Geoderma 288 (2017) 130–142

Contents lists available at ScienceDirect

Geoderma

journal homepage: www.elsevier.com/locate/geoderma

Non-saturated soil organic horizon characterization via advanced proximal sensors

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ARTICLE INFO

Article history:
Received 14 February 2016
Received in revised form 31 August 2016
Accepted 30 October 2016
Available online 15 November 2016

Keywords:
Spectroscopy
O horizons
Proximal sensors

ABSTRACT

The organic fraction of soils is critically important to soil health and optimal ecosystem functioning. Traditional analysis of soil organic horizons (O horizons) has been dependent upon laboratory-based instrumentation. Simultaneously, the use of proximal sensors such as portable X-ray fluorescence (PXRF) spectrometry along with visible near infrared diffuse reflectance spectroscopy (VisNIR DRS) has gained popularity for providing rapidly acquired spectral and elemental data useful for soil physicochemical property quantification. However, PXRF and VisNIR DRS have mostly been applied to the assessment of mineral soils. This preliminary study evaluated 136 organic laden soil samples (most aptly described as upland, non-saturated O horizons) using both laboratory based instrumentation (CN analyzer) and proximal sensors to evaluate total carbon (TC) and total nitrogen (TN). Results revealed that combining model outcomes using model fusion improved TC and TN prediction accuracies relative to using an individual instrument (PXRF or VisNIR DRS) or model averaging with improvements in root mean square error (RMSE) on the order of 10–47% and 10–67% for TC and TN, respectively. Partial least squares + random forest (PLS + RF) approaches emerged as the best model for predicting both TC and TN in organic laden soil samples. These results suggest that the strong predictive applications of proximal sensors extensively documented on mineral soils, may show similar promise for determination of a wide number of physicochemical properties on organic soil matrices, yet further exploration with a larger and more diverse dataset is recommended.

1. Introduction

Organic matter decomposition is a fundamental process for sustaining life on Earth (Gosz et al., 1976). The term soil organic matter (SOM) refers to all organic material in soil, from freshly deposited detritus or litter to highly decomposed, stable forms such as humic and fulvic acids (Stevenson, 1994). Organic matter cycling helps to maintain ecosystem functionality as several ecological functions are correlated to the decay processes of the organic layers of forest soils. Indeed, decomposition and mineralization processes of organic residues affect nutrient cycling and induce the release of elements that represent the principal resources for plants and microbes (Berger et al., 2002; Berg and McClaugherty, 2008), such as macro- and micro-nutrients, and essential molecules for energy metabolism, photosynthesis, and membrane transport (Huttl and Schaaf, 1997). One of the main factors controlling the organic matter decomposition processes is the quality of the litter produced by plants (Ge et al., 2013). The specific chemical proprieties of the plant litter and its decay products, in turn, influence the underlying mineral soil (Wardle et al., 2004; Ball et al., 2014). Six et al. (2004) noted that the decomposition of SOM has an impact on several important soil properties as it improves soil aggregation (Bronick and Lal, 2005), enhances the activity of the soil microbial community (Ball et al., 2014; Carrillo et al., 2012; García-Palacios et al., 2013), and affects

Abbreviations: SOM, soil organic matter; TC, total carbon; TN, total nitrogen; VisNIR-DRS, visible near infrared diffuse reflectance spectroscopy; PXRF, portable X-ray fluorescence.

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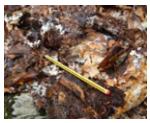
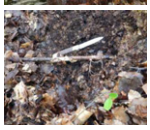
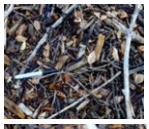
http://dx.doi.org/10.1016/j.geoderma.2016.10.036
0016-7061/

Table 1
General description of the different types of organic horizons collected divided by study sites. For symbols see legend. a, b

	Classification		Description
Italy Study site: Central Apennines - Mount Acuto, Mount San Vicino, and Mount Terminillo.			
	Horizon[a] OLn	Horizon[b] Fibric	Easily recognizable beech cupules, leaves, twigs and bark. Thickness of 2 to 5 cm. Absence of tree roots and micelia. Very few and few presence of small macrofauna and mesofauna.
	OLv	Hemic	Brownish and degraded beech cupules, leaves, twigs and partially degraded bark and beechnuts. Thickness of 2 to 11 cm. General absence of tree roots; where present they are very few or few. Micelia is present from few to plentiful. Presence of small macrofauna and mesofauna from few to abundant.
	OH	Sapric	Extensive decomposition, plant parts are not recognizable. Darkish beechnuts. Reduced thickness of 1 to 4 cm. Dark horizon. Tree roots vary from absent to abundant. Micelia are generally abundant. Small macrofauna and mesofauna are plentiful to abundant.
Texas Study site: Lubbock - North Fork of the Brazos River; Houston - George Bush Intercontinental Airport, WG Jones State Forest, San Jacinto River and Sam Houston National Forest.			
Lubbock			
	Horizon[a] OLn	Horizon[b] Fibric	Organic layer originated by deposition after an alluvial event. Recognizable branches, leaves, with a predominance of twigs and bark. Spot with accumulation of grass leaves. Thickness of 4 to 6 cm. No roots and micelia. No small macrofauna or mesofauna activities.
	OLv	Hemic	Brownish and darkish degraded vegetal material made by not easily recognizable leaves, twigs, and bark. Thickness from 5 to 10 cm. Roots and micelia are not present. Very few and few presence of small macrofauna and mesofauna.
Houston			
	OLn	Fibric	Non-decomposed pine leaves, pine cones, twigs and bark. Thickness of 1 to 5 cm. Absence of root and micelia. Few presence of small macrofauna and mesofauna.
	OLv	Hemic	Brownish and pressed recognizable pine leaves, bark, and twigs. Thickness of 2 to 6 cm. General presence of tree roots from very few to few. Micelia generally goes from very few to abundant, with spots of very abundant presence. Considerable small macrofauna and mesofauna activities.
	OH	Sapric	Extensive decomposition, plant parts are not recognizable. Thickness of 1 to 2 cm. Tree roots vary from absent to few. Micelia is reduced from very few to plentiful. Small macrofauna and mesofauna are plentiful to abundant.
New Mexico Lincoln County - Lincoln National Forest.			
	Horizon[a] OLn	Horizon[b] Fibric	Not decomposed pine and deciduous leaves, pine cones, twigs, and bark. In spots, woody parts of bark from degradation of dead trees. Thickness of 1 to 7 cm. Absence of roots and micelia. The presence of degraded tree parts induces a considerable presence of small macrofauna and mesofauna, in general absent or few.
	OLv	Hemic	Degraded pine leaves and deciduous twigs, presence of pine cones. Degraded barks reduced in fine dust, structure not recognizable. Brownish horizons. Thickness of 1 to 8 cm. Few roots. Micelia generally goes from few to plentiful. Considerable small macrofauna and mesofauna activities.
	OH	Sapric	Vegetal material completely decomposed, only pine cones are still recognizable. Thickness from 2 to 3 cm. Generally few tree

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