A New Approach to Measuring Hydraulic Properties of Urban Soils.

William C. Fonteno and Stuart L. Warren
North Carolina

Nature of Work

Two of the major problems presented by urban soils are compaction and drainage. To successfully ameliorate these problems, organic matter is often added to the soil. Empirical data is needed on water transport factors such as drainage, percolation, and hydraulic conductivity, as well as for capacity factors of porosity, aeration, and available water. While limited information is available for specialized systems, such as golf green construction, there is no such information for urban soils. The following is a suggested approach to analyzing the effects of additions of organic matter to urban soils using empirical data and mathematical models.

For illustration, a loamy sand (82% sand, 12% silt, 6% clay) was amended with 0, 10, 20, 30, 40, and 50% composted poultry litter(CPL) by volume. the CPL had a particle size distribution of 18% < 0.05 mm, 39% between 0.05 and 2.0 mm, and 43% between 2.0 and 6.3 mm. Each combination was put into nineteen 3.8 l containers, placed in a greenhouse at 24/18°C day/night temperatures and watered daily. After 13 weeks, an intact, naturally compacted 348 cm^3 sample was taken from the center of each of 7 containers per treatment using an aluminum cylinder (7.6 cm diameter × 7.6 cm high) following the procedures of Fonteno et al. (1981). The remaining substrate in each of the sampled containers was used to determine unavailable water content.

Total porosity was determined for each treatment combination using the NCSU Porometer™, following the procedures of Warren and Fonteno (1993). An estimate of unavailable water (UW) was defined as the amount of water held at 1.5 MPa, using procedures of Milks et al. (1989).

Eight replications of six media were packed (Bilderback and Fonteno, 1987) in aluminum cylinders (7.6 cm x 7.6 cm). Data were collected for moisture retained at 10 moisture tensions from 0 to 30 kPa using a pressure plate apparatus and procedures of Fonteno et al. (1981), Karlovich and Fonteno (1986) and Milks et al. (1989a) . After the measurement at 30 kPa, each sample was removed and bulk density determined by calculating its volume and weighing each sample after it was dried 24 hr at 105 C (Klute, 1986).

A nonlinear, five-parameter function developed for soils by Van Genuchten and Nielsen (1985) and adapted to horticultural media by Milks et al. (1989a) was used to describe the moisture retention data. The function is defined as

$$\Theta = \Theta_r + (\Theta_s - \Theta_r)/[1+(\alpha h)^n]^m \qquad [1]$$

where Θ_s is the mean percent moisture at saturation, Θ_r is the mean percent moisture at asymptotic residual (taken to be 30 kPa), h is the log of moisture tension, and α, n and m are predicted through iteration.

In order to determine the effects of organic matter additions on the parent soil at various depths, a landscape soil profile model was developed. TP and UW were equal to the volume wetness (Θ) at saturation and 1.5 MPa, respectively. Water content (WC) was predicted using procedures similar to those used by Karlovich and Fonteno (1987). This model was based on the Equilibrium Capacity Variables (ECV) model described by Bilderback and Fonteno (1987) and refined by Milks, et al, 1989b). The soil column to be modeled was mathematically sectioned into 0.5 cm tall increments. The nonlinear equation [1] was used to predict the percentage of water values at the midpoint of each 0.5 cm section. Multiplying the percentage of water value by the volume of each soil column section gave the water volume held in that section at field capacity. The water volumes of all zones were summed to give the total water volume in the soil column at field capacity. AS was calculated as the difference between TP and WC. AW was calculated as the difference between WC and UW.

Results and Discussion:

Total porosity increased linearly with increasing rate of CPL amendment from 42 to 55% (Table 1). Bulk density decreased linearly, as reflected by increasing pore space. Twenty percent and higher rates of CPL were within the ideal bulk density range proposed by Craul(1986).

Using the landscape drainage profile, water content increased with increasing CPL rate (Figure 1). Water content was increased from 10 to 35% within the upper 35 cm of soil. Although most organic matter has high water retention capacity, much of it is held at potentials > 1.5 MPa, and is unavailable to plants. This is reflected in the increasing UW with increasing CPL rates (Table 1). Any increase in water content should be divided into available and unavailable water before the value of the organic amendment can be evaluated. In this loamy sand, increasing CPL additions improved overall water content from 10 to 34%, while the AW was only increased from 6 to 12%. CPL reduced air space from 33% down to 18% within the top 35 cm. The largest decrease in AS occurred between the 20 and 30% CPL rates.

Significance to Industry:

The landscape drainage profile can be adjusted to model incorporation of organic matter to other depths. For practical purposes, models from 10 to 90 cm have been developed (not shown). This allows the examination of organic matter additions at any rate and to any depth of incorporation. These models and empirical data, combined with appropriate field information such as percolation and slope could provide a systems approach to understanding the hydraulic properties of urban soils.

Table 1. Effect of composted poultry litter (CPL) amendment on total porosity, unavailable water, and bulk density of a loamy sand soil.

CPL amendment (% vol)	**Total porosity**	**Unavailable water**	**Bulk density** (Mg/m^3)
	(% soil volume)		
0	42.0	4.0	1.48
10	45.2	7.1	1.39
20	46.9	8.9	1.33
30	47.0	14.4	1.29
40	49.4	21.3	1.20
50	55.5	21.4	1.08
Significance[z]			
Linear	***	***	***

[z]Significant at 0.001 level.

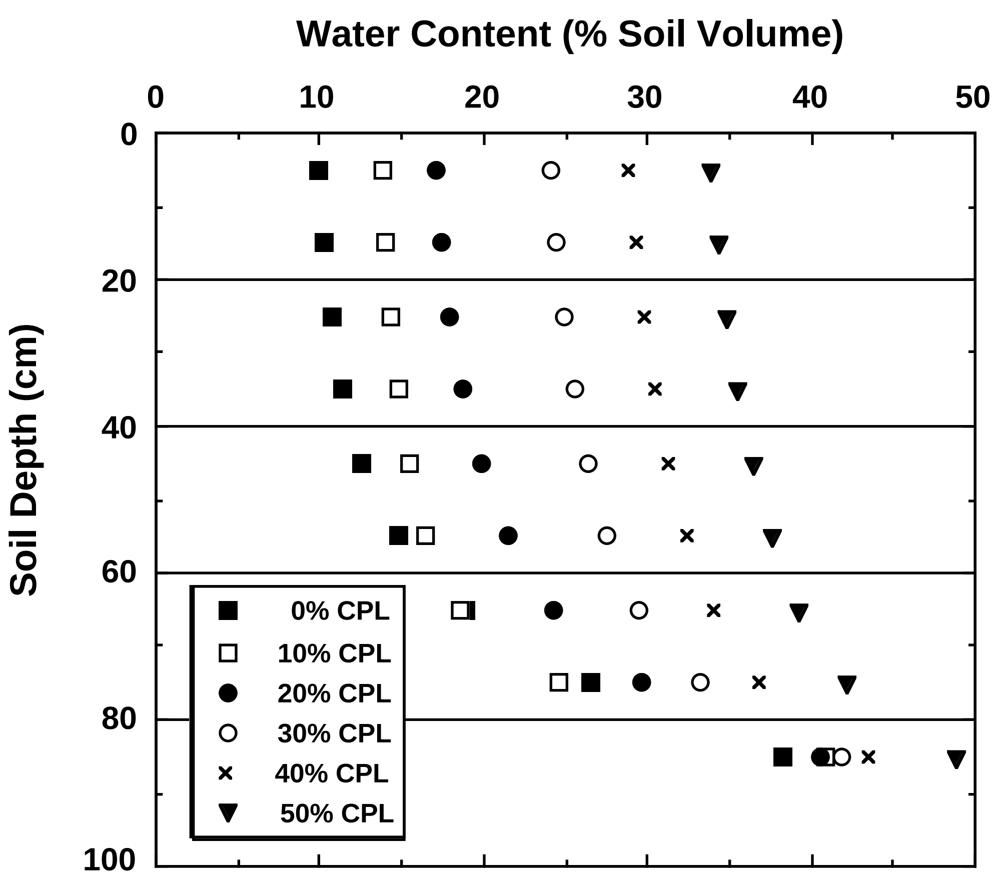

Figure 1. Effect of composted poultry litter (CPL) on water content of a loamy sand soil.

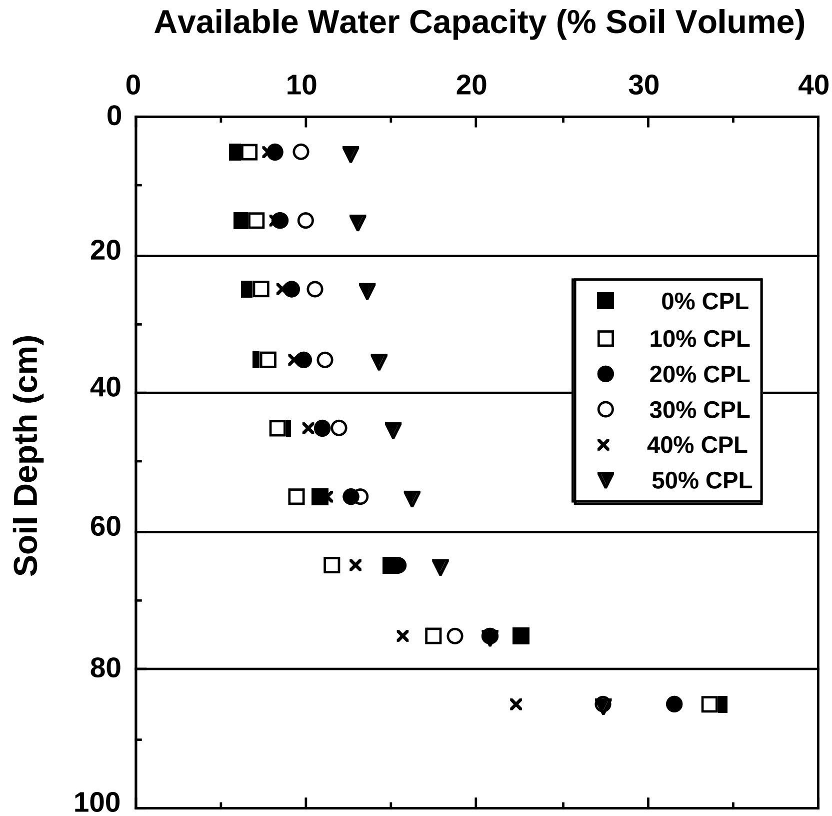

Figure 2. Effect of composted poultry litter (CPL) on available water capacity of a loamy sand soil.

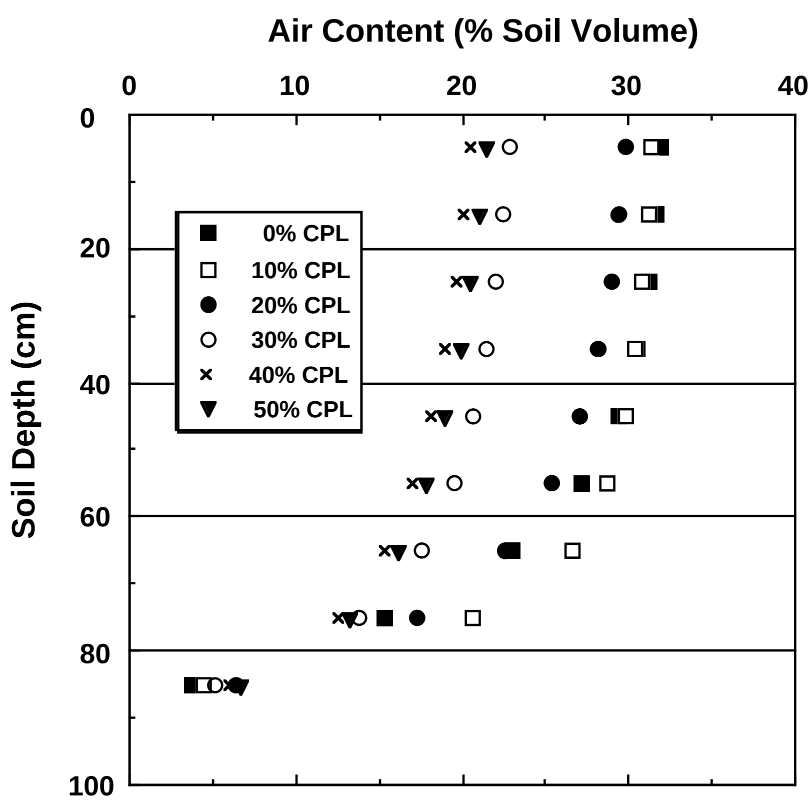

Figure 3. Effect of composted poultry litter (CPL) on air space of a loamy sand soil.

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