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SOIL, WATER, AND VEGETATION CONDITIONS IN SOUTH TEXAS

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for Period January 13, 1976 to April 13, 1976

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16. Abstract

Software development for a computer-aided crop and soil survey system is nearing completion. The system has been modified and tested by periodically classifying the crops and land uses in a 390,000 hectare county of diverse agricultural enterprises.

Computer-aided variety classification accuracies using LANDSAT-1 MSS data for a 600 hectare citrus farm were 83% for Redblush grapefruit and 91% for oranges. These accuracies indicate that there is good potential for computer-aided inventories of grapefruit and orange citrus orchards with LANDSAT-type MSS data.

The standard errors of estimate for the calibration of computer compatible tape coordinate system (pixel and record) to earth coordinate system (longitude and latitude) for 6 LANDSAT scenes ranged from 0.72 to 1.50 pixels and from 0.58 to 1.75 records. The regression coefficients appear to be good enough to closely locate ground sites of interest even for scenes in which clouds obliterate most of the 30 reference landmarks.

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TYPE II QUARTERLY PROGRESS REPORT

January 13, 1976 to April 13, 1976

A. Problems:

Cloudy conditions during the April to June 1975 period are making it difficult, and in many cases will prevent the location of ground-truthed fields in the CCT data. Thus, the data analysis effort is slowed and only a fraction of the anticipated data will be available.

We have exhausted our account for CCT at the EROS Data Center and are approaching exhaustion of the account of the ASCS Photographic Laboratory. These accounts need to be supplemented, or a convenient payment arrangement needs to be effected.

B. Accomplishments:

Distinguishing Between Grapefruit and Orange Trees

A paper entitled "Use of LANDSAT-1 Data to Distinguish Grapefruit from Orange Trees and Estimate Their Hectarages" has been prepared by H. W. Gausman, D. E. Escobar, A. J. Richardson, R. L. Bowen, and C. L. Wiegand. The Abstract follows: the entire manuscript is appended (APPENDIX):

Our objective was to determine if Earth Resources Technology Satellite (LANDSAT-1) multispectral scanner (MSS) data could be used to distinguish between Redblush grapefruit (*Citrus paradisi* Macf.) and orange (*Citrus sinensis* (L.) Osbeck) citrus varieties and estimate their hectarages satisfactorily. Accordingly, LANDSAT-1 MSS data for a December 11, 1973, overpass (scene I.D. 1506-16293) were used in conjunction with Productive Properties' 600-ha citrus farm in Hidalgo County, Texas. Computer-aided variety classification accuracies for the farm with MSS data were 83, 91, and 86% for Redblush grapefruit, orange, and total hectarages, respectively. The percentage comparisons of computer and farm manager's farm inventory estimates for Redblush grapefruit, orange, and total hectarages were 16.9% underestimate, 13.9% overestimate, and 2.4% underestimate, respectively. These classification and hectarage comparison accuracies indicate that there is a good potential for computer-aided inventories of grapefruit and orange citrus orchards with satellite MSS data. This projected use will become more realistic with further refinements in MSS ground resolution, and data acquisition and processing.

Rangeland

The major range sites in Kenedy and Willacy Counties have been botanically characterized for the fall (October 1975) and winter (January 1976) periods, and biomass measurements were made for these two seasons. Table 1 presents the means for herbaceous biomass for the various study sites during

the fall and winter seasons. The sites generally reached their peak production in early October. Following a frost in mid-November, production decreased rapidly. The January means were indicative of the dormant winter period. The two improved tight sandy loam sites and the coastal sand site were the most productive study sites, while the tight sandy loam-native and the salt flat were the least productive.

We are currently locating our study sites and additional training sites on a computer printout of the October 17, 1975 LANDSAT-2 overpass. In the next reporting period we will be subjecting the various sites to computer identification algorithms for both the October and December 1975 overpass dates. Comparisons between the two dates will be made to ascertain the spectral differences in relation to green biomass amounts determined at the two times.

In February 1976 we started taking herbaceous biomass measurements on the Coastal sand and deep sand-native sites each month. These two sites were selected because they have few or no woody plants; that is, they are essentially native grassland areas.

We are separating the hebaceous measurements into four different components: (1) apical stem fractions and heads, (2) standing brown biomass, (3) standing green biomass (green leaves and green basal stem fractions), and (4) litter. These parameters are being measured each month as the range greens up this growing season. The measurements will continue until the range reaches peak flush. These data will be presented in a later report.

Table 1. Herbaceous biomass production (air-dry weight) for various range sites in Kenedy and Willacy Counties, Texas, sampled in October 1975 and January 1976.

Range site	Forage production	
	Oct. 1975	Jan. 1976
	- - - - kg/hectare - - - -	
Tight sandy loam-native	202	142
Tight sandy loam-improved, re-established native grasses and herbs	2376	1050
Tight sandy loam-improved, re-seeded with Aliciagrass	1865	816
Coastal sand-native	1461	832
Sandy mound-native	- [1]	140
Deep sand-native	302	213
Deep sand-improved, re-established native grasses and herbs	942	- [2]
Salty flat	330	207

[1] This site was inaccessible due to high water.
[2] Not sampled in January 1976.

LANDSAT Computer-aided County-wide Survey Results

Software development for the computer-aided LANDSAT crop and soil survey system is nearing completion (see Quarterly Progress Report for the period July 13, 1975 to October 13, 1975). Some additional software development and modification will be needed for final crop hectarage estimates and crop yield forecasting.

Computer compatible tapes (CCT) have been received for LANDSAT overpasses on April 2, July 10, and October 17, 1975 and are being processed through the computer-aided survey system for classification accuracy and hectarage estimation results. Processing for the April data set is almost complete, and the July and October data set processing is well along.

Some results from regression analysis calibration of CCT coordinate system (record and pixel) to earth coordinate system (longitude and latitude) are given in Table 2. The regression coefficients (A_1 and A_2) for estimating CCT coordinates given earth coordinates were very similar for three LANDSAT overpasses in 1973 and three LANDSAT overpasses in 1975. Biggest differences appeared to be among the intercept terms (A_0) that are a function of how the CCT's are merged to include Hidalgo County. The regression coefficients are a good calibration approximation for LANDSAT overpasses where cloud cover obliterates most of the 30 calibration landmarks. Trial and error would be used to correct intercept values to achieve good registration.

The April 2, 1975 LANDSAT-2 digital value mean and standard deviations for the four MSS bands of the training data for eight crop, soil, water, and atmospheric conditions found in Hidalgo County, are given in Table 3. The digital value means for mature sorghum are generally higher for all four bands than either citrus or rangeland. Thus, there appeared to be some sorghum fields in April that were in an advanced stage of maturity. Some other less mature sorghum fields were confused as rangeland. Cotton was very young and sugarcane had just been harvested so the spectra of these two crops in April were indistinguishable from bare soil. Therefore, immature sorghum and cotton and recently harvested sugarcane were not considered in the county hectarage estimation studies.

Two bare soil conditions were apparent in April that may be attributable to soil moisture conditions in the county. The digital count differences between the wet and dry bare soil for April 1975 for each of the four LANDSAT MSS bands were 5, 9, 14, and 6, respectively. This compares with the average digital count differences between wet and dry bare soil for May 1973 (Type II Quarterly Progress Report for October 13, 1975 to January 13, 1976) for the four LANDSAT MSS of 13, 16, 14, and 6, respectively. Thus, even though the bare soil digital counts for May 1973 and April 1975 differed in magnitude, the wet and dry bare soil digital count differences for MSS 6 and 7 were exactly the same. Bands 4 and 5 did not compare as well.

Table 2. Regression analysis calibration of computer compatible tape coordinate system (pixel and record) to earth coordinate system (longitude and latitude) using 30 landmarks in Hidalgo County for 6 LANDSAT overpasses. Regression coefficients and standard errors of estimate are listed.

LANDSAT	Pixel = $A_o + A_1$ (Long.) + A_2 (Lat.) [1]				Record = $A_o + A_1$ (Long.) + A_2 (Lat.) [1]			
overpass dates	A_o	A_1	A_2	Sy•x	A_o	A_1	A_2	Sy•x
1/21/73	179901.1	-1703.83	-453.102	1.50	15792.82	208.682	-1357.10	1.36
5/27/73	179619.3	-1700.57	-453.025	0.76	14979.69	214.690	-1342.94	0.72
12/11/73	177364.7	-1680.43	-436.938	0.82	14913.75	216.715	-1351.30	0.58
4/2/75	177161.5	-1667.46	-476.706	1.62	14761.77	222.105	-1361.06	1.75
7/10/75	179505.9	-1700.96	-449.194	1.84	13420.52	233.612	-1352.86	1.03
10/17/75	178795.2	-1691.11	-449.789	0.72	16402.11	206.033	-1364.94	0.63

[1] The multiple correlation coefficients for all regression analyses were 0.9999.

Table 3. Mean and standard deviation of the four LANDSAT-2 multispectral scanner bands using digital data from an April 2, 1975 overpass for eight crop, soil, water, and atmospheric conditions found in Hidalgo County, Texas.

Crop, soil, water or atmospheric condition in Hidalgo County	LANDSAT BAND MEANS				LANDSAT BAND STANDARD DEVIATIONS			
	MSS 4	MSS 5	MSS 6	MSS 7	MSS 4	MSS 5	MSS 6	MSS 7
Citrus	24	27	53	27	2	3	6	3
Sorghum	28	32	67	33	4	8	5	5
Rangeland	26	32	49	23	2	3	6	3
Bare soil (wet)	26	31	36	15	2	3	4	2
Bare soil (dry)	31	40	50	21	4	7	6	3
Clouds	99	109	111	50	28	24	22	13
Shadow	24	24	31	12	7	9	10	5
Water	34	32	16	2	5	9	6	2
Saturation value for the band	127	127	127	63	-	-	-	-

The mean digital values for cloud conditions were considerably higher than for the crop, soil, and water conditions within the county. The mean digital values for shadow conditions differed enough from crop and soil conditions to be distinguishable.

The computer hectarage estimate of eight crop, soil, water, and atmospheric conditions found in Hidalgo County using April 2, 1975 LANDSAT-2 digital data are given in Table 4. The citrus and rangeland computer hectarage estimates were 57- and 148-thousand hectares, respectively, for April 1975, compared with estimates of 33- and 190-thousand hectares, respectively, for the January 1973 overpass (Richardson et al., Proc. Amer. Soc. Photog., 42nd Ann. Meeting, Washington, D.C. pp. 379-394. 1976). For the April 1975 data some rangeland was misclassified as citrus thereby overestimating citrus and underestimating rangeland. Since rangeland occurs in the northern half and along the western edge of the county (A), as shown in Figure 1, it was decided to count all citrus classifications that occured in these areas as rangeland. Classifications occurring in the rest of the county (B) were counted normally. Using this procedure, the computer hectarage estimates for citrus and rangeland conditions in the county were 36- and 169-thousand hectares, respectively (Table 4).

These final figures are about 44% too large for citrus, according to the 1973 Texas Crop and Livestock Reporting Service citrus hectarage estimate of 25 thousand hectares and about 12% too small for rangeland according to the January 1973 computer estimates of 190 thousand hectares. Areas such as the Santa Ana National Wildlife Refuge, that were misclassified as citrus (about 1 thousand hectares; 4%), explain some of the problem for estimating citrus in the southern part of the country. Trees and brush along canals and drainage ditches, in pastures, and around homes and farmsteads also contribute to classification errors.

The area where most rangeland was misclassified as citrus was in the northeastern part of the county where most of the clouds and cloud shadows existed. Even though cloud and cloud shadow combined equaled only 3.1% of the total county area (Table 4), the atmospheric effect among and around these scattered cloudy areas apparently caused rangeland to resemble citrus.

The April 1975 computer hectarage estimate for bare soil was 174 thousand hectares compared with 144 thousand hectares in January 1973. The extra 30 thousand hectares classified as bare soil in April 1975 further explains why the rangeland hectarage estimate (169 thousand hectares) was lower than in January 1973 (190 thousand hectares). A reason for a higher bare soil estimate in April 1975 than in January 1973 is that a severe drought was occurring in 1975 and not in 1973. Thus, growth of all kinds of vegetation in nonirrigated areas was impeded. Consequently, more soil background was sensed in April 1975 than in January 1973.

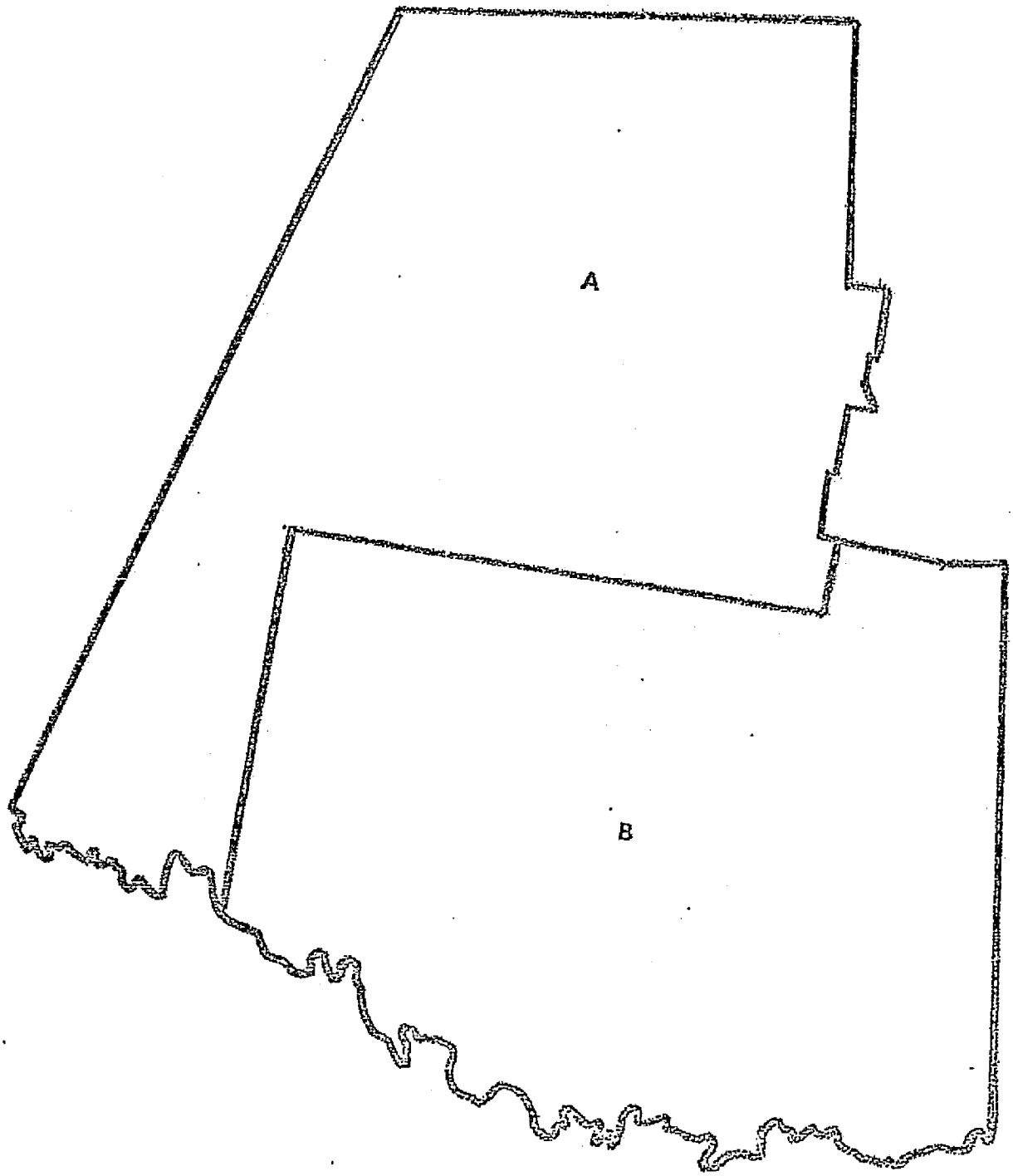

Fig. 1. Division of rangeland and citrus classifications for Hidalgo County, Texas. Citrus classifications in area A of the county are counted as rangeland. Citrus classification in area B of the county are counted normally.

No ground truth was collected specifically for the April 1975 LANDSAT-2 overpass from the 197 experimental county segments for checking validity of computer hectarage estimates. These data will be available for the July 1975 LANDSAT-1 overpass.

Table 4. Computer hectarage estimates using digital data from an April 2, 1975 LANDSAT-2 overpass for eight crop, soil, water, and atmospheric conditions found in Hidalgo County, Texas.

Crop, soil, water or atmospheric conditions in Hidalgo County	April 2, 1975 hectarage estimate	
	ha (thousand)	Percent of land area
Citrus	36	8.5
Sorghum	19	4.5
Rangeland	169	39.9
Bare soil (wet)	47	11.1
Bare soil (dry)	127	29.9
Clouds	5	1.2
Cloud shadow	8	1.9
Water	4	0.9
Threshold	9	2.1
County total	424	100.0

LANDSAT-2 (4/2/75, I.D. 2070 - 16203) Digital Counts vs Ground Truth Data

This section presents the linear and multiple linear regression analyses relating LANDSAT-2 digital and ground truth data for irrigated and nonirrigated (drought stressed) grain sorghum in 1975. The ground truth data were taken April 4 through May 2, 1975, and May 6 through 20, 1975 (about 1 field/day) for irrigated and nonirrigated grain sorghum, respectively. The LANDSAT-2 data were for the April 2, 1975 overpass. The relation of the other plant parameters to LAI was presented in the section entitled "LAI Relation to Other Plant Parameters" in Quarterly Progress Report #4, Jan. 14, 1976.

Table 5 presents the linear and multiple linear regression equations and their coefficients of determination (r^2, R^2) for nonirrigated grain sorghum. LANDSAT-2 digital counts (DC) were the dependent variable and leaf area index (LAI), plant height (PH) (cm), percent cover (PC), and plant population (POP) (plants/18.4 m of row) were the independent variables. The regression equations for each band are grouped separately and headed by band number. The r^2 or R^2 values express the best

relationship between dependent and independent variables, since r^2 X 100 or R^2 X 100 is the percentage of the variation within a data set that is attributable to linear regression.

For nonirrigated grain sorghum (Table 5), POP was the single variable (linear regression) most closely related to digital counts (DC) for all bands. For band 4, 12.0%; band 5, 11.3%; band 6, 9.2% and band 7, 9.4% of the variation in the DC sum of squares was accounted for by POP, whereas for multiple linear regression PH, PC, and POP were the three variables most closely related to DC by accounting for 14.9%, 12.4%, 11.5% and 12.8% of the variation in the DC sum of squares for band 4, 5, 6 and 7, respectively. There was less than one percent more of the variation accounted for in all bands, when LAI was added to the regression analysis. It can also be noted in Table 5 that only those analyses (simple and multiple) that include POP have F ratios (ss due to regression/ss due to deviation from regression) that were statistically significant.

The generally poor relationships among ground truth and LANDSAT-2 digital data are accounted for, in part, by the earliness of the LANDSAT coverage in the growing season and by the temporal separation between LANDSAT-2 data acquisition (April 2) and ground truth acquisition (May 6 to May 20). The LANDSAT-2 data were obtained approximately a month after planting when ground cover by the plants was very low (10-20%), and soil background was dominating the spectra. The ground truth that was related to the April LANDSAT digital counts were obtained more than a month later. Consequently, highly correlated results would require that spectral changes in the individual fields in the intervening 5 to 6 weeks be closely associated with their spectra on April 2.

In the last report it was shown that of the plant parameters, POP had the closest relation to LAI and in this report POP explained more of the variation in the digital counts (DC) than any other plant parameter. Thus it appears, that as early as April 2, differences in plant population were appreciably influencing the spectra observed for the nonirrigated grain sorghum fields.

Table 6 presents the linear and multiple linear regression equations and their corresponding r^2 or R^2 for irrigated grain sorghum. The single variable most closely related to the LANDSAT-2 digital counts by bands was: 4, PC; bands 5 and 7, POP; and for band 6, LAI; they accounted for 3.2%, 6.0%, 16.8% and 10.0% of the variation in the DC sum of squares, respectively. For multiple linear regression, all four variables (LAI, PH, PC and POP) accounted for 20.1%, 26.2%, 16.7% and 26.2% of the variation in the DC sum of squares for bands 4, 5, 6, and 7, respectively.

The relationships between plant parameters and DC for both nonirrigated and irrigated grain sorghum were poor because plants were 15 to 20 cm tall with 10 (nonirrigated) to 25 (irrigated) % ground cover at the April 2nd overpass date. The relationships between plant parameters and DC were better for irrigated than for nonirrigated, in keeping with a higher PC for irrigated associated with two rows of plants per bed rather than the one row

Table 5. Linear and multiple linear regression equations and their corresponding coefficients of determination (r^2 or R^2) for LANDSAT-2 bands 4, 5, 6, and 7 digital counts (DC) from the April 2 overpass regressed on leaf area index (LAI), plant height (PH), percent cover (PC) and plant population (POP) of nonirrigated grain sorghum measured between May 6 and May 20, 1975.

Equations	
Band 4	r^2
DC = 31.41 - 0.0227LAI	0.0147
DC = 30.37 + 0.009PH	0.0082
DC = 30.32 + 0.043PC	0.0114
DC = 35.88 - 0.018POP	0.1199*
	R^2
DC = 30.34 - 0.001PH + 0.045PC	0.0114
DC = 35.10 + 0.012PH + 0.014PC - 0.019POP	0.1399**
DC = 35.17 - 0.184LAI + 0.010PH + 0.026PC - 0.018POP	0.1491**
Band 5	r^2
DC = 42.18 - 0.172LAI	0.0035
DC = 41.48 + 0.006PH	0.0013
DC = 41.05 + 0.051PC	0.0066
DC = 49.28 - 0.027POP	0.1133**
	R^2
DC = 41.38 - 0.023PH + 0.126PC	0.0113
DC = 48.37 - 0.004PH + 0.079PC - 0.028POP	0.1242**
DC = 48.41 - 0.107LAI - 0.005PH + 0.086PC - 0.027POP	0.1255**
Band 6	r^2
DC = 51.06 - 0.257LAI	0.0071
DC = 49.36 + 0.018PH	0.0115
DC = 49.42 + 0.073PC	0.0124
DC = 57.58 - 0.026POP	0.0923**
	R^2
DC = 49.32 + 0.007PH + 0.049PC	0.0129
DC = 56.26 + 0.026PH + 0.002PC - 0.028POP	0.1152**
DC = 56.33 - 0.193LAI + 0.024PH + 0.015PC - 0.027POP	0.1190**
Band 7	r^2
DC = 22.28 - 0.143LAI	0.0130
DC = 21.48 + 0.008PH	0.0133
DC = 21.72 + 0.019PC	0.0050
DC = 24.92 - 0.011POP	0.0937**
	R^2
DC = 21.50 + 0.015PH - 0.031PC	0.0167
DC = 24.48 + 0.023PH - 0.051PC - 0.012POP	0.1281**
DC = 25.52 + 1.00LAI + 0.022PH - 0.045PC - 0.011POP	0.1342**

*, ** Significant at the 0.05 and 0.01 levels, respectively.

Table 6. Linear and multiple linear regression equations and their corresponding coefficients of determination (r^2 and R^2) for LANDSAT-2 bands 4, 5, 6, and 7 digital counts (DC) for the April 2, 1975 overpass regressed on leaf area index (LAI), plant height (PH), percent cover (PC) and plant population (POP) of irrigated grain sorghum, measured during the time interval April 15 to May 2, 1975.

Equations	
Band 4	r^2
DC = 25.84 + 0.035LAI	0.0005
DC = 26.17 - 0.005PH	0.0009
DC = 26.68 - 0.024PC	0.0320*
DC = 26.40 - 0.002POP	0.0117
	R^2
DC = 24.07 + 0.096PH - 0.096PC	0.1096**
DC = 24.43 + 0.103PH - 0.100 PC - 0.002POP	0.1286**
DC = 24.71 + 0.700LAI + 0.107PH - 0.120 PC - 0.007POP	0.2011**
Band 5	r^2
DC = 30.16 - 0.089LAI	0.0012
DC = 30.94 - 0.019PH	0.0052
DC = 31.28 - 0.042PC	0.0341*
DC = 31.80 - 0.006POP	0.0604**
	R^2
DC = 28.12 + 0.116PH - 0.129PC	0.0738*
DC = 29.30 + 0.140PH - 0.142PC - 0.007POP	0.1438**
DC = 29.91 + 1.510LAI + 0.149PH - 0.185PC - 0.017POP	0.2623**
Band 6	r^2
DC = 40.78 + 0.861LAI	0.0998**
DC = 38.37 + 0.087PH	0.0941**
DC = 40.95 + 0.059PC	0.0595**
DC = 40.36 + 0.008POP	0.0950**
	R^2
DC = 37.67 + 0.120PH - 0.032PC	0.0978**
DC = 36.45 + 0.095PH - 0.019PC + 0.007POP	0.1654**
DC = 36.53 + 0.204LAI + 0.096PH - 0.024PC + 0.005POP	0.1674**
Band 7	r^2
DC = 17.90 + 0.589LAI	0.1428**
DC = 16.38 + 0.057PH	0.1235**
DC = 17.83 + 0.046PC	0.1142**
DC = 17.43 + 0.006POP	0.1681**
	R^2
DC = 16.71 + 0.041PH + 0.015PC	0.1260**
DC = 15.72 + 0.021PH + 0.026PC + 0.006POP	0.2612**
DC = 15.70 - 0.064LAI + 0.020PH + 0.028PC + 0.006POP	0.2617**

*, ** Significant at the 0.05 and 0.01 levels, respectively.

of plants per bed for the nonirrigated sorghum. The irrigated grain sorghum was preplant irrigated and plants were not drought-stressed as the non-irrigated plants were.

The LANDSAT-1 CCT for 5/17/75 (I.D. 5028-16113), 6/4/75 (I.D. 5046-16103) and 7/10/75 (I.D. 5082-16083) are on hand for obtaining the digital counts corresponding more closely in time to the ground truth observations. However, cloud cover was approximately 40% on both the earlier dates, eliminating data for many fields and considerably complicating its extraction for the others. By July 10, grain harvest was well underway; cloud cover was low, but ground truthing had been discontinued. LANDSAT-2 tapes for coverages on May 8, May 26, and July 1 have not been ordered because the images received indicated more cloud problems than for LANDSAT-1 data.

C. Significant Results:

Software development for a computer-aided crop and soil survey sytem is nearing completion. The system has been modified and tested by periodically classifying the crops and land uses in a 390,000-hectare county of diverse agricultural enterprises.

Computer-aided variety classification accuracies using LANDSAT-1 MSS data for a 600-hectare citrus farm were 83% for Redblush grapefruit and 91% for oranges. These accuracies indicate that there is good potential for computer-aided inventories of grapefruit and orange citrus orchards with LANDSAT-type MSS data.

Mean digital values of clouds differed statistically from those for crop, soil, and water entities, and those for cloud shadows were enough lower than sunlit crop and soil to be distinguishable. Hence, both cloud and cloud shadow data can be separated from the crop and soil data of interest.

The standard errors of estimate for the calibration of computer compatible tape coordinate system (pixel and record) to earth coordinate system (longitude and latitude) for 6 LANDSAT scenes ranged from 0.72 to 1.50 pixels and from 0.58 to 1.75 records. The regression coefficients appeared to be good enough to closely locate ground sites of interest even for scenes in which clouds obliterated most of the 30 reference landmarks.

For the April 2, 1975 LANDSAT-2 overpass (scene I.D. 2070-16203), plant population was the single ground truth most closely related to MSS digital counts for drought-stressed nonirrigated grain sorghum; in the last report, it was also the plant parameter most closely related to leaf area index (LAI). Irrigated grain sorghum had higher plant population (POP), percent ground cover (PC), and LAI than nonirrigated grain sorghum; the single variable most closely related to digital counts by bands and parameters, respectively, for the irrigated sorghum was: 4, PC; 5 and 7, POP; and 6, LAI.

D. Publications:

Gausman, H, W., D. E. Escobar, and A. Berumen. 1975. Differences in visible and near-infrared light reflectance between orange fruit and leaves. F. Shahrokhi (ed.), Remote Sensing of Earth Resources, Univ. of Tennessee, Tullahoma. 4:147-160.

Richardson, A. J., C. L. Wiegand, R. J. Torline, and M. R. Gautreaux. Land use comparison of Hidalgo County, Texas, for January 21 and May 27, 1973 LANDSAT-1 overpasses. Proc. of the Amer. Soc. Photogram., Feb. 22-28, 1976, Washington, D.C., pp. 379-394.

Gausman, H. W., R. R. Rodriguez, and A. J. Richardson. 1976. Infinite reflectance of dead compared with live vegetation. Agron. J. 68: 295-296.

Gerbermann, A. H., J. A. Cuellar, and C. L. Wiegand. 1976. Ground cover estimated from aerial photographs. Photogram. Eng. and Remote Sens. 42:551-556.

E. Recommendations:

None

F. Funds expended:

The following statement of expenditures covers the period January 13, 1975 to the date indicated for each item.

	FY '75 (1/13/75 - 6/30/75)	FY '76
Salaries	$6,010.	$27,100. (7/1/75-3/12/76)
Supplies and Equipment	15,821.	23,896. (7/1/75-3/31/76)
Local Flying Service	589.	2,287. (7/1/75-3/31/76)
G & A (18%)	6,560.	12,600. (For year)
	$ 28,980.	$ 65,883.

APPENDIX

USE OF LANDSAT-1 DATA TO DISTINGUISH GRAPEFRUIT FROM ORANGE TREES AND ESTIMATE THEIR HECTARAGES*

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INTRODUCTION

Successful citrus variety identification by remote sensing from aircraft or spacecraft would greatly facilitate updating citrus hectarage and tree population surveys (Caudill et al., 1974). Some citrus varieties have been distinguished by their appearance on infrared color photos taken from aircraft (Gausman, Cardenas, and Hart, 1970). Moreover, different densities of citrus plantings have been identified with infrared color photos taken from SKYLAB (Hart, Ingle, and Davis, 1975).

We conducted this study to determine if Earth Resources Technology Satellite (LANDSAT-1, formerly ERTS-1) multispectral scanner (MSS) data could be used to distinguish between grapefruit and orange citrus varieties and estimate their hectarages satisfactorily.

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MATERIALS AND METHODS

Computer compatible digital tapes (CCT) for the LANDSAT-1 4-band MSS were obtained for the December 11, 1973, overpass of the Productive Properties, Inc. citrus farm located northwest of Edinburg in Hidalgo County, Texas. The farm has approximately 600 ha with five citrus varieties: Redblush grapefruit (*Citrus paradisi* Macf.) and Valencia, Marrs, Hamlin, and Navel oranges (*Citrus sinensis* (L.) Osbeck). A ground truth map showing the location, hectarage, and content of citrus orchards within the farm, as of 1973, was acquired from the farm manager in order to test the validity of the computer-aided citrus inventory of the farm.

A line printer graymap was generated of an area, including the citrus farm, using digital data differences between MSS band 5 (0.6 to 0.7 μm) and 7 (0.8 to 1.1 μm). The farm ground truth map was used to delineate the citrus orchards within the farm on the graymap. The CCT data record and picture element data sample (pixel) coordinates of approximately half of the various Rubyred, Hamlin, Valencia, Navel, and Marrs citrus training orchards were determined from their locations delineated on the graymap, and the digital data from these citrus orchards were selected from the CCT to train a computer-aided crop classifier (IBM 1800*). The classifier was used to classify all the digital count data within the farm into orange (Hamlin, Valencia, Navel, and Marrs training orchards) and grapefruit (Rubyred training orchards) hectarage inventory categories. All idle cropland, young citrus, and water body categories were classified into a threshold (other) category. A maximum likelihood classifier (Fu *et al.*, 1969) implemented with a table look-up procedure (Eppler *et al.*, 1971) were the computer-aided methods used to classify these data.

The results of the computer-aided survey of the citrus orchards within the farm were summarized by a line printer classification map and a hectarage inventory classification table (Table 1). The classification map indicates the distribution of orange and grapefruit orchards throughout the farm with respect to the actual orchard's boundaries delineated on the classification map. From the classification map the number of pixels classified as oranges, grapefruit, and threshold by the computer-aided classification procedures, within the boundaries known to be oranges and grapefruit, were counted and a hectarage inventory classification table was developed to demonstrate the computer classification accuracy.

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*Mention of company or trademark is for the readers' benefit and does not constitute endorsement of a particular product by the U.S. Department of Agriculture over others that may be commercially available.

RESULTS AND DISCUSSION

Pictorial comparisons of the LANDSAT-1 color composite, an aerial infrared color photo of the citrus farm, and a printout classification map of the farm are shown in Fig. 1. A comparison of the farm manager's and computer-aided inventory hectarage estimates of grapefruit and orange citrus orchards on the Productive Properties, Inc. citrus farm is given in Table 1. Interpretation (pixel count) of computer generated graymaps yielded hectarage estimates of the farm that compared with the farm manager's hectarage estimate as follows: grapefruit hectarage was underestimated by 3.2% (308 vs. 318 ha), orange hectarage was overestimated by 3.0% (244 vs. 237 ha), and total hectarage was underestimated by 0.5% (552 vs. 555 ha).

If the maximum likelihood classification procedures could perform with 100% classification accuracy, then the computer hectarage estimates would be the same as the interpreted hectarage estimate for the farm. However, classification accuracies were 83, 91, and 86% for classification of grapefruit, orange, and total, respectively (Table 1). These classification accuracies yielded computer-estimated hectarage estimates of the farm that compared with the farm manager's hectarage estimate as follows: grapefruit hectarage was underestimated 16.9% (272 vs. 318 ha), orange hectarage was overestimated 13.9% (270 vs. 237 ha), and total hectarage was underestimated 2.4% (542 vs. 555 ha). It should be pointed out that the computer-estimated hectarage is dependent not only on the hectarage correctly classified as a specific category, but also on the hectarage incorrectly classified as that specific category and on threshold classifications (see footnote 4, Table 1).

Results comparable to those of December 1973 for oranges and grapefruit, were obtained for a May 1973, LANDSAT-1 overpass. However, Richardson et al. (1976) have shown that citrus can be satisfactorily distinguished from other crops only during the winter months in Hidalgo County, Texas.

Even though these classification accuracies were not high enough to yield computer hectarage estimates equal to the interpreted or farm manager's hectarage estimates, they were judged high enough to indicate a good potential for computer-aided inventories of orange and grapefruit citrus orchards. This projected use will become more realistic with further refinements in satellite MSS ground resolution and data acquisition and processing.

ACKNOWLEDGMENT

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LITERATURE CITED

Caudill, C. E., P. M. Williamson, D. M. Humphrey, Jr., L. P. Garrett, and C. W. Wallis, 1974, "Texas Fruit and Pecan Statistics," Texas Crop and Livestock Reporting Service, Austin, Texas. 41 pp.

Eppler, W. G., C. A. Helinke, and R. H. Evans, 1971, "Table Look-Up Approach to Pattern Recognition," Proc. Seventh International Symposium on Remote Sensing of Environment II:1415-1425.

Fu, K. S., D. A. Landgrebe, and T. L. Phillip, 1969, "Information Processing of Remotely Sensed Agricultural Data," Proc. IEEE 57(4): 639-655.

Gausman, H. W., R. Cardenas, and W. G. Hart, 1970, "Aerial Photography for Sensing Plant Anomalies," 3rd Ann. Earth Resources Aircraft Program Status Review, MSC-NASA, Houston. Dec. 1-3, Vol. II:24-1 to 24-15.

Hart, W. G., S. J. Ingle, and M. R. Davis, 1975, "The Use of SKYLAB Data for the Early Detection of Insect Infestation of Crop Plants and Host Plant Distribution," NASA Earth Resources Survey Symposium (Abstracts), Lyndon B. Johnson Space Center, Houston, Texas. p. 65.

Richardson, A. J., C. L. Wiegand, R. J. Torline, and M. R. Gautreaux, 1976, "Land Use Survey Comparison of Hidalgo County, Texas, for January 21 and May 27, 1973 LANDSAT-1 Overpasses," ACSM-ASP Convention Proc., February 22-28, Washington, D.C., pp. 379-394.

Table 1. Farm manager's and computer-aided inventory of grapefruit and orange citrus orchards located on the Productive Properties, Inc., citrus farm for a December 11, 1973, LANDSAT-1 overpass. Areas with idle cropland, young citrus and water bodies (76 ha) form a threshold category for the maximum likelihood classifier because the computer was trained on mature citrus spectra. Photo interpreter's graymap pixel identities are judged against farm manager's ground observations.

Category	Overall farm manager's estimate from ground observations	Overall computer estimate from maximum likelihood classifier[1]	Overall interpreter's estimate from graymap pixel count	Percent correct classification, pixel count relative to manager's estimate
	ha	ha	ha	%
Grapefruit	318	272	308	83[2,4]
Oranges	237	270	244	91[3,4]
Total	555	542	552	86[5]

[1] Overall computer estimate from maximum likelihood classifier (oranges or grapefruit) = correct + incorrect computer estimates from maximum likelihood classifier (oranges or grapefruit).

[2] 48 ha incorrectly classified as oranges; 6 ha classified as threshold.

[3] 17 ha incorrectly classified as grapefruit; 4 ha classified as threshold.

[4]
$$\text{Percent correct classification for oranges or grapefruit} = \frac{\text{Overall interpreter's estimate from graymap pixel count (oranges or grapefruit)} - \left[\text{Pixels incorrectly classified as grapefruit or oranges} + \text{Pixels incorrectly classified as threshold (oranges or grapefruit)}\right]}{\text{Overall interpreter's estimate from graymap pixel count (oranges or grapefruit)}} \times 100$$

[5]
$$\text{Percent correct classification for total} = \frac{\left[\text{Percent correct classification for oranges}\right] \times \left[\text{Overall interpreter's estimate for oranges from graymap}\right] + \left[\text{Percent correct classification for grapefruit}\right] \times \left[\text{Overall interpreter's estimate for grapefruit from graymap}\right]}{\text{Overall interpreter's estimate from graymap pixel count (total)}} \times 100$$

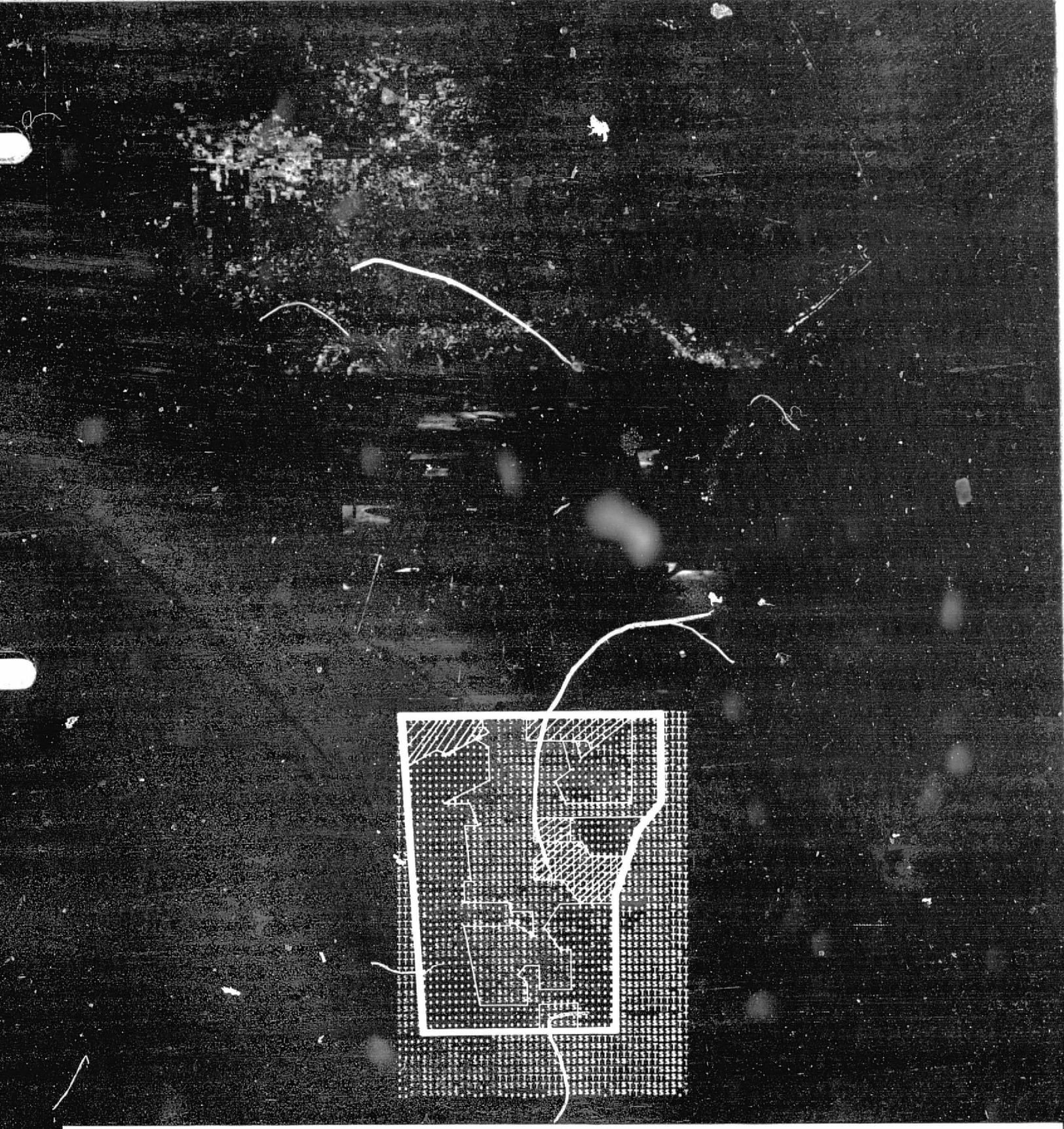

Fig. 1. The upper picture is a LANDSAT-1 color positive print composite [MSS bands 4, 5, and 7 from an overpass for December 11, 1973, (ID-1506-16293)] of the Lower Rio Grande Valley of Texas showing the location of the Productive Properties, Inc., citrus farm by dashed lines. The middle image is a close-up oblique infrared color photograph (positive print) of the farm taken on September 22, 1975, at 3048 m. The lower picture is a computer printout classification map from the LANDSAT-1 data of the citrus farm showing the localized areas of grapefruit (•), oranges ($), water bodies and bare soil (/). Middle and lower pictures are delineated the same for comparative purposes. A comparison of the farm manager's and computer estimated farm hectarages for grapefruit and oranges is given in Table 1.

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