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MULTISPECTRAL CLASSIFICATION OF CROPS IN THE IMPERIAL VALLEY, CALIFORNIA FROM DIGITIZED APOLLO 9 PHOTOGRAPHY

PAUL E. ANUTA

The Laboratory for Applications of Remote Sensing

Purdue University,   West Lafayette, Indiana

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Crops in the Imperial Valley, California

from Digitized Apollo 9 Photography

by

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INTRODUCTION

Data were collected by the Apollo 9 astronauts over a large region of
Southern California. Specific areas in the Imperial Valley, California such as
15A Dogwood Road and 15D McCabe Road were studied in more detail. The results
of crop analysis by pattern recognition techniques using a computer are reported
herein. Analyses were performed on the entire test site S065 and will be reported
in another LARS information note.

Earlier results reported as "Green Vegetation" on the Dogwood Road and McCabe
Road test sites were classified in more detail as barley, sugar beets and alfalfa.
Other classes used in the classification included bare soil, salt flats and water.

DATA COLLECTION

Three 70mm black and white transparencies and one color infrared transparency
of the Imperial Valley and the surrounding area were obtained simultaneously by
the Apollo 9 astronauts. "The color infrared film was used as a panchromatic band
covering .51 to .79 micrometer, Channel 1. The black and white photographs were
taken with different films and filters to obtain data as follows: green filter
.46-.61 micrometer range, Channel 2; reflective infrared black and white film,
.68-.89 micrometer range, Channel 3; and red filter .59-.71 micrometer range,
Channel 4.

The "B&W and color" multispectral exposures of the Apollo 9 frame 3698 were digitized with a microdensitometer. They were then overlayed and gray scale printouts were produced by the LARS system.

DATA ANALYSIS

Training data were extracted for test sites 15A Dogwood and 15D McCabe Roads (Figure 1) using histogram inspection and clustering analysis. In analysis of the Dogwood area the following number of sub-classes were selected for use: barley-2, sugar beets-3, alfalfa-2, bare soil-6, salt flats-2, and water-1. In the analysis of the McCabe area, the following number of sub-classes were selected: barley-3, sugar beets-3, alfalfa-3, bare soil-3, salt flats-1, and water-0. There were 554 fields in the two test sites and approximately 40 or 7.2 percent were chosen for training fields; 174 or 31.4 percent were chosen for test fields.

Field numbers used were those defined in the ground truth report over the Imperial Valley by Miss Norma Spansail, University of Michigan.

RESULTS

Table 1 contains the individual field results for the Dogwood area in the per field classification. Listed by the field numbers in flightline 15A are the classification by ground truth and the classification by the LARS computer system. With this flight line, 15A, the classification was best when all channels were utilized. The overall classification accuracy was 70.8 percent.

Table 2 contains the results for each field in the McCabe area. The best results were obtained using channels 2, 3, and 4. Ground truth and final computer classification by field number are given for each field. The overall classification accuracy for the area was 70.6 percent.

The test field classification accuracies for the Dogwood area in flightline 15A are presented for all classes and channels in Figure 2. The same information for the McCabe area in flightline 15D are presented in Figure 3.

Certain channels or combinations of channels were found to produce the highest classification results depending on the area and crop being analyzed. Table 3 lists the crop, highest accuracy obtained and the channel(s) used to obtain the results for the Dogwood Area. Similar results for the McCabe area are presented in Table 4.

DISCUSSION

The results of the classification of the two flightlines (15A and 15D) over the Dogwood and McCabe Roads areas point out that no single channel or combination of channels were best for all crops. The green crops with a high percentage of ground cover (barley, sugar beets and alfalfa) had similar spectral responses: medium in the green, very low in the red, and high in the near infrared portion of the spectrum. The differences in the responses of these crops were sufficient to provide reasonable separability. Because the bare soil, salt flat and water spectral responses are very different, they are more easily separated and a higher classification accuracy is achieved for each.

These results indicate that for optimum classification, channels best suited for each crop and/or each surface feature must be utilized. For example, the barley classification is low when the channel containing green (.46-.61 micrometers) is used alone and fairly good for all other combinations. The sugar beet recognition is good using all four channels, but tends to fall off in accuracy, especially when green (.46-.61 micrometers) and infrared (.51-.79 micrometers) channels are used individually.

It is known that on aerial photography, green vegetation, bare soil, salt flats and water can be accurately distinguished. The research results reported herein from digitized photographs indicated that the barley and sugar beets can be separated. However, they may not be separated with high enough accuracy for crop control surveys or other work demanding precise classifications. Low ground cover crops such as lettuce, onions and carrots appear to be indistinguishable from bare soil.

Table 1. Per field classification in the Dogwood Road area flightline 15A

utilizing data collected in the .51-.79, .46-.61, .68-.89, .59-.71

micrometer ranges

Field No.	Ground Truth Classification	Computer Classification	Field No.	Ground Truth Classification	Computer Classification
2	Barley	Barley	267	Sugar Beets	Sugar Beets
6	Barley	Barley	289	Sugar Beets	Sugar Beets
12	Barley	Barley	290	Sugar Beets	Sugar Beets
17	Barley	Sugar Beets	291	Sugar Beets	Alfalfa
18	Barley	Barley	292	Sugar Beets	Sugar Beets
19	Barley	Barley	298	Sugar Beets	Barley
20	Barley	Alfalfa	13	Alfalfa	Sugar Beets
36	Barley	Barley	15	Alfalfa	Barley
47	Barley	Barley	14	Alfalfa	Barley
48	Barley	Barley	22	Alfalfa	Alfalfa
71	Barley	Barley	42	Alfalfa	Sugar Beets
76	Barley	Barley	39	Alfalfa	Sugar Beets
104	Barley	Barley	50	Alfalfa	Sugar Beets
105	Barley	Sugar Beets	58	Alfalfa	Sugar Beets
119	Barley	Sugar Beets	186	Alfalfa	Sugar Beets
143	Barley	Bare Soil	282	Alfalfa	Sugar Beets
173	Barley	Barley	288	Alfalfa	Barley
198	Barley	Barley	1	Bare Soil	Bare Soil
199	Barley	Barley	5	Bare Soil	Bare Soil
213	Barley	Barley	7	Bare Soil	Bare Soil
227	Barley	Barley	8	Bare Soil	Bare Soil
240	Barley	Sugar Beets	11	Bare Soil	Bare Soil
243	Barley	Barley	21	Bare Soil	Bare Soil
244	Barley	Barley	44	Bare Soil	Bare Soil
249	Barley	Barley	41	Bare Soil	Bare Soil
279	Barley	Barley	45	Bare Soil	Bare Soil
284	Barley	Barley	46	Bare Soil	Bare Soil
285	Barley	Barley	61	Bare Soil	Bare Soil
16	Sugar Beets	Alfalfa	155	Bare Soil	Bare Soil
51	Sugar Beets	Sugar Beets	157	Bare Soil	Salt Flat
52	Sugar Beets	Sugar Beets	222	Bare Soil	Bare Soil
55	Sugar Beets	Alfalfa	230	Bare Soil	Salt Flat
59	Sugar Beets	Alfalfa	258	Bare Soil	Bare Soil
62	Sugar Beets	Sugar Beets	269	Bare Soil	Sugar Beets
66	Sugar Beets	Sugar Beets	98	Salt Flat	Salt Flat
77	Sugar Beets	Sugar Beets	101	Salt Flat	Salt Flat
154	Sugar Beets	Sugar Beets	106	Salt Flat	Salt Flat
163	Sugar Beets	Sugar Beets	125	Salt Flat	Salt Flat
164	Sugar Beets	Sugar Beets	126	Salt Flat	Salt Flat
245	Sugar Beets	Barley	127	Salt Flat	Salt Flat
248	Sugar Beets	Sugar Beets	128	Salt Flat	Salt Flat
263	Sugar Beets	Sugar Beets	158	Salt Flat	Salt Flat
262	Sugar Beets	Sugar Beets	159	Salt Flat	Salt Flat
266	Sugar Beets	Barley	221	Salt Flat	Salt Flat
			99	Water	Water

Table 2. Per field classification in the McCabe Road area (flightline 15D) utilizing data collected in .51-.79, .46-.61, .68-.89 and .59-.71 micrometer range

Field No.	Ground Truth Classification	Computer Classification	Field No.	Ground Truth Classification	Computer Classification
235	Barley	Sugar Beets	160	Alfalfa	Alfalfa
101	Barley	Barley	159	Alfalfa	Alfalfa
100	Barley	Barley	185	Alfalfa	Alfalfa
130	Barley	Barley	225	Alfalfa	Sugar Beets
2	Barley	Sugar Beets	124	Alfalfa	Sugar Beets
116	Barley	Sugar Beets	99	Alfalfa	Barley
213	Barley	Barley	236	Alfalfa	Barley
202	Barley	Barley	119	Alfalfa	Alfalfa
75	Barley	Barley	223	Alfalfa	Sugar Beets
26	Barley	Sugar Beets	104	Alfalfa	Alfalfa
115	Barley	Sugar Beets	117	Alfalfa	Barley
19	Barley	Barley	177	Alfalfa	Barley
48	Barley	Sugar Beets	216	Alfalfa	Alfalfa
62	Barley	Sugar Beets	29	Alfalfa	Barley
18	Barley	Barley	17	Alfalfa	Sugar Beets
90	Barley	Barley	51	Alfalfa	Barley
198	Barley	Barley	171	Alfalfa	Barley
79	Barley	Barley	14	Alfalfa	Alfalfa
60	Barley	Barley	12	Alfalfa	Alfalfa
89	Barley	Barley	209	Bare Soil	Bare Soil
80	Barley	Barley	158	Bare Soil	Bare Soil
52	Barley	Barley	127	Bare Soil	Bare Soil
34	Barley	Barley	157	Bare Soil	Bare Soil
82	Barley	Barley	128	Bare Soil	Bare Soil
16	Barley	Barley	156	Bare Soil	Bare Soil
59	Barley	Barley	163	Bare Soil	Bare Soil
87	Barley	Barley	122	Bare Soil	Bare Soil
83	Barley	Alfalfa	103	Bare Soil	Bare Soil
15	Barley	Barley	164	Bare Soil	Bare Soil
58	Barley	Alfalfa	118	Bare Soil	Bare Soil
57	Barley	Barley	45	Bare Soil	Bare Soil
179	Sugar Beets	Alfalfa	135	Bare Soil	Bare Soil
40	Sugar Beets	Sugar Beets	201	Bare Soil	Bare Soil
190	Sugar Beets	Sugar Beets	166	Bare Soil	Bare Soil
178	Sugar Beets	Alfalfa	168	Bare Soil	Bare Soil
214	Sugar Beets	Sugar Beets	76	Bare Soil	Bare Soil
39	Sugar Beets	Sugar Beets	151	Bare Soil	Bare Soil
74	Sugar Beets	Sugar Beets	169	Bare Soil	Bare Soil
63	Sugar Beets	Sugar Beets	114	Bare Soil	Bare Soil
170	Sugar Beets	Barley	77	Bare Soil	Salt Flat
86	Sugar Beets	Sugar Beets	78	Bare Soil	Bare Soil
55	Sugar Beets	Sugar Beets	61	Bare Soil	Salt Flat
			47	Salt Flat	Salt Flat

Table 3. Highest classification accuracy per field for each cover type
in the Dogwood area (flightline 15A) and channel(s) with which
results were obtained

Cover Type	Highest Accuracy in Per Cent	Channel(s)[a]
Barley	82.1	1
Sugar Beets	68.2	1 + 2 + 3 + 4
Alfalfa	27.3	2 + 4 - 1 + 3 + 4
Bare Soil	88.2	2 + 3
Salt Flats	100	All combinations except 1 + 2 + 3 - 1 + 2
Water	100	All combinations except - 4

[a] Channel 1 = .51-.79 micrometers, Channel 2 = .46-.61 micrometers, Channel 3 = .68-.89 micrometers, Channel 4 = .59-.71 micrometers.

Table 4. Highest Classification accuracy per field for each cover type in the McCabe area (flightline 15D) and channel(s) with which results were obtained

Cover Type[a]	Highest Accuracy in Per Cent	Channels[b]
Barley	83.9	3 + 4
Sugar Beets	72.7	1 + 3 - 1 + 4 - 1 + 2 + 4 - 2 + 3 + 4
Alfalfa	52.6	2 + 3
Bare Soil	100	2 - 2 + 3 - 2 + 4
Salt Flats	100	All combinations except 2 + 4 - 2 - 3

[a] No water was present in the area.

[b] Channel 1 = .51-.79 micrometers, Channel 2 = .46-.61 micrometers, Channel 3 = .68-.89 micrometers, Channel 4 = .59-.71 micrometers.
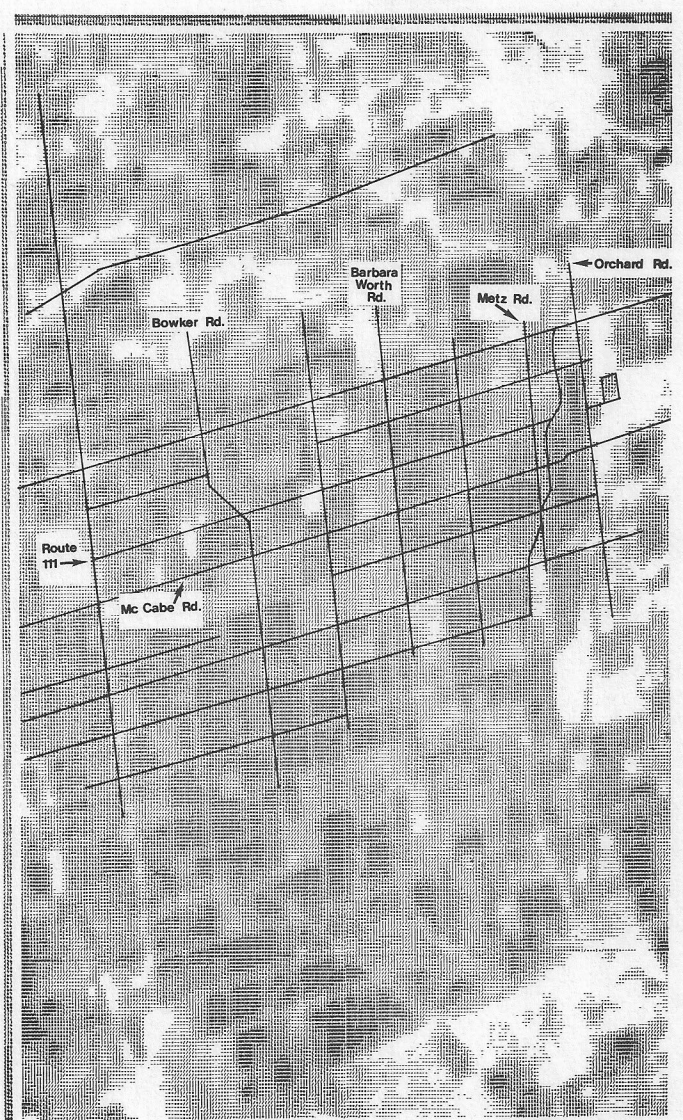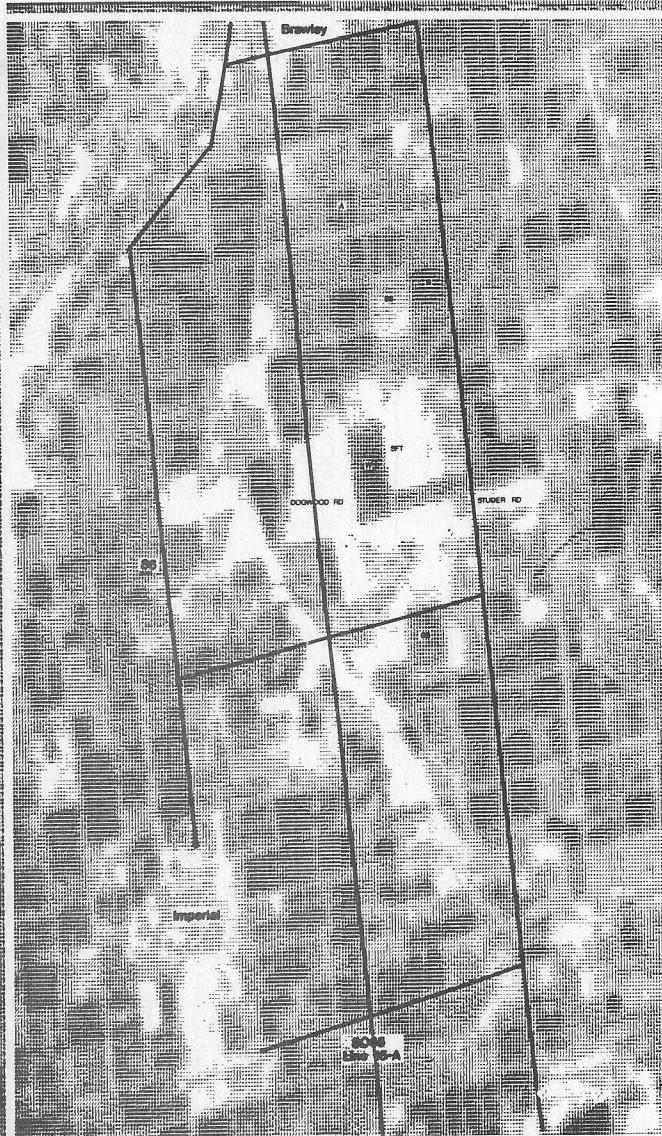
Figure 1   Gray scale printouts of Dogwood Road Area (left) and
McCabe Road area (right) in Imperial Valley with major
roads and cities indicated.
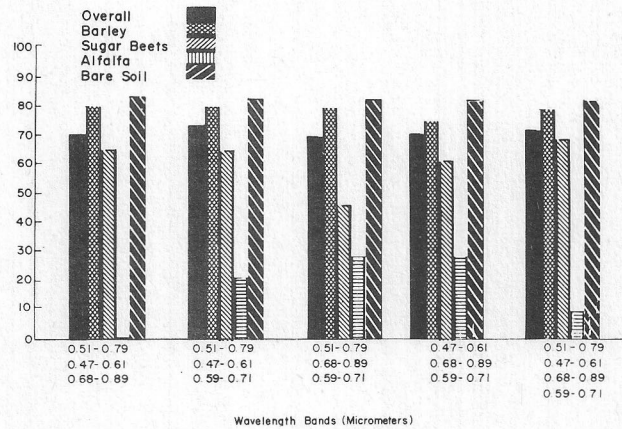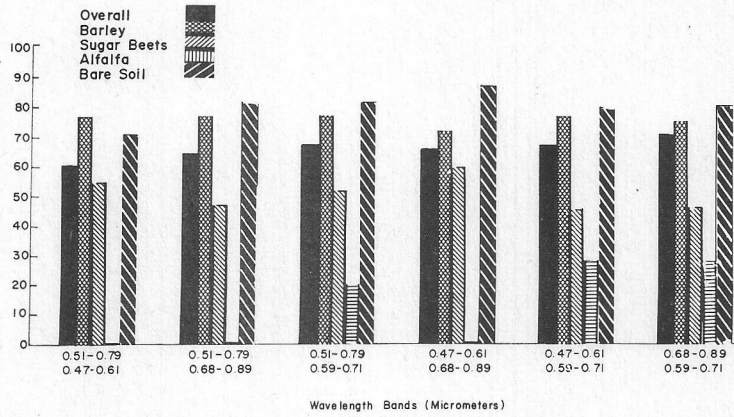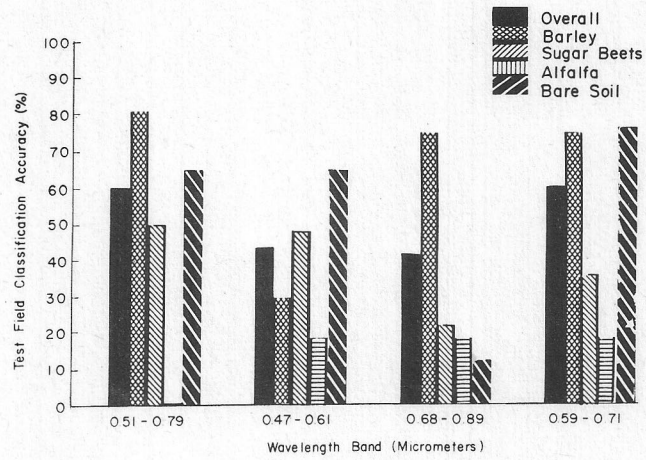
Figure 2   Test field classification accuracies for the Dogwood
            Road area (SO65 Flightline 15A) using the "Per Field"
            classifier. Results for all combinations of the four
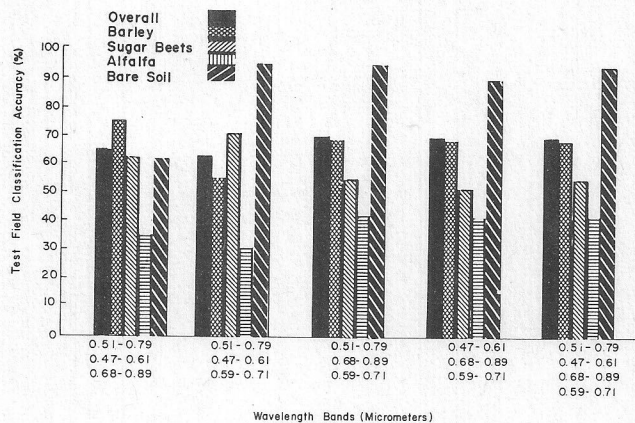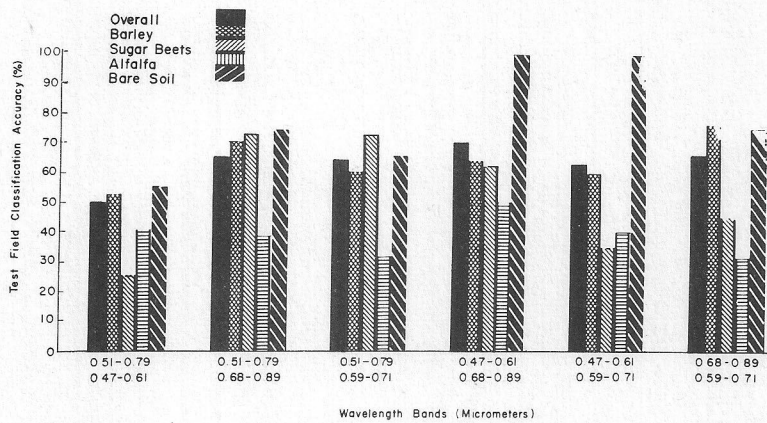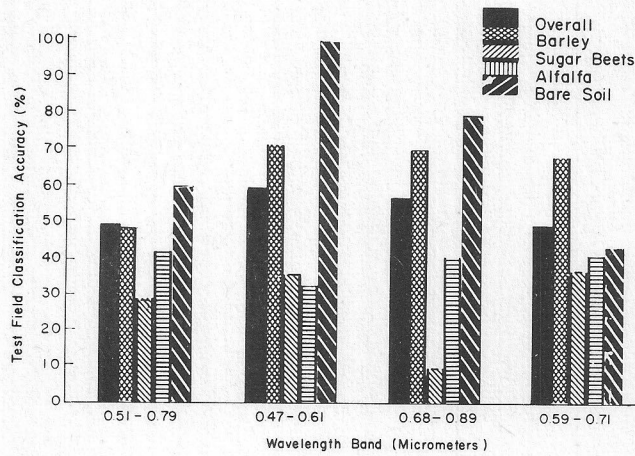   channels are shown.

Figure 3   Test field classification accuracies for McCabe Road
(Flightline 15D) using the "Per Field" classifier.
Results for all combinations of the four channels.