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FINE STRUCTURE IN THE SPECTRAL REFLECTANCE OF VEGETATION AND SOILS

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The spectral reflective response of plants, soils, and rocks may contain information concentrated in relatively narrow spectral regions defined by the light absorption properties of the constituent atoms and molecules. The hope exists that such information will be of value in remote sensing in discriminating information classes, in identifying growth stages and stress conditions in crops, and in delineating the chemical and physical properties of soils and rocks. Satellite sensors measuring spectral regions possibly as narrow as 0.02 μm, a spectral resolution significantly better than that (0.1 μm) of the Landsat multispectral scanner, appear feasible.

Fine structure in crop spectra has been reported by Collins who identified a shift in the radiance of wheat measured in the far red (near-infrared 0.73 μm) wavelengths, a shift that occurs at the onset of heading. Wiersma grouped spectra from bare soil and vegetation and found a significant amount of non-redundant information in the near-infrared wavelength region in bands 0.02 μm apart.

The paper addresses the key issue raised by Wiersma; if there is information in narrow wavelength bands in reflectance spectra of bare soil and vegetation, is that information attributable to properties of the soil, the vegetation, or both. Four hundred eighty-one spectra representing soils from throughout the United States were analyzed. More than 1000 wheat spectra from four fields measured at four growth stages, several view directions, and several illumination angles were analyzed. The analyses involved the correlation coefficient computed for the spectral reflectance of adjacent wavelengths 0.02 μm apart.

The analysis results show clearly the large water absorption bands at 1.4 and 1.9 μm, prominent in soil and vegetation spectra. The iron oxide absorption band at 0.9 μm is quite pronounced in the analysis results of the soils data. The vegetation analysis results show clearly the transition wavelength region between the visible and the near-infrared, anomalies at 0.53 and 0.57 μm, and minor water absorption bands at 0.95 and 1.15 μm. At three wavelengths, 0.85, 1.05, and 1.25 μm, small anomalies in the results may indicate fine structure in the reflectance data but the finding is tenuous at best.

VARIABILITY OF REFLECTANCE MEASUREMENTS DUE TO THE INTERACTION OF ROW AZIMUTH AND SOLAR ILLUMINATION ANGLE

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Pronounced effects on the reflective response of a crop canopy due to changes in solar azimuth and row azimuth angle have been noted on soybeans planted in wide rows. Understanding the interaction between row azimuth and illumination direction on the crop canopy spectral response is necessary in order to utilize effectively the spectral data collected on row crops.

The objective of this experiment was to determine the effects of rows and row direction on the reflective response of a soybean canopy as a function of solar azimuth and zenith angles. Data were acquired over eleven plots in 1979. One plot was planted in east-west and north-south rows 25 cm wide to obtain, at later growth stages, a canopy with negligible row effects. A bare soil plot was included in order to monitor the sunlit soil background reflectance of the soybean plots. The remaining nine plots were planted in soybeans with 76 cm wide rows with the following azimuthal directions: 90-270, 105-285, 120-300, 135-315, 150-330, 165-345, 180-360, 210-030, and 240-060 degrees. The row directions were selected to favor the data collections during the morning hours when cloud free conditions are more likely. Reflectance data were acquired with a Landsat band radiometer (Exotech 100) at 15 minute intervals throughout the day on three days, representing three canopy growth stages with 65, 75 and 95 percent soil cover for those plots with 76 cm wide rows.

Analysis of the data has shown minor effects on reflectance due to solar zenith angle. (Significant effects may be observed at lower latitudes whose wider diurnal variations of solar zenith angle are observed.) The two visible bands (0.5-0.6 μm) and (0.6-0.7 μm) were significantly affected by the interaction of solar and row azimuth angles. Reflectances of canopies with rows parallel to the solar azimuth illumination angle were more than double the reflectance of canopies with rows perpendicular to the illumination angle.

Mathematical models relating the spectral response of a soybean canopy changing in size and shape to the projected solar angle (Θsp) will be discussed. ($\Theta sp = \tan^{-1}(\tan\Theta s \sin\Phi s)$ where Θs = solar zenith angle; Φs = solar azimuth - row azimuth angle)

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VARIABILITY OF REFLECTANCE MEASUREMENTS WITH SENSOR ALTITUDE AND CANOPY TYPE

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Reliance on portable, ground-based sensors for measuring crop reflectance has created a need for comparable and reliable measurement procedures capable of providing calibrated and reproducible canopy reflectance data. Acquisition of reproducible data is assured in part if the field of view (FOV) of the measuring sensor contains a representative sample of the canopy. The particular portion of the canopy in the sensor FOV changes with the altitude of the sensor above the canopy. For example, readings taken at low altitudes might tend to be erratic because a single leaf might fill the sensor FOV, biasing the measurements. As the sensor altitude above the canopy increases, the repeatability of the measurements should improve because the canopy components (stalks, leaves, soil, shadows, etc.) viewed by the sensor tend to better represent the canopy.

The objective of the experiment was to determine how the canopy reflectance varies as a function of sensor altitude above the crop, and particularly, what minimum altitude is needed to acquire repeatable reflectance measurements with a desired precision. Data were acquired in 1979 on three canopies, mature corn planted in 76 cm rows, mature soybeans planted in 96 cm rows with 75 percent ground cover, and mature soybeans planted in 76 cm rows with 100 percent ground cover. Data were acquired using a Landsat band radiometer (Exotech 100) with a 15 degree field of view at ten altitudes ranging from 0.2 m to 10 m above the canopy. At each altitude, measurements were taken at 15 cm intervals along a 2.0 m transect perpendicular to the crop rows.

The reflectance data were plotted as a function of altitude and horizontal position to verify that the variance of measurements at low altitudes was attributable to row effects which disappear at higher altitudes where the sensor integrates across several rows. The coefficient of variation of reflectance in the red (0.6-0.7 μm) band decreased exponentially from 34.8 percent at 1.0 m above the corn canopy to 1.9 percent at 10 m. In the near infrared (0.8-1.1 μm) band, the coefficient of variation decreased exponentially from 18.9 percent at 1.0 m above the corn canopy to 1.3 percent at 10 m. With simple random sampling at least 13 measurements of red reflectance at 1.0 m or one measurement at 6.0 m above the corn canopy were required for ±10 percent precision at the $\alpha = 0.05$ level.

RELATIONSHIP BETWEEN SCENE CHARACTERISTICS AND LANDSAT CLASSIFICATION PERFORMANCE OF CORN AND SOYBEANS

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Accuracy of classification of Landsat MSS data depends on a number of parameters such as scene characteristics, training, classification, and area estimation procedures selected. The variability in accuracy that one may find using the same classification procedure applied at different locations is due primarily to scene variability. The understanding of the way that characteristics of a scene affect classifier performance is an important step to determine the amount of training, classification algorithm, and area estimation procedures that would be suitable to achieve an optimal accuracy.

The objective of this paper was to sample a variety of corn and soybean areas in the U.S. Corn Belt and classify them using fixed training and classification procedures in order to determine how agronomic parameters of a scene affect the classification accuracy. The classifications were based on multitemporally registered Landsat MSS data acquired during the 1978 crop year over LACIE-type sample segments in several regions of the U.S. Corn Belt. Digital "ground truth" consisted of both wall-to-wall field observations of all ground covers present throughout the growing season and agronomic observations acquired simultaneously with Landsat passes, including percent ground cover, height and growth stage for several corn and soybean fields within each segment. Color IR aerial photographs were available for all segments. The classifications were performed using the per point maximum likelihood classifier implemented in LARSYS, based on one visible and one near infrared channel from acquisitions at planting and after tasseling of corn. Segments selected for analysis had similar Landsat data acquisition histories. A modified supervised training approach was used in a consistent fashion for all segments. Several characteristics of the scenes studied involving aspects of crops, soils and weather conditions were compared to classification performances.

Analysis conducted in this investigation to date reveals that segment-to-segment variability has a significant effect on classification performance. Although high overall performances have been achieved for most of the segments, individual class performances have varied considerably from segment-to-segment. For example, accuracy for corn varied from 71 to 99 percent; for soybeans, it varied from 82 to 93 percent. Preliminary results have shown that units of the size of a segment are too large for comparisons with many of the important agronomic characteristics of a scene. Therefore, qualitative and quantitative comparisons between scene characteristics and classification performance of smaller units (1 nm square) are currently underway.

In our presentation we will discuss several specific characteristics of the scenes involving particular aspects of crops, soils properties, and weather parameters that affect classification performances on a segment basis and within a segment based on smaller units.

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