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Objective of the Contract:

The seasonal changes in reflectance of soils and of various crops grown in Hidalgo County, Texas, are being studied using ERTS-1, ground, and low to medium altitude (3,000-10,000 ft AGL) aircraft spectral data. Discrimination of specific crop and soil conditions is being attempted; chlorophyll content of plant leaves is being correlated with reflectance in the visible channels, and comparisons are being made between ERTS data and predictions from analytical models describing interaction of light with plant canopies.

Plant Residue Detection:

Crop residues remaining on the soil surface after harvest play an important role in preventing and controlling wind and water erosion. If the reflectances measured by ERTS-1 can be related quantatively to surface residue, a tool is available for helping to assess erosion hazard in relation to crop residue management. Multispectral scanner (MSS) data were used from the ERTS-1 overpass of January 21, 1973, to determine if bare soils could be distinguished from plant residue (vegetation frozen January 12, 1973). There were statistically significant differences between residue-covered soil reflectance and bare soil reflectance more times for band 4 than for bands 5, 6, and 7 or band ratios 4/7, 5/7, 4/6, and 5/6. In the majority of the comparisons for band 4, residue-covered soil had less reflectance than bare soil.

In rangeland, the grasses are usually frozen to the ground in winter. The relation between this standing dry biomass and its reflectance needs to be known. The mapping of soils in rangeland is also best done in winter after the vegetation has been frozen. In this case, the influence of the standing and littered vegetation on the mappability of soils needs to be determined. The experiment described is a forerunner to such practical applications.

Plant Parameters and MSS Digital Counts:

A paper was presented at the ERTS Symposium in December discussing the relation of ERTS-1 digital data to vegetation density. At that time the digital data that had been furnished us for band 7 for the May 27, 1973, overpass were defective. Those data were redigitized by the NDPF and have subsequently been received and examined in terms of the ground truths: leaf area index (LAI), plant population (POP), plant cover (PC), and plant height (PH). The regression equations expressing the digital counts (DC) as a function of the plant parameters are:

Crop	Band	Regression Equation	R^2
Cotton	7	DC = 14.00+1.098(LAI)+.007(POP)+.015(PC)+.280(PH)	.959
Sorghum and corn	7	DC = 13.54+2.52(LAI)-.0000(POP)-.006(PC)+.066(PH)	.782

Thus, the plant parameters explain 95.9% of the variation in band 7 digital counts for cotton and 78.2% of the variation in digital counts for the combined crops, sorghum and corn. These data indicate, as did the data for bands 4, 5, and 6, that measurable plant parameters explain most of the signal variations from cropland. The equation for sorghum and corn shows that the coefficient for the POP term is zero. The reason for this is that POP and LAI are so highly correlated that only one of them is needed to explain the digital counts. The same result was obtained for band 6. Since POP is much easier to measure than LAI it is the one to use.

Shadows cast by plants are an additional factor that could influence the digital counts. We are developing a model that uses sun azimuth and elevation, row direction (angle), and plant height to estimate the amount of interrow area viewed by the sensor that would be shaded by row crop plants. It will be tested using the data from the May 27, 1973, ERTS-1 overpass and ground truth parameters from 22 fields of cotton, corn, and sorghum.

Relation Between Plant Parameters and Yield:

Crop yields have been obtained from growers for 11 sorghum and corn fields (hundreds of pounds grain per acre) and for 6 cotton fields (pounds lint per acre). The highest simple correlations (r) between yield and plant parameters for the sorghum and corn yields were: yield vs plant population, 0.809; and, yield vs leaf area index, 0.820. The same two plant parameters were most closely correlated for the 6 cotton fields also (yield vs plant population, 0.444; yield vs leaf area index, 0.692) but the generality of the cotton results is open to question due to the low number of observations.

The occurrence of plant population as a variable that correlates well with yield is encouraging in terms of regional estimates of crop conditions and probable yields. This parameter needs to be determined only once per crop season (after the crop stand has been established). Since a roving ground truth team could cover a large geographical area, to obtain a sample to calibrate the ERTS data against, the ground truthing efficiency would be very high.

Ground Truth Summarization:

The ground truth data from the test County are being summarized as they affect the interpretation of computer recognition results using the ERTS-1 digital reflectance data, as they characterize the nature of the agriculture (field sizes and land uses) being dealt with, and as they affect the definition of an operational data analysis system to meet USDA needs.

Field sizes and land uses. Eleven sets of ground truth from a sample of 1,400 fields, coinciding with ERTS-1 overpasses, have been examined for field size distribution and land uses. These data show that field size distribution and land uses are well established and quite stable for the County as a whole. They also show that 40% of the fields are smaller than 10 acres in size, but that these small fields occupy only 8.2% of the land area. Thus if no fields smaller than 10 acres can be correctly identified with data of the ERTS-1 resolution, less than 10% of the land area would be involved.

The dominant land cover and the percentage of the land area in each from the sample of 1,400 fields, averaged over the eleven sets of ground truth, are:

Vegetables	3.04%
Citrus	9.38
Field crops	17.41
Introduced grasses	9.11
Native grasses	0.86
Mixed shrubs	32.93
Weeds	5.40
Bare soil	15.28
Non-agricultural	1.95
Dry debris	4.46
Unclassified	0.13

The low percentage of the area in native grasses compared with mixed shrubs indicates the need for brush control.

Natural County stratification. There are three major geographical areas in Hidalgo County. The Northern region is mainly pasture and rangeland with a little irrigated farming centered around local water supplies. Soils tend to be sandy. The Central region is irrigated, medium-textured soil. Cultivated land is generally broken into small fields devoted to mixed field- and vegetable-row crops, citrus, and miscellaneous farm operations. The Southern region is predominantly fine-textured soil that is used extensively for winter vegetable production. The majority of land in the Southern region is irrigated.

Low rainfall limits the choice of land uses in the non-irrigated Northern region. Irrigation systems, drainage ditches, fence lines, and roads limit the number of boundary changes that can easily be made in the Central and Southern regions.

Total area of the Northern range- and pasture-land region is approximately the same as of the Central irrigated region, however, there are about nine times as many fields in the Central region. The Northern and Southern regions have about the same number of fields although the Northern region contains almost five times the area of the Southern region.

Eighty-five percent of the area of the Northern region is in fields larger than 100 acres whereas more than 50% of the Central region is in fields of less than 30 acres. The Southern region tends to have larger fields than the Central region. In the Southern region 50% of the acreage is in fields 30 to 100 acres in size.

Rangeland Biomass and Reflectance:

After the clear ERTS-1 overpass on March 29, 1974, biomass production samples were taken from each of the different rangeland sites in Hidalgo County, Texas. Biomass production was determined, by clipping one meter square plots, as described by Brown (Brown, Dorothy, 1954, "Methods of Surveying and Measuring Vegetation", Commonwealth Agricultural Bureaux, Farnham Royal, Bucks, England, 223 pp.).

Spectral characteristics for rangeland sites in Hidalgo County, Texas have been summarized and compared for four different satellite overpasses. Vegetation characteristics for each of the rangeland site types have been compiled and summarized.

Recognition Performance of ERTS-1 MSS Data for January 21, 1973, in Hidalgo County, Texas:

Recognition results were reported using the land use classification system developed by Anderson et al. (Anderson, James R., Hardy, Ernest E., and Roach, John T., 1972, "A Land-Use Classification System for Use With Remote-Sensor Data," Geological Survey Circular 671). Ground truth collection in Hidalgo County is centered on two level I categories, agriculture and rangeland, that are subdivided into 5 level II categories, vegetable, citrus, idle cropland, grass, and mixed shrubs. Recognition results (Table 1) for 1,290 fields, on a per pixel basis, for agriculture (74.6%) and rangeland (74.9%) were higher than the per field results for agriculture (65.9%) and rangeland (60.7%) because recognition errors due to small fields affected the per field results more adversely than the per pixel results. The overall level II category recognition result (54.3%), on a per pixel basis, was lower than the overall level I category result (74.7%).

The low overall level II category recognition results (54.3%) prompted investigations of the effects of field stratification by size, plant cover, and plant height on recognition results (Table 2). Computer recognition improved as field, percent plant cover, and plant height increased. Of the 1,290 fields of known size and crop in the January 21, 1973, data, 502 fields were >15 acres in size, and had either >25% plant cover or plants >30 cm tall. When these 502 fields were classified, the overall level I category recognition result, on a per field basis, improved from 64.5 to 84.3%, and for level II categories the improvement was from 57.5 to 74.5%.

Attempts to further improve recognition results were made by stratifying the County into northern, central, and southern regions. Training fields were specifically selected from each region rather than depending on one general set of training fields for the entire County. Overall level I and level II category recognition results (83.8 and 72.6%, respectively), on a per field basis using regionalized training fields, were not significantly different from the previous results (84.3 and 74.5%, respectively) using the general training fields.

Both the 502 fields and the entire County were classified by the computer into various land use categories using the ERTS-1 digital data for bands 4, 5, and 7. The percentage of total acreage of 502 fields in the agricultural category (62.1%) determined from the ground truth was greater than both computer estimates (52.6% based on 502 fields, and 46.2% based on the complete County). The rangeland category estimate (37.9%) from the ground truth for the 502 fields was less than both computer estimates (42.8% based on 502 fields, and 48.0% based on the complete County). Part of the comparison error between computer and ground truth acreage estimates is probably introduced in this analysis by eliminating fields smaller than 15 acres and those with <25% ground cover and <30-cm high plants compared with what would be obtained if no selection criteria had not been imposed. Use of the selection rule was intended to improve classification accuracies rather than acreage estimates.

ASCS vs ARS Acreages in Individual Fields:

Acreage records kept by the Agricultural Stabilization and Conservation Service (ASCS) serve as an independent source of county-wide acreage estimates to judge our computer and statistical sample county estimates against. It is important that our and the ASCS acreages be in close agreement for the same fields. To check their agreement, 16 ERTS-1 segments (plots of land about 160 acres in size) consisting of 91 fields were selected. Only fields with closely similar boundaries in both agencies' photographs were chosen.

We measured one field in each of the 16 segments with a surveyor's chain and calculated its size in acres. A planimeter was used to determine the acreage, from 1971 enlarged high-altitude photographs, of all other fields in the same segment using the chain-measured field as a calibrator. The acreage in these same fields were obtained from records in the county ASCS office.

The simple correlation (r) between the acreages for the 91 fields in the two data sets was 0.99. Among the 91 fields, our and the ASCS acreages differed by 0.5 acre or less for 48% of the fields, and by 2 acres or less for 76% of the fields. Only 6 of the fields differed by more than 4 acres.

The 91 fields totaled 2,823 acres in the ASCS and 2,885 acres in the ARS measurements, a difference of 2.2%. Since there are 402,000 acres of cropland in Hidalgo County, a difference of this magnitude over the whole county would amount to almost 9,000 acres. The main source of differences between our and the ASCS acreages seems to be in the planimetry, particularly in the amount of area that was allowed for turnrows. ASCS measurements were documented by photography from 1968 and earlier compared with the 1971 photographs ARS used; however, date of photography should not have been a factor since only fields very similar in appearance in the two photographic records were chosen for the comparison.

Significant Results and Practical Applications:

Reflectance of crop residues, that are important in reducing wind and water erosion, was more often different from bare soil in band 4 than in bands 5, 6, or 7. The plant parameters leaf area index, plant population, plant cover, and plant height explained 95.9% of the variation in band 7 (reflective infrared) digital counts for cotton and 78.2% of the variation in digital counts for the combined crops sorghum and corn; hence, measureable plant parameters explain most of the signal variation recorded for cropland. Leaf area index and plant population were both highly correlated with crop yields; since plant population can be readily measured (or possibly inferred from seeding rates), it is a useful measurement for calibrating ERTS-type MSS digital data in terms of yield.

Forty percent of the fields in the test county are smaller than 10 acres in size, but they occupy only 8.2% of the land area. Recognition results for 1,290 test fields for two level I categories (USGS Circular 671), agriculture and rangeland, were 74.6% and 74.9%, respectively, on a per pixel basis and 65.9% and 60.7%, respectively, on a per field basis. When only the 502 fields that were >15 acres in size or had either >25% plant cover or plants >30 cm tall were classified on a per field basis, the recognition results for 5 level II categories (vegetable, citrus, idle cropland, grass, and mixed shrubs) improved from 57.5% to 74.5%.

Publications:

Manuscripts and publications will be cited in next Type II report.

Recommendations Concerning Changes in Operations, Additional Investigations, Efforts and Effort/Results as Related to the ERTS System:

More complete investigation of the effect of plant residues on MSS digital counts and their relation to wind and water erosion susceptibility is merited. A regional effort to calibrate infrared reflectance in terms of grain sorghum yields, then to apply it to predict yields is also merited.

Changes in Standard Order Forms:

None.

ERTS Image Descriptor Form:

Attached.

Changes in Retrospective Data Requests:

None.

Planned Work for the Next Reporting Period:

Follow through on the investigations reported on herein and prepare manuscripts for publication.

Begin formulating a handbook of recommendations for an operational data analysis system useful to agriculture based on ERTS-1 experience.

Further fit the leaf area indices measured in 22 cotton, sorghum, and corn fields to the analytical models describing interaction of light with plant canopies.

TABLE 1 RECOGNITION RESULTS FOR 1290 TEST FIELDS USING MSS DATA FROM ERTS-1 COLLECTED JANUARY 21, 1973. CATEGORIES ARE LISTED USING ANDERSON'S LAND USE CLASSIFICATION SYSTEM. CHANNELS 4, 5, AND 7 WERE USED TO DISCRIMINATE 2 LEVEL I AND 5 LEVEL II CATEGORIES ON A PER PIXEL AND PER FIELD BASIS.

GROUND TRUTH LAND USE CATEGORIES	COMPUTER LAND USE CATEGORY RESULTS			
	NUMBER OF FIELDS	PERCENT RECOGNITION	NUMBER OF PIXELS	PERCENT RECOGNITION
01 URBAN	-	-	-	-
02 AGRICULTURE	944	65.9	20569	74.6
01 VEGETABLE	125	18.4	2474	16.9
02 CITRUS	231	57.6	3482	49.7
04 OTHER CROP	68	-	1627	-
05 IDLE CROPLAND	468	72.6	11614	74.1
06 DRY DEBRIS	52	-	1372	-
03 RANGE LAND	346	60.7	14782	74.9
01 GRASS	139	51.1	3450	45.9
05 MIXED SHRUBS	93	43.0	9750	44.7
06 NON AGRIC.	114	-	1582	-
05 WATER	-	-	-	-
TOTAL(LEVEL I)	1290	64.5	35351	74.7
TOTAL(LEVEL II)	1290	57.5	35351	54.3

TABLE 2 THE EFFECT OF FIELD SIZE (1290 FIELDS), AND PLANT COVER, AND PLANT HEIGHT (588 FIELDS) ON CLASSIFICATION RESULTS (PER FIELD BASIS) FOR ERTS-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 ACRES	OVERALL CORRECT RECOG-NITION	ACCUMU-LATIVE TOTAL FIELDS	CROP COVER IN PERCENT	OVERALL CORRECT RECOG-NITION	ACCUMU-LATIVE TOTAL FIELDS	CROP HEIGHT IN CM	OVERALL CORRECT RECOG-NITION	ACCUMU-LATIVE TOTAL FIELDS
0	54.0	1290	0	55.4	588	0	55.4	588
5	57.0	1127	5	56.3	566	10	57.4	533
10	61.3	828	10	56.8	540	20	61.6	451
15	64.2	649	15	58.0	517	30	64.8	378
20	67.6	479	20	59.1	495	40	64.8	353
40	74.4	188	25	59.7	485	100	66.6	303
50	79.1	120	40	61.6	415	200	66.6	276
100	84.3	51	60	63.5	239	300	70.1	164
-	-	-	80	69.4	131	400	62.5	16

ERTS IMAGE DESCRIPTOR FORM

Page 1

USER NAME Craig L. Wiegand

DATE 4-19-74

USER ID AG 339

AGENCY USDA-ARS

PRODUCT ID (Include Band and Product)	Weslaco File #:	Frequently Used Descriptors * COAST	CROPLAND	RANGELAND	LAKES	DESCRIPTORS	FLIGHT DATE:
1399-16364-5	#211					Clouds	8/26/73
1399-16370-5	#215					Clouds	"
1416-16303-5	#259	X					9/12/73
1416-16310-5	#263	X	EEO	X			"
1417-16362-5	#243					Clouds	9/13/73
1417-16364-5	#247					Clouds	"
1434-16301-5	#235					Clouds, EEO	9/30/73
1434-16303-5	#239			X		Clouds	"
1435-16355-5	#267					Clouds	10/1/73
1435-16361-5	#270			X		Drainage	"
1452-16293-5	#251	EEO	X	X			10/18/73
1452-16300-5	#255		X	X		Party Cloudy	"
1453-16352-5	#273			X			10/19/73
1453-16354-5	#277			X		Clouds	"
1470-16295-5	#281					Clouds, EEO	11/5/73
1489-16350-5	#285			X		Clouds	11/24/73
1489-16353-5	#288					Geology, EEO	"
1506-16290-5	#291					Clouds	12/11/73
1506-16293-5	#295		X	X			"
1507-16345-5	#299			X		Cirrus	12/12/73
1507-16351-5	#303			X		Geology	"

ERTS IMAGE DESCRIPTOR FORM

Page 2

USER NAME Craig L. Wiegand

DATE 4-19-74

USER ID AG 339

AGENCY USDA - ARS

PRODUCT ID (INCLUDE BAND AND PRODUCT)	Weslaco File #	FREQUENTLY USED DESCRIPTORS * COAST	CROPLAND	RANGELAND	LAKES	DESCRIPTORS	Flight ~~Date:~~
1524-16284-5	#315		x			Clouds	12/29/73
1524-16291-5	#319					Clouds	"
1525-16342-5	#307		x	x			12/30/73
1525-16345-5	#311			x	x		"
1543-16341-5	#323					Clouds	1/17/74
1561-16331-5	#327		x	x			2/4/74
1561-16333-6	#330			x		Clouds(1/5)	"
1579-16325-5	#333			x			2/24/74
1579-16332-5	#337						"

*For descriptors which will occur frequently, write the descriptor terms in these column heading spaces now and use a check (✓) mark in the appropriate ID lines. (For other descriptors, write the term under the DESCRIPTORS column).

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