Minnesota Forestry Research Notes

No. 243
April 15, 1973

Bulk Density Estimation Based on Organic Matter Content of Some Minnesota Soils

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INTRODUCTION

Bulk density of soils is of interest to foresters and ecologists alike, both from an ecological and hydrological point of view. If soil bulk density is known, soil properties may be expressed on a volume basis. The measurement of soil bulk density is time consuming, as well as difficult in some soils, and is therefore avoided in many studies where it should perhaps be included. Thorud and Frissell (1969), Mace (1970, 1971), and Mace, Williams, and Tappeiner (1971) discuss bulk density measurements on mechanically compacted soils. The method discussed in this note was tested on, and would best be applied to, natural conditions.

METHODS

The determination of organic matter content by the method of dry combustion is a relatively easy procedure. An oven dry sample (approximately 5 grams) is fired in a muffle furnace at 600° C. for 3 hours. The percent weight loss of the sample is an expression of the organic matter content. Errors may result, however, from decomposition of inorganic compounds on firing (such as calcium carbonate), but this error is usually small for most soils.

The relationship between bulk density (BD) and organic matter (OM) content is approximately $1/BD = a + b(\%OM)$ and was tested using 80 samples collected by the author in the prairie-forest transition of southern and western Minnesota and 56 by Henry (1972) from the Itasca State Park region. The following families of soils were represented: Typic Eutroboralfs, fine-loamy, mixed; Aquic Eutroboralfs, very-fine, montmorillonitic; Mollic Eutroboralfs, fine-loamy, mixed; Glossoboric Hapludalfs, fine-loamy, mixed,

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mesic; Typic Udipsamments, mixed, frigid; Typic Haplaquolls, coarse-loamy, mixed, calcareous, frigid; Typic Haplaquolls, fine-loamy, mixed, frigid; Udic Argiborolls, fine-loamy, mixed; Udic Argiborolls, fine montmorillonitic; Aquic Argiborolls, fine montmorillonitic; Udic Haploborolls, sandy, mixed; Udic Haploborolls, fine-loamy, mixed; Typic Hapludolls, fine-loamy, mixed, mesic. The soils ranged in organic matter content from 0.17 to 13.5%, with the majority between 0.5 and 10.0%; bulk densities (by the core technique) ranged from 0.77 to 1.70 g/cc, with most between 1.00 and 1.68 g/cc.

RESULTS AND DISCUSSION

The plotting of BD on %OM indicated a somewhat curvilinear relationship; Andersson (1970) shows a similar BD : OM relationship. The data were analyzed using the least squares regression technique treating the variables as linear, and also using square, logarithmic, and reciprocal transformations. Of the 16 regression equations derived from all possible combinations of transformations (Table 1), the equation 1/BD = a + b(%OM) gave the best correlation (0.842). This equation would be expected to give the best fit as it is the regression of bulk density on organic matter based on the above model. The next best fit was log BD = a + b(%OM). Jeffrey (1970), however, found that using 80 soil samples of approximately 1 to 95% OM content, BD = a + b(log %OM) gave the best fit while the model 1/BD = a + b(%OM) gave a good fit with values in the 1 to 30% OM content range.

Table 1. Regression equations tested in this study.

Equation	a	b	correlation
BD = a + b(%OM)	1.5697	-0.0552	-0.827
BD = a + b(1/%OM)	1.2776	0.1361	0.588
BD = a + b(log %OM)	1.4964	-0.1730	-0.822
BD = a + $b(\%OM)^2$	1.4918	-0.0043	-0.749
1/BD = a + b(%OM)	0.6268	0.0361	0.842
1/BD = a + b(1/%OM)	0.8073	-0.0788	-0.534
1/BD = a + b(log %OM)	0.6776	0.1061	0.791
1/BD = a + $b(\%OM)^2$	0.6751	0.0029	0.796
log BD = a + b(%OM)	0.4568	-0.0442	-0.839
log BD = a + b(1/%OM)	0.2302	0.1023	0.565
log BD = a + b(log %OM)	0.3966	-0.1338	-0.812
log BD = a + $b(\%OM)^2$	0.3962	-0.0035	-0.776
BD^2 = a + b(%OM)	2.4479	-0.1431	-0.807
BD^2 = a + b(1/%OM)	1.6772	0.3693	0.605
BD^2 = a + b(log %OM)	2.2648	-0.4573	-0.824
BD^2 = a + $b(\%OM)^2$	2.2430	-0.0109	-0.717

CONCLUSIONS

It is concluded that bulk density may be predicted from organic matter content; the equation

$$1/BD = 0.6268 + 0.0361(\%OM)$$

gives the best relationship based on the soils sampled for this study. Table 2 gives values of BD based on this equation. The confidence intervals are not symmetric because the transformation is an inverse. It is suggested that if a large number of bulk densities are required, or if the %OM lies very far outside the range listed in the table, a regression of inverse bulk density on organic matter be run on a sample of the investigator's materials to provide confidence in the estimation.

Table 2. Bulk density estimated from % organic matter.

%OM	BD (g/cc)	Confidence Interval ($t_{.05}$)	
0.5	1.55	1.26	2.02
1.0	1.51	1.22	1.95
2.0	1.43	1.18	1.82
3.0	1.36	1.13	1.71
4.0	1.29	1.09	1.61
5.0	1.24	1.04	1.52
6.0	1.18	1.01	1.44
7.0	1.14	0.97	1.37
8.0	1.09	0.94	1.31
9.0	1.05	0.91	1.25
10.0	1.01	0.88	1.20
11.0	0.98	0.85	1.15
12.0	0.94	0.82	1.10

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Published as Sci. Jour. Ser. Paper No. 8333 of the Univ. of Minn. Agr. Expt. Sta.