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Extension of Laboratory~Measured Soil Spectra to Field Conditions

by E.R. Stoner, M.F. Baumgardner, R.A. Weismiller,
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| 16. Abstract Spectral responses of two glaciated soils, Chalmers silty clay loam and Fincastle silt loam, formed under prairie grass and forest vegetation, respectively, were measured both in the laboratory under controlled moisture equilibria and in the field under various moisture and crop residue conditions. An Exotech Model 20C spectroradiometer was used to obtain spectral data in the laboratory under artificial illumination. Reflectance measurements ranged from 0.52 to 2.32 μm in 0.01 μm increments. Asbestos tension tables were used to maintain a 0.10-bar moisture equilibrium following saturation of crushed, sieved soil samples. The same spectroradiometer was used outdoors under solar illumination to obtain spectral response from dry and moistened field plots with and without corn residue cover, representing the two different soils. Results indicate that laboratory-measured spectra of moist soil are directly proportional to the spectral response of that same field-measured moist bare soil over the 0.52 to 1.75 μm wavelength range. The magnitudes of difference in spectral response between identically treated Chalmers and Fincastle soils are greatest in the 0.6 to 0.8 μm transition region between the visible and near infrared, regardless of field condition or laboratory preparation studied. | | | |
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Extension of Laboratory-measured Soil Spectra to Field Conditions¹

ERIC R. STONER, MARION F. BAUMGARDNER, RICHARD A. WEISMILLER, LARRY L. BIEHL, AND BARRETT F. ROBINSON²

ABSTRACT

Spectral responses of two glaciated soils, Chalmers silty clay loam and Fincastle silt loam, formed under prairie grass and forest vegetation, respectively, were measured both in the laboratory under controlled moisture equilibria, and in the field under various moisture and crop residue conditions. An Exotech Model 20C spectroradiometer was used to obtain spectral data in the laboratory under artificial illumination. Reflectance measurements ranged from 0.52- to 2.32- μm in 0.01- μm increments. Asbestos tension tables were used to maintain a 0.10-bar moisture equilibrium following saturation of crushed, sieved soil samples. The same spectroradiometer was used outdoors under solar illumination to obtain spectral response from dry and moistened field plots with and without corn residue cover, representing the two different soils. Results indicate that laboratory-measured spectra of moist soil are directly proportional to the spectral response of that same field-measured moist bare soil over the 0.52- to 1.75- μm wavelength range. The magnitudes of difference in spectral response between identically treated Chalmers and Fincastle soils are greatest in the 0.6- to 0.8- μm transition region between the visible and near infrared, regardless of field condition or laboratory preparation studied.

Additional Index Words: remote sensing, spectroradiometry, crop residue, soil moisture.

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RECENT ADVANCES in remote sensing technology applied to soil survey have shown promise of enhanced speed and accuracy in the preparation of these surveys (Weismiller and Kaminsky, 1978; Westin and Frazee, 1976). Similar techniques have been applied to soil erosion monitoring and crop residue detection (Gausman et al., 1975). Such remote sensing applications rely on the existence of characteristic spectral differences among components of the soil scene.

A variety of soil parameters and conditions individually and in association with one another contribute to the spectral reflectance of soils. These parameters are known to include the physicochemical properties of organic matter, moisture, texture, and iron oxide content as well as other variables less well defined as contributors to reflectance (Beck, 1975;³ Bowers and Hanks, 1965; Condit, 1970; Montgomery and Baumgardner, 1974; Montgomery, 1976). Conditions affecting the radiation and characteristics of soils in their natural state are green vegetation, shadows,

surface roughness, and nonsoil residue, all of which vary according to tillage operations, cropping systems, or naturally occurring plant communities (Cipra et al., 1971; Gausman et al., 1975; Gausman et al., 1976; Gausman et al., 1977; Hoffer and Johannsen, 1969; Silva et al., 1971). Although spectroradiometric studies of soils under laboratory and field conditions have contributed to an understanding of soil reflectance, the validity of comparing laboratory-measured soil spectra to field conditions has not been documented.

The objectives of this study were to differentiate between two widely occurring glaciated soils on the basis of spectroradiometric response under varied field and laboratory conditions and to verify the validity of laboratory-measured soil spectra for characterizing soil reflectance in the field.

MATERIALS AND METHODS

Field Spectroradiometric Data

A field experiment to measure the effects of corn crop residue and soil moisture content on the reflectance of glaciated soils differing greatly in soil color, organic matter content, and natural drainage was conducted on 12 May 1977. Factorial treatment combinations consisted of two levels of soil moisture content (dry and moist) along with two surface soil conditions, i.e., with and without 2.2 metric tons/ha corn stover (about a 35% cover). Two plot sites were chosen at the Purdue University Agronomy Farm to represent the two soils under investigation: Chalmers silty clay loam, a fine-silty, mixed, mesic Typic Haplaquoll, and Fincastle silt loam, a fine-silty, mixed, mesic Aeric Ochraqualf (Soil Survey Staff, 1975).

At each soil site 12 plots measuring 3 by 3 m were delineated on soil which had been raked smooth to reduce crusting, providing three replications of each treatment combination randomized in three blocks. An Exotech Model 20C spectroradiometer was used in a 15° field of view mode to obtain spectral data at discrete 0.01- μm intervals over the 0.52- to 2.32- μm wavelength range from a 1.6-m diam viewing area on the ground (Leamer et al., 1973). A panel painted with BaSO₄ was used as a calibration standard.

Laboratory Spectroradiometric Data

Composite surface soil samples from both of the above soil sites were collected from each of the 12 plots. Sample preparation involved drying, crushing, and sieving all soil samples to remove particles larger than 2 mm in diam. Special sample holders were designed and constructed of PVC rings 2 cm deep by 10 cm diam with 50-mesh brass strainer cloth stretched taut and fastened in a countersunk groove in one end. Nonreflecting black paint was applied to reduce unwanted reflection from the sample holders.

To provide a uniform moisture environment two plexiglass-framed 61 by 91 cm asbestos tension tables were constructed and set up with a 100-cm column of water in order to maintain a 0.10-bar moisture tension (Jamison and Reed, 1949; Leamer and Shaw, 1946). The 0.10-bar moisture tension can be thought to approximate the drainage tension of soils tilled at the 1-m depth. The pore space at this tension has been closely associated to the yield response of many field crops (Leamer and Shaw, 1946). After saturation of the soil samples for about 4 hours, the samples were placed on the tension tables for 24 hours equilibration.

Duplicate subsamples of the composite surface soil samples were measured with an Exotech Model 20C spectroradiometer in an outdoor configuration with a bidirectional reflectance factor (BRF) reflectometer (DeWitt and Robinson, 1976). The illumination source was a 1,000-W tungsten iodide coiled filament lamp which transfers a highly collimated beam by means

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³R. H. Beck. 1975. Spectral characteristics of soils related to the interaction of soil moisture, organic carbon and clay content. M.S. Thesis, Purdue Univ., West Lafayette, Ind.

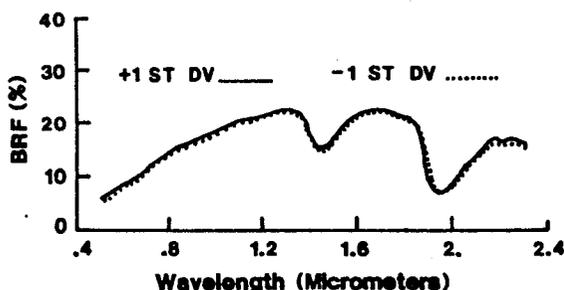


Fig. 1—Spectral bounds of the 95% confidence limits on reflectance of 20 Fincastle silt loam check samples measured on 10 different days.

of a paraboloidal mirror to the sample-viewing plane. A three-fourths degree field of view mode was used with the detector placed 2.4 m above the sample. Spectral measurements of soil samples as well as the pressed BaSO_4 laboratory reflectance standard were recorded on analog tape for later conversion to annotated digital format for computer processing using the LARSPEC analysis program (Simmons et al., 1975).

As with field measurements, reflectance is reported as percent bidirectional reflectance factor (BRF) to correctly express the geometry of the spectral measurement. Bidirectional reflectance factor (BRF) can be described as the ratio of the flux reflected by an object under specified conditions of irradiation and viewing to that reflected by the ideal, completely reflecting, perfectly diffusing surface, identically irradiated and viewed with the restriction that measurements are made through negligibly small solid angles of illumination and viewing (Nicodemus et al., 1977).

RESULTS

The standard deviations from the average spectral reflectance of 20 Fincastle silt loam check samples measured on 10 different days attest to the reproducible nature of soil spectra measured under a controlled moisture tension equilibrium (Fig. 1). Soil moisture contents for the 20 check samples equilibrated at 0.10-bar tension ranged from 30.3 to 35.1% water by weight with an average of 31.3%. The slight differences in reflectance and water content of these check samples can be attributed to sample preparation and do not represent significant procedural errors.

Laboratory- and field-measured spectra for Chalmers silty clay loam and Fincastle silt loam are shown in Fig. 2. The familiar concave trend of the high organic matter Chalmers soil from 0.5 to 1.3 μm , typical of soils in the Mollisol soil order, is altered only by the presence of residue cover (Condit, 1970; Montgomery and Baumgardner, 1974). Similarly, the convex trend of all spectral curves in the 0.5- to 1.3- μm region for the Fincastle soil is typical of observed spectral response for the Alfisol soil order (Montgomery and Baumgardner, 1974). Field-measured spectral curves do not contain data in the 1.4- and 1.9- μm water absorption bands because of practical difficulties in collecting data in this region where the solar illumination is almost completely absorbed.

Chalmers and Fincastle soils under similar field conditions appear to be spectrally separable throughout the reflective wavelength region regardless of soil moisture level or surface residue cover. This would seem to confirm the observed separability of different soils when areas with similar tillage practices are isolated and classified separately using airborne multi-spectral scanner data (Stoner and Horvath, 1971).

Dividing the spectral response of a given soil by

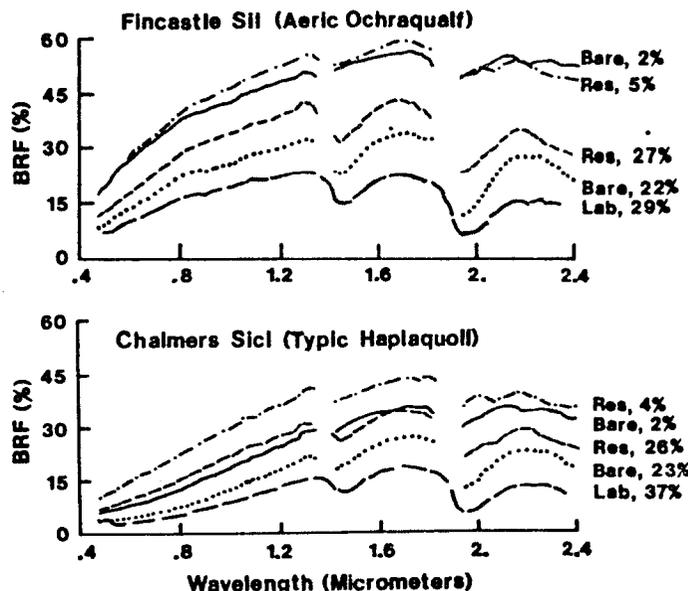


Fig. 2—Comparison of field- and laboratory-measured spectra of two soils. Percentage figures are moisture content by weight; RES = field-measured, corn residue-covered soil; BARE = field-measured, residue-free soil; LAB = laboratory-measured soil.

the spectral response of another identically treated soil allows for identification of the spectral regions in which the greatest magnitudes of difference occur. Response ratios for Fincastle/Chalmers soil comparisons indicate that the greatest difference in spectral response between identically treated soils appears in the 0.6- to 0.8- μm transition region between the visible and near infrared, regardless of field condition or laboratory preparation studied (Fig. 3). Field- and laboratory-measured moist soils show similar magnitudes of spectral difference between the two soils. Corn residue cover reduces the spectral difference between these two soils by an equal magnitude for both moist and dry soils.

Using the same ratio technique, it was demonstrated that laboratory-measured spectra of soils at 0.10-bar tension are directly proportional to the spectral response of the same soil when measured in the field under bare moist conditions (Fig. 4). This relationship holds for the 0.52- to 1.32- μm region as well as for the 1.55- to 1.75- μm region. Reflectance of either the Fincastle or Chalmers soil as measured under bare moist field conditions was found to be about 1.5

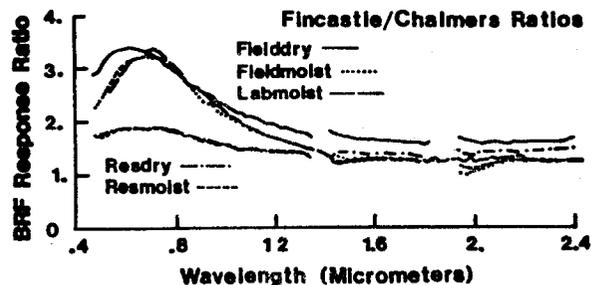


Fig. 3—Response ratios demonstrating the magnitude of differences in spectral response between spectral curves for identically treated Fincastle/Chalmers soils. FIELD DRY = bare dry soil; FIELD MOIST = bare moist soil; RES DRY = dry soil with corn residue; RES MOIST = moist soil with corn residue; LAB MOIST = laboratory-measured moist soil.

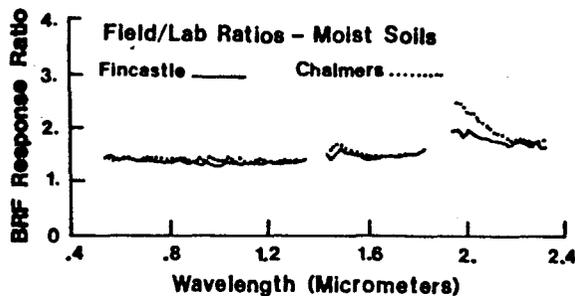


Fig. 4—Response ratios demonstrating the magnitude of difference in spectral response between spectral curves for field-measured bare moist soil and laboratory-measured soil at 0.01-bar tension. FINCASTLE — Fincastle silt loam soil; CHALMERS = Chalmers silty clay loam soil.

times greater than the reflectance of laboratory-measured moist soils at 0.10-bar tension at any given wavelength within these spectral ranges. Higher reflectances of field-measured soils are not inconsistent with lower field moisture contents, observations which previous studies indicate may explain reflectance differences of the magnitude seen here (Bowers and Hanks, 1965; Hoffer and Johannsen, 1969).

CONCLUSIONS

The ability to extend laboratory-measured soil spectra to field conditions has important implications in applying remote sensing techniques to soil survey, monitoring of land degradation, and crop inventory. By bringing soil samples into a controlled laboratory environment it is possible to study the spectral properties of large numbers of soils from diverse climatic and geographic regions without having to transport a spectroradiometer to scattered field studies. Experimental results verify the validity of comparing laboratory-measured soil spectra under controlled moisture equilibria to field-measured spectral response from bare moist soil for two glaciated soils from a humid mesic climate.

A technique of ratioing comparably treated soils indicates that the spectral differences between Fincastle silt loam and Chalmers silty clay loam is most prominent in the transition region between visible and near infrared wavelengths. Current Landsat bands 5 (0.6–0.7 μm) and 6 (0.7–0.8 μm) would seem to be ideal for discrimination of spectral differences between these two unvegetated soils regardless of their field condition.

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