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The Use of MIR for Supporting Routine Soil Property Analysis for U.S. Soil Survey Under Field Conditions

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Introduction

Mid-infrared (MIR) spectroscopy is a noninvasive method for soil property analysis. The MIR provides an opportunity for increasing the density of measured points that are needed to improve the accuracy of predicting soils and soil properties. MIR spectroscopy can also provide more accurate and faster data analysis than typical field office laboratory procedures. However, expanding the use of the MIR as a routine analysis would require an evaluation of this technology under field office conditions. The study was conducted in the Salina Soil Survey Office (SSO) in Kansas, United States. Soil samples from the study area (Kansas and Nebraska) were analyzed for selected soil properties at the Kellogg Soil Survey Laboratory (KSSL) using standard methods. MIR scans were also performed on the same soil samples at the KSSL using a Vertex-70 Fourier-transform infrared (FTIR) (Vertex) spectrometer (Bruker Optics Inc., Billerica, MA) and in the SSO in Salina using an Alpha FTIR (Alpha) spectrometer (Bruker Optics Inc., Billerica, MA). The values from the KSSL based on standard methods and Vertex spectrometer (Bruker Optics Inc., Billerica, MA) were used for model development. The models were used to determine the soil properties using scans from the Alpha in the SSO. A suite of soil properties that included clay content, organic carbon, total carbon, the presence of carbonates (effervescence), calcium carbonate equivalent (CCE), cation exchange capacity (CEC), pH, and 15 bar water were evaluated. These predicted soil properties can assist in the correlation of soil series for updating soil mapping and interpretations by providing relatively quick data over a large geographic area. Though the MIR use and expansion under field laboratory conditions needs further improvement, its error predictions in certain cases, like for determining particle size class (PSC), are comparable with standard laboratory analyses (i.e. hydrometer method). The improvement of current models and creation of new ones continues for narrowing the gap between predicted values in the SSOs and measured values in the KSSL. The objective of this study was to evaluate the transfer of the MIR spectroscopy from laboratory to field office conditions.

Data Use

The predicted soil properties can assist in the correlation of soil series for updating soil mapping and interpretations and acquiring data for use in dynamic soil property and soil health projects by providing relatively quick data over a large geographic area.

Variables

One caveat of using this equipment in the SSOs is the variability in environmental conditions and user execution. The KSSL is set up to have better control of the environment (temperature, humidity, human traffic, etc.) than an SSO. The Salina SSO has an average fluctuation in temperature of 3.9°C from morning to night and a total fluctuation of 39% in humidity, from 10% to 49% depending on season and current weather conditions. A fan is placed near the Alpha spectrometer opposite the user to attempt to regulate the atmosphere around the instrument and remove CO_2 from others passing by the area while the spectrometer is being operated.

Effects of humidity and CO_2 have been observed while running scans on the Alpha spectrometer. Humidity discrepancies cannot be corrected but seem to be less impactful on the data integrity. Problems with data due to CO_2 can be recovered by removing the spacer from the front of the Alpha spectrometer to “purge” the atmosphere inside the scan area and starting the scan over with the surrounding area clear.

User error is another problem that may arise, especially if the SSO is not using the Alpha spectrometer on a regular basis. Control samples that have been validated through the KSSL must be kept on site . These samples can be used to reacclimate users with the scanning process and validate proper equipment adjustment and atmospheric conditions. Care must be taken to always wear gloves when handling the equipment to prevent moisture and oil contamination.

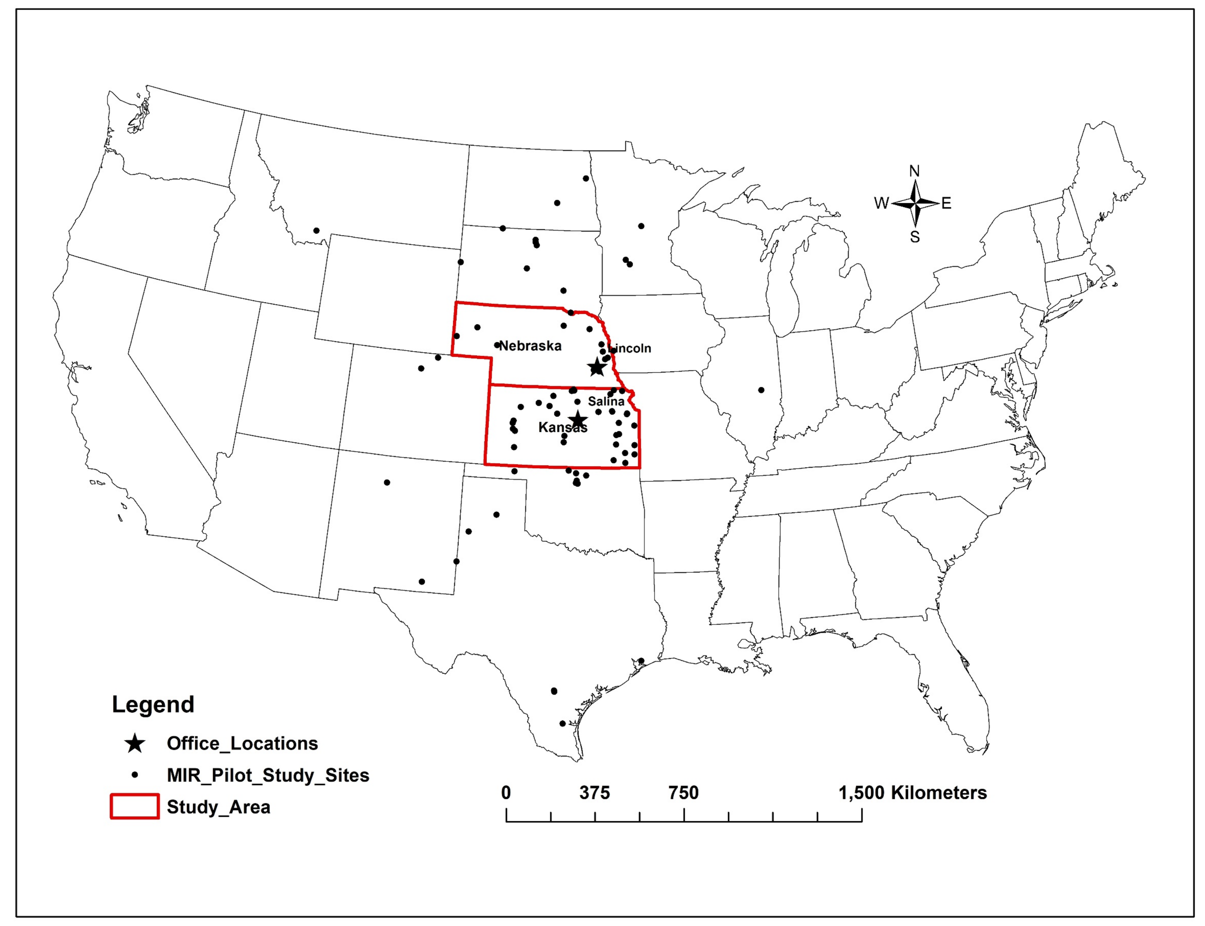

Figure 1. Location of KSSL (Lincoln, Nebraska), SSO (Salina, Kansas) and sampling sites.

Figure 3. Alpha FTIR spectrometer used at the SSO.

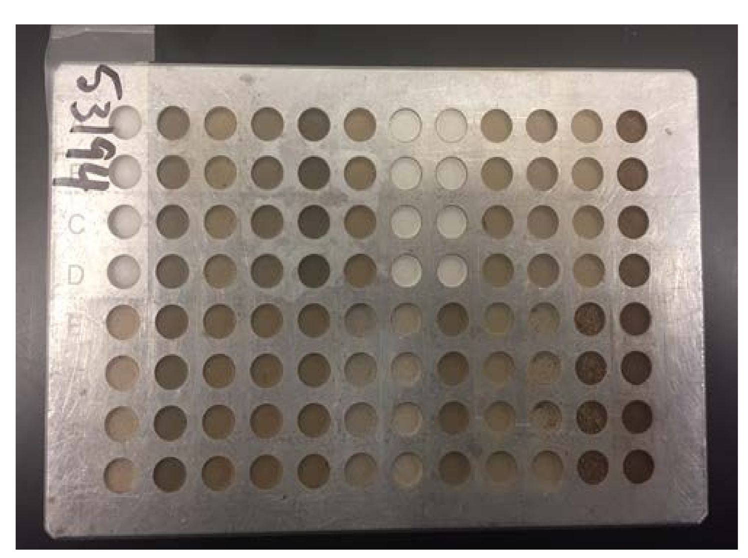

Figure 4. 96 sample spot plate used with the Vertex-70 FTIR spectrometer.

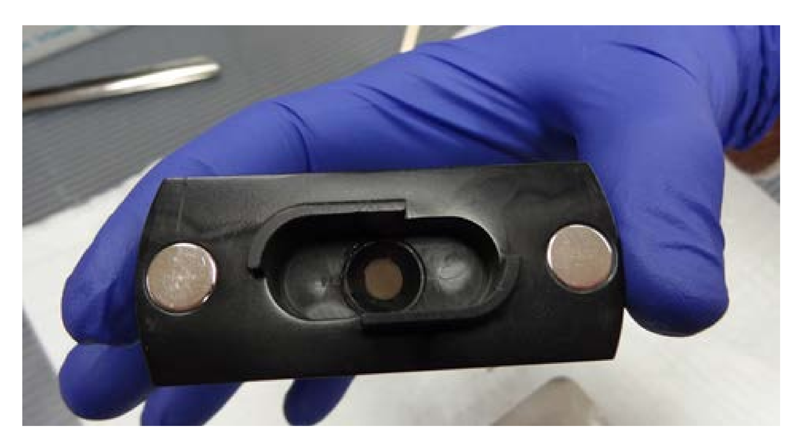

Figure 5. Single sample spacer used with the Alpha FTIR spectrometer.

Data Integrity

For the first 30 samples scanned by the Salina SSO, only one scan was performed prior to sending the samples to the KSSL. To improve prediction, the Salina SSO started scanning samples in quadruplicate, the same as the process done at the KSSL, and taking an average of the scans to derive each property value. This adaptation of procedure provided values closer to the measured ones at the KSSL for most properties.

Due to environmental variables, most of which the SSO has little control over, inconsistencies can occur in the scanned data that do not get flagged as outliers. These discrepancies are typically obvious by large deviations from the comparable scans or from the range in characteristics of a known soil. These disagreements in the data can be easily corrected by rescanning the soil sample.

Figure 2. Vertex-70 FTIR spectrometer used at the KSSL.

Expansion of Data

Interest in this method of data collection is relatively new throughout the Natural Resources Conservation Service (NRCS) for use in completing and updating soil map products. This method and technology are only useful if a database of previously scanned data by the KSSL exists to be used for the development of models. This could potentially limit the use of MIR spectroscopy by many of the SSOs across the country. SSOs will have to work with the KSSL to see what data gaps exist in the repository and what needs to be collected to expand the use of MIR spectroscopy into their area. Once enough data exists, the SSO will need to work with the National Soil Survey Center (NSSC) and KSSL to develop models that are specifically designed for the types of soils found in those areas.

Discussion

Thorough and reliable soil survey data is imperative to improving land management decisions and soil conservation efforts. MIR spectroscopy provides an opportunity for increasing the amount of measured point data that can be used to improve the prediction of soils and soil properties. This offers a more thorough product for the end user by providing relatively quick data over a large geographic area. Care by the SSOs needs to be taken to replicate the KSSL soil sample processing and scanning procedure as closely as possible to produce valid predictions. SSOs will need to work with the NSSC and KSSL to fill data gaps, improve current models, and create new ones to expand the use of MIR spectroscopy from the KSSL to the field.