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Soil characterization across catenas via advanced proximal sensors

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ABSTRACT

As countries of Eastern Europe look to advance their agricultural markets through large scale agronomic production, high resolution mapping of soil resources will be essential. Portable X-ray fluorescence (PXRF) spectrometry and diffuse reflectance spectroscopy (DRS) are non-invasive, proximal sensing techniques which provide quantitative data germane to physicochemical soil properties in seconds. While these techniques have been widely used to characterize individual soil samples, sample sets, or variability across individual fields, less work has been done at the catena scale (even less so in Eastern Europe), where variability due to topographic differences substantively affects a wide number of soil properties. The present study was conducted on three catenas of the Transylvanian Plain, Romania, each with 100 sampling points randomly established in ArcGIS. Laboratory analysis (particle size analysis, total carbon, total nitrogen, soil organic matter) was conducted at Texas Tech University, USA. Following Savitzky–Golay first derivative transformation, DRS spectra were used to predict soil physicochemical parameters of interest via support vector regression. The whole dataset was randomly divided into a 70% training (n = 210) and 30% test set (n = 90). Across all catenas, a combined PXRF + DRS approach showed better parameter prediction relative to either sensor independently as evidenced by higher R^2, lower RMSE, higher RPD, and higher RPIQ values. For each parameter, the 100 points per catena were used as input data to develop a PXRF + DRS predictive model, and the output data from each model was kriged using ArcGIS 10.3.1. Spatial analysis strongly reflected management and landscape dynamics across the catenas. Combined proximal sensor approaches show considerable advantages over traditional laboratory approaches, allowing for high sample throughput, greater analytical density, and less expensive data, with minimal fall off in data quality. The combined PXRF + DRS approach showed excellent potential for providing the data needed to support optimized soil resource mapping and land management decisions in Eastern Europe or worldwide.

1. Introduction

Proximal sensors are rapidly gaining popularity for soil assessment owing to the ease of data acquisition, inexpensiveness, and data robustness. Two proximal sensors which have seen their application to soil mapping and assessment grow are portable x-ray fluorescence (PXRF) spectrometry and diffuse reflectance spectroscopy (DRS). These two sensors provide a measure of evaluating soil properties in-situ or laboratory, providing quantitative data. Most beneficially, these approaches provide advantages over traditional laboratory analyses such as non-destructiveness, alacrity, and low cost (Chakraborty et al., 2010). Numerous soil parameters are uniquely correlated with mixtures of specific reflectance and/or emission spectra. Comprehensive synopses of PXRF, DRS, and their potential synthesis in soil analyses are offered by Weindorf et al. (2014) and Horta et al. (2015), respectively. DRS and PXRF have been individually used to quantify a broad range of soil properties, including soil organic carbon (Morgan et al., 2009; Chakraborty et al., 2013), gypsum content (Weindorf et al., 2009;Weindorf et al., 2013a), soil salinity (Swanhart et al., 2014), soil pH (Sharma et al., 2014), soil texture (Zhu et al., 2011), soil cation exchange capacity (Sharma et al., 2015), diagnostic subsurface horizons/features (Weindorf et al., 2012a), and organic/inorganic pollutants

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in soils (Weindorf et al., 2013b; Paulette et al., 2015). Weindorf et al. (2012b) demonstrated that PXRF could be used for enhanced soil horizonation through which horizons can be discerned using elemental data from PXRF in nondescript soil profiles. Relative to PXRF, DRS approaches are generally more adept at organic carbon prediction in mineral or organic soils and more sensitive to soil moisture (Lobell and Asner, 2002; Bricklemyer and Brown, 2010; Zhu et al., 2010; Cardelli et al., 2017).

PXRF is a "gun shaped" proximal sensor that allows for elemental quantification from energy fluoresced from ~10 to 40 keV (Zhu et al., 2011). Low power X-rays strike the soil, which then emits secondary wavelengths (energy) which are unique to each element; the intensity of emissions is proportional to elemental abundance. Linear regression is then commonly used to relate PXRF elemental data with a parameter of interest determined through traditional laboratory analysis (Kalnicky and Singhvi, 2001).

By comparison, DRS is a proximal sensor which uses visible (350–700 nm) and near infrared (700–2500 nm) (Ben-Dor et al., 1999) region of the electromagnetic spectrum to infer soil properties from reflectance patterns carried back to the spectrometer via fiber optic cable. The spectrometer measures a continuous spectrum from 350 to 2500 nm whereby unique spectra, or combinations of spectra, are used to predict various soil properties (Ben-Dor and Banin, 1995; Reeves et al., 2000; Reeves et al., 2002; Dunn et al.,

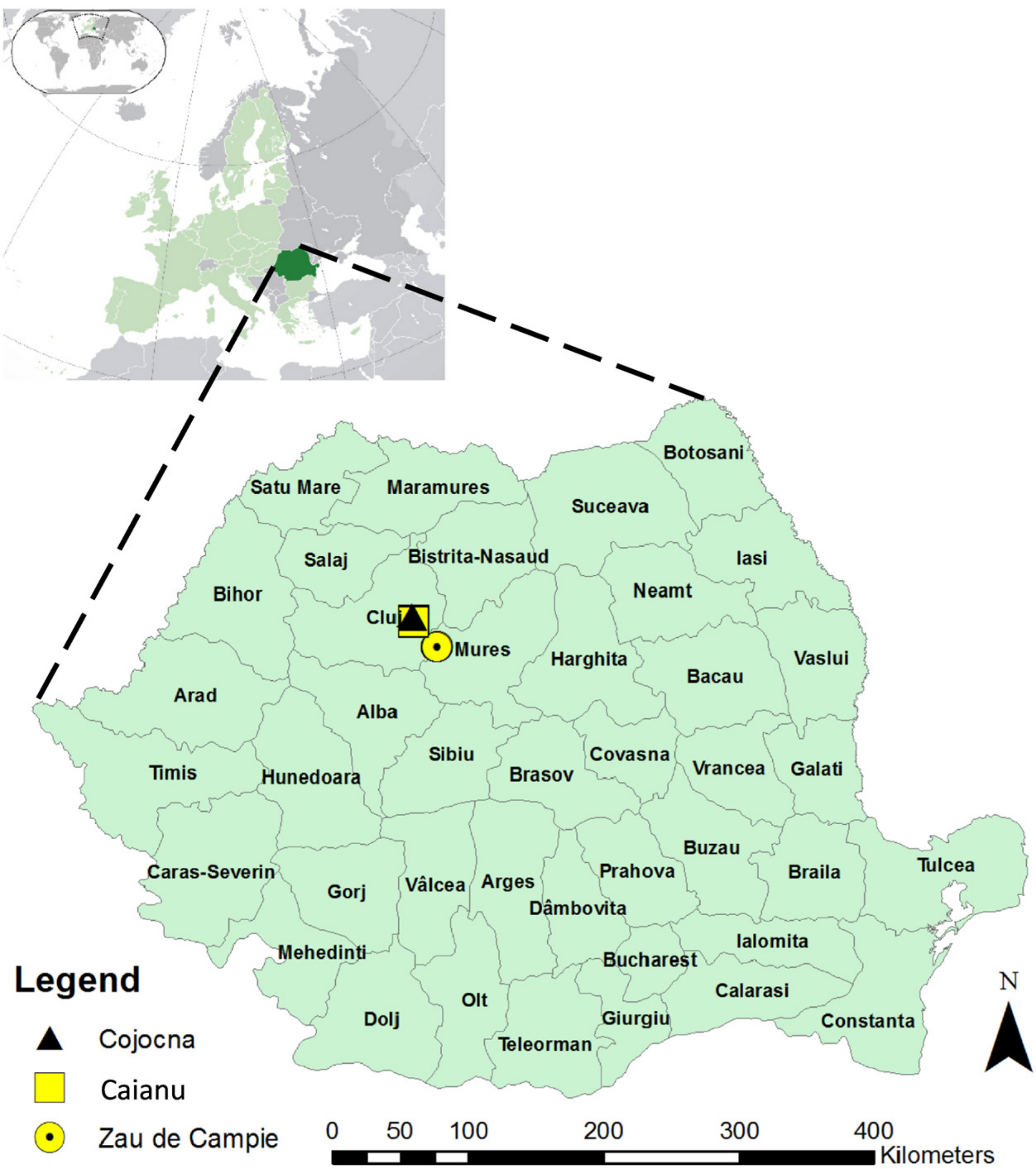

Fig. 1. Plot showing the study site at the Transylvanian Plain, Romania.