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Diversity of diagnostic horizons in soils of the contiguous USA: A case study

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ABSTRACT

Many previous studies of pedodiversity have emphasized the lateral variability of soils. In this study, the vertical distribution of diagnostic horizons is examined at the soil-series level. Unlike genetic horizons, diagnostic soil horizons are based on quantitatively defined morphological and analytical properties; and they form the basis of modern soil classification systems. An examination of 1600 soil series in 63 representative (out of 226) Major Land Resource Areas (MLRAs) in contiguous USA revealed that they contain from one to seven diagnostic soil horizons, with an average of 2.6 ± 1.2. About 20% of the soil series contain 4 or more diagnostic horizons; 80% of these soil series are in seven great groups: the Glossudalfs, Haplorthods, Fragiorthods, Endoaquods, Epiaquods, Fraglossudalfs, and Glossaqualfs. The Laurentide Great Lakes region contains a discordant number (57%) of soils with 4 or more diagnostic horizons, the most common being ochric (100%), albic (91%), argillic (85%), glossic (69%), spodic (51%), and a fragipan (19%). Several factors appear to contribute to the diversity of diagnostic horizons, including proximity to the Great Lakes where abundant snowfall precludes soil freezing and enables water to percolate rapidly through the soil in a short interval during the spring, the prevalence of stratified glacial deposits often containing a lithologic discontinuity, and a fluctuating water table, all of which enable specific weathering products to accumulate at different depths.

1. Introduction

Diagnostic soil horizons were first identified in the 1957 *Sixth Approximation of Soil Taxonomy* (Smith, 1986). In the *Seventh Approximation* (Soil Survey Staff, 1960), six diagnostic epipedons and 12 subsurface horizons were recognized. The most recent *Keys to Soil Taxonomy* (Soil Survey Staff, 2014) recognize eight diagnostic epipedons and 20 subsurface horizons. Unlike genetic horizons (A, B, C, etc.), diagnostic horizons are based on quantifiable morphological and analytical soil properties; they form the basic framework of modern soil classification systems. In *Soil Taxonomy* (Soil Survey Staff, 1999), diagnostic horizons are used at the four highest categories: order, suborder, great group, and subgroup. Diagnostic horizons are also used in the World Reference Base (IUSS Working Group WRB, 2014) and in the national soil classification systems of Russia (Lebedeva and Gerasimova, 2012), China (Shi et al., 2004), and other countries. Targulian and Krasilnikov (2007) perceived diagnostic horizons as more or less stable and representing "mature" degrees of soil development.

Pedodiversity has been defined on the basis of the (i) relative abundance of pedotaxa (Fridland, 1974), (ii) complexity of soil patterns (Ibáñez et al., 1995), (iii) taxonomic richness of soil communities (Guo et al., 2003), and (iv) "taxonomic distance" between soils (McBratney and Minasny, 2007). Most of the pedodiversity research has examined the lateral variability of soils; there have been only a few studies of the diversity of diagnostic horizons. Saldaña and Ibáñez (2007) examined the pedodiversity of soil taxa and the number and type of diagnostic horizons in a chronosequence of soils on fluvial terraces in central Spain. Diagnostic horizons accounted for the genetic pedodiversity, with diversity values increasing with greater soil development. Liess et al. (2012) used the vertical order and extent of diagnostic horizons and regression analysis to depict soil continua in southern Ecuador.

Deep soils with several diagnostic horizons were identified on Holocene and late Wisconsinan surfaces in the Laurentide Great Lakes region (Bockheim, 2003, 2015). These soils often feature a combination of albic, spodic, glossic, and argillic horizons, and they may contain a fragipan or ortstein. Reasons for the relatively large number of diagnostic horizons in these soils are not fully known.

The purposes of this study are (i) to explore the vertical distribution of diagnostic horizons in soils of contiguous USA; (ii) to relate the diversity of these horizons to soil-forming factors and processes; and (iii) to offer the vertical distribution of diagnostic horizons as a measure of pedodiversity.

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2. Methods and materials

2.1. Land Resource Regions and Major Land Resource Areas of the USA

For management purposes, the USA and its territories have been divided into 28 Land Resource Regions (LRRs) that are designated by an upper-case Arabic letter (e.g., A) and occasionally by a number where the region has been subsequently subdivided (e.g., W1 and W2) (Natural Resources Conservation Service, 2006). Each LRR is subdivided into from 1 to 27 (average = 10) Major Land Resource Areas (MLRAs) that are designated by a number (e.g., 7) and often by an upper case Arabic letter where the area has been subsequently subdivided, e.g., 91A and 91B. There are a total of 278 MLRAs in the USA and its territories and 226 in the contiguous USA.

LRRs are defined on the basis of similar land uses and physiography, e.g. Western Range and Irrigated Region (LRR D) (Natural Resources Conservation Service, 2006). MLRAs are further distinguished on the basis of physiography and geology (e.g., Pierre Shale Plains). In general the MLRAs have distinguishable physiography, geology, climate, water, soils, and biological resources.

Europeans have developed comparable systems such as the Corine Land Cover (Co-ordinated Information on the Environment), GlobCover, and other approaches (Manakos and Braun, 2014).

2.2. Methods

This study was restricted to the contiguous (conterminous) USA; therefore, Alaska, Hawaii, the Pacific Basin, and the Caribbean were not included in the analysis. Initially, from 1 to 10 MLRAs were selected randomly from each of the 20 LRRs in the contiguous USA, yielding a total of 57 MLRAs. The MLRA handbook (Natural Resources Conservation Service, 2006) lists from 10 to 50 (average = 17) dominant soils in each MLRA. The Official Soil Series Description (OSD; Natural Resources Conservation Service, 2017) was examined for each of 1600 soil series for taxonomic structure, the kinds and thicknesses of diagnostic horizons, soil-forming factors, and land use. These data were compiled into spreadsheets that could be sorted by number of diagnostic horizons and other categories.

A preliminary examination of the data suggested that the Great Lakes region had an unusually large number of soil series with 4 or more diagnostic horizons so that an additional 6 MLRAs were examined in MLRA K, the Northern Lake States Forest and Forage Region, bringing the total numbers of MLRAs examined to 63 (Fig. 1).

The analysis showed that 313 (20%) of the 1600 soil series contained 4 or more diagnostic horizons. Therefore, further analysis was conducted on these soils, including taxonomic structure, percent occurrence of diagnostic horizon, and dominance of a soil-forming factor.

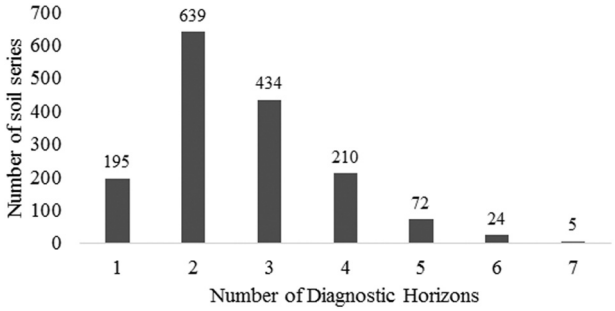

Fig. 2. Distribution of soil series in accordance with numbers of diagnostic horizons.

3. Results

3.1. Frequency distribution of diagnostic horizons

The number of diagnostic horizons for nearly 1600 soil series examined range from 1 to 7 and follow a somewhat left-skewed normal distribution (Fig. 2). The largest proportion (40%) of the soils contain two horizons, usually an ochric epipedon and an argillic or cambic horizon. Another 27% of the soil series contain three diagnostic horizons, which usually included an ochric, argillic, and either an albic or a glossic horizon.

3.2. Diagnostic horizons by Major Land Resource Area

The average number (standard deviation in parentheses) of diagnostic horizons for a given Major Land Resource Area (MLRA) ranges from 1.1 in the Gulf Coast Marsh (MLRA 151) to 3.6 in the Superior Stony and Rocky Loamy Plains and Hills (MLRA 93) (Table 1). The average number of diagnostic horizons for the 14 MLRAs located along the Great Lakes (shown in bold face in Table 1) is 2.9; for the remaining 49 MLRAs the average number of diagnostic horizons is 2.3. Seven of the 11 highest values for mean numbers of diagnostic horizons are for MLRAs associated with the Great Lakes.

3.3. Diagnostic horizons by soil great group

The average number of diagnostic horizons by great group ranges from 1.0 for four great groups in the Entisols to 5.2 for Fragiorthods

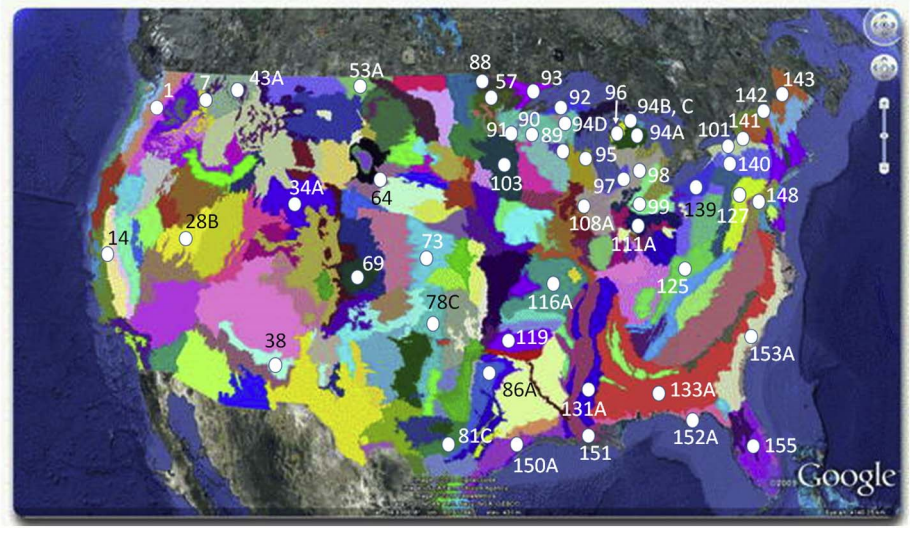

Fig. 1. Map of Major Land Resource Areas in the contiguous USA (Natural Resources Conservation Service, 2006). Study areas are identified with white dots.
Source: Google Earth Library: http://www.gelib.com/mlra.htm.