

Chapter 9: Marking and Assessing Forest Heterogeneity

M. North¹ and J. Sherlock²

Introduction

Marking guidelines commonly use stocking level, crown class, and species preferences to meet management objectives. Traditionally, these guidelines were applied across the extent of the stand. Current marking guidelines are more flexible, responding to within-stand variability with different stocking level, crown class, and species preference guidelines in response to fine-scale variability in forest structure and composition. By varying marking guidelines within stands, managers can meet potentially conflicting prescription objectives such as reducing crown bulk density while maintaining an average target canopy cover (Sherlock 2007). In this chapter, we discuss marking guidelines that may help explicitly implement a fine-scale response to within-stand variability and provide ways of measuring and assessing posttreatment heterogeneity. The emphasis in U.S. Forest Service General Technical Report PSW-GTR-220 “An Ecosystem Management Strategy for Sierran Mixed-Conifer Forests” (North et al. 2009) is still on using topography to help vary treatments, but silviculturists also need to respond to the stand conditions they have to work with.

In forests with frequent, low-intensity fire regimes, fine-scale heterogeneity makes it difficult to identify and demarcate stands (“group(s) of trees and associated vegetation having similar structures and growing under similar soil and climatic conditions” [Oliver and Larson 1996]). Structure analysis at the Teakettle Experimental Forest found that mixed conifer was made up of three

¹ Research ecologist, U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, 1731 Research Park Dr., Davis, CA 95618.

² Assistant regional silviculturist, U.S. Department of Agriculture, Forest Service, Pacific Southwest Region, 1323 Club Dr., Vallejo, CA 94592.

Summary of Findings

1. **GTR 220 suggests creating three general patch conditions: tree groups, gaps, and a matrix with a low density of large, preferably pine, trees.** The relative proportion of these three patch conditions may change with topographic position and in response to the forest conditions managers have to work with.
2. **It may help marking crews to first identify tree groups and gaps as anchor points around which to mark the remainder of the treatment area.** Reconstruction studies suggest most tree groups and gaps were 0.1 to 0.5 ac (0.04 to 0.2 ha). It may be most difficult to develop prescriptions and mark stands lacking large legacy trees or that have fairly uniform spacing.
3. **The Forest Vegetation Simulator (FVS) and stand exam plots may be used to assess forest heterogeneity** by classing plots by patch type, using the “process plots as stands” option and then comparing the mean and coefficient of variation between all plots and plots by patch type. Details are provided on using “Suppose” within FVS to model current and future conditions, and outputting results to Excel[®] to calculate the coefficient of variation.

Within stands, GTR 220 describes three general conditions: (1) high-density, closed-canopy groups of trees; (2) open gaps; and (3) a matrix of low-density areas dominated by large, preferably pine, trees.

dominant vegetation conditions: tree groups, gaps, and shrub patches. An average “stand” in Teakettle’s mixed-conifer forest supports about 70 percent of the stand area in tree groups or scattered large trees, 16 percent in gaps, and 14 percent in shrub patches (North et al. 2002). Teakettle studies also found that ecological processes were best understood at this patch scale, before and after fuels reduction treatments were applied (Ma et al. 2010, North and Chen 2005, Wayman and North 2007, Zald et al. 2008). These patches differed in size but most were between 0.02 to 0.3 ac, fitting the general patch size pattern noted by Knapp et al. (chapter 12). For ecological restoration and the provision of habitat and microclimate variability, marking and measuring forest structure at finer patch scales may be an important complement to stand average assessments.

General Marking Suggestions

Within stands, GTR 220 describes three general conditions: (1) high-density, closed-canopy groups of trees; (2) open gaps; and (3) a matrix of low-density areas dominated by large, preferably pine, trees. These three conditions were also found in a recent meta-analysis of all studies of tree patterns in fire-frequent forests of western North America (Larson and Churchill 2012). With these conditions, one approach to marking might be to start with the areas that most easily fit either a group or gap as anchor points. Both groups and gaps could have a range of sizes anywhere from 0.1 to 1.0 ac (0.04 to 0.4 ha), but reconstructions suggest that before fire suppression, size more commonly ranged from 0.1 to 0.5 ac (0.04 to 0.2 ha).

If a stand lacks gaps, the goal in creating them is to produce a high-light environment favoring both regeneration of shade-intolerant trees and some shrub patches. Areas currently lacking pine, and fir groups with evidence of root disease, could be recognized as priority locations for gaps. Some gaps may be created by enlarging existing openings or low-density areas, particularly if the higher light environment may benefit a struggling shade-intolerant such as a remnant black oak (*Quercus kelloggii* Newberry). Gaps may occasionally include a large pine that would act as a seed source. If a tree were left in a gap, it would ideally be located near the edge or the northern end of the opening to maximize the amount of light available to regenerating pines in the remaining area. To increase light, the gap edge may also be “feathered” by thinning trees, particularly those on the gap’s southern edge. Groups of tree may be identified by focusing on the attributes that make them potential wildlife habitat such as the presence of large, old trees and higher levels of canopy closure. Particular priority for retaining a group is when it has additional attributes that may enhance habitat value such as broken stems, evidence of heart rot organisms, mistletoe brooms, etc. (see defect tree section in chapter 14 and

the appendix). The size and shape of groups should depend on obvious breaks in composition or size of trees in the existing stand.

After groups and gaps are identified, low-density areas may be marked with the intent of restoring a more open, pine-dominated forest condition in topographic locations where historical fire would have produced these conditions (see Stand Visualization System examples below). Most leave trees would be selected based on size, species, and vigor, but also on important habitat features.

As the climate changes and temperatures increase, water stress will increase on trees. If trees are left in groups, will they experience increased water stress and a higher rate of mortality? Any increase in tree density will increase competition for resources and generally reduce growth. However, it is clear in all reconstruction studies in the Sierra Nevada that large trees have historically been clumped, and this pattern existed even during past periods of extended drought. We do not know the exact reasons for this drought resilience but one consideration may be the broader environment that the clump exists within. Recognizing the opportunistic nature of root growth, gaps adjacent to tree clumps may have provided greater resource availability to sustain large trees during drought periods.

An important concern, then, is the stem density of areas adjacent to the group. Historically, low-density areas or gaps surrounded clumps, and these openings may have increased resource availability for trees in the clump. With fire suppression, many of these areas are now filled with shade-tolerant trees, which may increase stress within the large tree clump. This suggests that, when emphasizing the large tree clump, thinning around clumps may be warranted, in place of the more traditional radial release thinning where much of the clump is thinned to increase the growth of one leave tree.

Stand Visualization Simulator Examples

Using the Stand Visualization Simulator, we constructed representative stands of common Sierra Nevada forest conditions. These images were then edited to demonstrate how treatments might increase heterogeneity in tree spacing and canopy layering, while reducing standwide fuel ladders.

A thinning following GTR 220 concepts might be based on producing different groups of trees and leave-tree densities. In most treated stands, the largest trees are left, regardless of their relative height in the overall stand, and suppressed trees, which may act as ladder fuels, are removed (e.g., left and right sides of fig. 9-1). However, in tree groups valued for potential wildlife habitat, understory trees (the intermediate and suppressed crown class) can be important clump components (e.g., central clump in fig. 9-1). While these suppressed trees provide understory cover in

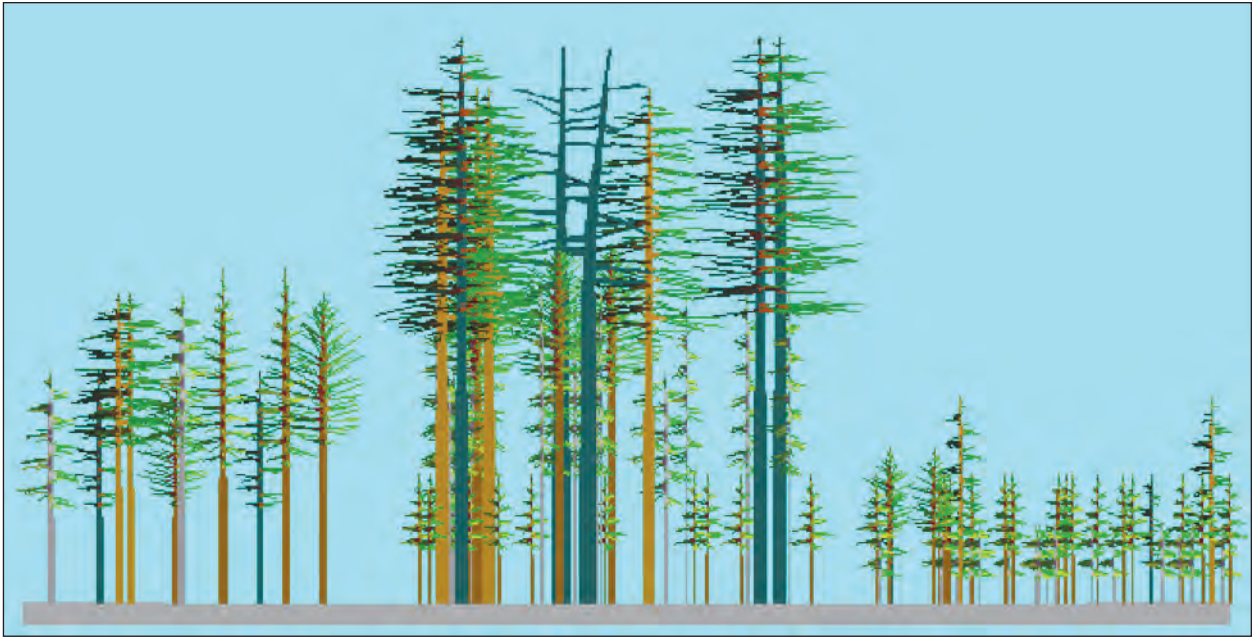


Figure 9-1—Stand Visualization Simulator image of a hypothetical stand treated following U.S. Forest Service General Technical Report 220 concepts producing a high-density tree group, a gap, and lower density matrix (North et al. 2009).

tree groups with high habitat potential, they also increase the hazard of crown fire, as they can provide fuel ladders into the upper canopy. If the tree group is burned, fire may cause some level of overstory mortality, but gaps and low-density areas surrounding the tree group may reduce the risk of further crown fire spread. While potentially reducing the numbers of larger trees within the area, high postfire mortality in the tree group would contribute to large snag and down log recruitment. Over time, as other locations in the area develop into new groups, landscape-level conditions would be expected to compensate for the short-term loss of live large trees.

In fire-suppressed forests, current stand structure conditions may not significantly differ with slope position. After treatments designed to increase landscape heterogeneity have been completed, valley bottom, midslope and ridgetop stands would have different tree densities and resultant canopy cover levels (figs. 9-2 to 9-4). In general, upslope changes in slope position often correspond with reduced soil moisture availability and lower productivity. Parker (1982) developed the topographic relative moisture index (TRMI) to provide a relative measure of xeric (TRMI value of 0) to mesic (maximum value of 60) conditions that has been found to correspond with historical differences in stand structure (Taylor 2004, 2010). Historically, slope position also may have corresponded with increasing fire intensity that would have also affected stand density and canopy cover.

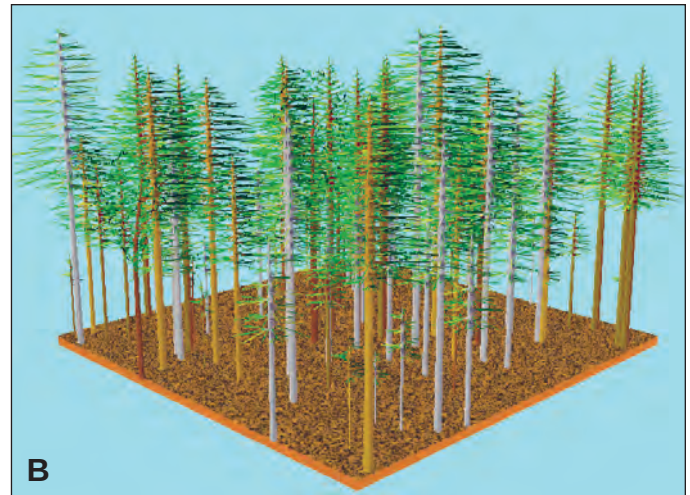
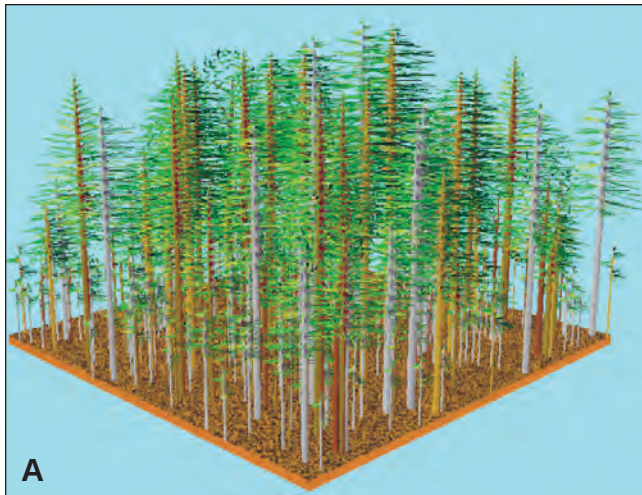


Figure 9-2—Valley bottom stand (A) before and (B) after treatment.



Figure 9-3—Mid-slope stand (A) before and (B) after treatment.

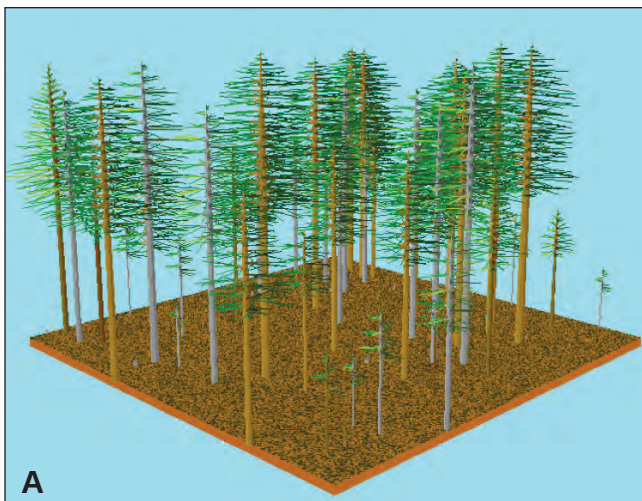


Figure 9-4—Ridgetop stand (A) before and (B) after treatment.

Forests lacking large trees, or that have uniform spatial distributions, may be the most difficult to mark when keying off of existing conditions.

Forests lacking large trees, or that have uniform spatial distributions, may be the most difficult to mark when keying off of existing conditions. Following GTR 220 concepts, microsite and landscape topography can be used to vary treatments. However many forests affected by early 1900s railroad logging and pre-1980s timber management plans have little topographic variation and few, if any, large legacy trees to anchor the location of tree groups (fig. 9-5). In most of these stands, however, there are differences in stem densities and sizes that can be used to increase the variability in tree distributions. Even in fairly homogeneous second growth, some trees are larger, and these may serve to identify leave-tree groups (fig. 9-5).

Younger planted forests with little crown class differentiation can be very difficult to shift toward higher levels of spatial heterogeneity because of relatively uniform distribution and tree size (fig. 9-6). In this case, thinning that enhances large tree development may take priority over creating spatial heterogeneity. Although the primary management objective might be tree density reduction to increase growth rates, even in plantations there are often opportunities to favor natural regeneration and to increase heterogeneity in both species composition and tree arrangements.

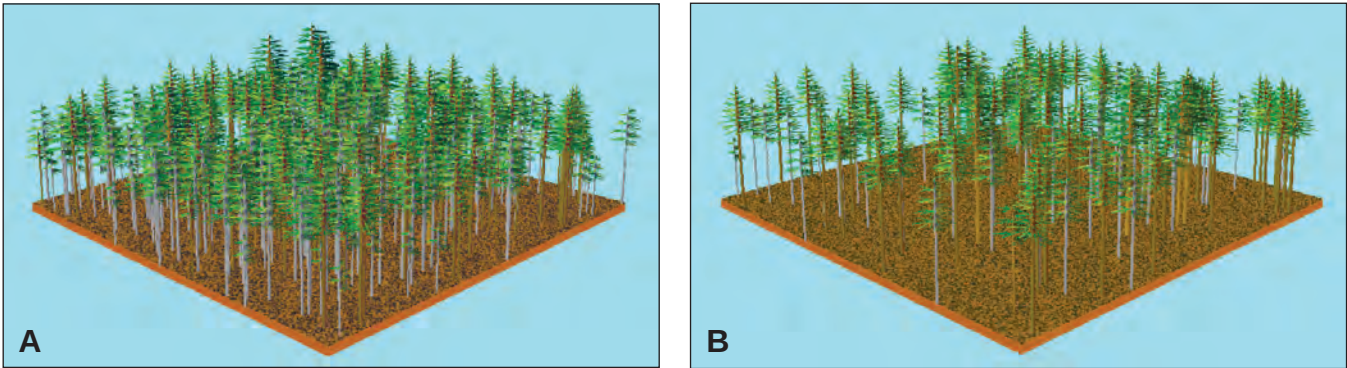


Figure 9-5—Second-growth stand with few older legacy structures (A) before and (B) after treatment.

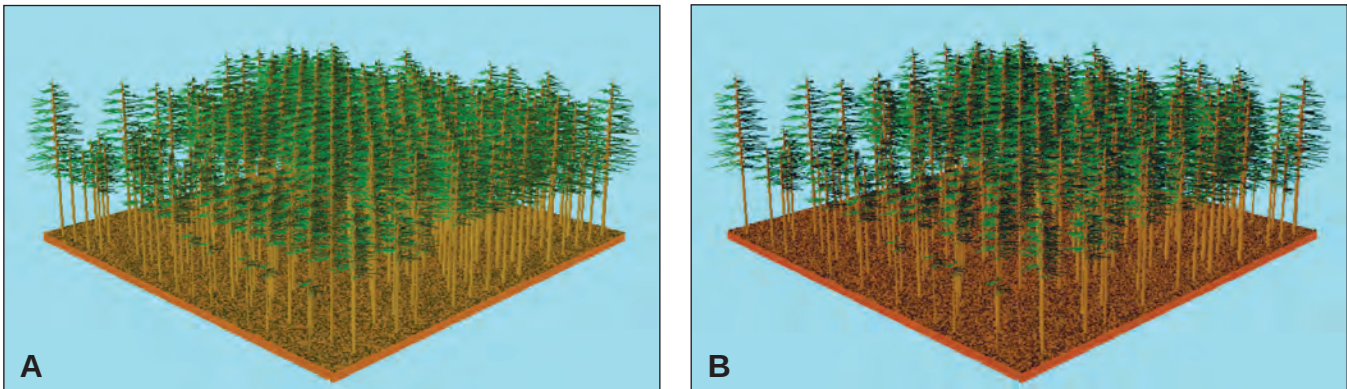


Figure 9-6—Pine plantation (A) before and (B) after treatment.

Using FVS to Assess Heterogeneity

With a slight modification, both Common Stand Exam (CSE) data and the Forest Vegetation Simulator (FVS) can be used to assess whether treatments have increased forest heterogeneity. Here we present an approach that provides an effective estimation of the mean and variation in stand-level and within-stand forest attributes.

In practice, variable-radius sample plots are small. For example, using a 20-basal area factor (BAF) prism, sample area differs with target tree diameter, yet even for a 30-in (76-cm) diameter at breast height (d.b.h.) tree the sample area will be 0.24 ac (0.1 ha). This plot size falls within the range of tree group and gap sizes found in many reconstruction studies. This is important because statistical analyses can only detect patterns of variability at scales equal to or larger than the plot size.

The Field Sampled Vegetation (FSVeg), CSE, and FVS can be customized to annotate plots and assess different stand conditions such as high-density, low-density, and gap areas. For example with CSE-protocol stand exams, the Plot User field can be used to categorize the “type” of forest condition sampled such as high-density (HD tree cluster), low-density (LD matrix), and Gap.

After using FSVeg to create an FVS-ready Access database, an FVS_PlotInit table is available to simulate plots as stands. To enable this option, Suppose preferences must be set to “Process plots as stands” (fig. 9-7). Plots can then be grouped for simulation in the Select Stands process step. For example, if 15 plots are sampled in an analysis area, field technicians may have indicated that plots 1, 5, 12, and 14 are HD (tree cluster) plots in the Plot User field. These four plots are selected and “grown” or “treated” in the simulation together to provide information on HD tree group response. Several methods exist to summarize the results of this within-stand simulation approach. The use of the Average Summary Table post processor is one option (fig. 9-8). Continuing with our example, the same analysis can be completed for the LD, and Gap condition plots within the stand, and also completed for the entire set of plots to yield a stand-level average.

The creation of a table to compare variation between the entire sample and the posttreatment patches is simplified by using Suppose and Excel together. Within Suppose, specify an output database, in this case an Excel file, to capture the forest structural variable of interest. After each simulation, copy and paste the output for that variable into an Excel worksheet. Using Excel’s statistical functions, the mean and coefficient of variation for stand- and patch-level attributes can be calculated using all plots and plots by patch type, respectively. By dividing a population’s standard deviation by its mean, the coefficient of variation (CV) permits a comparison

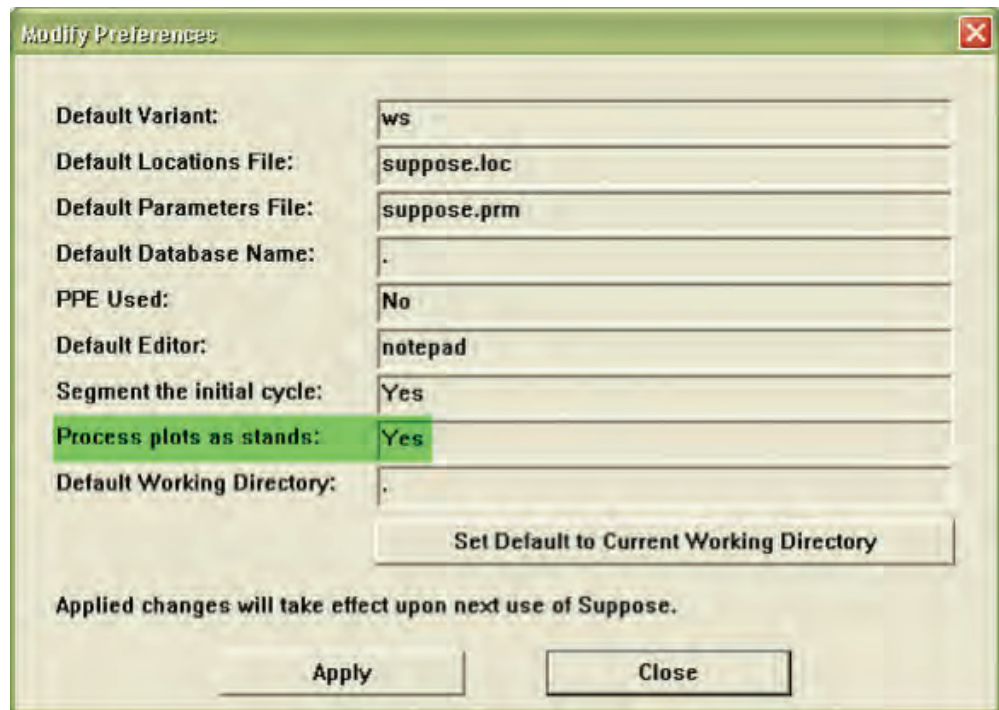


Figure 9-7—Screen capture image of the preferences menu in the Suppose module of the Forest Vegetation Simulator.

Average Summary Table - FVS Post Processor

File Edit View Table Help

FVS SIMULATION: 2
SIMULATION DONE: 06-30-2011 17:25:47

AVERAGE* SUMMARY STATISTICS BY COMMON CYCLE

START OF SIMULATION PERIOD										REMOVALS**				AFTER TREATMENT				GROWTH THIS PERIOD				MAT MERCH CU FT	
YEAR	AGE	NO OF TREES	BA	SDI	CCF	HT	QMD	TOTAL CU FT	MERCH CU FT	MERCH BD FT	NO OF TREES	TOTAL CU FT	MERCH CU FT	MERCH BD FT	BA	SDI	CCF	HT	QMD	PERIOD YEARS	ACCRE PER YEAR		MORT PER YEAR
2006	0	678	191	384	111	65	8.2	4251	3482	17669	0	0	0	0	191	384	111	65	8.2	10	107	11	0.0
2016	10	600	217	419	140	73	9.1	5210	4271	21843	0	0	0	0	217	419	140	73	9.1	10	110	26	0.0
2026	20	482	234	430	136	81	10.3	6056	5006	26103	0	0	0	0	234	430	136	81	10.3	10	110	34	0.0
2036	30	405	247	435	129	87	11.4	6810	5750	30246	0	0	0	0	247	435	129	87	11.4	10	110	38	0.0
2046	40	348	259	439	123	92	12.5	7531	6461	35088	0	0	0	0	259	439	123	92	12.5	10	114	45	0.0
2056	50	296	269	439	116	98	13.7	8219	7120	39792	0	0	0	0	269	439	116	98	13.7	10	115	47	0.0
2066	60	256	278	439	111	103	14.9	8892	7727	44279	0	0	0	0	278	439	111	103	14.9	10	114	52	0.0
2076	70	225	286	437	107	108	16.2	9513	8348	48960	0	0	0	0	286	437	107	108	16.2	10	116	60	0.0
2086	80	197	291	431	102	112	17.6	10074	8890	52827	0	0	0	0	291	431	102	112	17.6	10	116	67	0.0
2096	90	168	293	421	96	117	19.2	10562	9397	56808	0	0	0	0	293	421	96	117	19.2	10	114	72	0.0
2106	100	142	294	409	90	122	20.8	10983	9851	60486	0	0	0	0	294	409	90	122	20.8	0	0	0	0.0

*STANDS WERE GIVEN EQUAL WEIGHT.
**REMOVAL AVERAGES ARE BASED ON VALUES FROM ALL STANDS, INCLUDING THOSE IN WHICH ZERO VOLUME WAS HARVESTED THAT CYCLE.

THE FOLLOWING STANDS WERE SUMMARIZED:

051651104SF0004_1	051651104SF0004_2	051651104SF0004_3	051651104SF0004_4
051651104SF0004_5	051651104SF0004_6	051651104SF0004_7	

Ready

Figure 9-8—Screen capture image of the Average Summary Table post processor in the Forest Vegetation Simulator.

of relative variability about different-sized means. In effect, CV, often expressed as a percentage, standardizes variability around the mean of the sample population.

In the example provided (fig. 9-9), basal area per acre was selected from each plot for a common year. After pasting the data into Excel, the program's statistical functions SDEV and AVERAGE are used. After these values are calculated, enter a user-defined formula for the CV (coefficient of variation = SDEV/AVERAGE).

A highly heterogeneous stand, after treatment, should have a large CV when all plots are pooled. This is because some plots will have sampled tree groups with high basal area, stand density index, and canopy cover, and other plots will sample gaps and the LD matrix, which will have much lower values. For each patch type, means should be significantly different from each other and be widely varied compared to the all-plots mean. The CVs for each patch type should be smaller than the CV for all plots combined. As a rule of thumb, higher stand-level CV and greater differences between the patch-type means will usually be associated with increased structural heterogeneity.

As a rule of thumb, higher stand-level CV [coefficient of variation] and greater differences between the patch-type means will usually be associated with increased structural heterogeneity.

	A	B	C	D	E	F
1						
2			Basal Area / Acre			
3		Plot	All	HD	LD	Gap
4		1	310	310		
5		2	300	300		
6		3	280	280		
7		4	300	300		
8		5	280	280		
9		6	290	290		
10		7	170		170	
11		8	150		150	
12		9	120		120	
13		10	160		160	
14		11	170		170	
15		12	180		180	
16		13	180		180	
17		14	150		150	
18		15	180		180	
19		16	140		140	
20		17	150		150	
21		18	150		150	
22		19	150		150	
23		20	150		150	
24		21	140		140	
25		22	10			10
26		23	10			10
27		24	10			10
28		25	5			5
29		26	10			10
30		27	5			5
31						
32		SDEV	98	12	17	3
33		AVERAGE	154	293	156	8
34		CV	64%	4%	11%	31%

Figure 9-9—Screen capture image of an Excel spreadsheet where the mean (average), standard deviation (SDEV) and coefficient of variation (CV) have been calculated for data pasted from the Forest Vegetation Simulator's Suppose module. HD = high density tree cluster; LD = low density matrix.

If sample plots are arranged on a systematic grid covering the treatment area, the percentage of plots in each patch type will also indicate the project's overall ratio of HD tree groups, gaps, and LD areas. Recording plot locations with a global positioning system receiver allows the data to be easily incorporated into geographic information system software and facilitates plot relocation for future repeated sampling. This type of analysis has the advantage of providing both mean and CV for the entire sample stand and the finer scale, patch type variability that creates within-stand structural heterogeneity.

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