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SOIL, WATER, AND VEGETATION CONDITIONS IN SOUTH TEXAS

Craig L. Wiegand, Principal Investigator
Co-Investigators: Harold W. Gausman
Ross W. Leamer
Arthur J. Richardson

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P. O. Box 267
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16. Abstract
The largest reflectance differences between the dead leaves of corn, cotton, sorghum, sugarcane, citrus, and avocado and the bare soils where the leaves were lying on the ground occurred in the infrared waveband 0.75- to 1.35 μm. This waveband is suggested for relating crop residues to susceptibility of soil to erosion by wind and water.

The LANDSAT-1 MSS 6/5 ratio (IR/RED) was studied for 4 major soil types in the wet and dry conditions from 17 sites in Hidalgo County. Spectral differences among soils in single bands may be large enough to complicate deductions about vegetation conditions since soil background variability is superimposed on the spectra for vegetation. The IR/RED ratio is not as sensitive to soil type and soil moisture variation as single bands are.

Leaf area index (LAI) was predicted from plant height (PH), percent ground cover (PC) and plant population (POP) for irrigated and non-irrigated grain sorghum fields for the 1975 growing season. For drought-stressed grain sorghum, the plant parameters explained only about 1/3 of the variation in LAI while they explained about 3/4 of the LAI variation of irrigated grain sorghum.

17. Key Words (Selected by Author(s))
Ground truth; IR/RED ratio; Soil reflectance; Crop residues; Reflectance of dead leaves; Leaf area index, plant parameters.

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TYPE II QUARTERLY PROGRESS REPORT

October 13, 1975 to January 13, 1976

A. Problems:

We were unable to read the CCT received from the EROS Data Center for LANDSAT-1 scenes 5028-16113 (5/17/75) and 5046-16103 (6/4/75). The scenes were reordered and the CCT arrived 1/6/76. The new tapes are readable. Location of test fields and segments in those tapes and in the tapes for scene 5082-16083 (7/10/75), and extraction of spectral signatures to relate to ground truth obtained in the spring and early summer of 1975 will proceed during the next reporting period. Data quality ratings in the catalog are FGFF, GFFG, and FFFF for the scenes in chronological order and portend suboptimal results.

CSC and other regulations are causing us difficulty in keeping a team of temporary employees together to perform the necessary tasks. In addition, pay rates have increased since the proposal was written causing us to use money budgeted for salaries faster than anticipated.

B. Accomplishments:

Dead Leaves' vs Bare Soils' Reflectances

A paper entitled "Spectrophotometric Reflectance Differences Between Dead Leaves and Bare Soils" has been prepared by H. W. Gausman, R. R. Rodriguez, and C. L. Wiegand. The Abstract follows: the entire manuscript is appended (APPENDIX A):

> Reflectance differences between dead leaves and bare soils were characterized by measuring spectrophotometric reflectance in the laboratory over the 0.5- to 2.5-μm waveband for dead leaves from six crops [avocado (*Persea americana* Mill.), citrus (*Citrus sinensis* (L.) Osbeck), corn (*Zea mays* L.), cotton (*Gossypium hirsutum* L.), sorghum (*Sorghum bicolor* (L.) Moench.), and sugarcane (*Saccharum officinarum* L.)] and for the respective bare soils next to the place where the dead leaves were lying on the ground.
>
> Reflectance differences between the dead leaves of five of the six crops and the respective bare soils were largest (15.3 to 24.5 percentage points) within the near-infrared waveband (0.75 to 1.35 μm) except for sugarcane whose largest reflectance difference was 19.2 percentage points at the 1.9-μm wavelength; however, the difference was 18.7 percentage points at the 0.85-μm wavelength within the near-infrared waveband. Thus, this waveband should be the best spectral region to distinguish dead leaves (leaf litter) from bare soils.

These findings have application in assessing soil susceptibility to erosion by wind and water in relation to crop residues.

Soil Reflectance

If soil reflectance variability, as measured by LANDSAT-1 and LANDSAT-2, was better understood, crop production forecasts and estimates of vegetation conditions could be improved, since soil reflectance variability is superimposed on the reflectance spectra for vegetation. Condit (1970) concluded that soil reflectance variability is primarily caused by soil type (texture, mineral composition, etc.) and soil water content. Soils with a dry surface have a higher reflectance than soils wet on the surface, and, for most soil types, soil reflectance increases with increasing wavelength over the visible and near-IR regions. Colwell (1975) hypothesized that the ratio of reflectance signals at the 0.75- and 0.65-μm wavelengths (IR/RED) would be less sensitive to soil type and soil moisture variation than single wavelengths. Using Condit's data, Colwell found that the IR/RED ratio averaged 1.19, with a standard deviation of 0.12, for a large sample of major soil types in the United States.

In terms of LANDSAT multispectral scanner (MSS) data, Colwell's IR/RED ratio can be formulated as MSS6/5. The specific objective of this study was to determine Colwell's IR/RED ratio for selected experimental sites in Hidalgo County using LANDSAT-1 MSS digital data collected May 27, 1973. Digital data were selected from light- and dark-appearing soils, as observed in LANDSAT color composite (bands 4, 5 and 7) transparencies, within or closely associated with 17 experimental sites within four major soil types in Hidalgo County (Fig. 1). Ground truth was not available to assess the precise soil moisture condition at each experimental site, but light-appearing soils probably had not been irrigated or disturbed for several weeks and were relatively dry. Dark-appearing soils probably had been either irrigated recently or had been tilled to expose wetter soil from below on the soil surface. Thus, it was assumed that soil darkness and lightness on the LANDSAT color transparency were correlated with relative soil wetness and dryness, respectively. It was not possible to find both light and dark soils for each of the 17 sites.

The MSS6/5 ratio, for the 17 sites, ranged from 0.93 to 1.23 (Table 1) in reasonable agreement with Colwell's IR/RED ratio of 1.19 determined from Condit's data.

Condit, H. R., 1970. The spectral reflectance of American soils. Photogrammetric Engineering and Remote Sensing, Vol. 36(9):955-966.

Colwell, J. E. and G. H. Suits, 1975. Yield prediction by analysis of multispectral scanner data. Environmental Research Institute of Michigan, Ann Arbor, NASA CR-ERIM 109600-17-F.

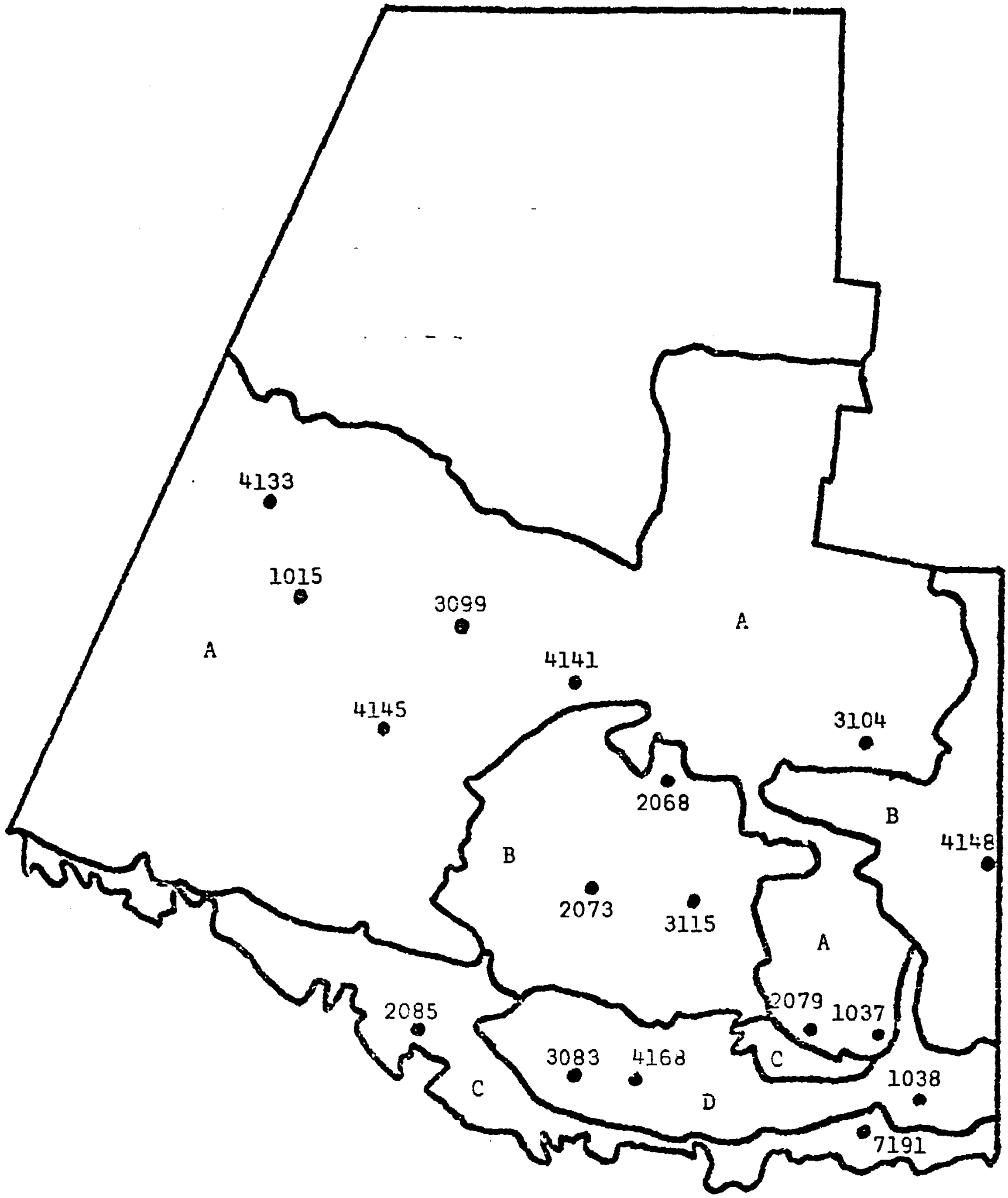

Figure 1. Map of Hidalgo County, Texas, showing the location of 17 experimental sites within the four major soil areas defined as follows:

A. Gently sloping, moderately permeable, loamy soils of uplands.
B. Level, moderately and slowly permeable, loamy and clayey soils of uplands.
C. Level, moderately and slowly permeable, loamy soils of flood plains and low terraces.
D. Level, very slowly permeable, high shrink-swell clayey soils of low terraces and uplands.

Table 1. Digital data collected on May 27, 1973 (Scene ID 1308-16323) for 17 sites within four soil types in Hidalgo County, Texas. Segment number and soil type codes are given for each site. The average digital data for light- and dark-appearing soil (dry and wet, respectively) for each soil type are also given, using only those sites within each soil type that have digital data for both light- and dark-appearing soil.

Segment number	Soil type code[1]	Light-appearing soil MSS4	MSS5	MSS6	MSS7	MSS6/5	Dark-appearing soil MSS4	MSS5	MSS6	MSS7	MSS6/5
1015	A	53	58	66	32	1.14	45	49	50	24	1.02
1037	A	60	58	64	30	1.10	43	41	49	25	1.20
2079	A	--	--	--	--	--	41	40	49	24	1.23
3099	A	56	72	68	30	0.94	44	48	45	22	0.94
3104	A	--	--	--	--	--	39	40	44	22	1.10
4133	A	--	--	--	--	--	46	47	55	27	1.17
4141	A	--	--	--	--	--	44	45	54	26	1.20
4145	A	--	--	--	--	--	44	45	53	27	1.18
Mean	(A)	56	63	66	31	1.06	44	46	48	24	1.05
2068	B	52	56	56	26	1.00	42	41	47	23	1.15
2073	B	56	57	62	28	1.09	46	48	53	25	1.10
3115	B	52	54	60	29	1.11	41	42	46	22	1.10
4148	B	70	81	78	34	0.96	44	45	43	19	0.96
Mean	(B)	58	62	64	29	1.04	43	44	47	22	1.08
2085	C	56	60	59	26	0.98	45	45	48	21	1.07
7191	C	61	64	65	29	1.02	44	42	49	23	1.17
Mean	(C)	59	62	62	28	1.00	45	44	49	22	1.12
1038	D	55	59	54	23	0.92	44	42	46	20	1.10
2083	D	53	58	55	25	0.95	--	--	--	--	--
4168	D	51	54	51	22	0.94	43	45	42	22	0.93
Mean	(D)	53	57	53	23	0.93	44	44	44	21	1.02

[1] Soil type code definitions are based on a general soil map of Hidalgo County, Texas (December 1972, USDA-SCS, Temple, Texas).

A - Gently sloping, moderately permeable, loamy soils of uplands.
B - Level, moderately and slowly permeable, loamy and clayey soils of uplands.
C - Level, moderately and slowly permeable, loamy soils of flood plains and low terraces.
D - Level, very slowly permeable, high shrink-swell clayey soil of low terraces and uplands.

There is a clear downward trend in the average digital data by soil types A, B, C and D for bands 5, 6 and 7 (Table 1) for the light-appearing soils. For example, the average digital values for MSS band 7 were 31, 29, 28, and 23, respectively, for the light-appearing soil types A, B, C, and D defined in Table 1. This trend is not very evident for the dark-appearing soils. The MSS6/5 ratios also trended downward, being 1.06, 1.04, 1.01, and 0.94 for the light-appearing soil types; the trend does not hold for the dark-appearing soil types which had 6/5 ratios of 1.05, 1.08, 1.12, and 1.02.

The mean MSS6/5 ratios for dark-appearing soils are higher than for light-appearing soils for 3 of 4 soil types; the exception was soil type A. For several sites within soil types B and D the MSS6/5 ratios were very close (segments 4148 and 2073) and in two cases (segments 3115 and 4168) the dark- was lower than the light-appearing soil ratio.

The trends depicted in Table 1 show that the MSS6/5 ratio is probably not as sensitive to soil type and soil moisture variation as the single LANDSAT MSS bands are; thus, Colwell's hypothesis is supported.

LAI Relation to Other Plant Parameters

This section presents the linear and multiple linear regression analyses applied to the ground truth data collected on nonirrigated (drought-stressed) and irrigated grain sorghum during the spring and summer of 1975.

Table 2 presents the linear and multiple linear regression equations and their coefficients of determination (r^2, R^2) for nonirrigated grain sorghum. Leaf area index (LAI) was the dependent variable, and plant height (PH) (cm), percent cover (PC), and plant population (POP) (plants / 18.4 m of row) were the independent variables. 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 regression.

The data for nonirrigated grain sorghum were collected during two time periods: May 6-20 and June 3-10, 1975, respectively. For the May 6-20 time period, POP was the single variable (linear regression) most closely related to LAI (explained 30% of the variation in LAI sum of squares), whereas for multiple regression POP + PC explained 41% of the variation in LAI. All three variables (POP + PC + PH) explained 48% of the variation in LAI.

Table 2. Linear and multiple linear regression equations and their corresponding coefficients of determination (r^2 or R^2) for leaf area index (LAI) regressed on plant height (PH), percent cover (PC) and plant population (POP) for nonirrigated grain sorghum grown during the spring and summer of 1975.

Equations	Coefficients
Data period May 6 - 20, 1975	
	r^2
LAI = 1.343 + 0.003 PH	0.058
LAI = 1.230 + 0.019 PC	0.140
LAI = 0.580 + 0.004 POP	0.299
	R^2
LAI = 1.315 + 0.005 PH + 0.034 PC	0.168
LAI = 0.334 + 0.017 PC + 0.003 POP	0.414
LAI = 0.468 + 0.002 PH + 0.003 POP	0.327
LAI = 0.361 + 0.007 PH + 0.041 PC + 0.004 POP	0.480
Data period June 3 - 10, 1975	
	r^2
LAI = 0.136 + 0.012 PH	0.192
LAI = 0.739 + 0.024 PC	0.135
LAI = 0.545 + 0.002 POP	0.152
	R^2
LAI = 0.098 + 0.009 PH + 0.015 PC	0.237
LAI = 0.363 + 0.018 PC + 0.002 POP	0.221
LAI = -0.112 + 0.010 PH + 0.002 POP	0.266
LAI = -0.118 + 0.008 PH + 0.011 PC + 0.001 POP	0.291

For ground truth measurements made during the June 3-10 time period, PH was the single variable (linear regression) most closely related to LAI, accounting for 19% of the variation; for multiple regression, PH + POP explained 27% of the variation in LAI, and PH + POP + PC explained 29% of the variation attributable to regression. All r^2 or R^2 values were low, probably because of the drought that made within field sampling site variation high through soil and topographic factors.

Table 3 presents the linear and multiple linear regression equations and their corresponding r^2 or R^2 for irrigated grain sorghum in the same manner as Table 2 did for nonirrigated grain sorghum. The data were taken during two time periods: April 15 to May 2, and from May 21 to June 30, 1975. For the April 15 to May 2 data set, PC was the single variable most closely related to LAI (r^2 = .775), while PC + POP were the two variables most closely related to LAI (R^2 = .803). The addition of PH to the regression did not improve R^2 (R^2 = .803).

For the May 26 to June 30 data set, PC was most closely related for linear regression to LAI (r^2 = .743), with PC + PH for multiple regression being most closely related to LAI (R^2 = .764). The addition of POP did not improve the R^2.

The determination of LAI is very time consuming compared with the determination of PH and PC. In the future LAI may be determinable from PC and POP information using the equations presented for the first data period. During this time period (April and early May) grain sorghum is in the prehead stage. For the second time period (post head stage) LAI might be determined by first determining PC and PH and then using the equation presented for that time period.

Grain Sorghum Head and Grain Weights

The following are linear regression equations expressing the relationship between dry head weight (HW) and dry grain weight (GW) (kg/ha) for nonirrigated and irrigated grain sorghum produced in spring and summer of 1975:

nonirrigated	GW = -34.32 + 0.74 HW	r^2 = .961	(1)
irrigated	GW = -220.83 + 0.83 HW	r^2 = .983	(2)

Results indicate that 96.1% and 98.3% (r^2 X 100) of the variation in each data set are attributable to linear regression for nonirrigated and irrigated grain sorghum, respectively. In the future, dry grain weight can be calculated from dry head weight without threshing the heads using equation 1 or 2. Since it is desired to relate crop spectral signatures and plant parameters to grain yield, heads can be sampled from test fields, and field-basis-yields calculated from average grain weight/head and average plant populations per hectare.

Table 3. Linear and multiple linear regression equations and their corresponding coefficients of determination (r^2 or R^2) for leaf area index (LAI) regressed on plant height (PH), percent cover (PC), and plant population (POP) for irrigated grain sorghum grown during the spring and summer of 1975.

Equations	Coefficients
Data Period April 15 to May 2, 1975	
	r^2
LAI = −1.145 + 0.083 PH	0.596
LAI = 0.685 + 0.077 PC	0.775
LAI = 0.1[illegible]3 + 0.008 POP	0.528
	R^2
LAI = 0.0871 − 0.007 PH + 0.082 PC	0.776
LAI = 0.156 + 0.063 PC + 0.003 POP	0.803
LAI = −1.480 + 0.056 PH + 0.004 POP	0.699
LAI = 0.337 + 0.006 PH + 0.068 PC + 0.003 POP	0.803
Data Period May 26 to June 30, 1975	
	r^2
LAI = −1.247 + 0.040 PH	0.269
LAI = −0.019 + 0.065 PC	0.743
LAI = 0.037 + 0.008 POP	0.491
	R^2
LAI = 1.161 − 0.061 PH + 0.076 PC	0.764
LAI = −0.023 + 0.001 PH + 0.007 POP	0.491
LAI = −0.009 + 0.065 PC − 0.0001 POP	0.743
LAI = 1.194 − 0.018 PH + 0.072 PC + 0.001 POP	0.766

The spectral data are not yet available corresponding to fields from which ground truth was obtained. It is planned to locate as many of the test fields as cloud conditions permit on the CCT for the LANDSAT-1 passes for 5/17/75, 6/4/75, and 7/10/75 (scene I. D. 5028-16113, 5046-16103, and 5082-16083, respectively) and for LANDSAT-2 pass 4/02/75 (scene I. D. 2070-16203) and relate the spectral signatures to ground truth (PH, PC, POP) and grain yields for those fields. This effort will receive high priority during the next reporting period.

C. Significant Results:

The reflectance differences between the dead leaves of six crops (corn, cotton, sorghum, sugarcane, citrus and avocado) and the respective bare soils where the dead leaves were lying on the ground were determined from laboratory spectrophotometric measurements over the 0.5- to 2.5-µm wavelength interval. The largest differences were in the near-infrared waveband 0.75- to 1.35-µm This waveband should be the best spectral region in which to distinguish leaf litter from bare soils. This finding has application in assessing soil susceptibility to erosion by wind and water in relation to crop residues.

Leaf area index (LAI) has been predicted from plant height (PH), percent ground cover (PC) and plant population (POP) for irrigated and nonirrigated grain sorghum fields for the 1975 growing season. For drought-stressed grain sorghum, these variables typically explained only about 1/3 of the variation in LAI while they explained about 3/4 of the LAI variation of irrigated grain sorghum.

D. Publications:

Allen, L. H., Jr., H. W. Gausman, and W. A. Allen. Solar ultraviolet radiation in terrestrial plant communities. J. Environ. Qual. 4:285-294. 1975.

Gausman, H. W., R. R. Rodriguez, and D. E. Escobar. Ultraviolet radiation reflectance, transmittance, and absorptance by plant leaf epidermises. Agron. J. 67:720-724. 1975.

Gausman, H. W., C. M. Heald, Jr., and D. E. Escobar. Effect of nematodes on reflectance of cotton plant leaves. J. of Nematology 7:368-374. 1975.

Richardson, A. J., C. L. Wiegand, H. W. Gausman, J. A. Cuellar, and A. H. Gerbermann. Plant, soil, and shadow reflectance components of row crops. Photogram. Eng. & Remote Sensing 41:1401-1407. 1975.

E. Recommendations:

That NASA provide more information about the scenes available with high gain in the visible bands.

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.	$19,402. (7/1 - 12/6/75)
Supplies and Equipment	15,821.	19,761. (7/1 - 1/7/76)
Local Flying Service	589.	1,830. (7/1 - 1/7/76)
G & A (18%)	6,560.	12,600. (for year)
	$ 28,980.	$ 53,593.

APPENDIX A

SPECTROPHOTOMETRIC REFLECTANCE DIFFERENCES BETWEEN DEAD LEAVES AND BARE SOILS[1]

H. W. Gausman, R. R. Rodriguez, and C. L. Wiegand[2]

1 Soil and Water Conservation Research, Southern Region, Agricultural Research Service, USDA, Weslaco, Texas. This study was supported in part by the National Aeronautics and Space Administration under Contract No. S-70251-AG, Task 3.

2 Plant Physiologist, Biological Technician, and Soil Scientist, respectively, USDA, Weslaco, TX 78596.

Using field spectroradiometric measurements, at the 0.5- to 1.8-µm waveband, we (Gausman et al., 1975) have shown that crop residue littered on the soil surface had a higher reflectance than bare soil, but standing crop residue had lower reflectance than bare soil. Consequently, we have been asked, "what is the reflectance difference between a dead leaf[3] and a bare soil?" This question has been answered partially by Hoffer and Johannsen (1969) who showed that corn leaves with a low water content (3 to 18%) had 10 to 30 percentage points more spectrophotometrically measured reflectance than did a dry clay soil (water content of 3 to 6%) over the 0.5- to 2.5-µm waveband. However, further study is needed to more fully understand the difference.

The objective of this study was to characterize reflectance differences between dead leaves of six crops and the respective bare soils next to the place where the dead leaves were lying on the ground by spectrophotometrically measuring reflectance in a laboratory over the 0.5- to 2.5-µm waveband.

MATERIALS AND METHODS

A Beckman Model DK-2A spectrophotometer,[4] equipped with a reflectance attachment, was used to measure the total diffuse reflectance for five replications of soils and dead crop leaves. Data were recorded at discrete 0.05-µm intervals over the continuously measured 0.5- to 2.5-µm waveband (41 wavelengths). Data were corrected for decay of the $BaSO_4$ standard to give absolute radiometric data (Allen and Richardson, 1972).

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3 In this paper, dead leaves are considered vegetation devoid of chlorophyll with much lower water content than living tissue. Such leaves are yellow or "bleached," dry, and brittle. They may be naturally senescent leaves still attached to either live or dead plants such as mature wheat and corn, naturally shed leaves, and dry leaves resulting from physical damage such as hail and mowing or from physiochemical damage such as freezing and extreme drought. Under field conditions, the term dead leaves may cover "stubble" and crop residues of those plants whose living stems, leaf sheaths, and petioles contained chlorophyll.

4 Mention of company name 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.

Five intact dead leaves were selected from the littered residue of six crops [avocado (Persea americana Mill.), citrus (Citrus sinensis (L.) Osbeck), corn (Zea mays L.), cotton (Gossypium hirsutum L.), grain sorghum (Sorghum bicolor (L.) Moench.), and sugarcane (Saccharum officinarum L.)] for spectrophotometric reflectance measurements. Each brittle, "bleached," and partially dehydrated leaf was placed over the spectrophotometer's port for reflectance measurements. Average water contents on a dry-weight basis for avocado, citrus, corn, cotton, grain sorghum, and sugarcane leaves were 6.3, 11.8, 8.0, 15.0, 4.7, and 9.7%, respectively.

Avocado, citrus, cotton, grain sorghum, and sugarcane leaves were lying on a Hidalgo sandy clay loam soil; corn leaves were lying on a Hidalgo clay loam soil. The bare surface soil, next to where the leaves were collected, was sampled to about a 2-cm depth for each crop. Average soil water contents on a dry-weight basis were 2.3, 6.8, 5.1, 5.3, 3.9, and 5.4% for soils for avocado, citrus, corn, cotton, sorghum, and sugarcane leaves, respectively. Laboratory spectrophotometric reflectance measurements were made on five subsamples of each composite soil sample. Using the methods of Mathews, Cunningham, and Petersen (1973), soils were hydraulically pressed into bottle caps so that samples could be mounted vertically over the spectrophotometer's port; noncompacted soil would have fallen into the spectrophotometer's integrating sphere.

Water content of soils and leaves was determined on samples oven dried at 68C for 72 hr and cooled in a desiccator before weighing.

The reflectances for the soil and leaves of each crop were analyzed for variance (Steel and Torrie, 1960). The least significant difference (LSD, P - 0.01) was used to test the mean difference between soil and leaves for each crop at each of 41 wavelengths.

RESULTS AND DISCUSSION

The reflectance of dead sugarcane leaves was significantly (P = 0.01) greater than the bare soil reflectance at all wavelengths measured (Fig. 1). The reflectances of dead avocado leaves and the bare soil were statistically alike at 0.70-, 0.75-, 1.90-, 1.95-, 2.00-, 2.05-, 2.15-, 2.20-, and 2.25-μm wavelengths; for citrus at the 0.65-, 1.70-, and 1.75-μm wavelengths; for corn at 0.50- and 0.55-μm wavelengths; for cotton at 0.60-, 0.65-, 2.25-, 2.30-, 2.35-, 2.40-, 2.45-, and 2.50-μm wavelengths; and for sorghum at the 0.55- and 0.60-μm wavelengths. At all other wavelengths, reflectances of these leaves were statistically different than respective soil reflectances.

The largest reflectance difference in percentage points (PP) between dead leaves and bare soil and the corresponding wavelength for each crop (Fig. 1) were: avocado, 15.7 PP, 1.05 μm; citrus, 15.3 PP, 0.95 μm; corn, 24.5 PP, 1.3 μm; cotton, 18.1 PP, 1.00 μm; grain sorghum, 22.1 PP, 0.95 μm; and sugarcane, 19.2 PP, 1.9 μm. Except for sugarcane, the reflectance differences between dead leaves and bare soils were greatest on the near-infrared plateau over the 0.75- to 1.35-μm waveband. On the near-infrared plateau, the largest reflectance difference between sugarcane leaves and soil was 18.7 PP at the 0.85-μm wavelength.

CONCLUSION

Laboratory spectrophotometric results indicated that the 0.75- to 1.35-μm waveband should be the best spectral region for distinguishing dead leaves from bare soils. Within this waveband, reflectance differences between dead leaves and bare soils for six crops ranged from 15.3 to 24.5 percentage points. However, under field conditions, dead leaves are superimposed on the soil background's reflectance; thus, a composite reflectance is sensed. Duplicating field soil surface conditions in the laboratory is also difficult, since the soil surface usually becomes smoother and lighter colored with time after tillage. Nevertheless, the laboratory data represented pure reflectance from bare soils and dead leaves and indicated useful wavelengths for distinguishing dead leaves from bare soils.

The spectral reflectance contrast between dead leaves and bare soils found in this study suggests that efforts should be made to relate aircraft and spacecraft spectral data to estimated (or measured) amounts of crop residue standing or littered on the soil surface for several test fields in various locations. If the amount of residue can be estimated spectrally, then the already established principle that crop residues reduce wind or water erosion susceptibility of soils can be used.

LITERATURE CITED

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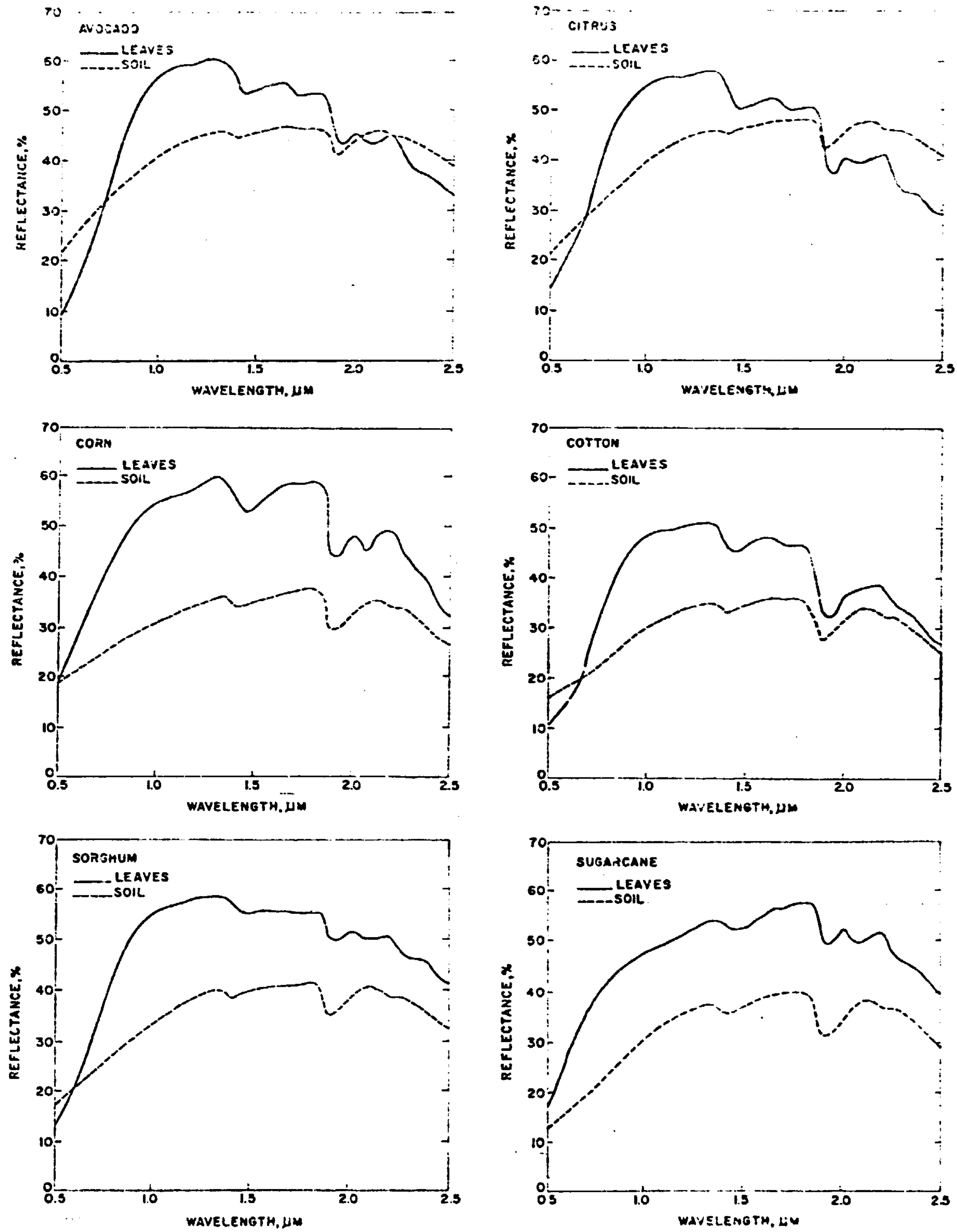

Fig. 1. Laboratory spectrophotometrically measured reflectances of dead leaves and bare soils for avocado, citrus, corn, cotton, sorghum, and sugarcane crops over the 0.5- to 2.5-µm waveband.