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Predicting Scenic Beauty of Timber Stands

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ABSTRACT. The psychophysical approach to developing scenic beauty models is extended to the timber stand level. Ponderosa pine timber stands are shown to be quite homogenous in terms of variables important in the prediction of scenic beauty. Candidate timber stand scenic beauty models are presented, along with the results of cross-validation experiments. The models agree with earlier studies that focused on one-acre plots, suggesting that scenic beauty increases with increases in herbage and large pine and with decreases in downed wood, and tree grouping. Finally, judgments of the scenic beauty of individual color slides taken within timber stands provide valid estimates of overall stand scenic beauty. These results suggest substantial potential for modeling the scenic beauty of conventionally delineated timber stands based on standard forest inventory information. FOREST SCI. 32:471–487.

ADDITIONAL KEY WORDS. *Pinus ponderosa*, ponderosa pine, forest esthetics, landscape assessment.

THE NEED to better integrate scenic quality into the multiple use decision-making framework for wildlands has gradually become more pressing. The Multiple-Use Sustained-Yield Act of 1960 required that national forests be managed for the full range of forest products, including outdoor recreation. The National Environmental Policy Act of 1969 was more specific, requiring that federal agencies "identify and develop methods and procedures . . . which will ensure that presently unquantified environmental amenities and values may be given appropriate consideration in decision making along with economic and technical considerations" (42 U.S.C. §4332) so as to assure "productive and esthetically . . . pleasing surroundings" (42 U.S.C. §4331). The Forest and Rangeland Renewable Resources Planning Act of 1974 and the National Forest Management Act of 1976 reinforced the mandate for consideration of amenity resources, specifically identifying aesthetic along with wildlife, recreation, and wilderness resources, and emphasized the evaluation of tradeoffs in the course of comparing feasible management alternatives. These laws reflect growing public desire for consideration of amenities and more analytical and better documented planning procedures.

Integrating forest scenic beauty into the multiple use decision-making process requires that scenic beauty be systematically related to physical forest features (e.g., trees and herbage) that are managed to meet broader goals. Progress in this direction has been made recently utilizing what Zube and others (1982) and Daniel and Vining (1983) call the "psychophysical" approach. The psychophysical approach to scenic beauty is an extension of classical research, such as that of Fechner (1860) and Stevens (1958). Their work established quantitative relationships between human perception and physical features of environmental stimuli, such as lights, sounds, or objects varied on a dimension, such as brightness, loudness, or weight. Psychophysical studies dealing with scenic beauty have quantified relationships between human perception of the "scenic beauty" or "scenic quality"

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or "preference" for forest scenes and measures of physical attributes of those scenes. The psychophysical approach provides (1) that groups of people, who are typical of forest visitors, provide their aesthetic judgments of actual or simulated forest sites, and (2) that the attributes of the sites are objectively measured. This approach differs fundamentally from those which rely on an expert's assessment of the visual quality of a site reached from considering numerous formal design criteria (e.g., the Visual Management System, USDA Forest Service 1974).

Within the psychophysical approach, four methods have been used to characterize landscape scenic beauty. Shafer and others (1969) summed rankings given to scenes to achieve a measure of scenic beauty. Brush (1979), Dearden (1980), and Briggs (1980) simply averaged ratings assigned to landscape scenes. Arthur (1977) and Daniel and Boster (1976) transformed ratings to obtain Scenic Beauty Estimates (SBE's), which theoretically (according to Thurstone's Law of Categorical Judgement—see Torgerson 1958) express scenic beauty on an interval scale. Buhyoff and Leuschner (1978) and Buhyoff and Wellman (1980) used a scaling of paired comparisons based on Thurstone's Law of Comparative Judgment (Torgerson 1958). Buhyoff and others (1982) found that, consistent with theoretical expectations (Hull and others 1984), SBE's and scaled paired comparison judgments for identical scenes were very similar. However, they concluded that the SBE method was generally more efficient.

Psychophysical studies of landscape quality have focused on either "vista" or "near-view" scenes. Near-view scenes focus on forest characteristics generally within 100 yards of the viewer and do not include distant elements. Near-view forest scenes are incurred when the viewer is "in the forest," as opposed to viewing the forest from afar, and in relatively flat country or in a dense enough forest so that distant mountains are not obvious. Vista scenes emphasize more distant landscape features, although they may include some near-view features.

This study is about near-view forest scenic beauty. Arthur (1977) developed the first models of near-view forest scenic beauty by estimating physical features in the assessed photographs; she used one photograph per case in modeling. Schroeder and Daniel (1981), Schroeder and Brown (1983), and Brown and Daniel (1984) measured physical features in areas of less than 1 acre and then used 4 photographs taken at the center of each area to represent the visual characteristics. The inventoried and photographed area, called a "site," was the case for modeling. These studies showed that scenic beauty is consistently related to near-view physical features; combinations of these features measured on-site accounted for at least 50 percent of the variance in observer groups' color slide-based judgments of scenic beauty.

The near-view site-level models predict relative scenic beauty for small areas (sites) seen from individual points in the forest. Yet, forest inventory and planning generally are based on larger land units. Typically, the timber stand is the smallest land unit delineated and inventoried in the course of forest management. Thus, while near-view scenic beauty modeling efforts have focused on individual sites, managers need timber stand-level models to predict the near-view scenic beauty of entire timber stands. Near-view stand scenic beauty pertains to the set of near-view scenes one might encounter while walking or riding through a stand. With stand-level models, data such as that routinely obtained during compartment examinations could be used to determine pre-harvest scenic beauty, as well as to predict and compare the effects of alternative harvest prescriptions.

This paper presents results of three studies related to the development of models for predicting the near-view scenic beauty of ponderosa pine timber stands in the Southwest. The first study examined the homogeneity of timber stands with respect to important variables to determine how well stand boundaries differentiated sites for variables considered important in the prediction of scenic beauty. The second study developed specific stand-level scenic beauty models, compared site-level and stand-level models, and used cross-validation to examine the validity of predicting stand scenic beauty with site-level and stand-level models. The third study, concerning the measurement of stand scenic beauty, focused on whether the average of scenic beauty estimates for sites within a stand is a valid measure of stand scenic beauty.

METHODS

The psychophysical approach to assessing near-view forest scenic beauty requires that perception and judgment information, providing the dependent variable, be quantitatively related to independent variables reflecting forestry and rangeland information. Scenic beauty values were based on aesthetic judgments by groups of observers viewing and rating color slides. Conventional forest mensuration procedures applied at the photographed sites provided an array of physical variables which were related to scenic beauty indexes using correlation and multiple regression procedures.

Study Area.—Forest sites in north central Arizona were inventoried to provide the data for the three studies. The sites are found in Woods Canyon (12,000 acres) and Bar-M (16,360 acres) watersheds, in the larger Beaver Creek Watershed, on the Coconino National Forest. The Woods/Bar-M area ranges in elevation from 6,400 to 7,740 feet and is predominantly forested with ponderosa pine, with Gambel oak interspersed throughout. Bedrock underlying the area consists of igneous rocks of volcanic origin. Soils are mostly residual and less than 4 feet deep, consisting of the Siesta-Sponseller series and the heavier Brolliar series (Williams and Anderson 1967). New Mexican locust grows on the Siesta-Sponseller soils. Arizona fescue and mountain muhly are the dominant grasses under the ponderosa pine canopy in both soil types, although pine dropseed, black dropseed, June grass, and squirreltail also are common. The area had been selectively harvested about 30 years prior to inventory, but few signs of that harvest remain.

Timber Stands and Sites.—Areas of at least 10 acres of similar density (percent crown canopy), tree distribution and grouping, tree height, and crown size were delineated on aerial photographs of the entire Woods/Bar-M area. The delineation process was similar to standard USDA Forest Service timber management procedures, with the possible exception that smaller, more homogenous stands tended to be delineated than is sometimes considered practical for operational management. The 504 delineated stands averaged 56 acres. Seven, 17, and 76 percent of the stands were poletimber, sawtimber, and mixed sawtimber and poletimber stands, respectively. One percent of the stands was of less than 10 percent crown canopy, 15 percent were from 10 to 39 percent, 49 percent were of 40 to 69 percent, and 35 percent were of at least 70 percent crown canopy.

Twenty-three of the stands were inventoried in 1979. Stands to be inventoried were selected in a stratified random fashion; the proportion of inventoried stands in each stand type and crown density class reflected the full distribution of stands in the Woods/Bar-M area. The 23 stands were inventoried around 15 equidistant sample points located to minimize sampling bias associated with stand topographic or drainage characteristics (Fig. 1). The sample points were always placed at least 1 chain within the stand and at least 2 chains apart.

Site Inventory Procedure.—Upon arriving at a sample point, the inventory crew first chose a compass heading from a 1 to 360 random number table and took a color slide in that direction and at 90°, 180°, and 270° from the selected random direction. Photos were taken on ASA 64 color slide film using a 35 mm camera

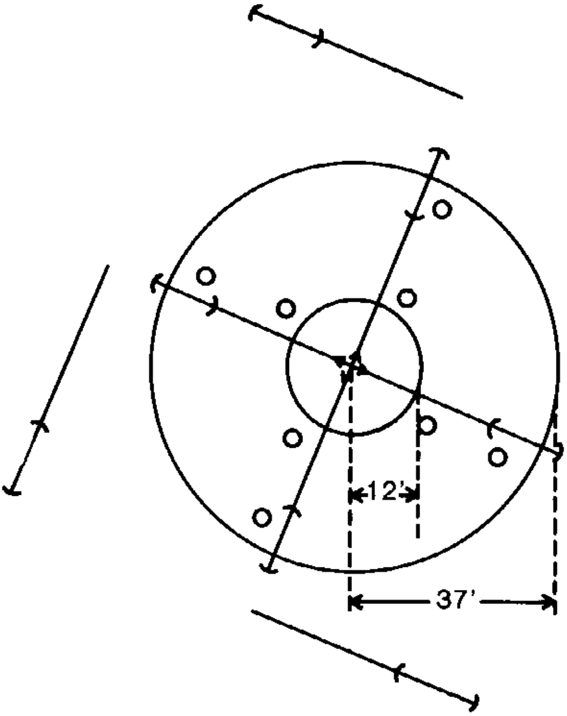

FIGURE 1. Inventory site layout: • Sample point (10-factor tally, crown cover). > Photographs from sample point. ○ 9.6 ft^2 plot (ground cover, herbage weight, canopy, and height). (——) Downed wood transect, showing the first 12' in parentheses. 12' radius plot (seedlings). 37' radius plot (tree stories, tree grouping, stumps).

with a 55 mm lens. On steeper slopes, photos took in the view naturally seen by an observer looking off into the stand. Branches hanging so close to the lens as to present focusing problems were held back so that they would not interfere. In some cases, the photographers needed to move a few feet to the left or right to avoid a serious obstruction to the view. All photos were taken from 8:00 a.m. to 4:00 p.m., when the sun was high enough to provide sufficient light and not cause excessive shadows. Care was taken to not include people, wildlife, vehicles, or equipment in the photos.

Biophysical characteristics were measured at each site using common forest and range inventory techniques. Seedlings and saplings were tallied by species in a 1/100-acre plot centered at the point (Fig. 1). Larger trees were tallied, by species in a variable plot determined by a 10-factor prism. Crown canopy was measured by averaging four readings of a spherical densiometer. Stumps were tallied in a 1/10-acre plot. Tree stories and tree grouping were recorded according to the procedure outlined by Patton (1977).

Herbage and ground cover measurements were taken on eight 9.6-square-foot plots around the point (Fig. 1). Herbage was measured for three species groups: grasses, forbs, and shrubs. Daubenmire's (1959) procedure was used for herbage canopy. Height of the tallest plants was measured. Herbage weight was estimated, and herbage in one of the eight plots, randomly chosen, was clipped, dried, and weighed. Ratios of estimated to dry weight were calculated for each estimator each month and were used to adjust field estimates to dry weight estimates (Pechanec and Pickford 1937). Percent of ground cover in gravel, cobble, stone, bare soil, litter, downed wood, herbage, and trees was estimated. For each of these herbage and ground cover variables, estimates for the eight plots were averaged to yield a site estimate.

Downed wood measurements were taken, following Brown's (1974) procedure, along eight 40-foot transects located around the point (Fig. 1). Measurements for the eight transects were averaged to yield site estimates of downed wood volume by size, creation (natural or slash), and condition (sound or rotten) classes, percent of the small downed wood which was harvest created, and fuel depth.

Site index (Minor 1964) was not measured for each site. Instead, it was measured for seven trees with appropriate characteristics scattered throughout each stand. The seven measurements were averaged to yield an estimate of stand site index.

The site inventory procedure allows a partial lack of correspondence between the view in the four photographs taken at a site (upon which the dependent variable is based) and the physical measurements (providing the independent variables). This lack of correspondence, or mismatch, has two forms. First, some physical measurements are taken in areas not seen in the photographs. This occurs both because overstory features are measured for the full 360° around the inventory point while the four photographs encompass only about 128°, and because in dense stands, physical measurements may be taken beyond the depth of field of the photograph. Second, the photographs can include areas not measured for physical characteristics. This occurs both because features are only sampled (e.g., downed wood at the site may not fall on the eight line intercepts per site), and because in sparse stands the photographs may show much area beyond the reach of the physical measurements. The mismatch limits the correspondence between SBEs and estimates of physical variables; but as shown later, the limitation is not serious.

Scenic Beauty.—The slides taken at each sample point were shown to groups of observers who rated them on a 10-point scale. Only the poles of the scale were anchored; one indicated "very low scenic beauty" and ten indicated "very high scenic beauty." At least 25 people rated each slide. Each slide presentation contained 105 slides randomly selected from among those taken at the inventory sites, plus 25 "baseline" slides. The baseline slides, which were taken in Woods Canyon Watershed, but not in the 23 stands at issue here, were interspersed at a regular interval among the slides in each presentation. The same set of baseline slides was included in each presentation, as required by the SBE scaling procedure (mentioned below).

Each slide rating session began with the reading of standardized instructions and presentation of preview slides which depicted the range of slides to be rated subsequently. The first one-half of the rated slides were exposed for 8 seconds, and the second half for 5 seconds, which has been found to be sufficient time for observers to view the slide, record a judgment on a sense-mark sheet, and prepare for the next slide. After all slides had been shown, participants' questions about the study were answered. See Brown and Daniel (1984) for more detail on the slide rating procedure.

The ratings were scaled to SBE's using the "by slide" procedure developed by Daniel and Boster (1976) and used in several studies, including Arthur (1977), Schroeder and Daniel (1981), Buhyoff and others (1982), and Anderson and Schroeder (1983). This procedure combines ratings across observers to yield one SBE per slide (i.e., information specific to individual observers is not maintained when SBE's are calculated using the "by slide" procedure). SBE's of the four slides

TABLE 1. Information on selected variables for stand-level data.

Variable				Range	
Description	Name	Mean	SD[a]	Min.	Max.
Scenic beauty estimate	SBE	15.8	24.8	−32	64
Pine basal area (ft^2/acre)	PPBA	125.0	36.8	68	218
Oak basal area (ft^2/acre)	GOBA	18.8	12.9	2	51
Overstory crown canopy (%)	CC	57.2	12.0	39	90
Tree grouping[b]	TG	1.7	0.7	1	3
Tree stories[c]	TS	2.3	0.6	1	3
Pine saplings (no./acre)	PPSAP	179.0	128.1	9	500
Pine trees 5″ to 16″ dbh (no./acre)	PP516	166.9	70.2	57	326
Pine trees 16″ to 24″ dbh (no./acre)	PP1624	12.5	5.8	6	31
Pine trees ≥24″ dbh (no./acre)	PP24PL	3.6	1.7	1	8
Oak trees ≥5″ dbh (no./acre)	GO5PL	24.0	16.6	2	66
Herbage weight (pounds/acre)[d]	PDTOT	82.7	49.4	15	233
Herbage canopy (%)	CCTOT	15.8	9.9	5	48
Downed wood <¼″ dia. (ft^3/acre)	DWVO	10.8	4.2	5	22
Downed wood ¼″ to 1″ dia. (ft^3/acre)	DWV14	67.3	13.4	42	99
Downed wood 1″ to 3″ dia. (ft^3/acre)	DWV1	112.7	30.6	40	156
Downed wood ≥3″ dia. (ft^3/acre)	DWV3PL	1,088.6	502.2	300	2,343
Total downed wood (ft^3/acre)	DWVTOT	1,279.5	533.5	390	2,611

[a] Standard deviation.

[b] An ordinal variable, where 1 = trees in groups with many interlocking crowns, 2 = some tree grouping but little interlocking of crowns, and 3 = very little tree grouping (Patton 1977).

[c] An ordinal variable, where 1 = one tree story, 2 = generally one but partially two tree stories, and 3 = generally two but partially three tree stories (Patton 1977).

[d] Total air dry weight of grasses, forbs, and shrubs.

per site were averaged. SBEs for the 333 usable sites in the 23 stands[1] ranged from −83 to 122 and averaged 16, with a standard deviation of 36.[2]

Fifty slide presentations were made to separate observer groups in the course of obtaining ratings for Woods/Bar-M slides of this and other studies (Brown and Daniel 1984). All of the groups, which consisted of student, church, or civic groups, are considered general public groups, because they do not represent any particular outdoor or natural resource management interests. The student groups were obtained from introductory psychology classes, containing students of a variety of majors, and from student organizations such as fraternities and dormitory associations. The agreement among groups was checked by comparing SBE's for the baseline slides. Pearson correlations of one group's SBE's for the baseline slides to another group's SBE's for identical baseline slides ranged from 0.61 to 0.94, with a median of 0.84. Most of the correlations ranged from 0.80 to 0.90. No consistent differences between student and nonstudent groups were detected.

DATA

The physical feature estimates for each site were collated and merged into a data file with the SBE values for each site. The site-level estimates in each stand then were averaged to yield 23 stand-level cases. In addition, averages for the two

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[1] Some sites were not used because of incomplete data, recording errors, or the lack of photographically acceptable slides. Each stand was represented by at least 14 sites.

[2] The zero point of the SBE scale is determined by the baseline slides. Thus, sites having positive SBE's were preferred to the average baseline slide, and sites with negative SBE's were preceived as having lower scenic beauty than the baseline.

ordinal variables (number of tree stories and degree of tree grouping—defined in footnotes to Table 1) were rounded to the nearest whole number to maintain the ordinal characteristics of those variables. The stands ranged in site index (Minor 1964) from 64 to 89 and in average slope up to 29 percent. Overstory consisted of ponderosa pine and Gambel oak, which averaged 125 and 19 square feet of basal area per acre, respectively. The stands averaged 2,628 cubic feet and 10,200 board feet (Schribner) of ponderosa pine per acre. They contained an average of 22, 51, and 13 pounds per acre of grasses, forbs, and shrubs, respectively, during the inventory period. Total downed wood averaged 1,280 cubic feet and ranged up to 2,611 cubic feet per acre. Ground cover averaged 77 percent litter, 6 percent downed wood, 10 percent rock, and 3 percent bare soil. The stand means, standard deviations, and ranges for selected variables are shown in Table 1, and intercorrelations between physical variables and SBE and among the physical variables are shown in Table 2.

Generally, areas of greater pine density were associated with greater tree grouping, more pulp, small sawtimber, and intermediate-sized sawtimber trees, fewer mature pine trees, less herbage, more downed wood, and lower scenic beauty. Stands of greater herbage quantities tended to have fewer immature pine trees and lower pine density, less downed wood, and higher scenic beauty.

STUDY 1: SIGNIFICANCE OF STAND BOUNDARIES

The potential for development of stand-based scenic beauty models can partly be appraised by examining how clearly stand boundaries differentiate sites for important variables. Analysis of variance was used to partition the variance among sites, for selected variables, into within- and between-stand components. The proportion of the variance (eta^2) allotted to the between-stand component indicates the percent of the variance accounted for by the stand boundary distinction.

Interestingly, as seen in Table 3, the stand boundary distinction accounted for as much variance in SBE (44 percent) as for any other variable, although the stands were delineated on aerial photographs without consideration for scenic beauty. Correspondingly, the stand distinction accounted for from 30 to 34 percent of the variance in most site-level overstory summary characteristics (i.e., cubic feet, board feet, pine basal area, crown canopy, and number of tree stories). Only for the variable representing degree of tree grouping was the stand distinction more important than it was for SBE, accounting for 48 percent of the variance in site-level estimates. The stand distinction accounted for no more than 23 percent of the variance in stand table variables (numbers of trees within species and size class distinction), but from 40 to 43 percent of the variance in herbage and small downed wood variables.

In general, the stand distinction accounted for at least 30 percent of the variance in site-level estimates for several variables which other studies have shown to be important in predicting scenic beauty. Perhaps most important, the stand distinction isolates areas of similar scenic beauty. This suggests that scenic beauty summarizes to some extent the physical variables upon which the stands were actually delineated.

STUDY 2: VALIDITY OF MODELS FOR PREDICTING TIMBER STAND SCENIC BEAUTY

Relationships of scenic beauty to physical characteristics of ponderosa pine in northern Arizona have been documented at the site level (Schroeder and Daniel 1981, Schroeder and Brown 1983, Brown and Daniel 1984). Briefly, all studies show that herbage, Gambel oak, and large pine contribute to scenic beauty, while

TABLE 2. Correlations among selected variables[a] for stand-level data.

Variable name	Variable name																
	SBE	PPBA	GOBA	CC	TG	TS	PPSAP	PP516	PP1624	PP24PL	GO5PL	PDTOT	CCTOT	DWVO	DWV14	DWV1	DWV3PL
	Pearson correlation coefficients[b]																
SBE	1.0																
PPBA	−.38	1.0															
GOBA	−.15	.41	1.0														
CC	−.25	.63	.61	1.0													
TG	.64	−.33	.19	−.04	1.0												
TS	−.25	−.07	−.51	−.35	−.40	1.0											
PPSAP	−.23	−.12	−.49	−.37	−.22	.42	1.0										
PP516	−.39	.85	.24	.46	−.24	−.07	−.01	1.0									
PP1624	−.31	.63	.49	.55	−.34	.07	−.17	.22	1.0								
PP24PL	.35	−.26	−.39	−.41	−.03	.33	−.06	−.43	−.11	1.0							
GO5PL	.05	.51	.91	.64	.02	−.31	−.47	.34	.62	−.44	1.0						
PDTOT	.77	−.27	.37	−.10	.62	−.12	−.15	−.20	−.24	.05	.25	1.0					
CCTOT	.82	−.29	.46	−.04	.69	−.39	−.31	−.26	−.25	.00	.29	.89	1.0				
DWVO	−.73	.61	.13	.40	−.50	.11	−.04	.49	.47	−.22	.14	−.54	.50	1.0			
DWV14	−.20	.11	−.22	.03	.25	−.08	−.02	.33	−.38	−.23	−.20	−.04	−.04	.20	1.0		
DWV1	.07	.08	−.31	−.01	.11	−.03	−.04	.21	−.27	.17	−.36	−.05	.01	.01	.40	1.0	
DWV3PL	−.32	.27	−.21	−.02	−.04	.17	.17	.46	−.13	−.23	−.19	−.17	−.16	.32	.62	.69	1.0
DWVTOT	−.31	.27	−.22	−.01	−.03	.14	.16	.46	−.15	−.21	−.20	−.17	−.15	.31	.64	.72	1.0

[a] See Table 1 for descriptions of the variables.

[b] A correlation coefficieent of ≥/0.35/ is significant at the 5 percent level.

TABLE 3. Significance of stand boundaries for selected variables.[a]

Variable				Analysis of variance	
Description	Name	Mean[b]	SD[c]	*F*[d]	Eta^2
Scenic beauty estimate	SBE	16.2	36.2	11.0	0.44
Gross pine volume (ft^3/acre)	CUFT	2,617.7	1,309.3	7.2	.34
Gross pine board feet per acre	BF	10,154.9	5,625.8	5.9	.30
Pine basal area (ft^2/acre)	PPBA	124.9	63.3	6.9	.33
Oak basal area (ft^2/acre)	GOBA	18.8	25.9	4.5	.24
Overstory crown canopy (%)	CC	57.1	20.5	6.7	.32
Tree grouping[e]	TG	2.2	.9	13.2	.48
Tree stories[e]	TS	2.6	.8	6.3	.31
Pine trees 0.1" to 5" dbh (no./acre)	PPSAP	179.3	341.4	2.2	.13
Pine trees 5" to 16" dbh (no./acre)	PP516	167.6	145.8	4.1	.23
Pine trees 16" to 24" dbh (no./acre)	PP1624	12.4	11.9	4.2	.23
Pine trees ≥24" dbh (no./acre)	PP24PL	3.5	4.0	2.9	.17
Herbage (pounds/acre)	PDTOT	83.6	74.4	10.4	.42
Herbage canopy (%)	CCTOT	15.9	14.9	10.6	.43
Herbage maximum height (inches)	HTMAX	10.0	6.2	9.4	.40
Downed wood ≤¼" dia. (ft^3/acre)	DWVO	10.7	6.0	10.7	.43
Total downed wood (ft^3/acre)	DWVTOT	1,277.3	1,001.3	5.5	.28
Fuel depth (inches)	FD	2.8	1.5	4.5	.24
Ground cover in litter (%)	LIT	76.7	12.0	5.0	.26

[a] The data set contains 333 sites located in 23 stands (some stands had only 14 sites because of missing data). The analyses are based on 22 and 310 degrees of freedom for the numerator and denominator, respectively.

[b] Mean of site-level estimates.

[c] Standard deviation of site-level estimates.

[d] All *F*-ratios are significant at the ≤0.0001 probability level, except that for variable PPSAP which is significant at the 0.002 probability level.

[e] See Table 1 for a description of this variable.

downed wood and pine saplings, poles, and small- to intermediate-sized sawtimber detract from scenic beauty. Furthermore, Brown and Daniel (1984) show that increases in pine basal area and tree grouping detract from scenic beauty. The objective of this study was to examine the extent to which *stand-level* scenic beauty could be predicted based on limited sets of variables representing physical characteristics for which estimates are likely to be available to forest managers. Three models developed from stand-level data are presented, followed by results of efforts to determine the validity of such models and the validity of site-level models for predicting stand scenic beauty.

Although a large data set was collected (e.g., 25 ratings for each of 1,380 color slides, 460 estimates of stand table variables), only 23 cases were available for stand-level models. Because of the resulting low case-to-variable ratio, and because of an interest in the viability of practical models requiring limited data, only variables found to be effective predictors of scenic beauty in site-level studies (e.g., Arthur 1977, Schroeder and Daniel 1981, Brown and Daniel 1984) were investigated. A stepwise regression procedure with an entry/deletion criterion (of an *F*-level of 4.0) limited the number of independent variables included in the final models and avoided inclusion of intercorrelated variables where they did not make a significant independent contribution to explanation of the dependent variable. Because of the low number of cases in this initial study, because the resulting models have few variables, and because of the intercorrelation among physical site characteristics (see Table 2), the specific coefficients of the models must be interpreted with some caution. However, the similarity of the stand models to independently derived site-level models indicates that the general relationship found here would generalize to other appropriate data sets.

Some of the detailed variables available from the inventory were combined, as in the earlier site-level modeling efforts, to arrive at the variables which were subjected to the regression procedure. For example, grass, forb, and shrub weights were combined to form the variable total herbage weight, number of pine trees per acre were combined into four size classes, and downed wood volumes were combined across size, condition, and creation classes. These combinations were based on similarity of the variables from an ecological or management standpoint and on previous research findings.

The three models presented here resulted from availability of groups of variables listed in Tables 1 and 2. Coefficients, significance levels, standard errors, R^2's, and adjusted R^2's for the models are presented in Table 4.[3] The first of the three models, the "basic" model, resulted from availability of the following independent variables: number of ponderosa pine per acre in the sapling (PPSAP), pulp and small sawtimber (PP516), intermediate sawtimber (PP1624), and large sawtimber (PP24PL) size classes; herbage weight per acre (PDTOT); and total downed wood volume per acre (DWVTOT). The solution included two terms expressing the positive contribution to scenic beauty of herbage and large pine:

$$\mathrm{SBE} = -32.47 + 4.70\ \mathrm{PP24PL} + 0.38\ \mathrm{PDTOT}. \tag{1}$$

The "detailed downed wood" model is a solution to the same variable set which produced the basic model, except that total downed wood volume (DWVTOT) was replaced by variables describing downed wood volume in the less than ¼-inch (DWVO), ¼- to 1-inch (DWV14), 1- to 3-inch (DWV1), and greater than 3-inch (DWV3PL) diameter classes. The solution (Table 4) includes the herbage and large pine variables of the basic model plus a small downed wood variable.

Finally, the "overstory" model results from availability of only overstory variables, including ponderosa pine trees per acre by size class, number of 5 inches dbh or greater Gambel oak trees per acre (GO5PL), pine basal area per acre (PPBA), oak basal area per acre (GOBA), number of tree stories (TS), degree of tree grouping (TG), and percent crown canopy (CC). This solution (Table 4) includes number of large pine trees and tree grouping variables.

All models are significant ($P < 0.001$), with standard errors ranging from 11 to 18 percent of the range in SBE for the sample (Table 4). The models imply

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[3] The shrinkage adjustment for r^2 used in this paper was that provided in the SPSS computer program (and in BMPD), which shrinks the obtained R^2 in proportion to the difference between the number of cases (23 stands in this study) and the number of independent variables in the multiple regression equation. This procedure is described in a number of statistic tests and is quite common in research literature. We acknowledge, however, that other more stringent procedures are advocated by some authors, including formulas that shrink R^2 in proportion to the number of independent variables potentially available for the multiple regression equation. The issue of R^2 shrinkage is complex—the amount of R^2 inflation by chance being a product of both case-to-variable ratio and the magnitude of error in the measurement of the variables involved (and thus of their intercorrelations). Most authors conclude that currently available shrinkage formulas are inadequate and that cross-validation provides the most effective approach to dealing with the problem. In any event, the stand models presented here are only offered as preliminary—23 cases is hardly a sufficient basis for establishing final models. Although the adjusted R^2s of those models probably overestimate, to some unknown extent, the potential of the models for predicting stand SBE of most ponderosa pine areas, the results of our cross-validation tests indicate considerable potential for development of useful stand-level scenic beauty models.

TABLE 4. *Pre-harvest stand-level scenic beauty models.*[a]

Terms in the equations		Models[b]					
		(1) Basic[c]		(2) Detailed downed wood		(3) Overstory	
Description	Name	Coef	Beta	Coef	Beta	Coef	Beta
Number of mature pine trees per acre	PP24PL	4.6999	0.32	3.6079	0.24	5.5076	0.37
Herbage weight, total (pounds/acre)	PDTOT	.3806	.76	.2788	.56		
Small diameter downed wood volume (ft^3/acre)	DWVO			−2.2606	−.38		
Tree grouping[d]	TG					22.5761	.65
Constant		−32.47		4.35		−41.17	
Model summary statistics							
R^2		0.70		0.80		0.55	
Adjusted R^2		.67		.76		.50	
F-level[e]		23.06		24.81		12.05	
Standard error		14.29		12.02		17.50	

[a] Based on 23 cases.

[b] All variables have an F-level ≥ 4.0 and are significant at the 0.05 probability level.

[c] From Brown and Daniel, 1984.

[d] See Table 1 for a description of this variale.

[e] All models are significant at the 0.001 probability level.

that stands of less tree grouping, with more herbage and mature pine and less small downed wood, have higher scenic beauty. Of course, the small geographical area represented by the data, as well as the small sample from which the stand-level models were developed, precludes their immediate use in providing management direction.

The ideal procedure for validating the stand-level scenic beauty models would be to sample some number of new stands from the same basic forest type, subject each new stand to a complete inventory and scenic beauty assessment, and then use the stand models to predict the new stands' SBE's. The correlation between predicted and obtained SBE's would indicate the validity (generalizability) of the models. In practice, such "cross-validation" is often accomplished by splitting the available cases into two sets, developing models independently for each set, and then cross-validating each model on the other set of cases. Neither of these procedures was attempted in the present study because of the expense involved in the first procedure and because the small number of cases available (also related to the expense factor) precluded a meaningful split of the cases as required by the second procedure.

In lieu of these preferred procedures, two sources of validation information are provided: the current stand models were compared with site-level models developed for other similar forest areas, and a modified cross-validation was based on a within-stand split of sites which yielded two separate estimates of biophysical and SBE values for each stand.

Arthur (1977) and Schroeder and Daniel (1981) presented scenic beauty models for southwestern ponderosa pine forests. Arthur's study related forest inventory measures estimated from single color slides of a forest scene to SBE's for each scene. Schroeder and Daniel measured forest characteristics directly at each forest site and based SBE's on four randomly oriented color slides at each site, essentially using the same procedures as used at sites within stands in the present study. As in the current stand models, both previous studies found that large pines and vegetation ground cover were positive scenic features and that downed wood was a negative feature. Other variables also entered the models (e.g., small diameter pines were negative scenic features), but the basic form of these earlier models was very similar to the stand models reported here.

For the second approach to stand model validation, the 15 sites within each of the 23 stands were split into two groups. Seven or eight sites were randomly chosen from each of the 23 stands, and the site data (both physical and SBE values) were averaged per stand, to create data set A. The remaining seven or eight sites per stand were then averaged to create data set B. For each of these two new stand-level data sets, three models were derived using the stepwise regression procedure that had been employed to obtain the models presented in Table 4. For example, using data set A (and separately data set B), SBE was regressed on PPSAP, PP516, PP1624, PP24PL, PDTOT and DWVTOT to obtain a model comparable to equation 1.

Comparison of the model coefficients showed that set A and B models were similar to the models developed from the full data set. In all cases, comparing models across data sets, the respective coefficients maintained the same sign and were similar in magnitude. Most important, set A models were largely successful in predicting set B SBE, and vice versa. The three set A models accounted for 53, 67, and 52 percent of the variance in set B SBE, respectively, while the three set B models accounted for 57, 67, and 46 percent of the variance in set A SBE.

An alternative to using models developed from stand-level data to predict stand SBE is to base the predictions on site-level models. To test this approach, site-level models developed from the Woods/Bar-M data set were used to predict stand-level SBE. Site-level models, of the same variables as the site-level models developed by Brown and Daniel (1984), were developed from subsets of the 333 sites used to generate the stand-level data. The variables and coefficients from site-level models were then used to predict stand-level SBE's from stand-level physical features.

In comparison to site-level models for the same data base, the stand-level models used essentially the same but fewer variables. For example, the site-level model corresponding to the basic stand model (#1) included three ponderosa pine variables (PPSAP, PP516, and PP24PL), two herbage variables (PDTOT plus an exponential of PDTOT),[4] and one downed wood variable (DWVTOT). When this model was specified using data from as few as 3 randomly chosen sites per stand (69 sites), it accounted for over 60 percent of the variance in stand SBE. Of course, using data from more sites per stand yielded models that accounted for more of the stand-level variance in SBE. Similarly, detailed downed wood site-level models of 3 sites per stand, containing independent variables PPSAP, PP516, PP24PL, PDTOT, DWVO, and DWV3PL, plus an exponential of PDTOT, accounted for over 70 percent of the variance in stand SBE.

Conversely, models developed from stand-level data did not account for as much of the variance in site-level SBE as similar models developed from site-level data. For example, the basic site model accounted for 49 percent, but the basic stand model accounted for only 36 percent, of the variance in SBE among the 333 sites. The site models contain the same variables as the stand models plus additional variables which are relatively unimportant to predicting stand-level SBE. Not surprisingly, the stand models lack sufficient variables to adequately distinguish among the sites, especially those within the same stand.

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[4] Although an exponential term for herbage was included in the site-level model, exponential terms were not tested in developing the stand models presented here.

The relationship between stand scenic beauty and site-level models was further tested in a cross-validation design. The 23 stands were randomly split into two groups, set A of 12 stands and set B of the remaining 11 stands. Regression models were then specified for set A using the 174 site-level cases in that set, and the models were used to predict stand SBE for the 11 stands in set B. Similarly, site-level models from set B (159 cases) were used to predict set A stand SBE. Both the basic and detailed downed wood site-level models (Brown and Daniel 1984), described above, were tested. For both sets, model coefficients were identical in sign and similar in magnitude to those of the original models. The set A basic site-level model accounted for 85 percent of the variance in set B stand SBE, while the set B basic site-level model accounted for 65 percent of the variance in set A stand SBE. Corresponding percentages for the detailed downed wood model were 70 and 90, respectively. These findings suggest that models developed from site-level data can safely be used to predict timber stand SBE.

To summarize the validity evidence: (1) the stand-level models reported here are substantially similar to site-level models developed for the same area, and for different areas in the same forest type; (2) division of cases within stands yielded separate stand models with similar coefficients to the stand models based on all sites, and substantially cross-validated with each other; and (3) site-level models based on data from half of the stands were quite successful in predicting stand-level SBE's for the other half of the stands. In addition, site-level models developed from as few as 3 sites per stand accounted for most of the variance in stand average SBE. Model validation is, of course, an incremental process, and there is no clear point at which a model may be declared "valid." The evidence reviewed above is sufficient to support the conclusion offered here, that the potential is substantial for modeling the scenic beauty of conventionally delineated timber stands based on forest inventory information that is typically available to forest managers.

STUDY 3: VALIDITY OF STAND-LEVEL SCENIC BEAUTY JUDGMENTS

The dependent variable of the stand models presented previously was represented by the mean of the scaled scenic beauty judgments of 60 independently judged slides (4 at each of 15 sites) per stand. The slides were shown to respondents in random order, without reference to site or stand distinctions. Does such a mean adequately represent stand scenic beauty? In other words, is the overall scenic beauty judgment for a stand (the judgment of the stand's global scenic beauty) represented by the mean of individual judgments for separate scenes found in the stand? Assuming that the individual scenes are an adequate sample of the entire stand, one would expect the mean of the judgments obtained for the individual scenes to represent the stand as a whole as long as people, in arriving at their global judgments, do not, for example, weight some scenes more heavily than other scenes. This third study considers whether SBE's of global judgments for relatively homogenous areas such as stands match the means of individual slide SBE's for the same areas.

Two published studies compared SBE's obtained from judgments made on-site in relatively homogenous areas of ponderosa pine to the means of SBE's obtained from judgments of slides taken in the same areas. Each study used six areas. The on-site judgments were "global," because subjects were free to look in all directions at several locations within each area they visited.

Boster and Daniel (1972) compared SBE's for single on-site global judgments per area to the means of SBE's for 25 slides per area. The slides were each taken at separate locations per area not restricted to the on-site view points. Mean slide SBE's accounted for 98 percent of the variance in on-site global SBE's. Daniel and Boster (1976) compared the average of of three on-site global SBE's per area found a correlation of 0.86 between the mean of single slide judgments and one estimate of global judgment. When 4 global judgment SBEs were averaged per stand, the correlations improved to an average of 0.89. Thus, the mean judgments for individual randomly arranged slides appear to provide a good estimate of global stand SBE's, especially when fewer than 11 slides are used per global judgment and when more than one global estimate can be averaged for each stand.

Conclusions

Traditional stand delineation procedures in ponderosa pine timber stands were found to group sites of like scenic beauty. The stand distinction accounted for 44 percent of the variance in site scenic beauty, and for 17 to 43 percent of the variance in individual physical site features known to be important predictors of site-level scenic beauty. Stand-level regression models showed that relative scenic beauty could be largely interpreted in terms of physical features.

Previous research has focused on site-level models, which are less expensive to develop because of the data required to adequately represent each stand. However, scenic beauty models are more likely to be used for stand-level projections, using stand-level estimates for the required independent variables, perhaps obtained as a routine part of forest management. Fortunately, site-level models predict stand scenic beauty about as accurately as stand-level models.

Color slides have been shown elsewhere to be good substitutes for actual on-site scenes. If scenic beauty judgments of sufficient slides from an area are obtained, their mean closely matches on-site judgments of the area. Further, global judgments for sequences of slides representing timber stands correlate well with stand SBEs based on the means of individually presented slides. More study is needed, however, to better understand the nature of global slide judgments and the relationship of such judgments to on-site judgments of the scenic beauty of stands.

The models developed in this paper suggest, for areas of relatively dense ponderosa pine exhibiting few signs of previous harvest, that less horizontally complex stands with more herbage and mature pine and less small downed wood have higher scenic beauty. These preferred conditions occur in less dense (more open) stands.

A possible implication is that scenic beauty of stands similar to those of the study area can be improved by reducing overstory densities, leaving some mature trees, and restricting grazing sufficiently to maintain visibly healthy herbage. However, it is not appropriate to conclude from these models that large areas of low density stands are preferable to areas with a mixture of densities. The reported models reflect the particular mix of sites represented in the study area. The stands averaged 145 square feet of basal area (ranging from 84 to 260 square feet) in pine and oak combined, making the occasional sparse stand with more herbage relatively rare.

Further, most sparsely treed inventory sites were surrounded by areas of greater density, allowing slides to show (untallied) trees beyond the inventoried site. More importantly, all subjects responded to a mixture of slides representing a wide range of stand densities, somewhat similar to the mixture of sites one would see on an actual trip through similar forests. The fact that, in relation to a preponderance of relatively dense sites, sparse sites were preferred, does not prove that uniformly sparse forests are preferred to denser forests or forests of mixed density. The importance of spatial distribution and of a variety of stand conditions on preferences for forest areas must be understood before the near-view scenic beauty models can be fully and appropriately applied to forest management.

The fact that the current models have been shown to be effective in predicting sample scenic beauty at the timber stand level suggests the potential of psychophysical scenic beauty models for use in actual forest planning and management situations in southwestern ponderosa pine. For example, such models could be easily linked to physical simulation models allowing prediction of near-view scenic effects along with traditionally measured forest characteristics. Such models would allow estimation of the change in scenic beauty with harvest, grazing, and slash cleanup. The availability of models that provide precise and reliable estimates of the publics' perception of scenic beauty could significantly enhance the ability of forest managers to protect and enhance aesthetic benefits in balance with other products and management objectives.

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