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Prediction Equations for Water-Holding Capacity of Some Minnesota Forest Soils*

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ABSTRACT

Prediction equations for 1/3-bar and 15-bar water-holding capacity were developed for forest soils in northern Minnesota. Particle-size distribution was determined for about 400 soil samples. Five samples were then selected from each of the 12 soil - texture classes for determination of water relationships. Percent sand and percent clay were the best predictors of water-holding capacity for subsurface horizons (1/3-bar R^2 = 0.94; 15-bar R^2 = 0.96). Soil organic matter in surface horizons affected predictions for those horizons. For prediction of water-holding capacity of both surface and subsurface horizons, percent nitrogen (N) was used with percent sand and percent clay (1/3-bar R^2 = 0.92; 15-bar R^2 = 0.91). The range in the independent variables (sand 0 to 97 percent, clay 2 to 89 percent, nitrogen 0.01 to 0.37 percent) should allow application of these equations to a variety of forest soils in northern Minnesota.

INTRODUCTION

The importance of soil water to forest productivity has been well-documented (Carmean 1975, Balmer 1978). Although other prediction equations for soil water-holding capacity have been developed (e.g., Gupta and Larson 1979), none exist for forest soils of northern Minnesota. This paper presents prediction equations for 1/3-bar and 15-bar water-holding capacity. Available water can be estimated as the difference between 1/3-bar an 15-bar water.

METHODS

Soil samples were collected from each horizon of 76 soil pits (1 meter in depth) from the areas of the Chippewa and Superior National Forests in northern Minnesota (Harding 1982). To develop prediction equations for 1/3-bar and 15-bar water-holding capacity, these approximately 400 soil samples were grouped into the 12 commonly-defined textural classes (Brady 1974). Five samples were randomly selected from each class, yielding a total of 60 samples. The percent water at 1/3-bar (an estimate of field capacity) and at 15-bar (an estimate of wilting point) were determined for the 60 samples using a pressure membrane apparatus (Black 1965).

Bulk densities were determined for each horizon using the core method (Black 1965), with the modification that samples were not sieved. Particle-size distribution (percent sand, silt, and clay) for each horizon was determined by a modified hydrometer method (Grigal 1973). Percent nitrogen (N) was determined as total Kjeldahl (Black 1965). Nitrogen was determined for horizons in the top 25 cm of the soil profile. A value of 0.01 percent N was assigned to horizons below 25 cm.

Multiple regression analysis was used to determine soil properties that could best predict 1/3-bar and 15-bar water-holding capacity. Soil properties considered as independent variables included sand, silt, clay, N, and bulk density. Model selection was based on lowest adjusted R^2 and smallest standard error (Sy.x) for each model (Nie et al. 1975).

Predictions from the equations were compared to tabulated data collected for forest soils by the USDA Soil Conservation Service (SCS) (Soil Conservation Service, 1978, 1979). We compared data from soils sampled in Minnesota and Wisconsin. Not more than three horizons were selected per soil, the soils must have formed under forest vegetation and did not contain Ap horizons, and the data for selected horizons must have included both 1/3- and

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15-bar water-holding capacity. Estimates of water-holding capacity at 1/3-bar and 15-bar, and of available water as the difference between those values, were compared with the tabulated data by paired t-tests (Nie et al. 1975). Data from 67 horizons were compared, ranging from 1 to 82 percent sand, 3 to 73 percent clay, and 0.001 to 0.60 percent N computed from organic carbon data.

RESULTS AND DISCUSSION

Percent sand and clay were the best predictors of water-holding capacity at 1/3-bar and 15-bar (Table 1). Percent sand was most strongly correlated with water at 1/3-bar, while percent clay had the strongest correlation at 15-bar (Table 1). Inspection of residuals revealed that outliers for predictions using sand and clay were associated with under-estimates of water-holding for surface horizons. Surface horizons have more organic matter (OM), resulting in greater water-holding capacities than texture alone would indicate (Brady 1974).

The addition of N to the prediction raised the R^2 for both models (Table 1), but more so for the prediction of 15-bar water. In this case the result was a 20% reduction in Sy.x. Percent N as used in this model can be estimated from OM using recognized conversion ratios (%N = %OM/19.89; assuming the carbon-nitrogen ratio = 11.7:1, and the organic carbon-soil organic matter ratio = 1:1.7, Brady 1974).

Estimates of water-holding capacity for subsurface horizons were greatly improved by deletion of surface horizons during model development (Table 1). Sand and clay were the best predictors with R^2 values of 0.94 for 1/3-bar and 0.96 for 15-bar water-holding capacity (Table 1). The Sy.x for prediction of 15-bar water-holding capacity was reduced by 51 percent and the Sy.x for 1/3-bar was reduced by 28 percent, compared to estimates for all horizons.

There was no significant difference between estimates of 1/3-bar water-holding capacity from any of the three equations in Table 1 and the tabulated data from SCS. Estimates of 15-bar water were significantly higher ($p < 0.05$) than tabulated values for the two equations from Table 1 that included surface horizons, but were not higher for the equation without surface horizons. In the former cases, mean differences between tabulations and estimates were less than one percent for the equation based only on sand and clay, and less than two percent for the equation based on sand, clay, and N. Available water also did not differ significantly between that computed from the equations and that from the tabulations. The significant differences in some of the 15-bar estimates were not sufficiently large to affect available water.

The range in the independent variables (0 to 97 percent sand, 2 to 89 percent clay, 0.01 to 0.37 percent N), should allow application of these equations to a variety of forest soils in northern Minnesota.

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Table 1. Prediction equations for water-holding capacity at 1/3-bar and 15-bar for forest soils from northern Minnesota.

Prediction Equations	Independent Variables	t values	R^2	n	Sy.x (% dry wt.)
Physical Properties-All Horizons					
1/3-bar water (% dry wt.) =	27.85	13.36	.89	59	3.79
	+ 0.14 (% clay)	4.84			
	- 0.27 (% sand)	- 9.07			
15-bar water (% dry wt.) =	10.69	6.28	.86	60	3.12
	+ 0.16 (% clay)	7.25			
	- 0.11 (% sand)	- 4.49			
Physical and Chemical Properties-All Horizons					
1/3-bar water (% dry wt.) =	24.50	12.16	.92	59	3.35
	+ 0.17 (% clay)	6.28			
	+ 29.93 (% N)	4.08			
	- 0.23 (% sand)	- 8.51			
15-bar water (% dry wt.) =	7.08	4.75	.91	60	2.52
	+ 0.19 (% clay)	10.07			
	30.74 (% N)	5.58			
	- 0.07 (% sand)	- 3.53			
Physical Properties -Subsurface Horizons					
1/3-bar water (% dry wt.) =	24.59	13.56	.94	50	2.72
	+ 0.18 (% clay)	7.17			
	- 0.23 (% sand)	- 9.49			
15-bar water (% dry wt.) =	5.57	5.64	.96	51	1.53
	+ 0.22 (% clay)	16.94			
	- 0.05 (% sand)	- 3.72			

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