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CROP IDENTIFICATION FROM RADAR IMAGERY OF THE HUNTINGTON COUNTY, INDIANA TEST SITE

Remote Sensing Laboratory
RSL Technical Report 177-58

P. P. Batlivala
F. T. Ulaby

November, 1975

Supported by:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Lyndon B. Johnson Space Center
Houston, Texas 77058

CONTRACT NAS 9-10261

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CROP IDENTIFICATION FROM RADAR IMAGERY OF THE HUNTINGTON COUNTY, INDIANA TEST SITE

ABSTRACT

The results of a study to discriminate crop types using L-band, dual polarization (HH and HV) radar data are reported. X-band data unfortunately were not available for analysis due ro problems encountered during the flight. The flight was made over Huntington County, Indiana on September 13, 1973 using the ERIM radar. The test site consisted of fields of corn, soybeans, woods and pasture.

The analysis resulted in the following observations:

a) Like polarization was successful in discriminating corn and soybeans, however pasture and woods were consistantly confused as soybeans and corn, respectively. The probability of correct classification was about 65%.

b) The cross polarization component (highest for woods and lowest for pasture) helped in separating the woods from corn, and pasture from soybeans and when used with the like polarization component, the probability of correct classification increased to 74%.

1.0 INTRODUCTION

On September 13, 1973 the ERIM* synthetic aperture radar was flown over Huntington County, Indiana. The test site was covered by two passes (Pass 2 and Pass 3). Both passes were flown at 6500' msl and had a display width of 19,000'. Both X (3.2 cm) and L-band (23.0 cm) imagery for HH and HV polarizations were obtained, however the two channels of the X-band data were not supplied by ERIM. Two problems, which have been documented in greater detail [1] in another report, encountered during the flight were responsible for degradation of the X-band image. The first problem was the "failure of the interface between the aircraft interial navigation system (INS) and the two signal film drives. . . . The second problem encountered . . . (was) that an X-band antenna wander problem had occurred."[1]

The objective of this report is to document the data processing and analysis of the L-band radar imagery and report the results of a discriminant analysis performed on the data.

2.0 TEST SITE

Map 1 shows the areas imaged for both Pass 2 and Pass 3. An aerial photograph of the entire test site along with an ASCS** overlay indicating field boundaries and field numbers were used to obtain coordinates. Figure 1 shows a portion of the aerial photograph and overlay. About 70-75% of the fields were corn and soybeans, the other two vegetation types (about 20%) were woods and pasture, 5% of the fields were unidentified. There was an equal percentage of corn and soybean fields. The ground truth data supplied were the field numbers, corresponding crop types, percent cover and row direction (if applicable).

The natural vegetation for the area is predominantly beach-maple forest, and some oak hickory forest. Both corn and soybeans in September are mature and ready for harvest.

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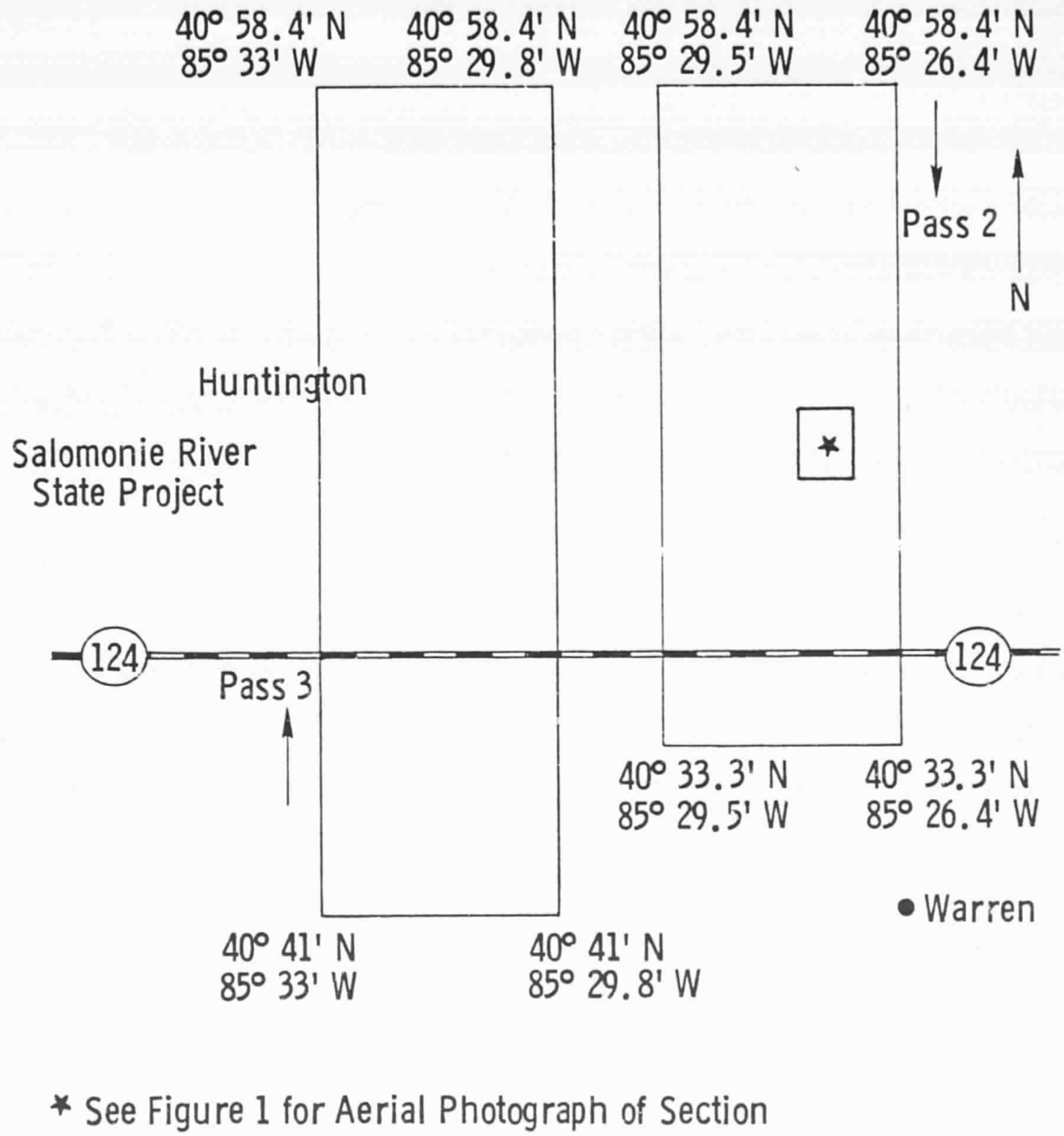
* Environmental Research Institute of Michigan.

** Agricultural Stabilization and Conservation Service.



Map 1. Huntington County test site.

Figure 1. Aerial photograph and overlay showing section of test site. Scale 2" = 1 statute mile.

3.0 DATA PROCESSING

Two magnetic tapes with radar data of Pass 2 and Pass 3 were mailed to the University of Kansas from ERIM on January 17, 1975. The tapes contained only two channels of data — L(HH) and L(HV) — and were registered and interleaved in the LARSYS III format. The tapes were generated on ERIM's PDP-11/45. The first set of tapes sent by ERIM for the Phoenix experiment [2] were generated on the Michigan Computing System (MTS). The computational center facilities at the University of Kansas (KUCC) encountered unacceptable number of parity errors. A possible explanation was an incompatibility of the two systems (MTS and KUCC). It was then decided that all data to be delivered by ERIM to the University of Kansas were to be generated on ERIM's PDP-11/45 computer which KUCC had no problem in reading.

As the HW 635 is a 36-bit/word machine, transliteration programs were written to generate HW 635 compatable tapes [3]. A digital printout of the entire test site was produced on which field boundaries were marked. The coordinates of the fields were input into the computer, which extracted data from each field and stored the information on tape to be later corrected.

For an imaging radar, the backscattered return from a given type of target (such as corn fields) can vary across the image between the near range and far range because of the following reasons: (a) antenna gain variations as a function of look angle, (b) path loss variation as a function of range and (c) scattering coefficient variations as a function of angle of incidence.

The relative radar response curves (taken from an ERIM report [1]) shown in Figure 2 correct for antenna gain and range variation as a function of angle of incidence but were not used by ERIM to correct the data due to lack of confidence in them*. To inspect the trend of the data the test site was broken up into five strips (parallel to the flight direction of the aircraft) and from each strip all corn and soybeans data were averaged separately and plotted. The data are shown in Figure 3. The shapes of the curves in Figures 2 and 3 are very similar. Corn gave a higher return than soybeans consistently over the entire range.

To correct the data, the test site was broken up into 250 strips and all soybeans data (having the largest number of points) within each strip were averaged and plotted

*Personal communication, D. Ausherman, ERIM.

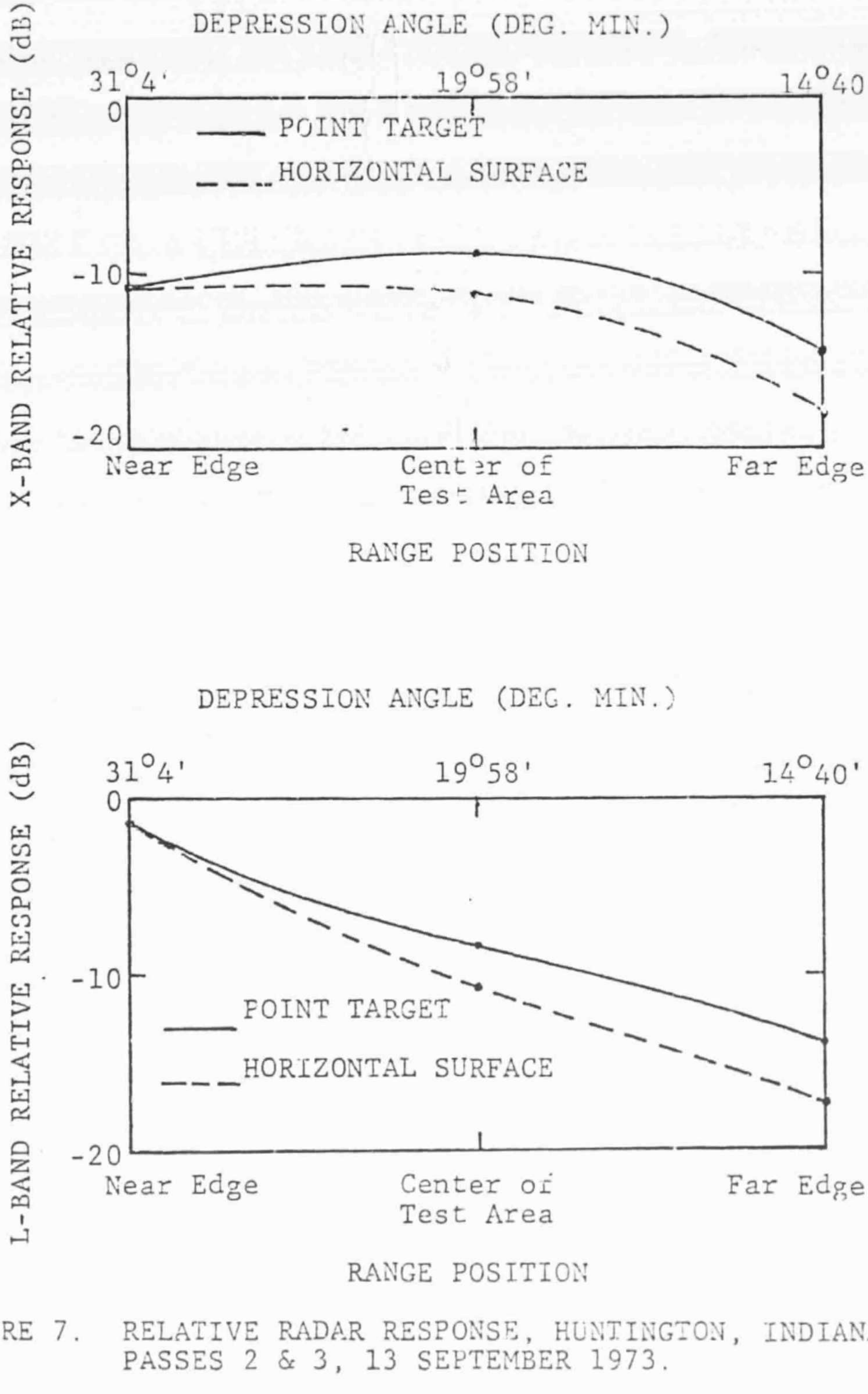


FIGURE 7. RELATIVE RADAR RESPONSE, HUNTINGTON, INDIANA, PASSES 2 & 3, 13 SEPTEMBER 1973.

Figure 2. (From ERIM, 1975).

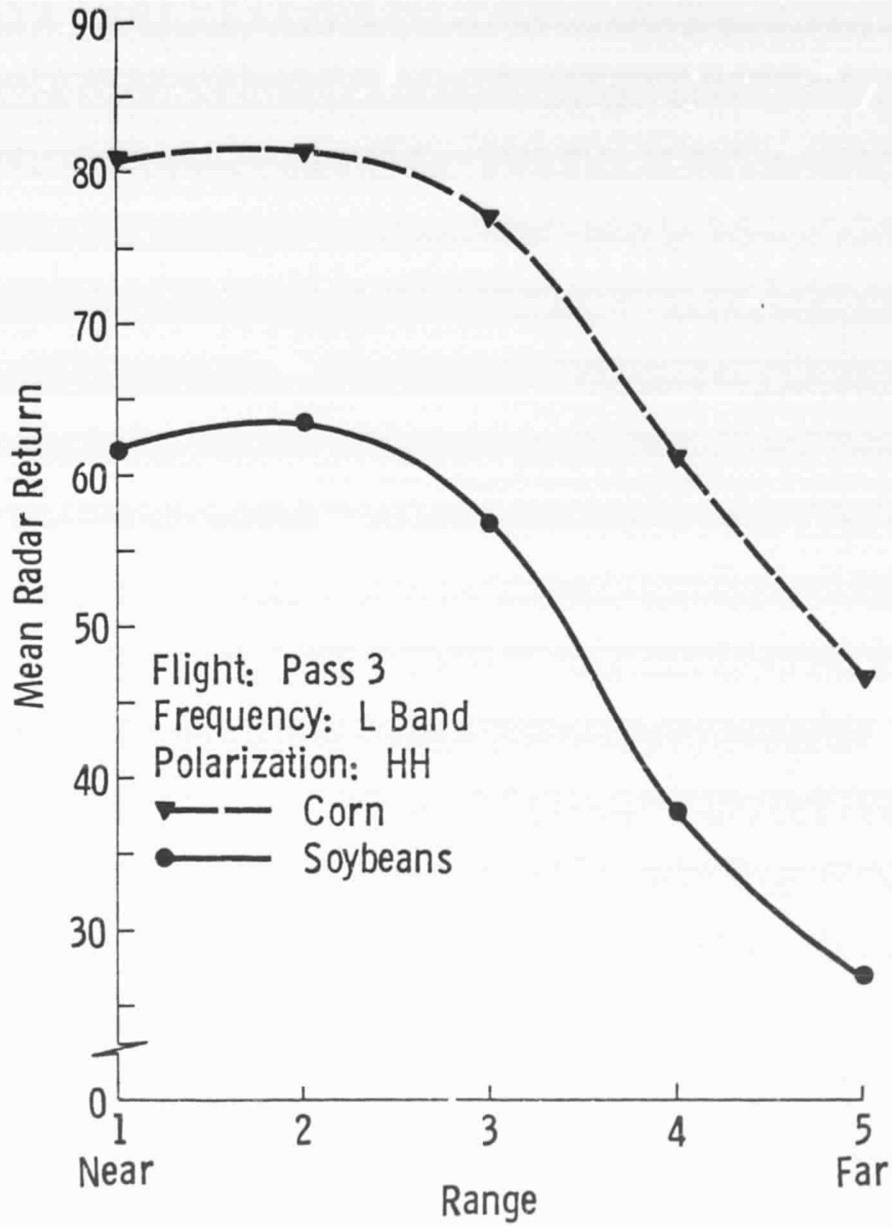


Figure 3. Mean radar return as a function of range. The test site was divided into 5 strips parallel to the flight line.

for each of the two passes (Figures 4 and 5). Passes 2 and 3 were processed separately to minimize any biases incorporated into the data due to variations in aircraft altitude. The curves in Figures 4 and 5 are similar in shape (there was no soybeans data for Pass 2 beyond range 180) with peaks and valleys occurring at approximately the same ranges.

The radar data were then corrected and means and standard deviations from each field were generated.

4.0 DATA ANALYSIS

Figures 6 and 7 are scattergrams of the data for Passes 2 and 3, respectively with the two axes being the mean radar return for HH polarization and HV polarization. Hyperplanes are drawn on the scattergrams to separate categories. They correspond to a discriminant analysis which will be discussed later. The woods give consistently high returns, and there is some separability between corn and soybeans. The average return from all corn and soybeans fields from Passes 2 and 3 were 34.48, 19.46 and 26.22, 20.96 respectively. Table 1 gives the total number of fields per category for each of the two passes.

PASS 2

Crop Type	Number of Fields
Fallow	6
Grains	5
Pasture	10
Woods	10
Corn	40
Soybeans	42
Total	113

PASS 3

Crop Type	Number of Fields
Fallow	0
Grains	6
Pasture	17
Woods	16
Corn	35
Soybeans	42
Total	116

TABLE 1. Number of fields per category for Pass 2 and Pass 3.

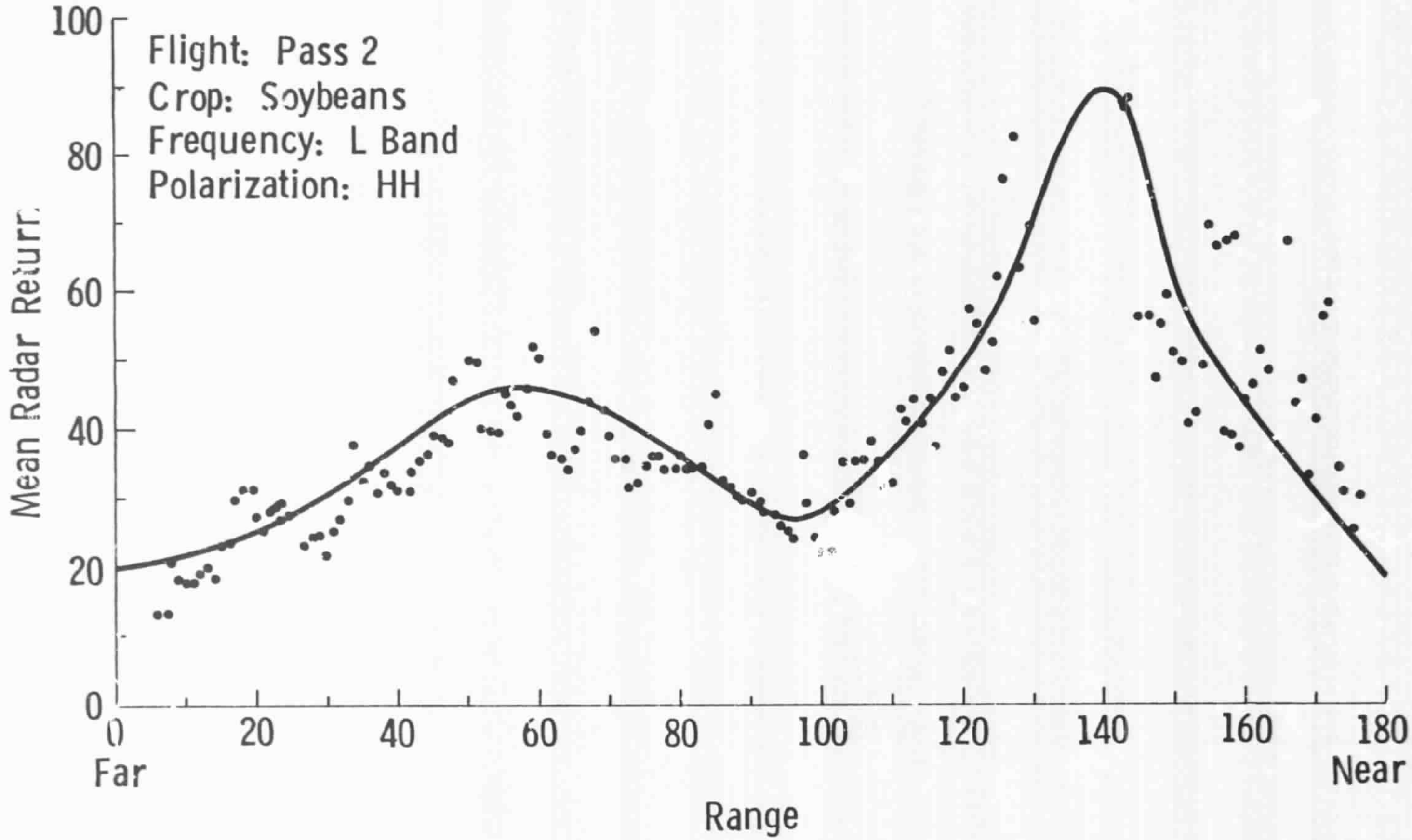


Figure 4. Mean radar return for soybeans as a function of range. The test site was divided into 250 strips parallel to the flight line (Pass 2).

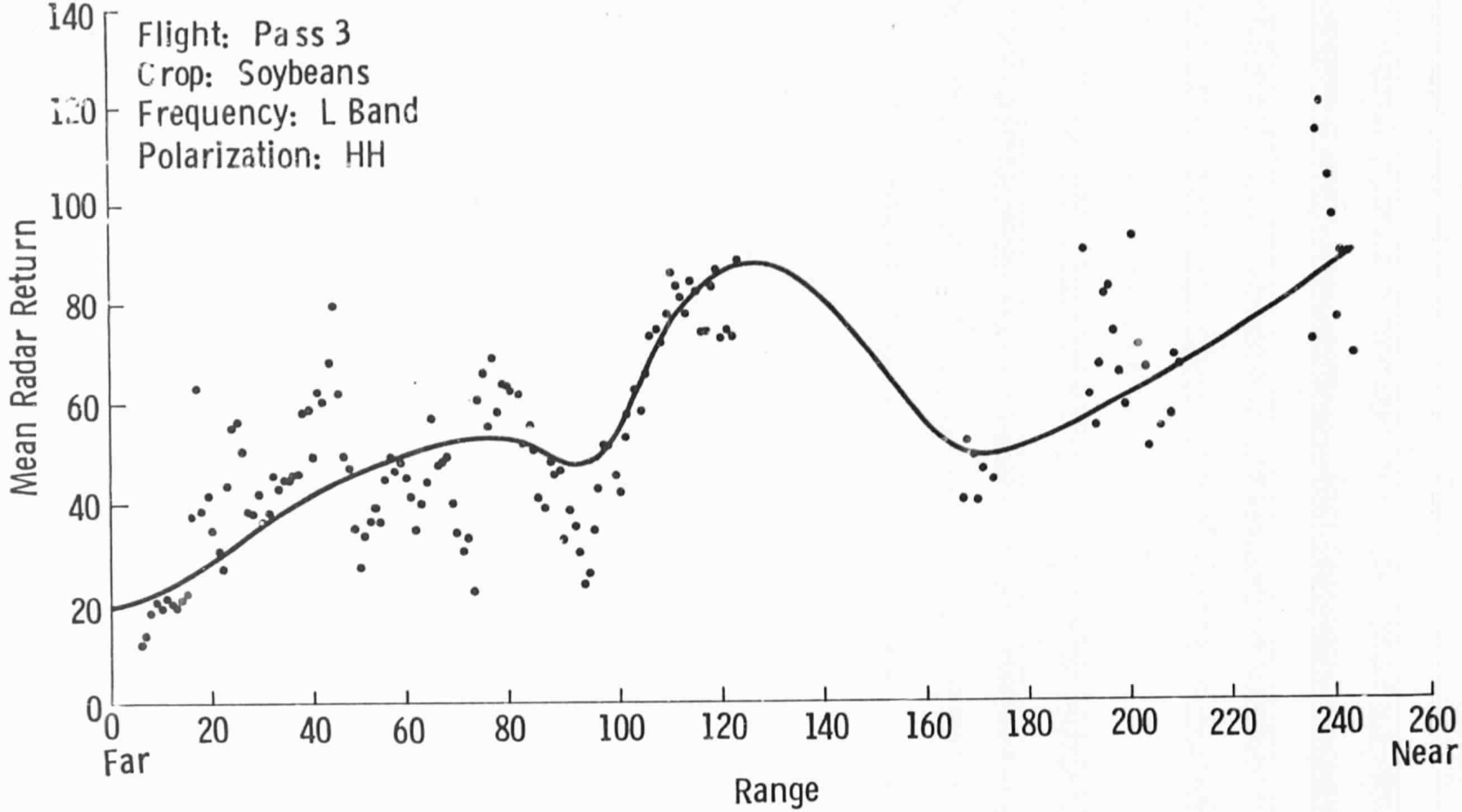


Figure 5. Mean radar return for soybeans as a function of range. The test site was divided into 250 strips parallel to the flight line (Pass 3).

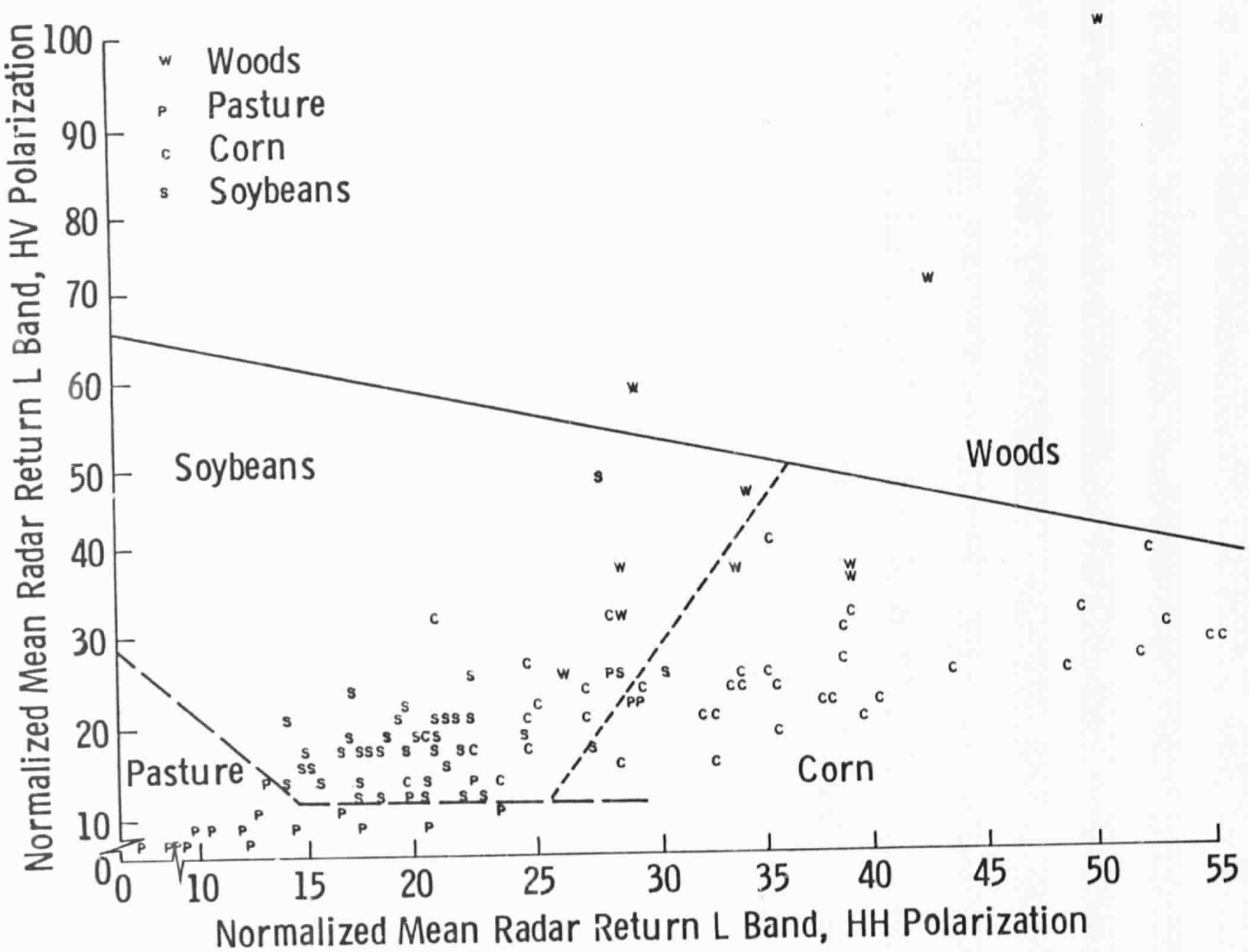


Figure 6. Scattergram for Pass 2.

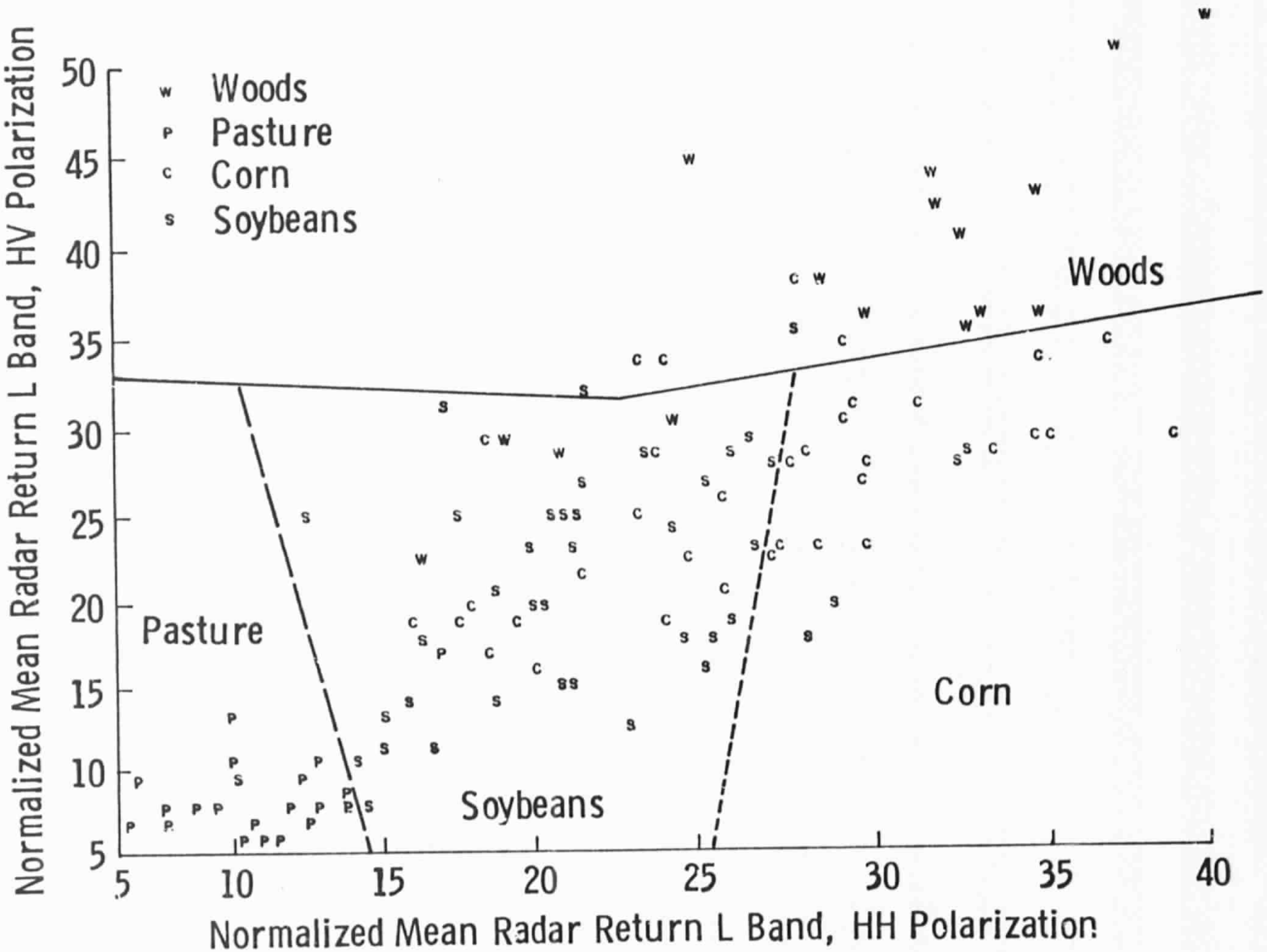


Figure 7. Scattergram for Pass 3.

To quantify the measure of separability a linear discriminant analysis was performed on the data. Fallow and grains were grouped with pasture for two reasons: (a) the returns of all three categories were comparable, (b) the grouping increased the number of measurements for pasture.

The discriminant analysis uses a regression algorithm which generates a set of hyperplanes for separating the training patterns. A total of NC(NC−1)/2 hyperplanes are determined, where NC = number of categories. The test patterns are classified on the basis of a majority vote on these hyperplanes [5]. For all the analyses 50% of samples were randomly selected to form the training patterns, the remaining samples were used as test patterns. Each pattern vector was made up of four measurements—like polarization mean and standard deviation and cross polarization mean and standard deviation—which shall be represented by HH(μ), HH(σ), HV(μ) and HV(σ) to facilitate brevity.

Table 2 shows discriminant analysis results grouping data from both passes for four crop types (pasture, woods, corn and soybeans). The probability of correct classification is calculated as the number of training + test patterns correctly classified/total number of patterns. HH(μ) is the optimum variable to discriminate crop types if only one measurement per pattern vector is used. The optimum combination of two variables is HH(μ) and HV(μ) which improves the probability of correct classification from 64.6% (for HH(μ)) to 71.2% (for both HH(μ) and HV(μ)). Table 3 gives the contingency tables. The cross polarization component (HV(μ)) when added to the like polarization return, helps in separating seven fields of woods which were all classified as corn when only the like component was used in the analysis. Some improvement is also noted in the fields of pasture. When woods and pasture were dropped from the analysis HH(μ) and HH(μ)/HV(μ) still gave the best results but both yielded a 76.1% probability of correct classification. This reinforced the statement that the cross polarization return aided only in the separation of woods and pasture from corn and soybeans. Adding dimensions to the data did not improve the classification.

As mentioned previously the data for Pass 2 and Pass 3 were corrected separately due to the possibility of system parameters (in particular aircraft height) differing for the two passes. A similar analysis as the one mentioned above was conducted separately for the two passes. The results are given in Tables 4, 5, 6 and 7. For both passes a combination of HH(μ) and HV(μ) gives the best results and is an improvement of about 10% when compared to results using HH(μ) or HV(μ) alone. HH(μ) does a good

One Dimensional Analysis

Variable	Classification		Probability of Correct Classification %
	Training Patterns	Test Patterns	
HH(μ)	67/107*	70/105	64.6
HH(σ)	61/107	63/105	58.5
HV(μ)	60/107	67/105	59.9
HV(σ)	56/107	65/105	57.1

Two Dimensional Analysis

Variable	Classification		Probability of Correct Classification %
	Training Patterns	Test Patterns	
HH(μ)/HH(σ)	66/107	73/105	65.6
HH(μ)/HV(μ)	76/107	75/105	71.2
HH(μ)/HV(σ)	75/107	74/105	70.3
HH(σ)/HV(μ)	73/107	70/105	67.5
HH(σ)/HV(σ)	69/107	67/105	64.2
HV(μ)/HV(σ)	61/107	67/105	60.4

*67 out of 107 fields were correctly classified.

Table 2: Discriminant analysis results grouping data for both passes and using four crop types.

One Dimensional Analysis (HH(μ))

Contingency Table for Training Patterns

True Category				
Woods	0	0	10	1
Pasture	0	8	1	5
Corn	0	0	24	14
Soybeans	0	2	7	35
	Woods	Pasture	Corn	Soybeans
	Assigned Category			

Contingency Table for Test Patterns

True Category				
Woods	0	0	10	5
Pasture	0	9	0	4
Corn	0	0	26	11
Soybeans	0	0	5	35
	Woods	Pasture	Corn	Soybeans
	Assigned Category			

Two Dimensional Analysis (HH(μ)/HV(μ))

Contingency Table for Training Patterns

True Category				
Woods	3	0	7	1
Pasture	0	11	1	2
Corn	0	0	24	14
Soybeans	0	1	5	38
	Woods	Pasture	Corn	Soybeans
	Assigned Category			

Contingency Table for Test Patterns

True Category				
Woods	4	0	6	5
Pasture	0	11	0	2
Corn	0	0	25	12
Soybeans	0	1	4	35
	Woods	Pasture	Corn	Soybeans
	Assigned Category			

Table 3: Contingency tables for HH(μ) and HH(μ)/HV(μ) corresponding to Table 2.

One Dimensional Analysis

Variable	Classification		Probability of Correct Classification %
	Training Patterns	Test Patterns	
HH(μ)	34/58	34/55	60.2
HH(σ)	33/58	33/55	58.4
HV(μ)	34/58	34/55	60.2
HV(σ)	33/58	35/55	60.2

Two Dimensional Analysis

Variable	Classification		Probability of Correct Classification %
	Training Patterns	Test Patterns	
HH(μ)/HH(σ)	38/58	38/55	67.3
HH(μ)/HV(μ)	42/58	41/55	73.5
HH(μ)/HV(σ)	40/58	31/55	62.8
HH(σ)/HV(μ)	39/58	35/55	65.5
HH(σ)/HV(σ)	40/58	35/55	66.4
HV(μ)/HV(σ)	39/58	32/55	62.8

Table 4: Discriminant analysis results for Pass 2 using four crop types.

One Dimensional Analysis (HH(μ))

Contingency Table for Training Patterns

True Category	Woods	Pasture	Corn	Soybeans
Woods	0	0	5	0
Pasture	0	0	2	8
Corn	0	0	14	6
Soybeans	0	0	3	20
	Assigned Category			

Contingency Table for Test Patterns

True Category	Woods	Pasture	Corn	Soybeans
Woods	0	0	4	1
Pasture	0	0	1	10
Corn	0	0	15	5
Soybeans	0	0	0	19
	Assigned Category			

Two Dimensional Analysis (HH(μ)/HV(μ))

Contingency Table for Training Patterns

True Category	Woods	Pasture	Corn	Soybeans
Woods	2	0	2	1
Pasture	0	6	1	3
Corn	0	1	14	5
Soybeans	0	1	2	20
	Assigned Category			

Contingency Table for Test Patterns

True Category	Woods	Pasture	Corn	Soybeans
Woods	1	0	1	3
Pasture	0	9	1	1
Corn	0	0	15	5
Soybeans	0	2	1	16
	Assigned Category			

Table 5: Contingency tables for HH(μ) and HH(μ)/HV(μ) corresponding to Table 4 (Pass 2).

One Dimensional Analysis

Variable	Classification		Probability of Correct Classification %
	Training Patterns	Test Patterns	
HH(μ)	43/61	28/55	61.2
HH(σ)	36/61	29/55	56.0
HV(μ)	41/61	29/55	60.3
HV(σ)	40/61	26/55	56.9

Two Dimensional Analysis

Variable	Classification		Probability of Correct Classification %
	Training Patterns	Test Patterns	
HH(μ)/HH(σ)	45/61	30/55	64.7
HH(μ)/HV(μ)	47/61	37/55	72.4
HH(μ)/HV(σ)	42/61	31/55	62.9
HH(σ)/HV(μ)	42/61	36/55	67.2
HH(σ)/HV(σ)	41/61	30/55	61.2
HV(μ)/HV(σ)	42/61	36/55	67.2

Table 6: Discriminant analysis results for Pass 3, using four crop types.

One Dimensional Analysis (HH(μ))

Contingency Table for Training Patterns

True Category	Woods	Pasture	Corn	Soybeans
Woods	0	0	5	1
Pasture	0	13	0	0
Corn	0	0	9	7
Soybeans	0	2	3	21
	Assigned Category			

Contingency Table for Test Patterns

True Category	Woods	Pasture	Corn	Soybeans
Woods	2	0	4	4
Pasture	0	9	0	1
Corn	2	0	8	9
Soybeans	0	3	4	9
	Assigned Category			

Two Dimensional Analysis (HH(μ)/HV(μ))

Contingency Table for Training Patterns

True Category	Woods	Pasture	Corn	Soybeans
Woods	5	0	0	1
Pasture	0	13	0	0
Corn	1	0	7	8
Soybeans	1	0	3	22
	Assigned Category			

Contingency Table for Test Patterns

True Category	Woods	Pasture	Corn	Soybeans
Woods	7	0	1	2
Pasture	0	9	0	1
Corn	3	0	8	8
Soybeans	1	0	2	13
	Assigned Category			

Table 7: Contingency tables for HH(μ) and HH(μ)/HV(μ) corresponding to Table 6 (Pass 3).

job of separating corn and soybeans but confuses woods as corn and pasture as soybeans (for Pass 2). HV (μ) on the other hand does a better job of separating woods and pasture from corn and soybeans but in terms of total separation it is slightly inferior to HH(μ).

Hyperplanes separating categories are drawn on Figures 6 and 7 corresponding to the discriminant analysis results given in Tables 5 and 7.

5.0 CONCLUSIONS

Analysis of the Huntington County radar data at L-band led to the following conclusions:

1. The relative radar returns from corn and soybeans at L-band agree with the data reported by Ulaby [4] at 4.7 GHz.

2. It is possible to separate corn, soybeans, woods and pasture with a confidence of about 74% if both like and cross polarization returns are employed.

3. If only one polarization is used HH yields good overall results (65%) and is able to separate corn, soybeans and pasture. However woods are consistently confused with corn.

4. The cross polarization component HV is able to differentiate woods from the other crop types and if used in conjunction with the like polarization component improves the overall confidence of prediction by about 10%.

Ground based radar data (1-18 GHz) being currently processed and analyzed at the University of Kansas were collected over two growing seasons for a variety of crop types [6-10] (bare soils, alfalfa, corn, soybeans, milo and wheat). The answer to the question of what are optimum radar system parameters for the discrimination of crops, will be the subject of a future report.

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