Available online at www.sciencedirect.com
ScienceDirect
Catena 73 (2008) 174–179
CATENA
www.elsevier.com/locate/catena

Saturated hydraulic conductivity of soils in the Southern Piedmont of Georgia, USA: Field evaluation and relation to horizon and landscape properties

L.T. West *, M.A. Abreu, J.P. Bishop [1]

Received 1 December 2006; received in revised form 23 July 2007; accepted 25 July 2007

Abstract

Saturated hydraulic conductivity (K_s) is one of the soil properties used most often to predict soil behavior and suitability for a variety of uses. Because of the difficulty in K_s measurement and its variability with depth and across the landscape, K_s is commonly predicted from other more easily evaluated properties including texture, clay mineralogy, bulk density, pedogenic structure and cementation. Of these, texture and pedogenic structure are most commonly used to estimate K_s, but the reliability of these estimates has not been evaluated for common soils in the Southern Piedmont of Georgia. Thus, the objectives of this study were to evaluate K_s for major horizons in soils and landscapes in the Georgia Piedmont and to relate K_s to morphological properties of these horizons. Ten sites across the region were selected, and 21 pedons arranged in three transects were described from auger holes and pits. For each pedon, K_s was measured in upper Bt horizons, at 140 cm below the surface (Bt, BC, or C horizon), and at a depth intermediate between the shallow and deep measurements (Bt, BC, or C horizon) with a constant head permeameter. The K_s of individual horizons ranged from 1×10^{-8} to 2×10^{-5} m s^{-1}. At six of 10 sites evaluated, clayey upper Bt horizons had higher K_s than deeper horizons with less clay. This difference was attributed to weaker structure in the deeper BC horizons. Structural differences did not explain all variation in K_s with depth, however. Other soil and landscape properties including parent material composition, colluvium on lower slope positions, C horizon cementation, and depth of soil development also affected K_s of horizons in these soils and should be used to better estimate K_s.

Keywords: Saturated hydraulic conductivity; Soil structure; Constant head permeameter; Ultisols

1. Introduction

Saturated hydraulic conductivity (K_s) is one of the more often used properties for evaluating soil suitability for different uses and for predicting the fate of anthropogenic materials applied on or in soil. Texture, clay mineralogy, bulk density, pedogenic structure, and cementation influence a horizon's K_s, and these properties are commonly considered when estimating K_s of a horizon (Bouma et al., 1983; Southard and Buol, 1988; Bouma, 1991; Tyler et al., 1991; Soil Survey Division Staff, 1993; Vervoot et al., 1999). Because it is easily evaluated in the field and data are available for many soils, texture is often the property given the greatest weight in estimates of K_s, although texture by itself cannot correctly predict K_s (Lin et al., 1999).

Upland residual soils in the Southern Piedmont of the southeast U.S. commonly have clayey upper Bt horizons and clay content gradually decreases to loam or sandy loam saprolitic C horizons (Perkins, 1987). Because of this clay distribution, estimates of K_s used to evaluate soil and horizon suitability for onsite wastewater management systems in Georgia are the inverse of the clay distribution with clayey upper Bt horizons having lowest estimated K_s and higher estimated K_s for subjacent BC and C horizons with less clay. This distribution of estimated K_s results in onsite system drainfields commonly being installed in BC or C horizons below clayey-textured Bt horizons.

In contrast to these estimates based on horizon clay content, several reports on similar soils have indicated that clayey upper Bt horizons in these soils have higher K_s than subjacent BC horizons (Bruce et al., 1983; O'Brien and Buol, 1984; Schoeneberger and Amoozegar, 1990; Schoeneberger et al., 1995; Vepraskas et al.,

* Corresponding author.
E-mail address: lwest@uga.edu (L.T. West).
[1] Professor and former Graduate Research Assistants, Department of Crop and Soil Sciences, University of Georgia, Athens, GA, 30602-7272 USA. Fax: +1 706 542 0914.

0341-8162/$ - see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.catena.2007.07.011

1996). Most of these studies have attributed rapid water movement through the Bt horizons to well-developed pedogenic structure that form a network of stable macropores in these kaolinitic soils with low shrink-swell potential. Underlying BC horizons have less clay but also have weaker structure and consequently, fewer macropores available for water transmission under saturated conditions. In addition, macropores that are present in BC horizons may be filled with translocated clay and Fe oxides which reduces their capacity to transmit water (Vepraskas et al., 1991). Deeper loamy textured C horizons have relatively high K_s because coarse packing pores are open and capable of rapid transmission of water under saturated conditions (O'Brien and Buol, 1984; Schoeneberger et al., 1995).

If the reported relationships between K_s and horizon properties, especially structure, holds true for a range of Southern Piedmont landscapes in Georgia, onsite system drainfields would be expected to perform better if installed in better structured Bt horizons instead of deeper BC horizons that may be the most hydraulically limiting horizon in the profile. Thus, the objectives of this study were:

1. to evaluate K_s of major horizons of common upland soils in the Southern Piedmont in Georgia on a range of hillslope positions, and
2. to develop relationships between K_s and morphological properties of soil horizons that can be used to better estimate K_s for soils in the region.

The hypothesis was that pedogenic structure has a major influence on K_s in these soils and that morphological properties observable in disturbed samples can be used to better predict relative K_s of major horizons.

2. Methods and materials

Ten sites in the Southern Piedmont in Georgia were selected for this study (Fig. 1). Land use at all sites was long-term pasture. Slopes ranged from 4 to 10%, and local relief was typical for Piedmont landscapes. At each site, 21 pedons along three transects that extended from the summit or upper backslope to the footslope were chosen for K_s evaluation. Alluvium at the base of the slope was avoided. Direction of the transects were chosen to represent the range of hillslope conditions present and because of landscape complexity, they were not always parallel. The transects were separated by at least 15 m. Distance between pedons along each transect was approximately equal and ranged from 15 to 30 m.

Each pedon was described from bucket auger borings by the authors and USDA-NRCS Soil Scientists using standard terminology (Soil Survey Division Staff, 1993). Because the soils were disturbed, descriptions emphasized color and texture. The landscape position of each pedon was designated as upper, middle, or lower hillslope. Three of the pedons at each site, chosen to represent the range in K_s and hillslope positions at the site were described and sampled from pits excavated by backhoe. Structure and other morphological characteristics from these pit descriptions were assumed to be representative of

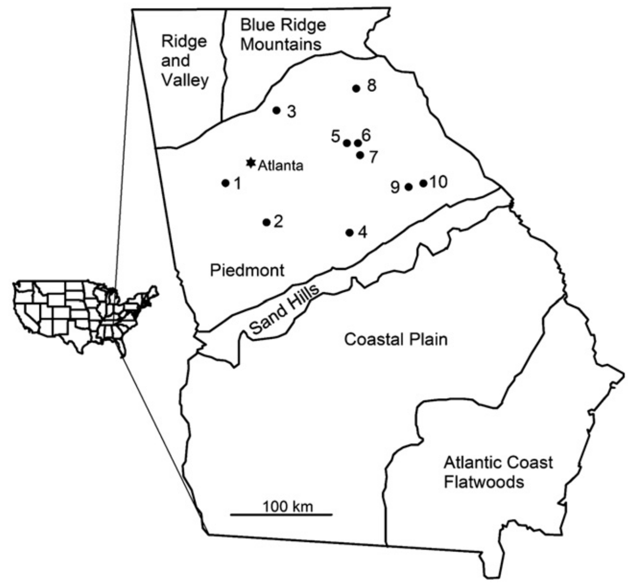

Fig. 1. Location of the study sites in the Georgia Piedmont.

nearby pedons described from auger borings. Samples were air dried and crushed to pass a 2 mm sieve. Particle-size distribution was determined in the laboratory by pipette and sieving (Kilmer and Alexander, 1949).

For each pedon, K_s was measured in a 10 cm diameter borehole with a constant head permeameter at three depths; 20 cm below the upper boundary of the Bt horizon (shallow), 140 cm below the soil surface (deep), and approximately 1/2 way between the shallow and deep measurement depths (middle). Goal depths were adjusted to avoid horizon boundaries. The middle and deep measurement depths represented lower Bt, BC, or C horizons depending on horizon thicknesses and depth of soil development. The deep K_s measurement was made in the auger boring used to describe the soil and evaluate goal depth for the more shallow K_s measurements which were made in separate boreholes about 1 m from the boring used for soil description. All K_s measurements were made with a 0.02 M $CaCl_2$ solution to minimize clay dispersion. The designed sampling scheme (10 sites × 21 pedons × 3 depths) should have resulted in 630 measurements of K_s. At Site 7, however, an extra transect with six pedons was evaluated which increased the goal number of measurements to 648. Large rocks or other anomalous features prevented K_s measurement for 28 of the planned depth-pedon combinations, however, which resulted in 620 K_s measurements that were available for analysis.

Measurement of K_s by an *in situ* borehole method was used because similar methods are commonly used to evaluate sites and design wastewater systems in the area, and use of *in situ* a method avoids questions of sample volume and potential soil disturbance during collection of samples for laboratory measurement of K_s. Soils were relatively dry at time of K_s measurement and no indication of sidewall smearing was observed. All borehole measurements were continued until three consecutive measurements with at least 15 min between measurements yielded similar values of Q.