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Processing Data From Soil Assessment Surveys With the Computer Program SOILS

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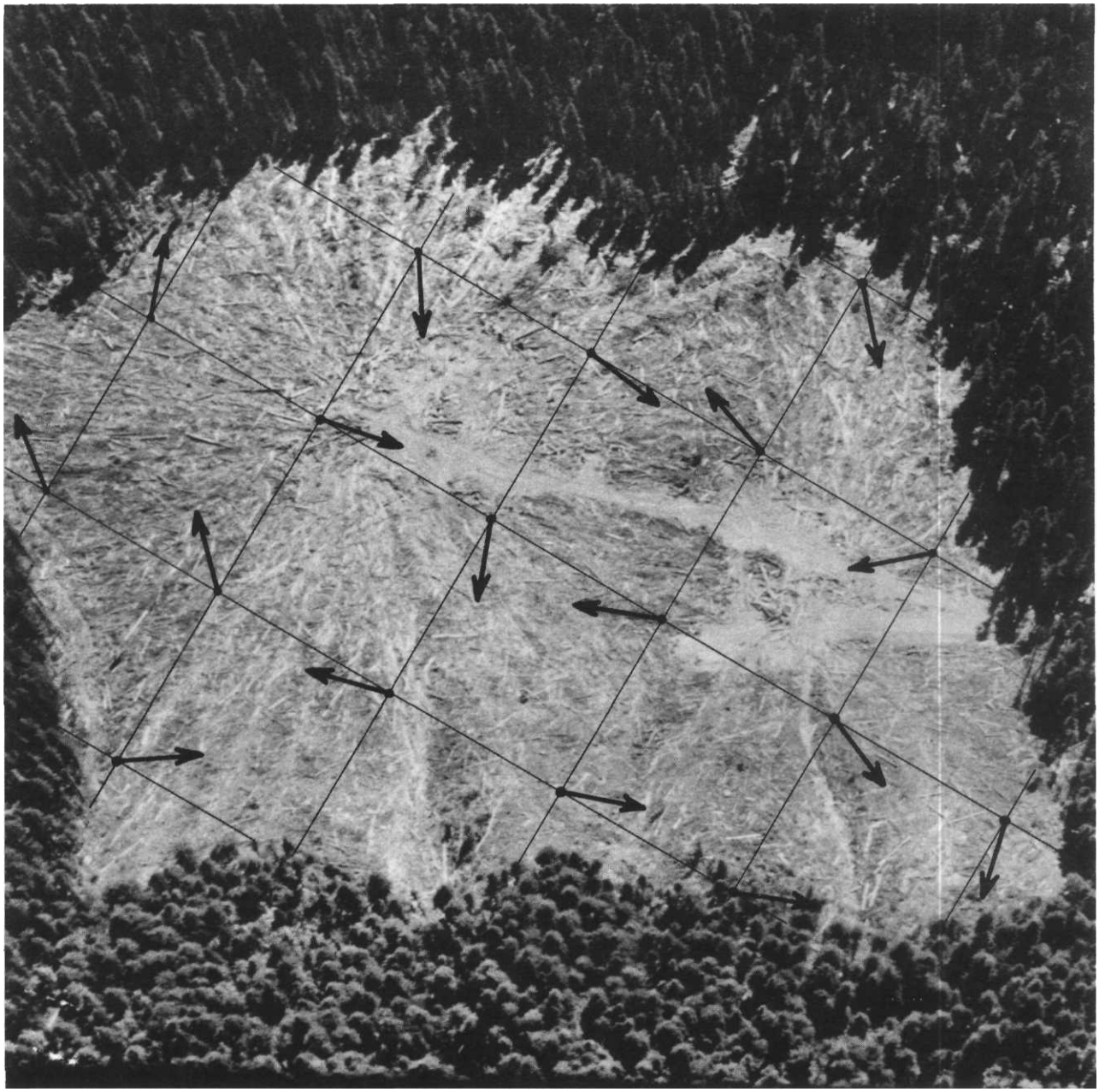

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Abstract

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Program SOILS processes data from soil assessment surveys following a design adopted by the Pacific Northwest Region of the USDA Forest Service. It accepts measurements from line transects and associated soil subsamples and generates estimates of the percentages of the sampled area falling in each soil condition class. Total disturbance is calculated by combining certain detrimental soil condition classes. Variances and confidence intervals of the percentage of each class are computed. Summary or preliminary estimates may be inserted into the program for computing sample sizes to help in planning future surveys.

A summary of the soil survey design for the Pacific Northwest Region, the estimation procedures, and the sample size calculation procedures are also provided.

Keywords: Soil surveys, computer programs/programming, sampling designs.

Contents

Introduction

Soil assessment surveys are designed to estimate soil conditions at specified points in time, such as before and after management activities. The reason might be to determine if soil productivity has been impacted by management activities.

The Resources Planning Act of 1974 and the National Forest Management Act of 1976 require National Forest managers to monitor and evaluate resources (including soils) affected by management activities and to attempt to predict the consequences of management decisions in relation to planning alternatives.

The Pacific Northwest Region (Region 6) of the National Forest System has issued a directive which addresses policies and standards for maintaining land productivity under multiple use and sustained yield principles. The directive addresses the monitoring of mass wasting, soil displacement, deposition, puddling, compaction, and erosion.

Region 6 soil assessment surveys are required to generate estimates of total damage and soil condition classes—undisturbed, displaced, deposited, puddled, compacted, eroded, and "other" soil condition classes—with indices of the reliability of these estimates. In addition, statistical tests are desired to determine if the realized level of detrimental influence from management activities for each survey situation exceeds standards for the Region.

The objective of this paper is to provide instructions for and an example of processing data from surveys conducted according to the soil assessment survey design used by Region 6,[1/] with a computer program called SOILS. In addition, a brief description of the design, the estimation procedures, and the sample size calculations are provided.

The program SOILS was written to process soil assessment surveys of Region 6. It accepts measurements from transects and associated subsamples and generates estimates of the percentages of the area sampled (activity unit) in each of the condition classes. Total disturbance is calculated by combining the detrimental condition classes (displaced, puddled, eroded, and compacted). Variances and confidence intervals for the percentages of disturbance in each class are computed. In addition, preliminary or summary estimates can be inserted into the computations to provide sample size approximations to help in planning future surveys.

[1/] Detailed instructions appear in Howes, S. W.; Hazard, J. W.; Geist, J. M. Guidelines for sampling some physical conditions of surface soils. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, Range and Watershed Management; 1983.

The Pacific Northwest Region Design

The soil assessment survey design for Region 6 is a systematic sample located on a square grid. Surface soil characteristics are measured continuously along each transect radiating from the grid intersections. Subsurface characteristics such as compaction are measured at fixed points along the transects. The transects are randomly oriented around the respective grid points. They can vary in length and there can be one or more per grid point.[2/]

The point subsamples along the transects are located at equal intervals, but the number of subsamples can vary; 10 and 20 points have been most frequently used with 100-foot transects? The program SOILS is currently restricted to a maximum of 20 points per transect.

There are two types of observed values for each transect: the length of each line falling in the respective surface soil condition classes (data type 1 records) and the soil compaction reading of each point subsample (data type 2 records).

The individual soil compaction reading is compared with the standard for compaction (which is set independent of the sample) and is classified into compacted or uncompacted categories within each of the surface soil conditions for each transect. The length of each line transect in the surface soil conditions is combined with the summary of the compaction data to form the adjusted percentages for each transect. as follows:

Data from type 1 and 2 records of each transect are summarized into a 2×7 matrix. The row entries of the matrix represent the compacted and uncompacted classes, and column entries represent the seven surface soil condition classes. The entries are formed by proportioning the percentages of line length in each soil condition class into compacted and uncompacted categories, based on the percentage of the point subsamples in each condition class that were compacted or uncompacted. The number of point subsamples involved in each class is also represented in this matrix.

The estimates for the activity unit totals are formed by combining the adjusted transect percentages as outlined in appendix A. The procedures for sample size calculations appear in appendix B.

Program SOILS

This section presents the details and explanations for data setup, selection of soil assessment statistical analyses, and results. An example is provided to illustrate these details.

The computer program is written in FORTRAN V and meets the current ANSI standards (FSH 6609.33). It is assumed that users have a basic knowledge of FORTRAN format codes, and of accessing the Fort Collins Computer Center UNIVAC where the program is on file. For information contact Jeralyn Snellgrove, Forestry Sciences Laboratory, P.O. Box 3890, Portland, OR 97208 (503-231-2098).

[2/] The existing version of SOILS handles only one transect per grid point. Certain spatial distributions of soil conditions may warrant more than one transect.

[3/] 1 foot = 0.3048 meter. Bulk density readings appear as they are commonly measured in grams per cubic centimeter. All other units are in English.

Input Control Records

Computer program SOILS may require up to three types of control records each time an activity area is processed. Control type 1 is the title record and control type 2 is the options record. Both are required. Control type 3 is required only when compaction readings are taken outside the designated activity area to compute the Region 6 standard.

The following are detailed formats and descriptions of the input control records. Each control record format identifies the "variable name" used in the program to reference that particular piece of information, the number and location of "columns" reserved for the respective information, the FORTRAN "format" in one of three types (A = alphanumeric, FX.X = floating point numeric, and IX = integer numeric characters), and a description of the "information" being recorded. These specifications must be followed rigorously.

Control type 1 — title record.—Every activity unit being processed requires a title record. It can be used for providing additional introductory information or instructions for interpreting the results that will follow.

Variable name	Columns	Format	Information
LABEL	1-80	A	Description of activity unit being analyzed.

Control type 2 — options record.—The options record provides the specifications of the analysis problem for the activity unit being processed. It includes the following specifications: To print all data entries in labeled fields; the type of compaction measurements to be processed (air permeameter and/or bulk density, or no compaction measurements); the method of computing the standard for compaction (either calculated from an outside area or given by the soils resource scientist responsible for that analysis); the option to compute confidence intervals for estimates of all condition classes; and the option to compute sample sizes.

When the options to compute confidence intervals and sample sizes are chosen, the desired probability levels (two-tailed) are required to be specified in the options record. The margins of error and the condition class of interest must also be specified when sample sizes are calculated. A second iteration of the sample size calculation is optional.

Variable name[4]	Columns	Format	Information
NRDGS	1	I1	Determines type of data to be analyzed. Blank or zero = process both air permeameter and bulk density readings. Use only when all transects contain both types of readings. Otherwise, process each type independently in separate runs. 1 = process air permeameter only. 2 = process bulk density only. 3 = compaction measurements omitted (that is, surface measurements only).[5]
	2	1X	Blank.
LIST	3	I1	Option to print data. Blank = don't list. 1 = list.
	4	1X	Blank.

[4] All variables on the control records and the data records are to be justified on the right.

[5] Option 3 was included to allow summarization of surface measurements only. This option is recommended when surface measurements are made without classification error and soil core measurements are not necessary.

Variable name	Columns	Format	Information
NCMPBD	5-6	I2	Standard for bulk density given or to be computed. Blank or zero = standard for bulk density given in columns 8-11. n = number of control type 3 records (used for computing standard for bulk density).
	7	1X	Blank.
STDBD	8-11	F4.3	Standard for bulk density (if given, columns 13-25 will be blank).
	12	1X	Blank.
NREPS	13	I1	Specifies the number of times the activity unit is to be analyzed using different standards for compaction'. If specified, columns 8-11 must be blank. Maximum of three possible standards. Blank or 1 = unit will be processed one time. Columns 15-17 must contain the percentage increase in bulk density. 2 = unit will be processed two times. Columns 15-17 and 19-21 must contain percentages. 3 = unit will be processed three times. Columns 15-17, 19-21, and 23-25 must contain percentages.
	14	1X	Blank.

Variable name	Columns	Format	Information
STDPCT(1)	15-17	F3.2	Relative (percentage) increase in bulk density. Used to compute the absolute standard for compaction in the initial analysis (that is, 15, 20, 30).
	18	1X	Blank.
STDPCT(2)	19-21	F3.2	Percentage increase in bulk density. Used to compute the absolute standard for compaction in the second analysis (optional).
	22	1X	Blank.
STDPCT(3)	23-25	F3.2	Percentage increase in bulk density. Used to compute the absolute standard for compaction in the third analysis (optional).
	26	1X	Blank.
NOPT3	27	I1	Option for calculating confidence intervals. Blank or zero = no confidence intervals desired. (Columns 28-30 will also be blank.) 1 = compute confidence intervals. (Columns 28-30 must be filled.)
PRBLVL(4)	28-30	F3.2	Probability level (two-tailed) used in confidence interval calculation (must be 80, 90, or 95).
	31	1X	Blank.

Variable name	Columns	Format	Information
NOPT2	32	I1	Option for computing sample size table(s). (Refer to appendix B for further explanations.) Blank or zero = no computation desired. (Columns 34-63 will also be blank.) 1 = alternative 1 (relative margin of error). (Columns 35-37 and columns 44-46 must also be filled. Columns 38-43 and 47-52 are optional for this alternative.) 2 = alternative 2 (absolute margin of error). (Columns 35-37 and columns 53-55 must also be filled. Columns 38-43 and 56-61 are optional for this alternative.) 3 = alternative 3 (relative and absolute margins of error). Columns 35-37, 44-46, and 53-55 must also be filled. Columns 38-43, 47-52, 56-61 are optional for this alternative.)
	33	1X	Blank.
ICLASS	34	I1	Class of interest used in sample size calculation (additional classes of interest require separate runs): 1 = visual compaction; 2 = displaced; 3 = deposition; 4 = puddled; 5 = eroded; 6 = undisturbed; 7 = other; 8 = total disturbance.

Variable name	Columns	Format	Information
PRBLVL(1)	35-37	F3.2	First probability level used in sample size calculation for either alternative 1 or 2, appendix B (three or fewer probability levels can be specified, levels must be 80, 90, or 95).
PRBLVL(2)	38-40	F3.2	Second probability level (80, 90, or 95) used in sample size calculations (optional).
PRBLVL(3)	41-43	F3.2	Third probability level (80, 90, or 95) used in sample size calculation (optional).
E1	44-46	F3.2	First margin of error value used in alternative 1 of sample size calculation, appendix B (three or fewer margin of error values can be specified).
E2	47-49	F3.2	Second margin of error value used in alternative 1 of sample size calculation. (Optional).
E3	50-52	F3.2	Third margin of error value used in alternative 1 of sample size calculation (optional).
E4	53-55	F3.2	First margin of error value used in alternative 2 of sample size calculation, appendix B (three or fewer margin of error values can be specified).
E5	56-58	F3.2	Second margin of error value used in alternative 2 of sample size calculation (optional).
E6	59-61	F3.2	Third margin of error value used in alternative 2 of sample size calculation (optional).
	62	1X	Blank.
ITERS	63	I1	Option to print first or second iteration of sample size calculation. 1 = print first iteration only (d.f. = ∞). 2 = print second iteration only (d.f. = n−1 where n is calculated in first iteration).

Control type 3 — outside area record (optional). — Control type 3 records are used to input compaction measurements taken outside the activity unit. These readings are taken on a representative sample of the undisturbed soil condition surrounding the activity unit. The mean reading is calculated and multiplied by the desired percent increase in bulk density, specified in STDPCT(1), STDPCT(2), or STDPCT(3) of control type 2 record, to produce the standard for compaction. This procedure is designed to be used only for bulk density measurements of compaction.

Variable name	Columns	Format	Information
BD	1-80	20F4.3	Contains bulk density readings from outside the area. Used when computing the standard for bulk density. Each record can contain up to 20 readings. Readings are recorded continuously on records. The number of records used is the value of NCMPBD (columns 5-6) on control type 2.

Data Records

Data records follow the control records. Data records are organized by transect number and by condition class within transects. The program SOILS currently processes a maximum of 40 transects per activity area. There are two types of data records. Type 1 records contain the line length surface measurements in each condition class by transect. Type 2 records contain the compaction measurements at subsample points along the transect. A maximum of 12 air permeameter readings can be recorded (one or two at a point) per record, and six bulk density measurements (one at a point) per record. Additional measurements appear in subsequent data records.

Data type 1 — surface measurements.—

Variable name	Columns	Format	Information
NCT	1	I1	First record of a transect, enter value of 1.
NTR	2-3	I2	Transect number.
	4-5	2x	Blank.
A(1)	6-8	F3.0	Length of line that falls in visual compaction condition class (to nearest foot).
A(2)	9-11	F3.0	Length of line that falls in displaced condition class (to nearest foot).
	12-15	4x	Blank.
A(3)	16-18	F3.0	Length of line that falls in deposition condition class (to nearest foot).
A(4)	19-21	F3.0	Length of line that falls in puddled condition class (to nearest foot).
	22-25	4x	Blank.
A(5)	26-28	F3.0	Length of line that falls in eroded condition class (to nearest foot).
A(6)	29-31	F3.0	Length of line that falls in undisturbed condition class (to nearest foot).
	32-35	4x	Blank.
A(7)	36-38	F3.0	Length of line that falls in other condition class (to nearest foot).
A(8)	39-41	F3.0	Total length of transect line (to nearest foot).

Data type 2 — compaction measurements.—

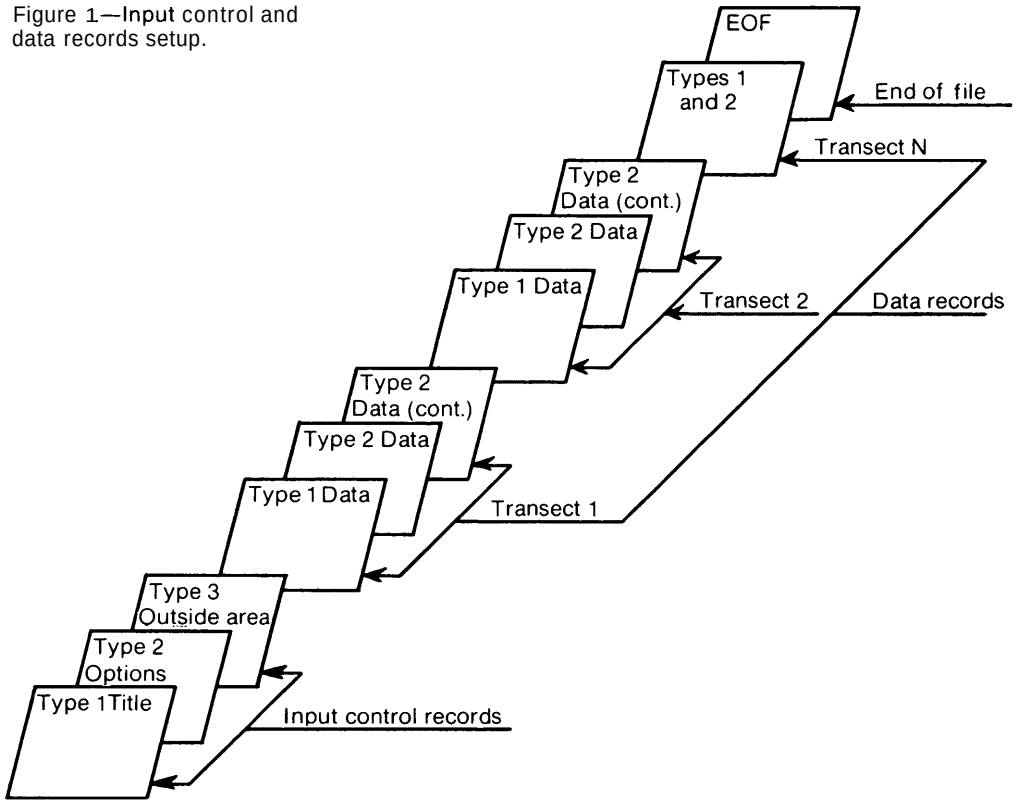
Variable name	Columns	Format	information
NCT	1	I1	Second data record of a transect, enter value of 2.
NTR	2-3	I2	Transect number.
NCC	4	I1	Condition class: 1 = visual compaction; 2 = displaced; 3 = deposition; 4 = puddled; 5 = eroded; 6 = undisturbed; 7 = other.
NCONT	5	I1	Condition class record number. Data are grouped by condition class within transects. If more than the maximum number of readings for a record occur for a condition class, more than one record will be necessary. Additional records must be numbered sequentially. Enter value of 1, 2, 3, or 4 to indicate the record number of a specified condition class. For example, a condition class containing seven bulk density readings would require two records to obtain the seven readings; thus, the value of NCONT (the first record) for the first six readings would be 1, and NCONT would be 2 on the second record, which would contain the seventh reading.
A(1)	6-8	F3.1	Air permeameter reading. Other instrument readings of compaction can be recorded in the place of permeameter readings; however, different standards would have to be introduced into the program.
A(2)	9-11	F3.1	Second air permeameter reading taken at same point location. If only one air permeameter reading is taken at each point, leave second air permeameter reading field blank.

Variable name	Columns	Format	Information
B(1)	12-15	F4.3	Bulk density reading.
A(3)	16-18	F3.1	Air permeameter reading.
A(4)	19-21	F3.1	Second air permeameter reading.
B(2)	22-25	F4.3	Bulk density reading.
A(5)	26-28	F3.1	Air permeameter reading.
A(6)	29-31	F3.1	Second air permeameter reading.
B(3)	32-35	F4.3	Bulk density reading.
A(7)	36-38	F3.1	Air permeameter reading.
A(8)	39-41	F3.1	Second air permeameter reading.
B(4)	42-45	F4.3	Bulk density reading.
A(9)	46-48	F3.1	Air permeameter reading.
A(10)	49-51	F3.1	Second air permeameter reading.
B(5)	52-55	F4.3	Bulk density reading.
A(11)	56-58	F3.1	Air permeameter reading.
A(12)	59-61	F3.1	Second air permeameter reading.
B(6)	62-65	F4.3	Bulk density reading.

Record Order

Figure 1 illustrates the setup for a typical analysis. As shown, the input control records come first. They consist of a title record; an options record; and, if necessary, an outside area record(s). Immediately following the input control records are the data records. They are grouped by transects and contain type 1 and type 2 records. A type 1 data record is always the first record of a transect; the remaining records of that transect are type 2. If only surface measurements are being analyzed, the data records are all type 1.

Figure 1—Input control and data records setup.



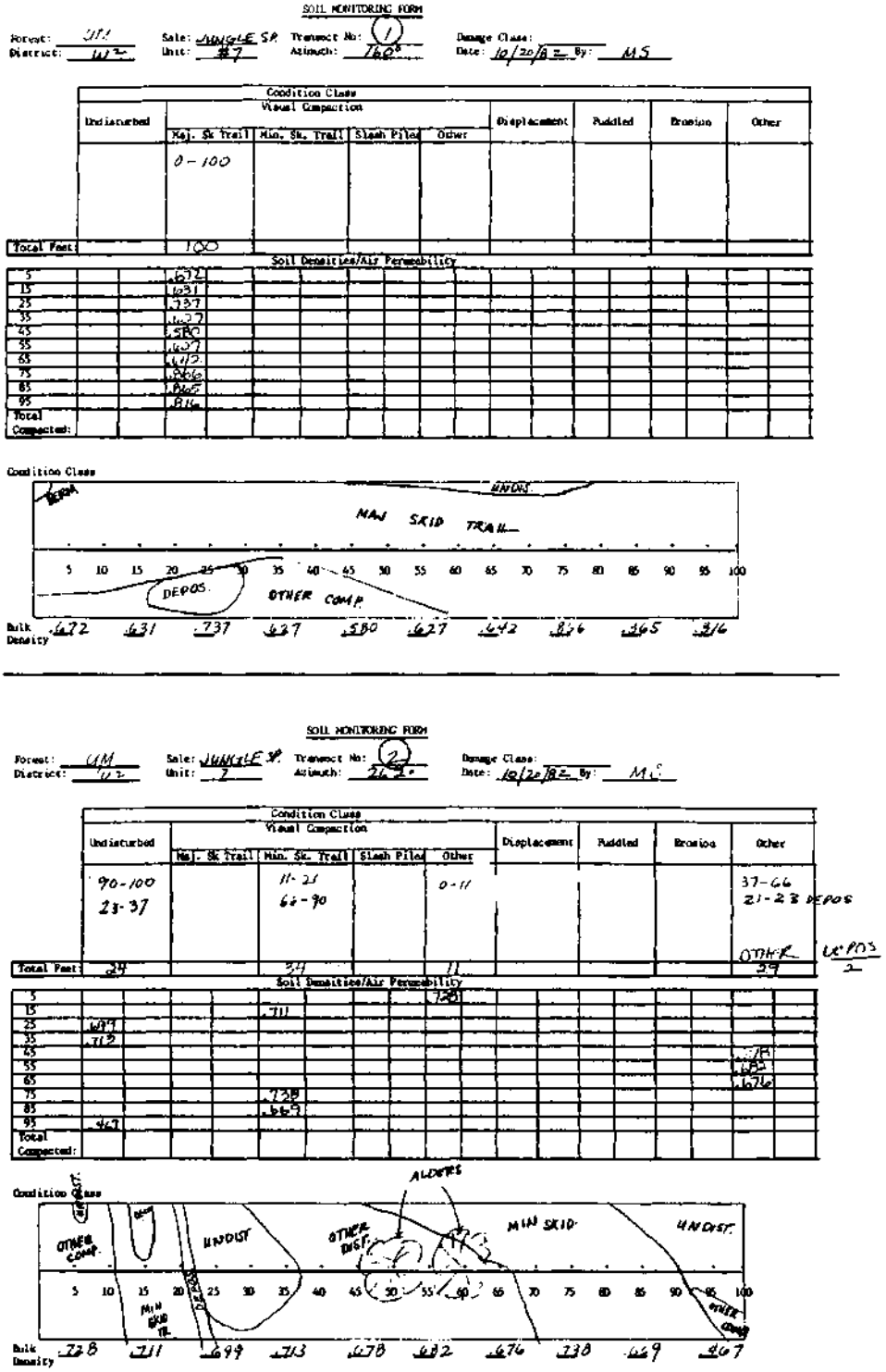
FCCC set-up to execute a run:

@RUN
@ASG,A SLS6*SOILS.
@XQT SLS6*SOILS.PRG-M
@ADD SLS6*SOILS.DATA-M
@FIN

Input Record Forms

Figure 2 represents the field sheets for transect 1 and transect 2 of the activity unit used in the following example. On this particular form the visual compaction condition class is broken down into four groups (major skid trail, minimum skid trail, slash piles, and other). For data entry purposes these four groups should be combined and the line lengths added together to get only one length for the visual compaction class; that is, in transect 2, the line length for visual compaction would be 45 feet. Also note that this form does not include a separate column for deposition. As shown in transect 2, measurements falling into the deposition condition class were recorded under "other." During the data entry process, however, care must be taken to ensure that these measurements are recorded under the correct condition class.

Figure 2.—Field forms with bulk density compaction readings for transect 1 (top) and transect 2 (bottom).



SOIL MONITORING FORM

Forest: UM Sale: JUNGLE SP. Transect No: 1 Damage Class:
District: 112 Unit: #7 Azimuth: 160° Date: 10/20/82 By: MS

Condition Class

Undisturbed	Visual Compaction: Maj. Sk Trail	Visual Compaction: Min. Sk. Trail	Visual Compaction: Slash Piles	Visual Compaction: Other	Displacement	Puddled	Erosion	Other
	0-100							
Total Feet:	100							

Soil Densities/Air Permeability

5			.672																	
15			.631																	
25			.737																	
35			.627																	
45			.580																	
55			.627																	
65			.642																	
75			.816																	
85			.365																	
95			.316																	
Total Compacted:																				

Condition Class

Bulk Density: .672 .631 .737 .627 .580 .627 .642 .816 .365 .316

SOIL MONITORING FORM

Forest: UM Sale: JUNGLE SP. Transect No: 2 Damage Class:
District: 112 Unit: 7 Azimuth: 215° Date: 10/22/82 By: MS

Condition Class

Undisturbed	Visual Compaction: Maj. Sk Trail	Visual Compaction: Min. Sk. Trail	Visual Compaction: Slash Piles	Visual Compaction: Other	Displacement	Puddled	Erosion	Other
90-100 23-37		11-21 66-90		0-11				37-66 21-23 DEPOS OTHER DEPOS 2
Total Feet: 24		34		11				39

Soil Densities/Air Permeability

5												.728								
15							.711													
25	.699																			
35	.713																			
45																		.678		
55																		.682		
65																		.676		
75							.738													
85							.669													
95	.467																			
Total Compacted:																				

Condition Class

Bulk Density: .728 .711 .699 .713 .678 .682 .676 .738 .669 .467

Example

Figure 3 is the complete file which was read into program SOILS for the example, Umatilla National Forest, Jungle Springs unit. This particular activity unit contained bulk density compaction readings only. The "options record" specified the following: Only bulk density compaction readings will be processed (column 1 = 2); no listing of the data is desired (column 3 = blank); the standard for bulk density will be computed (columns 8-11 = blank) with data taken from an "outside area" which is recorded on two records (column 6 = 2); the area will be analyzed once (column 13 = 1 and columns 19-25 = blank); a 15-percent increase in bulk density is used for computing the standard for compaction (columns 15-17 = 15); confidence intervals will be computed (column 27 = 1) with a 90-percent probability level (columns 29-30 = 90); both absolute and relative sample size calculations are desired (column 32 = 3) with total disturbance being the condition class of interest (column 34 = 8); three probability levels (80, 90, and 95 percent), which will be used for all sample size calculations, are desired (columns 35-43 = 80, 90, 95); two margin of error values (20 and 10 percent) will be used in calculating the first (relative) sample size table (columns 44-49 = 20 and 10); the same two values will be used in the second (absolute) sample size calculations (columns 53-58 = 20 and 10); and the second iteration for the sample size calculations is to be printed (column 63 = 2).

There are two "outside area records" with 30 bulk density readings on the undisturbed condition. These readings begin with 0.545 g/cm^3 and end with 0.505 g/cm^3.

Transect 1 has three data records, one type 1 and two type 2 records. The type 1 data record for transect 1 contains 100 feet of visual compaction (on the field form (fig. 2) this condition is shown as a major skid trail); 100 also occurs in columns 39-41 indicating the total line length. There were 10 bulk density readings recorded on the two type 2 data records, beginning with 0.672 g/cm^3 and ending with 0.816 g/cm^3. The data records for the remaining 14 transects follow in order.

```
TITLE RECORD          UMATILLA FOREST, JUNGLE SPRINGS UNIT
OPTIONS RECORD        2    2      1  15          1 90 3 8 80 90 95 20 10    20 10    2
OUTSIDE AREA RECORD    545 575 768 539 571 740 642 669 583 597 636 635 577 697 763 579 704 643 692 666
OUTSIDE AREA RECORD    676 665 641 656 643 594 620 618 565 505
TYPE 1 DATA RECORD    1 1  100                                  100
TYPE 2 DATA RECORD    2 111      672       631       737       627       580       627
TYPE 2 DATA RECORD    2 112      642       866       865       816
TYPE 1 DATA RECORD    1 2  45        2          24     29100
TYPE 2 DATA RECORD    2 211      728       711       738       669
TYPE 2 DATA RECORD    2 261      699       713       467
TYPE 2 DATA RECORD    2 271      678       682       676
                      1 3  56                        44       100
                      2 311      681       702       687       573       671       654
                      2 361      603       687       532       536
      etc.            1 4  45       10          10     35100
                      2 411     1003       739       716       779
                      2 431      690
                      2 461      603
                      2 471      805       843       511       670
                      1 5  40                        26     34100
                      2 511      780       755       735       760
                      2 561      638       605       730
                      2 571      706       671       654
                      1 6  69       25                   6100
                      2 611      849       697       772       948       893       820
                      2 612      731
                      2 631      752       814
                      2 671      710
                      1 7  68       14                  18100
                      2 711      699       649       610       734       793       747
                      2 712      841
                      2 731      688
                      2 771      603       688
                      1 8  96        4                     100
                      2 811      848       730       862       683       696       665
                      2 812      695       737       676
                      2 831      626
                      1 9  87       13                     100
                      2 911      654       630       707       717       672       689
                      2 912      710       739
                      2 931      587       546
                      110  37       23                  40100
                      21011      799       627       674       624
                      21031      734       712
                      21071      678       674       524       587
                      111  73                        12     15100
                      21111      710       709       668       523       663       643
                      21112      747       692       705
                      21171      677
                      112  89       11                     100
                      21211      737       563       704       806       745       706
                      21212      725       789       976
                      21231      620
                      113  56       19                  25100
                      21311      823       681       642       748       779       678
                      21331      656       548
                      21371      742       558
                      114  94        6                     100
                      21411      691       673       767       627       683       750
                      21412      775       646       642
                      21431      617
                      115  79                             21100
                      21511      633       702       666       789       782       739
                      21512      618       679
                      21571      621       745
                      EOF
```

Figure 3.—Input control records and data records with bulk density compaction readings.

Output Summaries

The data appearing in figure 3 are input into the program SOILS, and three output summaries are produced: figure 4, output summary for each transect; figure 5, output summary for the activity unit; and figure 6, sample size calculations. The estimation procedures for these summaries appear in appendixes A and B.

Figure 4 presents the 2 x 7 matrices (described previously) for each transect. There are 15 of these matrices corresponding to the 15 transects taken in the Jungle Springs unit. Note that the 100 feet of visual compaction has been partitioned into "compacted" and "uncompacted" classes based on the bulk density readings in data type 2 records. Refer to figure 5; the average bulk density of the 30 readings, taken on the outside area, was 0.633 g/cm^3. The relative standard percent was 15 percent. Therefore, the bulk density standard is 1.15 x 0.633 = 0.728 g/cm^3. The 10 bulk density readings, noted on transect 1 on the input data type 2 records, show that four were greater than 0.728 and six were equal to or less than 0.728. Thus, the partition of the 100 feet was 60/40 to the uncompacted/compacted classes. This process is repeated for each transect.

Figure 5 presents a summary of each transect for the activity unit. Definitions of which cells in the 2 x 7 matrix are combined to form the transect summary appear in appendix A. The mean and variance are computed for all transects in the activity unit for each condition class. Note that the Jungle Springs unit had an estimated 34.53 percent damaged, 65.47 percent undisturbed, 8.47 percent deposition, and 14.87 percent other.

Confidence intervals are computed for the mean percentages of each condition class. These appear at the bottom of figure 5. Recall that the "options record" designated a 90-percent confidence interval.

Sample sizes are calculated for the conditions designated in the "options record." These are done for planning purposes and for determining whether the activity unit met an acceptable level of disturbance. Additional explanations of these calculations appear in the reference in footnote 1 and in appendix B.

UMATILLA FOREST, JUNGLE SPRINGS UNIT

BULK DENSITY - TRANSECT 1.
LINE LENGTH PERCENTAGES

	UNDISTURBED	DISPLACED	DEPOSITION	PUDDLED	ERODED	VISUAL COW.	OTHER
COMPACTED	.0(0.)	.0(0.)	.0(0.)	.0(0.)	.0(0.)	40.0(4.)	.0(0.)
UNCOMP.	.0(0.)	.0(0.)	.0(0.)	.0(0.)	.0(0.)	60.0(6.)	.0(0.)

BULK DENSITY - TRANSECT 2.
LINE LENGTH PERCENTAGES

	UNDISTURBED	DISPLACED	DEPOSITION	PUDDLED	ERODED	VISUAL COW.	OTHER
COMPACTED	.0(0.)	.0(0.)	.0(0.)	.0(0.)	.0(0.)	11.2(1.)	.0(0.)
UNCOMP.	24.0(3.)	.0(0.)	2.0(0.)	.0(0.)	.0(0.)	33.8(3.)	29.0(3.)

BULK DENSITY - TRANSECT 3.
LINE LENGTH PERCENTAGES

	UNDISTURBED	DISPLACED	DEPOSITION	PUDDLED	ERODED	VISUAL COMP.	OTHER
COMPACTED	.0(0.)	.0(0.)	.0(0.)	.0(0.)	.0(0.)	.0(0.)	.0(0.)
UNCOMP.	44.0(4.)	.0(0.)	.0(0.)	.0(0.)	.0(0.)	56.0(6.)	.0(0.)

BULK DENSITY - TRANSECT 4.
LINE LENGTH PERCENTAGES

	UNDISTURBED	DISPLACED	DEPOSITION	PUDDLED	ERODED	VISUAL COMP.	OTHER
COMPACTED	.0(0.)	.0(0.)	.0(0.)	.0(0.)	.0(0.)	33.7(3.)	17.5(2.)
UNCOMP.	10.0(1.)	.0(0.)	10.0(1.)	.0(0.)	.0(0.)	11.3(1.)	17.5(2.)

BULK DENSITY - TRANSECT 5.
LINE LENGTH PERCENTAGES

	UNDISTURBED	DISPLACED	DEPOSITION	PUDDLED	ERODED	VISUAL COMP.	OTHER
COMPACTED	8.7(1.)	.0(0.)	.0(0.)	.0(0.)	.0(0.)	40.0(4.)	.0(0.)
UNCOMP.	17.3(2.)	.0(0.)	.0(0.)	.0(0.)	.0(0.)	.0(0.)	34.0(3.)

BULK DENSITY - TRANSECT 6.
LINE LENGTH PERCENTAGES

	UNDISTURBED	DISPLACED	DEPOSITION	PUDDLED	ERODED	VISUAL COMP.	OTHER
COMPACTED	.0(0.)	.0(0.)	25.0(2.)	.0(0.)	.0(0.)	59.1(6.)	.0(0.)
UNCOMP.	.0(0.)	.0(0.)	.0(0.)	.0(0.)	.0(0.)	9.9(1.)	6.0(1.)

BULK DENSITY - TRANSECT 7.
LINE LENGTH PERCENTAGES

	UNDISTURBED	DISPLACED	DEPOSITION	PUDDLED	ERODED	VISUAL COMP.	OTHER
COMPACTED	.0(0.)	.0(0.)	.0(0.)	.0(0.)	.0(0.)	38.9(4.)	.0(0.)
UNCOMP.	.0(0.)	.0(0.)	14.0(1.)	.0(0.)	.0(0.)	29.1(3.)	18.0(2.)

Figure 4.—Output summary for each transect.

BULK DENSITY - TRANSECT 8.
LINE LENGTH PERCENTAGES

	UNDISTURBED	DISPLACED	DEPOSITION	PUDDLED	ERODED	VISUAL COW.	OTHER
COMPACTED	.0(0.)	.0(0.)	.0(0.)	.0(0.)	.0(0.)	42.7(4.)	.0(0.)
UNCOW.	.0(0.)	.0(0.)	4.0(1.)	.0(0.)	.0(0.)	53.3(5.)	.0(0.)

BULK DENSITY - TRANSECT 9.
LINE LENGTH PERCENTAGES

	UNDISTURBED	DISPLACED	DEPOSITION	PUDDLED	ERODED	VISUAL COW.	OTHER
COMPACTED	.0(0.)	.0(0.)	.0(0.)	.0(0.)	.0(0.)	10.9(1.)	.0(0.)
UNCOW.	.0(0.)	.0(0.)	13.0(2.)	.0(0.)	.0(0.)	76.1(7.)	.0(0.)

BULK DENSITY - TRANSECT 10.
LINE LENGTH PERCENTAGES

	UNDISTURBED	DISPLACED	DEPOSITION	PUDDLED	ERODED	VISUAL COMP.	OTHER
COMPACTED	.0(0.)	.0(0.)	11.5(1.)	.0(0.)	.0(0.)	9.2(1.)	.0(0.)
UNCOW.	.0(0.)	.0(0.)	11.5(1.)	.0(0.)	.0(0.)	27.8(3.)	40.0(4.)

BULK DENSITY - TRANSECT 11.
LINE LENGTH PERCENTAGES

	UNDISTURBED	DISPLACED	DEPOSITION	PUDDLED	ERODED	VISUAL COMP.	OTHER
COMPACTED	.0(0.)	.0(0.)	.0(0.)	.0(0.)	.0(0.)	8.1(1.)	15.0(0.)
UNCOMP.	12.0(0.)	.0(0.)	.0(0.)	.0(0.)	.0(0.)	64.9(8.)	

BULK DENSITY - TRANSECT 12.
LINE LENGTH PERCENTAGES

	UNDISTURBED.	DISPLACED	DEPOSITION	PUDDLED	ERODED	VISUAL COW.	OTHER
COWACTED	.0(0.)	.0(0.)	.0(0.)	.0(0.)	.0(0.)	49.4(5.)	.0(0.)
UNCOMP.	.0(0.)	.0(0.)	11.0(1.)	.0(0.)	.0(0.)	39.6(4.)	.0(0.)

BULK DENSITY - TRANSECT 13.
LINE LENGTH PERCENTAGES

	UNDISTURBED	DISPLACED	DEPOSITION	PUDDLED	ERODED	VISUAL COMP.	OTHER
COMPACTED	.0(0.)	.0(0.)	.0(0.)	.0(0.)	.0(0.)	28.0(3.)	12.5(1.)
UNCOW.	.0(0.)	.0(0.)	19.0(2.)	.0(0.)	.0(0.)	28.0(3.)	12.5(1.)

BULK DENSITY - TRANSECT 14.
LINE LENGTH PERCENTAGES

	UNDISTURBED	DISPLACED	DEPOSITION	PUDDLED	ERODED	VISUAL COMP.	OTHER
COWACTED	.0(0.)	.0(0.)	.0(0.)	.0(0.)	.0(0.)	31.3(3.)	.0(0.)
UNCOMP.	.0(0.)	.0(0.)	6.0(1.)	.0(0.)	.0(0.)	62.7(6.)	.0(0.)

BULK DENSITY - TRANSECT 15.
LINE LENGTH PERCENTAGES

	UNDISTURBED	DISPLACED	DEPOSITION	PUDDLED	ERODED	VISUAL COW.	OTHER
COMPACTED	.0(0.)	.0(0.)	.0(0.)	.0(0.)	.0(0.)	29.6(3.)	10.5(1.)
UNCOMP.	.0(0.)	.0(0.)	.0(0.)	.0(0.)	.0(0.)	49.4(5.)	10.5(1.)

Figure 4.—Output summary for each transect (continued).

UMATILLA FOREST, JUNGLE SPRINGS UNIT

BULK DENSITY READINGS
CONDITION CLASSES (PI.)
(PERCENT)

UNDISTURBED MEAN B.D. = 0.633

DAMAGE LEVEL (UNDIST.MEAN X 1.15) B.D. = 0.728

TRANSECT NUMBER	TOTAL DAMAGE*	UNDISTURBED	COMPACTED	DISPLACED	DEPOSITION	PUDDLED	ERODED	OTHER
1.	40.	60.	40.	0.	0.	0.	0.	0.
2.	11.	89.	11.	0.	2.	0.	0.	29.
3.	0.	100.	0.	0.	0.	0.	0.	0.
4.	51.	49.	51.	0.	10.	0.	0.	35.
5.	49.	51.	49.	0.	0.	0.	0.	34.
6.	84.	16.	84.	0.	25.	0.	0.	6.
7.	39.	61.	39.	0.	14.	0.	0.	18.
8.	43.	57.	43.	0.	4.	0.	0.	0.
9.	11.	89.	11.	0.	13.	0.	0.	0.
10.	21.	79.	21.	0.	23.	0.	0.	40.
11.	8.	92.	8.	0.	0.	0.	0.	15.
12.	49.	51.	49.	0.	11.	0.	0.	0.
13.	41.	59.	41.	0.	19.	0.	0.	25.
14.	31.	69.	31.	0.	6.	0.	0.	0.
15.	40.	60.	40.	0.	0.	0.	0.	21.
P.. (MEAN) =	34.53	65.47	34.53	.00	8.47	.00	.00	14.87
V(PI.) (VARIANCE) =	466.93	466.93	466.93	.00	77.27	.00	.00	225.55

*TOTAL DAMAGE = 100-(UNCOWACTED VISUAL COWACTION t UNCOMPACTED DEPOSITION + UNCOMPACTED UNDISTURBED + UNCOMPACTED OTHER)

CONFIDENCE INTERVALS (.90)

TOTAL DAMAGE =	34.53	+OR-	9.83
UNDISTURBED =	65.47	+OR-	9.83
COMPACTED =	34.53	+OR-	9.83
DISPLACED =	.00	+OR-	.00
DEPOSITION =	8.47	+OR-	4.00
PUDDLED =	.00	+OR-	.00
ERODED =	.00	+OR-	.00
OTHER =	14.87	+OR-	6.83

Figure 5.—Output summary for the activity unit.

* * * * * * * ITERATION 2 * * * * * * * *

SAMPLE SIZE CALCULATIONS BASED ON SPECIFIED CONFIDENCE INTERVALS ON TOTAL DAMAGE

VARIANCE 466.93 MEAN = 34.53

MARGIN OF ERROR (RELATIVE)

PROBABILITY LEVEL	.20	.10	.00
0.80	17.50	65.77	.00
0.90	28.49	108.03	.00
0.95	40.34	150.43	.00

* * * * * * * * ITERATION 2 * * * * * * * *

SAMPLE SIZE CALCULATIONS BASED ON SPECIFIED MINIMUM STANDARD ON TOTAL DAMAGE

VARIANCE =466.93 MEAN = 34.53

STANDARD (ABSOLUTE)

PROBABILITY LEVEL	20.	70.	0.
0.80	5.93	7.35	.00
0.90	8.98	6.62	.00
0.95	71.76	14.37	.00

Figure 6.—Sample size calculations.

Appendix A
Estimation **Procedures**

The estimation procedures not documented in Howes and others (see footnote 1, p. 1) are presented here.

Symbology.—Let l_{ij} be the length of the i^{th} transect observed in the j^{th} soil condition class.

Soil condition classes are defined as:

j = 1 visual compaction (roads, heavy skid trails, etc.);
2 displaced;
3 deposited;
4 puddled;
5 eroded;
6 undisturbed; and
7 other.

The values $l_{i1}, ..., l_{i7}$ are the lengths in classes 1-7 for the same i^{th} transect,

and $\sum_{j=1}^{7} l_{ij} = l_i$ is the total length of the i^{th} line. The length of transects in a soil survey should be kept constant.

Let d_{ijk} be the bulk density or another variable of interest for the k^{th} core (subsample) in the j^{th} class on the i^{th} transect. The point subsample may be at intervals of 5 or 10 feet, so that k = 1, ..., 10, or 20.

Define d_o as the established average undisturbed bulk density (from an independent source or "outside area records"), and $d_s = 1.15d_o$ as the damage level standard, provided by the Region 6 directive mentioned earlier.

Logic.—Compare d_{ijk} with d_s; if

$d_{ijk} > d_s$, set $d_{ijk} = 1$ implies the d_{ijk}th point is compacted, or

$d_{ijk} \leq d_s$, set $d_{ijk} = 0$ implies the point is uncompacted.

$d_{ij} = \sum_{k=1}^{n_{ij}} d_{ijk}$ is the number of cores compacted falling in the j^{th} condition class on the i^{th} transect,

n_{ij} is the total number of cores in the j^{th} condition class on the i^{th} transect;

$d_{ij.} = \sum_{k=1}^{n_{ij}} \frac{d_{ijk}}{n_{ij}}$ is the proportion of points in the j^{th} condition class of the i^{th} transect which are compacted (a dot subscript symbolizes that entries have been averaged over the replaced subscript);

$1 - d_{ij.}$ = the compliment percentage of points in the ij^{th} transect-condition class not compacted;

$p_{ij.} = \frac{l_{ij}}{l_i}(d_{ij.})$ is the percentage of the i^{th} transect in the j^{th} condition class which is damaged by compaction; and

$q_{ij.} = \frac{l_{ij}}{l_i}(1 - d_{ij.})$ is the percentage of the i^{th} transect in the j^{th} condition class which is not compacted.

The estimates for the activity unit are:

$$\hat{P}\ \text{undisturbed} = \sum_{i=1}^{n} (q_{i1.} + q_{i3.} + q_{i6.} + q_{i7.})/n;$$

where n is the number of transects in the sample. The entry $q_{i1.}$ is the proportion of the visual compaction condition class classified on the i^{th} transect which is adjusted into undisturbed on the basis of the proportion of compaction points that were uncompacted. Similarly, $q_{i3.}$, $q_{i6.}$, and $q_{i7.}$ are the proportions of "deposition," "undisturbed," and "other" classes that were uncompacted as was determined from the subsample of cores.

$$\hat{P}\ \text{compacted} = \sum_{i=1}^{n} \sum_{j=1}^{7} p_{ij}./n;$$

$$\hat{P}\ \text{displaced} = \sum_{i=1}^{n} (p_{i2}. + q_{i2}.)/n = \sum_{i=1}^{n} \frac{1_{i2}}{1_i};$$

$$\hat{P}\ \text{deposited} = \sum_{i=1}^{n} (p_{i3}. + q_{i3}.)/n = \sum_{i=1}^{n} \frac{1_{i3}}{1_i};$$

$$\hat{P}\ \text{puddled} = \sum_{i=1}^{n} (p_{i4}. + q_{i4}.)/n = \sum_{i=1}^{n} \frac{1_{i4}}{1_i};$$

$$\hat{P}\ \text{eroded} = \sum_{i=1}^{n} (p_{i5}. + q_{i5}.)/n = \sum_{i=1}^{n} \frac{1_{i5}}{1_i};$$

$$\hat{P}\ \text{other} = \sum_{i=1}^{n} (p_{i7}. + q_{i7}.)/n = \sum_{i=1}^{n} \frac{1_{i7}}{1_i};$$

$$\hat{P}\ \text{total disturbance} = 1 - \sum_{i=1}^{n} (q_{i1}. + q_{i3}. + q_{i6}. + q_{i7}.)/n;$$

$$\text{variance} = \sum_{i=1}^{n} \frac{(p_i. - p..)^2}{n - 1}\ \text{(see footnote 1, p. 1);}$$

where $p_i.$ is the proportion from the i^{th} transect in the j^{th} class constructed with the p_{ij}'s and q_{ij}'s defined above, and $p..$ is the average of the $p_i.$ for all transects in the sample.

For example, the $v(\hat{P}$ undisturbed) is

$$v(\hat{P}) = \sum_{i=1}^{n} \frac{(p_i. - p..)^2}{n - 1},$$

but

$$\hat{P}\ \text{undisturbed} = \sum_{i=1}^{n} (q_{i1}. + q_{i3}. + q_{i6}. + q_{i7}.)/n$$

$$= \sum_{i=1}^{n} (p_i.)/n \text{ if } p_i. = q_{i1}. + q_{i3}. + q_{i6}. + q_{i7}.$$

$$= p.$$

Therefore,

$$v(\hat{P}) = v(\hat{p}..) = \sum_{i=1}^{n} \frac{((q_{i1}. + q_{i3}. + q_{i6}. + q_{i7}.) - \hat{P})^2}{n - 1}$$

Appendix B
Sample Size Calculations

The systematic sample is processed as a random sample. Sample sizes will be conservative because the true variance of a systematic sample of soil disturbance will generally be less than that estimated by random sampling.

Two alternative sample size calculations exist, and the choice depends on the specific objective of the survey.

Alternative 1.—The objective is to estimate P (the proportion of the activity area in a specific soil condition class) at a specified level of precision; that is, P is within plus or minus a fixed percentage of the true value, unless a stated probability of error occurs. For example, if an estimation of the true value ± 10 percent at the 95-percent confidence probability is desired, the sample size is approximated as

$$n \doteq \frac{t^2 s^2}{(0.10\hat{P})^2} ;$$

where:

in the first iteration, t is the Student's t value for ∞ degrees of freedom for $\alpha = 0.05$ (1 − the confidence probability). If a second iteration is desired, a new t value with the first iteration n−1 (where n has been incremented to the next whole number) degrees of freedom will be used.

s^2 is the variance among transect values for the soil condition class on which the sample size will be controlled.

$\hat{P}$ is the estimate of the proportion of that soil condition class.

A table (for either iteration 1 or iteration 2) is printed with three levels of the confidence probability $(1 - \alpha)$ and three levels of the specified relative margin of error (for example, ± 10 percent in the previous example).

Alternative 2.—The objective in alternative **2** is to test whether $\hat{P} \geq P_o$, at a stated probability of significance. For example, frequently, a simple decision is desired of whether the resulting proportion of disturbance, $\hat{P}$, exceeds a standard P_o. If this is the objective then n is calculated as

$$n \doteq \frac{t^2 s^2}{(\hat{P} - P_o)^2} .$$

For example, based on the example from the Umatilla National Forest in the text, $\hat{P}$ (total damage) is expected to be **34.53** percent. The standard, P_o, is specified at 20 percent. With $t_{0.05} = 1.96, s^2 = 466.93,$

$$n \doteq 1.96^2(466.93)/(34.53-20)^2 = 8.5 \text{ transects.}$$

A second iteration produces n = **11.8;** refer to figure **6** in the text.

If we use alternative 1 and set the margin of error to be **f20** percent of $\hat{P}$ at $a = 0.05$, with $s^2 = 466.93,$

$$n = 1.96^2(466.93)/(0.20(34.53))^2 = 37.6 \text{ transects}$$

A second iteration produces n = **40.3;** see figure **6.**

Thus, how the results are applied in relation to the standards and decision criteria is important for the resulting sample size. The practical implications on budget requirements are obvious.

Two tables of sample sizes (for either iteration) were constructed. Refer to control type **2,** the "options record" (p. **3).** Note that in column **32** the decision of which table(s) to construct is made. Both tables have the capability of being 3 x **3** matrices (that is, three Student's t values with corresponding critical regions, and three margins of error expressed in either relative or absolute units).

*GPO 595 - 487 (1985)

Hazard, John W.; Snellgrove, Jeralyn; Geist, J. Michael. Processing data from soil assessment surveys with the computer program SOILS. Gen. Tech. Rep. PNW-179. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1985. 26 p.

Program SOILS processes data from soil assessment surveys following a design adopted by the Pacific Northwest Region of the USDA Forest Service. It accepts measurements from line transects and associated soil subsamples and generates estimates of the percentages of the sampled area falling in each soil condition class. Total disturbance is calculated by combining certain detrimental soil condition classes. Variances and confidence intervals of the percentage of each class are computed. Summary or preliminary estimates may be inserted into the program for computing sample sizes to help in planning future surveys.

A summary of the soil survey design for the Pacific Northwest Region, the estimation procedures, and the sample size calculation procedures are also provided.

Keywords: Soil surveys, computer programs/programming, sampling designs.

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