DIVISION S-6—SOIL AND WATER MANAGEMENT AND CONSERVATION

Physical Properties of Peats as Related to Degree of Decomposition[1]

D. H. BOELTER[2]

ABSTRACT

Important physical characteristics, such as water retention, water yield coefficient, and hydraulic conductivity, vary greatly for representative northern Minnesota peat materials. The differences are related to the degree of decomposition, which largely determines the porosity and pore size distribution. Fiber content (> 0.1 mm) and bulk density are properties often measured to indicate the degree of decomposition of peat materials and are criteria used to distinguish fibric, hemic, and sapric peat types.

Regression analyses showed a curvilinear relationship of water contents at saturation, 5 mbar, 0.1 bar, and 15 bar suctions, to fiber content (> 0.1 mm) and bulk density with coefficients of multiple determination (R^2) ranging from .66 to .88. Regression analyses of the logarithm of hydraulic conductivity on fiber content (> 0.1 mm) and bulk density indicate a linear relationship (r^2 = .54), although not as great due to the variability of hydraulic conductivity.

Thus the classification of peat materials and organic soils based primarily on degree of decomposition as measured by fiber content and bulk density would relate significant information about their physical characteristics.

Additional Key Words for Indexing: **fiber content, bulk density of peats, classification of peats, organic soils.**

KNOWLEDGE of the physical properties of organic soils is necessary to develop useful resource management plans for peatland areas. Water retention, porosity, water yield coefficient, and hydraulic conductivity vary greatly for different peat types and organic soils (2, 3, 4). Any inventory or classification of organic soils to be most useful should indicate these properties.

Hydrologic characteristics of soil, such as water storage and rate of water movement, depend to a large degree on the porosity and pore-size distribution of the material. These are in turn related to the particle-size distribution and structure of the soil. In peat materials, the particle size, structure, and resulting porosity are determined by the state of decomposition.

While degree of decomposition appears to be a key property of organic soils, it is not clearly defined and therefore difficult to quantify. It is a relative quantity that is usually approximated using a measure of one of the chemical or physical characteristics that change with advanced decomposition. Fiber content and bulk density are two measures used to estimate degree of decomposition from peat materials (4, 5). These characteristics can also be used to identify and classify peat material because they are distinguishable in the field and can be easily measured. The study reported here shows that they are also good indicators of the physical properties of the peat material.

MATERIALS AND METHODS

One hundred nineteen peat samples were collected from undrained organic soils in 12 northern Minnesota bogs representing various peatland types. The samples represent moss peat and herbaceous peat as well as peats with a high wood content. They ranged from raw undecomposed peat with fiber contents as high as 98% to relatively well-decomposed peat with 15% fiber content.

Fibers are fragments or pieces of plant tissue greater than 0.10 mm in size. The most decomposed peat materials are designated "sapric" and have less than one-third of the total mass of organic material made up of fibers (4). "Hemic" (formerly mesic) materials represent intermediate decomposition and have fiber contents between one-third and two-thirds. "Fibric" materials are least decomposed, having more than two-thirds of the total organic material in fibers greater than 0.1 mm[3] (Fig. 1).

All procedures used in this study were designed to measure the properties of undisturbed peat materials as they exist in the field. Undisturbed cores and bulk samples were collected for analysis of water retention, bulk density, and fiber content. Sampling depth ranged from the surface to 100 cm using a caisson, as described by Boelter (2), when necessary to sample below the water table. The samples were not allowed to dry and were stored at approximately 5C to discourage any biochemical activity.

Fiber content of the total mass of organic material was determined with a wet sieving process. (This technique is similar to that developed by Dr. Rouse Farnham, Soil Science Department, University of Minnesota, St. Paul.) A weighed sample (100–200 g) of peat at field water content was soaked 15–20 hours in a 5% Calgon solution (dispersing agent). This sample was then washed through a nest of five sieves (2.0 mm—10 mesh, 1.0 mm—18 mesh, 0.5 mm—35 mesh, 0.25 mm—60 mesh, and 0.1 mm—140 mesh) using a gentle stream of water. Caution was used to prevent rubbing or abrasion which could reduce the fiber size. The fiber retained on each of the sieves was collected, ovendried, weighed, and compared to the calculated oven-dry weight of the original sample. The oven-dry weight of the original sample was calculated using the water content of a duplicate sample of the material.

Water retention at each of several water suctions was determined using soil water extraction equipment. A single sample pressure cell was used for suctions of 0.1 bar or less using an undisturbed core. Water retention at higher suctions was

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[2] Soil physicist at the Station's Northern Conifers Laboratory in Grand Rapids, Minn.

[3] The fibers must be sufficiently preserved to resist being disintegrated when rubbed. However, since the measurement of rubbed fiber content is as yet subjective, only the unrubbed fiber content was considered in this study.

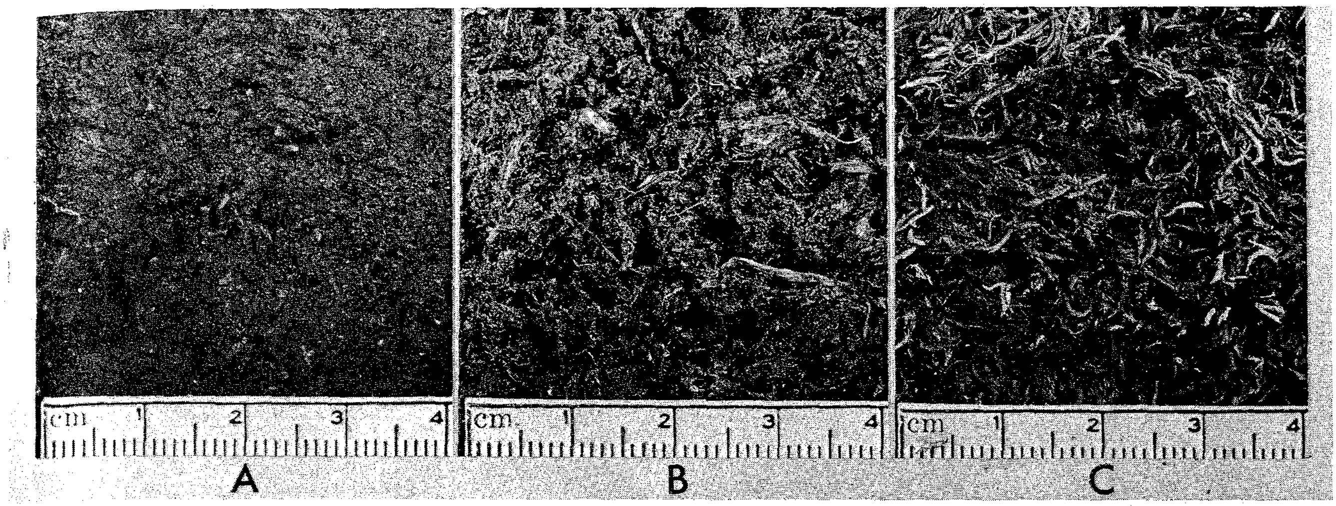

Fig. 1—Examples of three peat types: (A) Sapric—fiber content = 15.5%, D_B = .25 g/cc; (B) Hemic—fiber content = 43.5%, D_B = .16 g/cc; and (C) Fibric—fiber content = 87.3%, D_B = .04 g/cc.

determined using undisturbed samples on pressure membrane and pressure plate extractors. All water contents were determined on a volume basis.

Total porosity is considered to be equal to the water content at saturation.

Water yield coefficient is the ratio of the quantity of water removed from (or added to) a peat profile to the change in water table elevation. It includes water removed from the saturated zone and water released from horizons in the capillary fringe above the original zone of saturation. Values presented in this paper are calculated from laboratory measured water retention values. They are equal to the differences in water contents at saturation and 0.1 bar suction and represent the change in water content with water level fluctuations in a profile consisting entirely of the particular type of peat material.

Bulk density of each sample was measured using the oven-dry weight of a core of the peat obtained in the field at field water contents.

Hydraulic conductivity was measured in the field using the piezometer method. This method is considered to measure horizontal water movement. However, earlier work indicated no significant difference between horizontal and vertical hydraulic conductivity in similar peats (3).

RESULTS AND DISCUSSION

FIBER SIZE AND BULK DENSITY

Fiber content and bulk density are both used to estimate the degree of decomposition and are closely related to each other. As decomposition proceeds, the size of organic particles decreases, resulting in smaller pores and higher bulk density. While fiber size greater than 0.1 mm was arbitrarily selected to classify peat materials (4), the larger size fractions tested are equally related to bulk density and

Table 1—Regression equations and coefficients of multiple determination (R^2) for the relation of the content of each of several fiber sizes (Y) to bulk density (X)

Fiber size, mm	Regression equation	R^2
> 0.10	$\hat{Y} = 98.87 - 494.51X + 803.80X^2$	.85
> 0.25	$\hat{Y} = 98.98 - 704.41X + 1,522.54X^2$	.87
> 0.50	$\hat{Y} = 91.55 - 781.52X + 1,869.23X^2$	.86
> 1.00	$\hat{Y} = 84.68 - 840.19X + 2,165.11X^2$	.86
> 2.00	$\hat{Y} = 78.80 - 825.48X + 2,176.44X^2$	.86

would probably be as well correlated with other physical characteristics of the soil (Table 1).

Apparently there is still some question regarding the minimum fiber size to be used for classification of peat materials. A recent proposal suggests that fibers be defined as particles greater than 0.15 mm in size (Supplement to the Soil Classification System (7th approximation) Histosols by Soil Survey Staff, SCS, USDA, September 1968). Data presented here show that for fiber content to be an indicator of the physical properties of the peat material, the minimum fiber size finally selected may not be critical since all of the sizes tested were equally well related to decomposition and bulk density.

Since bulk density is used to help identify the types of peat material, it is necessary to know the range of values for each of the peat types. Using a fiber size greater than 0.1 mm and the appropriate regression equation (Fig. 2), fibric materials were found to have bulk densities < 0.075 g/cc and sapric materials > 0.195 g/cc with hemic materials intermediate.

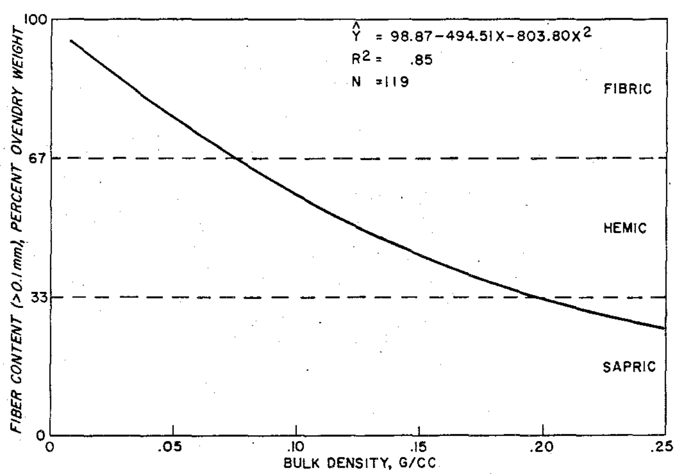

Fig. 2—The relation of fiber content (> 0.1 mm) to bulk density.

WATER RETENTION AND DEGREE OF DECOMPOSITION

Water retention values at saturation, 5 mbar, 0.1 bar, and 15 bar suctions were correlated with both fiber content (> 0.1 mm) and bulk density (Fig. 3 and Table 2). Curvilinear relations were found and R^2 values are slightly higher for bulk density than for fiber content, particularly at high water suctions. Similar results were obtained at 15, 25, and 65 mbars and 0.2, 0.5, 1.0, and 3.0 bars.

With suctions of 5 mbar (5 cm of H_2O) or more, the water retention of peat materials increases with increasing decomposition, because the more decomposed peat materials have more small pores that are not easily drained. However, the saturated water content decreased with decomposition ranging from nearly 100% for the least decomposed to 82% for the most decomposed. It is apparent that the difference in pore size distribution is more significant than the difference in total porosity.

Kuntze (6) also found that water retention characteristics of peat, such as field capacity and permanent wilting point, were dependent on degree of decomposition. Substance volume, ash content, and humus content were used to estimate the degree of decomposition.

When the water retention of peats is measured at very low suctions, a precise and consistent water suction must be applied. Simply changing the height of sample will alter the amount of water suction when measuring maximum water-holding capacity. Because of the large quantity of water released by saturated undecomposed peats at low suctions, a small change in suction can greatly alter the resulting water content. The data show that fibric peats retain more water at saturation than either hemic peats or sapric peats (Fig. 3). However, at only 5 mbar suction the relationship is different and the water contents of fibric peats are less than hemic and sapric peats.

It is also important to recognize that these values are volumetric water contents. Water contents expressed on a weight basis are nearly always higher for fibric peat than hemic or sapric peat at any suctions. However, because of the large differences in dry material per unit volume (bulk

Table 2—Curvilinear regression equations and coefficients of multiple determination (R^2) for the relation of water content (Y) at saturation, 5 mbar, 0.1 bar, and 15 bar suctions to fiber content (> 0.1 mm) and bulk density

Independent variable (X)	Regression equation	R^2
	Saturation	
Fiber content	$\hat{Y} = 84.23 - .0279X + .00185X^2$	.68
Bulk density	$\hat{Y} = 99.00 - 123.45X + 252.92X^2$	.66
	5.0 mbar	
Fiber content	$\hat{Y} = 52.45 + 1.5619X - .01728X^2$	.69
Bulk density	$\hat{Y} = 39.67 + 638.29X - 2{,}010.89X^2$	.70
	0.1 Bar	
Fiber content	$\hat{Y} = 67.91 + .4136X - .01064X^2$	.80
Bulk density	$\hat{Y} = 2.06 + 719.35X - 1{,}809.68X^2$	.88
	15.0 Bar	
Fiber content	$\hat{Y} = 29.34 - .3420X + .00072X^2$	.73
Bulk density	$\hat{Y} = 1.57 + 115.28X - 107.77X^2$	.82

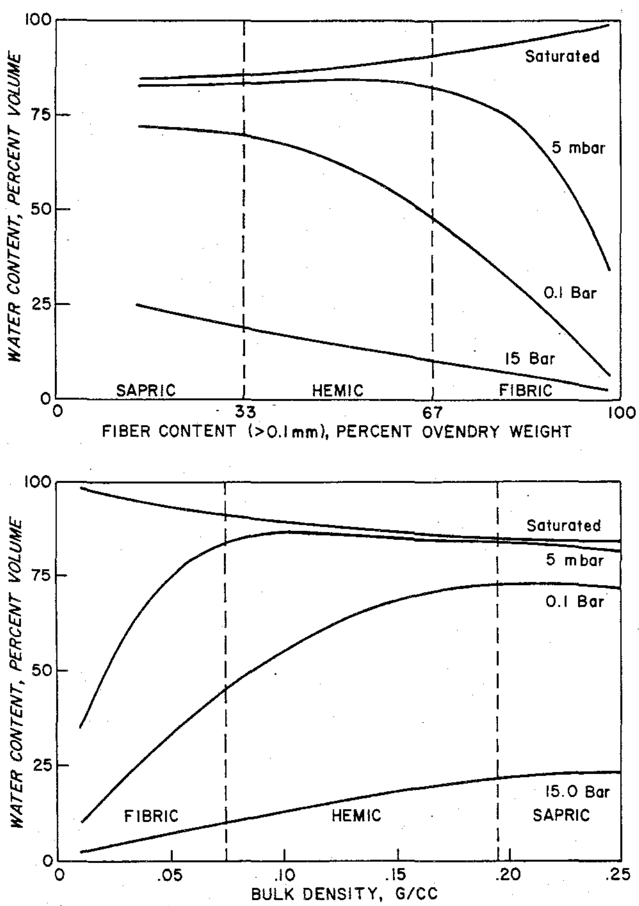

Fig. 3—The relation of water content at saturation, 5 mbar, 0.1 bar, and 15 bar suctions to fiber content (> 0.1 mm) and bulk density.

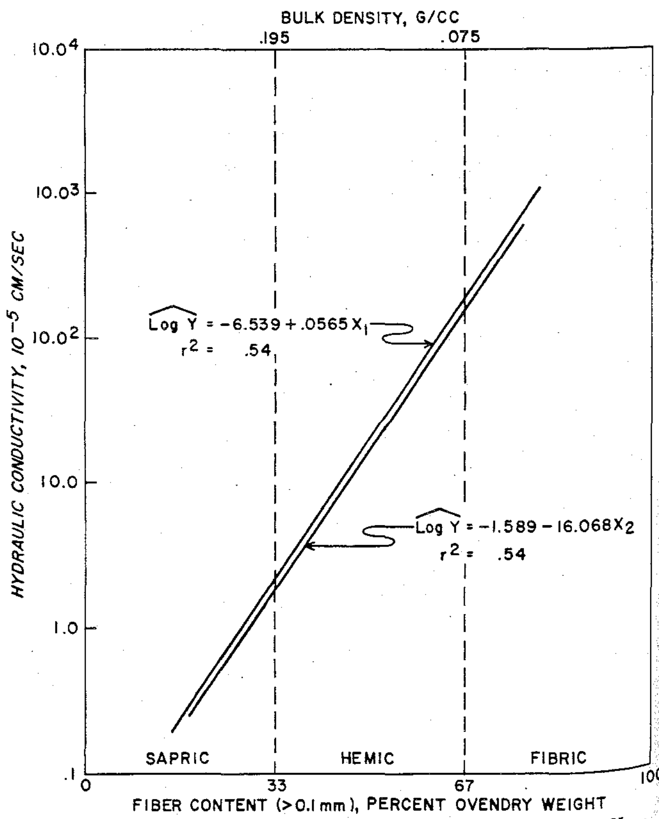

Fig. 4—The relation of hydraulic conductivity (Y) to fiber content (X_1) (> 0.1 mm) and bulk density (X_2).

density), water content by weight fails to show the actual content of water in the soil.

The water yield coefficient as defined earlier is represented by the area between the saturated and 0.1 bar curves (Fig 3). These values were also well related with fiber content ($R^2 = .84$) and bulk density ($R^2 = .89$), again indicating a high proportion of large pores in undecomposed peat.

HYDRAULIC CONDUCTIVITY AND DEGREE OF DECOMPOSITION

Previous studies have shown extremely large differences in the hydraulic conductivity of various peat types (3). The flow of water in undecomposed surface or near surface horizons was too rapid to measure with the techniques used. When it could be measured, it was found to be variable, particularly for the least decomposed peats. A linear regression analysis was used to relate the logarithm of hydraulic conductivity to fiber content (> 0.1 mm) and bulk density (Fig. 4). Because of the smaller number of values and their variability, r^2 values were not as high as with water-retention values. However, the differences are striking as the larger pores of the less decomposed peats permit much greater water movement than the many small pores of the decomposed peats.

Baden and Eggelsmann (1) showed similar relations of hydraulic conductivity to substance volume and the Von Post measure of decomposition.

The range in hydraulic conductivity, as well as the other physical properties discussed, was determined for fibric, hemic, and sapric peat materials (Table 3). The values were calculated using the regression equations presented earlier and the fiber contents defined for each of the peat types.

Table 3—Range of important physical characteristics of fibric, hemic, and sapric peat materials from northern Minnesota bogs

Organic material	Bulk density	Total porosity	0.1 bar H_2O content	Water yield coefficient	Hydraulic conductivity
	g/cc	%	%		10^{-5} cm/sec
Fibric	< .075	> 90	< 48	> .42	> 180
Hemic	.075-.195	85-90	48-70	.15-.42	2.1-180
Sapric	> .195	< 85	> 70	< .15	< 2.1

Values given show a big range for each of the properties except perhaps for total porosity. Numerical differences between the peat types are significant and are related to differences in decomposition. Thus any classification of these peats based on degree of decomposition as measured by fiber content and bulk density would be useful to soil scientists and resource managers by providing significant information about the physical and hydrologic characteristics of the organic soils.

LITERATURE CITED

1. Baden, W., and R. Eggelsmann. 1963. Zur Durchlässignkeit der Moorboden (English summary). Zeitschrift für Kulturtechnik und Flurbereiningung 4:226–254.
2. Boelter, D. H. 1964. Water storage characteristics of several peats *in situ*. Soil Sci. Soc. Amer. Proc. 28:433–435.
3. Boelter, D. H. 1965. Hydraulic conductivities of peats. Soil Sci. 100:227-231.
4. Farnham, R. S., and H. R. Finney. 1965. Classification and properties of organic soils. Advance. Agron. 17:115–162.
5. Kaila, Armi. 1956. Determination of the degree of humification of peat samples. J. Sci. Agr. Soc. Finland 28:18–35.
6. Kuntze, H. 1965. Physikalische Untersuchungsmethoden für Moor—und Anmoorboden (English summary). Landwirtschaftliche Forschung 18:178–191.

Evaporation from a Simulated Soil Shrinkage Crack[1]

JOHN E. ADAMS, JOE T. RITCHIE, EARL BURNETT, AND D. W. FRYREAR[2]

ABSTRACT

A simulated soil shrinkage crack, 46 cm wide and 62 cm deep, was constructed in such a manner that depth could be varied by 15.2-cm increments and width could be adjusted between 10 and 70 mm by 20-mm intervals. The walls of the crack were lined with porous ceramic plates connected to a water supply maintained at −5 mb potential. The simulated crack was installed in the floor of a laboratory wind tunnel located in a controlled environment room maintained at 24.0 ± 1.5C air temperature and 43 ± 3% relative humidity. Evaporation from the simulated crack walls (ceramic plates) was determined for all combinations of four crack widths (10, 30, 50, and 70 mm), three crack depths (30, 45, and 60 cm) and five windspeeds (0, 2.2, 4.5, 6.7, and 8.9 m sec^{-1}).

Total water loss (evaporation) from the walls of the simulated crack increased as any one or all of the three variables (windspeed, crack depth, or crack width) increased. These three variables accounted for 99.1% of the variability in total evaporation from the crack walls. Turbulent air movement within the simulated crack was the major factor affecting the evaporation.

Both straw and gravel mulches reduced evaporation from the crack walls 85 to 90% with no wind and about 60% at 8.9 m sec^{-1} windspeed. The results suggest that evaporation from soil shrinkage cracks may be reduced by closer plant or row spacing or by surface residues such as trash and clod mulches.

Total evaporation from a simulated crack 60 cm deep varied from 0.5 cm^3 hr^{-1} (10 mm wide, 0 m sec^{-1} windspeed) to 18 cm^3 hr^{-1} (70 mm wide, 8.9 m sec^{-1} windspeed). In simulated cracks 60 cm deep and 30–70 mm wide, 50–60% of the total evaporation occurred below 15 cm and 30–40% occurred below 30 cm.

Additional Key Words for Indexing: **evaporation control, soil-water evaporation.**

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[2] Research Soil Scientists, ARS, USDA, Temple, Texas 76501, and Research Agricultural Engineer, ARS, USDA, Big Spring, Texas 79720, respectively.