United States Department of Agriculture
US Forest Service
Natural Resource Manager (NRM)

FSVeg Common Stand Exam User Guide
Chapter 2: Preparation and Design

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TABLE OF CONTENTS

INTRODUCTION

This guide describes the sampling design methodology and field data collection techniques for the Common Stand Exam (CSE) protocols. The guide includes information on loading the data into the Field Sampled Vegetation (FSVeg) database and accessing the data to produce a variety of reports.

A “stand” is a polygon defined by local delineation criteria. It is spatially locatable on the ground. Within a stand, one or more points are established around which tree data, vegetation composition, ground surface cover, and down woody material can be collected.

Although this guide is oriented toward collecting information on stands that contain trees, the CSE protocols may be used to collect information on stands that do not contain trees.

The CSE protocols provide maximum flexibility for collecting data to meet a variety of information needs about a stand or area, including the ability to use a multitude of sampling criteria to collect data.

A stand examination is an unbiased, systematic, on-the-ground vegetative evaluation of a stand or site. Its purpose is to obtain the site and setting characteristics required to identify stand conditions and capabilities. Stand examinations may be simple observations, or formal, intensive examinations. The method used depends on factors such as stand complexity, the decisions to be made, and the purpose of the exam. Each examination method has varying data and accuracy requirements.

This chapter describes the process and minimum standards necessary to prepare and design stand examinations. The instructions apply specifically to stand examination procedures and were developed to assure uniformity of basic concepts. Definitions and classifications for conducting stand examinations are also provided. Design considerations and data acquisition are conceptual rather than directional. Regions and/or Forests may supplement this chapter with additional information.

Stand examination data provide information that can be used to:

- Determine Silvicultural treatments
- Collect data for growth and yield models such as the Forest Vegetation Simulator (FVS)
- Prioritize sites within an area for treatment
- Monitor post-treatment effects
- Develop relationships such as stand volume tables
- Evaluate wildlife habitat
- Model water yields
- Compute fuel loading
- Evaluate old growth stand characteristic
- Determine pathological and insect presence and/or spread
- Supplement cruise plots for timber sale volume estimates

A synopsis of this chapter in the form of a recorded webcast (CSE Spotlight – Stand Exam Preparation and Design) is available from the FSVeg Training webpage.

INVENTORY TYPES

Stand examination are one “type” of inventory conducted on National Forest Service lands. Strategic and tactical inventories are also installed. As the data coverage is expanded by integrating various data sets, it is imperative to understand the strengths and limitations of each exam project. Without knowing the compatibility of scope, scale, and objective, there is a risk of introducing bias into a combined data set. It is essential to understand the function of each inventory design to avoid introducing bias into analysis when data is combined. The following is a description of how stand examination data compares to other types of inventories

> *At the national level, strategic inventories are designed to sample “all forested lands across all ownerships.” The primary objective is to produce estimates of forest conditions and trends for regional, national, and international reporting. The strategic inventories encompass a large scale and have specifically defined population criteria (forested land), a fixed sampling intensity, a fixed set of core variables, and a quality assurance process necessary to accommodate national expectations. Forest Inventory and Monitoring (FIM) manage the national strategic inventory.*

FSVeg data is stored in an Oracle relational database. Data includes stand exams, grid inventories, pest surveys, research studies, and FIA data.

> *At the project level, stand examinations are designed to sample a specific stand or “homogeneous area.” The primary objective is to produce estimates for analysis and implementation of management direction. The stand examination encompasses a small scale, and has populations, sample intensities, an core variables that vary around the resource conducting the examination and very by management purpose. Flexibilty is necessary to meet managers’ informational needs for site-specific data. District resource managers direct the stand examinations.*

Strategic inventories, tactical inventories, and stand examinations differ subtly, but significantly with respect to how the data is acquired, shared, and analyzed. The most obvious difference is scale. The strategic inventory scale is national, the tactical inventory scale is Region or Forest, and the stand examination scale is a project area, stand, or vegetative condition. The stand examination procedures defined in this document provide useful resource and multi-resource information at the project level only. It is undesirable to aggregate stand examination data with strategic or tactical level data, or to use stand examination data in landscape level models because:

- Measuring a large number of stands does not, by itself, provide a basis for extrapolation of information if the stands are not a probability-based sample of the population. This is true if stands are selected on the basis of some management criteria, and are not representative of non-selected stands. In this case, it is not possible to make design-based statistical inference for the population.
- Measurement techniques and data resolution vary by stand objective and thus preent interpretation across stands.

OBJECTIVES

Stand examination objectives vary by resource, stand condition, and management issue. Each stand examination should have a clearly defined objective. Objectives are tied to scale—the finer the scale, the more encompassing the objective. Both objective and scale influence the sample design. The stand examination, by design, is intended to sample a vegetative condition that meets a pre-defined objective. A stand is generally selected to meet a resource need in an arbitrary, biased, or subjective manner. A stand is usually not selected in a manner to determine its inclusion probability.

A stand examination will only meet its objective if change and innovation are considered within stand sample design and variable detail. This flexibility affects data use. Stand examination data provides the best information for a particular site. For statistical reasons, however, aggregating project inventories to a larger scale for quantitative estimates is invalid or results in biased estimates.

Regardless of the size of the geographic area of interest, further defining the existing populations offers the greatest gain in sampling efficiency. Keep in mind "populations" is plural, implying that the various vegetative conditions need to be delineated with a specific label that distinguishers each stand. By delineating stand conditions and labeling each stand as to its condition, it is possible to further locate populations that potentially meet the objective of interest for which sample designs will be developed. This is basically the same as the strategic and management inventories defining the target population at the national or region/forest level. The only difference is the size of the population to be sampled. The more detailed and consistent the criteria for delineating and defining each population is, the more efficient the sampling protocol.

Once the stand or population of interest is delineated, the next task is to clearly define the sampling objectives by resource. An explicit and detailed sampling objective facilitates an appropriate sampling design. For example, if the objective is to determine existing volume, variable radius plot sampling is the appropriate sampling design. If the objective is to determine composition and structure, large fixed area plots are the appropriate sampling design. If the objective is to determine the occurrence of rare plants, very large fixed area plots are the appropriate sampling design. The CSE protocols are designed to address multiple objectives at varying intensity levels if the objectives are well defined prior to determining the sampling process.

SAMPLE DESIGN

Developing a sample design requires a clear identification of how the information will be used, the data needed to provide that information, and the budget available to collect the data. The goal is to produce a "statistically sound" sample. The cost of a decision error caused by an inadequate sample is often higher than the cost of taking more plots. A stand examination should be designed to obtain the necessary data at the lowest possible cost, and in the most efficient manner. Some of the factors affecting the sample design include:

- Required stand descriptors
- Final format of the data
- Budget
- Stand structure variability or complexity
- Resource data needs
- How soon the data is needed
- Degree of reliability

PLOT TYPES

There are three plot types: fixed radius, variable radius, and line transect. Each plot type has different strengths and weaknesses, provides efficiencies for different objectives, and is limited to certain applications. They may be used on the same setting at the same time.

The fixed radius plot design is best suited for obtaining estimates of per acre composition (e.g., trees per acre, species list, and site classification). This design is easy to implement and understand. It is often used for remeasured data since there are few complications in accounting for change over time. The size of the fixed area plot depends on the objective.

The variable radius plot is best suited for selecting large trees with higher probabilities rather than smaller trees. While per acre estimates are calculable with this design, many of the less frequent and/or smaller trees will not appear in the sample. This is advantageous for volume estimation but may not be suitable for estimating the frequency of rare plants.

Line transect sampling is an efficient way to collect data on down woody material. Only items crossed by a line are measured.

The common practice is to use a "Double Plot" system. This system includes a large plot and a small plot with the same plot center. The large plot can be variable or fixed radius plot designed to measure large trees. The small plot is generally a fixed radius plot designed to measure small trees, ground surface cover, vegetation composition, and down woody material. Trees are measured on the large or small plot based on diameter. The minimum diameter on the large tree plot is often set to 5.0 inches Diameter Breast Height (DBH) or 3.0 inches Diameter Root Collar (DRC).

If adequate dead tree information cannot be obtained on the variable or large fixed plot, a third plot size can be specified for dead trees. For example, a Basal Area Factor (BAF) of 40 can be used to sample large live trees and a BAF of 10 can be used to sample large dead trees.

If a regeneration survey does not include overstory data, then a single fixed radius plot is suitable. Timber stand improvement inspections commonly use a single fixed radius plot to determine contract compliance. This information can serve as an inspection plot for contract compliance and post-treatment inventory. Usually, reforestation and pre-commercial thinning surveys are designed to measure specific stand components (small trees). FSVeg allows for measuring other stand components to determine if the desired stand structure is met by including a variable radius plot.

An average of 4-8 live trees per plot is desirable. If a 10 BAF is used, the 4-8 trees per plot average standard is waived. Large fixed plot size may be from 1/10 acre to 1/1000 acre. If a 1/10 acre plot is used, the 4-8 trees per plot average is waived. For either method, the same BAF and fixed plot size must be used throughout the setting.

EXAM INTENSITY

The survey intensity is based on the stand complexity or the need for specific detailed information. Survey objectives should be well defined to assure the survey intensity meets the requirements.

QUICK PLOT

A quick plot exam may group trees by species, diameter, heights, and/or damage classes. Measurement tolerances are relaxed to allow for ocular estimation of many parameters. Limiting the information gathered and reducing measurement accuracy standards can significantly reduce cost.

EXTENSIVE

An extensive exam collects tree measurements to tolerance standards tither than a quick plot, but not as tight as an Intensive exam. Fewer data are required on each plot than with an intensive exam, but more data are required than with a quick plot exam.

INTENSIVE

An intensive exam collects accurate tree measurements to tight tolerance standards. It provides a comprehensive inventory for unique stands in their entirety.

SAMPLING METHODS

UNBIASED SYSTEMATIC SAMPLE

This is the recommended method for a statistically accurate and unbiased sample. The most common pattern is a grid with equally spaced rows and a constant distance between plots within rows. A systematic sample consists of installing a sample plot grid with a random start, over the stand area. Starting at the randomly selected point, plots are located at fixed directions and distances throughout the stand. The distance between plot centers varies according to the size of the stand, number of plots, and stand layout. Variations in stand layout include use of squares, parallel lines transects, and equilateral triangles.

The distance between plots for a square grid pattern can be determined by using a dot grid or by taking the square root of the number of square feet in the exam area divided by the number of plots. For example, the plot spacing for an 80-acre stand exam of 11 plots is:

$$\text{Plot spacing} = \sqrt{80\,acres \times 43{,}560\,squarefeet/acre \big/ 11\,plots}$$

$$= \sqrt{3{,}484{,}800\,squarefeet \big/ 11\,plots}$$

(80 *acres x* 43,560 *square feet/acre = 3,484,800 square feet)*

= 562.85 feet between plots

At least one plot per acre is installed. More than one plot per acre is required for an adequate sample (10% standard error of the mean within one standard deviation, or 68% confidence limits). In general, the smaller the stand, the more plots per acre required. For regeneration surveys the plot size is 1/100 are or larger, resulting in a minimum of a one percent sample of the area.

Systematic sampling is without replacement and provides uniform distribution of plots throughout the stand. The end product is a map, where subdivision of the stand can occur, since each plot represents an area. The disadvantage is it may be costly to implement because of travel time between plot centers

BIASED SYSTEMATIC SAMPLE

There are two biased sampling methods: (1) the representative sample plot method, and (2) the transect cross-section method. For the **representative sample plot method**, the field crew selects a plot(s) on the ground that best represents the stand attributes that are targeted for sampling.

For the **transect cross-section method**, a line is established through the long axis of the stand, or diagonal to drainages and ridges. The line should give a good representation of the stand. The total length of the line is measured in ground distance. Divide the ground distance by the number of plots, plus 1, to get plot interval. Space the plots equal distances along the line. Locate plots by the hand compass and pacing.

NUMBER OF PLOTS

The exam objective is to obtain a reliable estimate at minimum cost. To reach this objective, the sampling error can be fixed and the minimum number of plots computed. The number of plots varies depending on the exam objective. The following describes minimum standards. If a more reliable estimate is desired, the number of plots may be increased.

The minimum number of exam plots is based on the homogeneity of the sample unit. Homogeneity consists of landform (aspect, slope, configuration, etc.), stand density, over story composition, and habitat type. For example:

- More than 90% of the stand has uniform stand density
- One dominant habitat type
- Uniform over story composition
- Aspect varies less than 20 degrees from average

A general rule is:

- If the stand is homogeneous, plan one plot per 10 acres, a minimum of three plots for stands less than 10 acres.
- If the stand is not homogeneous, plan one plot per 5 acres, a minimum of two plots for stands less than 5 acres.

If the above general rule does not provide the necessary accuracy, the sampling error can be fixed and the number of plots computed using the following formula:

$$\text{Number of plots} = \frac{t^2 CV^2}{E^2}$$

This formula estimates the number of plots with one standard deviation. The true value of the estimate is within ± the sampling error percent, 68.4% of the time ($t = 1$).

The sampling error used is dependent upon the exam objective. Experience in statistically analyzing stands will help predetermine the number of plots for various types of stands. A sampling error of 10-20% is generally adequate for most uses of the exam data. The sampling error shown in reports can be used as a measure of how well the stand exam met the expected sampling error. Stand size does not directly influence the number of plots needed for a given accuracy, however larger stands generally have more variation as measured by the coefficient of variation.

The coefficient of variation (CV) in the above formula is the ratio of the standard deviation to the mean. It facilitates comparisons of variability about different sized means. To determine the number of plots, CV must be estimated on the basis of experience in similar stands or calculated. The following examples of stand structures include experienced CVs that could be used.

Note: This discussion of CV uses “trees per acre” as the stand attribute of interest. Some stand attributes, such as the number of snags per acre, may have an entirely different CV, and may require an entirely different sample design depending on the exam objectives.

Examples of Stand Structures

Low Coefficient of Variation (Range .27-.42, Average .34)

- Homogeneous
- Diameter and heights are same or similar
- Continuous canopy, even spacing or closure
- No openings or holes
- Single-storied
- Even-aged
- Photo texture fine and smooth

Low to Medium Coefficient of Variation (Range .20-.68, Average .41)

- Similar to low, except some type of stocking control
- Homogeneous
- Few or no openings or holes
- Mostly single-storied
- Mostly even-aged
- Photo texture fine to medium
- Low tree defect (minor sweep and crook)

Medium Coefficient of Variation (Range .22-.65, Average .42)

- Moderate range of diameters and heights
- Could be multi-storied
- Even-aged to all-aged
- Photo texture medium to rough
- Minimal tree defect, ≤5%
- Minimal past logging
- Mature, ≥100+ years
- Could have some scattered over story

Medium to High Coefficient of Variation (Range .22-.73, Average .53)

- Could be two-storied or multi-storied
- Uneven-aged or all-aged
- Photo texture coarse
- Tree defect medium to high, ≥10%; root rots, stem decays
- Evidence of past logging; roads or small holes as a result
- Could be decadent
- Patchy and/or clumpy

High Coefficient of Variation (Range .41-1.22, Average .78)

- Multi-storied to mosaic
- Photo texture fine to rough, open parks, changes in color
- Past logging or fire
- Wide variation between young saplings to over-mature timber
- Spacing is irregular, scattered, widely spaced crowns

CV Calculation

The CV can be calculated using the following formulas for stands that do not fit any of the above descriptions:

$$\text{Coefficient of Variation (CV)} = \frac{\text{Standard Deviation (SD)} \times 100}{\text{Mean Value } (X_{ave}) \text{ average trees per plot}}$$

To calculate CV, the standard deviation (SD) and means must be determined. The SD is a measure of the dispersion of values about the mean. The mean is the average of the actual value. The standard error (SE) is the standard deviation of sample means about their mean. The sampling error (E) is the difference between the sample estimate and tree value being estimated, as a percentage of the sampling mean. An example to determine the number of plots needed for a 20% sampling error (E = 20%) is shown below.

1. Determine the CV from a set of sample data

Table 1: Calculate trees per plot

Plot Number	Trees per plot (X)	(Trees/plot)^2 (X^2)
1	2	4
2	4	16
3	1	1
4	3	9
5	2	4
	$\sum X$ = **12**	$\sum X^2$ = **34**

2. Determine average trees per plot (X)

$$X_{ave} = \frac{trees/plot}{\#\ plots} = 12/5 = 2.4 \text{ trees per plot}$$

3. Determine the standard deviation (SD)

$$SD = \left\{ \left[\sum X^2 - \left(\left(\sum X\right)^2 / \#\ plots \right)\right] / (\#\ plots - 1) \right\}^{1/2} = [34 - (12^2 / 5)] / (5-1) =$$

approx. 1.14 trees per plot

4. Determine the coefficient of variation

$$CV = (SD/X_{ave}) = (1.14/2.4) = .4750$$

5. Express CV as a percent

.4750 x 100 = 47.5%

6. Determine the standard error (SE)

$$SE = SD/\sqrt{\#\text{ of plots}} = 1.14/\sqrt{5} = .51$$

7. Determine the sampling error (E%)

$$E\% = (SE/X_{ave}) \times 100 = (.51/2.4) \times 100 = 21.25\ \%$$

8. Determine number of plots for a 20% sampling error

$$\text{Number of plots} = (CV^2 / E^2) = (47.50^2)/21.25^2) = 4.9966 \text{ plots}$$

PLOT SIZE

BASAL AREA FACTOR

The proper Basal Area Factor (BAF) is dependent upon stand density and size. Plots should average 4-8 large tally trees per plot. This will provide adequate diameter distribution data. If a site estimate of average basal area per acre is available, divide the basal area by the desired number of tally trees per plot to determine the correct BAF. Local experience and data from other exams, inventories, or cruises, may indicate the correct BAF. Once a BAF has been selected and used on the first plot, it must be used throughout the exam. A single stand cannot be examined with multiple basal area factors.

FIXED PLOT SIZE

The fixed plot radius should be larger than the average spacing between the sample trees. Plot radius should be large enough to include a sufficient number of trees for meaningful stocking information. If a fixed area plot is too small, the plots could fall into "holes" and not measure any trees. The exam data may incorrectly indicate an under-stocked stand.

Table 2: Fixed plot size and radius

Fixed Plot Size	Fixed Plot Radius
1 acre	117.75 feet
1/2 acre	83.3 feet
1/3 acre	67.9 feet
1/4 acre	58.9 feet
1/5 acre	52.6 feet
1/10 acre	37.2 feet
1/50 acre	16.7 feet
1/100 acre	11.8 feet
1/150 acre	9.6 feet
1/200 acre	8.3 feet
1/250 acre	7.4 feet
1/300 acre	6.8 feet
1/400 acre	5.9 feet
1/500 acre	5.3 feet
1/1000 acre	3.7 feet

CALCULATE SAMPLE SIZE (TUTORIAL)

Calculating sample size refers to the **number** of plots, not the **size** of each plot.

Know what you are sampling for. Before determining the correct number of plots, identify:

- **Population type** – what are you analyzing
- **Purpose of the analysis** – what you are trying to decide
- **Relevant variable** – the population attribute of most importance to your analysis
- **Justification** – why you should consider using this variable to calculate sample size

The sample size will vary depending on your choice of sample variable. Table 3 offers a few suggestions.

Table 3: Population types and information

Population Type	Purpose of the Analysis	Relevant Variable	Justification
Seedlings and Saplings	Whether to thin or plant (Yes/No)	Trees per acre	The prescription will be based on actual and desired stem density.
Merchantable Second Growth	Is the stand ready for commercial thinning?	Basal Area	Basal Area is the basis for existing and desired Stand Density (Stand Density Index or Relative Density)
	Can you afford to thin commercially?	Net Board Feet or Net Cubic Feet per Acre	Merchantable volume is the basis for value. Keep in mind that cut volume pays the bills, but is likely to have a higher variance than total volume.
Mature Stands	Which stands have priority for harvest?	Net Board Feet or Net Cubic Feet per acre	Merchantable volume is the basis for value. Variances are usually lower (= fewer plots)
Wildlife Trees	Do you have enough trees for sustainable habitat?	Trees per acre	Basal Area and Volume have no relevance. Expect high variances (high variances may be acceptable)

Population Type	Purpose of the Analysis	Relevant Variable	Justification
All Stands	Post Treatment Conditions	Use the variable you used in prescribing treatment objectives	• Planting and pre-commercial thinning: trees per acre • Commercial thinning: Basal Area and Volume • Mature stands: Volume

ESTIMATE VARIABILITY

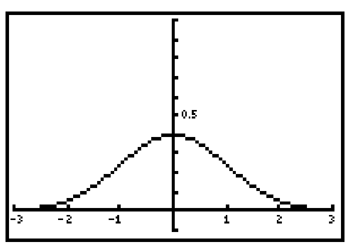
Population and Sample

The **population** (N) is all the units (in this case, plots) that could be sampled in a given area. The **sample** (n) is a subset of the population that was actually measured. The goal of statistics is to say something about the entire population by just looking at a small sample.

Standard Deviation (S_y)

The **standard deviation** is the "mean of the mean," and can often help you find the story behind the data. To understand this concept, it's helpful to understand the term normal distribution. A normal distribution of data means that most of the examples in a set of data are close to the "average," while relatively few examples tend to one extreme or the other.

Figure 1: Normal distribution, bell-shaped curve



The standard deviation tells you how tightly all tree measurements are clustered around the mean in a set of data. When the examples are tightly bunched, the bell-shaped curve is steep, indicating a relatively large standard deviation. In a normally distributed population, on average, about 66% of the values of a population will be within one standard deviation of the mean; about 95% will be within two standard deviations; and about 99% within 2.6 standard deviations.

Standard deviation is calculated by taking the distance of each number (x) from the mean ($\bar{x}$), squaring it, averaging the result, then taking the square root. It is the root mean square of the distances (or differences and therefore *deviation*) from the mean. It's usually abbreviated as SD, σ , or S_y.

$$S_y = \sqrt{\frac{\sum (x - \bar{x})^2}{n - 1}}$$

Coefficient of Variation (CV)

The **coefficient of variation** is a measure of the deviation of a variable from its mean. In nature, populations with large means often show more variability (i.e,. a higher standard deviation) than populations with smaller means. The coefficient of variation is the standard deviation expressed as a percent of the mean. It is calculated by dividing the standard deviation by the mean:

$$CV = \frac{Sy}{x} \times 100$$

Variance (S_y^2)

The **variance** is a measure of how spread out a distribution is. It is computed as the average squared deviation of each number form its mean (the square of the standard deviation).

Use your experience in similar stands to establish an estimate of the population variance. If you have already taken some plots in a stand, you can calculate variance directly (with data, you would use the previous equation for standard deviation then square it to get a "true" variance). If you do not know the variance, you can estimate it with the following equation, even if you don't have data. For example:

$$S_y^2 = \left(\frac{R}{4}\right)^2$$

Where:

- Sy^2 = population variance
- R = the range between the highest and lowest expected value

Example:

- With a BAF of 40, you decide all plots will have at least four trees (= 160 sq. ft. of Basal Area)
- No plot will have more than 10 trees (=400 sq. ft.)
- Therefore:

$$R = 400\text{-}160 - 240$$

$$S_y^2 = (240/4)^2 = (60)^2 = 3600$$

KNOW YOUR COMFORT LEVEL

Confidence Interval

The **confidence interval** is the likely range of the true value of the mean. There is only one true population mean, which can only be obtained by measuring all the trees in a stand (an extremely labor-intensive, unrealistic task). Instead of measuring every tree, samples are used to calculate a range in which the population mean is most likely to fall. A sample is only an approximation for the population; the mean is also an approximation of the "true" or population mean. If you drew a different sample, you'd get a different mean.

The confidence interval defines this range where the population mean is most likely to fall. It is like a target size or allowable margin of error. It is easier to hit big targets than small targets so a broad margin of allowable error is more likely to include the sample mean.

The values at either end of the interval are called the confidence limits. The difference between the upper and lower confidence limits is the confidence interval.

The confidence interval is always expressed in the same units as the mean. If you want to establish the mean basal area per acre of a stand, your confidence intervals must also be stated in terms of basal area per acre.

For example, a commercial prescription thinning of a stand with 300 square feet of basal area per acre is ± 45 square feet.

The prescription won't change if the basal area per acre is as low as 255 square feet or as high as 345 square feet:

- Below 255 square feet – you might postpone commercial thinning
- Above 345 square feet – you might consider regeneration cutting

Your confidence interval is 45 square feet per acre (or 15%, if 300 square feet per acre).

Set Your Odds – Confidence Level

Once you have decided on the confidence interval, you need to decide the margin of error, or **confidence level**, you will accept for being within that confidence interval. In other words, how important is it that your estimate is correct? If the consequences of an error are minor, you might accept a reasonable chance of being off-target with your estimate. Severe consequences, however, may lead you to maximize your chance of being on target, or conversely, minimize chances that you'll miss your target.

For example, two or three plots might give you a 40/60 chance of being on target—over half the time, you'll miss your target because such a small sample won't capture the variation within the stand. This is unacceptable for many forestry analyses. More appropriate margins of error are a one in three, one in 20 (95% confidence level) or one in 100 (99% confidence level) chance of being on target. A 95% confidence level is sufficient for establishing the value of a forestry project, such as stumpage value for a timer sale appraisal.

The confidence level is the probability value associated with a confidence interval. It is defined as:

(estimate of the mean) $\pm t$ (standard error)

Where *t* is usually derived from a table.

The value for *t* depends on two things:

1. The number of sampling points (n) or plots in this case (n-1 = degrees of freedom)
2. How much certainty is needed (i.e., do we want to be 95% or 99% sure that the true mean is within the confidence limits?)

Table 4: Student's *t*

Df	70%	80%	90%	95%	99%
1	1.963	3.078	6.134	12.706	63.657
2	1.386	1.886	2.920	4.303	9.925
3	1.250	1.638	2.353	3.182	5.841
4	1.190	1.533	2.132	2.776	4.604
5	1.156	1.476	2.015	2.571	4.032
6	1.134	1.440	1.943	2.447	3.707
7	1.119	1.415	1.895	2.365	3.500
8	1.108	1.397	1.860	2.306	3.355
9	1.100	1.383	1.833	2.262	3.250
10	1.093	1.372	1.812	2.228	3.169
11	1.088	1.363	1.796	2.201	3.106
12	1.083	1.356	1.782	2.179	3.055
13	1.079	1.350	1.771	2.160	3.012
14	1.076	1.345	1.761	2.145	2.977
15	1.074	1.341	1.753	2.131	2.947
16	1.071	1.337	1.746	2.110	2.921
17	1.069	1.333	1.740	2.110	2.898
18	1.067	1.330	1.734	2.101	2.878
19	1.066	1.328	1.729	2.093	2.861
20	1.064	1.325	1.725	2.086	2.845
21	1.063	1.323	1.721	2.080	2.831
22	1.061	1.321	1.717	2.074	2.819
23	1.060	1.319	1.714	2.069	2.807
24	1.059	1.318	1.711	2.064	2.797

Df	70%	80%	90%	95%	99%
25	1.058	1.316	1.708	2.060	2.787
26	1.058	1.315	1.706	2.056	2.779
27	1.057	1.314	1.703	2.052	2.771
28	1.056	1.313	1.701	2.048	2.763
29	1.055	1.311	1.699	2.045	2.756
30	1.055	1.310	1.697	2.042	2.750
Infinity	1.036	1.282	1.645	1.96	2.576

Put It All Together – Calculate the Number of Plots

Once you have chosen the relevant variables, estimated variance, confidence interval, and confidence level for your analysis, you can calculate the number of plots.

Depending on the scenario you choose, you can use one of several equations, shown below, to calculate the number of plots. All of the equations are derivatives of the same formula, they differ on the level of confidence or margin of error you want to place on your analysis. They are short-cuts to the standard statistical formulas.

$$n = \frac{t^2 Sy^2}{E^2}$$

Where:

- n = the number of plots you need
- S_y^2 = population variance (can be on any useful scale of measurement)
- E = the specified error you set as the maximum; the confidence level; allowable margin of error (must be on the same scale as the population variance)
- *t* = value selected from the table of distribution of Student's *t*

Table 5: Confidence level equations

Odds (confidence level)	Quickest Equation	Use
Three to one $(t^2 = 1^2 = 1)$	$N = \frac{1S_y^{\ 2}}{E^2}$	When you plan to write a silvicultural prescription or set treatment priorities among stands
20 to one $(t^2 = 2^2 = 4)$	$N = \frac{4S_y^{\ 2}}{E^2}$	When money will change hands on your estimate, such as timber appraisal

Odds (confidence level)	**Quickest Equation**	**Use**
100 to one ($t^2 = 2.576^2 = 6.666667 = 20/3$)	$N = \frac{20S_y^2}{3E^2}$	When you have a lot of money for stand exams and you can't afford to be wrong
Complete range of options	$N = \frac{t^2 S_y^2}{E^2}$	When you want to fine-tune an elaborate study When you plan to use the exam to support a research project

The odds are a rough probability or chance that the population mean will be within the acceptable margin of error (±E). Remember, you must define your margin of error in the same terms as the variance—board feet per acre, number of trees per acre, basal area per acre, etc. You cannot mix them.

All formulas are equivalent. If you know your required odds (confidence level) in advance, the first three formulas allow you to calculate without consulting the Student's *t* table (Table 5).

Summary

For a given confidence interval, identify your confidence level, convert it to a probability, and calculate the number of plots using the appropriate equation.

If you have taken a preliminary sample, or have appropriate data from a similar stand, choose a *t* value from the Student's *t* table (Table 5). To do this, read the value from the row represented by n-1 degrees of freedom from n is the number of plots in the preliminary or existing sample.

Example

You are using a 40 BAF in a second-growth stand. Based on your experience in similar stands, you expect to find no less than three, no more than 10 trees on every plot. How many plots do you need?

1. Estimate the variance

$$S_y^2 = \left(\frac{R}{4}\right)^2 = \left(\frac{(40x10)-(40x3)}{4}\right)^2 = \left(\frac{(400)-(120)}{4}\right)^2 = \left(\frac{280}{4}\right)^2 = 70^2 = 4900$$

2. Specify the allowable margin of error (confidence interval); for example, 10% of 300 sq. ft. of basal area per acre is 30 square feet of basal area per acre
3. Establish the odds (confidence level) you are willing to accept that the true mean or total will be within the margin of error you set in Step 2. For example, 20 to one
4. Enter the values in the formula and calculate.

$$n = \frac{t^2 Sy^2}{E^2} = \frac{4S_y^2}{E^2} = \frac{4x4,900}{30^2} = \frac{19,600}{900} \sim 22$$

Food for Thought: For three to one odds, you need just six plots. What's the worst that can happen?

Tips

- Unless the stand is very small and the plots are large, the population is not statistically finite. For example, a stand exam in a campground might require that you account for a finite population.
- One Standard Deviation gives three to one odds that the mean will be within the margin of error you are willing to accept. Two Standard Deviations gives 20 to one odds and three Standard Deviations gives 100 to one odds. With the table of Distribution of Student's t (Table 5), you can fine-tune the odds to meet your needs by selecting a different probability column.
- Using more than one Standard Deviation will result in a sample size so high you cannot afford it without materially improving the quality of your analysis. Save your money to do more stands.
- Ask yourself "Will my decision or prescription for this stand change if the variable I based it on turns out to be more than 15% off my estimate?" If the answer is no, you can comfortably go ahead with the indicated number of plots. You may have to explain your minimal sample but your decision will be OK.
- You are close to the go/no-go margin when you think your prescription would change if the variable turns out to be more than 15% off the estimate. The question then is "Am I willing to bet three to one odds that the decision I make based on this average is right?" If your answer is still yes, you've successfully established the number of plots you need.
- If you or your boss won't accept those odds, start looking at a 10 percent confidence interval. You will need more than twice as many plots for three to one odds on an error of no more than 10% of the mean. To reduce your acceptable error with three to one odds from10% to 5% of the mean, you will need four times as many plots.
- You have enough plots when you think that your decision or prescription won't change even if your data turns out to be on the unlucky side of three to one odds. Looking at it another way, if you like the confidence interval but don't like three tone odds, you can recalculate for 20 to one odds or even 100 to one odds.

Suggested Readings

- A New View of Statistics by Will G. Hopkins; uses examples from the sports field
- Booklets adapting statistics to forestry by Frank Freese:
    - "Elementary Statistical Methods for Foresters"
    - "Elementary Forest Sampling"
    - "A Guidebook for Statistical Transients"

PLOT CONFIGURATION

Once the number of plots is known, plot location must be determined. Plots can be randomly or systematically distributed using line transects, cluster plots, or grids. Plot configuration can vary between projects based on the intensity of the sample and required data.

RANDOM DISTRIBUTION

The first plot is selected by choosing a random azimuth and a fixed distance into the stand using a table of random numbers. Additional plot centers are installed at fixed distances but random directions from each other. If the random direction makes a plot fall outside the stand, another azimuth is randomly chosen. Variations include using a random azimuth and random distances. This configuration may be difficult to implement.

LINE TRANSECTS

A line is placed using a randomly selected starting point and a random direction either along or across the contours. The line is drawn on the aerial photo or stand map and its length measured. To obtain the distance between plot centers, the line length is divided by the number of required plots. Plots are placed along the transect line at calculated intervals on either side of the starting point. Sampling is without replacement. Knowledge of the stand is needed to ensure the line does not cross stand boundaries or fall near a boundary edge.

CLUSTER PLOTS

Cluster plots consist of three to 10 subplots systematically distributed around a randomly selected starting point. The cluster pattern is determined prior to sampling. Subplots are located at a specified distance and azimuth from each other.

The cluster plot is very efficient when variability within the cluster is high, but the variation within the stand is low. Subplots within the cluster are usually as widely spaced as possible for maximum dispersion on measurement of variation across the stand. If the initial subplot falls close to the edge of the stand, it should be substituted for another subplot that falls in the stand.

Subplots are frequently similar since the subplots within a cluster plot are located close to one another. The cluster plot may provide less information than randomly located independent points. Cluster plots yield cost effective data due to reduced travel time.

GRID

The most common configuration is a grid with equally spaced rows and an constant distance between plots within rows. The grid is started at a routinely selected first plot. Additional plots are located at fixed directions and distances throughout the stand. The distance between plots varies according to the stand size, number of plots, and stand layout. Variations in stand layout include use of squares, parallel lines transects, and equilateral triangles. Distance between plots can be determined by using a dot grid or by taking the square root of the total square feet in the exam area divided by the number of plots.

PLOT LOCATION

To avoid biasing the sample, it is important to find the exact location of each sample plot, as pinpricked on the aerial photograph. The scale and orientation of the aerial photo must be determined in order to accurately locate a plot on an aerial photo.

STEP 1: SELECT A REFERENCE POINT

The Reference Point (RP) references the first plot. It is usually a tree that is prominent, apt to be present at the next visit, and easily located on the ground. Select an RP near the first readily identifiable pinpricked plot on the photo and on the ground. The reference point should be a tree, rock, house, fence, or other permanent object. It should be 600 feet or less form the first plot, if possible. A permanent reference point, farther than 600 feet is preferable to a close reference point that is not permanent. After selecting the reference point, prick it on the photo, circle, and label it "RP" on the back of the photo. Enter this information in the setting remarks. If more than one reference point is used, label them consecutively starting with "RP1."

Reference points must be adequately marked so that quality control personnel can relocate each plot. Drive a stake at the reference point and mark it with flagging. On the flagging, write "RP," RP number, stand number, true azimuth, and distance to first plot with a waterproof marker. Record this information on the stand sketch map.

STEP 2: PHOTO AZIMUTH AND DISTANCE

Determine the azimuth and distance from the reference point to the first plot as follows:

- On the photo, scribe a line connecting the RP and the first plot
- Record the azimuth from the RP to the first plot
- Using the proper photo scale, measure the distance, on the photo, from the RP to the first plot
- On the back of the photo, record azimuth to the nearest degree, and distance to the nearest 12.5 feet

STEP 3: LOCATE FIRST SAMPLE PLOT ON THE GROUND

Use a compass and a 100-foot tape to measure from RP to the first plot. Use the calculated direction (azimuth) and distance recorded on the back of the photo. Correct for slope. Upon arrival at the first plot, check the photo to determine if you are at the correct location. If the ground location is clearly not the point pinpricked on the photo, move to the correct point on the ground, note the correct direction and distance on the back of the photo and in the setting remarks. Stand conditions or cover should not influence this shift.

STEP 4: SAMPLE PLOT MARKING

Mark each plot with a wooden, metal, or plastic stake (do not use tree branches) driven securely into the ground. Tie flagging securely to the stake, and mark plot number and stand number on the flagging with a waterproof pen. Hang additional flagging at eye level on vegetation overhanging plot center, or hang as near as possible to plot center. Facing plot center, use aerosol paint to mark the first variable tree at each plot with plot number and tree number. Or, tie flagging securely around the first tree at DBH.

The azimuth and distance to subsequent plots can be measured from the photo. In some cases where plots are distributed over a large area or where stands are on more than one photo, it may be necessary to establish more than one base line and/or reference point to accurately locate the pinpricked plots.

Leave flagging at least every two chains along the traverse line between plots. When a change in direction is made at a location other than a plot, two flats should be securely tied to a tree limb or other suitable object. One flag should have the change in azimuth written on it with a waterproof marker.

STEP 5: SKETCH MAP

Include a good sketch map with the setting data. The map does not have to be a particular scale, but should be large enough to label all plot locations. Indicate starting point, inter-plot distance, and azimuths. Include an arrow referencing magnetic North. Note cardinal directions, roads, trails, and other physical features that assist in relocating plots.

General comments and observations concerning the setting and plots should be included in the remarks. Do not repeat codified information. Indicate appropriate conditions or variations not represented by the plots, such as riparian areas, intensive wildlife use, large rock outcrops, adjacent stand conditions, possible archaeological sites, accelerated soil erosion or slumps, and genetically superior tree candidates.

QUALITY ASSURANCE & QUALITY CONTROL

Quality Assurance and Quality Control (QA/QC) has historically been given little importance due to expense and limited knowledge on how to use the information. The first step is to set the **measurement standard** that defines how to acquire the data. This varies by exam type. For example, on quick plot exams, DBH may be measured in two-inch classes. On intensive exams, DBH must be measured to the nearest 1/10 inch. The next step is to set the **accuracy standard** that defines the acceptable range about the measurement standard, or how well the data must be collected. The accuracy standard is defined as the acceptable range (±X%) about the measurement standard.

Each data field in this manual has an associated measurement and accuracy standard. Many exam collection contracts are written to these QA/QC specifications. However, this does not insure that the accuracy objectives have been attained. To determine if the standards have been met requires revisiting the site and re-measuring a sub-sample of the plots. The comparison of the two sets of measurements can be used to determine the accuracy of the data, and with proper analysis, adjustments can be made. Data that is obviously far outside of the accuracy standard should not be stored in the FSVeg database.

Data Collection Equipment Checklist

Data Recording Items

- Hand-held data recorder (PDR) and extra batteries
- GPS unit with fully charged batteries
- Mechanical pencils, red photo pen, black pen, eraser, waterproof marker or grease pencil
- Blank forms if not using a PDR
- Tatum and tatum aids
- CSE Field Guide
- Plant ID guide, plant association guide, and plant disease guide

Photo Interpretation Items

- Aerial photo (stereo pair is helpful)
- Stereoscope (2x and/or 4x) with case and sharp straight pins
- Photo scale (Timber Survey Aid #16)
- 6-inch ruler calibrated with 1/20th inches
- Hand lens
- Needle, mounted in a retractable ball point pen

Plot Measuring Items

- Compass, azimuth type with declination set screw
- Relascope
- Diameter tape, scaled in inches and tenths of inches
- Increment borer with sheath
- WD-40 to clean increment borer of pitch
- Loggers tape, 75-foot or 100-foot, scaled in feet and tenths of feet
- Hand axe, hatchet, or pocket knife with sheath
- Laser height/rangefinder or clinometer
- Flagging tape
- BAF angle gauge, prism, or Relaskope
- Boxwood scale in twentieths of an inch
- Binoculars
- Cruiser vest or small backpack
- Calculator

First Aid Items

- First aid kits
- Bee sting medicine
- Snake bite kits
- Sunscreen
- Bug repellent

PERSONNEL AND SAFETY GEAR

- Canteens with water
- Lunches
- Vest and hardhat
- Rain gear
- Gloves
- Flashlight and batteries
- Extra clothing
- Extra food

SAFETY

Personnel working in the field are subject to safety hazards. Each person must always be conscious of these hazards to avoid accidents:

- Don't take chances!
- Eliminate horseplay and carelessness!
- Think safety!
- No task is more important than personal safety!
- Always make sure that someone else knows where you plan to work each day!

SAFETY IN THE WOODS

Wear protective clothing. Long-sleeved shirts, long pants, and gloves provide protection from brush, rocks, poison oak, and stinging insects. Trouser legs should be loose enough to avoid binding of cramping, and should not have cuffs. Wear a hardhat at all times. During hunting season, wear bright red or orange clothing.

Wear good quality boots that provide good support and traction. For example, 8-inch leather work boots with lug-soles (Vibram-type soles).

Walk. Do not run in the woods. Take your time and plan your route. Avoid plunging through the brush. The best route of travel may be the shortest. Routes across brushy, irregular terrain with rocks and down logs can be hazardous.

Be watchful of twigs and branches, which may cause eye injury. Be especially alert when stepping up to trees, which retain their small dead twigs. Keep sufficient distance between you and person the persons before and behind you to avoid being slapped by branches.

Lift knees high to clear obstacles in heavy undergrowth or slash. Slow down and watch your step.

When contouring a steep slope, do not lean into the hill. This tends to loosen footing. Erect posture or slightly leaning out gives more secure footing.

Know how to fall to avoid hard impacts. Keep flexible with knees slightly bent. If you feel yourself slipping, pick a landing spot. Do not stick your arms out to break a fall. Roll with the fall. Try to take the impact on the side of your body rather than your back.

Don't take chances by walking across ravines on small logs.

Bee aware. Keep an eye out for yellow jacket and hornet activity. Yellow jackets nest in the ground, often in well-decayed logs or in thick moss on trees or in snag cavities. Yellow jackets are particularly active (nasty) during late summer and early fall when forest conditions are very dry. Hornets nest above ground in "paper" nests that are suspended from branches; woe befalls those who unwittingly bump their head against a nest, or shake the sapling from which a nest is suspended. If allergic to insect stings, carry medication to counteract the effects of stings.

Be alert to rattling or buzzing noises. Look before putting hands or feet on or under rocks and logs. Be alert when walking in snake-infested areas.

Avoid poison oak, if possible. Place oil on exposed skin before going into the field. After contact with poison oak, remove clothes carefully, wash exposed areas with cool, soapy water, and wash clothes before wearing them again.

Keep someone posted as to where you plan to work each day, particularly on long hikes into the forest, so that if you do not return in a reasonable time, someone can find you.

Keep hatchets in their sheath except when actually using them, and snap the sheath shut.

First Aid. Keep your individual first-aid kit completely supplied, and know how to use it. Treat all wounds promptly. Each vehicle is supplied with a large first-aid kit—keep it stocked.

Carry matches and a small flashlight. On long hikes, take extra food, clothing, and matches in case you are caught out in the woods at night. Never build fires in forest duff or leave a campfire until it is dead out.

Check for ticks. They carry Lyme disease.

Carry plenty of water. Don't expect your partner to carry water for you.

Beware of lightning. Watch for approaching storms. Avoid prominent high exposed ground and tall/lone trees. Abandon field gear, especially gear made of metal. Seek shelter in the vehicle if possible, otherwise in thick timber, large caves, or in valley bottoms Crouch on the balls of your feet with your head covered. Separate 100 feet from other crewmembers.

SAFETY ON THE ROAD

It all pays the same, so drive with care, with courtesy, regardless of others' actions, and with common sense. Follow these tips.

Seat belt is required in all government-owned or leased vehicles. Do not ride in the back of pickups.

DRIVE DEFENSIVELY! Expect the other person, whether a vehicle operator or a pedestrian, to do the worst thing and be prepared. Observe all speed regulations and traffic signs.

Do not drive when sleepy, taking medication, or when other personal conditions make it unsafe to drive a vehicle. Get someone else to drive or, if alone, stop driving and nap (out of the public view).

Always drive with your headlights on. This practice increases the visibility of your vehicle. It is particularly important when driving in fog, on dusty roads, traveling in and out of shadows, and any other low light/visibility situations. Turn lights off when you park the vehicle.

Do not operate a vehicle in an unsafe condition. Check your vehicle frequently to keep it in good mechanical condition. Lights, horn, steering, and brakes should be kept in proper adjustment at all times. Make necessary repairs as soon as unsafe condition develops. Report any unsafe conditions to your supervisor.

Keep the vehicle clean. Windows, mirrors, and lights should be kept clean and free of obstructions to increase visibility. Keep the cab and driver area clean so material is not rolling under pedals or distracting the driver.

Shift to a lower gear at the beginning of a grade if the grade is a long, steep descent Adjust vehicle speed to the driving conditions. Wet, icy, or snowy roads and decreased visibility require decreased speed. Be aware of speed when changing from one type of road to another, i.e., freeway to secondary highway to gravel, and adjust speed accordingly.

Don't tailgate. Allow at least three seconds of travel distance between yourself and the vehicle ahead. Under slippery road conditions and poor visibility, allow more distance.

Be aware of your vehicle's idiosyncrasies and adjust your driving accordingly.

Be alert for heavily loaded trucks moving at high speeds when driving on privately owned log-haul roads. Observe all traffic control signs, particularly signs requiring you to drive on the left side of the road.

Back up safely. Walk around your vehicle to check for hazards before backing and use a spotter to guide you.

Do not drive and navigate at the same time. If the driver needs to look at maps and photos, stop at a safe place, and then look at them.

Watch for animals on the road. Most hoofed animals travel in groups, so where there is one, assume there are many, with all just itching to jump out in front of your vehicle. Stop and let the animal move off the road, look for others to follow, and then proceed on. If you cannot stop in time to avoid hitting an animal, it is generally better to hit it, than to go off the road or hit another vehicle.

Park the vehicle so that it is not a hazard to other drivers. Do not park where dry grass or other potential fuels can come in contact with your vehicle's hot exhaust system.

Keep as far right as is safely possible on blind curves on logging roads. If the curve is blind and less than two lanes wide, slow way down and be ready to take evasive action.

Yield to uphill vehicles on roads wide enough for only one vehicle.

WHAT TO DO IF INJURED

Treat the injury promptly. If immediate medical attention is required, go directly to a hospital emergency room. Try to make contact with your supervisor or the office to get instructions and assistance. Make sure the doctor fills out his/her part on the CA-1 form.

Inform your supervisor of all injuries and ask which, if any, forms need to be filled out. Supervisors must inform the office at the earliest opportunity.

Fill out Federal accident forms completely with signatures. ALWAYS make a copy for your personal records. Give the completed forms to your supervisor. Have the supervisor check your entries for mistakes, fill out their section, and forward the completed forms to the appropriate person.

Gather information. If you are in a multi-vehicle accident, provide the other parties with enough written information so that they can easily get in touch with you, your crew supervisor, and the office. In turn, you must get the following information from all involved parties and witnesses—names, addresses, phone numbers, vehicle license numbers, driver's license numbers, insurance company names and policy numbers, and police report numbers. If possible, do not admit responsibility without first contacting your supervisor.

REGION AND/OR SPECIFIC PREPARATION AND DESIGN INFORMATION