

TITLE OF PROJECT: Using Diffuse Reflectance Spectroscopy to Characterize Soil Properties

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FUNDING REQUESTED: \$8,000

PROJECT

Need:

Spatial heterogeneity of soil affects the quality and quantity of water in streams, reservoirs, and groundwater. The ability to characterize the spatial distribution of soil properties is paramount to understanding water movement, nutrient transport, and soil erosion on a landscape. Current spatial measurement techniques are limited in spatial resolution by time-consuming quantification of soil properties with soil coring. Information about small-scale horizontal variability is not feasible. Information about horizontal variability is inferred from landscape topography. Considering the limits of current characterization techniques, new methods to measure the soil profile at a high resolution (cm) and rapidly cover a landscape at a high horizontal resolution need to be developed.

In an attempt to fill this measurement gap, truck- or ATV-mounted soil penetrometers have been used to quickly collect information about a soil profile at higher horizontal resolution. Current penetrometer technology is limited to measuring relative differences in soil bulk density, water content, and soil color (Grunwald et al., 2001; Vaz and Hopmans 2001). Soil color is determined by an optical sensor mounted inside the sleeve of the penetrometer. If the capabilities of the optical sensor on the penetrometer could be expanded to measure percent clay, calcium carbonate, and organic carbon using spectral reflectance measurements, then soil heterogeneity could be quantified more quickly. Higher spatial resolution would lead to improved capabilities in modeling and management of water on landscapes.

The long term goal of this research is to improve soil mapping techniques that will lead to the development of more accurate and efficient resource management plans, such as BMPs and nutrient management plans. As a part of this long term goal, a specific objective is to develop a refined optical sensor to be mounted into a soil penetrometer. Laboratory research has demonstrated the effectiveness of Diffuse Reflectance Spectroscopy (DRS) to provide rapid prediction of soil physical and chemical properties (Chang et al., 2001; Shepard and Walsh, 2002). However, little published information is available for the use of DRS for *in situ* analysis of soil properties (Sudduth and Hummel, 1993). Because of the strong spectral absorbance characteristics of soil moisture and natural heterogeneity of organic matter and clay distribution within aggregates, *in situ* use of DRS will not be as accurate as when it is used on dried and ground samples. Nonetheless, *in situ* soil reflectance measurements combined with locally calibrated empirical models should prove a valuable and efficient tool for rapidly approximating soil properties across a landscape. I would like to investigate the extent to which soil reflectance measurements can quantify soil physical properties in impaired watersheds of Texas.

Description

The primary objective of this proposed study is to determine the extent that DRS can determine texture, calcium carbonate, organic carbon, and moisture content of a range of soil types and to compare of DRS of *in situ* to dried and ground soil samples to standard analytical

laboratory methods. By determining the analytical accuracy of DRS, an informed decision can be made regarding the future applicability of this technique.

Spectral Reflectance Measurements

All of the soil spectral reflectance measurements will be obtained using a Fieldspec Pro FR (Analytical Spectral Devices, Boulder, CO) spectroradiometer. This spectroradiometer measures the Visible and Near Visible infrared spectral range (350-2500 nm) with a spectral resolution of 3 nm at 700 nm and 10 nm at 1400 and 2100 nm. The raw data must be processed and reduced before it can be used to predict soil properties. A smoothing spline must first be fit to the spectral curve, and then the first derivative of the spline is extracted at 10 nm intervals resulting in 206 predictor values for each scan (Brown, personal communication). Multiple scans per sample allow the derivatives for a sample to be averaged and used to predict soil properties. The two main statistical methods used in soil spectrometry are Partial Least Squares and Multivariate Adaptive Regression Splines (Friedman, 1991; Chang and Laird 2002). Both methods can be performed in R – a programming language as well as a statistical package.

Sampling Procedure

Since a goal of this research is to characterize soil properties that affect the water transport across landscapes of impaired watersheds, soil sampling will take place in the North Bosque River Watershed. Three representative landscapes will be selected in the North Bosque River Watershed, which include the following: (1) Maloterre-Purves-Dugout association of shallow, calcareous soils over limestone, (2) the Windthorst-Duffau association of moderately deep soils of sandy loam over sandy clay, and (3) the Houston Black-Denton-Purves association that is clayey throughout with calcareous lower horizons. In each landscape, 20 soil cores (3 cm diameter) will be collected to a depth of 1 m. Each core location will be marked using a DGPS (<1 m precision) so that the sample locations can be relocated in the future. The soil cores will be split in half, vertically, and three types of spectroradiometer measurements will be made within each horizon of each soil core, (1) *in situ* at the field moisture content, (2) *in situ* as the core dries, and (3) dried and crushed samples passed through a 2 mm sieve. Laboratory analysis of percent clay, total soil carbon, organic carbon, and moisture will be performed on the remaining half of the soil core. The analysis will be performed by the Soil Characterization Laboratory at Texas A&M University.

Expected Outcomes

1. Baseline data will be collected and analyzed for submitting a USDA-NRI research proposal to develop a penetrometer-mounted DRS system.
2. An empirical model will be developed for using DRS to rapidly map soil organic matter at a high spatial resolution in soils located in the North Bosque River Watershed. This type of calibration could lead to using DRS to investigate spatial and temporal stability of organic matter distributions with soil depth on manured fields.
3. Soil landscape models for three landscapes in the North Bosque River Watershed will be created for future modeling purposes and BMP evaluation

Evidence of collaboration:

Project will include collaboration with Dr. David Brown, Assistant Professor of Landscape Analysis & Management, at Montana State University – Bozeman. Dr. Brown has

received seed money from USDA-NRICPG for developing soil reflectance capabilities. The “Fieldspec Pro FR” used in this research will be borrowed from Dr. Brown’s program. Dr. Brown and I expect to use the data collected this summer as supporting data for a full research proposal to USDA-NRICPG. We also have a verbal agreement to collaborate with EarthIT a consulting company in Madison, WI. EarthIT will provide us with the technical assistance in fabricating a penetrometer with DRS and outreach component of the proposed NRI grant.

References:

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Grunwald, S., K. McSweeney, D.J. Rooney D.J., and B. Lowery. 2001. Soil layer models created with profile cone penetrometer data. *Geoderma.* 103:181-201.

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Sudduth, K.A. and J.W. Hummel. 1993. Soil organic matter, CEC and moisture sensing with a portable NIR spectrophotometer. *Trans. ASAE.* 36:185-193.

Vaz, C.M.P. and J.W. Hopmans. 2001. Simultaneous measurement of soil penetration resistance and water content with a combined penetrometer-TDR moisture probe. *Sci. Soc. Am. J.* 65:4-12.

**TAES/TWRI
Water Resources Research
Project Budget Form**

Expenditure Description	Amt. Requested	Other Sources	Total
Staffing Requirements:			
1) M.S. Student		\$ 7,000	\$ 7,000
2) Undergraduate Hourly Wages	\$ 3,080		\$ 3,080
Fringe Benefits	\$ 19	\$ 2,976	\$ 2,995
Total Staff Costs	\$ 3,099	\$ 9,934	\$ 13,033
Travel:	\$ 1,401	\$ 999	\$ 2,400
Materials & Soil Sample Analysis	\$ 3,500	\$ 1,900	\$ 5,400
Other Direct Costs (tuition)		\$ 3,220	\$ 3,220
Total Project Costs	\$ 8,000	\$ 16,095	\$ 24,095