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BULK DENSITY AND WATER HOLDING PROPERTIES OF INDIANA SOILS

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ABSTRACT: Scientists have accumulated much information about the soils of Indiana, but most of it is in a form that is not useful to people who make recommendations about managing specific tracts of land. A method is needed to bridge the gap between those who produce scientific information and those who use it for managing our soil resources. Developing that system is the over-all objective of the Indiana Soil Information System. This paper reports on one phase of this system. The objective of this report is to summarize the relationship between some soil morphological characteristics, that are known for many soils, and some soil physical variables, that have been determined for only a few soils. This information can then be used to predict soil physical properties from morphological information. Soil bulk density and the water held at 33 kPa (0.33 bar) matric potential (field capacity) are related to the natural fabric of the soil and can be predicted best from morphological information. At 1,500 kPa (15 bars) matric potential (wilting point), water is held mainly on the surface of soil particles, and water content can be predicted from the clay content. The difference between the water contents at 33 kPa and 1,500 kPa is an estimate of the amount of water available to plants. The information in this paper can be used with a soil pedon (profile) description to estimate the available water holding capacity of that soil.

INTRODUCTION

We face a dilemma in applying research information to managing specific tracts of land. On the one hand, much scientific information about soils has been collected. Research results are published in scientific journals and other reports. Also, many pedons have been analyzed in soil characterization laboratories. Some of these results are published in journals and other reports, but much of this information has not been published and is available only in filing cabinets or in computer files. On the other hand, practitioners who need this information for predicting how a soil or land area will respond to various treatments do not have the wherewithal to locate the information, to integrate and digest it, and to apply it to the problem at hand.

The Indiana Soil Information System is being developed to help bridge the gap between production of scientific information and its use. In this system, the goal is to develop a data base for each kind of soil that contains all the information needed to help people make any kind of land use decision. The "kind" of soil for which data will be accumulated is a phase of a soil series—that for which a Soil Interpretation Record (SIR or SOIL-5 form) has been developed by the National Cooperative Soil Survey. Data will be summarized or estimated for each soil horizon of all SIRs used in Indiana.

Some information for this data base can be derived from data averages for a particular SIR (Franzmeier, 1990). However, not all the necessary determinations have been made for each pedon, and for many SIRs, there are no data of any kind available. For these soils, the needed parameters must be estimated using the best information available. The estimates can be made by extrapolating from data for a similar soil or by referring to relationships between the missing parameter and other data that are known for the soil in question. This paper deals with the relationships between some soil physical properties that have been determined for relatively few pedons, and soil properties, genetic information, and morphological descriptions that are known for many soils.

The bulk density of soils and their water contents at certain matric potentials, the variables to be estimated, are very important soil physical properties. From the bulk density, one can calculate the amount of pore space in the soil, which is important because that is where water moves and roots grow. Water contents at certain matric potentials, or suctions, represent the soil moisture conditions at several key states. The water content at saturation (zero matric potential) represents the amount of water in the soil, when all the pore space is occupied by water. After a saturated or nearly saturated soil drains for a few days, water is removed from the large pores but remains in the smaller ones. This condition, field capacity, is estimated from the water content at 10 kPa or 33 kPa matric potential in the laboratory. In some cases, 10 kPa has been used to estimate field capacity for sandy soils and 33 kPa has been used to estimate it for finer textured soils. In other cases, the two potentials have been used to allow for the influence of a high water table on available water. For example, Dale, *et al.* (1982) used the water content at 10 kPa for poorly drained soils and that at 33 kPa for well drained soils as the field capacity for calculating the soil moisture budget for different drainage conditions. When a plant has removed all the water it can from a soil, the soil is at the wilting point, which corresponds to 1,500 kPa matric potential. The difference between the water contents at field capacity and at wilting point, the water retention differences or WRD, represents the water available for plant growth; it is estimated by the difference between the laboratory-measured water contents at 10 kPa or 33 kPa and that at 1,500 kPa. The objective of this paper is to determine how soil bulk density and water contents at certain matric potentials are related to other soil properties and to soil genetic and morphological information.

MATERIALS AND METHODS

The report summarizes some soil physical properties measured in the Purdue University laboratories and the National Soil Survey Laboratory (NSSL). In the field, both natural-fabric samples and bulk samples were collected. The natural-fabric samples retained the natural structure of the soil during laboratory analyses, but the bulk samples were crushed and sieved prior to analysis. The natural fabric samples were core samples at the Purdue laboratory (Franzmeier, *et al.,* 1977) and natural clod samples at the NSSL (Soil Conservation Service, 1984).

The bulk density of a soil sample is its mass, when the soil is oven dry, divided by its volume. Most soils swell upon wetting and shrink upon drying, so the volume of a given mass of soil can change with its water content. For both core and clod samples, the mass of the sample brought to the laboratory is fixed. In the core method, the volume of the sample is fixed by the volume of the cylinder used to collect it, but in the natural-fabric (clod) method, the volume of the sample can change with a change in its matric potential and water content.

Total porosity was calculated from bulk density using this relationship:

$$\text{Porosity} = 1 - \text{BD}/2.65,$$

where BD is the bulk density and 2.65 is the assumed average density of soil particles.

In the laboratory, clod samples were saturated and then desorbed at a suction (negative of matric potential) of 33 kPa, *or* 10 kPa for sandy soils, and the water content was then measured. Core samples were desorbed at both 10 kPa *and* 33 kPa. The volume of the irregularly shaped clod was measured by displacement in water. Water content at 1,500 kPa was measured on crushed and sieved samples in both laboratories. Water contents were measured as weight percentages in the laboratory and converted to volume percentages by multiplying by bulk density.

Most of the Purdue physical property data were published in a report by Wiersma (1984). Other data are in Harlan and Franzmeier (1974) and McGhee (1986). The NSSL data are mainly in unpublished reports; the data currently stored on the NSSL computer were used in this paper.

Clay content was determined by the pipette method in both the Purdue Soil Characterization Laboratory (PSCL) and the NSSL. Organic C was determined by the Walkley-Black method in the NSSL and by the Mebius method in the PSCL; these methods gave similar results. Methods used by the PSCL and the NSSL are described in articles by Franzmeier, *et al.* (1977) and the Soil Conservation Service (1984), respectively.

The data were entered into a data base management system (Knowledgeman version 2.01, Micro Data Base Systems, Inc., Lafayette, IN 47902). Each sample was assigned an index number based on the kind of genetic horizon (which includes soil structure information), kind of parent material, and soil texture, and this index number was used to sort the data. Averages and standard deviations were calculated by the data base management system, and all regression analyses were determined using the Statistical Analysis System (SAS Institute, 1985).

RESULTS AND DISCUSSION

Some soil properties are inherited from their parent materials. For example, soil horizons formed in dense glacial till still have a higher bulk density than horizons formed in loess. To reflect this influence, we established classes of soil horizons based, in part, on their parent materials. Soil horizons formed in Wisconsin-age loess and in Wisconsin-age glacial till are summarized in Table 1. South of the Wisconsin till boundary, loess is thick near the major source areas, the Wabash and White River valleys, and it thins eastward. It covers paleosols—

Table 1. Physical properties of soil horizons formed in loess and glacial till in northern Indiana (Soil Regions 7, 8, and 9).

Lab	*n*	Bulk Density		Total Porosity	Water Content						WRD
					10 kPa		33 kPa		1,500 kPa		
		$\bar{x}$	SD	$\bar{x}$	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
		g/cm^3		cm^3/cm^{3}soil							
Loess parent material											
AP horizons (light color, ochric; Miami, Corsby, Blount, Oakley) [1] **											
P	23	1.35	0.15	0.49	0.34	0.04	0.30	0.05	0.09	0.02	0.21
N	17	1.55	0.11	0.42			0.35	0.14	0.14*	0.02*	0.21
AP horizons (dark color, nollic; Dana, Raub, Elliott) [16]											
P	12	1.37	0.13	0.48	0.35	0.04	0.31	0.04	0.14	0.03	0.17
E or BE horizons (Miami, Crosby, Blount, Ockley) [2]											
P	29	1.45	0.14	0.45	0.33	0.03	0.29	0.04	0.11	0.03	0.18
N	8	1.46	0.14	0.45			0.33	0.02	0.10*	0.02*	0.23
Bt horizons (Miami, Crosby, Toronto, Raub) [3]											
P	55	1.48	0.09	0.44	0.36	0.05	0.34	0.05	0.20	0.05	0.14
N	11	1.53	0.06	0.42			0.36	0.03	0.19*	0.02*	0.17
Loam till parent material											
2Bt or Bt horizons (Miami, Fincastle, Crosby, Parr) [6]											
P	20	1.55	0.06	0.42	0.35	0.04	0.33	0.04	0.19	0.04	0.14
N	50	1.57	0.06	0.41			0.32	0.03	0.19*	0.03*	0.13
2BC or BC horizons (Miami, Fincastle, Crosby, Parr) [7]											
P	14	1.54	0.09	0.42	0.30	0.06	0.26	0.07	0.12	0.05	0.14
N	9	1.68	0.17	0.36			0.28	0.05	0.18*	0.05*	0.10
2C or C horizons (non-compact till; Miami, Fincastle) [8]											
P	9	1.63	0.08	0.38	0.31	0.07	0.28	0.06	0.13	0.04	0.15
2C or C horizons (compact till; Miami, Fincastle, Crosby, Parr) [5]											
P	19	1.86	0.07	0.30	0.28	0.05	0.25	0.04	0.17	0.07	0.08
N	46	1.89	0.08	0.29			0.24	0.03	0.13*	0.03*	0.11
Silty clay loam or clay loam till parent material											
Bt or 2Bt horizons (Blount, Morley, Glynwood) [10]											
P	20	1.42	0.07	0.46	0.37	0.02	0.35	0.02	0.23	0.04	0.12
N	20	1.52	0.10	0.43	0.41#	0.00#	0.38	0.04	0.24	0.04	0.14

BC or 2BC horizons (Blount, Morley, Glynwood) [11]												
N	12	1.69	0.13	0.36	0.37#	0.00#	0.33	0.03	0.24	0.03		0.09
C or 2C horizons (Blount, Morley, Glynwood) [12]												
P	5	1.62	0.11	0.39	0.35	0.05	0.32	0.06	0.20	0.04		0.12
N	17	1.80	0.07	0.32	0.37#	0.02#	0.31	0.03	0.24	0.04		0.07

n = Sample size

$\bar{x}$ = Arithmetic mean

SD = Standard deviation

WRD = Water retention difference (W33 to W1,500)

P = Purdue Laboratory

N = National Soil Survey Laboratory

= 1 to 4 observations

* = 5 or more observations but less than *n*

** = Numbers in brackets, [ ], refer to the index number in the data base

old eroded soils that developed in pre-Wisconsin glacial drift or various sedimentary rocks. Table 2 includes data averages for soils south of the Wisconsin glacial boundary that formed in deep loess and in loess over paleosols in other parent materials.

Poorly drained soils that usually occur in landscape depressions (Aquolls) were excluded from Tables 1 and 2, because their parent materials were deposited largely by fluvial processes. Horizons from these soils, and all the rest of the horizons not included in Tables 1 and 2, are included in Table 3. Most of the parent materials of these horizons were water deposits, such as outwash, lacustrine, and recent alluvial deposits, but other parent materials, such as dune sand, pre-Wisconsin till, and weathered bedrock, are also included.

Summary by genetic horizon, parent material, and texture. The results are presented in Tables 1, 2, and 3, which have a similar format. The map of the soil regions listed in the Table captions is in several bulletins, such as Franzmeier, *et al.* (1989). The water content at saturation is approximately equal to total porosity. Within the Tables, horizons are listed by parent material and kind of horizon in Tables 1 and 2, and by texture and major horizon (A, B, or C) in Table 3. A list of examples of soil series represented in each group is also provided. The index number (in brackets) could help relate this summary to others derived from the same data base.

Some trends are apparent between the results obtained using the core method (Purdue laboratories) and the natural clod method (NSSL). The clod method gave higher values for bulk density in 17 of 22 cases, where comparisons could be made (Tables 1, 2, and 3). Harlan and Franzmeier (1974) found similar relationships. Volumetric water contents at 33 kPa and at 1,500 kPa were calculated by multiplying gravimetric water contents by bulk density, so a higher bulk density results in higher calculated volumetric water contents at both suctions.

Table 2. Physical properties of soil horizons formed in loess, mostly in southern Indiana. (Refer to Table 1 for the meaning of the abbreviations and superscripts).

Lab	n	Total Density		Total Porosity	Water Content						WRD
					10 kPa		33 kPa		1,500 kPa		
		x̄	SD	x̄	x̄	SD	x̄	SD	x̄	SD	
		g/cm³		cm³/cm³ soil							
Ap horizons (Bartle, Zanesville, Switzerland, Tilsit, Iva) [17]**											
P	27	1.40	0.12	0.47	0.35	0.04	0.30	0.03	0.11	0.03	0.19
N	20	1.48	0.10	0.44			0.33	0.03	0.12	0.03	0.21
E or BE horizons (Clermont, Bartle, Bedford, Zanesville) [18]											
P	25	1.39	0.13	0.48	0.36	0.04	0.32	0.03	0.13	0.03	0.19
N	20	1.46	0.06	0.45			0.34	0.22	0.13	0.03	0.21
Bt (silt loam) horizons (Zanesville, Clermont, Steff, Elkinsville) [13]											
P	19	1.47	0.13	0.44	0.34	0.04	0.30	0.05	0.12	0.03	0.18
N	12	1.54	0.06	0.42			0.34	0.02	0.15	0.02	0.19
Bt (silty clay loam) horizons (Vigo, Iva, Bartle, Switzerland, Crider) [19]											
P	25	1.43	0.08	0.46	0.39	0.03	0.36	0.03	0.19	0.02	0.17
N	24	1.49	0.07	0.44			0.36	0.02	0.19	0.02	0.17
Bx horizons (Zanesville, Bartle, Clermont, Bedford) [15]											
P	25	1.53	0.07	0.42	0.36	0.04	0.34	0.04	0.18	0.05	0.16
N	25	1.63	0.09	0.38			0.33	0.03	0.18	0.04	0.15
Bc horizons (Clermont, Iva) [9]											
P	4	1.54	0.11	0.42	0.38	0.03	0.36	0.02	0.18	0.02	0.18
C horizons (Clermont, Stendal) [14]											
P	19	1.47	0.13	0.44	0.34	0.04	0.30	0.05	0.12	0.03	0.18

Water retention difference (WRD) is the difference between the water contents at 33 kPa and at 1,500 kPa, so shifts of both values in the same direction tend to offset each other and result in similar WRDs for the two methods.

Table 4 lists three sets of soil horizons that have the same texture and horizon designations but differ in the kind of parent material. Silt loam Ap horizons formed in loess over Wisconsin till have about the same WRD as those formed in loess over pre-Wisconsin till, but this WRD is somewhat greater than that for horizons formed in fluvial materials. The same relationship holds for silty clay loam Bt horizons. For the loam C horizons, however, the nature of the parent material is more important. Horizons formed in fluvial materials have much higher WRD than those formed in compact till. Those formed in non-compact till have intermediate WRD.

Table 3. Physical properties of soil horizons formed in parent materials other than loess or Wisconsin till in regions 7, 8, and 9. (Refer to Table 1 for the meaning of the abbreviations and superscripts).

Lab	n	Bulk Density		Total Porosity	Water Content						WRD
					10 kPa		33 kPa		1,500 kPa		
		x̄	SD	x̄	x̄	SD	x̄	SD	x̄	SD	
		—g/cm³—		—cm³/cm³—							
Fine sand or sand B horizons (Morocco, Plainfield, Tracy, Oshtemo) [31 and 32] **											
P	13	1.52	0.07	0.43	0.10	0.04	0.07	0.03	0.02	0.01	0.05
Fine sand or sand C horizons (Plainfield, Brems, Coloma, Newton, Maumee) [41 and 42]											
P	73	1.55	0.08	0.42	0.14	0.07	0.10	0.06	0.03	0.02	0.07
Loamy sand or loamy fine sand A horizons, light color (Morocco, Oaktown) [21]											
P	8	1.39	0.08	0.48	0.20	0.09	0.16	0.07	0.06	0.02	0.10
Loamy sand of loamy fine sand A horizons, dark color (Maumee, Newton) [23]											
P	20	1.31	0.23	0.51	0.32	0.08	0.27	0.07	0.12	0.03	0.15
Loamy sand or loamy fine sand B horizons (Oaktown, Morocco, Coloma, Hanna) [33]											
P	35	1.46	0.07	0.45	0.14	0.07	0.11	0.06	0.04	0.02	0.07
Loamy sand or loamy fine sand C horizons (Maumee, Warsaw, Door) [43]											
P	8	1.52	0.13	0.43	0.20	0.03	0.17	0.03	0.09	0.03	0.08
Sandy loam or fine sandy loam A horizons (Maumee, Gilford, Tracy) [24]											
P	31	1.48	0.13	0.44	0.24	0.06	0.19	0.05	0.07	0.03	0.12
Sandy loam or fine sandy loam B horizons (Tracy, Hanna, Fox, Rensselaer) [34]											
P	52	1.53	0.07	0.42	0.20	0.05	0.16	0.05	0.07	0.02	0.09
N	6	1.43	0.06	0.46			0.28	0.04	0.13	0.02	0.15
Sandy loam or fine sandy loam C horizons (Maumee, Door, Tracy) [44]											
P	4	1.54	0.09	0.42	0.21	0.02	0.17	0.02	0.08	0.02	0.09
Sandy clay loam B horizons (Fox, Tracy, Door, Warsaw) [4]											
P	14	1.48	0.09	0.44	0.28	0.04	0.25	0.05	0.13	0.03	0.12
N	16	1.39	0.15	0.48			0.34	0.04	0.16	0.02	0.18
Loam A horizons (Newton, Rensselaer, Hanna, Door, Strawn, Fox) [25]											
P	27	1.42	0.13	0.46	0.30	0.05	0.26	0.05	0.11	0.03	0.15
N	8	1.61	0.08	0.39			0.29	0.02	0.14	0.02	0.15
Loam B horizons (Brookston, Chalmers, Wawasee,Tracy) [35]											
P	20	1.66	0.13	0.37	0.31	0.04	0.27	0.05	0.13	0.03	0.14
N	7	1.57	0.07	0.41			0.30	0.03	0.16	0.02	0.14

Lab	n	Bulk Density		Total Porosity	Water Content						WRD
					10 kPa		33 kPa		1,500 kPa		
		x̄	SD	x̄	x̄	SD	x̄	SD	x̄	SD	
		g/cm³		cm³/cm³							
Loam C horizons (Brookston, Elkinsville) [45]											
P	3	1.59	0.10	0.40	0.37	0.03	0.34	0.05	0.14	0.02	0.20
Silt loam A horizons, not Ap (Miami, Fox, Morley) [20]											
P	7	1.17	0.26	0.56	0.34	0.03	0.30	0.02	0.10	0.03	0.20
N	6	1.26	0.17	0.53			0.37	0.05	0.13	0.03	0.24
Silt loam Ap horizons (Vincennes, Genessee, Wea, Chalmers, Tracy) [26]											
P	26	1.40	0.14	0.47	0.35	0.03	0.31	0.05	0.14	0.03	0.17
Silt loam B horizons (Genessee, Pekin, Wheeling, Vincennes) [36]											
P	19	1.47	0.12	0.44	0.32	0.03	0.28	0.03	0.14	0.03	0.14
Silt loam C horizons (Genessee, Wheeling) [46]											
P	7	1.42	0.05	0.46	0.31	0.03	0.26	0.06	0.11	0.04	0.15
Silty clay loam A horizons (Brookston, Chalmers, Pewamo, Vincennes, Zipp) [27]											
P	38	1.42	0.12	0.46	0.36	0.03	0.34	0.03	0.20	0.04	0.14
Silty clay loam B horizons (Brookston, Eel, Vincennes, Zipp) [37]											
P	51	1.44	0.11	0.46	0.36	0.03	0.34	0.03	0.20	0.04	0.14
N	6	1.53	0.12	0.42	0.39#	0.00#	0.38	0.04	0.25	0.03	0.13
Silty clay loam C horizons (Eel, Vincennes, Pewamo, Pate) [47]											
P	7	1.47	0.03	0.44	0.38	0.02	0.36	0.02	0.18	0.02	0.18
Clay loam or sandy clay A horizons (Lewisburg, Bono, Fox) [28]											
N	8	1.55	0.22	0.41	0.37#	0.00#	0.32	0.06	0.19	0.03	0.13
Clay loam or sandy clay B horizons (Vincennes, Warsaw, Treaty, Crider) [38]											
P	29	1.45	0.11	0.45	0.36	0.05	0.34	0.05	0.20	0.04	0.14
N	16	1.51	0.12	0.43			0.36	0.04	0.22	0.04	0.14
Silty clay or clay A horizons (Bono, Eden, Montgomery, Zipp) [29]											
P	4	1.37	0.13	0.48	0.38	0.02	0.37	0.02	0.23	0.04	0.14
N	4	1.31	0.16	0..51	0.40#	0.00#	0.44	0.05	0.27	0.03	0.17
Silty clay or clay B horizons (Bono, Eden, Crider Pate, Pewamo, Frederick) [39]											
P	6	1.48	0.04	0.44	0.39	0.03	0.38	0.02	0.25	0.02	0.13
N	45	1.44	0.14	0.45	0.38#	0.00#	0.41	0.05	0.29	0.04	0.12
Silty clay or clay C horizons (Switzerland, Carmel, Eden, Pate, Bono) [49]											
N	8	1.61	0.13	0.39			0.36	0.05	0.27	0.03	0.09

Table 4. Bulk density and water contents at 33 kPa and 1,500 kPa metric potentials for soil samples that have similar textures and horizon designations. (Refer to Table 1 for the meaning of the abbreviations and superscripts.)

Parent material	Lab	Bulk Density	Water Content			Index Number
			33 kPa	1,500 kPa	WRD	
		—g/cm^3—	—cm^3/cm^{3}soil—			
Silt loam Ap horizons						
Loess over Wisconsin age materials	P	1.35	0.30	0.09	0.21	1
	N	1.55	0.35	0.14	0.21	1
Loess over pre-Wisconsin age materials	P	1.40	0.30	0.11	0.19	17
	N	1.48	0.33	0.12	0.21	17
Fluvial and other materials	P	1.40	0.31	0.14	0.17	26
Silty clay loam Bt horizons						
Loess over Wisconsin age materials	P	1.48	0.34	0.20	0.14	3
	N	1.53	0.36	0.19	0.17	3
Loess over pre-Winsconsin age materials	P	1.43	0.36	0.19	0.17	19
	N	1.49	0.36	0.19	0.17	19
Fluvial and other materials	P	1.44	0.34	0.20	0.14	37
	N	1.53	0.38	0.25	0.13	37
Loam C horizons						
Compact glacial till	P	1.86	0.25	0.17	0.08	5
	N	1.89	0.24	0.13	0.11	5
Non-compact glacial till	P	1.63	0.28	0.13	0.15	8
Fluvial and other materials	P	1.59	0.34	0.14	0.20	45

Correlation of horizon properties. Many more data are available for clay and organic C contents than for water contents at various matric potentials. In addition, clay and organic C contents can be estimated with reasonable accuracy in the field. Thus, a statistical correlation between these variables will make it possible to make an accurate estimate of water contents from laboratory and field information. The following relationships were calculated:

$$W1{,}500g = 0.367 \times Clay + 1.84;\ n = 1563,\ r^2 = 0.90, \text{ and}$$
$$W1{,}500g = 0.369 \times Clay + 0.947 \times OC + 1.23;\ n = 1408,\ r^2 = 0.92,$$

where W1,500g is the gravimetric water content at 1,500 kPa suction, Clay is the clay content, and OC is the organic carbon content, all in weight percent. At 1,500 kPa suction, water is held mainly on the surface of the soil particles. Clay and organic matter provide most of the surface area of a soil, hence the good correlation between these two variables and 1,500 kPa water.

Step-wise regression analyses were also done for gravimetric 33 kPa water content (W33g) and for the difference between gravimetric 33 kPa and 1,500 kPa water contents (WRDg) as dependent variables, and several other soil properties such as sand, silt, clay, and organic C contents as independent variables. The coefficient of multiple determination, R^2, was 0.60 for W33g as a function of percent clay (K), silt (S), and organic carbon (C). When various interactions of these variables were included, R^2 improved to 0.71. The resulting equation was

$$\begin{aligned} W33g = {} & 7.21 + 0.771\ K - 0.003\ K^2 - 0.301\ S - 0.005\ KS \\ & + 0.006\ S^2 + 13.45\ C - 0.244\ KC - 0.175\ SC + 0.003\ KSC \\ & + 0.556\ C^2;\ n = 325. \end{aligned}$$

The highest correlation coefficient for WRDg was only 0.09.

Because the correlation coefficients are so low, we conclude that W33 and WRD (the volumetric equivalents of W33g and WRDg) can be estimated better from Tables 1, 2, and 3 than from the regression equations. Apparently, the water content at lower suctions depends more on soil structure and packing of soil grains (as reflected by the kind of parent material) than on bulk soil properties such as clay, silt, and organic carbon contents. The values in the tables can be used with the horizon depths from specific soil descriptions to determine the water holding capacity of that soil.

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