Guidelines for Sampling Some Physical Conditions of Surface Soils

by

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AUTHORS

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R6-RWM-146-1983

July 1983

ABSTRACT

Procedures are provided for sampling and estimating the extent of some physical conditions of surface soils caused by forest management activities. Calculations and statistical methods enabling users to make quantitative statement of the precision of estimates are described.

CONTENTS

INTRODUCTION

The primary objectives of the USDA Forest Service watershed monitoring program are to secure sufficient data to aid line officers and resource managers in evaluating environmental effects of forest land uses on soil, to provide a means of detecting changes, and to monitor the results and impacts of land management activities.[1/] This is to be accomplished by monitoring soil quality.[2/] To provide meaningful information, each soil quality monitoring project must be properly conceived and conducted, and quantitative estimates of soil parameters should be accompanied by statements of precision.

These guidelines provide a statistically sound sampling system that can be used to evaluate soil status at one point in time, or, with repeated sampling, to measure changes over time. The sampling system provides the theoretical and practical basis for obtaining a representative sample of surface soil conditions, including bare soil exposure, displacement, puddling, erosion, and compaction (see glossary, appendix C). Multiple variables can be sampled concurrently, thus reducing field time and improving travel efficiency.

These guidelines are preliminary and do not cover all possible situations. Therefore, feedback to the authors documenting advantages and disadvantages of this sampling system is encouraged and will form the basis for future revisions of these guidelines.

Because soil quality standards and the requirements for use of specific measuring instruments may change, it is important to apply the most recent information available (currently Boyer 1979 and Boyer and Dell 1980) to the sampling system presented here. Computer programs have been developed to process the soil data collected according to these guidelines. Current soil quality standards have been built into these programs but can be revised if standards change.

SAMPLING SYSTEM

The system is a set of guidelines for choosing where to sample and how to estimate soil conditions from the data. It utilizes a grid of points and line transects originating from the points. The number of points and their spacing is determined by size of the area to be sampled, the variation in soil properties expected, and the precision (standard error and probability limits) desired. Several classes of soil condition are measured along horizontal transects. Compaction is assessed by sampling at specified intervals along the transects. Classes of damage can be assessed and the results compared to standards set for Region, Forest, or District.

Details of the sampling system are presented in three parts: planning, field execution, and data analysis.

Planning

The population from which samples are to be taken is called the activity area.[3/] Usually this is a unit of a timber sale, but it may be any other designated area for which estimates of soil conditions are desired. Where management prescriptions are not uniform or soil conditions differ significantly (for example, tractor versus cable logging systems within the same activity area), areas should be stratified and strata monitored individually.

The layout of sampling points consists of a predetermined, systematic square grid. The dimensions of the grid are determined by the size of area being sampled and a calculated sample size. Grid orientation is random. Grid intersections are the starting points for line transects, which for this discussion are 100 feet long (fig. 1). Orientation of

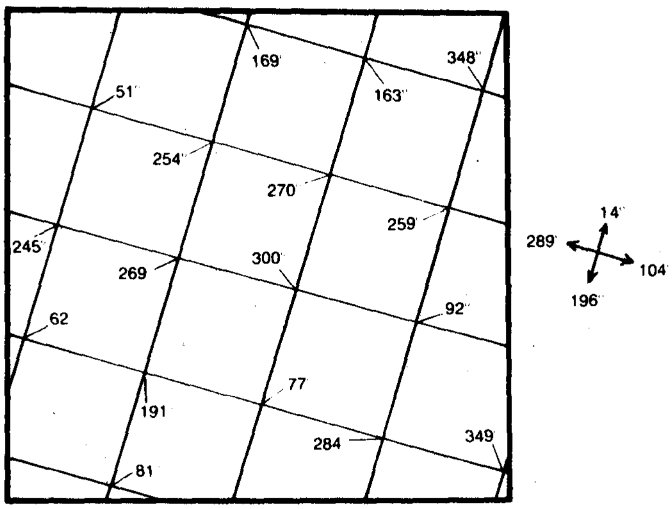

Figure 1

Figure 1.--Sample layout showing random grid orientation and randomly oriented line transects. Grid intersections are zero points of transects.

each line transect is also randomly assigned. Grid spacing and distribution of points provide complete coverage of the area to be sampled.

In this discussion, a sample point refers to a grid intersection from which a line transect originates. The total number of sample points is the sample size (n). A line transect is the randomly oriented 100-foot line originating at each sample point, along which visual estimates of surface soil condition are made and measurements of compaction are taken. A measurement unit refers to the smallest length of line transect in a soil condition class. Our examples will use measurement units recorded to the nearest foot.

For the Pacific Northwest Region of the USDA Forest Service (Region 6), the classes of soil condition monitored are: undisturbed, displaced, deposited, puddled, eroded, and observed compaction (in roads, skidroads, etc.). These classes are measured continuously along the line transects. Percentages for each class of surface soil condition are determined by totaling all measurements in each condition class and dividing by length of the line. With 100-foot lines, all linear measurements equal percentages. All condition classes must also be sampled for state of compaction to verify and modify estimates made from surface appearance.

Procedures are the same regardless of number of condition classes measured. The number of classes measured depends on how results will be used; however, as a minimum, the "critical condition" classes must be measured. Critical conditions are those for which standards have been set (see footnote 3). They include percentage of soil determined to be compacted and percentage of soil in the following conditions: displaced, puddled, and eroded. The Pacific Northwest Region has taken the position that material in the "deposition" category that is uncompacted has negligible effects on tree growth and is thus not a critical condition. Observed compaction that core samples subsequently show to be uncompacted, is treated as "undisturbed."

Compaction differs from other variables in that it usually is inconspicuous. The presence and degree of compaction must be assessed by soil core sampling, air permeameter, or other means at fixed intervals along the same transects used to measure surface conditions (fig. 2).

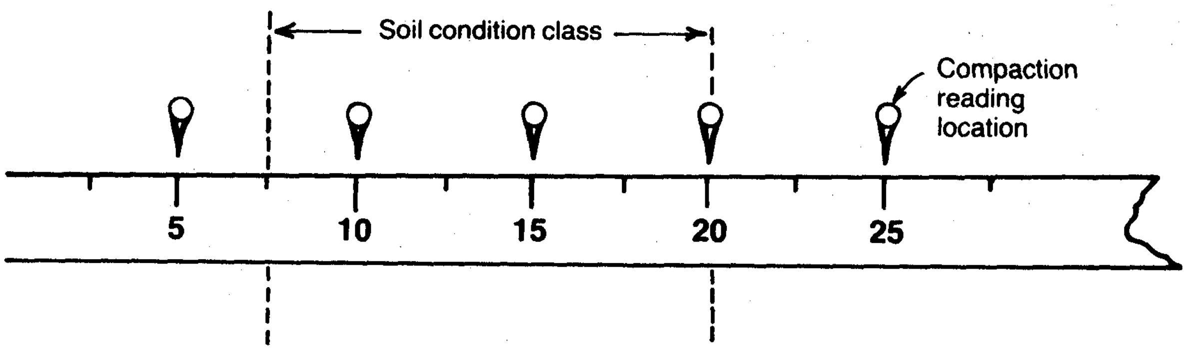

Figure 2

Figure 2.--Example of transect showing soil surface condition of 12-1/2 feet and location of commpaction measurement points at 5 foot intervals.

Twenty readings at 5-foot intervals are recommended for a 100-foot transect. If time is limited the interval can be lengthened and the number of measurements reduced. Reducing the number of measurement points, however, reduces the reliability of the estimate.

Computation of sample size.--The first step in determining grid spacing (interval) is to compute sample size (n). This requires consideration of the amount of variation in soil conditions of the area to be sampled. If an estimate of this variation is available from past similar areas, the task is easier. An alternative is to obtain an estimate by selecting a number of grid points (perhaps 10), taking field measurements, and performing the same calculations described for presample data. If a presample cannot be taken and estimates of variance do not exist for areas similar to the one to be sampled, use 10 to 15 grid points for intensive harvest areas of 20 to 30 acres.

Where presample data are available, the following equations are used to calculate the variance and sample size:

$$v(P_i) = s^2 = \sum_{i=1}^{n} \frac{(P_{i\cdot} - P_{\cdot\cdot})^2}{n-1}$$

$$n = \frac{t^2 s^2}{(EP_{\cdot\cdot})^2}$$

where: t = Student's t value with n-1 degrees of freedom for the desired probability level (α) which is obtained from statistical tables,[4/]

$P_{i\cdot}$ = the proportion in percent for the condition class of interest, for the ith line transect,

$$P_{\cdot\cdot} = \text{mean of } P_{i\cdot} = \sum_{i=1}^{n} \frac{P_{i\cdot}}{n} ,$$

E = acceptable margin of error expressed as a percent of the estimated true proportion. For example, if the desired precision is ± 20 percent of the true proportion, $E = 0.20$.

The values of α and E are chosen prior to sampling and are specified in the statement of the desired precision.

Following is an example of computing sample size for a planned monitoring project from presample data. It represents 10 line transects from an area with characteristics assumed to be similar to those of the area to be sampled. In this case, the $P_{i\cdot}$ values represent the total percentages of all classes of interest, with compaction adjustments included. Values of $P_{i\cdot}$ will exist for each variable for which measurements are taken. The choice of n will then be the largest calculated value. A value of n can be calculated for each variable of interest and the largest chosen for the sample size, or n can be based on the total of all classes.

transect number	$P_i.$	$(P_i. - P.)^2$
1	10	338.56
2	50	466.56
3	40	134.56
4	30	2.56
5	25	11.56
6	16	153.76
7	20	70.56
8	29	0.36
9	31	6.76
10	33	21.16

$$\Sigma P_i. = 284 \quad \Sigma(P_i. - P..)^2 = 1{,}206.40$$

$$P.. = \Sigma P_{i/n} = 28.4 \quad v(P_i.) = s^2 = \frac{1{,}206.40}{9} = 134.04$$

If $\alpha = 0.1$ (10-percent probability of error) with assumed infinite degrees of freedom, the tabulated Student's t value is 1.645. And, if it is desired to be within ± 20 percent of the true proportion of total of all classes of interest then:

$$\text{sample size } n = \frac{t^2 s^2}{(EP..)^2}$$

$$= \frac{(1.645)^2(134.04)}{[0.20(28.4)]^2}$$

$$= 11.3 \text{ or } 12 \text{ line transects}$$

Since infinite degrees of freedom are used to start this process, n = 12 is a first approximation, and this process must be repeated. Using t = 1.796 for 11 degrees of freedom produces n = 13.4, rounded up to 14 transects. This means that with 14 line transects, the true mean of the selected critical condition for the unit can be expected to be within ±20 percent of the sample estimate, unless a 1-in-10 chance of error occurs. It should be noted that as the acceptable margin of error narrows, n will increase. Funding may place constraints on the attainable level of precision.

Establishing the sample grid.--Given a calculated or selected sample size and the area to be measured, the next step is to construct the sampling grid. The grid interval (I) used to locate sample points is calculated by the following the following equation:

$$I = \left(\frac{A}{n}\right)^{1/2}$$

where: A = number of acres in activity area x 43,560 = square feet of area (the constant 43,560 is appropriate when the area of the population is measured in acres and grid interval is in feet)

n = number of sample points required for the desired level of precision.

For example, if A = 20 acres and n = 14, the grid interval would be:

$$I = \left(\frac{20 \times 43560}{14}\right)^{\frac{1}{2}}$$

$$= 241 \text{ feet, round to } 240 \text{ feet.}$$

The following preparations will improve the efficiency of the field operation. Obtain a map of the area in which monitoring activities are to be conducted. The portion of the map containing the activity area to be sampled should be photographically enlarged to a suitable, known scale. This can also be done using an opaque or overhead projector. A scale of 1:3600 (1 inch = 300 feet) is suitable.

Once the grid interval has been determined, select a grid transparency of proper size and scale (or one which closely approximates it) and overlay it on the map of the area being sampled. Grid transparencies can be constructed for the scale of maps or photographs used. Orientation of the grid overlay should be done randomly, either by selecting a pair of random numbers from 00 to 90 or by spinning the grid over the area map. Each grid intersection represents the starting location of a transect line. The number may be greater or less than calculated due to random placement of the grid. If calculated n is less than 10 and the number of grid intersections is even fewer, the grid can be randomly located a second time to get the calculated n. If n is greater than 10, accept the grid. Any convenient point near the area boundary can be used as a starting point to reference the grid.

A random azimuth is needed for each associated transect. The azimuths can also be assigned in the office by selecting a series of random numbers from 001 to 360.[6/] Enter the azimuth for each line on the enlarged map (see figure 1) and/or sampling forms (see appendix A). If a transect falls outside the area boundary, adjust the zero point to bring transect into the measurement area as in figure 3. A preliminary route

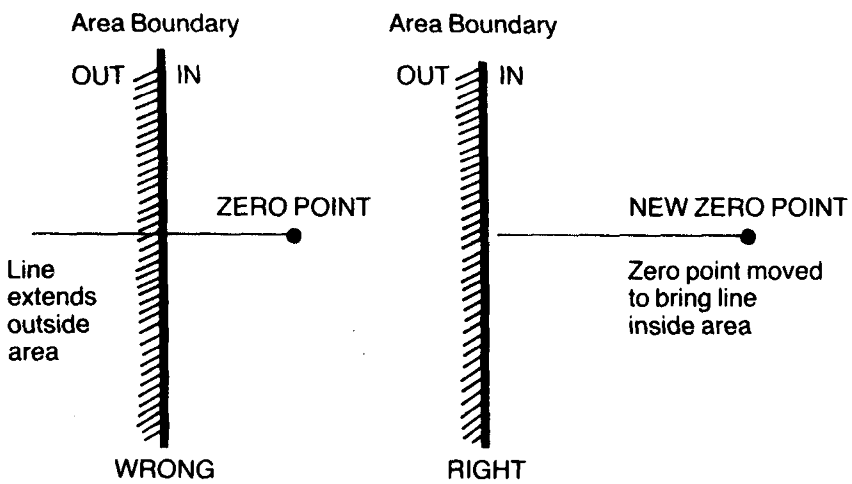

Figure 3

Figure 3.--Proper method of positioning line transect located near activity area boundary.

of travel that minimizes the amount of field movement can also be selected in the office and modified later to meet field conditions.

Field Execution

The manner in which data are collected and analyzed is critical to their usefulness. If conditions are not measured accurately, the credibility of the monitoring will be reduced.

After identifying a preliminary route for laying out the grid, begin measuring transects at the first grid point. Other grid points can be established by pacing distances and measuring azimuths with a hand compass. Starting with each grid intersection as the zero point, locate and measure the line transect. Record on the monitoring form (appendix A) horizontal transect distances occupied by soil displacement, deposition, puddling, and the three classes of erosion (sheet, rill, gully). Standards for these classes are descriptive (see glossary in appendix C) and do not require quantitative measurements. All that is necessary is to decide that a particular segment of the transect is in a particular condition class and measure the linear feet of that segment. Classify as observed compaction only situations where compaction appears to be detrimental (roads, landing sites, primary skid roads). When in doubt about whether compaction is detrimental compaction, classify the measured length as "other." "Other" classification includes areas that show evidence of equipment operation but not necessarily of detrimental compaction. Do not consider areas of soil deposition as soil displacement. Figure the total length of each soil condition for each transect by adding all segments of the same condition.

Because compaction may exist in all soil condition classes, including undisturbed, measurements are needed to classify soil as compacted or uncompacted. Measurements of compaction, in contrast to those of surface conditions, are quantitative and based on percent macropore space or bulk density.[7/] After soil surface conditions have been measured on a transect, measure compaction along the same transect by taking core samples or air permeability measurements at a selected depth at fixed intervals. Measurement points should be close enough to avoid missing compaction. We consider 5-foot intervals about right because this distance is less than the width of most mechanical equipment. Do not use the zero point as a measurement point. Record data in the appropriate condition class on the monitoring form (see appendix A).

Compaction measurement sites that happen to fall on stumps, logs, or other woody debris that existed prior to the management activity should be considered uncompacted. If, however, compaction measurement points fall on woody material overlying landings, obvious skid trails, YUM decks, and similiar cases should be considered compacted.

Measurement points will usually be distributed in proportion to soil conditions of the area being measured. It is possible that measurement points will not fall in all classes of soil condition observed, but these classes are likely to be small and contribute relatively little to estimates of condition for the entire area. It is not necessary to verify observed compaction for such areas; in some cases the location of measurement points will leave observation as the only indication of compaction.

If soil conditions are to be monitored for several years, permanent line transects should be established by staking and labeling end points and maintaining a record of the azimuth of each line transect. Subsequent measurements for compaction must be made at locations slightly offset from previous measurements to avoid excavation effects.

Computing Areas of Compaction and Other Conditions

Standards (see footnote 3) state that "a minimum of 80 percent of an activity area will be in a noncompacted, nonpuddled, and/or nondisplaced condition." (Additional standards apply to soil erosion.) Because the standards specify percentage of area, measurements of soil surface condition in feet and compaction measurements in macropore space or bulk density must be converted. This is done by first converting measurements for each transect to percentages, then adding the percentages for all transects and dividing by the number of transects.

Compaction is classified as detrimental on the basis of its effect on the growth of plants, specifically trees. The Forest Service Manual (see footnote 3) specifies three definitions of detrimental compaction:

(1) More than a 15-percent increase in soil bulk density.

(2) More than a 50-percent reduction in macropore space.

(3) Fifteen percent or less macropore space.

Meeting standards 1 and 2 requires assessing change by measuring before and after the management activity. If, however, change is defined as the difference between measurement made after the activity and a chosen arbitrary standard that represents either no disturbance or optimum compaction for tree growth, then compaction needs to be measured only after the activity. The difficulty with the latter approach is arriving at an arbitrary optimum level of bulk density or macropore space. Also, this approach does not measure the influence of the activity on the site but measures only the current status of the site. Regardless of the standard selected, the decision to make is whether each measurement of compaction exceeds the standard.

The percentage of area compacted along each transect can be determined by two methods: (1) the ratio of points falling in the detrimental compaction class to total points for an entire transect or (2) the ratio of points classified as detrimental compaction within a condition class to total points in that class. The percentages resulting from method 2 are multiplied by length of line in each class. They are then summed for the entire transect. The choice between these two methods should be based on sampling objectives. Where total damage is most important, method 2 is preferred. Method 1 offers the more precise estimate of compaction, but the percentages for all classes will not total 100 because compaction is estimated independently of surface condition.

If a critical level of compaction is set, then, regardless of the prior condition of the sample area, an average bulk density greater than, or a macroporosity less than, this level is considered detrimental. With this method, however, no distinction can be made between compaction present before a management activity and compaction caused by the activity.

Because there is natural variation in soil properties, we must provide for it in our standards. The easiest way is to define standards in terms of average bulk density prior to a management activity. To get this estimate, one can sample the area before the activity takes place, or, if the activity is complete, a representative area nearby can be sampled. Then if the standard says that increases in average bulk density of a given percent constitute damage, there is a preactivity figure to measure against. The positive and negative errors from using an average bulk density for conditions before an activity should compensate for one another.

Estimating the extent of soil disturbance and damage requires combining information from the two kinds of sampling. The parameters on which damage is judged are:

(1) Percent of area compacted.

(2) Percent of area displaced.

(3) Percent of area with deposition.

(4) Percent of area puddled.

(5) Percent of area eroded.

(6) Percent of area undisturbed.

As explained earlier, these six parameters are not always independent, because all soil classes can be compacted, and compaction may not always be observed. Soil that appears to be compacted may not meet the standard for macroporosity or bulk density. Compaction must be measured, and these measurements combined with surface measurements of soil condition.

Following is an example of disturbance indicated by surface conditions observed along a 100-foot transect:

Undisturbed	Displaced	Deposited	Puddled	Eroded	Observed Compaction	Other
70 feet	15 feet	5 feet	0 feet	0 feet	10 feet	0 feet

This example indicates that the 100-foot line intersected a 10-foot road or other observed compaction site. There were 15 feet of bare subsoil and 5 feet of soil deposited over existing soil. These measurements indicate that 30 feet out of 100 were disturbed.

The proportion of points compacted within each condition class provides the basis for dividing each class into compacted and uncompacted. These data provide a mathematical basis for determining the proportion of each soil condition class that is compacted. This is done by multiplying linear feet of soil class divided by length of line (P) by the proportion of points that are compacted (Q). Thus, the adjusted proportion of each class of soil condition (P.) is:

$$P. = PxQ \ ,$$

and the mean proportional values for each class of soil condition are calculated using the following equation:

$$P.. = \sum_{i=1}^{n} \frac{P_i}{n}$$

where: $P_i.$ = corrected proportion for soil class of interest, in the ith line transect

$P..$ = mean proportion for a given condition class on the entire activity area.

The following example illustrates how adjustments are made for compaction within the soil condition classes measured along the 100-foot line in the previous example. Percent macropore space is measured at 20 points along the line; points are classified as compacted or uncompacted on the basis of a hypothetical standard set for this example of 21-percent macropore space:

Undisturbed	Displaced	Deposited	Puddled	Eroded	Observed compaction	Other
70 feet	15 feet	5 feet	0 feet	0 feet	10 feet	0 feet
----------Percent macropore space----------						
27	13	29			10	
23	10				8	
25	7				7	
22						
27						
23						
30						
29						
25						
27						
24						
23						
25						
Points measured						
13	3	1	0	0	3	0
Points compacted						
0	3	0	0	0	3	0
Points uncompacted						
13	0	1	0	0	0	0

In this example macropore percentages at all measurement points in the undisturbed category (70 feet) meet our standard for uncompacted soil. The displaced area (15 feet) is compacted at all 3 points. The deposited area (5 feet) is uncompacted (1 point). The observed compaction (10 feet) is measurably compacted at all 3 points. These measurements are translated into soil disturbance and soil damage by multiplying the number of feet in each condition class by the proportion of points that are compacted. This exercise produces the following adjusted values for the example: total disturbed is 15+5+10=30 feet, or 30 percent, but total damage is 15+10=25 feet, or 25 percent, because deposition is not considered soil damage.

The following example illustrates a situation in which both compacted and uncompacted measurements are found within the same soil condition class and the linear measurement must be apportioned. Twenty measurements were taken along a transect line of 100 feet. The standard for compacted soil is 21-percent macropore space.

Undisturbed	Displaced	Deposited	Puddled	Eroded	Observed compaction	Other
40 feet	30 feet	10 feet	0 feet	0 feet	20 feet	0 feet
----------------------------Percent macropore space ----------------------						
23	14	28			14	
24	13	30			12	
15	10				23	
13	13					
29	12					
27	9					
14						
23						
Points measured						
8	6	2	0	0	4	0
Number compacted						
3	6	0	0	0	2	0
Number uncompacted						
5	0	2	0	0	2	0

To determine the extent of soil disturbance and damage along each transect, we have to adjust linear measurements of soil surface condition according to extent of compaction. We multiply length of line in each soil class (P) by the proportion of measurement points that fail to meet the standard (Q), using the equation P. = PxQ. In the above example total disturbance is:

40 feet (undisturbed) x 3/8 = 15 feet,

30 feet (displaced) x 6/6 = 30 feet,

10 feet (deposited) x 2/2 = 10 feet, and

20 feet (observed compaction) x 2/4 = 10 feet

for a total of 65 feet of disturbed soil along the 100-foot transect.

Disturbance, however, is not the same as soil damage. Because deposited soil is not considered damaged, the total damage is disturbed soil minus deposited soil, in this example 65 feet minus 10 feet for a total of 55 feet of damaged soil.

Computing Mean Percentages and Confidence Intervals

Once field measurements have been made and summary tables constructed for each transect, a summary for the entire area should be made. Begin by arraying all transect summaries and calculating the mean and variance as in the following example for a 12-transect area:

Transect Number	Total Damaged	Undisturbed	Displaced	Deposited	Puddled	Eroded	Observed Compaction	Other
1	55	25	30	10	0	0	55	0
2	10	80	10	0	0	0	10	0
3	28	62	18	10	0	0	28	0
4	40	45	20	5	0	0	35	0
5	30	70	30	7	0	0	25	0
6	25	69	19	9	0	0	19	0
7	26	74	26	0	0	0	26	0
8	20	80	20	0	0	0	26	0
9	29	61	18	10	0	0	29	0
10	31	69	31	0	0	0	30	0
11	33	67	6	15	0	0	27	0
12	28	72	13	0	0	0	15	0
P.. =	35.00	64.50	28.80	5.50	0	0	26.58	0
$v(P_i.)$ =	116.81	241.09	64.63	28.82	0	0	128.27	0

Note: Figures for transect 1 are those used in the earlier example. The mean (P..) and variance ($v(P_i.)$) are computed for each column or condition class according to equations presented under the section on determining sample size.

Note also that the mean proportion for total damage is not the sum of the individual classes because classes are not mutually exclusive.

The reliability of each estimate is computed with the equation:

$$CI_{1-\alpha} = P_{\cdot\cdot} \pm t_{\alpha,n-1} \left[\frac{v(P_{i\cdot})}{n}\right]^{\frac{1}{2}}$$

where:

$CI_{1-\alpha}$ = confidence interval at $1-\alpha$ probability level,

$t_{\alpha,n-1}$ = Student's t value with n-1 degrees of freedom for the α probability level,

$v(P_{i\cdot})$ = variance of the adjusted proportion,

n = sample size.

Using a probability level for 0.1 of the above sample, the true proportion of total damage for the area is expected to be in the interval with the stated confidence:

$$35.0 \pm 1.796 \left[\frac{116.81}{12}\right]^{\frac{1}{2}}$$

or 35.0 ± 5.6.

In addition to estimating the mean proportion and confidence interval level for each condition class in the entire area, a statistical test can be performed to determine whether conditions following an activity are equal to or less than a hypothesized standard.

For example, if a standard of 20 percent or less total soil damage is the desired maximum level, a test to determine whether damage exceeds this amount is made by solving the following equation:

$$t = \frac{P.. - 20}{\left[\frac{v(P_i.)}{n}\right]^{1/2}}$$

where the terms are defined as previously. The probability level for this test becomes $\alpha/2$ instead of α because this is a one-tailed test. The null hypothesis is HO: $P.. \leq 20$.

Substituting from the 12-transect sample into this expression produces:

$$t = \frac{35.0 - 20.0}{3.1} = 4.81$$

Thus, 4.81 is greater than the tabled t = 1.796, and it is concluded that the present level of total damage exceeds the 20-percent standard. The probability that an error has occurred or that the area has not exceeded the standard is $\alpha/2$ or .05.

EXTENSION TO MULTISTAGE OR STRATIFIED SAMPLING

In some cases, the area to be monitored may have been impacted by more than one management activity, or the area may include a cluster of units where different activities have taken place. Damage patterns may vary because of differences in activities, environmental conditions, or even size.

For these situations, the sampling allocation may be designed to sample the impact of activities on all units collectively rather than on each unit individually. The objective may be stated: estimate the total damage and its precision for all units in the entire area being monitored. In such situations, either multistage or stratified sampling can be used. Stratified sampling places transects in all units, but sampling is less intensive than when effects are estimated for each area individually. Multistage sampling allocates transects to only a sample of the activity areas. The following two situations provide examples of when to use each method.

Situation 1--There are several units, with quite different damage. Variation in damage within units is small relative to variation among units. Unit areas are known from records and each unit can be sampled independently. In addition, managers need estimates of damage for each unit.

Situation 2--There is a large number of units, all of approximately the same condition and treatment. Unit areas are also known and units can be sampled independently. Variation is greater within units than among units. In situation 1, the primary objective is to estimate the proportion of various soil condition classes for all units in the entire area with specified precision. The proper design is a stratified random sample with optimum allocation. The number of lines required to meet precision requirements for the entire area will be computed and allocated to units in proportion to estimated variances obtained from individual presamples.

In situation 2, the objective is to estimate the proportion of various soil condition classes for the entire area with specified precision. Estimates are not required for all units individually. The appropriate design for this situation is a multistage design. A sample of units will be drawn randomly, and each of the chosen units will be subsampled with the same number of transects.

Estimators for these two situations are the classical ones found in most texts on sampling techniques and will not be elaborated on in these guidelines.

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APPENDIX A

SOIL MONITORING FORM

District: ______________________________

Sale Name: ______________________________

Unit number/description: ________________

Date Monitored: ______________________________

Line transect number ____________ Azimuth ____________

Transect slope ____________ Unit slope ____________

Soil condition class (horizontal feet)								
				Eroded				
Undisturbed	Displaced	Deposited	Puddled	Sheet	Rill	Gully	Observed Compaction	Other

Point Samples (bulk density/percent macropore space)

APPENDIX B

Suggested Procedure for Measurements

A practical and convenient procedure for measuring horizontal distance is to:

(1) Begin measurements at each grid intersection and proceed along the random azimuth, marking every 5 horizontal feet with a chaining pin. Compaction (air permeability or bulk density) measurements will be taken at these locations on the return trip. While one person marks the compaction measurement point, another searches the 5-foot length of line for soil surface condition and records approximate or measured line length on the form under the appropriate soil condition class. This can easily be done if a 5-foot rigid measurer, such as a wood or metal rule, is held horizontal by the person who is downhill.

(2) As the crew returns to the grid intersection they take compaction readings at the designated locations. They must be sure the measurements are recorded in the correct condition class so the proportion of the line compacted can be estimated later.

(3) Back at the grid intersection, a crewperson shoots the average slope of the sampling line and the slope of the whole hillside with an Abney level or clinometer. This can be done before or after measurements are taken.

APPENDIX C

GLOSSARY

Activity area--The total area in which soil may be impacted by Activity area a completed or planned management activity. This may be a timber harvest unit, a slash disposal project, a site preparation project, a grazing allotment, or similar area.

Compaction--Compaction is a process in which soil bulk density is increased and macroporosity is decreased. It is the result of increased loads and/or vibration at the soil surface. Detrimental compaction has been defined (see footnote 3, p. 35) as more than a 15-percent increase in bulk density; more than a 50-percent reduction in macropore space; or 15-percent or less macropore space.

Displacement--Displacement is the horizontal movement and removal of soil from a site, caused by gouging and scraping of machines or logs. Detrimental displacement has been defined (see footnote 3, p. 35) as removal of more than 50 percent of the A horizon from more than 1 acre and/or covering more than 20 percent of an activity area.

Deposition--Deposition is the accumulated soil mass moved from its natural position to an adjacent location. Common examples are berms adjacent to skid trails or material deposited in windrows during machine piling of slash. Deposited materials are not considered to limit tree growth at this time.

Erosion 1/--The detachment and movement of soil particles by water, wind, ice, and gravity. Three types of erosion are considered in these guidelines: (a) sheet erosion--the removal of a uniform layer of soil from the land surface by runoff water, (b) rill erosion--a process in which numerous small channels only a few inches deep are formed, and (c) gully erosion--a process whereby water accumulates in narrow channels and, over short periods, removes soil from these narrow areas to depths of 1-100 feet.

Puddled Soil2/--Soil in which structure has been mechanically destroyed, allowing the soil to run together when saturated with water. A soil that has been puddled occurs in a massive nonstructural state.

Unit--A unit is a subdivision of an activity area managed and Unit monitored as a separate entity. An area may contain several units.

FOOTNOTES

1/ U.S. Department of Agriculture, Forest Service. Forest Service Manual 2525.02 - Objective FSM 8/79, Amend. 25. Washington, DC: 1982.

2/ U.S. Department of Agriculture, Forest Service. Forest Service Manual 2554 - Soil quality monitoring. FSM 6/79, Amend. 22. Washington, DC: 1979.

3/ U.S. Department of Agriculture, Forest Service. Forest Service Manual 2520.3 - Policy FSM 6/79, R-6 Supp. 38.

4/ Since n is unknown at this time, a first approximation can be obtained using t with infinite degrees of freedom. This first approximation of n can then be used to get a more accurate value for t. In rare situations this process may require repeating.

5/ Complete accuracy is not critical.

6/ Most statistics texts have random number tables, and some handheld calculators have random number generators.

7/ Instructions for use of specific equipment are provided in other regulations, directives, or publications.

GLOSSARY FOOTNOTES

[1/] Source: Soil Science Society of America. Glossary of soil science terms. Madison, WI; 1973.

[2/] Source: Hausenbuiller, R. L. Soil Science: principles and practice. Dubuque, Iowa: William C. Brown Co. Publishers; 1978. 611 p.