Classifying Stand Structure: A Comparison of SVS Images with Plot Visits and FVS-Generated Metrics

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Abstract—FVS is frequently linked with the Stand Visualization System (SVS) to provide computer-generated images of current and projected forest structure for use in research articles, forest planning documents, and public presentations. A small pilot study in the Sierra Nevada focused on whether observers classified stands in the same way from SVS images as from site visits. This survey, conducted in fall 2000, used groups of forest visitors (45 individuals) who toured seven 0.10 acre plots with a variety of stand structures. Results showed these visitors classified tree size, age, and canopy cover differently on real plots than from SVS images. Responses from both field visits and image viewing also differed from commonly used metrics output from the FVS program.

In recent years computer graphic simulation of forests has become more common, with uses varying from prototyping harvest equipment (Block and Fridley 1990) to animated "walk-throughs" of a forest environment (House and others 1998). Computer visualizations can range from the tree to landscape level, and from the abstract to near photographic quality. Several authors have noted the potential of computerized visualizations of forests to mislead as well as inform (McQuillan 1998; Wilson and McGaughey 2001), a problem that may be exacerbated when the goal of the visualization is to produce an illusion of the actual environment (Orland and Uusitalo 2001).

A substantial body of research on the use of computer graphics, simulation, and photography exists in fields such as landscape architecture, psychology, and urban and regional planning, but little is known about the effectiveness of visualization for forestry applications. In particular, uses of visualization specific to forestry, such as illustrating different forest types or demonstrating the effects of silvicultural treatments, have had little research. This research addresses one aspect of a forestry-related application, the use of images to represent classified forest structure.

Although it has been argued that all forest simulations are rhetorical in nature (Luymes 2001), compared to some applications of virtual environments, users of virtual forest representations may be more likely to be trying to provide impartial information (Orland and Uusitalo 2001). A computer visualization to illustrate forest type or structure could be characterized as this type of use; the image creator may be trying to convey a particular piece of information rather than achieve a preferred aesthetic reaction. This can be especially useful for communicating to a lay audience that has no experience with technical forestry terms such as basal area, canopy cover, even-aged, seed tree, or shelterwood. One program that has been used to convey information about forest type and structure is the Stand Visualization System (McGaughey 1998).

The Stand Visualization System, or SVS, is probably the most commonly used visualization program for forestry in the United States. Since the late 1990s, images generated by the program have appeared in journals, conference proceedings, forest management plans and assessments, and numerous presentations. The program creates graphical images of trees and forest stands (fig. 1 to 3) using input of individual tree species, diameter, height, crown width, crown ratio, and tree location. The SVS program can also generate tree location, and additional capabilities include the ability to portray understory vegetation, snags, and logs.

A general question that may interest SVS users is "How well do observers interpret the images?" Because of the frequent use of SVS in illustrating forest structure (the physical spatial distribution of tree vegetation), one indicator that might be useful in answering this question would be to know if people classify SVS images similarly to how they classify actual forested areas. To date, no research has been done on this question. This paper reports the results of one case study addressing this question. We surveyed three groups of visitors to a research forest in fall 2000. The visitors answered identical sets of questions about forest structure for SVS images and for real plots. Although results should not be extrapolated to a larger population or other forests, it is hoped that managers will find this case study useful in understanding some of the issues related to using a data-driven visualization program to convey information about forest structure.

Methods

Blodgett Forest, a 4,600-acre research forest for University of California-Berkeley, is located in the 4,000 to 5,000 feet elevation mixed-conifer region of the west slope Sierra Nevada. The forest is used for research and demonstration,

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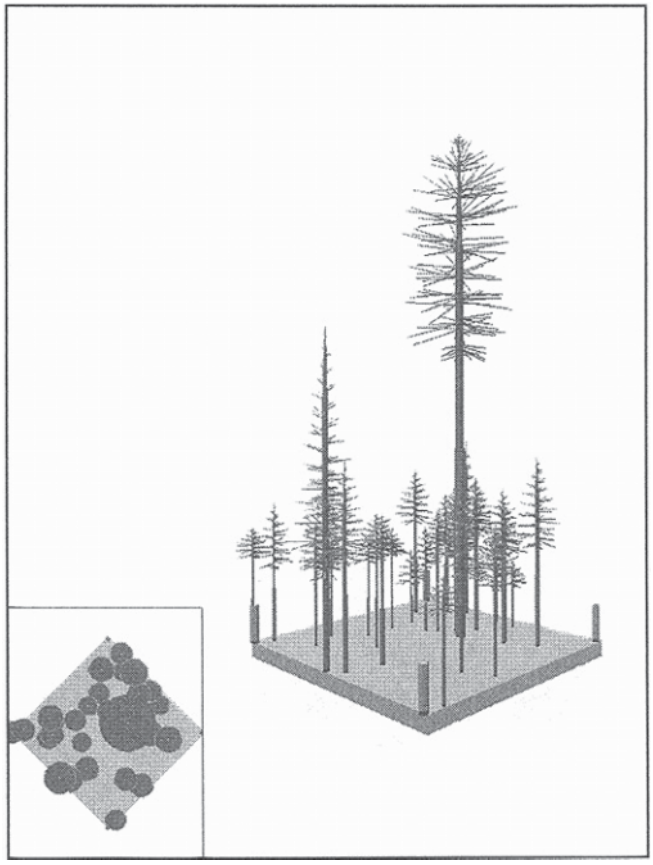

Figure 1—Tenth acre SVS image of plot 7.

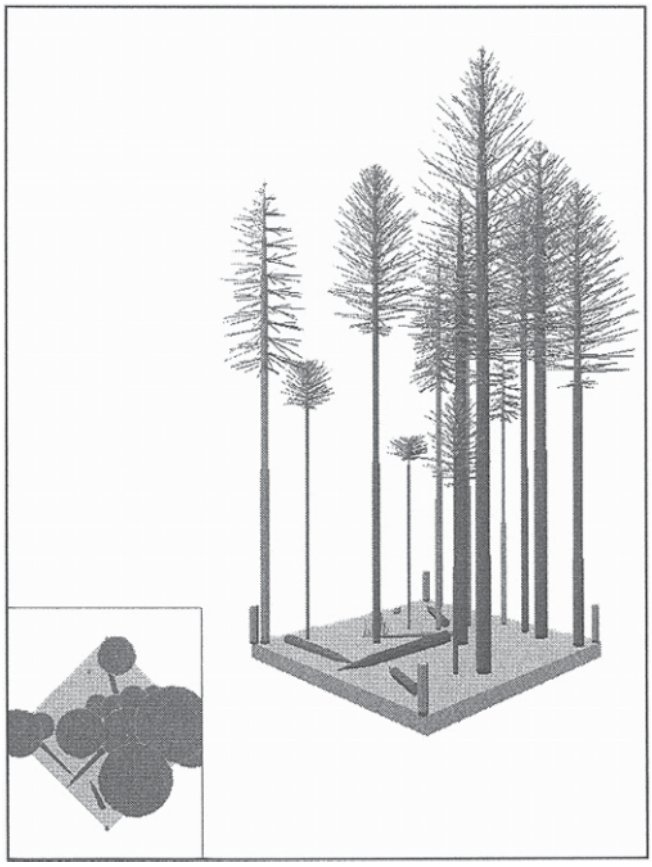

Figure 2—Tenth acre SVS image of plot 2 with logs.

and small groups of visitors occasionally stay at the forest and use the conference center for meetings. The forest was chosen for this case study because of the combination of visitor use and silvicultural demonstration sites.

Seven 0.10 acre permanent plots from the forest's continuous forest inventory (CFI) system were selected for use in the survey, based on proximity to the visitor center. Although in mature second-growth mixed conifer forest, the seven plots provided some diversity of structure: two of the plots were in stands managed as a shaded fuel break, two plots were in unmanaged stands, and three plots were in stands that have been managed using single tree selection.

Data for each plot were put into the 6.21 version of the West Side Sierra Nevada variant of the Forest Vegetation Simulator (FVS) (Dixon 1994; Wykoff and others 1982). Measured values input into the program were tree species, diameter, height, and live crown ratio; trees smaller than 4.5 inches dbh were not included. The FVS program was used to estimate maximum crown width; this estimation procedure uses a linear function of diameter, with species-specific coefficients. Using random spatial placement of trees, the output from FVS was converted into input for the Stand Visualization System 3.31 (McGaughey 2001) to create images.

The SVS default parameters for coloring and branch placement were used for all species, with the default ground surface. Tenth-acre images were created using a perspective view and overhead view (fig. 1). Viewer azimuth, elevation, and distance, lens focal length and aspect were kept constant for each 0.10 acre image. One plot, which contained several large logs, had an additional image created with graphical logs (fig. 2). Half-acre images, which duplicated each individual tree five times, included perspective, profile, and overhead views (fig. 3) and were only created for four of the plots. Both types of images included four orange corner posts scaled at 10 feet high and 2 feet in diameter. Each image also included a written description of the size of the plot and the diameter and height of the four orange corner posts.

In fall 2000, three groups of visitors to the forest participated in the survey: 14 people attending a mycology meeting, 17 people finishing their Forest Service silviculturist certification, and 14 people on a field trip for a college-level silviculture class. Each group viewed a 20-minute PowerPoint presentation of 12 SVS images: seven 0.10 acre images (one for each plot), a 0.10 acre image of one plot with logs, and four 0.50 acre images (for four of the seven plots). For each image, participants were asked questions on the tree size classification of the plot, whether the plot was even-aged or uneven-aged, the canopy cover class of the plot, and whether the image represented "old forest." The questions on the survey were:

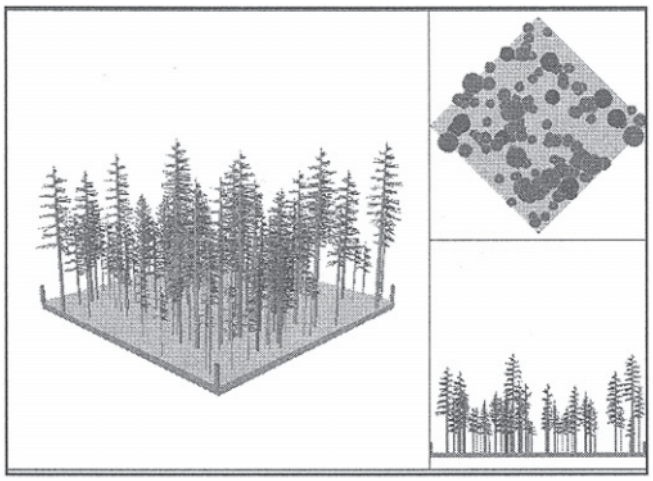

Figure 3—Half acre image of plot 6.

1. Which of the following best describes this image?
- *a. Seedlings (average tree diameter less than 1")*
- *b. Saplings (average tree diameter between 1" and 6")*
- *c. Poles (average tree diameter between 6" and 12")*
- *d. Medium (average tree diameter between 12" and 24")*
- *e. Large (average tree diameter greater than 24")*

2. Which of the following best describes this image?
- *a. Even-aged*
- *b. Uneven-aged*

3. Which of the following best describes this image?
- *a. Sparse (10% to 24% canopy cover)*
- *b. Open (25% to 39% canopy cover)*
- *c. Medium (40% to 59% canopy cover)*
- *d. Dense (60% to 100% canopy cover)*

4. Please give your best estimate of the percent canopy cover: _____

5. Would you describe this image as representing "old forest"? "Old forest" contains old, large trees. _____ (Yes / No)

The first three questions correspond to the California Wildlife Habitat Relationship (CWHR) forest classification system (Mayer and Laudenslayer 1988). Two departures from the system—(a) using average diameter instead of quadratic mean diameter for size class and (b) using the term "uneven-aged" instead of "multistory" —were made to increase participants' understanding of the questions.

These questions were read aloud to the participants to control the pacing of the survey; the 12 images were visually separated from each other by showing a blank white screen for a few seconds. Participants were not informed that some of the images were created from the same plot data. Participants were verbally reminded of the size of each visualized plot (0.10 or 0.50 acres), the size of the orange corner posts, and to estimate canopy cover as "the percentage of the gray square covered by tree canopy."

Following the indoor presentation, each group was given a guided walk to the set of forested plots; plots were separated by about 3 minutes walking time and screened from each other by intervening forest. Trees on the plot had trunks circled with yellow loggers tape, to provide a visual cue separating the plots from surrounding forest. At each plot location, participants answered the same set of questions that had been given for the SVS images. Time on the plot was longer than in viewing the images, due to the logistics of moving a group on and off a small plot with trees. In addition, participants were free to move about the plot and view it from different angles, whereas a single viewpoint was presented in each SVS image. Although each group viewed images and visited plots in the same order, the arrangement of SVS images did not correspond with the order of plot visitation.

Visitor estimates were compared with modeled and observed plot descriptors. Although not used for comparison against visitor estimates, for additional information canopy cover for each plot was also estimated with the FVS program (table 1). The FVS canopy cover estimate uses the method described by Crookston and Stage (1999) and accounts both for overlap and for off-plot trees. Canopy cover was also taken with a GRS densitometer using a grid within each plot of 61 points spaced at 7 foot intervals. This field measurement included only canopy within plot boundaries, using only trees whose stems were on the plot, to correspond to the way participants were asked to estimate canopy cover. Other plot level attributes, such as quadratic mean diameter, were also estimated with the FVS program (table 1).

Table 1—Plot characteristics calculated with FVS (West-side Sierra Nevada variant).

Plot	Trees per acre	Basal area	Stand density index	Quadratic mean diameter	Average diameter	Diameter range	Canopy cover[a]	CWHR[b]
		ft²/acre		- - - - - - - - - - - - -	*inches*	- - - - - - - - - - - - -	*percent*	
1	60	258	314	28.1	26.7	13–36	53	5M
2	140	491	623	25.5	22.6	7–42	73	7M
3	80	218	290	22.4	21.3	12–32	50	5M
4	120	196	289	17.3	15.7	7–29	43	4M
5	180	219	342	14.9	13.6	6–24	54	6M
6	250	177	308	11.4	10.0	5–25	50	4M
7	320	185	334	10.3	9.1	5 –31	58	4M

[a]Calculated with overlap correction (Crookston and Stage 1999)
[b]CWHR class as calculated by FVS's California Spotted Owl WHR postprocessor (VanDyck 2001)

Results

Canopy Cover

For all seven plots, the average canopy estimate from participants for the 0.10 acre SVS image was lower than the densitometer estimate (table 2). The discrepancy varied from 14 to 29 percent, with an average difference of 21 percent across the seven plots. The densitometer should give a relatively unbiased estimate of canopy cover compared to most field instruments because it takes a single reading at a vertical angle rather than using oblique angles. However, 61 points per plot result in only moderate precision (table 2). The densitometer estimate gave canopy estimates higher than for the SVS graphical method, even though a densitometer point that hit sky was not considered canopy regardless of whether it fell within the limits of maximum crown width for the tree.

Mean estimates of canopy for the 0.10 acre images were lower than for the corresponding 0.50 acre images for three of the four plots; it should be expected that estimates for 0.10 acre images would be lower because the percentage of canopy that falls outside of plot boundaries is higher for small plots. The mycologist group, silviculture group, and the students had similar estimates for canopy cover (fig. 4); the average difference between group means of canopy cover was less than 3 percent for both SVS images and the actual plots.

The participants' mean field estimates of canopy cover were higher than their estimates from the 0.10 acre images for six of the seven plots. Small saplings on the plot that weren't included on the images, and overlapping canopy from surrounding forest, could contribute to this, although participants were asked to exclude these factors from their estimates in the field. The participants' estimates of canopy cover for the actual plots in the field appeared to be at least as variable as their estimates of canopy cover for the SVS images (table 2).

Table 2—Mean canopy cover estimates by visitors for images (0.10 acre plots and 0.50 plots) and field visits

Plot	Survey responses SVS 0.10 image (with st. dev.)		SVS 0.50 image (with st. dev.)		Field estimate (with st. dev.)		n	Densitometer (with 90% CI)		SVS 0.10 acre[c]
	Percent							*Percent*		
1	40	(8)	—[a]		46	(9)	45	64	(10)	54
2	46	(10)	71	(9)	71	(12)	45	64	(10)	55
3	29	(10)	41	(9)	36	(8)	44	44	(10)	41
4	28	(9)	40	(8)	42	(10)	44	56	(10)	34
5	46	(8)	—		41	(11)	31[b]	61	(10)	56
6	45	(11)	43	(9)	67	(16)	45	66	(10)	50
7	48	(7)	—		55	(15)	45	77	(9)	55

[a]Plots 1, 5 and 7 did not have a corresponding 0.50 acre image
[b]One group did not make a field visit to plot 5.
[c]Canopy cover from SVS image estimated with the graphical method without subplot

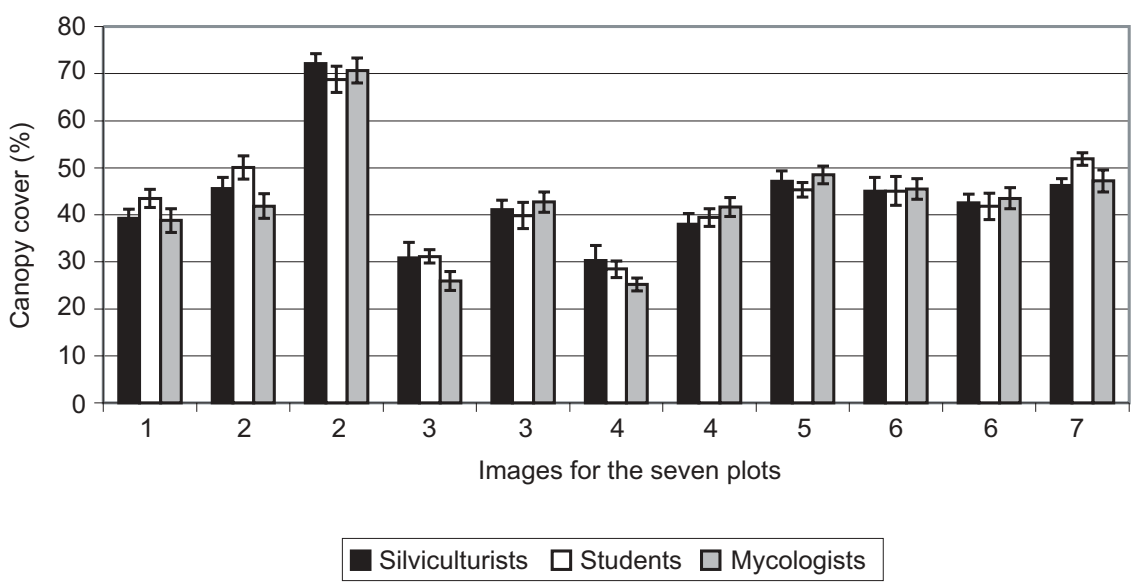

Figure 4—Means and standard deviations of canopy cover estimates for 11 SVS images by the three groups of visitors.

Plot 2 was used to create two 0.10 acre images, one with logs (fig. 2) and one without; these two images had different spatial placement of trees. All 45 participants estimated higher canopy cover for the version with logs; the mean of this difference was 26.3 percent. Estimates for the version with logs were much closer to the estimates made in the field, with a mean difference of less than 2 percent.

Because smaller image sizes have more canopy that falls outside the graphical plot boundaries (fig. 2 and 3) one would expect a greater correlation between canopy cover class responses for the actual plots and for the 0.50 acre images than between canopy cover class responses for the actual plots and for the 0.10 acre images. This was the case, with 53 percent of 180 responses matching for the 0.50 acre images and 36 percent of 300 responses matching for the 0.10 acre images.

The SVS program can compute the graphical cover for each image. Comparing this to participants' responses for canopy cover classes, the overall percentage of responses that were correct was 64 percent for the 0.10 acre images and 66 percent for the 0.50 acre images. For individual plots, this percentage varied from a low of 9 percent correct for the 0.10 acre image for plot 4 to a high of 93 percent correct for the 0.50 acre image of plot 2. For the 169 of 480 cover class responses that were incorrect, 92 percent assigned the image to a smaller-than-actual cover class, and 8 percent assigned the image to a larger-than-actual cover class.

Size Class

There were large differences between estimated tree size class for SVS images and in the field. For the 0.10 acre images, the percent of responses that were identical for the image and the real plot varied from 40 to 61 percent (table 3). For six of the seven plots, individuals classified the image as having smaller trees than the real plot. This tendency was even stronger for the 0.50 acre images; for one plot, 84 percent of individuals classified the real plot as having larger trees than the image (table 4).

Based on quadratic mean diameter (qmd), two of the plots would be in the large size class, three plots would be in the medium size class, and two plots would be in pole size class (table 1). Several of the plots had qmds or average diameters that were near the division point for size class. Of all field responses, 70 percent would have placed plots in categories the same as would the qmd method, ranging from 41 to 94 percent for the different plots. Of all responses for the SVS 0.10 acre images, 56 percent would have placed plots in the same category as the qmd method, ranging from 36 to 69 percent for the different plots.

As with canopy cover, there were differences in responses between the two SVS images with and without the inclusion of logs. While 51 percent of individuals placed the SVS 0.10 acre image for plot 2 in a smaller size category than they did for the real plot, only 22 percent placed the 0.10 acre image

Table 3—Participants' responses for size class of trees: 0.10 acre image compared to actual plot visit.

Plot	Agreement	Visitor image estimate larger than visitor field estimate	Visitor field estimate larger than visitor image estimate	n
	- -	*Percent*	- -	
1	61	7	32	44
2	47	2	51	45
3	53	9	58	45
4	58	7	36	45
5	52	3	45	31
6	40	2	58	45
7	47	36	18	45

Table 4—Participants' responses for size class of trees: 0.50 acre image compared to actual plot visit

Plot	Agreement	Visitor image estimate larger than visitor field estimate	Visitor field estimate larger than visitor image estimate	n
	- -	*Percent*	- -	
2	11	4	84	45
3	44	0	56	45
4	25	7	68	45
6	56	13	31	45

with logs in a smaller size class. The number of people placing the image in a larger size class than the real plot increased from 2 to 6 percent with the inclusion of logs. In addition to the inclusion of logs, the two images had differences in the spatial placement of trees, and this could also be a possible cause for differences in responses.

Structure: Even-Aged or Uneven-Aged

A total of 77 percent of responses showed identical classification of structure (even-aged or uneven aged) for the 0.10 acre image and the actual plot. The proportion varied somewhat by plot but was similar between the 0.10 acre images and the 0.50 acre images. The type of discrepancy – whether calling the image uneven-aged and the real plot even-aged, or calling the image even-aged and the real plot uneven-aged – varied by plot. For example, 42 percent of visitors called the SVS image shown in figure 3 even-aged but the real plot uneven-aged; and only 4 percent of visitors called the image uneven-aged and the real plot even-aged. In contrast, 11 percent of visitors called the SVS image shown in figure 1 even-aged but the real plot uneven-aged; but 33 percent of visitors called the image uneven-aged and the real plot even-aged.

Adding logs to the 0.10 image of plot 2 appeared to have no effect on the proportion of people who called the stand even-aged or uneven-aged.

Forest Age

Dominant trees in the forest surrounding Blodgett are generally around 80 to 120 years old. The percent of responses for whether the real plots were "old forest" ranged from 4 to 76 percent for the seven plots, perhaps indicating the variety of forest structure present. For these visitors, whether they answered identically for the real plot and the SVS image, appeared to vary by plot and image size (fig. 5). With the inclusion of logs in the 0.10 acre image for plot 2, the percent of people calling the plot (but not the image) old decreased from 22 to 4 percent, and the proportion of people calling the image (but not the plot) old increased from 9 to 18 percent.

The three groups differed in responses to the question about whether the plot was "old forest." Fewer silviculturists called plots old forest than students or mycologists (18 percent of all responses compared to 34 and 33 percent, respectively). Participants were also asked whether they considered themselves forestry professionals, and about half of the respondents answered yes. Fewer of those who responded affirmatively called real plots "old forest" (12 percent compared to 33 percent), and fewer called SVS images "old forest" (25 percent compared to 38 percent).

Complete Classification System

The California WHR classification system includes size class, canopy cover, and evenness of layering. When all three of the questions related to this classification system are included, for the plot with the greatest correspondence, only 32 percent of responses were identical for the 0.10 acre SVS images and the real plot. For the plot with the worst correspondence, only 4 percent of the responses were identical.

Discussion

Tree size class, evenness of structure, and canopy cover are common elements of many classification systems, just as they are of the California WHR system used in this study. Of these three elements, tree size class had the greatest discrepancy between participants' answers for the field visit and the SVS image.

Judging average diameter or qmd for a plot can be difficult, particularly for irregular or uneven size stands. Participants' field responses identical to an "average diameter" method of tree size classification were 69, 16, 51, 82, 94, 41, and 76 percent for the seven plots, respectively. Participants' field responses corresponding to CWHR tree size class metrics generated by the FVS postprocessor (VanDyck 2001) were 69, 84, 49, 82, 94, 59, and 13 percent for the seven plots,

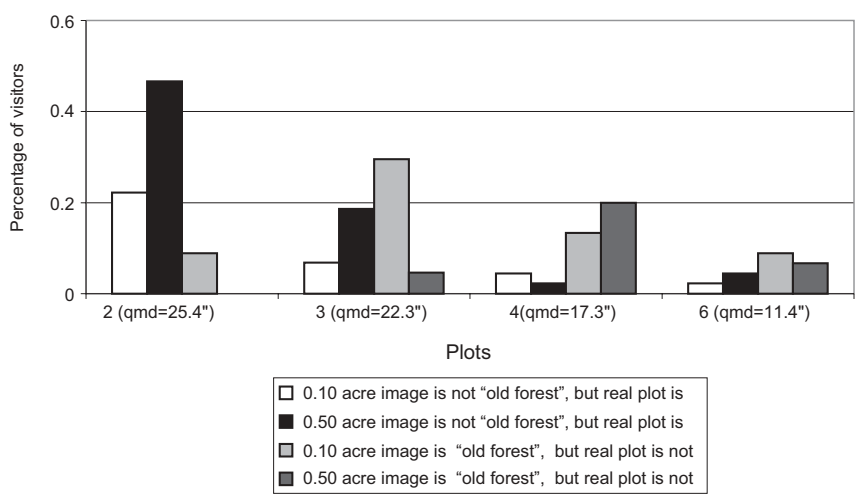

Figure 5—Discrepancies for responses for whether images and real plots were "old forest."

respectively. If real plots are difficult to classify "correctly," it is not surprising that there would be a variety of responses for size class of images, where tree trunks may be only a few pixels wide and where some trees may be hidden behind others. However, although the difficulties of estimating size class for both real plots and images might lead to a large amount of noncorrespondence, it would not explain systematic differences in classification. Overall, 45 percent of the 525 responses gave a smaller size class to the images than to the real plots, and only 8 percent gave a larger size class to the image.

This research was intended as a pilot study, to identify questions for further research and to estimate sample sizes needed to answer such questions. Because this was a noninferential case study, we cannot assume that misjudging the size class of trees in SVS images is a typical problem for other populations or other forests. But in some ways, these participants may have been better prepared to correctly interpret the size class of trees in SVS images than would be typical for many viewers. As forestry professionals, forestry students, or mycologists, the participants of this survey could be expected to be more familiar with trees than would be typical of the general public. In addition, the images contained a visual clue to tree size in the four corner posts, and the attention of the participants was directed to these posts both verbally and with written messages on each image.

It would be tempting to dismiss as an anomaly the one plot where more participants thought the tree size on the SVS image was larger than for the real plot. However, some characteristics of the structure on this plot may have led to this difference. This plot had a single large tree – 30 inches in diameter and 140 feet tall – and a fairly dense understory of smaller trees. In the SVS image, as can be seen in figure 1, this single large tree is quite noticeable. On the plot, however, the upper portion of this tree is obscured by the understory trees, and only the trunk is clearly visible. It is possible that the complexity of what influences people's classification of forest structure, both on the ground and in computer generated images, will make it difficult to draw simple generalizations about the relationship between the two.

The differences in estimation of canopy cover, size class, and age for the two 0.10 acre images of plot 2 – with and without the inclusion of logs – was a surprising but interesting result. A few of the other plots also had logs and branches on the forest floor, along with understory vegetation, or small trees that were not included in the SVS images. How the inclusion of these elements affects people's interpretation might prove a fruitful topic of further research. In addition, different spatial placement of trees in the images, the effect of distance and angle of view, and different choices for foliage or branches were not tested in this project, but could affect interpretation. Given the increasing use of computerized visualization tools, further research in this area would be helpful.

The general question facing SVS users may be "How well do observers interpret the images?" This research only addresses a narrow aspect of this question, by looking at the similarity of classifications of forest structure for images and real plots. There are a number of other important questions that researchers might consider for future work: Do images effectively communicate the results of silvicultural treatments? Can images be used to illustrate the dynamic nature of forest structure? Do they help individuals have a greater understanding of the variation among forest types?

Many of the visualization programs being developed for forestry are data-driven; in other words, the sizes of images of trees are determined through actual forest inventory measurements. It is important for managers and researchers to communicate to the public that this data-based aspect of visualization programs does not guarantee similarity between the images and the actual forest. Managers who are using computer visualization programs to illustrate the type of structures that were, are, or will be on their forests may wish to make sure that they consider this question: Is your audience interpreting the information in the image as you intended?

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