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LANDSAT Agricultural Land-Use Survey

Multispectral scanner data collected on January 21 and May 27, 1973 were used for classification and acreage estimation studies of crop and soil categories in Hidalgo County, Texas.

Introduction

Our study concerned the use of the first Earth Resource Technology Satellite (LANDSAT-1) as a land use survey tool (Aldrich, 1971) for inventorying agricultural crop and soil categories in Hidalgo County, located in the Lower Rio Grande Valley, Texas. The purpose of our research was to gain experience and knowledge necessary for developing an operational LANDSAT survey system in agriculture at Weslaco, Texas. One benefit of an operational agricultural survey system would be the production of timely and accurate forecasts of crop acreage surpluses or deficiencies in order to facilitate planning and implementation of domestic economic policies (local, regional, or national). For a LANDSAT-1 survey system in agriculture to be useful (operational), forecast improvement value (economic benefit) must exceed the cost (benefit/cost) (Castruccio, 1974; Merewitz, 1974).

Abstract: *Multispectral scanner (MSS) data collected by the first Earth Resources Technology Satellite (LANDSAT-1) on January 21 and May 27, 1973, were used for classification and acreage estimation studies of crop and soil categories in Hidalgo County, Texas. Classification results, based on approximately 1,400 fields, improved, using fields larger than 15 acres, with more than 25 percent plant cover, and with plants taller than 30 cm in both January and May 1973. Ground and LANDSAT acreage estimates for citrus, combined cotton and sorghum, and idle cropland categories were not significantly different for the respective dates of January, May, and January. The LANDSAT acreage estimates for citrus, combined cotton and sorghum, and winter vegetable categories differed from the Texas Crop and Livestock Reporting Service acreage estimates by 32, 8, and 47 percent, respectively. Thus, these results indicate a potential for an agricultural LANDSAT survey system for land-use categories like citrus, combined cotton and sorghum, idle cropland, and vegetables.*

Classification accuracy for land-use categories surveyed and reliability of acreage estimates will determine the economic success expected of an operational, land-use survey system for agriculture.

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Experimental Procedure

Hidalgo County was chosen as an experimental site for a LANDSAT-1 survey because a county is the logical governmental unit by which agricultural census data are collected and summarized. The January 21 and May 27, 1973, LANDSAT-1 overpasses provided MSS digital count data recorded on computer compatible tapes (CCT), for Hidalgo County where detailed ground truth was available. All four of the LANDSAT-1 MSS bands, for each date, covering the spectral region 0.5 to 1.1 μm were used for this study. Ground data in the county was compiled from 197 sample segments containing approximately 1,400 fields that comprise the total statistical sample for LANDSAT-1 crop, soil, and water reflectance studies in Hidalgo County conducted by the U.S. Department of Agriculture at

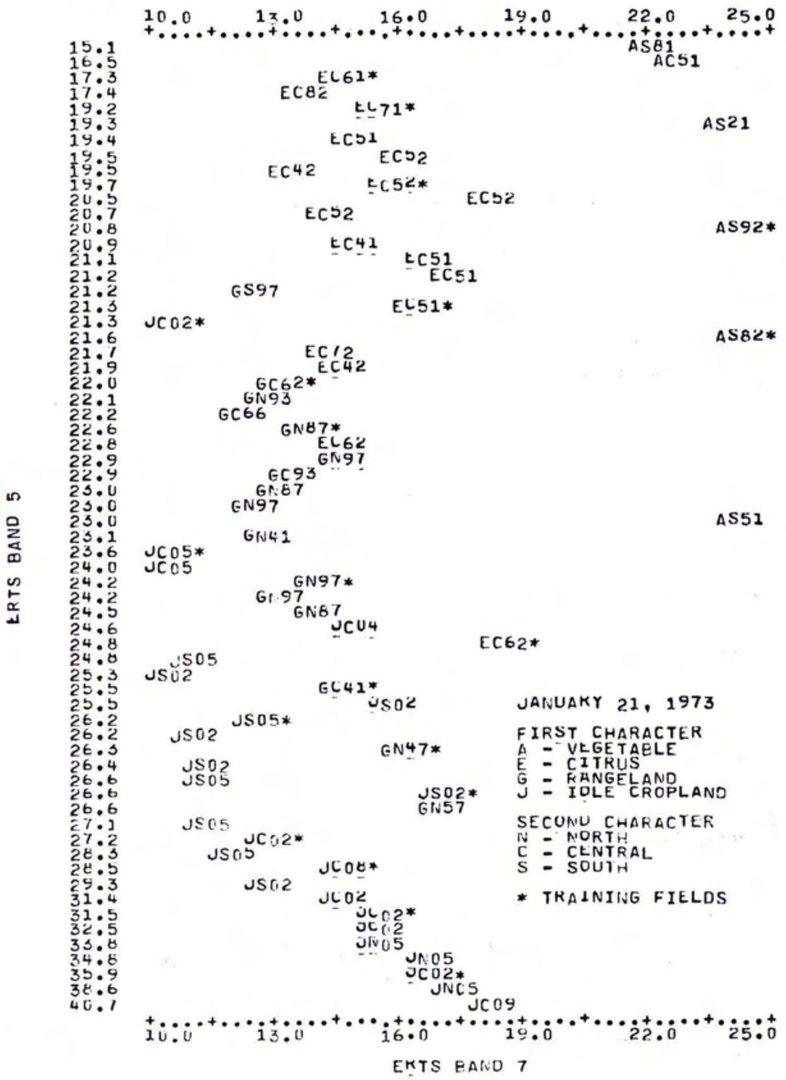

FIG. 1. Two-dimensional scatter diagram, using LANDSAT MSS channels 5 and 7, of the mean digital values (January 21, 1973 LANDSAT-1 overpass) determined for 67 of 1,400 test fields randomly located in Hidalgo County. Training fields are marked with asterisk for four spectrally distinct categories (vegetable, citrus, rangeland, and idle cropland). Definition of four character field identifiers are—class identification (character 1), northern (N), central (C), or southern (S) region of county (character 2), code number ranging from 0 to 9 for 0 to 90 percent crop cover (character 3), and crop and soil condition code ranging from 0 to 9.

Weslaco, Texas. Ground data provided actual crop and soil field condition status and identity as well as acreage of each field at the time of each LANDSAT-1 overpass.

Digital data were selected from the CCT for all of the test fields located (1,290 fields in January and 1,157 fields in May) and for each of the four LANDSAT MSS bands for both overpasses. The average digital count values for each field and band were determined for use in training field selection procedures for both overpasses.

The average digital values for LANDSAT-1 MSS bands 5 and 7 were displayed in a scatter diagram format (Figure 1) in order to determine the major distinguishable categories in the statistical county sampling and to select training fields that are representative of these distinguishable categories (Driscoll *et al.*, 1972). The computer was trained to classify these categories by determining the mean vector and covariance matrix for each category used in a maximum likelihood classifier (Fu *et al.*, 1969). The optimum channels to be used in the classifier (Table 1) were determined by using a channel (LANDSAT-1 MSS bands) optimization program CHOICE (Jones, 1973). The classifier and optimum bands were implemented in a table look-up procedure suggested by Eppler *et al.* (1971).

Classification and acreage estimation results were reported by using a system based on Anderson's land-use classification scheme (Anderson *et al.*, 1972). Four level I categories (urban, agriculture, rangeland, and water), and nine level II categories (vegetables, citrus, cotton, sorghum, idle cropland, dry debris, grass, mixed shrubs, and nonagricultural) were considered.

CLASSIFICATION OF TEST FIELDS

Test fields were stratified by incrementing field size, plant cover, and plant height in order to study classification accuracy dependence on these estimated ground parameters. As test fields were stratified, by successively discarding test fields less than an ascending incremental field size, plant cover, or plant height threshold, the classification accuracy was determined at each increment. The rationale was that the incremental combination of estimated field ground parameters, corresponding with the point of diminishing classification accuracy improvement, could be assessed by this field stratification process. Classification accuracy is directly related to LANDSAT acreage estimation accuracy because fields with estimated ground parameters less than the point of diminishing classification accuracy improvement will adversely affect LANDSAT acreage estimations.

ACREAGE ESTIMATES FOR HIDALGO COUNTY

Estimated ground acreage for Hidalgo County crop conditions was based on four independent samples (43 segments per sam-

TABLE 1. CLASSIFICATION RESULTS FOR TEST FIELDS USING MSS DATA FROM LANDSAT-1 JANUARY 21 AND MAY 27, 1973. RESULTS ARE REPORTED USING A SYSTEM BASED ON ANDERSON'S LAND-USE CLASSIFICATION SYSTEM. A TOTAL OF 1,290 FIELDS (35,351 PIXELS) WERE USED FOR THE JANUARY RESULTS AND 1,157 FIELDS (35,984 PIXELS) WERE USED FOR THE MAY RESULTS.

	January 21, 1973		May 27, 1973	
Crop, soil and water conditions	Percent correct classification (per pixel)	Percent correct classification (per field)	Percent correct classification (per pixel)	Percent correct classification (per field)
01 Urban	—	—	—	—
02 Agricultural	74.6	65.9	71.8	74.9
01 Vegetables	16.9	18.4	—	—
02 Citrus	49.7	57.6	33.3	34.7
03 Cotton & Sorghum	—	—	51.3	49.2
04 Idle cropland	74.1	72.2	65.9	58.0
05 Dry debris	—	—	—	—
03 Rangeland	74.9	60.7	74.8	51.5
01 Grass	45.9	51.1	41.6	27.8
02 Mixed shrubs	44.7	43.0	54.1	45.2
03 Non agricultural	—	—	—	—
04 Water	—	—	—	—
Total (Level I)	74.7	64.5	73.0	70.2
Total (Level II)	54.3	57.5	46.3	34.8

ple) of the county (approximately 4 percent of the land area) multiplied by an expansion factor:

$$\hat{Y}_i = 91.3256 \sum_{j=1}^{43} y_{ij}, \text{ where } i=1 \text{ to } 4, \quad (1)$$

$$\hat{Y} = \sum_{i=1}^{4} \hat{Y}_i/4, \text{ and} \quad (2)$$

$$\sigma_{\hat{y}} = \sqrt{\frac{1}{4(4-1)}\left[\sum_{i=1}^{4} \hat{Y}_i^2 - 4\hat{Y}^2\right]}, \quad (3)$$

where

Y_{ij} is the acreage of a specific crop condition in the i^{th} sample of the j^{th} segment,
$\hat{Y}_i$ is the total acreage estimate for the county for the i^{th} independent sample of a specific crop condition,
$\hat{Y}$ is the ground acreage estimate of a specific crop condition in the county, and
$\sigma_{\hat{y}}$ is the ground acreage sampling error for a specific crop condition in the county.

These ground acreage estimates of the county were derived from planimeter measurements of the test fields from aerial photographs.

LANDSAT acreage estimates were based on counting the number of pixels classified into each land-use category and the total multiplied by a pixel to acre conversion factor (0.467 ha (1.155 ac)/pixel) determined for the Hidalgo County area in a previous report (Richardson *et al.*, 1974). Thus, a classification was determined for every pixel (849,000 pixels in January and 948,000 pixels in May) in Hidalgo County for level I categories (agriculture and rangeland), and level II categories (vegetation, citrus, combined cotton and sorghum, idle cropland, grass, and mixed shrubs).

It was not possible to determine sampling errors for LANDSAT acreage estimates of crop conditions, as was done for the ground acreage estimate of crop conditions, since only one overpass for each date was available. Therefore, a 95 percent confidence interval (Steel and Torrie, 1960) of the ground estimated acreage, utilizing the t-distribution, was used to compare ground and LANDSAT acreage estimates for testing the validity of the Landsat results:

$$\hat{Y} - t_{0.05}\sigma_{\hat{y}} < \hat{X} < \hat{Y} + t_{0.05}\sigma_{\hat{y}} \;, \quad (4)$$

where $\hat{X}$ is the LANDSAT acreage estimate of a specific crop condition in the county. The value for $t_{0.05}$ for df=4−1=3 is 3.182. LANDSAT acreage estimates falling outside these confidence limits are significantly different at the 5 percent probability level.

In addition, citrus, combined cotton and sorghum, and vegetable category acreage estimates were compared to the Texas Crop and Livestock Reporting Service acreage estimates. Domestic crop reporting services are credited with crop estimates, by MacDonald *et al.* (1975), that are within 1 or 2 percent of actual production figures. The best known satellite survey program of crop acreages, LACIE (Large Area Crop Inventory Experiment), is credited with crop estimates that are within 10 percent of actual production figures.

HIDALGO COUNTY CLASSIFICATION MAPS

Two line printer classification maps of the county land-use survey were generated. The county was divided into successive 5 by 5 pixel matrices (25 pixels per matrix). Each matrix was classified by the category having the majority of pixels and represented a larger (degraded) pixel of the classification results. The final line printer classification maps (Figures 2 and 3) of the county were 25 to 1 (5X reduction in photographic sense) reductions of the original LANDSAT-1 MSS data with a resolution of 11.7 ha/line printer character.

EXPERIMENTAL RESULTS

The channel (LANDSAT-1 MSS bands) optimization program CHOICE, using MSS digital data from training fields for January (Figure 1) and May 1973, were used to rank all treble-wise combinations of the four LANDSAT MSS bands by four divergence criteria; the average pair-wise class divergence, the minimum pair-wise class divergence, maximum percent class separation, and maximum average class divergence. The LANDSAT treble-wise band combinations of 4, 5, and 7 and 5, 6, and 7 were most often ranked by these divergence criteria for these two dates as being the best treble-wise band combination to use in the maximum likelihood classifier. Thus, we concluded that bands 5 and 7 (selection common to both dates and divergence criteria) were more important for distinguishing this particular group of crop and soil categories than bands 4 and 6 that were of secondary importance, depending on the time of year and specific crop and soil category conditions.

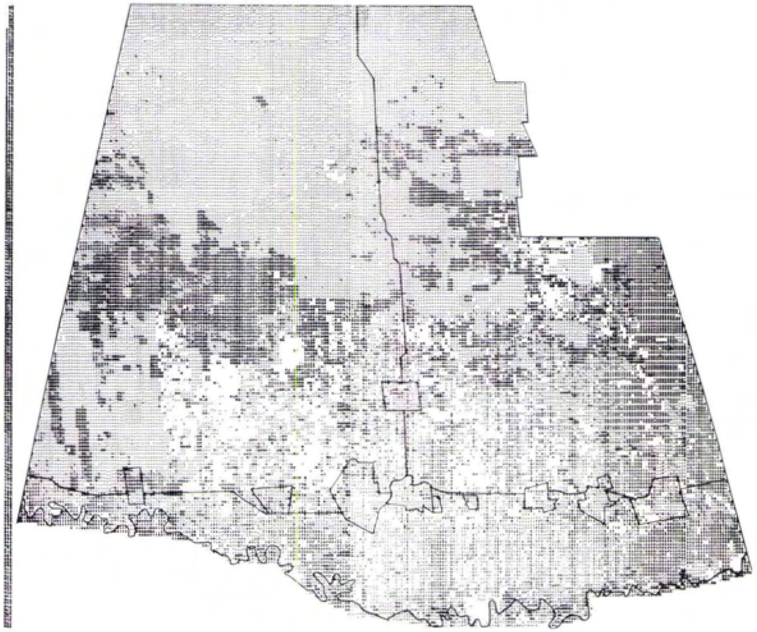

FIG. 2. Classification map of Hidalgo County for the January 21, 1973 LANDSAT-1 overpass. Resolution is 11.7 ha/symbol. Definition of categories in terms of pixel line printer symbols is given as follows: vegetable (/ overprinted −), citrus (blank), mixed grass (/), mixed shrubs (−), McAllen soil association (M overprinted W), Harlingen soil association ($), water (·), and threshold (T).

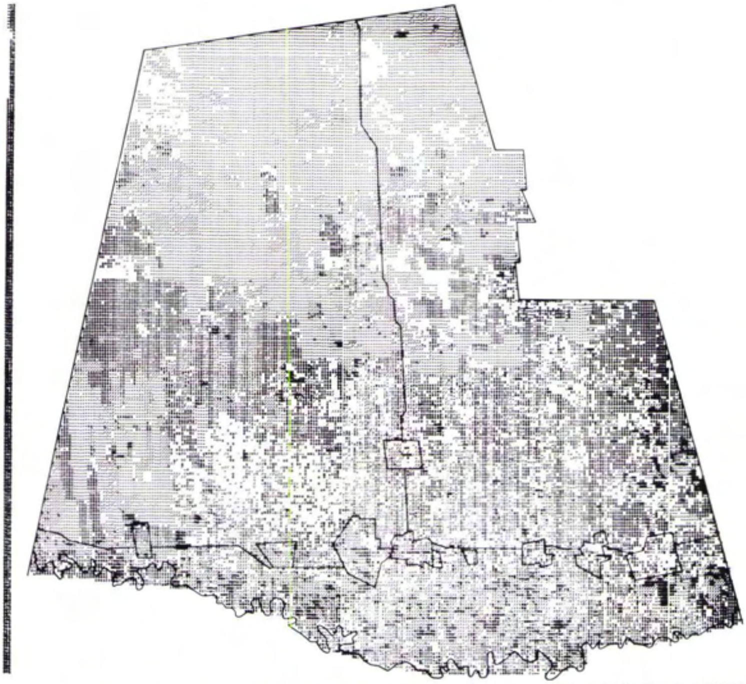

FIG. 3. Classification map of Hidalgo County for the May 27, 1973 LANDSAT-1 overpass. Resolution is 11.7 ha/symbol. Definition of categories in terms of pixel line printer symbols is given: cotton and sorghum (0), citrus (blank), mixed grass (/), mixed shrubs (−), McAllen soil association (M overprinted with a W), Harlingen soil association ($), water (·), and threshold (T).

CLASSIFICATION RESULTS FOR TEST FIELDS

All test fields (1,290 for January and 1,157 for May) selected from the digital data were used to determine the classification accuracy for January and May 1973, in Table 1. The level II percent classification accuracy (per pixel basis) for vegetables, citrus, idle cropland, grass, and mixed shrubs were 17, 50, 74, 46, and 45 percent respectively, for January. Similarly, the level II percent classification accuracies (per pixel basis) for citrus, cotton and sorghum, idle cropland, grass, and mixed shrubs were 33, 51, 66, 42, and 54 percent respectively, in May. These results were judged too low for reliable acreage estimates; thus, classification accuracy for these fields was stratified by field size, plant cover, and plant height in order to determine whether classification accuracy was dependent on any one or all of these estimated ground parameters.

Stratification by field size produced the greatest effect on classification accuracy for both January (54 to 84 percent overall correct classification for all fields greater than zero to 40.5 ha (100 ac) in size, respectively, per field basis, Table 2) and May (42 to 93 percent overall correct classification for all fields greater than zero to 40.5 ha in size, respectively, per field basis, Table 3). Crop cover stratification effects on classification accuracy were stronger in January (55 to 69 percent overall correct classification for all fields greater than zero to 80 percent crop cover, respectively, Table 2) than in May (41 to 51 percent overall correct classification for all fields greater than zero to 80 percent crop cover, respectively, Table 3). Similarly, stratification by crop height affected classification accuracy more in January than in May. There was no point of diminishing classification accuracy return that allowed a logical cut-off according to field size, crop cover, or plant height; that is, the larger the field or the greater the plant cover, or the taller the plant height, then the better the classification accuracy.

We decided that a field stratification criterion that would delete fields less than 6.07 ha (15 ac), with crop cover less than 25 percent and with plant height shorter than 30 cm, would retain at least half the fields (502 in January; 498 fields in May) for statistical testing of improvement in classification accuracy.

Table 4 indicates the improvment in classification accuracy after applying the field stratification criterion as compared with using all test fields (Table 1). On a per field basis for January, level I categories (agricultural and rangeland) overall classification accuracy improved from 65 (Table 1) to 84 percent (Table 4). The level I per pixel overall classification accuracy improved from 75 to 79 percent for January. The May classification accuracy comparing all fields with stratified fields showed similar improvements (Table 1 and 4). The difficulty in correctly classifying small fields accounts for the greater per field than per pixel classification accuracy improvement for both January and May.

ACREAGE ESTIMATE FOR HIDALGO COUNTY

The entire county acreage estimate comparisons for January and May are given in Table 5. The level I ground and LANDSAT acreage estimates were not significantly dif-

TABLE 2. THE EFFECT OF FIELD SIZE (1,290 FIELDS), PLANT COVER, AND PLANT HEIGHT (588 FIELDS) ON CLASSIFICATION RESULTS (PER FIELD BASIS) FOR LANDSAT-1 DATA COLLECTED ON JANUARY 21, 1973. MSS CHANNELS 4, 5, AND 7 WERE USED.

Field size stratification			Crop cover stratification			Crop height stratification		
Field size in hectare	Overall correct classification	Accumulative total fields	Crop cover in percent	Overall correct classification	Accumulative total fields	Crop height in cm	Overall correct classification	Accumulative total fields
0	54.0	1290	0	55.4	588	0	55.4	588
2	57.0	1127	5	56.3	566	10	57.4	533
4	61.3	828	10	56.8	540	20	61.6	451
6	64.2	649	15	58.0	517	30	64.8	378
8	67.6	479	20	59.1	495	40	64.8	353
16	74.4	188	25	59.7	485	100	66.6	303
20	79.1	120	40	61.6	415	200	66.6	276
40	84.3	51	60	63.5	239	300	70.1	164
—	—	—	80	69.4	131	400	62.5	16

TABLE 3. THE EFFECT OF FIELD SIZE (1,157 FIELDS), PLANT COVER, AND PLANT HEIGHT (975 FIELDS) ON CLASSIFICATION RESULTS (PER FIELD BASIS) FOR LANDSAT-1 DATA COLLECTED ON MAY 27, 1973. MSS CHANNELS 5, 6, AND 7 WERE USED.

Field size stratification			Crop cover stratification			Crop height stratification		
Field size in hectare	Overall correct classification	Accumulative total fields	Crop cover in percent	Overall correct classification	Accumulative total fields	Crop height in cm	Overall correct classification	Accumulative total fields
0	41.9	1157	0	41.0	975	0	41.0	975
2	43.1	931	5	43.5	950	10	44.9	916
4	46.7	671	10	43.9	935	20	46.3	876
6	49.8	528	15	44.1	920	30	49.8	786
8	52.5	386	20	44.5	886	40	54.2	676
16	67.0	161	25	46.0	842	100	55.5	452
20	74.0	104	40	49.0	660	200	46.6	302
40	93.1	44	60	51.1	459	300	45.2	199
—	—	—	80	44.6	179	400	33.3	12

ferent (0.01 probability level) for agriculture and rangeland in either January or May. Thus, these two categories can be distinguished at either time of the year.

The ground and LANDSAT estimate comparison for level II categories citrus and idle cropland were not significantly different (0.01 probability level) in January but were significantly different in May. Idle cropland and citrus were overestimated in May because cotton and sorghum and rangeland spectrally resembled these two categories; a result that was noted in previous studies using aircraft MSS digital data (Richardson *et al.*, 1972). Ground and LANDSAT acreage estimates for vegetable were significantly different (0.01 probability level) in January (May is an off-season). Vegetable acreage was underestimated by LANDSAT because much of the vegetable acreage, according to detailed ground estimates, was composed of sparse crop cover, or low plant height, and thus resembled idle cropland. The grass and mixed shrubs categories were not estimated very well by LANDSAT in either January or May because they spectrally resembled each other. There was no significant difference between the ground and LANDSAT esti-

TABLE 4. CLASSIFICATION RESULTS FOR STRATIFIED TEST FIELDS USING MSS DATA FROM LANDSAT-1 COLLECTED JANUARY 21 AND MAY 27, 1973. RESULTS ARE REPORTED USING A SYSTEM BASED ON ANDERSON'S LAND-USE CLASSIFICATION SYSTEM. A TOTAL OF 502 FIELDS (23,577 PIXELS) WERE USED FOR THE JANUARY RESULTS AND 498 FIELDS (28,078 PIXELS) WERE USED FOR THE MAY RESULTS.

Crop, soil and water conditions	January 21, 1973		May 27, 1973	
	Percent correct classification (per pixel)	Percent correct classification (per field)	Percent correct classification (per pixel)	Percent correct classification (per field)
01 Urban	—	—	—	—
02 Agricultural	77.2	85.7	74.0	77.2
01 Vegetables	34.2	50.0	—	—
02 Citrus	53.8	71.4	38.9	50.6
03 Cotton & Sorghum	—	—	56.1	56.1
04 Idle cropland	76.7	82.2	70.3	70.3
05 Dry debris	—	—	—	—
03 Rangeland	80.7	78.1	78.4	73.7
01 Grass	51.2	61.3	52.4	60.0
02 Mixed shrubs	50.8	56.0	55.3	56.6
03 Non agricultural	—	—	—	—
04 Water	—	—	—	—
Total (Level I)	78.5	84.3	76.0	76.5
Total (Level II)	62.9	74.5	51.8	51.4

TABLE 5. COMPARISON OF GROUND TO LANDSAT-1 ESTIMATED ACREAGE FOR CROP, SOIL, AND WATER CONDITIONS IN HIDALGO COUNTY SURVEYED ON JANUARY 21 AND MAY 27, 1973. RESULTS ARE REPORTED USING A SYSTEM BASED ON ANDERSON'S LAND-USE CLASSIFICATION SYSTEM. THE DIFFERENCES BETWEEN THE GROUND AND LANDSAT ESTIMATES WERE TESTED BY COMPARING THE LANDSAT ESTIMATE TO THE CONFIDENCE INTERVAL ABOUT THE GROUND ESTIMATE.

Crop, soil, and water conditions	January 1973		May 1973		Difference between ground and Landsat estimates in ha (Thousand)	
	Ground estimate in ha (Thousand)	Landsat estimate in ha (Thousand)	Ground estimate in ha (Thousand)	Landsat estimate in ha (Thousand)	January	May
02 Agricultural	197	184	203	223	13	20
01 Vegetables	19	7	12	—	12*	—
02 Citrus	36	33	36	56	3	20*
03 Cotton & Sorghum	13	—	145	126	—	19
04 Idle cropland	108	144	9	41	36	32**
05 Dry debris	21	—	1	—	—	—
03 Rangeland	183	190	175	185	7	10
01 Grass	40	99	34	71	59**	37**
02 Mixed shrub	127	91	128	114	36*	14
03 Non-agricultural	16	—	13	—	—	—
04 Water	—	2	—	2	—	—
Threshold	—	20	—	32	—	—
Total	380	396	378	442	—	—

* Significant at the 0.05 probability level.
** Significant at the 0.01 probability level.

mate for the combined category of cotton and sorghum in May.

The LANDSAT acreage estimate for citrus in January of 33,000 ha (Table 5) was 32 percent higher than the 1974 Texas Crop and Livestock Reporting Service (Caudill *et al.*, 1974) estimate of 25,000 ha. The LANDSAT acreage estimate, for the combined cotton and sorghum category in May, of 126,000 ha was 8 percent lower than the 1973 Texas Crop and Livestock Reporting Service (Caudill *et al.*, 1973a and 1973b) estimate of 136,000 ha. Even though the citrus estimate difference was 32 percent, the timing of the satellite overpasses in January and May were about right, according to Texas Crop and Livestock Reporting Service crop calendars, to insure that the best possible computer estimates of citrus and combined cotton and sorghum categories, respectively, were obtained.

The 1973 Texas Crop and Livestock Reporting Service harvested acreage estimate for winter vegetables (Caudill *et al.*, 1973c), for the October 1972 to May 1973 harvesting period in Hidalgo County (broccoli, cabbage, carrots, cauliflower, and lettuce), was 10,300 ha. This figure is 47 percent higher than the Landsat acreage estimate of 7,000 ha for vegetables in January 1973. In this instance, one reason that the LANDSAT estimate was low may be that the timing of the satellite overpass, in January 1973, was too late in the harvesting period, according to Texas Crop and Livestock Reporting Service crop calendars, for determining the best possible LANDSAT estimate of winter vegetables.

HIDALGO COUNTY CLASSIFICATION MAPS

Figures 2 and 3 are line printer recognition maps for January and May, respectively, with 11.7 ha/pixel resolution. Most of the rangeland was in the northern and southwestern portions of the county in both January and May. There is some scattering of rangeland in the agricultural area (southern half of the county) that probably corresponds with fields of dry debris. The McAllen—Brennan soil association (light colored highly reflective sandy loam soils) was mostly in the western central part of the county in January. In May this area was planted to cotton and sorghum. The Harlingen and Mercedes—Raymondville soil associations (darker color low reflective clayey soils) were mostly in the extreme south and east parts of the county in January. In May this area was also planted to cotton and sorghum.

Citrus was found mostly in the central part of the county in both January and May as expected. Misclassification of citrus as cotton and sorghum in May is evident from a comparison of the citrus area immediately south of the McAllen—Brennan soil in January and/or south of cotton and sorghum in May. In January this area has more citrus, with some grass and McAllen—Brennan soil, than in May because citrus was misclassified as cotton and sorghum in May.

Summary and Conclusions

Crop and soil categories of Hidalgo County were inventoried using MSS data collected from LANDSAT-1. The best two MSS bands, according to divergence criteria considering crop and soil conditions surveyed in January and May 1973, were 5 and 7.

Per pixel classification accuracy, using all test fields for January and May, was higher than per field classification accuracy because small fields degraded the per field classification accuracy. Field stratification studies indicated that classification accuracy could be improved by censoring fields smaller than 6.07 ha (15 ac) in size, with less than 25 percent crop cover, and with plants shorter than 30 cm for both January and May LANDSAT-1 overpasses.

Ground to LANDSAT acreage estimates, based on classification of all pixels in Hidalgo County, indicated that it should be possible to estimate the county acreage of level I categories, agricultural and rangeland, in either January or May. County acreage for level II categories, citrus, idle cropland, and vegetable, could be estimated in January but not in May. The combined cotton and sorghum level II category acreage could be estimated on a county basis in May but not in January. If a June or July LANDSAT-1 overpass were available, individual acreage estimates of cotton and sorghum could be possible.

The LANDSAT acreage estimates for citrus, combined cotton and sorghum, and vegetables differed from the Texas Crop and Livestock Reporting Service acreage estimates by 32, 8, and 47 percent, respectively. Even though these percent comparisons are higher than the 1 or 2 percent error in estimating actual production credited for domestic crop survey services and the 10 percent error claimed by the LACIE system, we believe our results indicate a potential for an operational land-use survey of agricultural and rangeland (level I categories) and citrus, combined cotton and sorghum, idle cropland, and vegetable (level II categories) using LANDSAT-1 MSS data in Hidalgo County.

References

Aldrich, R. C., 1971. Forest and range inventory and mapping, International Workshop on Earth Resource Survey Systems, II:83-107.

Anderson, J. R., E. E. Hardy, and J. T. Roach, 1972. *A land-use classification system for use with remote-sensor data*, Geological Survey Circular (671, USGS, Washington, DC).

Castruccio, P. A., and H. L. Loats, 1974. The practical utilization of remote sensing technology for the managment and conservation of natural resources, for The United Nations Outer Space Affairs Division, New York, March.

Caudill, C. E., P. M. Williamson, and M. D. Humphrey, Jr., 1973a. *1973 Texas Cotton Statistics.* Compiled by the Texas Crop and Livestock Reporting Service, Austin, Texas.

———1973b. *1973 Texas Field Crop Statistics.* Compiled by the Texas Crop and Livestock Reporting Service, Austin, Texas.

———1973c. *1973 Texas Vegetable Statistics.* Compiled by the Texas Crop and Livestock Reporting Service, Austin, Texas.

——— 1974. *1974 Texas Fruit and Pecan Statistics.* Compiled by the Texas Crop and Livestock Reporting Service, Austin, Texas.

Driscoll, R. S., and M. M. Spencer, 1972. Multispectral scanner imagery for plant community classification, *Proc.* Eighth International Symposium on Remote Sensing of Environment, II:1259-1278.

Eppler, W. G., C. A. Helmke, 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.

Jones, W. C., 1973. CHOICE: 36 band feature selection software with application to multispectral pattern recognition, Report No. 059, Earth Resource Laboratories, Mississippi Test Facilities, NASA, Bay St. Louis, MS.

MacDonald, R. B., F. G. Hall, and R. B. Erb. 1975. The Large Area Crop Inventory Experiment (LACIE): An assessment after one year of operation. *Proc.* Tenth International Symposium on Remote Sensing of Environment, I:17-37.

Merewitz, Leonard, 1974. On the feasibility of benefit-cost analysis applied to remote sensing projects, Annual Progress Report, Space Sciences Laboratory, University of California, Berkeley, VP:40-46.

Richardson, A. J., M. R. Gautreaux, R. J. Torline, and C. L. Wiegand, 1974. Land use classification and ground truth correlations from simultaneously acquired aircraft and ERTS-1 MSS data, Ninth International Symposium on Remote Sensing of Environment, II:1423-1440.

Steel, Robert G. D., and J. H. Torrie. 1960. *Principles and procedures of statistics.* McGraw-Hill Book Company, Inc. 481 p.

Engineering Reports

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Bendix Subsidiary Announces Acquisition

United Geophysical Corporation, a wholly owned subsidiary of The Bendix Corporation, and Omega Geophysical Survey Corporation, of Houston, Texas, have announced an agreement under which United will acquire the assets and business of Omega in exchange for Bendix common stock. United Geophysical, headquartered at Pasadena, Calif., operates in the petroleum and mineral exploration field as a service contractor of oil companies and governments in the United States, Australia, Bolivia, Brazil, Canada, Iran, New Guinea, Nigeria, and other areas. Omega provides similar services in the U.S.

Itek Corporation Reports 1976 Second Quarter Earnings

Itek Corporation reported a net income of \$744,000 or 24 cents a share on sales of \$50,708,000 for the quarter ended July 2. This compares with earnings of \$155,000 or 5 cents a share on sales of \$50,873,000 for the second quarter of 1975. For the first half of 1976, the company earned \$1,126,000 or 36 cents a share on sales of \$104,063,000 compared with a loss of \$469,000 or 15 cents a share on sales of \$95,980,000 for the first six months of 1975. During the second quarter improved gross profit margins in the commercial operations produced higher earnings on only a slight sales increase when compared with the year earlier figures. A similar pattern existed in the government businesses where improvements in operations resulted in higher earnings on slightly lower sales. Robert P. Henderson, president, said he expected the company's profitable operations to continue, but pointed out that Itek's third quarter results historically are lower than second quarter results, and that he expects that situation will continue this year.

Versatel Offers New Xerox Plotter

Eight new electrostatic plotters from Versatec offer a choice of 22″ or 22″ paper width, vertical plotting speed of one or two inches per second, and resolution of 100 or 200 dots per inch. Four

models offer character generator and simultaneous print/plot option for display of captions, legends, and other alphanumeric data while plotting. The new electrostatic units plot up to thirty times faster than a pen plotter. Plotting a raster scan of data at a time, they are not slowed by high data density or plot complexity. The can shade, tone, draw variable line widths, and draw a continuous plot of up to 500 feet in length. For more information contact: Carl Larson, Versatec Santa Clara, CA 95051, (408) 988-2800

Skylab Photomap of Hartford Area Available

An experimental satellite photomap of a 4,300 square mile area of Connecticut and New York made from pictures taken by cameras on board the Skylab space station has been prepared by the U. S. Geological Survey, Department of the Interior. Copies of the space view—the first photomap published by the USGS from Skylab pictures—are available for purchase by the public. The 23 by 31-inch "false color" photo map corresponds in scale and area covered to the Hartford