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ERTS-1 AIRCRAFT SUPPORT, 24-CHANNEL MSS CCT EXPERIENCES AND LAND USE CLASSIFICATION RESULTS

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ABSTRACT

Aircraft multispectral scanner (MSS) data collected by the NASA 24-channel MSS on July 26, 1972 (Mission 207) over the USDA, Research Farm at Weslaco, Texas, were evaluated for quality and for crop, soil, and water discrimination. The standard deviations for each of the 24 channels for a uniform surface, a water reservoir, were used as an indicator of system noise. By this criterion, channels 22, 20, 15, and 21 were of low quality. Based on the ratio of odd to even numbers in all channels, the conclusion was reached that the data are 7-bit precision. An optimum channel selection program selected channels 7, 8, 3, and 18 as the best 4 channels for distinguishing among seven vegetal categories: Stoneville 213 cotton, Anton SP-21 cotton, Valencia orange, Red Blush grapefruit, sugarcane, Coast-Cross 1 bermudagrass and African stargrass. These same channels also distinguished the nonvegetal categories (water, highway, rooftops, and bare soil) satisfactorily. Among the vegetal categories, sugarcane and cotton had distinctive signatures that allowed them to be distinguished from grass and citrus. Classification accuracies improved to about 81% when the intra plant genera categories (such as the two cotton varieties) were combined into one.

INTRODUCTION

One of the major proposed uses of remote sensing data is to inventory land use in agricultural areas. Distinctions are being made among crop, soil, and water categories and attempts are underway to distinguish among categories within each of these broad categories. This report summarizes work done with data collected from an airborne 24-channel multispectral scanner over portions of the Lower Rio Grande Valley of Texas.

The data were studied to determine what crop, soil, and water categories could be discriminated in an area where detailed ground truth was available. Specific objectives were: (1) To determine the optimal MSS channels for land use inventories, (2) to study factors indicating the general quality of the 24-channel multispectral scanner data, (3) to determine the spectral signature of various crop, soil, and water scenes, and (4) to measure the recognition performance of various data-processing procedures for crop, soil, and water discrimination.

EXPERIMENTAL PROCEDURE

The data were collected by the 24-channel multispectral scanner (Zaitzeff, et al., 1970) on board the NASA NC130B aircraft flown on July 26, 1972 over the Lower Rio Grande Valley in support of an ERTS-1 project. For this study the data set consisting of the signals from the 50-acre USDA Research Farm at Weslaco, Texas, was chosen for intensive study. Twenty-three areas representing a variety of crop, soil, and water categories within the 50 acres were selected from which training samples were drawn. All resolution elements from all 24 channels were selected for each of the 23 areas to be used for determining the recognition accuracy of the discrimination procedures and for determining average multispectral signatures.

Figure 1 shows the arrangement of the Research Farm and the location of the training areas. The wavelength intervals included in each channel are given in Table 1. The accuracy of acreage estimates was judged by comparing the number of resolution elements with the area measured on a photograph taken at the time of the overflight.

The farm and surrounding area in the photograph included 61.5 acres; the data set from this area includes 6.1×10^4 resolution elements. The ground area included in each resolution element thus is a square 6.63 feet on a side.

The water in the irrigation reservoir (area 1) was used to indicate the signal quality of each channel. The standard deviation of resolution elements from this uniform surface was used as an indicator of channel noise. The data are all reported as voltages measured as the output of each channel sensor. The factors to convert these voltages into absolute radiometric units ($mv/cm^2/sr$) had not been developed at the time of this overflight (Mission 207).

The seven vegetation categories were used to evaluate the effectiveness of the individual channels in making a land use inventory. Recognition results were compiled using all resolution elements in the training areas. Finally, recognition maps of the complete Research Farm were produced on a line printer and on a CRT-type display tube.

RESULTS AND DISCUSSION

Objective 1 - To determine the optimal MSS channels for land use inventories of agricultural scenes in Mission 207.

Vegetation categories were used to determine the channels giving the best discrimination because these are the most difficult categories to distinguish in agricultural land use categories (Richardson et al., 1972). It was assumed that whatever channels were best for distinguishing among vegetation categories would be satisfactory for distinguishing among such spectrally diverse categories as bare soil, water, rooftops, and asphalt pavement.

An analysis of variance test was run on each of the 24 channels, testing the hypothesis that there is no difference among the seven categories of vegetation (Stoneville 213 cotton, Anton SP-21 cotton) (*Gossypium* varieties); Valencia orange, Red blush grapefruit (*Citrus* varieties); Sugarcane (*Saccharum*); Coast-Cross 1 bermudagrass, and African Stargrass (*Cynodon* species). Table 2 ranks the 24 channels according to the F-ratio obtained. The standard deviation from the signals over the reservoir and an indication of the value of the least significant bit (LSB) in each channel is also shown in Table 2.

A program similar to STEPLIN of the University of Michigan was used to compute the pair, the trio, the quartet, etc. of channels giving the best recognition of the training samples. All pairwise combinations of channels are examined to find the pair that gives the highest percentage recognition; then each channel not included in the pair is combined with the best pair to find the best trio. Then the best three are combined with the ones not chosen until the best four have been found. This search pattern is continued until 14 channels have been ranked in their ability to discriminate among the vegetation categories. The best four channels chosen by this method are shown in column 1 of Table 2 by double asterisks, channels ranking fifth through tenth are indicated by single asterisks.

Including the categories of different varieties within a crop species rigorously tested the discriminating ability. Table 3 compares the classification accuracy of the best combinations of channels, both where the intra-species categories are included and where all categories of the species are grouped together. Table 3 shows that using the three best channels (7, 8, and 3) gave 82.6% overall correct classification of the training data where the intra-species categories were grouped. The four best channels (7, 8, 3, and 18) resulted in 86.6% correct classification. Using the five best channels increased the correct classification to 91.9% of the training data. If one accepts the criterion suggested by Anderson, Hardy and Roach (1972) of 90% correct classification necessary for a satisfactory classification system, then five channels are a minimum to use with these data.

The optimum five channels, in order of their selection are from the far red (0.72 - 0.76 μ), the reflective infrared (0.77 - 0.81 μ), the blue (0.466 - 0.495 μ), the thermal infrared (8.8 - 9.3 μ), and the ultraviolet (0.375 - 0.405 μ). These bands can be expected to contain spectrally independent information because of their spectral separation. Although the training data that resulted in their selection were all vegetal categories, their spectral diversity would be expected to make them useful for almost any set of categories. This expectation was upheld by the classification results obtained when pavement, water, and bare soil categories were included.

Objective 2 - To study factors indicating the general quality of the 24-channel multispectral scanner data.

Water in the reservoir was used as a uniform reflectance source to measure the variation in the MSS signals from individual channels. It is assumed that the variation measured over this uniform surface represents the noise in the system. The standard deviations of the signals within the reservoir are used as a measure of system noise. Those channels with the highest standard deviation (22, 20, 15, and 21) also ranked low in the F-ratio list in Table 2.

These data were recorded as digital values representing 8-bit precision (0 - 255 range). Unusual patterns were noticed in the data, in that some channels had a noticeably higher number of odd numbers than even numbers. Data with true 8-bit precision should have as many even numbers as odd numbers. If the least significant bit (LSB) is affected by something other than the value of the signal being recorded, the ratio between odd and even numbers can be affected.

An odd to even ratio of the values was determined for each channel from the data over the water reservoir. The ratios obtained are shown in the right-hand column of Table 2. The ratios for most of the channels are shown to be materially different from 1.

Objective 3 - To determine the spectral signature of various crop, soil, and water scenes as measured by the Bendix 24-channel multispectral scanner.

Figures 2 through 7 show the average spectral signature for the 23 study areas.

The bare soil and weed signature (Fig. 2) has a slightly higher response in the infrared region than the bare soil signatures in Fig. 3. This difference is reasonable because vegetation is highly reflective in the near infrared (Fritz, 1967). The three grasses (Fig. 2) yield similar spectra in the 0.7 to 1.3 µm WLI, even though the amplitudes differ slightly. The three sugarcane signatures (Fig. 3) also have the same characteristic shape in the 0.7 to 1.3 µm WLI. The highway, rooftop, and water reservoir areas of Fig. 4 are much lower beyond the visible wavelengths; there is a suggestion of a green peak at about 0.55 µm and an infrared peak in the 0.7 to 1.3 µm WLI, although not enough for them to be confused with vegetation.

The average spectral signatures in Figs. 5, 6, and 7 for various varieties of cotton and citrus are typical of vegetation. The citrus response, in the 0.7 to 1.3 µm WLI, is not quite as strong as cotton on the average, probably because of the bare soil areas between the trees.

Objective 4 - To measure the recognition performance of the 24-channel multispectral data for crop, soil, and water discrimination.

The recognition performance for the seven vegetal training categories was determined. The average pairwise probability ranking of the seven best channels was determined using the vegetal training data and are listed in Table 3. Channel 7 was the best single channel and yielded an overall percent recognition of 31.6% (column A) for the vegetal categories Stoneville 213, Anton SP-21, Valencias, Red blush, Sugarcane, Coast-Cross 1 bermudagrass, and African stargrass. Combining categories of similar plant species so that Stoneville 213 and Anton SP-21 became cotton, Red blush and Valencias became citrus, and so on raised the overall percent recognition to 56.9% (column B) for channel 7. The best two channels (7, 8) give overall recognition results of 49.7 and 66.9%, respectively, before and after combining similar plant species categories.

The optimum 4 channels (7, 8, 3, and 18)[a/] were used to classify all of the Research Farm and a complete recognition map of the Research Farm was made. (The increase in overall test site recognition, shown in Table 3, from using 5 channels (91.9%) versus 4 channels (86.6%) could be crucial in some cases and justify use of 5 channels. The use of more than 5 channels does not seem justified here because Table 3 indicates there would only be a 1% gain over using 5 channels for this study.

Tables 4 and 5 give the complete recognition performance results for the optimum four channels (7, 8, 3, and 18) for the training categories before and after combining categories of similar plant species. The two cotton varieties have high intra-species classification errors but there is very little misclassification of cotton as any other vegetal category (Table 4).

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a/ Corresponding to wavelengths 0.72 to 0.76, 0.77 to 0.81, 0.466 to 0.495, and 8.8 to 9.3 µm, respectively.

The two citrus categories exhibit the same intra-species classification errors as the cotton species. The citrus was confused with the grass categories as can be seen by the number of misclassifications of citrus as grass. Sugarcane was fairly distinctive, with only 18.8% of the sugarcane misclassified as cotton (Table 4). Very few vegetal categories were misclassified as sugarcane. The African stargrass was a fairly distinctive category as was Coast-Cross 1 bermudagrass. On the basis of these results it was decided to combine the categories of the same plant species, and Tables 4 and 5 show the overall recognition increased from 70.1 to 86.6%. This increased recognition is due mainly to reduced misclassifications within the cotton and citrus categories.

Using the same vegetal training statistics and including training statistics for the highway, water reservoir, bare soil, and bare soil plus weed area, the recognition performance of all 23 test areas was determined and the results are listed in Tables 6 and 7. The three most distinctive vegetal categories were stargrass, sugarcane, and cotton. The Coast-Cross 1 bermudagrass was not as distinctive as it was in the training data. The two citrus categories were frequently misclassified as grass and as bare soil (Table 7). The misclassification errors as grass cannot be justified because the area between the trees was mainly bare soil. Some samples from all vegetal categories were misclassified as sugarcane, but no sugarcane samples were misclassified as any other vegetal category.

Table 7 shows that combining the vegetal categories of similar plant species increased the recognition results from 61.3% (Table 6) to 78.1% (Table 7). The bare soil and bare soil plus weeds recognition results were 62.6 and 88.1%, respectively, because of high inter-category misclassification (Table 6). After combining these two bare soil categories, the recognition results increased to 95.2% (Table 7). These results agree with previous studies (Richardson et al., 1972) where bare soil was a distinctive category.

Table 8 summarizes the recognition and acreage estimate results using 61,000 resolution elements from the 50-acre Research Farm plus 11.5 acres of surrounding area. Of 61,000 resolution elements, 4,890 were recognized as cotton (Table 8). These resolution elements represent 8.01% of the total scene or 4.93 acres.

The threshold was set at two different probability levels (assuming a normal distribution) to study the effect on the threshold category[b/]. At a 5% threshold setting, 5% of the total number of samples should fall in the threshold category. Table 8 shows that 20.9% fell in the threshold category, indicating that the normal distribution assumption is not completely justified. At a 1% threshold setting, only 1% of the total number of samples should appear in the threshold category. About 1.1% of these samples actually fell in the threshold category.

Figure 8 is a recognition map of the 61,000 resolution elements that were classified in Table 8. The highway and reservoir were distinguished very well from their appearance in the recognition map. The best recognition for vegetal categories (Table 7) was sugarcane, grass, and cotton (88.2, 70.7, and 70.1% correct classification, respectively). The cotton and sugarcane categories show up very well on the recognition map. The results for cotton agree with previous results (Richardson et al., 1972) where cotton was one of the most distinctive categories in July. Bare soil and weeds are very distinctive categories in the recognition map. The citrus and grass areas are not as well defined (Fig. 8) as the cotton and sugarcane areas, so the acreage estimates in Table 8 for these two categories are probably not very representative. Red blush citrus is identified in the cotton categories as cotton root rot and appears in the alleyways between the sugarcane plots. Red blush is also classified as Valencia and Marrs as well as bare soil and weed. The stargrass area (Fig. 8) was very distinctive but it was also misclassified as citrus (Table 6) and this misclassification shows up in Fig. 8. The Coast-Cross 1 bermudagrass had low recognition results (Table 6) of 57.7%.

CONCLUSIONS

The optimum four MSS channels, out of 24, from Mission 207 flown July 26, 1972, for discriminating among typical vegetal categories on the USDA Research Farm at Weslaco, Texas, were 7, 8, 3, and 18. The diverse categories--bare soil, water, and highways--could also be distinguished using these same four channels.

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b/ Any sample values not classified as any of the 10 training categories were placed in an "other" category called threshold.

There are problems associated with noise and data precision that lower the overall quality of the MSS data. Statistical tests of the digital counts for each channel from a water reservoir indicate that some channels (mainly the thermal channels) were noisy. Studies of the LSB indicate the precision of the data is really 7-bit because the LSB of the 8-bit data is biased in favor of odd values. This is demonstrated by a tendency toward more odd than even numbers in all channels.

The ultraviolet, visible, and reflective infrared channels were used to determine average spectral signatures of 23 areas. The signatures for diverse areas such as water, highways, building roofs, and bare soil differed from those of the vegetal categories. Among the vegetal categories, sugarcane and cotton had distinctive signatures that distinguished them from grass and citrus.

The recognition performance with the MSS data in distinguishing among agricultural land use scenes was not as high as hoped for (overall recognition of 78.1%). Sugarcane, cotton, water and highway, were fairly well recognized but citrus trees and grass were poorly recognized. Citrus acreage was not representative because Red blush citrus was identified frequently as cotton root rot, Valencia and Marrs citrus, and as bare soil and weeds. The stargrass category was often misclassified as citrus. The Coast-Cross 1 bermudagrass was not very distinctive as a category.

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Table 1. Wavelength interval assignments for the Bendix 24-channel multispectral scanner.[a]

Channel	Wavelength interval in micrometers	Center of wavelength interval (micrometers)
1	0.375 - 0.405	0.394
2	0.40 - 0.44	0.420
3	0.466 - 0.495	0.474
4	0.53 - 0.58	0.555
5	0.588 - 0.643	0.623
6	0.65 - 0.69	0.670
7	0.72 - 0.76	0.740
8	0.770 - 0.810	0.792
9	0.82 - 0.88	0.850
10	0.981 - 1.045	0.999
11	1.20 - 1.30	1.100
12	1.533 - 1.62	1.550
13	2.3 - 2.43	2.350
14	3.78 - 4.04	4.170
15	4.50 - 4.76	4.630
16	6.0 - 7.0	6.500
17	8.27 - 8.7	8.530
18	8.8 - 9.3	9.050
19	9.38 - 9.876	9.620
20	10.1 - 11.0	10.580
21	11.1 - 12.0	11.400
22	12.0 - 13.0	12.400
23	1.133 - 1.170	1.152
24	1.06 - 1.095	1.078

[a] From Earth Resources Data Format Control Book, NASA, Houston, Sept. 1972, page 2.2 - 105.

Table 2. Channel optimization tests using analysis of variance and average pairwise probability of misclassification for 7 vegetative categories using the Bendix 24 channel MSS.

Channel [a]	F-Ratio	Reservoir	
		Standard deviation	Odd to even ratio
7**	45	1.70	3.10
8**	39	2.22	1.40
18**	39	6.51	2.47
10	38	2.11	9.21
9*	38	2.13	11.58
6	37	4.25	5.76
24	36	7.26	4.66
19*	34	6.29	6.03
3**	33	1.53	37.70
11	32	1.48	Infinity
2*	29	1.09	11.88
14*	27	1.65	1.45
1*	24	2.25	1.06
5	22	1.44	6.03
17	21	6.98	7.07
23*	18	6.44	.08
13	11	7.86	12.53
4	7	3.48	2.71
21	7	16.24	4.10
12	6	6.80	3.75
15	5	19.15	3.70
20	3	23.89	5.76
22	3	27.52	5.85
16	1	4.12	.11

[a] The 10 best channels, according to a pairwise probability test, are marked with double and single asterisks and the best 4 channels are marked with double asterisks.

Table 3. Overall percent recognition (column A) using the 24-channel multispectral scanner training data for seven vegetation categories (Stoneville 213 cotton, Anton SP-21 cotton, Valencia orange, Red blush grapefruit, sugarcane, Coast-Cross 1 bermudagrass, and African stargrass) are listed for the optimum seven MSS channels as ranked using an average pairwise probability of misclassification procedure. Percent recognition results are given for the best single channel (7), the best two channels (7, 8), the best three channels (7, 8, 3), and so on. Overall recognition results (column B) are given for four categories obtained from combining plants of the same genera of the original seven: Stoneville and Anton become cotton (Gossypium); Valencia orange and Red blush grapefruit become citrus (Citrus); and Coast-Cross 1 bermudagrass and African stargrass become grass (Cynodon).

Average pairwise probability ranking of MSS channels	Overall Percent recognition	
	A	B
7	31.6	56.9
8	49.7	66.9
3	65.6	82.6
18	70.1	86.6
1	76.7	91.9
14	77.9	92.8
2	77.9	92.8

Table 4. Recognition results, for the 7 training categories of vegetation, using the best 4 Bendix MSS channels of Mission 207 (7, 8, 3, 18).

Ground truth Identification of Training Categories	Number of Resolution Elements	Percent Recognition	Computer Identification of Training Categories							
			Stoneville 213	Anton SP-21	Valencias	Red Blush	Sugarcane	Coast Cross 1 Bermudagrass	African stargrass	Threshold a/
Stoneville 213	44	65.9	29	13	0	0	0	1	0	1
Anton SP-21	56	48.2	25	27	0	0	0	1	0	3
Valencia	128	60.9	0	0	78	34	0	4	10	2
Red Blush	128	64.8	1	1	19	83	2	13	5	4
Sugarcane	32	78.1	0	6	0	0	25	0	0	1
Coast-Cross 1 bermudagrass	112	83.9	0	2	0	2	7	94	4	3
African stargrass	79	88.6	0	0	0	5	0	1	70	3

Overall Percent Recognition Results 70.1

a/ Any sample values not classified as any of the 7 training categories were placed in an "other" category called threshold.

Table 5. Recognition results of training categories after combining the original 7 categories of Stoneville 213 cotton, Anton SP-21 cotton, Valencia orange, Red blush grapefruit, Sugarcane, Coast-Cross 1 bermudagrass, and African stargrass into the categories cotton, citrus, sugarcane, and grass.

Ground truth identification of training categories	Number of resolution elements	Percent recognition	Computer identification of training categories				
			Cotton	Citrus	Sugarcane	Grass	Threshold
Cotton	100	94.0	94	0	0	2	4
Citrus	256	83.6	2	214	2	32	6
Sugarcane	32	78.1	6	0	25	0	1
Grass	191	88.5	2	7	7	169	6

Overall Percent Recognition Results 86.6 percent

Table 6. Recognition results of 23 test areas of the USDA Weslaco Research Farm. Area 21 (bare soil east of Research Farm) was recognized almost totally as threshold (676 pts out of 766). For this reason an adjusted threshold percent recognition was also determined.

Test categories	Number of resolution elements	Percent correct recognition	Computer identification of test categories										
			Cotton	Reservoir	Sugarcane	Hwy 88	Stargrass	Coast-Cross 1 bermudagrass	Valencia	Red blush	Bare soil+ weeds	Bare soil	Threshold
Cotton	578	70.1	405	0	28	0	21	54	3	44	18	0	5
Reservoir	541	98.2	0	531	0	0	0	0	0	5	0	0	5
Sugarcane	102	88.2	0	0	90	0	0	0	0	0	0	0	12
Hwy 88	212	84.4	1	0	0	179	0	0	0	0	12	0	20
Stargrass	79	93.7	0	1	0	0	74	0	0	2	2	0	0
Coast-Cross 1 bermudagrass	194	57.7	1	0	35	0	7	112	17	10	0	12	0
Valencia	1611	33.4	2	0	6	0	122	42	538	622	124	131	24
Red blush	1052	50.8	46	0	33	0	41	104	96	534	79	27	92
Bare soil + weeds	842	88.1	0	0	0	0	0	24	6	9	742	60	1
Bare soil	452	62.6	0	0	0	0	0	11	4	7	147	283	0
Total	5663												

Overall Percent recognition 61.6 percent

Table 7. Percent recognition results of 23 test sites of the Research Farm for the categories cotton, water, sugarcane, highway 88, grass, citrus, and bare soil. Site 21 (bare soil east of Research Farm) was identified as almost totally threshold (676 pts out of 766). For this reason an adjusted percent recognition result was determined.

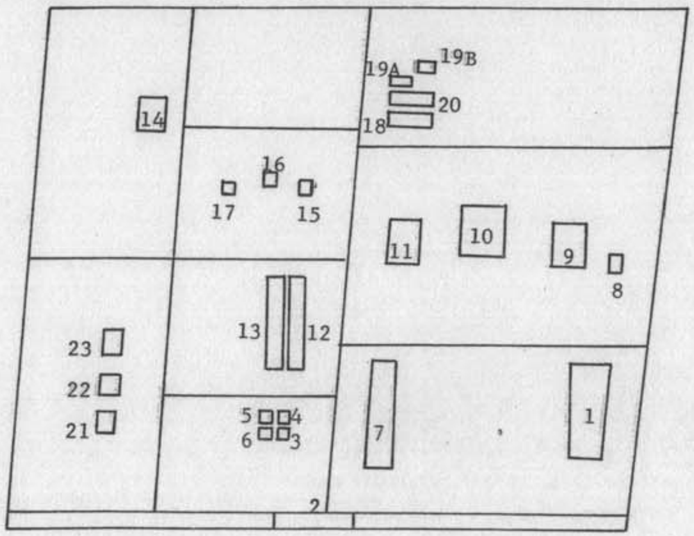
Test categories	Number of resolution elements	Percent correct recognition	Computer identification of test categories							
			Cotton	Reser-voir	Sugar-cane	Hwy 88	Grass	Citrus	Bare soil	Thres-hold
Cotton	578	70.1	405	0	28	0	75	47	18	5
Water	541	98.2	0	531	0	0	0	5	0	5
Sugarcane	102	88.2	0	0	90	0	0	0	0	12
Highway 88	212	84.4	1	0	0	179	0	0	12	20
Grass	273	70.7	1	1	35	0	193	29	14	0
Citrus	2663	67.2	48	0	39	0	309	1790	361	116
Bare soil	1294	95.2	0	0	0	0	35	26	1232	0
Total	5663									
Overall percent recognition		78.1 percent								

Table 8. Machine classification result of a scene that included the USDA Research Farm. Of the 61,000 resolution elements per channel in this scene the number of resolution elements classified into each category, the percent of total, and acreage estimate are given for each category for two different threshold settings.

Category	5.0 percent threshold a/			1.0 percent threshold b/		
	Number of resolution elements	Percent of total	No. of acres	Number of resolution elements	Percent of total	No. of acres
Cotton	3,509	5.75	3.53	4.890	8.01	4.93
Water	860	1.40	.86	880	1.44	.88
Sugarcane	2,150	3.52	2.16	2,532	4.15	2.55
H. W. 88	1,037	1.70	1.06	1,558	2.55	1.57
Stargrass	1,783	2.92	1.81	1,967	3.22	1.98
Coast-Cross 1	6,229	10.21	6.29	7,096	11.63	7.15
Valencias	2,899	4.75	2.92	4,075	6.68	4.11
Red blush	9,286	15.22	9.36	11,112	18.21	11.22
Bare soil & weeds	16,945	27.77	17.03	21,620	35.44	21.81
Bare soil	3,571	.85	3.61	4,608	7.55	4.64
Threshold	12,731	20.87	12.85	662	1.08	.66
Total	61,000	100.00	61.50	61,000	100.00	61.50

a/ A chi-square value was selected such that assuming a normal distribution only .5 percent of the samples would fall into a threshold category. As can be seen 20.87 percent of the samples fell into the threshold category so that our normal distribution assumption is not valid for the whole Research Farm.

b/ A chi-square value of 99.9 was used that effectually reduces the threshold category to zero percent. Some sites, mainly roof top, were still placed in the threshold category.



Identity:	Site number:
Water reservoir	1
Highway 88	2
Dwarf cotton	3
SP-37 cotton	4
Stoneville 213 cotton	5
Anton SP-21 cotton	6
Bare soil	7
Rooftop	8
Valencia oranges	9
Red blush grapefruit	10
Marrs oranges	11
Anton SP-21 cotton	12
Stoneville 213 cotton	13
Bare soil and weeds	14
Sugarcane (S2-I2)	15
Sugarcane (S2-I3)	16
Sugarcane (S2-I1)	17
Red blush grapefruit (1)	18
Red blush grapefruit (2)	19
Red blush grapefruit (3)	20
Coast-Cross 1 bermudagrass	21
Coastal bermudagrass	22
African stargrass	23

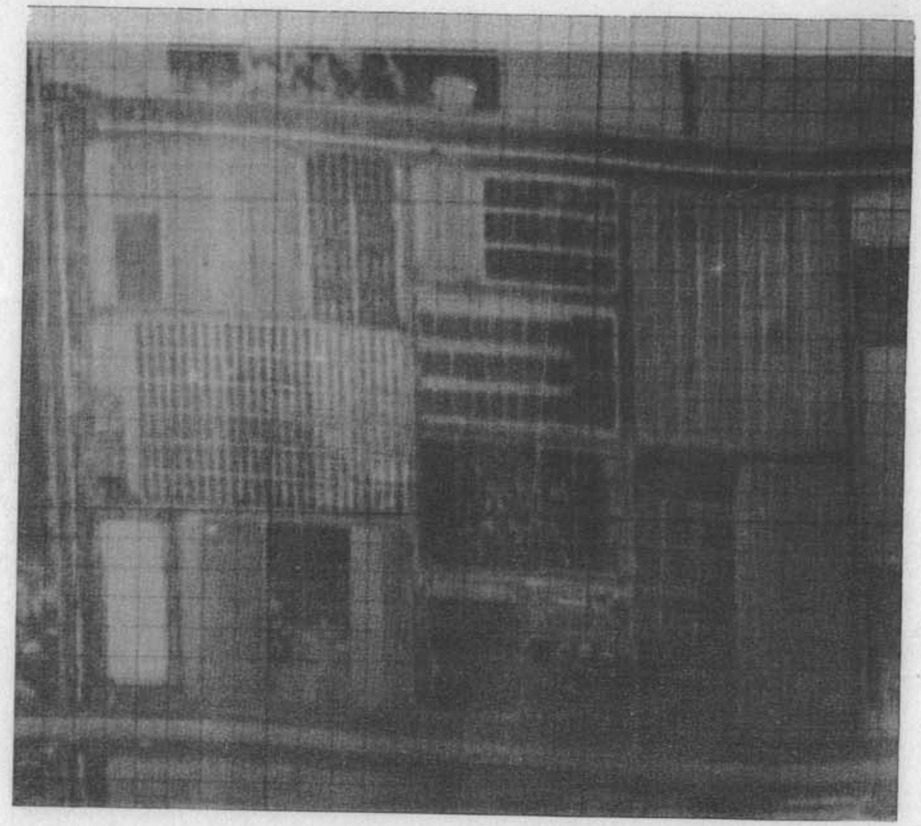


Figure 1. Dicomed D-36 display gray map of MSS channel 7 and diagram (on the left) showing where 23 test areas on the Research Farm were selected for agricultural land use studies.

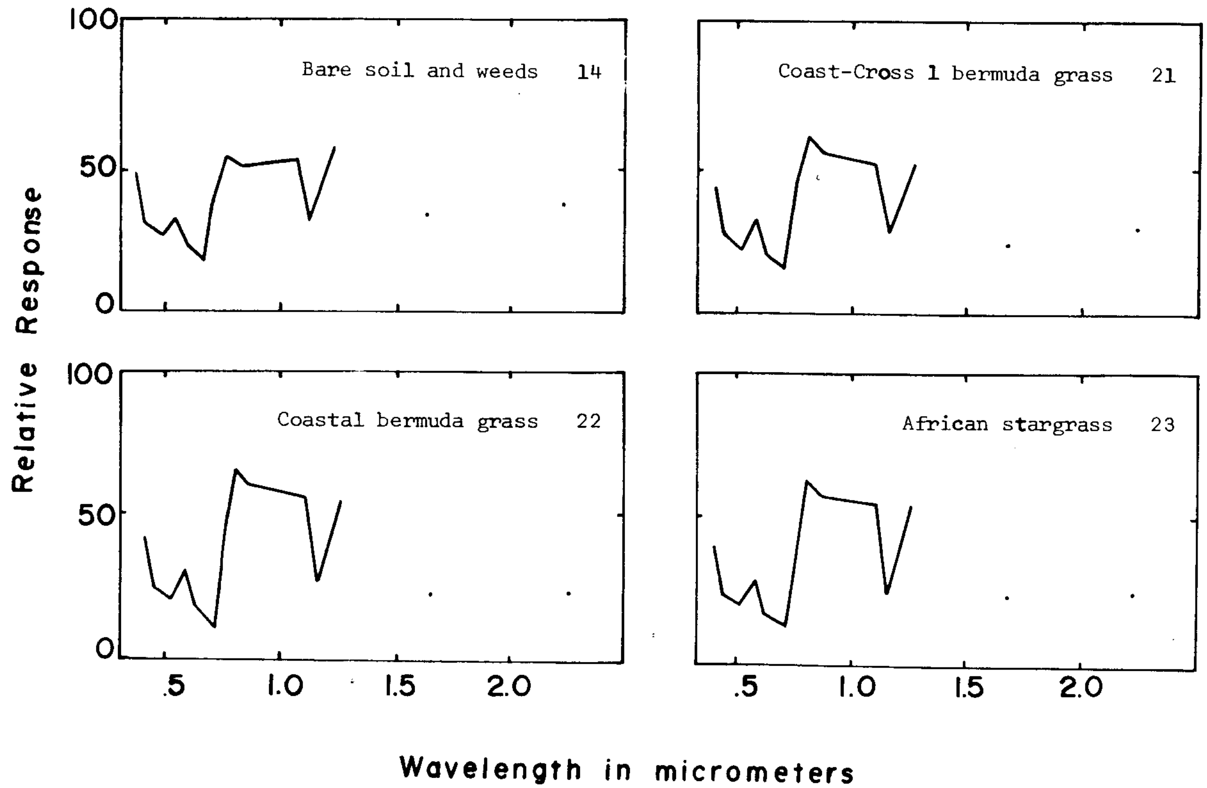


Figure 2. Average multispectral signatures of 4 of the 23 test areas over the wavelength interval 0.34 to 2.5 μm collected by the 24-channel ERTS-1 aircraft support multispectral scanner. For site number identification, see Table 2 or Figure 1 diagram.

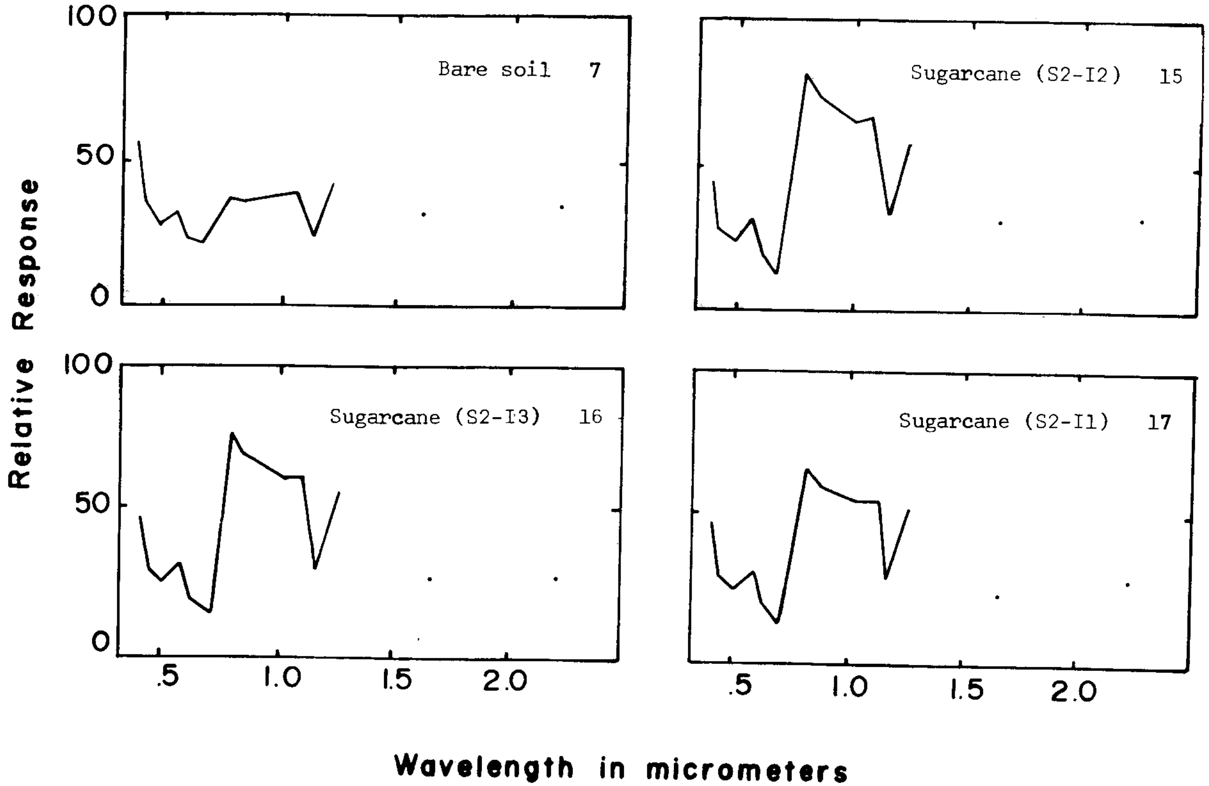


Figure 3. Average multispectral signatures of 4 of the 23 test areas over the wavelength interval 0.34 to 2.5 μm collected by the 24-channel ERTS-1 aircraft support multispectral scanner. For site number identification, see Table 2 or Figure 1 diagram.

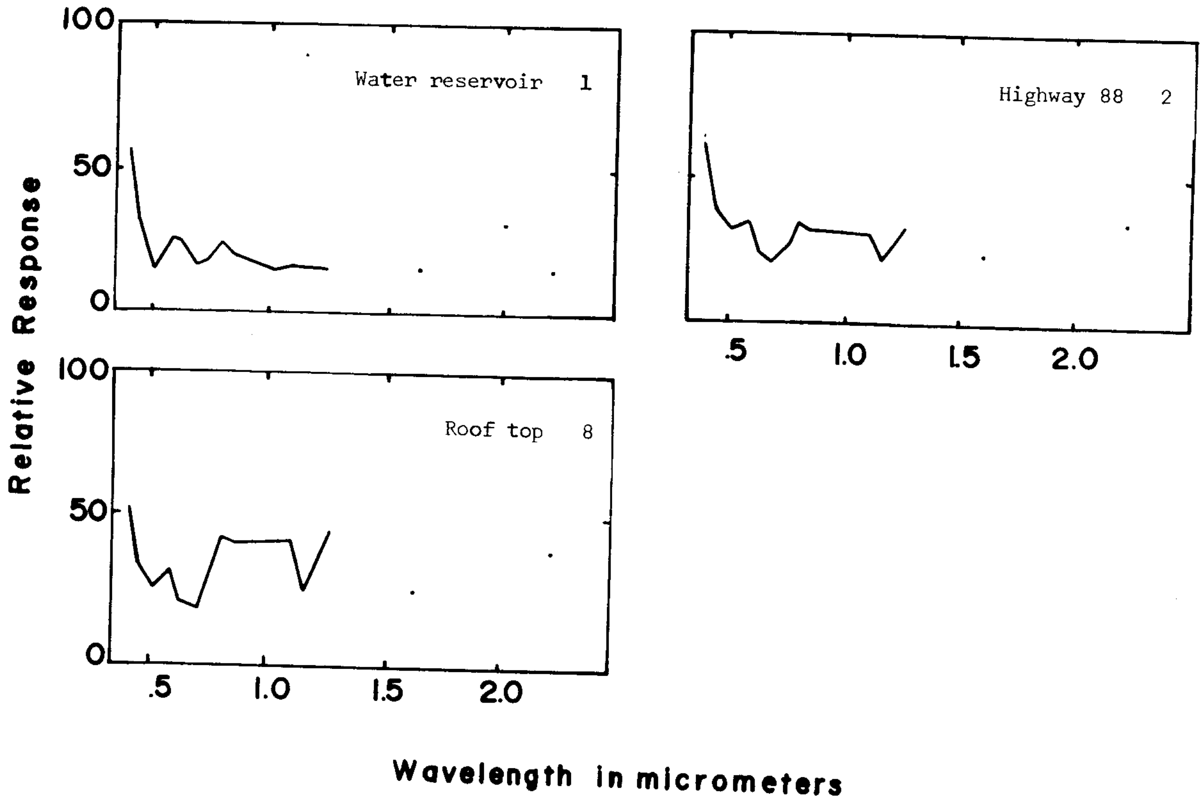


Figure 4. Average multispectral signatures of 3 of the 23 test areas over the wavelength interval 0.34 to 2.5 μm collected by the 24-channel ERTS-1 aircraft support multispectral scanner. For site number identification, see Table 2 or Figure 1 diagram.

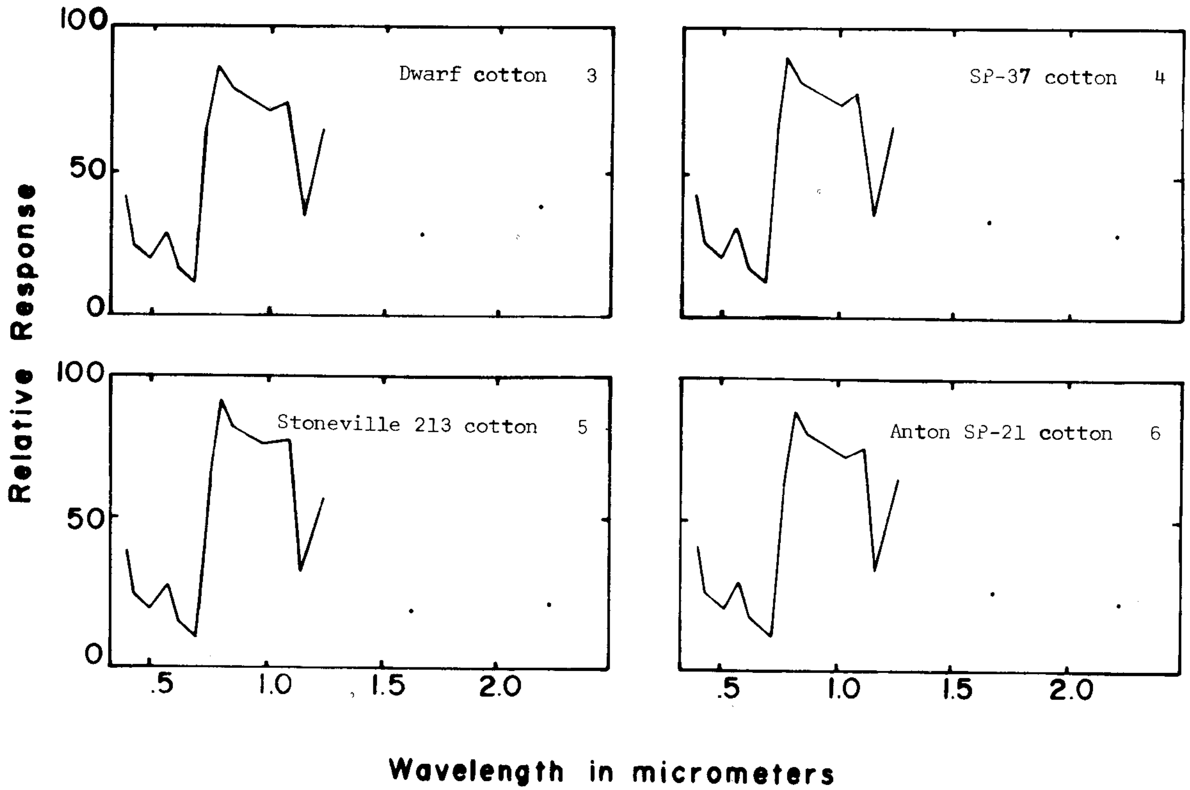


Figure 5. Average multispectral signatures of 4 of the 23 test areas over the wavelength interval 0.34 to 2.5 μm collected by the 24-channel ERTS-1 aircraft support multispectral scanner. For site number identification, see Table 2 or Figure 1 diagram.

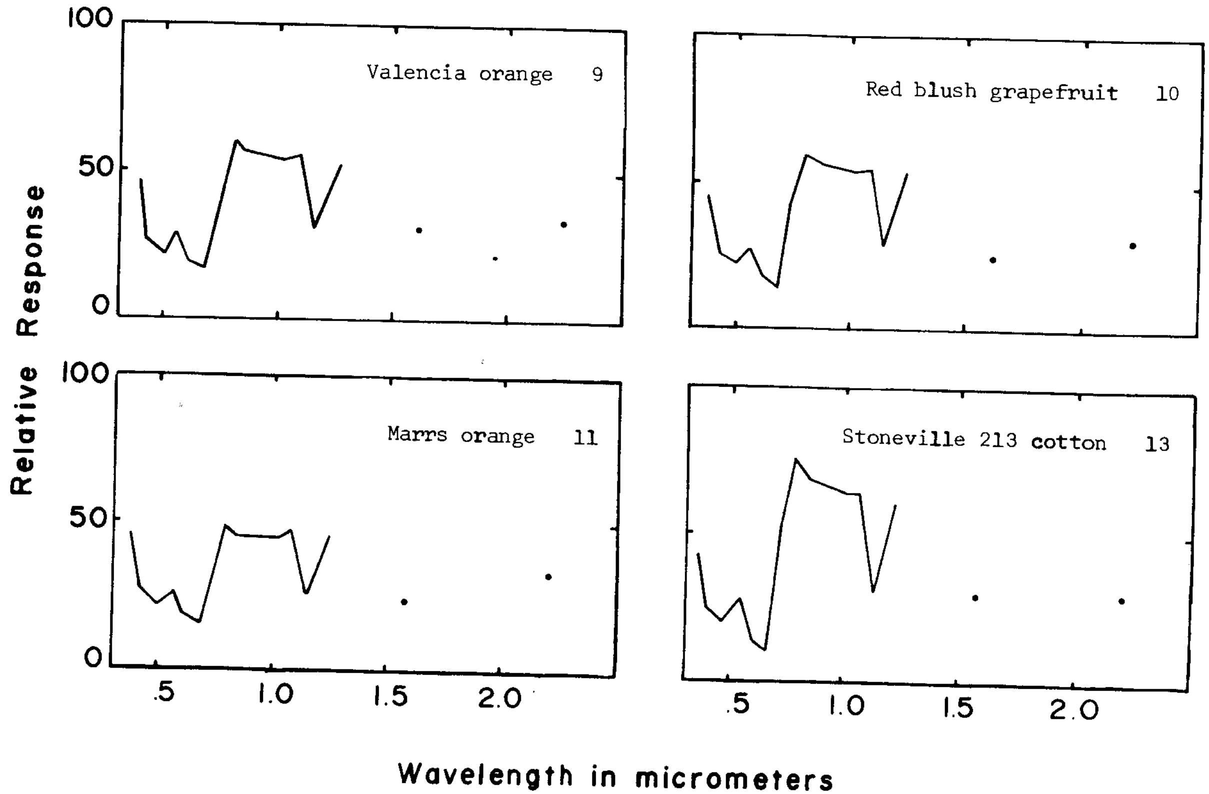


Figure 6. Average multispectral signatures of 4 of the 23 test areas over the wavelength interval 0.34 to 2.5 μm collected by the 24-channel ERTS-1 aircraft support multispectral scanner. For site number identification, see Table 2 or Figure 1 diagram.

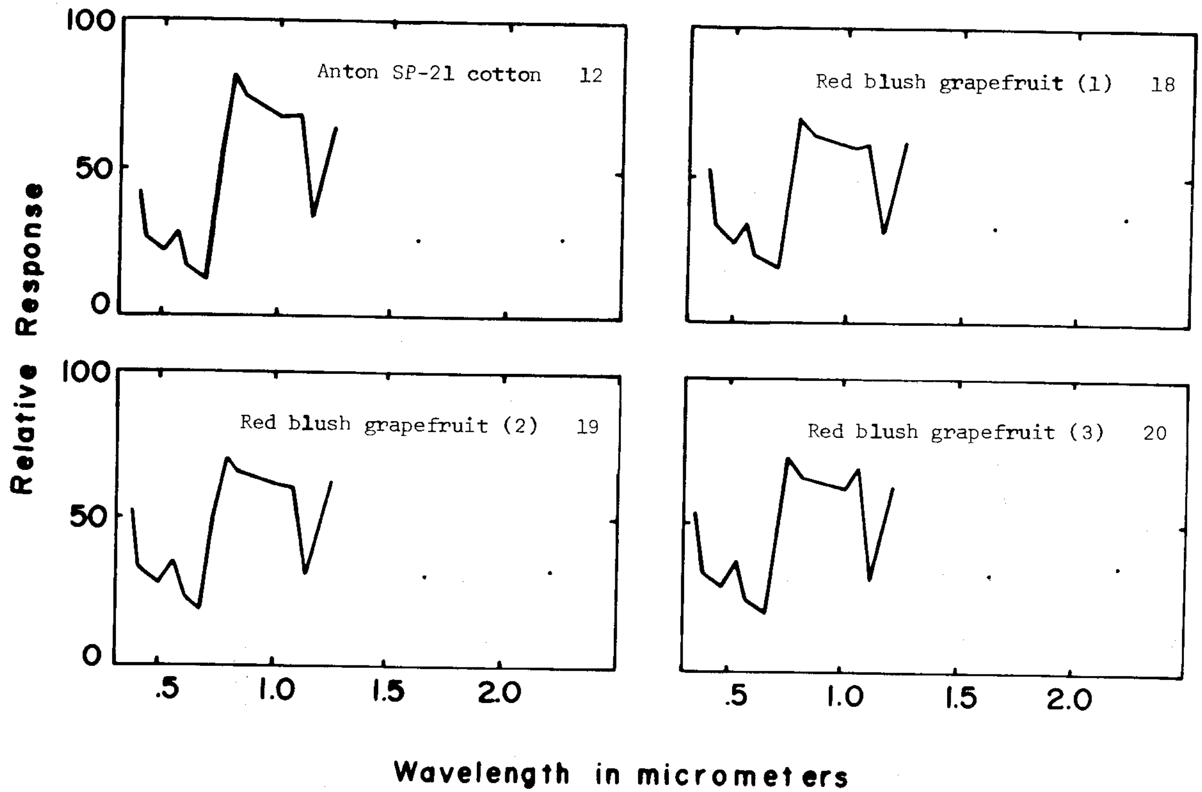


Figure 7. Average multispectral signatures of 4 of the 23 test areas over the wavelength interval 0.34 to 2.5 μm collected by the 24-channel ERTS-1 aircraft support multispectral scanner. For site number identification, see Table 2 or Figure 1 diagram.

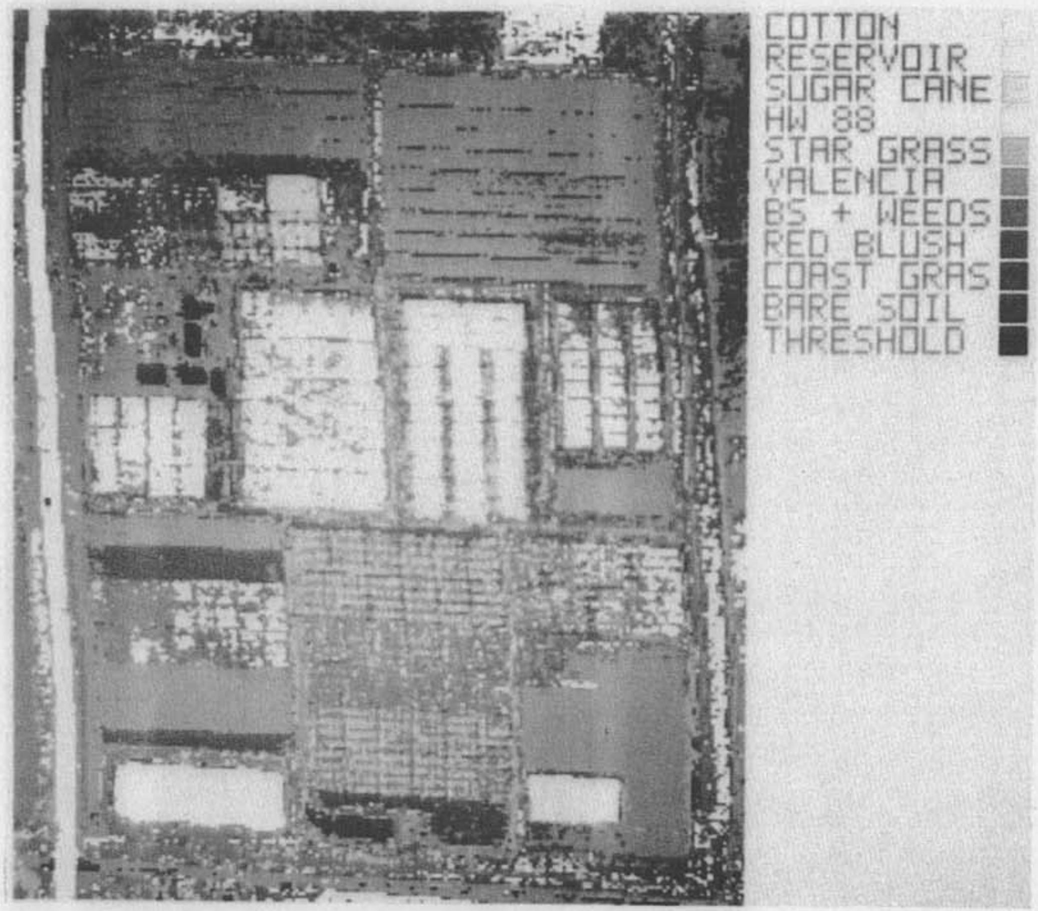


Figure 8. Recognition map of USDA Research Farm, at Weslaco, Texas, using the best 4 out of 24 Bendix multispectral scanner channels (8, 7, 3, 18) to classify 10 categories as listed in the figure.