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Coupling multistripe laser triangulation with hyperspectral imaging VisNIR spectroscopy to elucidate the feedbacks between soil structure, hydrology, and organic matter

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Recent advances in three-dimensional (3-D) laser scanning techniques and reflectance spectroscopy provide the high-resolution quantitative measures needed to unravel the feedbacks mechanism between soil structure, hydrology, and organic matter at the pedon scale. Multistripe laser triangulation (MLT) can be used to quantify the shape, size, orientation, abundance, and spatial distribution of soil peds and associated macropore networks, while imaging visible light near infrared spectroscopy (imVisIR) can be used to examine the spatial distribution, quality and quantity of total, labile, and non-labile organic matter (SOM), iron, and manganese oxides at high spatial resolutions. In this work, we sought to investigate the potential for coupling these two disparate sensors (MLT and imVisIR) to examine relationships between soil structure, soil hydrology, and SOM. Soils were sampled from four landscape positions (summit, backslope, footslope, and toeslope) along an oak-hickory forest catena at the University of Kansas Field Station (KUFS) Fitch Natural History Reserve in conjunction with the installation of a National Ecological Observatory Network (NEON) site. Soil pits were excavated at each position to 1 m, described in detail by US Department of Agriculture-Natural Resource Conservation (USDA-NRCS) soil scientists, and sampled by morphological horizon for standard chemical and physical soil analyses. In addition, samples were taken from each horizon for root density and size determination, cores sampled to estimate water content, pore-size distribution, and hydraulic conductivity via low field nuclear magnetic resonance (NMR), and clods taken for water retention determination. Two intact soil monoliths per pit, carefully carved from the excavation walls at two depths (0-40 and 30-70 cm), were sampled in custom steel trays that were 15 cm wide by 40 cm long with a lip around the edge approximately 2 cm deep. The monoliths were prepared and dried at 40°C for 12 hours in the laboratory to maximize the expression of the soil structure, moisture was determined for each horizon on a minor amount of soil taken near the edge of the tray after drying, and the monoliths were scanned using an MLT scanner. Images derived from the MLT scanner were binarized and the macropores outlining aggregates were projected on a 2-D plane and analyzed through ImageJ. Subsequently, the monoliths were imaged with a hyperspectral VisNIR camera (spectral resolution: 400-1000 nm in 160 spectral bands; spatial resolution: 63×63 μm^2 $pixel^{-1}$). Results were used to (1) assess the spatial variability of the distribution and properties of macropores; (2) extrapolate elemental concentrations of small sampling areas to the complete image and calculate high-resolution chemometric maps of C, N, Al, Fe and Mn; and (3) produce maps of the chemical composition of SOM. Both the hydraulic properties and the proximity of SOM and the various elements mapped in this study in relation to the occurrence of macropores were used to examine feedbacks between soil structure, hydrology, and SOM. These results as well as the opportunities and limitations for future application of this coupled-sensor approach will be discussed.