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Landsat-Simulating Radiometer for Agricultural Remote Sensing

Significant correlation was found in corn fields, little correlation occurred for small grain fields, and sun angle had a minimal effect.

THE ADVENT of satellite imagery has brought about many new advances and adaptations of established remote sensing equipment and procedures. One such adaptation is the use of ground-based spectral radiometers to obtain simulated Landsat data. Ground-based spectral radiometers permit non-destructive *in situ* measurements of reflectance data from a desired target and have been used by many investigators as a research tool and/or a source of ground truth in combination with data obtained from other platforms. The possibility of providing data that closely simulate the measurements made by multispectral scanners make them a potentially valuable tool in Landsat investigations.

ABSTRACT: *The reliability of a Landsat-simulating ground-based spectral radiometer for use in agricultural remote sensing was investigated. Significant correlation coefficients in all wavebands except Band 7 were found to exist between Landsat computer compatible tape* (CCT) *and ground-based radiometric data from several corn fields. No significant correlations were found within data from small grain fields. Combined data from several common agricultural crops yielded significant correlation coefficients in the wavebands most commonly employed in agricultural remote sensing.*

It was also found that sun angle within certain limits of a given day had minimal effect on ground-based radiometric measurements taken from a fallow and barley field.

The adaptability of spectral radiometers for agricultural research has been established by other investigators. Lee (1975) presents a general review of literature concerning the use of spectral radiometers. Gates (1970), Gausman (1970, 1972, 1974), and Knipling (1970) have probed many of the physical and physiological aspects behind reflectance patterns of leaves obtained from spectral radiometer measurements.

Tucker and Garratt (1977) have developed a stochastic leaf radiation model to predict absorbed, reflected, and transmitted radiation as a function of wavelength by considering many of the physical and physiological properties of leaves as reported in the literature. Their model provides a basis for a comprehensive understanding of the interactions among various wavelengths of light and plant leaves.

Bowers and Hanks (1965) and Myers (1968, 1970) have contributed much to the understanding of reflectance data obtained from soils. They have been able to demonstrate relationships among chemical, min-

PHOTOGRAMMETRIC ENGINEERING AND REMOTE SENSING,
Vol. 45, No. 1, January 1979, pp. 99-103.

eralogical, and physical soil properties and their association with radiation characteristics of soils.

Cipra (1971) successfully used a field spectral radiometer to distinguish between soils classified (Soil Survey Staff, 1975) as Mollisols and Alfisols. Weber (1972) determined that, when calibrated, a four channel spectrometer designed to simulate Landsat spectral waveband regions produced very accurate measurements in each of the four multispectral (MSS) bands.

Ground-based *in situ* spectral radiometers have generally suffered from lack of mobility. Pearson and Miller (1972) reported the development of a portable hand held spectral radiometer. Dry biomass was estimated by Pearson *et al.* (1976) for shortgrass prairie vegetation by the use of a hand held spectral radiometer. A linear relationship was established between dry biomass and a ratio of 0.65-0.70 μm and 0.775-0.825 μm. Tucker *et al.* (1978) used a hand held spectral radiometer to monitor corn, soybeans, and alfalfa on a temporal basis throughout the growing season. Vegetation index transformations were used to normalize data collected under varied irradiational conditions.

Variations in irradiational conditions coupled with atmospheric variables that interact with reflected exitance measured by a remote sensor needs to be considered when using such data. Pritts and McAllum (1974) found that gradients in atmospheric moisture between test sites and the remainder of a Landsat scene caused a decrease in classification accuracy when using Band 7 data. Turner and Spencer (1972) prepared a radiometric transfer model to correct multispectral scanner data for atmospheric interference. Kaneko and Engvall (1977) found the view angle of the sensor could result in a 5 percent reduction in sensor response. Smith *et al.* (1975) noted that the affect of sun angle variations, within 35 to 50°, depended upon canopy characteristics. Effects of the vegetation canopy were most pronounced at the larger solar angles. Waveband 7 data demonstrated a stronger sun angle dependence than Band 5 when Duggin (1977) considered the use of sequential Landsat imagery. He found that a 25 percent increase in ratio values of Band 7 over Band 5 resulted from a change in zenith angle from 30 to 60°.

This study was conducted to determine what relationships existed among data collected from an agricultural area by ground-based portable Landsat simulating spectral radiometer and Landsat computer compatible tape (CCT) values. Associated with this objective was the evaluation of the effect of sun angle upon ground-based spectral radiometer data collected within a single day. This study differs from many others in the literature in that data in the same spectral regions obtained from two platforms are related to one another. Sun angles investigated are limited to those that would occur in the use of a hand held spectral radiometer for the collection of field data within the time frame of a single working day.

Materials and Methods

During the 1974 growing season, an Exotech model 100 spectral radiometer* equipped with 2π diffuser screens to measure exitance and total irradiance was used to collect ground-based radiometric data from test fields on those dates that correspond with Landsat-1 overpasses of Brookings County, South Dakota. Reflectance data were recorded from three randomly selected locations within each test field. Measurements were taken approximately 1 meter above the vegetative surface. In order to comply with this, much of the season's measurements were taken atop a 1.8 metre step ladder. Before and after the collection of reflectance data, incoming radiation was recorded in each of the Landsat wavebands by the use of the same instrument. Mean reflected exitance and incoming total irradiance were determined for each field. Percent reflectance values were calculated for all Landsat wavebands for each field by Equation 1, as is suggested by Cipra (1971) and Gausman (1974).

$$\frac{\text{mean reflected existance}}{\text{mean incoming total irradiance}} \times 100 = \text{percent reflectance} \qquad (1)$$

Information concerning crop height, condition, row geometry, and sky conditions were also recorded for test fields when radiometric data were collected.

Unfavorable sky conditions during the overpasses permitted comparison of data from only one date, June 30, 1974. The computer compatible tape (number 1707-

* Mention of company or trademark is for the reader's benefit and does not constitute endorsement of a particular product by South Dakota State University over others that may be commercially available.

TABLE 1. CORRELATION COEFFICIENTS BETWEEN GROUND-BASED RADIOMETER AND LANDSAT CCT DATA IN SMALL GRAIN FIELDS. 30 JUNE 1974.

		Landsat Wavebands			
		4	5	6	7
Ground Based Wavelengths	4	0.009	−0.080	0.390	0.381
	5	0.065	−0.002	0.312	0.291
	6	−0.261	−0.191	−0.079	0.123
	7	−0.194	−0.126	−0.073	0.115

* Significant at 0.05 level with 14/D.F. (>0.497)
** Significant at 0.01 level with 14/D.F. (>0.623)

16361) of the Landsat overpass was obtained and an alphanumeric symbol sequence was assigned to the digital values. This procedure allowed each symbol to represent one pixel of data. The location of test fields by line and column was obtained from line printer output of the general area. An average value for each of the Landsat wavebands was determined from the computer compatible tapes for each of the fields from which ground based spectral radiometer data had been collected. These data were then correlated with the ground-based radiometric data.

Reflectance data collected at 15 minute intervals from 1015 to 1500 central daylight time on July 14, 1975 from a fallow field and a barley field were averaged and a mean percent reflectance for each field was determined. The deviation from this mean was calculated for each reading. These data provide a basis for investigating the effect of sun angle on reflectance data obtained via a Landsat simulating radiometer within the time frame of a single day.

RESULTS

Correlation coefficients from the comparison of Landsat and ground-based radiometric data from small grain fields are given in Table 1. The comparison of the same waveband between the two systems is underlined and forms a diagonal line when all four wavebands are considered. No significant correlations were found to exist between ground-based spectral radiometer data and Landsat data at either 0.05 or 0.01 levels of confidence.

Better correlation among Landsat data and ground-based radiometric data were found to exist when the corn data were analyzed (Table 2). Wavebands 4 and 5 (0.5 to 0.6 μm and 0.6 to 0.7 μm, respectively) of the two systems correlated significantly at the 0.01 level of confidence. No significant correlation was found to exist at either level of confidence within band 6 and band 7 (0.7 to 0.8 μm and 0.8 to 1.0 μm, respectively) of the two sources of data.

In Table 3 the correlation coefficients derived from the combination of all test fields (corn, small grain, and alfalfa) are shown. The two near infrared bands (wavebands 6 and 7) had correlation coefficients that were significant at the 0.01 level of confidence. Significant correlation at the 0.05 level of confidence was found to exist among the band 5 data but none was found among band 4 data.

The effect of sun angle (time of day the data were collected) upon ground-based spectral radiometer data is summarized in Table 4. The average of the 21 readings in each of the Landsat wavebands is given for a fallow and a barley field. There is no particular sun angle studied that had a

TABLE 2. CORRELATION COEFFICIENTS BETWEEN GROUND-BASED RADIOMETER AND LANDSAT CCT DATA IN CORN FIELDS. 30 JUNE 1974.

		Landsat Wavebands			
		4	5	6	7
Ground Based Wavelengths	4	0.779**	0.815**	0.599*	0.507
	5	0.759**	0.797**	0.575	0.486
	6	0.490	0.496	0.533	0.515
	7	0.492	0.581	0.455	0.423

* Significant at 0.04 level with 10/D.F. (>0.576)
** Significant at 0.01 level with 10/D.F. (>0.708)

TABLE 3. CORRELATION COEFFICIENTS BETWEEN GROUND-BASED RADIOMETER AND LANDSAT CCT DATA FROM COMBINED CROP DATA. 30 JUNE 1974.

		Landsat Wavebands			
		4	5	6	7
Ground Based Wavelengths	4	0.275	0.202	0.481**	0.385*
	5	0.351*	0.347*	0.264	0.221
	6	0.070	0.347*	0.669**	0.686**
	7	0.079	−0.287	0.648**	0.673**

* Significant at 0.05 level with 42/D.F. (>0.304)
** Significant at 0.01 level with 42/D.F. (>0.393)

stronger effect on the spectral radiometer readings than other sun angles. In both cases the standard deviation and coefficient of variation increased as the wavelength measured increased. Data from the barley field had more variation than those collected from the fallow field.

DISCUSSION AND CONCLUSIONS

It was concluded that ground-based Landsat-simulating spectral radiometers can be a useful tool in agricultural research using digital data from Landsat. The poor correlation between the two sources of data from small grain fields could have been due to the extreme variability found in small grain fields that are approaching senescence. Looking at the general spectrum of crops, good correlation exists in those wavebands that are most commonly used in agricultural remote sensing.

Phenological variability associated with the barley crop is likely to be the reason for standard deviations and coefficients of variability that exceed those of the fallow field. Variations in surface conditions, such as roughness or moisture content, would be responsible for most of the variation in the unvegetated fallow field while plant factors, such as crop condition, maturity, and density of stand along with soil variability, would affect exitance data from the barley field.

Coefficients of variability from these data are acceptable for most biological research. Standard deviations should be considered when using data collected from among locations or treatments.

The results indicating a minimal effect of sun angle on data collected within the specified time limits have practical implications. The small variance attributed to sun angle enables a field party to collect reliable data from several locations over a reasonable time period. If sun angle had had a strong influence on the measurements, the use of ground-based spectral radiometers would be limited to data collected within a narrow time span corresponding to the Landsat overpass. Time of day may have a stronger influence during other periods of the year when the sun is at a lower angle. This facet was not investigated because most agriculturally related remote sensing in the Midwest is performed during the summer months.

ACKNOWLEDGMENTS

The authors wish to acknowledge the assistance of the Data Handling Section and particularly Mary DeVries of the Remote Sensing Institute of South Dakota State University for the computer handling of the data. This report is authorized for publication as Journal Series No. 1479 South

TABLE 4. EFFECT OF SUN ANGLE UPON GROUND-BASED SPECTRAL RADIOMETER DATA. 14 JULY 1975.

Landsat	Mean Reflectance		Standard Deviation		CV*	
Waveband	Fallow	Barley	Fallow	Barley	Fallow	Barley
4	3.1%	6.6%	0.148	0.462	4.8%	6.9%
5	3.3%	6.6%	0.183	0.670	5.5%	10.1%
6	5.7%	19.0%	0.465	1.921	8.1%	10.1%
7	6.7%	22.9%	0.626	2.942	9.4%	12.8%

* CV = coefficients of variability

Dakota State Agricultural Experiment Station. The research was supported in part by NASA Grand NGL 42-003-007 to the Remote Sensing Institute, South Dakota State University.

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(Received February 16, 1978; revised and accepted September 11, 1978)