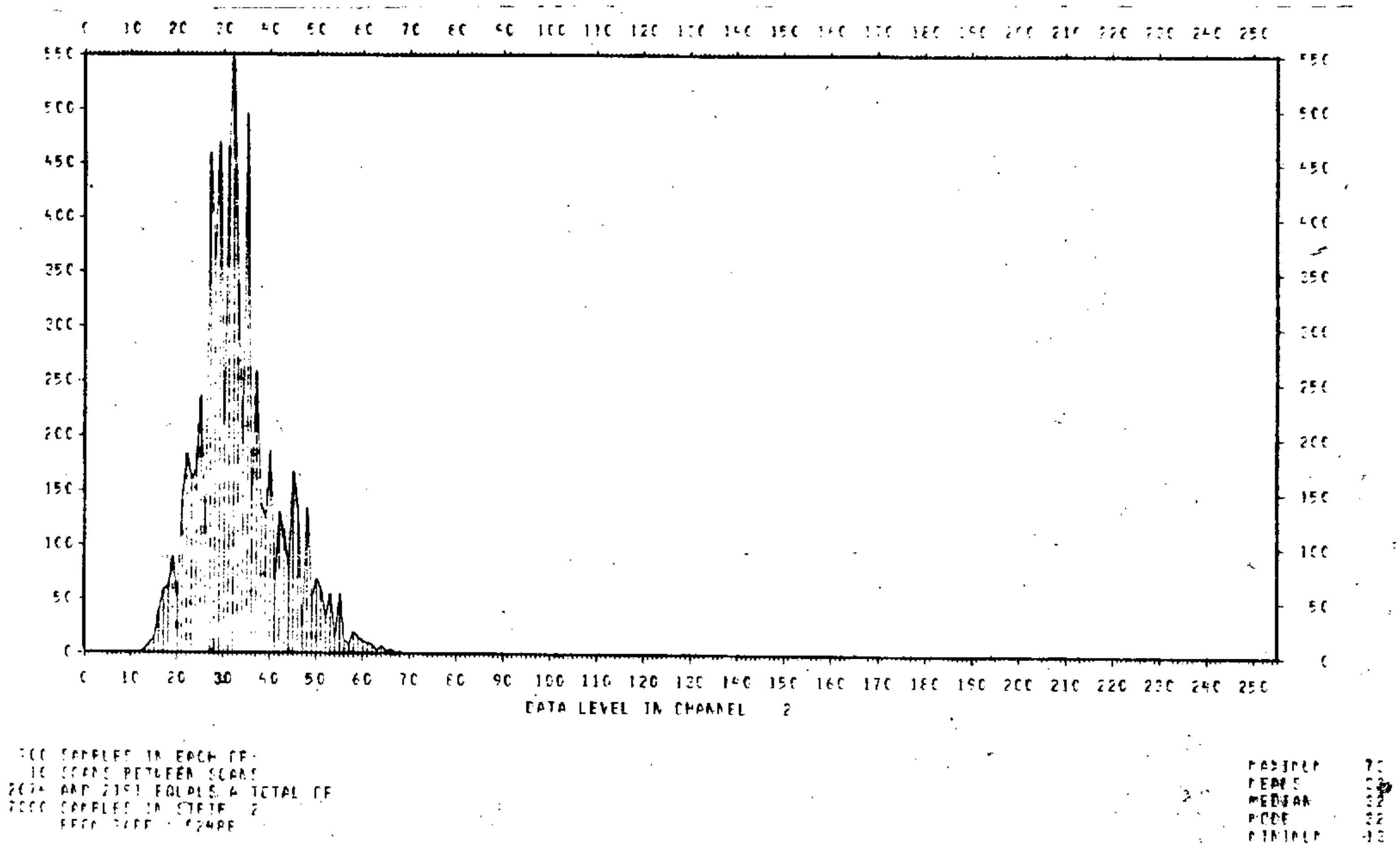


Figure 4. – Histogram for Holt County ERTS-1 data, based on 10 scans (700 samples/scan) between scans 2074 and 2191 of figure 3.

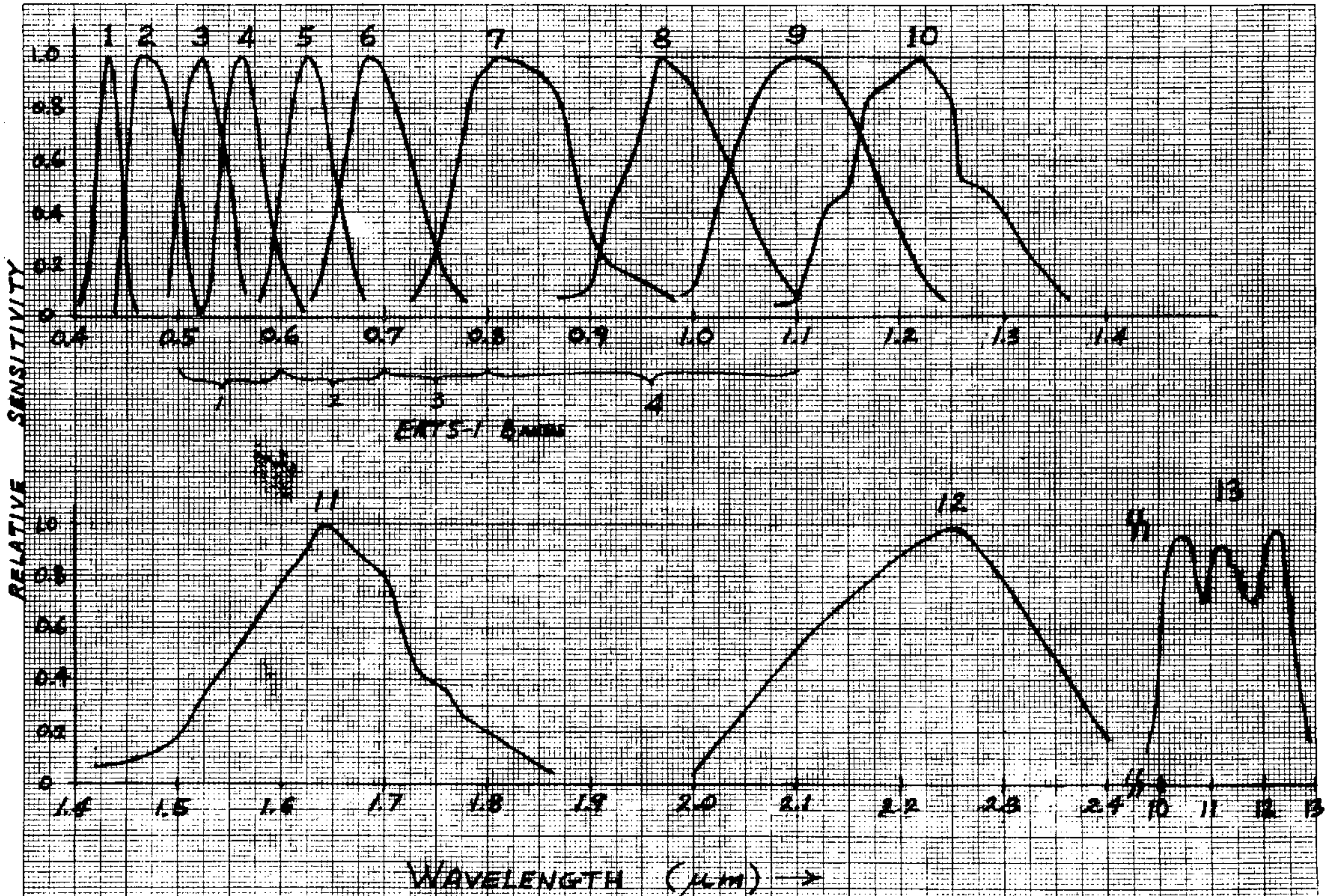


Figure 5. — S192 spectral bands.

Observations of S192 image were made primarily on the ERIPS screen. In general the data appeared to be very noisy. Typical noises as observed are as follows:

(1) Low frequency banding noise

(2) High frequency herringbone

(3) Bit dropping

A breakdown of all 14 bands in terms of their spectral coverage and image quality is tabulated below.

TABLE II.– S192 SPECTRAL COVERAGE AND DATA QUALITY

Band	Coverage (μm)	Quality
1	0.42 - 0.45	very poor, badly striped
2	.45 - .50	good
3	.50 - .55	fair, striped
4	.54 - .59	poor, snowy
5	.60 - .65	poor
6	.66 - .73	poor
7	.77 - .89	fair
8	.93 - 1.04	fair, snowy
9	1.03 - 1.18	fair, striped
10	1.15 - 1.28	poor, badly striped
11	1.56 - 1.73	the best of all
12	2.10 - 2.35	good, striped
[a]13	10.01 - 12.63	very poor
[a]14	10.01 - 12.63	very poor

It should be noted that the S192 multispectral scanner was designed to scan the object plane with conical lines

[a]Bands 13 and 14 are of the same spectral coverage but with different sampling rates.

instead of the conventional straight line scan. Obviously, image distortions in some areas, especially those toward both sides of the flight lines, are expected. In this study only the original uncorrected S192 data were available for analysis. Although it would have been preferable to have the conical scan lines straightened. Nevertheless, since the area of interest (Holt County, Nebraska) was located near the central portion of the flight lines, the effect of conical lines upon classification results would be insignificant.

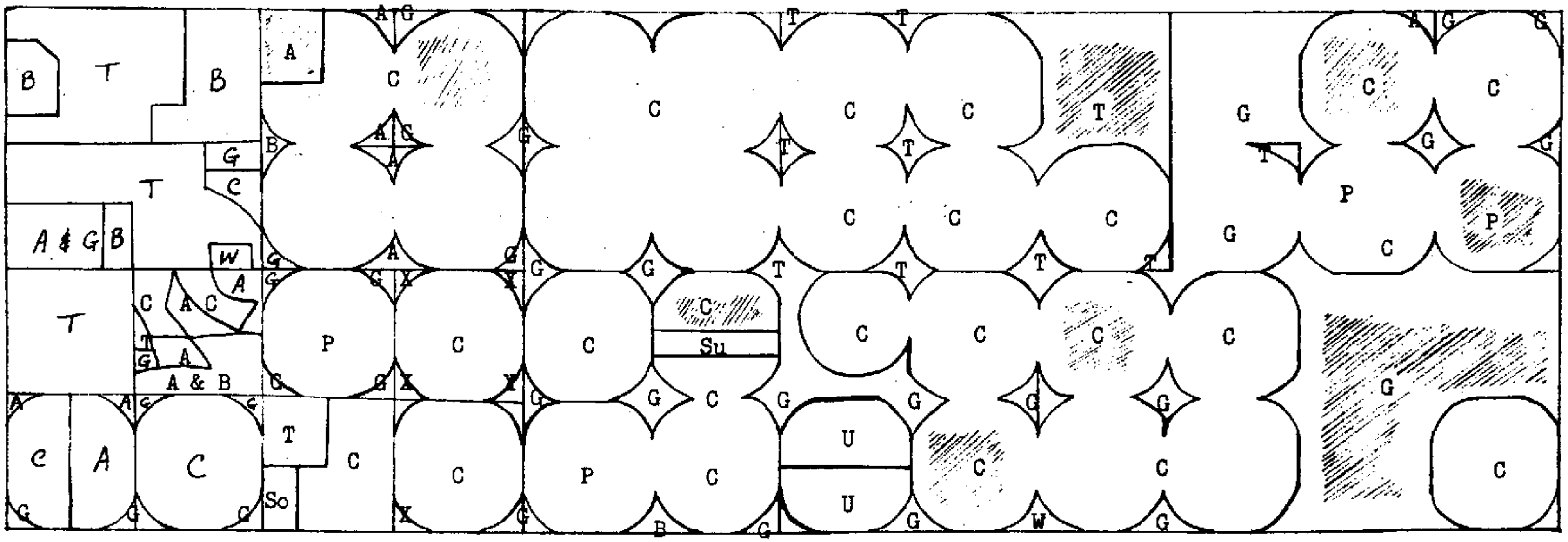
3.0 GROUND TRUTH AND HISTOGRAMS

The Holt County agricultural study area was characterized with many circular corn and popcorn fields. Its ground truth information is shown in figure 6*.

Although there were more than ten different classes in the study area, most of them had too small sample sizes to be trained and classified. As a result, only the following five classes were considered for classification: corn, popcorn, pasture, grass and alfalfa. Training field selections were made for these five classes with their approximate locations shown in figure 6. For illustrational purposes, the respective histograms for each class corresponding to S192 channel 11 and ERTS-1 channel 2 (channel 16 in the registered data format) are shown in figures 7 and 8. The histograms for both S192 and ERTS-1 data were derived from the registered tape. They were based on the same training fields within the accuracy of registration. In general, the radiance levels of S192 histograms appeared to be higher than those of ERTS-1. In the cases of grass and pasture, the variation in S192 histograms seemed larger than that of ERTS-1. There was, however, one thing in common: all the histograms were multimodal. Especially true were those for corn, popcorn and alfalfa which hardly behaved as Gaussian distribution.

---

*The Holt County ground truth information was provided by L. M. Flores.



C: Corn
P: Popcorn
T: Pasture
G: Grass
A: Alfalfa
X: Xmas Tree

B: Brome
Su: Sudan
So: Grain Sorghum
W: Weed
U: Unknown

Shaded Areas: Approx. Areas of Selected Training Fields

Figure 6. — Ground truth information for Holt County, Nebraska agricultural study area (June 1973).

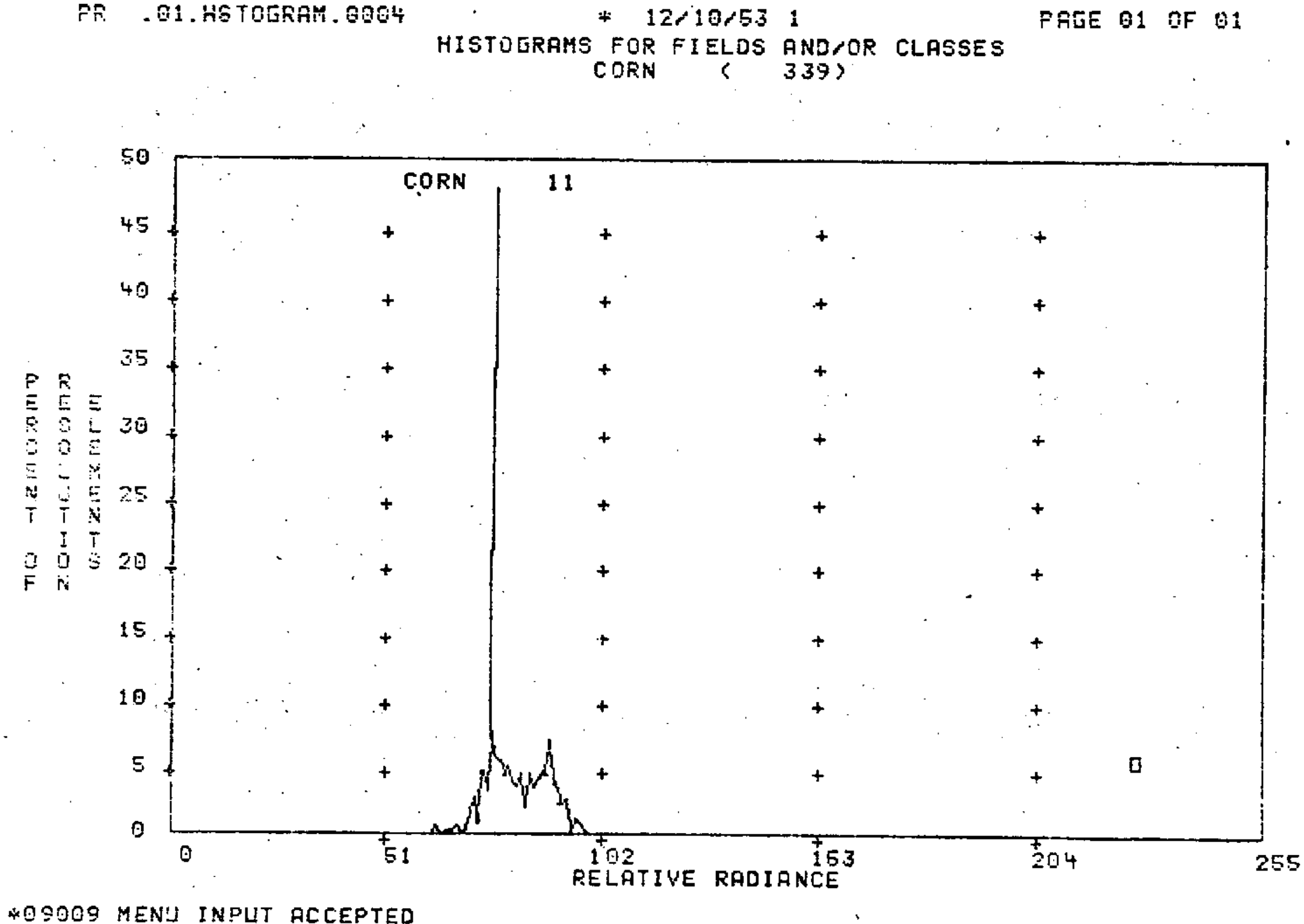
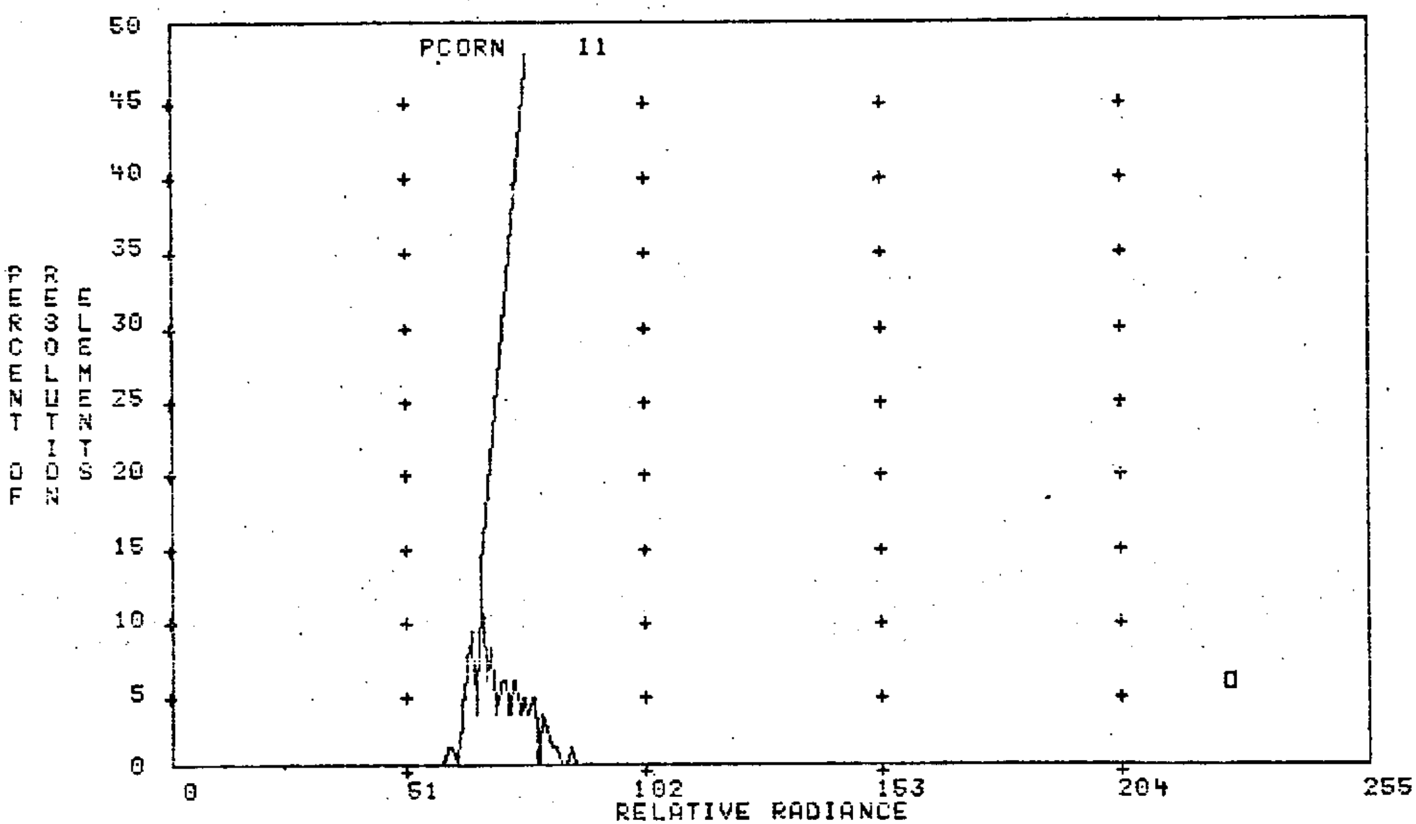

PR .01.HSTOGRAM.0004
* 12/10/53 1
PAGE 01 OF 01
HISTOGRAMS FOR FIELDS AND/OR CLASSES
CORN (339)
CORN 11
50
45
40
35
30
25
20
15
10
5
0
0
51
102
153
204
255
RELATIVE RADIANCE
*09009 MENU INPUT ACCEPTED

Figure 7(a)

PR .01.HSTOGRAM.0010 * 14/13/09 1 PAGE 01 OF 01

HISTOGRAMS FOR FIELDS AND/OR CLASSES

PCORN (68)



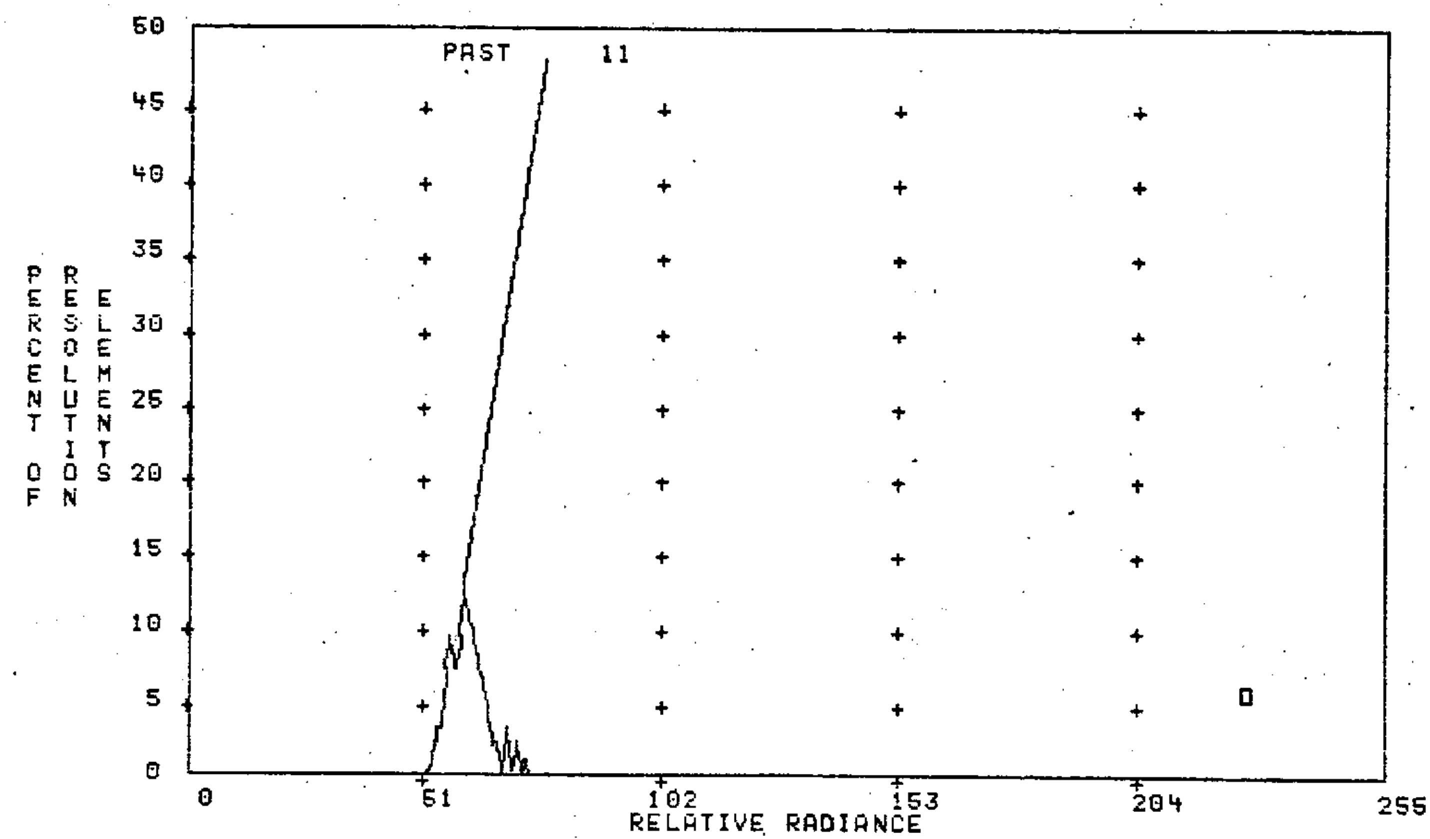
*09009 MENU INPUT ACCEPTED

Figure 7(b)

FR .01.HSTOGRAM.0012 * 14/17/27 1 PAGE 01 OF 01

HISTOGRAMS FOR FIELDS AND/OR CLASSES

PAST (97)



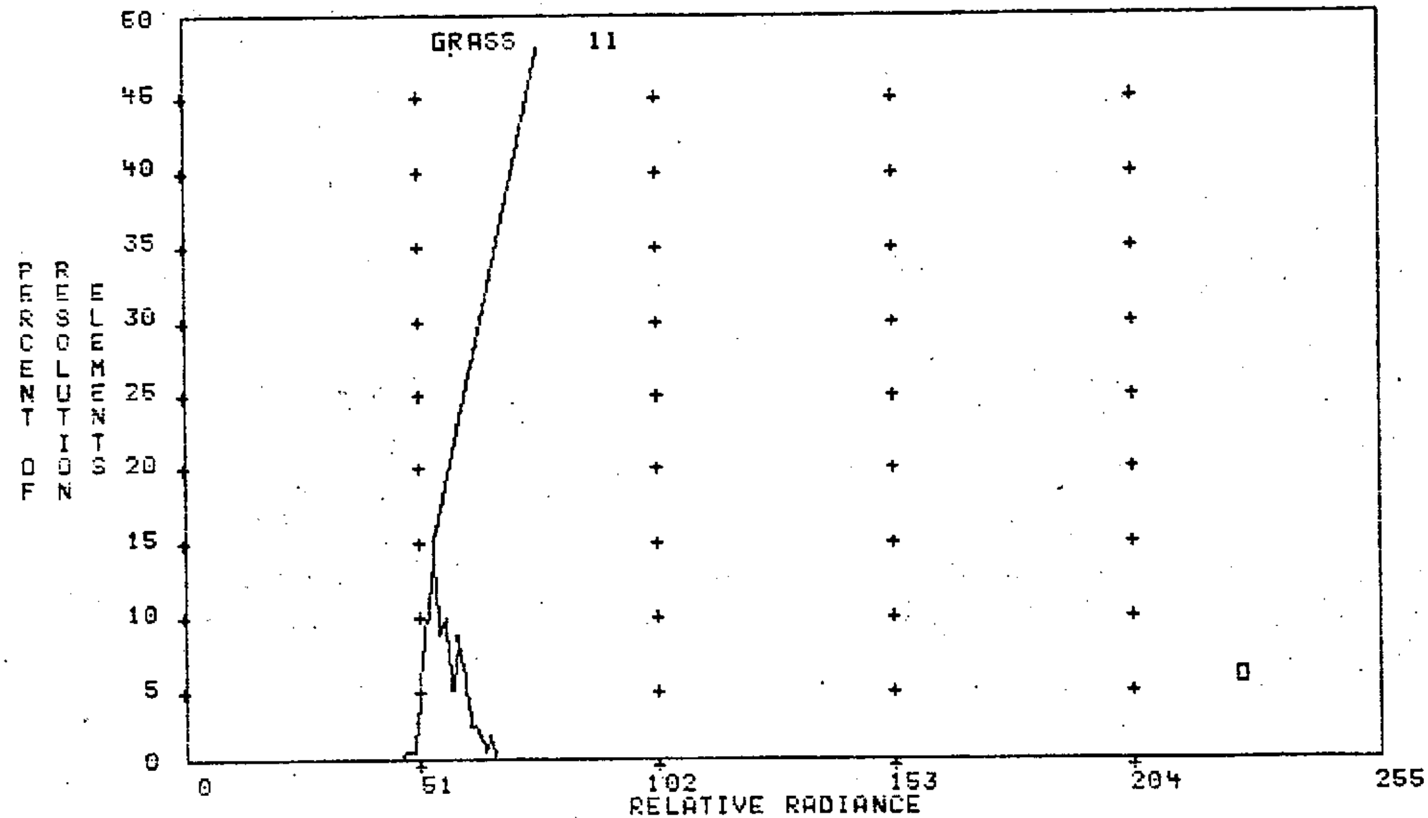
*09009 MENU INPUT ACCEPTED

Figure 7(c)

PR .01.HSTOGRAM.0013 * 14/18/14 1 PAGE 01 OF 01

HISTOGRAMS FOR FIELDS AND/OR CLASSES

GRASS (189)



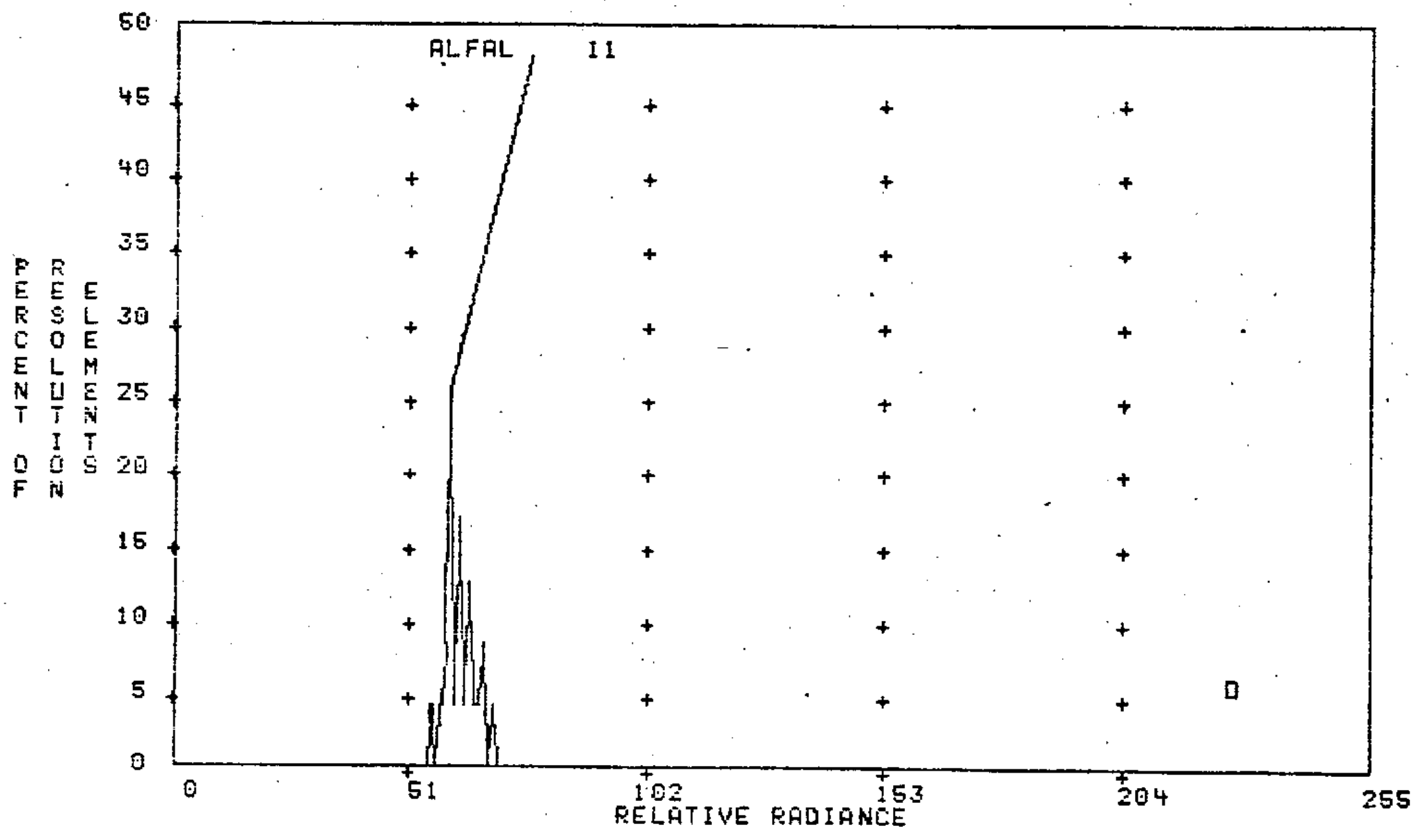
*09010 MESSAGES ARE STACKED FOR APPLICATIONS PR -09

Figure 7(d)

PR .01.HSTOGRAM.0014 * 14/18/49 1 PAGE 01 OF 01

HISTOGRAMS FOR FIELDS AND/OR CLASSES

ALFAL (24)



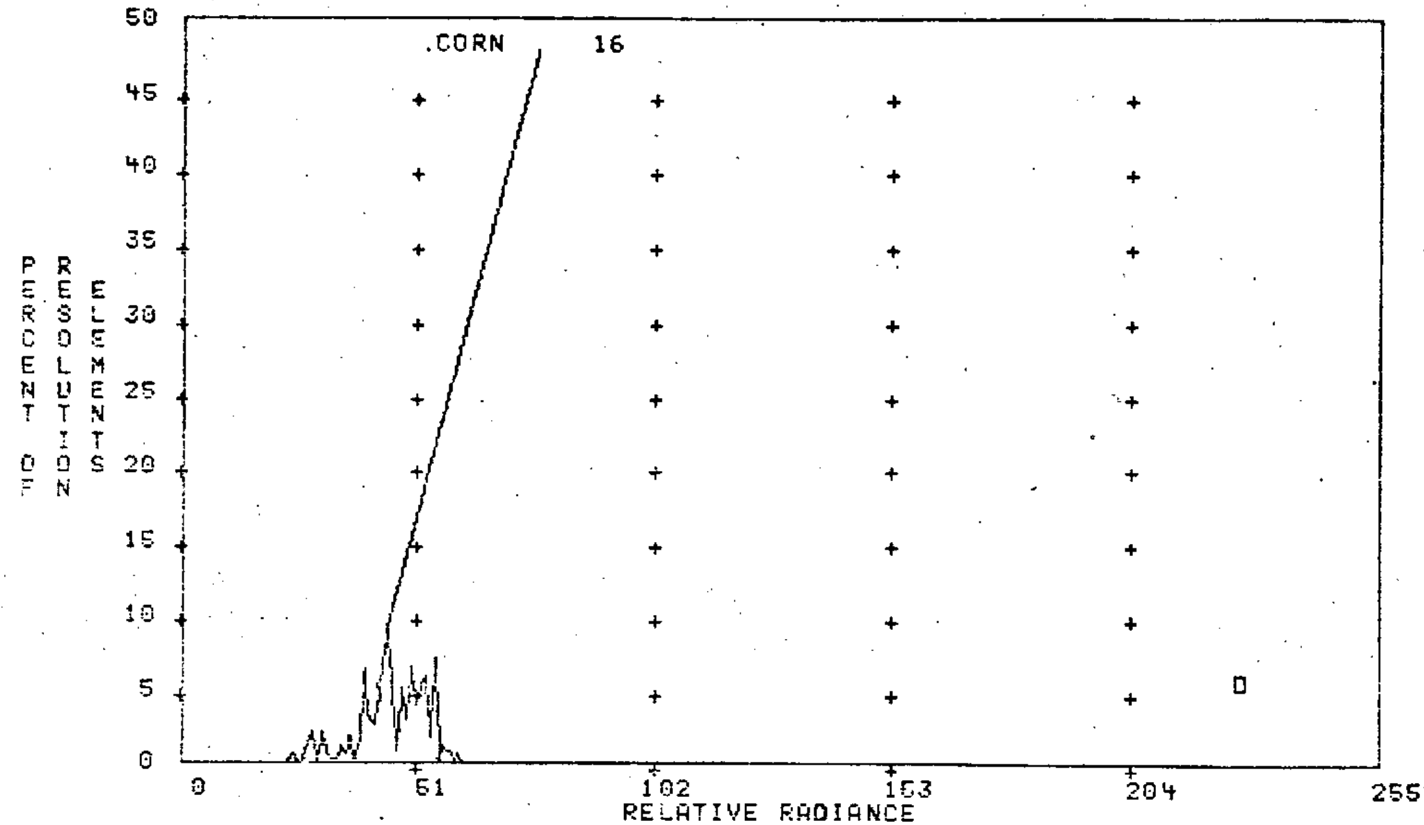
*09010 MESSAGES ARE STACKED FOR APPLICATIONS PR -10

Figure 7(e)

PR .01.HSTOGRAM.0006 * 12/13/23 1 PAGE 01 OF 01

HISTOGRAMS FOR FIELDS AND/OR CLASSES

CORN (339)



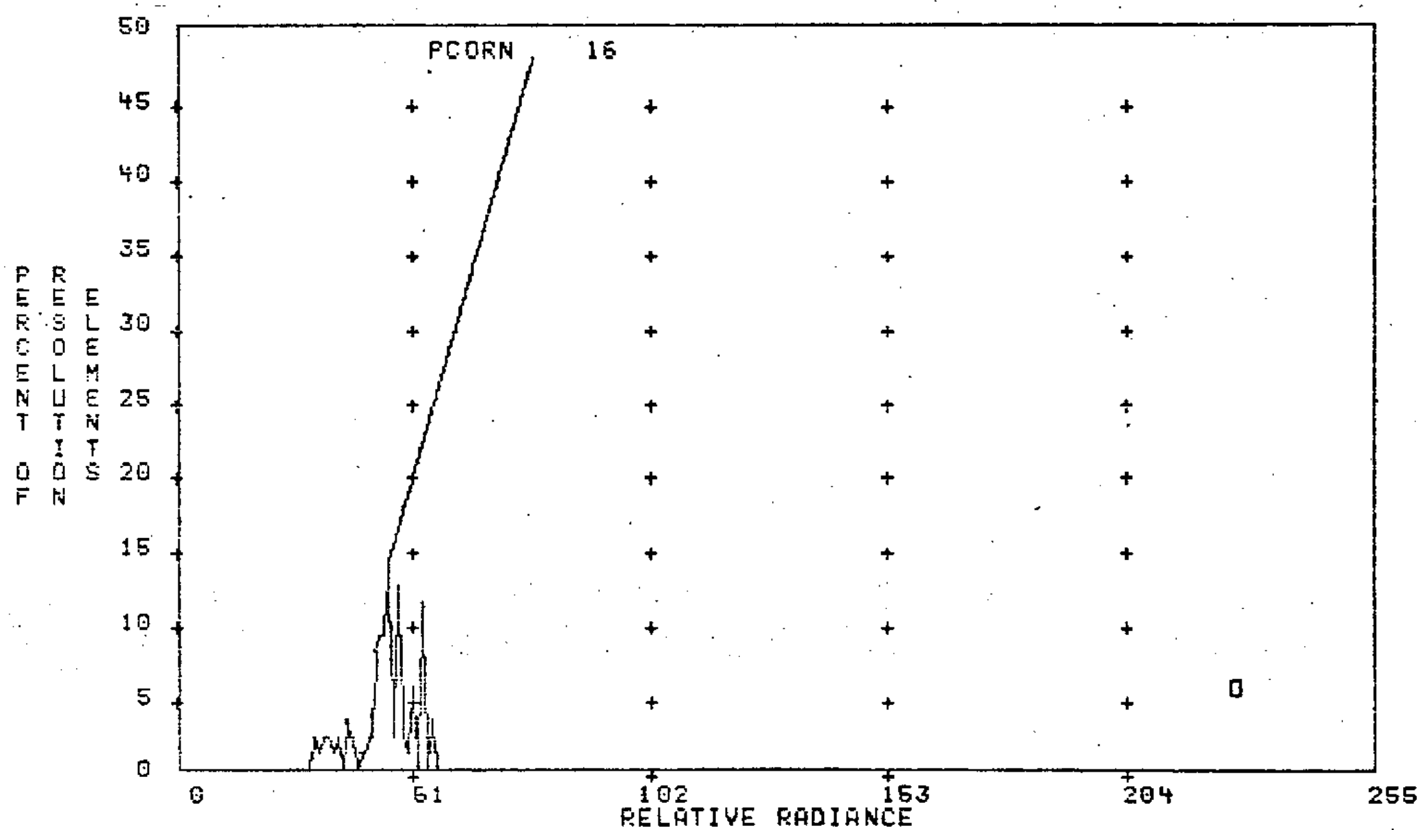
*09009 MENU INPUT ACCEPTED

Figure 8(a)

PR .01.HSTOGRAM.0021 * 14/34/34 1 PAGE 01 OF 01

HISTOGRAMS FOR FIELDS AND/OR CLASSES

PCORN (88)



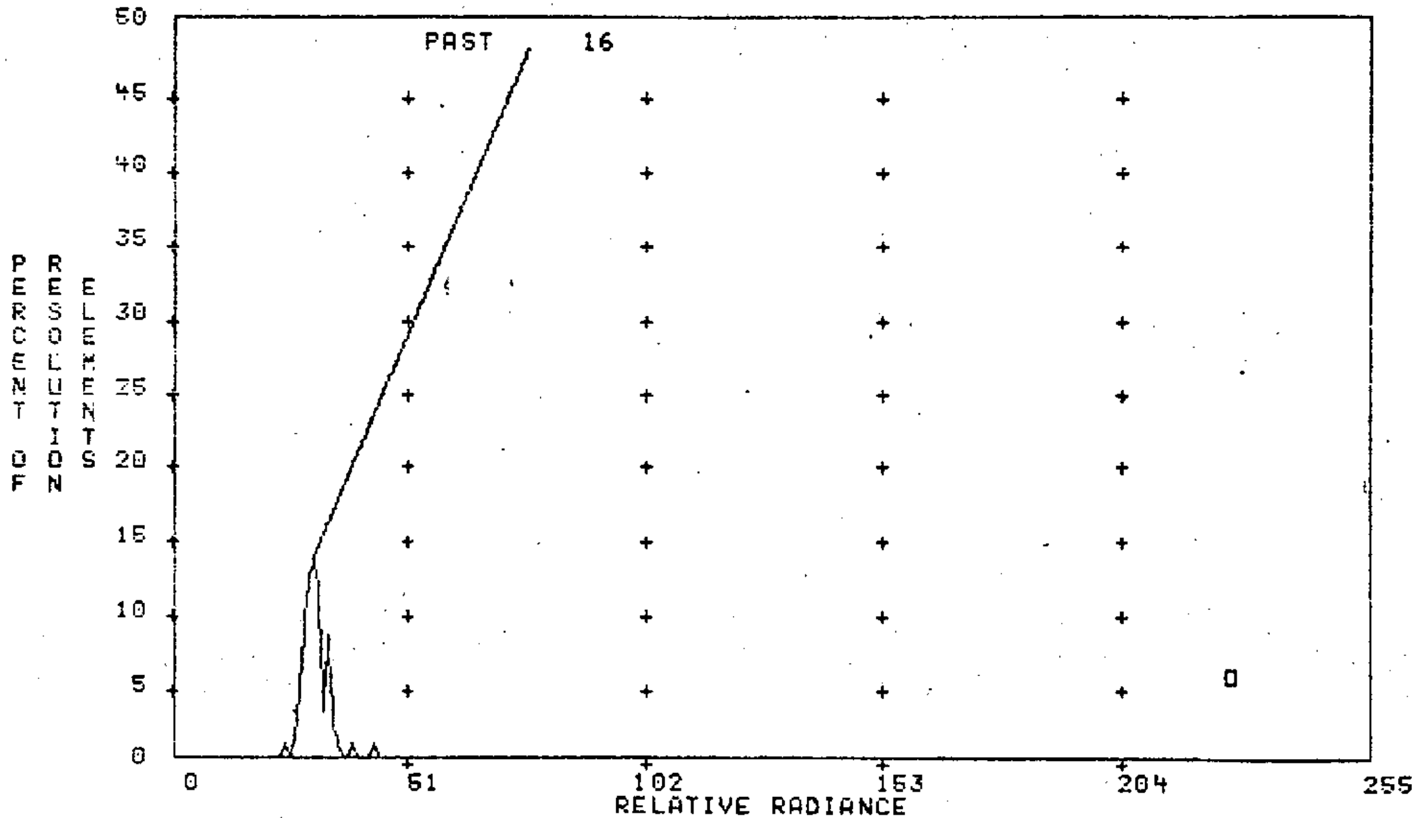
*09009 MENU INPUT ACCEPTED

Figure 8(b)

PR .01.HSTOGRAM.0023 * 14/36/40 1 PAGE 01 OF 01

HISTOGRAMS FOR FIELDS AND/OR CLASSES

PAST (97)



*09009 MENU INPUT ACCEPTED

Figure 8(c)

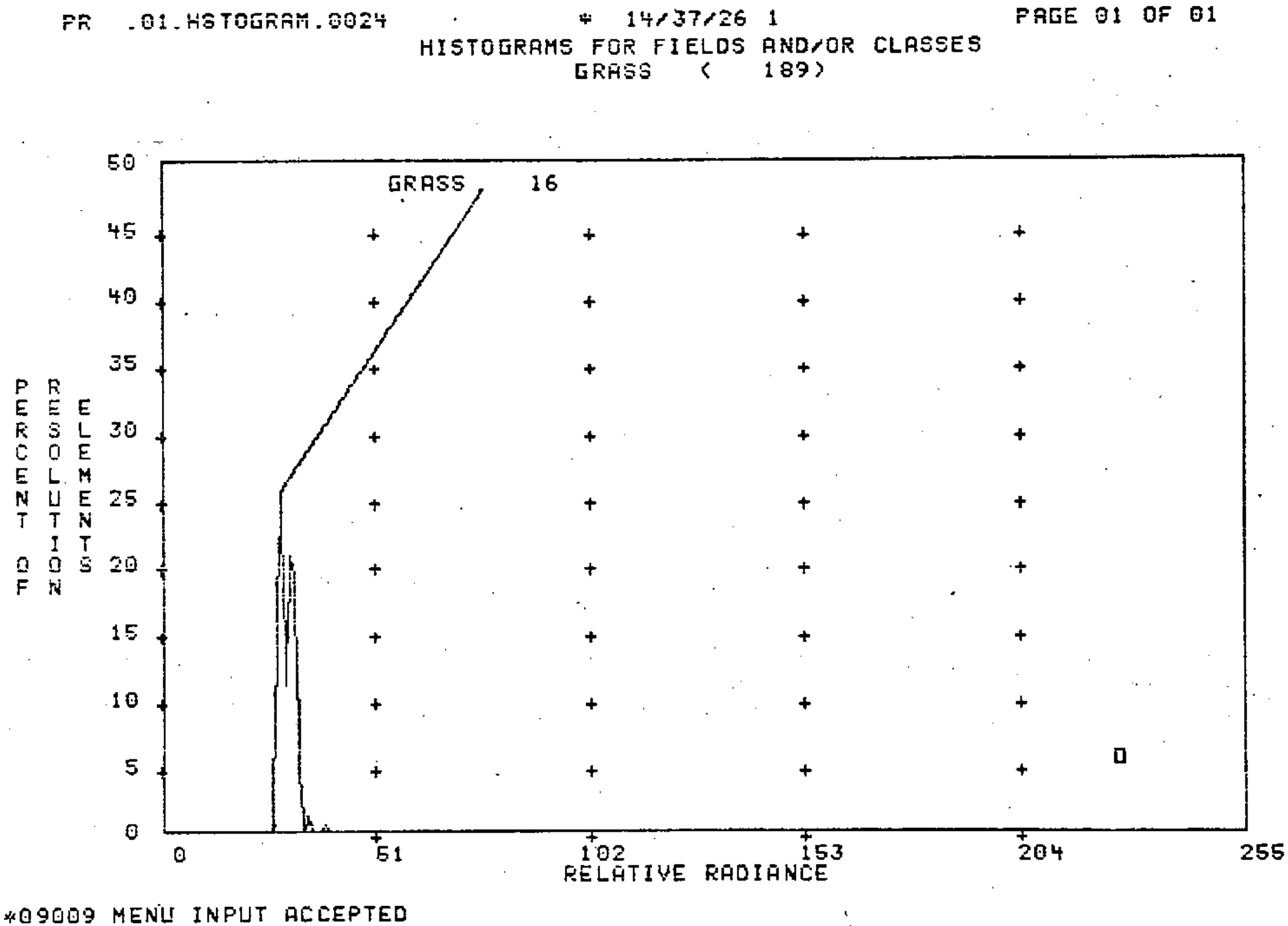

PR .01.HSTOGRAM.0024 * 14/37/26 1 PAGE 01 OF 01
HISTOGRAMS FOR FIELDS AND/OR CLASSES
GRASS (189)
GRASS , 16
PERCENT OF RESOLUTION ELEMENTS
50
45
40
35
30
25
20
15
10
5
0
0
51
102
153
204
255
RELATIVE RADIANCE
D
*09009 MENU INPUT ACCEPTED

Figure 8(d)

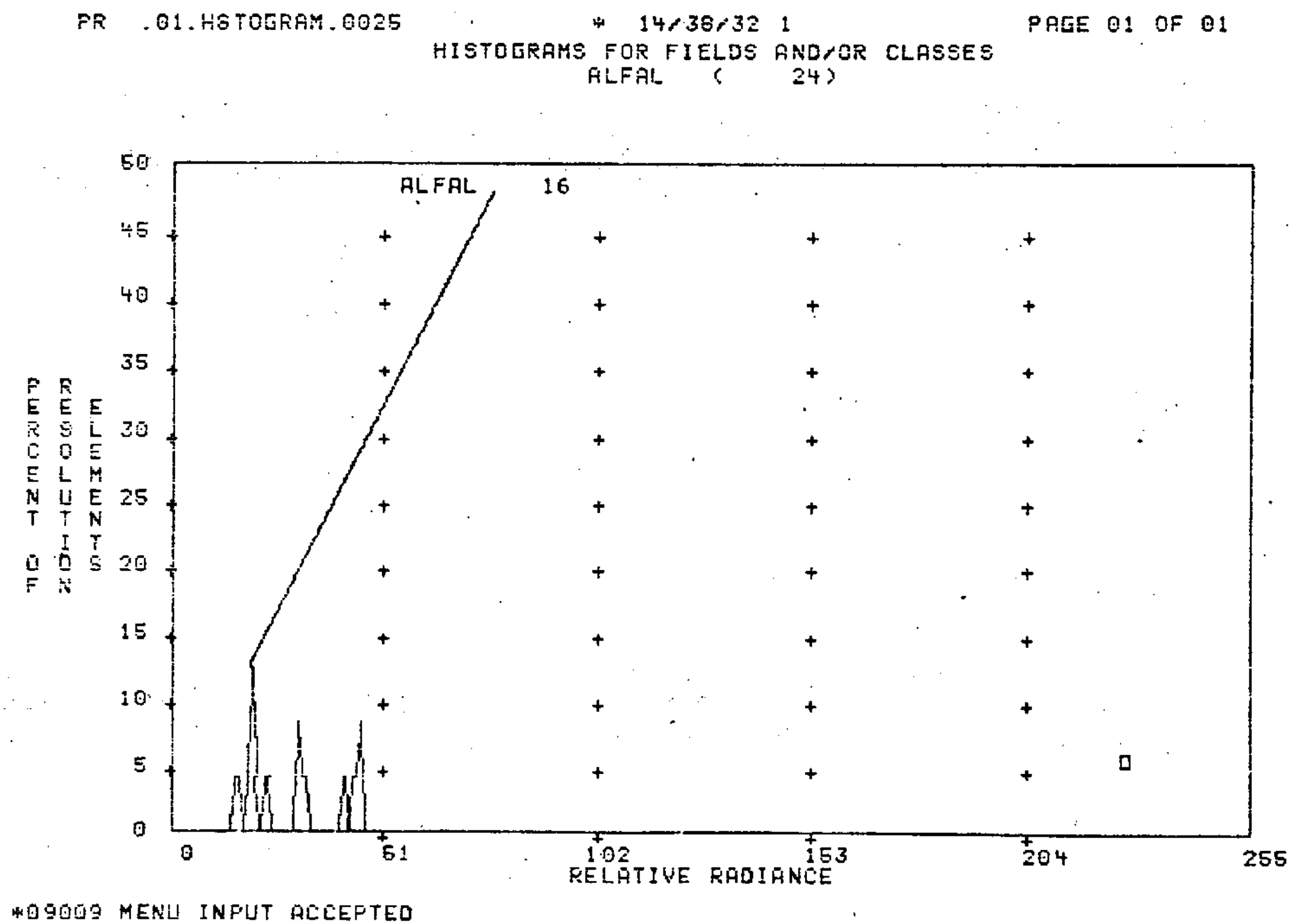

PR .01.HSTOGRAM.0025 * 14/38/32 1 PAGE 01 OF 01
HISTOGRAMS FOR FIELDS AND/OR CLASSES
ALFAL (24)
ALFAL 16
PERCENT OF RESOLUTION ELEMENTS
50
45
40
35
30
25
20
15
10
5
0
0
51
102
153
204
255
RELATIVE RADIANCE
*09009 MENU INPUT ACCEPTED

Figure 8(e)

4.0 DIVERGENCE RESULTS

4.1 Divergence Results on S192 and ERTS-1 Data — Unregistered Cases

In the cases when the S192 and ERTS-1 data were not registered, similar training fileds were selected in order to achieve valid comparisons. Figure 6 served as a basis for such training fields selection. The divergence results showing the computed best subsets of various band sizes are given in tables III - VII.

TABLE III.— BEST SUBSETS OF ONE BAND (S192)

(1)	11
(2)	12
(3)	9
(4)	2
(5)	14
(6)	13
(7)	10
(8)	7
(9)	3
(10)	8
(11)	6
(12)	5
(13)	1
(14)	4

TABLE IV.– BEST SUBSETS OF TWO BANDS (S192)

(1)	12	14
(2)	12	13
(3)	11	14
(4)	11	13
(5)	9	12
(6)	9	11
(7)	7	11
(8)	10	12
(9)	6	12
(10)	7	12

TABLE V.– BEST BAND SUBSET OF S192

Number of Bands	Best Subset					
1	11					
2	12	14				
3	9	12	14			
4	9	11	12	14		
5	1	9	11	12	14	
6	1	4	7	11	12	13

TABLE VI.– BEST SUBSETS OF FOUR BANDS OUT OF BANDS 3,4,5,6,7,8 (S192)

(1)	3	5	6	7
(2)	3	4	6	7
(3)	4	6	7	8
(4)	3	6	7	8
(5)	3	5	7	8

TABLE VII.—BEST BAND SUBSET OF ERTS-1

Number of Bands	Best Subset
1	2
2	2 4
3	2 3 4

When bands 13 and 14 were excluded from consideration, the best subset of four bands was found to be 1, 9, 11, 12.

A number of interesting observations can be made from the preceding tables. Namely,

(1) There is a strong indication that a thermal band (band 13 or 14 of S192), even though extremely noisy, is one of the most important bands as far as the divergence measure is concerned. Almost all of the best subsets of various band sizes contain one of the thermal bands (see table V).

(2) The above observation also applies to the near IR bands 11 and 12 of S192.

(3) The ranking of single bands as shown in table III favorably agrees with the observed image quality on S192 data. In particular, the first four best single bands 11, 12, 9, 2 do exhibit good images relatively free from banding noise. It is interesting to note that bands 3 through 8 which are equivalent to the ERTS-1 bands are ranked the lowest in table III.

(4) Of direct relevance to the Earth Observation Satellite (EOS) spectral bands requirement*, it is found that the correlation between the two best bands 11 and 12 (corresponding to EOS bands 5 and 6) is also evidenced from table IV. That is, the subset (11, 12) is not found in the upper ten pairs of S192 bands in table IV because the high correlation between these two bands considerably offsets any additional separability that might be gained through the combination of the two bands. However, when the number of bands increases to four and beyond, bands 11 and 12 are invariably included in the best subsets as can be seen in table V.

4.2 Divergence Results on Registered Data

Again, as mentioned earlier, training fields for registered data (see appendix A for the corresponding field definitions) were selected in accordance with figure 6. Divergence results based on the merged 18 spectral bands thus provided a direct comparison between the S192 and ERTS-1 bands. Tables VIII through X and figures 9 through 11 summarize these divergence results. Note that in the registered data format, bands 1 through 14 corresponded to the S192's 14 bands, and bands 15 through 18 corresponded to the original four ERTS-1 band. For possible future

---

*Utility of Proposed Earth Observations Satellite Spectral Bands, Based on Analysis of EREP S192 Data. LEC Technical Memorandum, November 1973, by J. F. Paris.

reference as to how the S192 and ERTS-1 data were registered, appendix B documents the control points used and other pertinent information for the registration.

TABLE VIII.– SINGLE BANDS RANKING

15
17
18
16
11
12
14
13
9
10
2
3
8
7
5
6
1
4

TABLE IX.– BEST SUBSET OF REGISTERED DATA

Number of Bands	Best Subset
1	15
2	16 17
3	11 14 17
4	9 11 14 17

TABLE X.– BEST SUBSET OF FOUR BANDS

Available Bands	Best Subset			
1-18	9	11	14	17
3-8	3	5	7	8
3-8 and 15-18	3	15	16	18
3, 6-8 and 11-13	7	11	12	13

It is interesting to note that the single band ranking as shown in table VIII clearly indicates the superiority in terms of the divergence measure of ERTS-1 bands over S192 bands. That is, if only one band is to be used for classification of the Holt County agricultural area, ERTS-1 bands would have more discriminatory power than S192 bands.

However, when the best subset of four bands was selected from the total 18 bands, the result as shown in table IX (i.e., 9, 11, 14, 17) contained only one ERTS-1 band. On the other hand, table X reveals that if the available bands included only four ERTS-1 bands, and six S192 bands which were equivalent to ERTS-1 bands, then the majority of the best subset (3, 15, 16, 18) was from ERTS-1 bands.

There is a slight discrepancy in the ranking of S192 bands between tables III and VIII. It is surmised that this is primarily due to the minor differences in the training fields selected between the original and registered data.

Figures 9 through 11 exhibit rather interesting comparisons in pairwise divergence among various band subsets. Only those pairwise divergences below the maximum

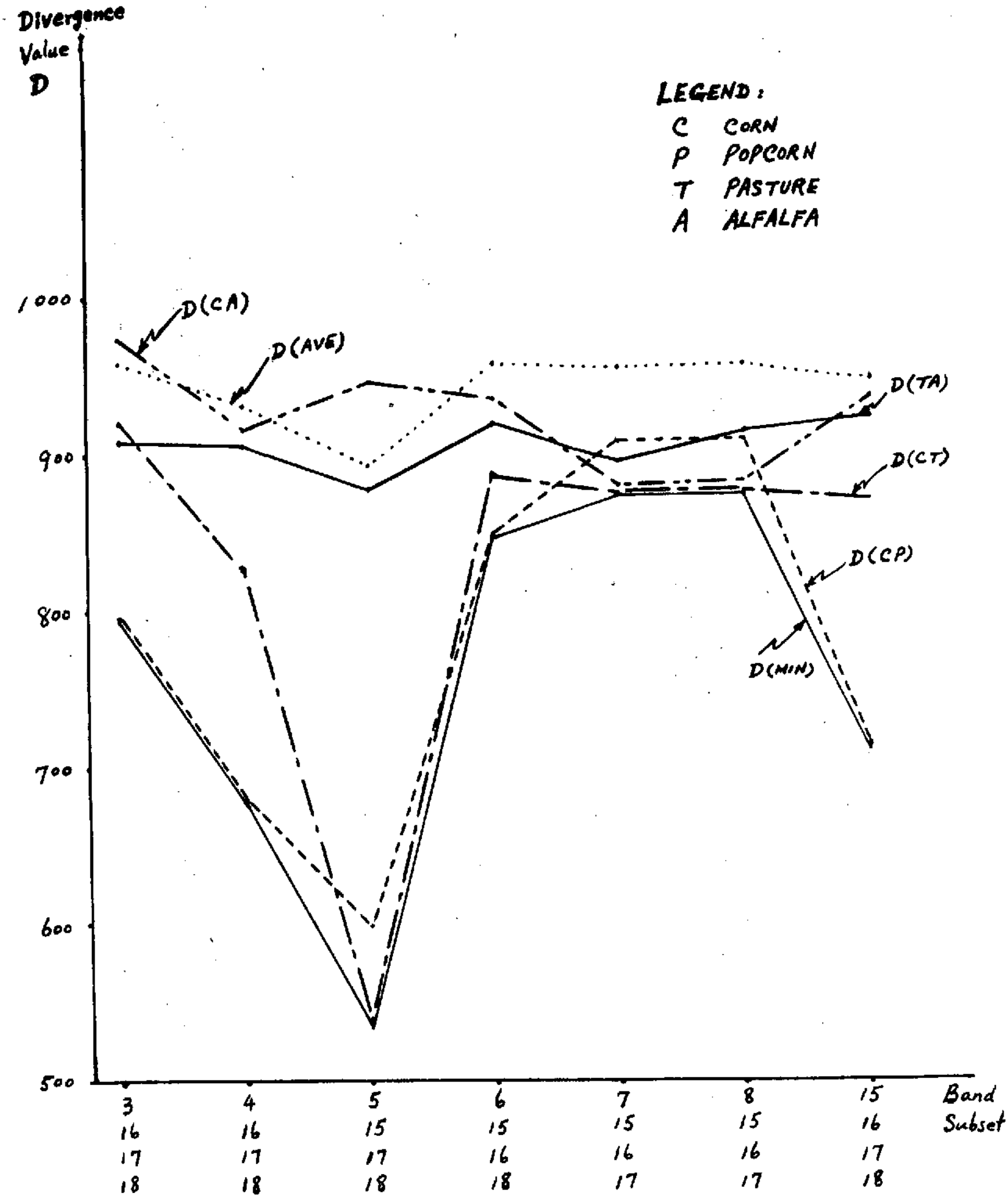


Figure 9. – Divergence study (I).

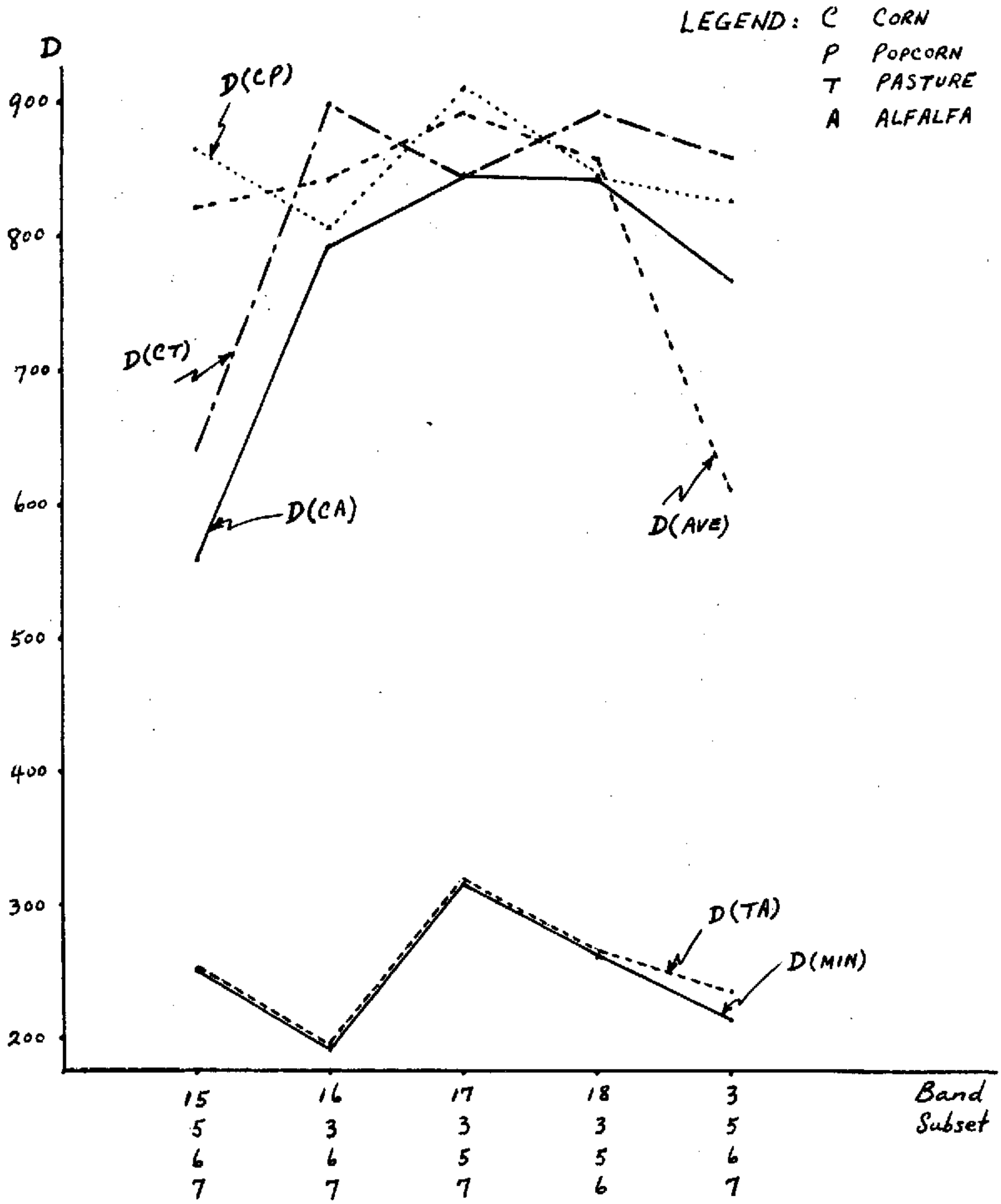


Figure 10. – Divergence study (II).

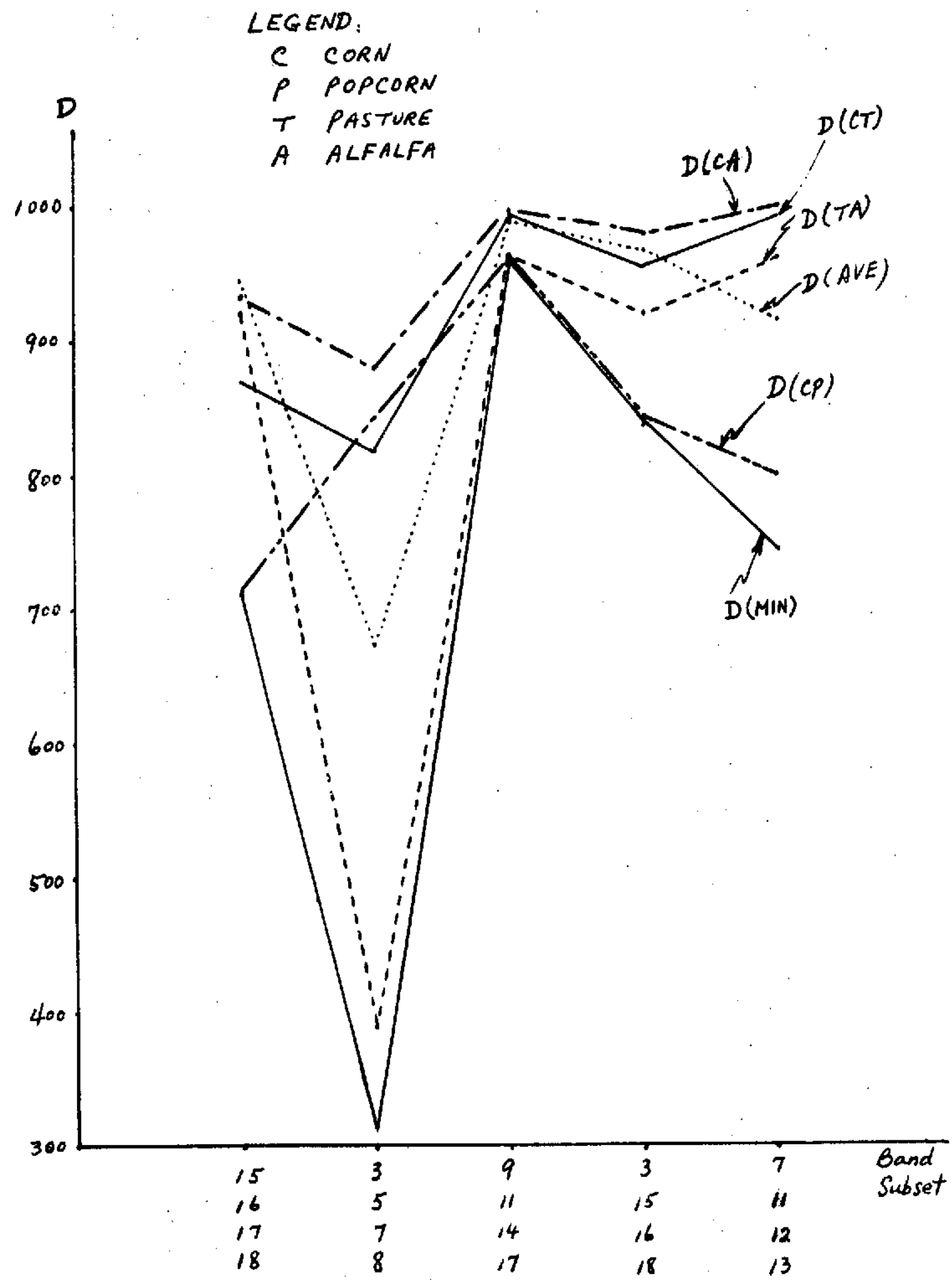


Figure 11. — Divergence study (III).

value of 999 were chosen for illustrations. Figure 9 presents the cases where one of the ERTS-1 bands was replaced by the corresponding S192 band. With ERTS-1 bands 15, 16, 17, 18 as a reference, one readily finds that a substitution of S192 band 5 resulted in the most adverse effect. It seems to indicate the inability of band 5 to differentiate corn from popcorn or pasture. Substitutions of bands 3, 6, 7 or 8 generally yielded favorable results.

In figure 10, one of four S192 bands 3, 5, 6, 7 was replaced by the corresponding ERTS-1 band. It is observed that any substitution of ERTS-1 bands for the corresponding S192 bands generally gave rise to some increases in divergence values. There is one exception, however. When band 3 was replaced by band 15 in the subset (15, 5, 6, 7), sharp decreases in divergences between corn and pasture or alfalfa were observed. Thus it seems reasonable to assert that band 3 was relatively effective in differentiating the aforementioned categories. Note that all subsets shown in figure 10 demonstrate the difficulty to separate pasture and alfalfa.

Figure 11 displays pairwise divergences for various best subsets. Recall that (3, 5, 7, 8) is the best subset from six S192 bands which are equivalent to ERTS-1 bands. A comparison in divergence between this best subset and the ERTS-1 bands again vividly shows the superiority of ERTS-1 bands over the corresponding S192 bands. The most impressive result seems to be the divergences for the best subset (9, 11, 14, 17): its large divergence values and the tightness among all pairwise divergence simply surpass all other band combinations. Since the majority constituents come from S192 bands, the usefulness of S192 data can thus be asserted.

As a final remark, the large pairwise divergences between grass and any other class imply that the differentiation of grass from other classes would be a relatively easy one.

5.0 CLASSIFICATION RESULTS

5.1 Classification Results Using S192 and ERTS-1 Data — Unregistered Cases

Those previously mentioned five classes were trained and classified on S192 and ERTS-1 data separately. In the course of analysis, however, it was found that the misclassification between corn and popcorn was rather high in some S192 and ERTS-1 cases. Consequently corn and popcorn were merged into one class, and the classification accuracies were recalculated. Results for 5-class and 4-class cases are presented in table XI.

Several conclusions can be drawn from the results of table XI:

(1) In general, the classification accuracies increased as the number of bands increased. One exception was for the best subset of six bands in the 4-class case in which the overall classification accuracy declined slightly to 92.7 percent from an all-time high of 93.1 percent for the corresponding five bands' result.

(2) After corn and popcorn were merged, the modified results generally indicated some improvements over those of 5-class cases. The most striking improvement was found in the ERTS-1 results where an increase of 28.3 percent in the overall classification accuracy was made by merging corn and popcorn. This clearly indicates the inability of ERTS-1 data to differentiate corn from popcorn in the early summer of the year (See footnote on page 5-9.)

TABLE XI.– CLASSIFICATION ACCURACIES – UNREGISTERED CASE

	Number of Bands	Best Subset	Classification Accuracies (Percentage) (5-class cases) Overall	(5-class cases) By-class av.	(4-class cases)[a] Overall	(4-class cases)[a] By-class av.
S192	1	11	69.7	60.4	80.1	62.5
S192	2	12 14	74.1	74.6	80.1	74.7
S192	3	9 12 14	88.9	90.5	91.4	90.8
S192	4	9 11 12 14	90.5	90.8	92.0	90.5
S192	5	1 9 11 12 14	91.6	93.0	93.1	92.1
S192	6	1 4 7 11 12 13	92.0	93.7	92.7	94.1
S192	4	3 5 6 7	72.6	74.8	73.7	71.7
ERTS-1 →	4	1 2 3 4	64.3	77.7	92.6	90.3

[a]In 4-class cases, corn and popcorn were merged into one class, and the classification accuracies were recalculated.

(3) A comparison between results using the best four bands 9, 11, 12, 14 of S192 and the four ERTS-1 bands revealed that the classification accuracies for both sets of data were practically the same for the 4-class cases. In the 5-class cases, however, the results of S192 appeared to be much better than those of ERTS-1. In light of the previous conclusions, the implication is that the best four S192 bands could, contrary to the ERTS-1 bands, effectively distinguish between corn and popcorn at this particular date (See footnote on page 5-9.)

(4) On the other hand, when the best four bands 3, 5, 6, 7 of S192 which are equivalent to the ERTS-1 bands were used for classification, an obvious deterioration in the classification accuracies was observed in the 4-class cases with respect to the ERTS-1 results. In view of table II S192 data quality as well as table III single band ranking, it is suggested that the poor and noisy nature of most of these four bands would account for this deterioration.

5.2 Classification Using Registered Data

Paralleling the presentations in section 4.2, various classification results on registered S192 and ERTS-1 data are given in table XII and figures 12 through 14. Like the unregistered cases, both 4- and 5-class results were obtained for evaluation. Generally figures 12 through 14 agree considerably with the divergence results of figures 9 through 11. For instance, figure 12 also evidences the worst classification accuracy that the substitution of band 5 brought about as

TABLE XII. — CLASSIFICATION ACCURACIES — REGISTERED CASE

Band Subset	Classification Accuracies (Percentage) (5-class cases)		(4-class cases)	
	Overall	By-class av.	Overall	By-class av.
15 16 17 18	49.8	57.0	82.4	67.4
3 16 17 18	70.5	65.7	83.6	68.6
4 16 17 18	60.2	60.6	81.2	66.4
5 15 17 18	52.2	58.0	81.0	67.2
6 15 16 18	72.3	69.5	83.4	70.8
7 15 16 17	78.2	72.5	84.4	71.9
8 15 16 17	77.8	74.5	83.9	75.5
3 5 6 7	70.0	64.5	72.4	60.4
5 6 7 15	73.7	68.9	77.7	66.4
3 6 7 16	78.6	69.8	83.0	67.3
3 5 7 17	79.0	75.2	82.6	73.6
3 5 6 18	71.6	69.1	80.0	69.3
3 4 5 6	54.4	51.2	61.1	52.2
3 5 7 8	73.2	70.7	75.0	67.4
9 11 14 17	89.1	89.5	91.3	90.3
3 15 16 18	71.5	67.3	83.9	69.2

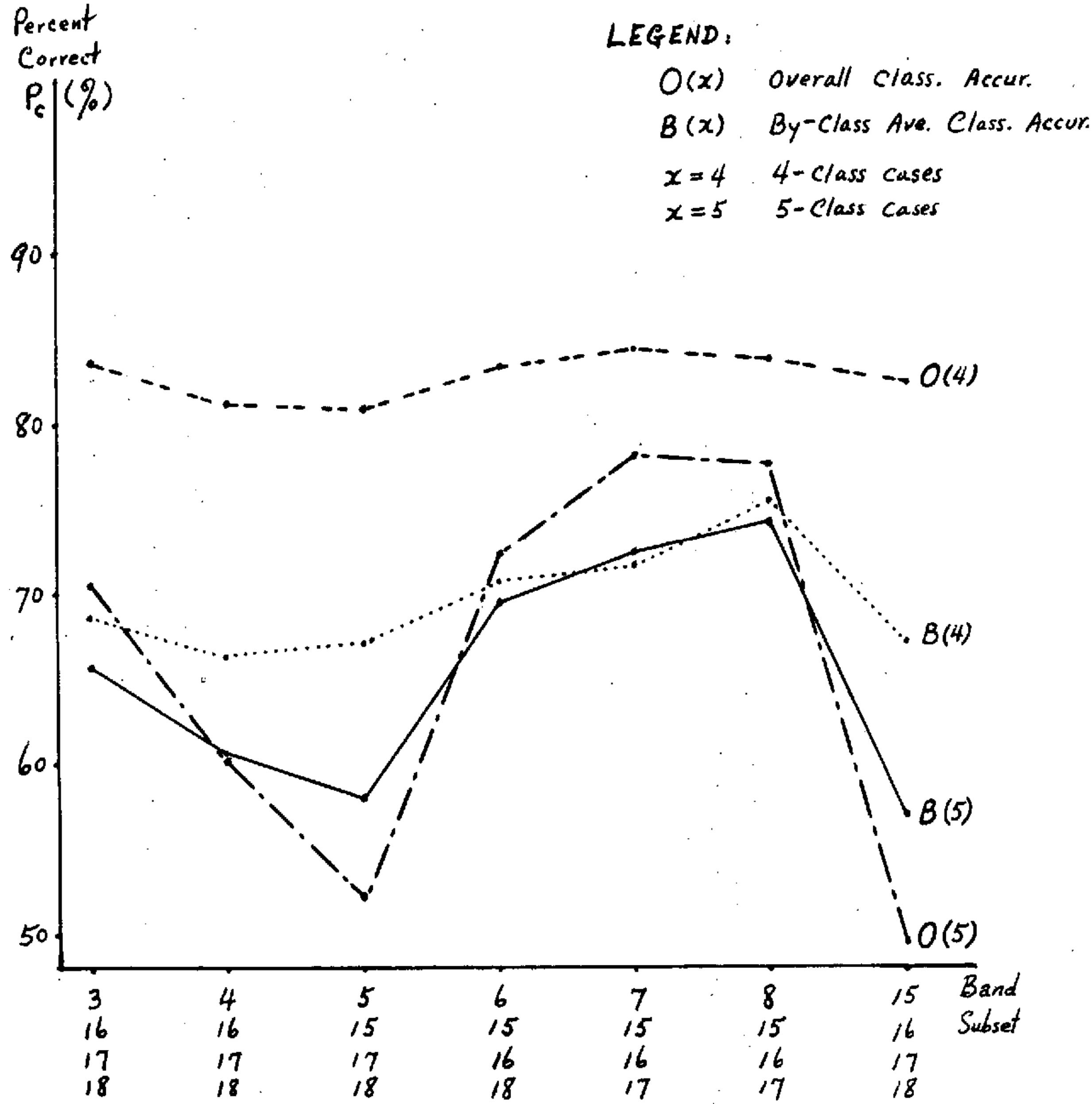


Figure 12. — Classification results (I).

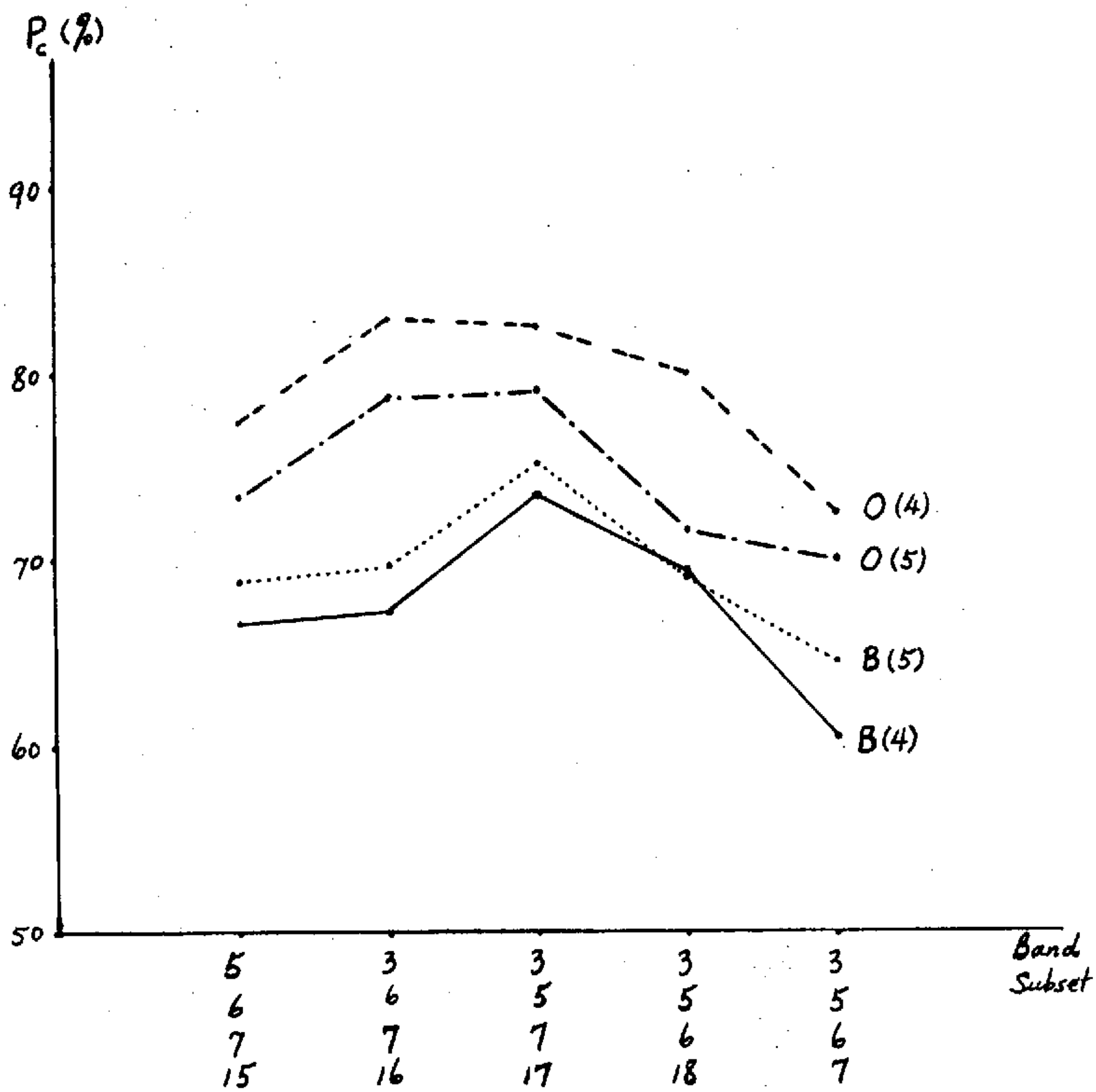


Figure 13. — Classification results (II).

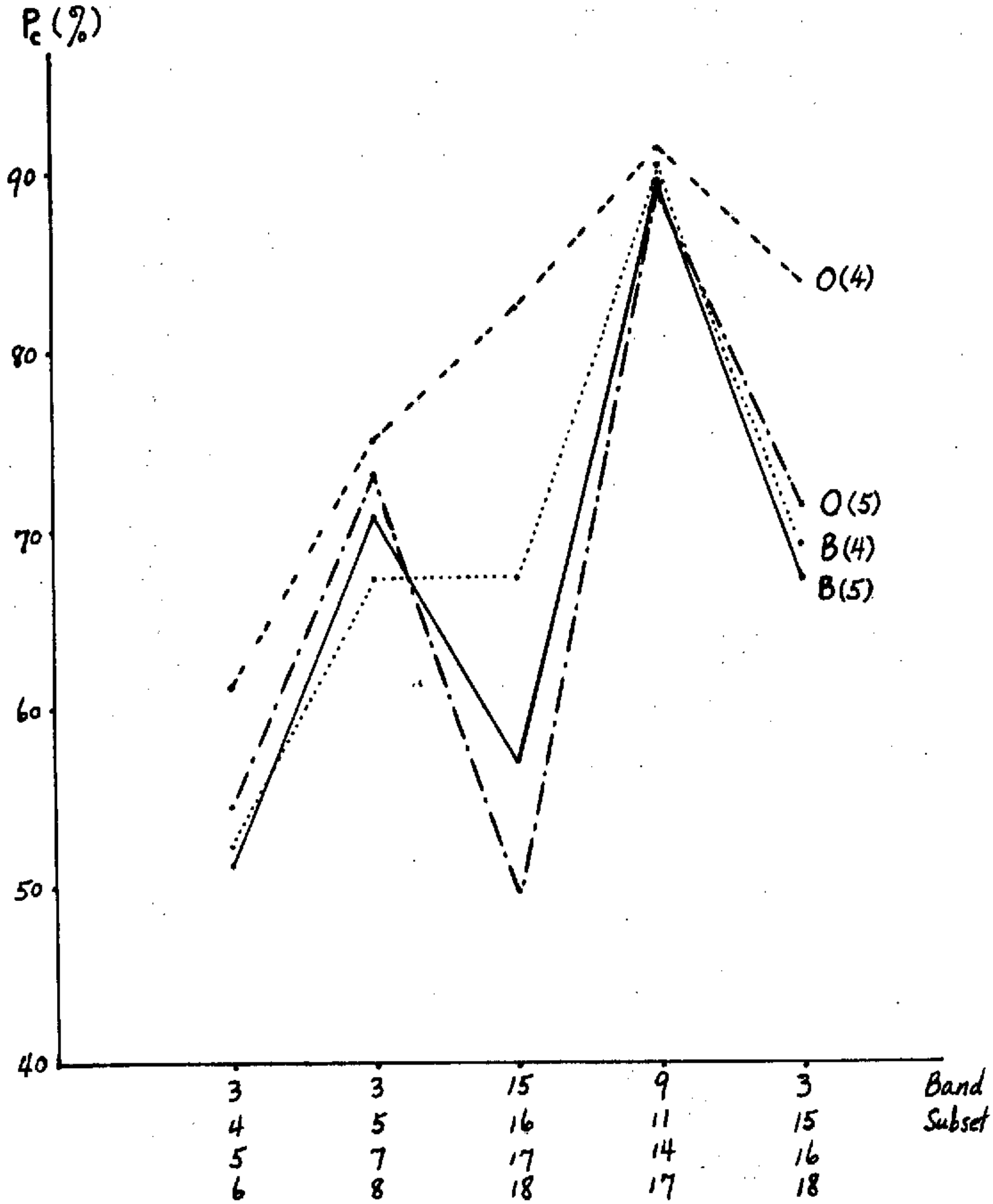


Figure 14. – Classification results (III).

was the case in figure 9. And a comparison (see figure 14) between 4-class results for subsets (15, 16, 17, 18) and (3, 5, 7, 8) again confirms the previous assertion that the performance of ERTS-1 bands was indeed superior over that of the corresponding best subset of S192 bands.

In figure 12 or 14, the marked difference in the classification accuracy between 4- and 5-class cases for ERTS-1 data (bands 15, 16, 17, 18) also supports the conclusion of the last section that ERTS-1 data did have difficulty in differentiating corn from popcorn.

It is very interesting to point out that there exists a close correspondence between the average divergences D(AVE) in figures 9 through 11 and the 4-class overall classification accuracies O(4) in figures 12 through 14.

Taking the curves O(4) of figures 12 and 13 for examples, the following comparison results can be obtained:

Based on P_c of (15, 16, 17, 18)

Substituted By Band	For Band	ΔP_c (%)
3	15	1.2
4	15	-1.2
5	16	-1.4
6	17	1.0
7	18	2.0
8	18	1.5

Based on P_c of (3, 5, 6, 7)

Substituted By Band	For Band	ΔP_c (%)
15	3	5.3
16	5	10.6
17	6	10.2
18	7	7.6

Clearly the two preceding results complement each other. In terms of percent changes in classification accuracies P_c, the impact on P_c by band substitutions can be quantitatively measured. The ranking of these six S192 bands based on such observed impact (ordered from favorable to adverse effect) is readily seen to be: bands 7, 8, 3, 6, 4, 5. Since this result is in substantial agreement with the observed image quality depicted in table II, it is believed that, besides the inherent separability capability, the signal-to-noise ratio of individual spectral bands also played an important role in the classification accuracy.

---

*S192 and ERTS-1 data considered herein were acquired on June 8, and May 31, 1973, respectively. The 8-day separation in the data acquisition at this critical crop growth stage might account for such differing results in separation between corn and popcorn using S192 and ERTS-1 data, as they were only a few inches tall on June 8. The other classes considered had developed solid ground covers.

6.0 FURTHER REMARKS AND CONCLUSIONS

Various classification results have been recorded in the form of color pictures. A threshold value of 5 percent for all five classes was used throughout. Selected results of 18 color classification maps are attached to the master copy of this report. The following are the subset bands that were used for classification in these selected results:

(1) ERTS-1 :	(1,2,3,4)	
(2) S192 :	(3,5,6,7)	– the best four from among those equivalent to ERTS-1 bands
	(9,11,12,14)	– the best four out of all S192 bands
(3) Registered Data:	(9,11,14,17)	– the best four out of all 18 bands
	(9,11,12,14)	
	(3,4,5,6)	– the worst from among those equivalent to ERTS-1 bands
	(3,5,7,8)	– the best four from among those equivalent to ERTS-1 bands
	(3,5,6,7)	
	(15,16,17,18)	–ERTS-1 bands
	(5,6,8,15), (3,6,8,16)	
	(3,5,8,17), (3,5,6,18)	
	(3,16,17,18), (4,16,17,18)	
	(5,15,17,18), (6,15,16,18)	
	(8,15,16,17)	

The preceding study has led to the following conclusions:

(1) The classification accuracy obtained on S192 data can be expected to be as high as that on ERTS-1 data. However, when a subset of S192 bands that are equivalent to the ERTS-1 bands were used for classification, an obvious deterioration in the classification accuracy was observed with respect to ERTS-1 results. Possible factors causing this deterioration are believed to be:

  (a) the poorer inherent separability of those S192 bands which have narrower spectral coverages than their corresponding ERTS-1 bands, and

  (b) the lower signal-to-noise ratio for most of these S192 bands.

(2) The thermal bands 13 and 14 as well as the near IR bands 11 and 12 were found to be relatively important in the classification of agricultural data.

(3) The differentiation of corn from popcorn was rather difficult on both S192 and ERTS-1 data acquired at this particular date of the year.

(4) The results on both data indicate that it was relatively easy to differentiate grass from any other classes.

(5) The close correspondence between the average divergence and the 4-class classification accuracy is significant, since the former results can be used to gauge the performance in 4-class cases.

7.0 RECOMMENDATIONS

It is recommended that

(1) S192 data be calibrated and straightened, and a further evaluation of S192 be made to substantiate the previous findings;

(2) S192 and ERTS-1 data at a later stage of crop growth be acquired for a similar study; and

(3) the S192 noise problems be resolved to improve the data quality, and thus enhance the classification performance of S192 data.

APPENDIX A

TRAINING FIELD DEFINITION FOR REGISTERED DATA

FIELD DEFINITION REPORT

FIELD ID	TYP	SYM		1ST VERTX	2ND VERTX	3RD VERTX	4TH VERTX	5TH VERTX	6TH VERTX	7TH VERTX	8TH VERTX	9TH VERTX	10TH VERTX
CORN1	T	C	LINE	34	38	41	43	39	35	0	0	0	0
			PIXL	59	63	62	57	55	55	0	0	0	0
CORN2	T	C	LINE	69	65	69	74	74	0	0	0	0	0
			PIXL	55	50	47	49	53	0	0	0	0	0
CORN3	T	C	LINE	98	99	94	90	90	94	0	0	0	0
			PIXL	55	51	49	51	55	58	0	0	0	0
CORN4	T	C	LINE	93	97	102	103	99	95	0	0	0	0
			PIXL	71	74	72	67	65	67	0	0	0	0
PCORN1	T	P	LINE	116	123	128	127	122	119	0	0	0	0
			PIXL	98	102	101	95	92	94	0	0	0	0
PAST1	T	T	LINE	81	84	88	92	91	88	84	0	0	0
			PIXL	89	83	84	88	92	95	93	0	0	0
GRASS1	T	G	LINE	122	114	129	131	129	124	122	126	126	0
			PIXL	67	82	90	87	83	82	78	74	68	0
ALFAL1	T	A	LINE	28	25	22	24	0	0	0	0	0	0
			PIXL	51	55	53	50	0	0	0	0	0	0
CORNSP	T	C	LINE	101	103	108	111	112	109	105	0	0	0
			PIXL	101	97	97	98	101	105	105	0	0	0
HOLTC			LINE	141	120	112	2	2	20	34	137	0	0
			PIXL	76	116	115	44	36	2	2	65	0	0

APPENDIX B

SOME PERTINENT INFORMATION ON THE REGISTRATION OF S192 AND ERTS-1 DATA

HIGHLIGHTS

The registration of S192 and ERTS-1 data over Holt County, Nebraska was expertly carried out by S. S. Yao using his REGSTR program. The work was accomplished on the UNIVAC 1108 computer. A first-order polynomial fit was employed for this particular registration task inasmuch as higher order polynomial fits would result in larger errors when applied to the data under consideration.

CONTROL POINTS

The control points used for registration are as follows:

	S192		ERTS-1	
	Line	Pixel	Line	Pixel
(1)	287	617	2152	335
(2)	291	632	2140	325
(3)	301	638	2138	312
(4)	294	649	2128	316
(5)	287	659	2119	319
(6)	315	635	2146	294
(7)	309	645	2136	298
(8)	325	641	2143	281
(9)	319	650	2134	285
(10)	323	667	2122	275
(11)	318	677	2112	279
(12)	343	653	2139	255
(13)	340	662	2129	258
(14)	332	673	2120	262
(15)	353	659	2137	241

	Line	Pixel	Line	Pixel
(16)	348	669	2127	245
(17)	342	679	2118	248
(18)	357	674	2125	231
(19)	362	690	2113	222
(20)	367	706	2102	212
(21)	372	696	2110	208
(22)	382	677	2131	199