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SEMI-AUTOMATIC CROP INVENTORY FROM SEQUENTIAL ERTS-1 IMAGERY

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ABSTRACT

The detection of a newly introduced crop into the Imperial (California) Valley by sequential ERTS-1 imagery is proving that individual crop types can be identified by remote sensing techniques. Initial results have provided an extremely useful product for water agencies. A system for the identification of field conditions enables the production of a statistical summary within two to three days of receipt of the ERTS-1 imagery. The summary indicates the total acreage of producing crops and irrigated planted crops currently demanding water and further indicates freshly plowed fields that will be demanding water in the near future. Relating the field conditions to the crop calendar of the region by means of computer techniques will provide specific crop identification for the 8000 plus fields.

1. INTRODUCTION

At the conclusion of the first named authors report on Crop Inventory of the Imperial Valley from Apollo IX it was stated that the identification of specific crops could be greatly improved over the 60% accuracy attained, if sequential imagery from satellites could be obtained. ERTS-1 has provided such imagery! Each successive image is supplying additional proof that in the laboratory environment of the Imperial Valley automatic crop identification is possible.

The objective of the current investigation is to develop a semi-automatic system that will identify the specific crop being produced in each of the 8000 plus fields in the Imperial Valley. Time is of the essence if data interpreted from ERTS is going to be useful to the water managers, the packers, the shippers, the market specialists, the loan bankers, ad infinitum. Therefore, any system must produce results in the shortest possible time, and certainly no longer than one week after the instant inventory is obtained.

Initial results from ERTS-1 indicate that the data can be interpreted, analyzed, and produced within two to three days with less than 40 man hours and a few minutes computer time. A "spin off" result of the procedure provides an immediate assessment of irrigation demands that will hold for the entire 18 days between ERTS-1 cycles.

2. ANALYSIS AND METHODOLOGY

The system adopted for the research is somewhat unique from several other types of crop identification systems. It combines the best talents of man and machine to produce rapid results. More unique is the lack of dependence on the variability of the color infrared response as the prime differentiation factor between crop types. The system does depend upon both: (1) the ability to detect individual field conditions from ERTS-1, and (2) the ability to relate sequential field conditions to the regional crop calendar. The key to rapid analysis in the current study is the use of the multi-spectral response to detect only the presence or absence of a producing crop in a field.

The quality of resolution from ERTS-1 imagery has proven to be better than that experienced with Apollo IX imagery. Superimposition of the imagery onto a 1:62,500 scale base map enables the detection of field conditions of fields as small as 10 acres (4 hectares) and a few even smaller 5 acre (2 hectares) plots. However, because of the uncertainty of detection (or identification) of all fields below 20 acres (8 hectares) the project is being limited to the monitoring of fields of 20 acres and greater. Less than 2% of the total farmable acres are affected by this decision. The resolution will permit the first dependent criteria of individual field detection to be met, but can the field condition be identified?

The first thing noted on the ERTS-1 imagery of the Imperial Valley was four distinct colors within the agricultural fields - red, purple, lavender or brown, and white. Certainly the red from false color multispectral infrared imagery relates to vegetation which we can identify as growing crops. The white color easily relates to dry bare fields in the arid desert climate. The bare fields can be either fallow fields awaiting the next crop rotation or they can be fields which have been abandoned because of uneconomical production due to salinity problems. The other two colors proved to be the transition activity from fallow field to producing field. The moisture content revealed by a freshly plowed field produces a light brown or lavender color on the ERTS-1 color combined image. Likewise, the moisture response of a freshly irrigated field in which the seed has not yet germinated will produce a deep purple or dark blue response on the color combined ERTS-1 image. The difference between purple and blue is in the quality control factor of the color combined image produced from bands 4, 5, and 7 of the multi-spectral scanner images. The detection of four simple colors enables us to follow the farming cycle from fallow, to plowed, to irrigated seed, to growing crop, and in the case of grain crops to the harvest cycle. The latter case occurs when the maturing crop turns to yellow or golden brown or even when only the yellow stubble remains in the field. A yellow response on the ERTS imagery thus indicates a mature or harvested grain crop. A color that has not yet occurred in Imperial Valley, but has been seen in the Central Valley of California is the black resulting from the burning of the grain stubble fields. Again we have seen that the detection of the individual field condition is possible from ERTS imagery and our first dependent identification factor can be satisfied. What about relating the field condition to the crop calendar?

Table 1 relates the Imperial Valley Crop Calendar to ERTS-1 cycles 2, 4, 6, and 8. For the purposes of computer manipulation the five field conditions detectable on ERTS have been coded 1 for growing crops, 2 for wet planted fields, 3 for plowed fields, 4 for bare fields, and 5 for harvested fields. Reference to the specialized calendar indicates how a crop such as sugar beets will change from bare soil to a growing crop over the four 36 day cycles of ERTS-1. A computer program that will examine the cyclic record of each of the 8000 plus fields and establish the most likely specific identification based upon the crop calendar is presently being written. Previous experience with a similar type computer program suggests that 93 to 97% accuracy can be anticipated.

The use of the variation in the red hues to assist in differentation of crop types has not been completely discarded by the authors, but previous experience has produced serious reservations about the effectiveness of the color variation factor. Uncontrollable factors of variation are introduced into color infrared imagery by initial film production, physical factors occurring at the time the image is obtained, phenelogical and maturation factors in the vegetation itself, even reproduction factors in the color combining process, and variations in the final film processing. Time restraints have made us decide that we should not rely too heavily on the red color variations for crop identification at this time.

The current timing for production of statistics for one ERTS-1 cycle is 5-6 hours of field condition interpretation from a superimposed image onto the base map. Approximately 25-30 hours of coding and keypunching the data from the base map to computer cards are required. To complete the statistical summaries shown in Table 2 about 30 seconds of IBM 360 computer time is required.

3. RESULTS

The detection on the December 12 (cycle 8) ERTS-1 imagery of a newly introduced crop into the Imperial Valley and subsequent reference to previous sequential imagery provides strong indications that the crop calendar system will be successful. On the December image eight fields totaling 900 acres (364 hectares) appeared as a very distinctive orange-yellow. Located in the northeast area of the valley, to the east of

Wiest Lake, the field conditions did not fit the crop calendar pattern for a harvested crop. These fields then became the first crops that did not fit into the 97% identifiable category. Reference to the 1972 Crop Report of the Imperial Irrigation District revealed a new crop under production. In 1971 80 acres (32 hectares) of a new crop (Alicia Grass) was tested. In 1972 over 1000 acres (405 hectares) of Alicia Grass was planted. Alicia Grass is a variety of Bermuda Grass and is grown to provide a high protein fresh hay that will produce in mid-winter. The calendar for Alicia Grass indicates that it should be ready for harvest in mid-December and will thus provide the only yellow response for this time of year in the Imperial Valley.

Table 2 summarizes the statistical "spin-off" generated by the investigation to date. The 460,000 farmable acres (186,155 hectares) can easily be monitored for field conditions as previously described. The decline of growing crop acreage from 33% down to 31% in the early fall is to be anticipated. Unlike many other areas of the United States the crop production begins to increase in November (43%) and will be expected to rise to a peak in late March or early April. The cyclic demands for irrigation water can be readily determined by both immediate crop demands and future needs. Future needs are indicated by the freshly plowed fields. Completion of the initial phase of the ERTS-1 project will provide the State Water agency and the Imperial Irrigation District a very definitive cyclic record of water demand throughout the year.

4. CONCLUSION

The ability to detect and identify individual field condition has been proven without question. The ability to automatically relate the field conditions to the crop calendar remains to be determined. The compilation of field condition data from four 36 day cycles from ERTS-1 provides the necessary input to test a computer program that will examine each of these cycles for each of the 8000 plus individual fields and predict what crop each of the fields is producing. The remaining months of the contract will be devoted to the completion and testing of the computer program.

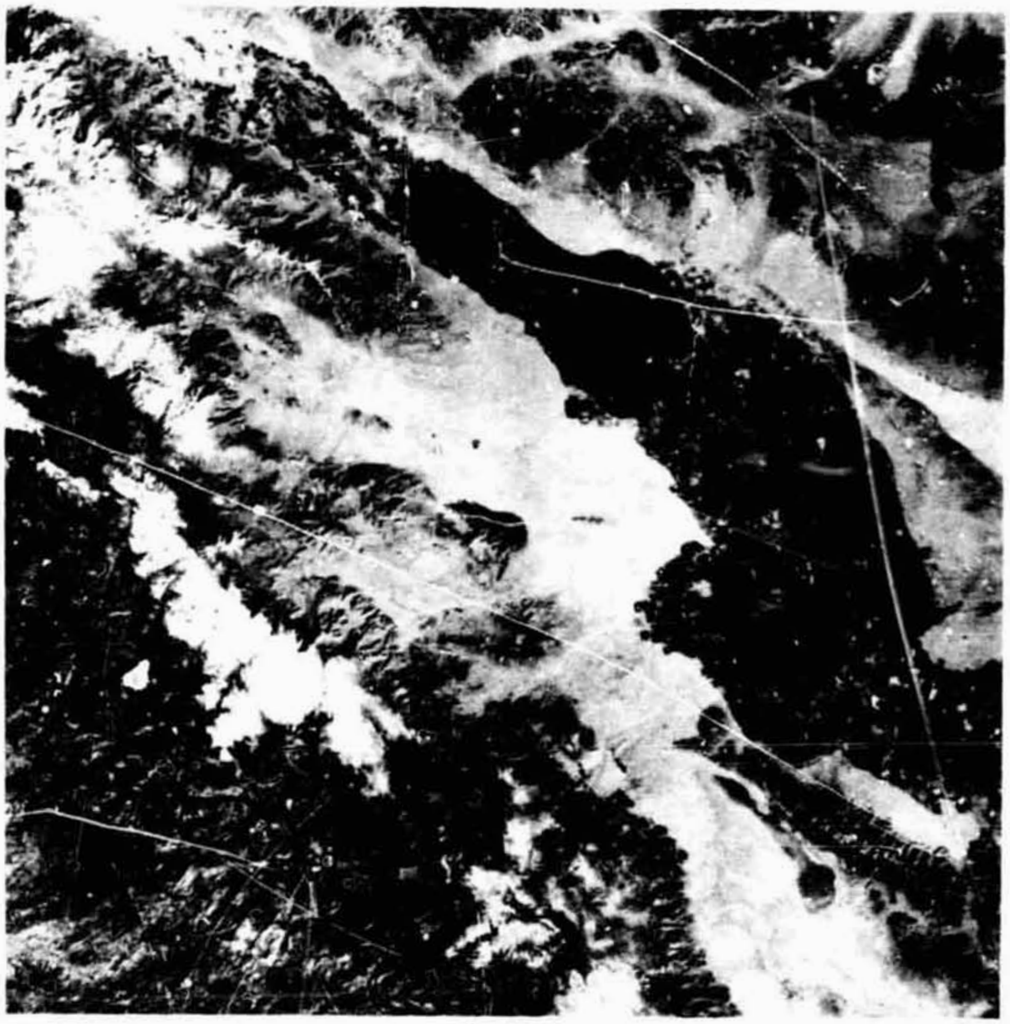

Figure 1. ERTS-1 December 12, 1972 MSS Band 5 image of Imperial Valley. Dark fields are growing crops. Note the lack of growth in the Mexicalli Valley in Baja California at this time of year.

TABLE 1

IMPERIAL VALLEY CROP CALENDAR FOR ERTS-1 DETECTED FIELD CONDITIONS

CROP TYPE	FIELD CONDITION CODE BY DATE			
	AUGUST 26	OCTOBER 1	NOVEMBER 6	DECEMBER 12
FIELD CROPS				
Barley (Pasture)	4	2	1	1
Barley (Grain)		4	3	2
Sorghum	1	5	5	
Oats		4	3	2
Wheat		4	4	3
Corn (Grain)			4	3
Grass (Bermuda & Alicia)	2	2/1	1	1/5
Grass (Rye)	4/3	3/2	2	1
Grass (Sudan)	1/5			
Alfalfa	1/4	1/2	1/2	1/2
Sugar Beets	3	2/1	2/1	1
Cotton	1	1	5/4	5/4
Rape	3	2	1	1
VEGETABLE CROPS				
Lettuce	3	2	2/1	1
Mustard	3	2	1	1
Cabbage	4	2	1	1
Cantaloupe (Fall)	1	1/5		
Cantaloupe (Spring)		4	3	2
Cucumbers (Fall)	2	1/5		
Cucumbers (Spring)		4	3	2
Watermelon			4	3
Tomatoes			4	3
Carrots	3	2	2/1	1/2/5
Onions (Bunching)	2	1	1	1/5
Onions (Dry)	4	4	2	2
Squash (Summer)	2	1/5		

(FIELD CONDITION CODE LEGEND: 1-(Red) growing crops; 2-(Purple) wet soil seeded crops; 3-(Lavender) plowed soil; 4-(White) bare soil; 5-(Yellow) harvested stubble)

TABLE 2

SUMMARY OF IMPERIAL VALLEY FIELD CONDITIONS DETECTED FROM ERTS-1

Field Condition / ERTS Color Code	GROWING CROPS (Red) (1)	WET PLANTED (Purple) (2)	DAMP PLOWED (Lavender) (3)	DRY BARE (White) (4)	HARVESTED STUBBLE (Yellow) (5)	PERMENENT AGRICULTURAL (8)	NO DATA (0)
	(Acres) (%)	(Acres) (%)	(Acres) (%)	(Acres) (%)	(Acres) (%)	(Acres) (%)	(Acres) (%)
August 26	153,528 (33.3)	40,374 (8.8)	128,219 (27.8)	123,025 (26.7)	2,636 (0.6)	3,640 (0.8)	9,599 (2.1)
October 1	142,047 (30.9)	69,115 (15.0)	150,351 (32.7)	83,642 (18.2)	787 (0.2)	3,640 (0.8)	10,470 (2.3)
November 6	199,197 (43.3)	120,330 (26.2)	48,736 (10.6)	80,221 (17.4)	315 (0.1)	3,640 (0.8)	7,627 (1.7)

	TOTAL PRODUCING ACRES	FEED LOTS	FARM ASSOCIATED	OFFSITES (Roads,Canals)	TOTAL AGRICULTURAL	URBAN	TOTAL ACRES
	(Acres)	(Acres)	(Acres)	(Acres)	(Acres)	(Acres)	(Acres)
August 26	461,021	2,698	180	51,508	515,407	14,640	530,047
October 1	460,052	2,703	184	51,467	514,406	15,140	520,546
November 6	460,066	2,747	463	51,442	514,718	15,350	530,068
December 12							