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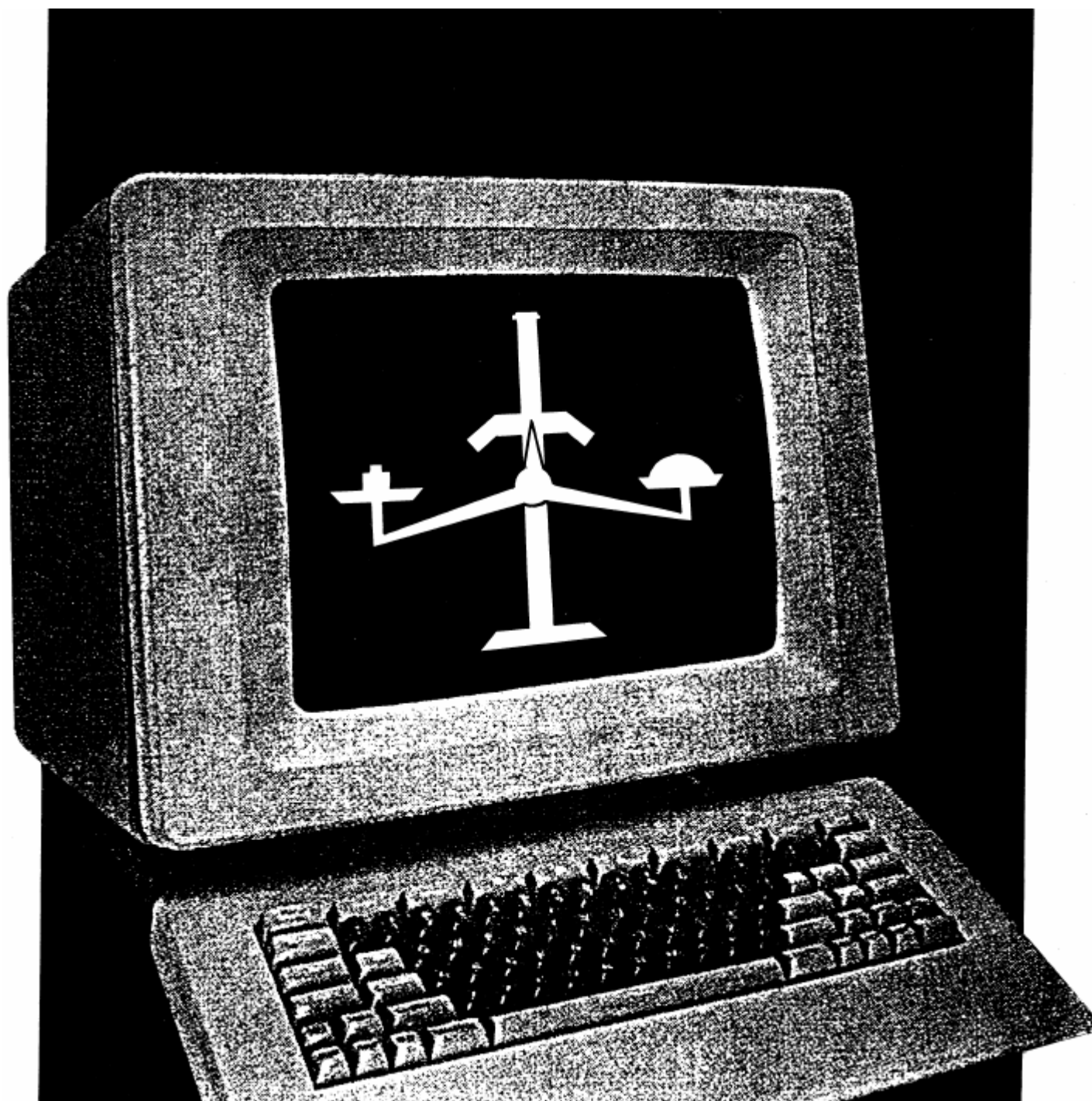
Pacific Northwest
Research Station

General Technical
Report
PNW-GTR-211



Soil Bulk Density and Soil Moisture Calculated With a FORTRAN 77 Program

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Abstract

Starr, G. Lynn; Geist, J. Michael. 1988. Soil bulk density and soil moisture calculated with a FORTRAN 77 program. Gen. Tech. Rep. PNW-GTR-211. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 6 p.

This paper presents an improved version of BDEN, an interactive computer program written in FORTRAN 77 that will calculate soil bulk density and moisture percentage by weight and volume. Calculations allow for deducting coarse fragment weight and volume. The program will also summarize the resulting data by giving the mean, standard deviation, and 95-percent confidence interval for one or more groupings of data.

Keywords: Soil bulk density, soil water, soil monitoring, computer programs, programming.

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Introduction

Soil bulk density is commonly the standard measurement for monitoring soil compaction resulting from land management activities. The monitoring process can generate large quantities of data to be computed and summarized. This program offers a simple way to save computing time and reduce errors.

An earlier version of this program written in BASIC attracted considerable attention among forest managers both in the United States and abroad (Starr and Geist 1983). Since the installation of a network of computers throughout the Forest Service, U.S. Department of Agriculture, there has been a need to rewrite the program in a language compatible with the new computers. The FORTRAN 77 version has also increased some program capability in response to user needs.

Program Capabilities

Our objective was to increase accuracy and speed calculation of individual soil bulk density values. Measurements for calculation may come from core samples of fixed or variable volumes. The calculations adjust for content of coarse fragments based on an assumed particle density of 2.65 megagrams per cubic meter (Mg/m^3), which is equivalent to grams per cubic centimeter (g/cm^3). Thus, core volume is reduced by the volume of coarse fragments, leaving only soil volume and weight for computation of soil bulk.

In addition to bulk density, if weights of moist soil samples are obtained, moisture percentages by both weight and volume can be calculated. Moisture values are expressed as percentages of dry soil volume and weight after adjustments for coarse fragments have been made. This computation is optional, so weights of moist samples are not required to calculate bulk density.

The program will also compute mean, standard deviation, and confidence interval for a user-selected group of observations. The 95-percent probability level was chosen for the confidence interval because it is the value most commonly reported. The program can be altered to allow selection of a different probability level, if the user desires, although this requires the assistance of a programmer.

File Preparation

Before the program can be used, data files, the program, and an auxiliary file named TTBLE must be loaded on disk storage. The executable program file for the Data General computer (DG)¹ can be obtained through software distribution by the Pacific Northwest Region, Forest Service.² The auxiliary file (TTBLE) may be obtained in the same way or can be keyed in using the SED editor exactly as shown in table 1. This file is a table of t-values and includes values for two-tailed probabilities of 0.2, 0.1, 0.05, 0.02, and 0.01.³ The program automatically selects the 0.05 value from this

¹ The use of trade names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture of any product to the exclusion of others that may be suitable.

² Pacific Northwest Region, Management Systems, P.O. Box 3623, Portland, OR 97208.

³ BDEN uses the 95-percent probability level (0.05 from the table). The additional values are used for other applications.

Table 1—TTBLE two-tailed t-table for probabilities from 0.2 to 0.01 and degrees of freedom from 1 to 99

	.2	.1	.05	.02	.01
1	3.078	6.314	12.706	31.821	63.657
2	1.886	2.920	4.303	6.965	9.925
3	1.638	2.353	3.182	4.541	5.841
4	1.533	2.132	2.776	3.747	4.604
5	1.476	2.015	2.571	3.365	4.032
6	1.440	1.943	2.447	3.143	3.707
7	1.415	1.895	2.365	2.998	3.499
8	1.397	1.860	2.306	2.896	3.355
9	1.383	1.833	2.262	2.821	3.250
10	1.372	1.812	2.223	2.764	3.169
11	1.363	1.796	2.201	2.718	3.106
12	1.356	1.782	2.179	2.681	3.055
13	1.350	1.771	2.160	2.650	3.012
14	1.345	1.761	2.145	2.624	2.977
15	1.341	1.753	2.131	2.602	2.947
16	1.337	1.746	2.120	2.583	2.921
17	1.333	1.740	2.110	2.567	2.898
18	1.330	1.734	2.101	2.552	2.878
19	1.328	1.729	2.093	2.539	2.861
20	1.325	1.725	2.086	2.528	2.845
21	1.323	1.721	2.080	2.518	2.831
22	1.321	1.717	2.074	2.508	2.819
23	1.319	1.714	2.069	2.500	2.807
24	1.318	1.711	2.064	2.492	2.797
25	1.316	1.708	2.060	2.485	2.787
26	1.315	1.706	2.056	2.479	2.779
27	1.314	1.703	2.052	2.473	2.771
28	1.313	1.701	2.048	2.467	2.763
29	1.311	1.699	2.045	2.462	2.756
30	1.310	1.697	2.042	2.457	2.750
99	1.282	1.645	1.960	2.326	2.576

table to be used in computing 95-percent confidence intervals in the summary step. To use another probability level, a programmer can easily alter the source code to accommodate the level desired.⁴

Data files must be entered by using the editor program in the computer. Site designation, date, and any other identifying information may be entered in the first few lines. Use any format and any number of lines; however, the last line of this information must have an asterisk in the first column. There must be two and only two lines for column headings before data begins. These headings are for the user's convenience only, because the program will skip two lines after the asterisk before reading data. The spelling and spacing of these headings is flexible; however, we suggest headings that will allow National Forests or Ranger Districts to standardize labels. Such standardization will avoid confusion when information is exchanged.

Directly after headings, sample data are entered in conformance with the formats shown by the following tabulation. An example of an actual data set is also provided in table 2. The sample number and class can be any combination of characters up to six characters each. The field class is provided to allow a way to group some of the samples of a data set in the summarization step. Total wet weight (wt) is the weight in grams of the container plus moist soil and coarse fragments (may be omitted if soil

⁴ The source code may be obtained from the authors if it is needed.

Table 2—Example of a correctly entered data set for program input.

Meadows Unit 25 11/80

*

Sample	Class	Total	Total	CF + Can	Can	Core
No.		Wet Wt	Dry Wt	Dry Wt	Wt	Vol
9-300	A	95.57	72.40	38.50	37.97	58.52
9-301	A	88.12	70.28	38.60	38.05	58.52
9-302	A	95.35	80.90	46.10	38.82	58.52
9-303	A	89.90	75.90	40.30	38.60	58.52
9-304	A	113.49	93.30	42.90	38.15	58.52
5-305	B	92.62	71.45	38.60	37.98	58.52
5-306	B	100.05	77.58	40.38	38.95	58.52
5-307	B	103.67	80.28	38.60	37.82	58.52
5-308	B	93.96	75.35	39.92	38.95	58.52
5-309	B	99.65	75.20	38.60	37.70	58.52
1-310	C	97.02	77.20	40.18	39.68	58.52
1-311	C	98.79	75.30	38.28	37.35	58.52
1-312	C	93.50	73.38	39.20	38.30	58.52
1-313	C	92.43	72.00	38.95	38.75	58.52
1-314	C	104.37	83.71	38.15	37.30	58.52
3-315	D	93.98	75.82	40.05	38.90	58.52
3-316	D	82.33	66.67	39.10	38.60	58.52
3-317	D	98.10	75.03	38.25	37.75	58.52
3-318	D	93.66	73.02	38.02	37.40	58.52
3-319	D	97.61	75.12	39.90	38.90	58.52

moisture is not of interest). Total dry wt is weight in grams of the container plus soil and coarse fragments after drying. DF + can wt is weight in grams of the container and coarse fragments after soil removal and drying. Can wt is the weight in grams of the empty container. Core volume is total volume in cubic centimeters of the soil core before any treatment. Character values (sample no. and class) may be justified on either the right or the left. Numeric values (all others) will be read correctly whether justified on the right or the left, as long as the decimal is included. Format for numeric variables allows for two decimal places, but one place should be sufficient. To facilitate summarizing by class, enter all members of a class consecutively. The program will not sort data. The tabulation below summarizes this information:

<u>Columns</u>	<u>Variable</u>	<u>Variable type</u>
1-6	Sample no.	Alphanumeric
8-13	Class	Alphanumeric
15-20	Total wet wt	Numeric
23-28	Total dry wt	Numeric
31-36	CF + can dry wt	Numeric
39-44	Can wt	Numeric
47-52	Core volume	Numeric

Program Execution

Once the data file(s), t-table, and program file are on disk, computations may proceed. Simply type X BDEN and respond to queries as they appear on the screen.

Your first response should be B to start calculation of bulk density and the percentage of water by volume and by weight for each sample in the file. These values are output as new columns added to the original data file (for example, see table 3). (Values for the percentage of water will be zero if no wet weights were entered.) If you wish to view or print the data file with computation results, you must first exit BDEN by pressing "return" ("new line" on DG) as prompted. Then view or print the file using your computer's print utility.

Once bulk density is calculated, you may compute the mean, standard deviation, and 95-percent confidence interval by entering an M. Output from this summarization step will be appended to the end of a disk file the user has named in response to screen inquiry. (You may exit BDEN by pressing "return" twice to view or print the output file, as mentioned above for the data file.)

The next query asks you to indicate how the data are to be handled in the summary step for the mean and confidence interval of soil parameters. Choose one of three ways to group samples for this step: 1. Where one class is involved, a mean can be computed on the entire file by responding ALL to the request and pressing "return" twice. An example of the result is shown in table 4. 2. With multiple classes, a response of EACH will compute a mean for each individual class in the file. (For this use, the members of a class must be consecutive in the data file.) Again, indicate the completion of your response by a second "return". 3. With multiple classes, certain classes may be grouped into one mean by entering the class codes to be selected. Follow each class code entry with "return". You may enter up to 20 class codes to be included in the mean. If you use less than 20 classes, you must indicate completion of your response by a second "return" after your last code entry. An example of this type of summary is shown in table 5.

If you want to compute a single mean on sample data contained in two or more files, you must first merge the files into one file via the editor (or SORT/MERGE) and then run BDEN.

By using the example data in table 2, you can quickly become familiar with the program function.

Table 3—Example of bulk density and water percentages resulting from program execution

Meadows Unit 25 11/80.									
*									
Sample No.	Class	Total Wet Wt	Total Dry Wt	CF + Can Dry Wt	Can Wt	Core Vol	Soil Vol	BD	%Water Vol Wt
9-300	A	95.57	72.40	38.50	37.97	58.52	58.32	0.581	39 68
9-301	A	88.12	70.28	38.60	38.05	58.52	58.31	0.543	30 56
9-302	A	95.35	80.90	46.10	38.82	58.52	55.77	0.624	25 41
9-303	A	89.90	75.90	40.30	38.60	58.52	57.88	0.615	24 39
9-304	A	113.49	93.30	42.90	38.15	58.52	56.73	0.888	35 40
5-305	B	92.62	71.46	38.60	37.98	58.52	58.29	0.564	36 64
5-306	B	100.05	77.58	40.38	38.95	58.52	57.98	0.642	38 60
5-307	B	103.67	80.28	38.60	37.82	58.52	58.23	0.716	40 56
5-308	B	93.96	75.35	39.92	38.95	58.52	58.15	0.609	32 52
5-309	B	99.65	75.20	38.60	37.70	58.52	58.18	0.629	42 66
1-310	C	97.02	77.20	40.18	39.68	58.52	58.33	0.635	33 53
1-311	C	98.79	75.30	38.28	37.35	58.52	58.17	0.636	40 63
1-312	C	93.90	73.38	39.20	38.30	58.52	58.18	0.587	34 58
1-313	C	92.43	72.00	38.95	38.75	58.52	58.44	0.565	34 61
1-314	C	104.37	83.71	38.15	37.30	58.52	58.20	0.783	35 45
3-315	D	93.98	75.82	40.05	38.90	58.52	58.09	0.616	31 50
3-316	D	82.33	66.67	39.10	38.60	58.52	58.33	0.473	26 56
3-317	D	98.10	75.03	38.25	37.75	58.52	58.33	0.631	39 62
3-318	D	93.66	73.02	38.02	37.40	58.52	58.29	0.600	35 58
3-319	D	97.61	75.12	39.90	38.90	58.52	58.14	0.606	38 63

Table 4—Example of data summary for entire file output by choice of ALL, for samples to be included in the means, standard deviations, and confidence intervals of soil parameters

Meadows Unit 25 11/80.				
*				
ALL				
	MEAN	N	STD.DEV.	95% CI
% WATER (VOL.)	34.9	20	5.1	2.4
% WATER (WT.)	56.1	20	8.8	4.1
BULK DENSITY	.627	20	.087	.041

Table 5—Example of data summary where classes A and D were selected for calculation of the combined means, standard deviations and confidence intervals of the soil parameters

Meadows Unit 25 11/80.					
*					
A	D				
		MEAN	N	STD.DEV.	95% CI
% WATER (VOL.)		32.9	10	6.0	4.3
% WATER (WT.)		53.9	10	10.5	7.5
BULK DENSITY		.618	10	.106	.076

Literature Cited

Starr, G. Lynn; Geist, J. Michael. 1983. BDEN: a timesaving computer program for calculating soil bulk density and water content. Gen. Tech. Rep. PNW-153. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 12 p.

Appendix

Formulas used:

$$\begin{aligned}\text{cm}^3 \text{ soil} &= \text{core vol} - \frac{\text{wt of coarse fragments}}{2.65} \\ &= \text{core vol} - \frac{(\text{cf} + \text{can wt}) - \text{can wt}}{2.65}\end{aligned}$$

$$\text{g dry soil} = \text{total dry wt} - (\text{cf} + \text{can wt})$$

$$\begin{aligned}\% \text{ water content} &= \frac{(\text{total wet wt} - \text{total dry wt})}{\text{cm}^3 \text{ soil}} \times 100 \\ \text{by volume}\end{aligned}$$

$$\begin{aligned}\% \text{ water content} &= \frac{(\text{total wet wt} - \text{total dry wt})}{\text{g dry soil}} \times 100 \\ \text{by volume}\end{aligned}$$

$$\text{Bulk density (Mg/m}^3 = \text{g/cm}^3) = \frac{\text{g dry soil}}{\text{cm}^3 \text{ soil}}$$

$$\begin{aligned}\text{Standard} &= \sqrt{\frac{\sum X^2 - \frac{(\sum X)^2}{n}}{n - 1}} \\ \text{deviation}\end{aligned} \quad \text{where } X = \%H_2O(v) \text{ or } \%H_2O(w) \text{ or BD}$$

$$\begin{aligned}\text{Confidence}^5 &= \bar{X} \pm \frac{t_{0.975} s}{n} \\ \text{interval}\end{aligned}$$

⁵ BDEN uses $t_{0.975}$ which is the proper value for t in a two-tailed 95 percent confidence interval.

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March 1988

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