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Modeling Forest Scenic Beauty: Concepts and Application to Ponderosa Pine

Thomas C. Brown and Terry C. Daniel



Abstract

Statistical models are presented which relate near-view scenic beauty of ponderosa pine stands in the Southwest to variables describing physical characteristics. The models suggest that herbage and large ponderosa pine contribute to scenic beauty, while numbers of small and intermediate-sized pine trees and downed wood, especially as slash, detract from scenic beauty. Areas of lower overstory density and less tree clumping were preferred. Moderate harvest of relatively dense stands tends to improve scenic beauty once the stand has recovered from obvious harvest effects. The recovery period can be greatly reduced by slash cleanup.

PREFACE

This paper was written for forest managers, landscape architects, and others interested in forest scenic quality. The paper presents the results of recent research directed at developing statistical models to predict the effects of changes in forest characteristics on public perception of scenic beauty. The foundation for this modeling effort is approximately a decade of research and development of methods to quantitatively assess the scenic beauty of forest landscapes. In that time, several related methods for measuring scenic quality based on public perception and judgment have been developed, tested, and successfully applied in forest management contexts. This progress in scenic beauty measurement and prediction model development has important implications for forest management and planning.

The introduction of this paper describes the place of scenic beauty modeling within forest management. The next section examines various efforts to assess forest scenic beauty. Then, the data used for this study are described. The next section presents several scenic beauty models and the procedure used to specify them. This is followed by a description of two aids for interpretation of scenic beauty estimates. Then, uses of the models are discussed, first in terms of forest management in general, and second in terms of landscape assessment and the Visual Management System. Last, some conclusions are offered. Detailed bivariate relationships among the variables are described in the appendix. The data and modeling sections are the most technical. Readers interested in an overview are directed to the management implications and introductory sections, then to the summary and conclusions, and then perhaps to the interpretation and use sections.

Modeling Forest Scenic Beauty: Concepts and Application to Ponderosa Pine

**Thomas C. Brown, Economist
Rocky Mountain Forest and Range Experiment Station¹**

and

**Terry C. Daniel, Psychologist
University of Arizona**

¹*Headquarters is in Fort Collins, in cooperation with Colorado State University.*

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MANAGEMENT IMPLICATIONS

Statistical models were developed relating the public's perception of scenic beauty to forest features. In order to develop these models, timber stands were delineated, using standard timber management criteria, in two watersheds on the Coconino National Forest, in north-central Arizona. All stands were predominately of ponderosa pine, with Gambel oak mixed in throughout, and ranged from 30 to 380 square feet of basal area. Overstory, herbage, downed wood, and ground cover features were measured in selected stands, at 15 points (sites) per stand, using widely accepted forest inventory procedures. Color slides were also taken at each site, from which scenic beauty judgments were obtained. The physical measurements of forest features were then statistically related to the scenic beauty judgments.

The models show that, for ponderosa pine stands similar to the study area, herbage and large pine contribute to scenic beauty, while numbers of pulp-sized and small sawtimber-sized pine trees and downed wood detract from scenic beauty. Gambel oak of all sizes improve scenic beauty. Slash is much more detrimental to scenic beauty than natural downed wood. Lower overstory densities are preferred, as are lower degrees of tree grouping.

The models suggest that moderate harvest of relatively dense stands, such as most of those inventoried for this study, would improve scenic beauty once the stand had recovered from obvious harvest effects, and that the recovery period could be shortened considerably by slash removal. Furthermore, leaving some mature pine and avoiding heavy grazing of the herbage response to harvest would enhance scenic beauty.

The scenic beauty models are well suited to use in forest planning. They can be used to estimate the relative scenic beauty of existing forest areas as well as to predict the impact of postulated changes in those areas given relatively modest measurement data inputs. And, because they use physical features as independent variables, they can be easily linked to physical simulation models, allowing prediction of near-view scenic effects along with more traditionally quantified forest characteristics. Furthermore, their use supplements the information available from application of the Visual Management System by providing scenic beauty estimates that are based directly on public perception and judgment, and that are mathematically related to manageable forest features.

INTRODUCTION

Public concern about the scenic beauty of outdoor environments is reflected in recent land management legislation. The Multiple-Use Sustained-Yield Act of 1960 and the National Environmental Policy Act of 1969 and associated regulations point specifically to the need to consider effects of public land management on environmental amenities, including wilderness, recreation, and esthetics. More recent legislation, the Forest and Rangeland Renewable Resources Planning Act of 1974 and the National Forest Management Act of 1976, emphasizes the need for systematic consideration of amenity resources, and specifically identifies esthetic along with wildlife, recreation, and wilderness resources.

Concern for esthetic resources has been addressed in part by the designation of special parks, monuments, and wilderness areas. The focus of this paper, however, is the substantial esthetic resources represented by the vast acreages of public lands managed under multiple-use guidelines. These lands support a wide variety of outdoor recreation activities and scenic experiences that are enjoyed by millions of visitors each year. Adequate consideration of the esthetic effects of land management alternatives for these areas requires some means for reliably determining whether esthetic quality is getting better or worse (i.e., at least an ordinal measurement capability is needed). To adequately examine "tradeoffs" between esthetic and other effects of management, a greater level of precision is necessary. In this case, interval level measurements of esthetic values are required to indicate how much esthetic quality changes with different management alternatives. Only with such precision can esthetic effects be evaluated along with more traditionally measured forest outputs (e.g., timber volume) in comparable terms.

Defining Forest Esthetics

Esthetic values (or resources) often are associated with outdoor recreation or wilderness, frequently in a way that implies they are interchangeable. At other times they are distinguished, so that esthetic resources are treated as separate from recreation or wilderness resources. In the latter case, esthetic value usually implies the scenic quality or natural scenic beauty experienced and appreciated by visitors, who may or may not be engaged in "recreation."

Esthetic experience involves a complex of environmental factors (smells, sounds, touches, and sights) and visitor expectations, goals, and feelings. A major aspect of visitors' esthetic experiences in forest environments, however, is visual. Research and management effort directed at forest esthetics (as distinguished from recreation) has principally focused on the visual characteristics of the forest environment and people's perception and esthetic judgment of the beauty of the forest landscape.

People who visit forest lands are motivated by a variety of needs, wishes, and desires, and receive a variety of physical, psychological, and spiritual benefits (Driver and Rosenthal 1982). Some visitor goals and benefits primarily relate to a recreation activity; others emphasize visual esthetic experience. A continuum of visitor interactions with the forest environment may be conceptualized. Off-road vehicle use or white water kayaking may tend to place relatively little emphasis on the visual esthetic component. The quality of hunting and fishing activities may depend somewhat more on the scenic quality of the forest setting, while hiking, camping and picnicking tend progressively to place more emphasis on visual esthetic experiences. Driving for pleasure or sightseeing depend almost entirely on the scenic beauty of the landscape.

Different individuals may emphasize activity or visual experience components more or less, regardless of the apparent character of their interaction with the environment. The same individual's emphasis may vary from visit to visit or even moment to moment during the same visit. Regardless, the scenic beauty of the forest environment probably always makes some contribution to visitor satisfaction, and in many cases is the predominant component.

The visual esthetic component is commonly referred to as "landscape quality," "visual quality," "scenic quality," or "natural beauty." Daniel and Boster (1976) and Daniel and Vining (1983) argue that "scenic beauty" best captures the meaning of the visually appreciated esthetic resources of the forest. This paper principally uses the term "scenic beauty."

ASSESSING FOREST SCENIC BEAUTY

Two recent publications classified approaches to "landscape quality assessment" (Zube et al. 1982, Daniel and Vining 1983). Both identified the "psychophysical approach" as a major direction in recent research. In the psychophysical approach, scenic beauty is conceptualized to result from the interaction between the physical features of the environment and the perceptual and judgmental processes of a human observer. That is, beauty is neither inherent in the landscape nor purely "in the eye of the beholder"; it is a product of an encounter between an observer and the landscape. This approach to landscape quality assessment requires comparisons of observers' perceptual responses to measures of landscape features for a set of different landscapes.

Zube et al. (1982) and Daniel and Vining (1983) both distinguish psychophysical models from "expert judgment" or "formal esthetic" models where emphasis is placed on landscape features, and "cognitive" or "psychological" models where observer interpretations are emphasized. The formal esthetic approach is exemplified by the USDA Forest Service (1974) landscape architects' "Visual Management System." This approach is based on the analysis by Litton (1968) of abstract formal landscape features, especially color, form, line, and texture, and their interrelationships (e.g., contrast, harmony, and variety). Focusing principally on the variety factor, professional landscape architects perform expert analyses of forest areas and classify them into essentially high, medium, and low visual quality categories (variety classes A, B, and C). Based on variety classifications and assigned categories of sensitivity (a combination of distance, duration of view, and intentions of potential viewers), management guidelines or "Visual Quality Objectives" are established. The formal esthetic approach, then, relies on an expert's analysis of both formal properties of the landscape and viewer incidence and interest. In contrast, the psychophysical approach is based on the collective esthetic judgment of groups of untrained "public" observers (i.e., a "consumer evaluation" approach) combined with empirically determined, scenically relevant landscape features.

The psychological or cognitive model is very similar to the psychophysical model, often using identical procedures to obtain indexes of landscape scenic beauty. The principal difference is in the nature of the landscape variables to which scenic quality (or preference) judgments are typically related. Psychological models emphasize meanings or interpretations assigned to landscapes rather than more direct assessments of physical characteristics. For example, the Kaplans emphasized the role of "mystery" in determining landscape preferences (R. Kaplan 1975, S. Kaplan 1975), and Ulrich (1977) suggested "legibility" as an important factor. The goal of the cognitive or psychological approach is to develop a psychological understanding (or theory) of landscape preference. The psychophysical approach has the less ambitious goal of developing the means to predict and control (manage) landscape quality. The emphasis is upon relating scenic quality perceptions to more directly and objectively measured features of the environment.

The basic psychophysical approach follows classical methods established by psychologists in the mid-19th century as they attempted to quantify relationships between changes in simple physical stimuli and human perceptual response. For example, precise mathematical relationships were developed between changes in the intensity of a light and human perception of brightness. Later, investigators applied these methods to more complex situations. Thurstone (1959) scaled esthetic qualities of several types of stimuli, and Stevens (1975) proposed a "metric for the social conscience." These and other investigators developed quite sophisticated mathematical models and analytic techniques to

measure perceptual responses and to describe psychophysical relationships. Thus, the basic approach and analytical procedures required for psychophysical assessments of landscape scenic beauty have been developed and tested for more than 150 years.

Early Research Efforts

The first studies assessing landscape quality in terms of human perception established a basic pattern that is evident in contemporary research. The typical format for psychophysical landscape studies includes three steps. First, color photographs of the landscape are shown to relevant groups of observers who express their esthetic judgment and preference by ranking, rating, or choosing scenes. Based on the observers' responses, the represented landscapes are scaled from low to high scenic quality. Second, characteristics of the landscape are measured. Finally, the measurements of the physical (used here to include biological) landscape features are related to the perceptual judgment-based indexes of scenic quality.

Shafer (1964) was among the first to suggest using color photographs and psychophysical techniques to measure the scenic quality of forest landscapes. Peterson (1967) successfully measured scenic preferences for residential landscapes using a Thurstone scaling metric. Shafer and his colleagues (Shafer et al. 1969, Shafer and Mietz 1970, Shafer and Richards 1974) went on to assess several wildland scenes and to propose a mathematical model for predicting preferences for vista scenes. These early studies, and many others at about the same period (e.g., Coughlin and Goldstein 1970, Fines 1968, Kaplan et al. 1972, Zube 1974) established that:

1. Individual human observers consistently evaluate the scenic beauty of different landscape scenes presented as either color slides or prints.
2. Scenic beauty judgments of color slides or prints adequately estimate judgments of actual landscapes.
3. There is good agreement among different observers regarding the relative scenic beauty of landscapes.

The work reported in this paper follows the psychophysical tradition. Specifically, it uses the "Scenic Beauty Estimation" (SBE) method of measuring scenic beauty, standard forest inventory techniques for measuring landscape characteristics, and statistical models to relate the two.

Measuring Scenic Beauty

Initial papers by Boster and Daniel (1972) and Daniel et al. (1973) introduced the basic features of the SBE method, and Daniel and Boster (1976) presented a more comprehensive and formal statement. They explained the foundation of the SBE method in psychological and

psychophysical measurement theory, especially Thurstone categorical scaling models (Torgerson 1958, Nunnally 1978) and some principles from signal detection theory (Green and Swetts 1966).

In a typical application of the SBE method, landscape areas are represented by a systematic photographic survey (e.g., a number of randomly located, randomly oriented color slides). These photos are presented to observers who independently rate each scene using a 10-point scale. Ratings are transformed following Thurstone's procedures and the guidelines from signal detection theory to yield an interval scale index of perceived scenic beauty, the SBE. Differences in observers' use of the rating scale (e.g., low raters vs. high raters) are adjusted by the scaling procedures so that the resulting SBEs provide an unbiased measure of differences in perceived scenic beauty.

Applications of the SBE method have covered a wide range of forest scenic quality assessment problems. Initial studies focused upon the different scenic consequences of alternative watershed treatments in ponderosa pine forests (Daniel et al. 1973, Daniel and Boster 1976). The method also has been applied to northeastern (Brush 1979) and northern Rocky Mountain (Benson and Ullrich 1981) forests, where scenic effects of silvicultural methods, species composition, harvest techniques, roads, and other management changes in the forest landscape were measured. Daniel et al. (1977) developed a "scenic beauty map" of a ponderosa pine forest area by using the SBE scale to compute "contours" (isoquants) of scenic quality. The scenic effects of prescribed fires and wildfires in ponderosa pine forests were observed by Anderson et al. (1982) and by Taylor and Daniel (1984). Schroeder and Daniel (1980) used the SBE method to develop "scenic beauty profiles" for measuring the relative beauty of views offered by different forest road alignments. Daniel et al.² provided a comprehensive assessment of the scenic impact of mountain pine beetle damage to ponderosa pine stands in the Front Range of Colorado. These and other applications of the basic SBE methodology have demonstrated the utility of the method for assessing forest scenic resources.

Several studies have substantiated the theoretical sufficiency of the SBE method. Daniel and Boster (1976) report two tests of the reliability and validity of using color slide representations to obtain scenic beauty values for forest areas. Buyhoff and his associates (Buyhoff and Leuschner 1978, Buyhoff and Wellman 1980, Buyhoff et al. 1980) provided some of the most successful and rigorous examples of psychophysical scenic quality assessments using a paired-comparison response format, rather than the rating scale method used in the SBE method. Observer choices among pairs of landscape scenes were subjected to psychophysical

²Daniel, Terry C., G. J. Buyhoff, and J. D. Wellman. 1981. *Assessment of public perception and values regarding mountain pine beetle and western spruce budworm impact in the Colorado Front Range. Final Report, Cooperative Agreement No. 16-930-GR, 36 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.*

scaling based on Thurstone's (1927) "Law of Comparative Judgment." The result was an interval scaled index of the observers' preferences based on the perceived scenic quality of the scenes. They found that this metric clearly distinguished among vista landscape scenes, and that it could be used to characterize scenic beauty in prediction models, thereby accounting for most of the variance in scenic beauty of the vista scenes.

Both the SBE and paired-comparison-based indexes purport to measure perceived scenic quality. Theoretically, they should yield very similar scale values for identical scenes. This theoretical expectation was tested in two studies (Buyhoff et al. 1982, Hull et al. in press) where identical landscape scenes were independently assessed using the rating and paired-comparison procedures. Resulting ratings and choice frequencies were subjected to appropriate transformations to yield SBE values and comparative judgment indexes, respectively. The two measures produced nearly identical scalings of the landscape scenes (correlations between the two scales were all greater than 0.90).

These same studies also provided a test of context stability, both with regard to the landscapes being assessed and the observers making the judgments. Observer groups represented general public populations (church and civic organizations) and college students in Arizona and Virginia. Paired-comparison groups saw only the 16 forest scenes involved in the theoretical tests, while SBE observers rated the 16 scenes randomly interspersed among more than 100 other similar scenes. None of these context differences produced significant degradation of the relationship between the SBE and paired-comparison metrics.

Near-View Scenic Beauty Prediction Models

Shafer et al. (1969) were the first to statistically relate public preference judgments of forest scenes to the physical features in the scenes. They studied vista scenes and measured the independent variables directly on the photographs of the scenes. Studies of near-view scenes and measurement of independent variables onsite, the focus of this paper, came later.

Daniel and Boster (1976) were the first to statistically relate public preferences for near-view forest scenes to physical features of the scenes. Using the SBE method of characterizing scenic beauty, they demonstrated that different harvest treatments produced different scenic beauty values in what were initially very similar ponderosa pine stands. These treatments differed in both overstory and ground cover manipulations, which suggested that these factors were important determinants of perceived forest scenic quality. Daniel and Boster (1976) reported relationships between SBEs and measures (judged from color slides) of forest density, tree size, vegetative ground cover, and amount and distribution of slash and downed wood. For example, stand density correlated 0.74, tree diameter correlated 0.73, and the amount of downed wood correlated -0.87 with SBE values.

Arthur (1977) used multiple regression analysis to develop the first models for predicting near-view scenic beauty based on vegetative characteristics of forest scenes. Individual color slides of ponderosa pine forest sites were subjected to observer rating and SBE scaling. The same slides were presented to two forest silviculturists familiar with the areas, who estimated values for several forest mensuration variables, including stand densities, tree size distributions, and downed wood volumes. Multiple regression models based on these mensuration variables explained 76% of the variance in SBE values, showing considerable precision in predicting the SBEs obtained for the slides. These models, and several others reported by Arthur (1977), confirmed that near-view response models could be developed and could be useful in managing forest areas where scenic quality effects were of concern.

Daniel and Schroeder (1979) and Schroeder and Daniel (1981) presented models based on direct field inventories of forest characteristics for many sites in northern Arizona and the Front Range region of Colorado. Each site was directly inventoried using conventional forest mensuration procedures to obtain estimates of overstory stand structure (e.g., stems per acre in 4-inch size classes), downed wood sizes and volumes (cubic feet per acre in several size classes), and vegetative ground cover (pounds per acre of grasses, forbs, and shrubs). For the Arizona sites, SBE values were based on observer judgments of eight color slides taken within each of 94 approximately 1-acre-sized forest sites. A number of aggregations and combinations of the independent (mensuration) variables were investigated, and several multiple regression models were developed for different subsets of the forest sites (e.g., sites with up to 40%, up to 60%, and up to 90% of the overstory in ponderosa pine). In all cases, final models accounted for more than 50% of variance in SBE values.

To test generalizability, Schroeder and Daniel (1981) applied the Arizona models to 40 independently assessed sites in the Boulder Canyon area, northwest of Denver, Colo. Because direct application of Arizona models was not successful, they developed similar models for the Colorado sites. Principal differences included adjustments of coefficients for variables common to both sets of models and the addition of insect damage variables in the Colorado models. The Boulder Canyon sites were selected for a study of the scenic impacts of the mountain pine beetle outbreak in the Colorado Front Range; the Arizona sites had no noticeable insect damage or mortality.

Further developments in scenic beauty modeling continue. Schroeder and Brown (1983), using the same data as that reported in this paper, tested the utility of nonlinear and interaction terms in regression models of near-view scenic quality, and found that such terms generally added little to simple linear terms in predictive capability.

Second, approximately 200 sites in the Colorado Front Range have been used to develop models sensitive to mountain pine beetle impacts (Daniel et al. 1981). These models have been incorporated into a comprehensive

computer-assisted system for projecting the socioeconomic impacts of insect damage and insect-targeted forest management actions. The Integrated Pest Impact Assessment System (Daniel et al. 1983) includes models for predicting the scenic consequences of alternative insect and forest management plans.

The potential utility of near-view scenic beauty response models is well documented by previous research. More extensive tests were needed, however, to examine the importance of mensurational variables not previously considered, to investigate the utility of separate models for preharvest and postharvest conditions, and to test the utility of near-view models in the context of operational scale forest management problems. In addition, the characteristics of a general near-view model for Southwestern ponderosa pine needed to be described. Finally, the meaning of the scenic beauty values provided by the models had to be more precisely described than it had been in previous papers; and the potential role of such models in national forest management, and the relationship of the models to the Visual Management System, needed to be described. This paper addresses these needs.

STUDY AREA AND METHODS

The psychophysical approach to modeling near-view forest scenic beauty combines environmental perception and judgment information (the dependent variable) with standard forestry and rangeland information (the independent variables). This section briefly reviews the study area and field inventory procedures and then describes the dependent variable and data sets. Bivariate relationships between the variables are described in some detail in the appendix, with a focus on intercorrelation and nonlinearity.

Study Area

The principal data for this paper were collected on Woods Canyon (12,000 acres), and Bar-M (16,360 acres) Watersheds, approximately 40 miles south of Flagstaff, Ariz., in the northern part of the 275,000-acre Beaver Creek Watershed, on the Coconino National Forest (fig. 1). The Woods/Bar-M area ranges in elevation from 6,400 feet in Woods Canyon to 7,740 feet at Gash Mountain. Slopes average about 10% and rarely exceed 40%. The area is predominantly forested with ponderosa pine, with Gambel oak interspersed throughout and alligator juniper interspersed at lower elevations. Bedrock underlying the area consists of igneous rocks of volcanic origin. Soils are mostly residual and less than 4 feet deep, and consist of the Siesta-Sponseller series and the heavier Broliar 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; but, pine dropseed, black dropseed, June grass, and squirreltail are also common. The area had been selectively harvested about 30 years

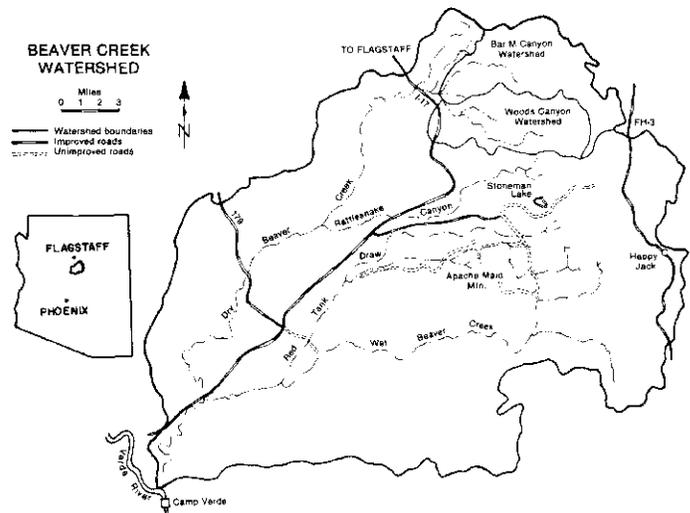


Figure 1.—Woods Canyon and Bar-M Watersheds.

before this study, but few signs of that harvest remained, giving the area a generally unmanaged appearance.

Timber stands of at least 10 acres of like density (crown closure), tree distribution and grouping, tree height, and crown size were delineated on aerial photos of the Woods/Bar-M area. Six percent of the stands were pole timber stands, 17% were sawtimber stands, and 76% were mixed sawtimber and pole timber stands. Forty-nine percent were from 40% to 70% crown canopy, and 34% were of greater than 70 percent crown canopy.

Inventory Procedure

Twenty-three of the delineated stands were inventoried in 1979, before the recent harvest. These stands were selected in a quasi-random fashion, with consideration given to accessibility and the predetermined logging schedule. The proportion of preharvest stands inventoried in each stand type and crown canopy class reflected the full distribution of stands in the Woods/Bar-M area. Four of the 23 stands were reinventoried in 1980 (after sawtimber harvest, but before any slash treatment) and again in 1981 (after pulpwood was additionally harvested and slash was piled). The postharvest inventories do not proportionally represent the entire Woods/Bar-M area. The modeling results presented are based on these preharvest and postharvest inventories.

The inventory period each year was from late-May until mid-August. Stands were inventoried around 15 equidistant sample points located along lines placed to avoid sampling bias associated with topographic or drainage characteristics of the stands. The sample points were always placed at least 1 chain within the stand and at least 2 chains apart. In this paper, the specific location of the inventory point is termed a "point," and the area around the point, where the forest characteristics were measured, is termed a "site." The layout of the site inventory procedure is depicted in figure 2.

Upon arriving at a sample point, the inventory crew first chose a random compass direction from a 1 to 360 random number table and took a color slide in that direction and 90°, 180°, and 270° from the selected random direction. Photos were taken on ASA 64 film using a 35-mm camera with a 55-mm lens. On flat ground, the camera aim was parallel to the ground. On slopes, the camera was tilted up or down to accommodate the terrain. Branches hanging so close to the lens as to present focusing problems were held back as not to 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. None of the photos include buildings or other structures. Dirt roads and barbed wire fences are only occasionally visible.

Physical characteristics were measured using common forest and range inventory techniques. Seedlings and saplings were tallied by species in a 0.01-acre plot centered at the point (fig. 2). Larger trees were tallied by species, using a 10-factor prism. Crown canopy was measured by averaging four readings of a crown canopy densiometer. Stumps were tallied in a 0.1-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 located around the point (fig. 2). 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). Percentage 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. Also, the percentage of mechanically disturbed area (e.g., skid trails) in a 66-foot radius plot centered at the sample point was estimated.

Brown's (1974) procedure was followed in taking downed wood measurements along eight 40-foot transects located around the point (fig. 2). 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, percentage of the small downed wood which harvest created, and fuel depth. Finally, number of brush piles, at least 5 feet in diameter, within the 66-foot radius plot were tallied. Site index (Minor 1964) was measured for seven site trees scattered throughout each stand. The seven measurements were averaged to yield an estimate of stand site index which was assigned to all sites in the stand.

Scenic Beauty

The slides taken at each sample point were shown to groups of at least 25 observers who rated the slides for scenic beauty on a 10-point scale. Twenty-five "base area" slides, which are slides common to all slide presentations, were evenly spaced among the 130 slides rated in each session. The base area slides were taken in Woods Canyon before the recent harvest at points other than those which received the full inventory.

For practical reasons, slides were shown in two contexts. Preharvest slides were shown in sets exhibiting no evidence of recent harvest. Postharvest slides (harvest occurred within 2 years and effects of harvest, such as slash piles, were obvious) were shown in slide sets containing about one-half recent harvest slides and one-half preharvest. The preharvest slides shown in the mixed preharvest and postharvest context were from ponderosa pine forests similar to the Woods/Bar-M area. Thus, in a given slide rating session, observers saw the 25 preharvest base area slides plus 105 slides unique to each group consisting either of only preharvest slides or of an equal mixture of preharvest and postharvest slides.

Slides to be shown in a session were scrambled into a random order and loaded into slide trays. The instructions in figure 3 were read to the observers; but, no other information was given prior to judging the slides. The first one-half of the slides were shown 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

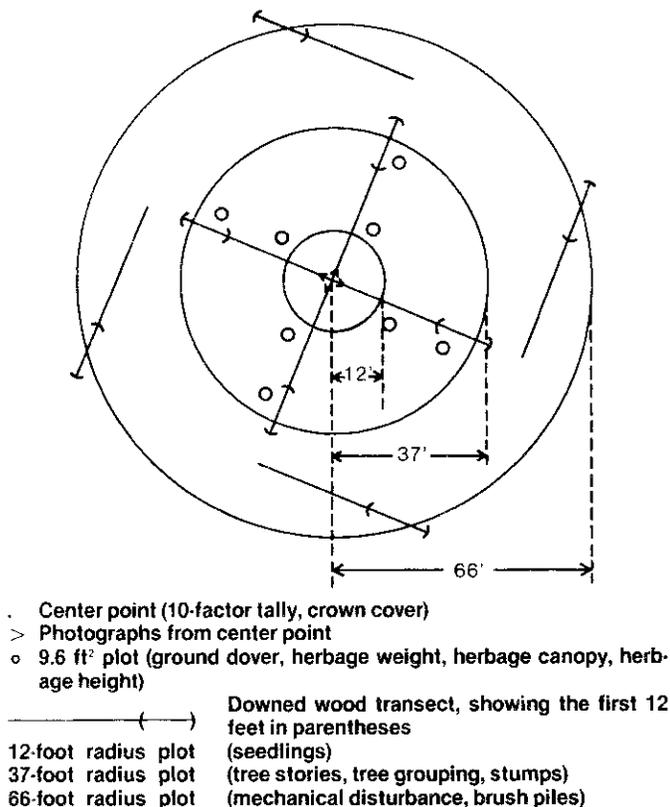


Figure 2.—Inventory site layout.

slide. After all slides of a given session had been shown, participants' questions about the study were answered.

The ratings were scaled using the "by slide" procedure developed by Daniel and Boster (1976). Ratings of each subject group were converted to a set of standardized (Z) scores, one per slide, based on the frequency distribution of ratings for all observers for that slide. This follows Thurstone's theory of categorical judgment (see Torgerson 1958) and adjusts groups' scores to a common interval size based on rating variances. The mean of the standardized scores of the base area slides (B) for each group was then subtracted from the standardized score for each other slide the group rated to yield a standardized difference (from B) for each slide. This procedure, taken from signal detection theory (Green and Swells 1966), adjusts groups' scores to a common origin. The scaling procedure yields an interval scale measure of scenic beauty, and allows the judgments from two or more groups of observers to be combined. The origin-adjusted standardized scores were multiplied by 100 to eliminate decimals, and called "SBEs." Any slide having a positive SBE was preferred to an average slide from the base area; slides having negative SBEs represent scenes preferred less than the base area.

Approximately 50 sets of slides were shown to observer groups in the course of obtaining ratings for all Woods/Bar-M slides. Most of the groups comprised student volunteers from introductory psychology classes at the University of Arizona; 10 were extracurricular student groups, and 10 were church and civic groups. All of the groups are considered general public groups, because they do not

represent any particular outdoor or natural resource management interest.

The agreement among groups was checked by comparing SBEs for the base area slides. Pearson's correlations of one group's SBEs for the base area slides to another group's SBEs for identical base area 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. Less than perfect (1.0) agreement is attributed to differences in esthetic perceptions among individuals in the groups and contextual differences introduced by the unique (non-base area) slides shown to the various groups. Psychology student groups could not be distinguished from extracurricular student groups, and student groups could not be distinguished from church and civic groups, in terms of the base area correlations. This confirms earlier findings (Daniel and Boster 1976, Buyhoff et al. 1982) that student volunteers adequately represent the general public for these types of studies.

The four SBEs representing the four slides taken at each point were averaged to yield the site SBE. Of the 345 sites inventoried before harvest in the 23 stands, 12 sites were eliminated because of unacceptable slide quality. SBEs for the remaining 333 preharvest sites ranged from -83 to 122, averaged 16, and had a standard deviation of 36. Preharvest site-level results for the Woods/Bar-M area, presented in the following sections, are based on data from these 333 sites.

SBEs for 120 sites inventoried in the recently harvested stands ranged from -48 to 93, averaged 9, and had a standard deviation of 31. Note that harvest effects were not obvious at all of the 120 sites. Postharvest results for the Woods/Bar-M area, presented in the following sections, are based on data from these 120 sites.

Figure 4 shows two locations typical of the Woods/Bar-M area viewed in the three consecutive inventory years. The 1979 photos show the locations before harvest, and the 1980 and 1981 photos show the locations at stages during the harvest and slash cleanup process. The SBEs for the 1979 photos were obtained in the preharvest slide presentation context, while the SBEs for the 1980 and 1981 photos were obtained in the mixed preharvest and postharvest slide presentation context. Note that the orientation of these photos changed slightly from one year to the next.

MODELS OF SCENIC BEAUTY

Many different models relating scenic beauty to physical characteristics could be developed, given the data available for the Woods/Bar-M area. Such models could differ in terms of independent variables included, equation form, and statistical model and criteria. In selecting the models presented below, the objective was to provide practical models for use in forest management. Thus, the models were restricted to variables of physical characteristics for which estimates are more likely to be available to forest managers, and contained only those

I am going to read some standardized instructions, so that everybody participating in these experiments will have the same information.

Today, more than ever, prudent management of wildlands such as our national forests is very important. Many wildland researchers are conducting investigations on the effects of alternative vegetative management procedures. Included among these effects are the scenic impacts of various management practices. In this research, we are attempting to determine the public's esthetic or scenic perception of such management alternatives, and we greatly appreciate your time in this effort.

We are going to show you, one at a time, some color slides of several wildland areas. Each scene represents a larger area. We ask you to think about the area in which the slide was taken rather than about the photographic quality of the individual slide.

The first slides will be shown very quickly, just to give you an idea of the kinds of areas you will be evaluating. Try to imagine how you would rate these slides, using the "rating response scale" at the top of your scoring sheet. Note that the scale ranges from one, meaning you judge the area to be very low in scenic beauty, to ten, indicating very high scenic beauty.

Then, after these initial slides, I will announce that you are to begin rating the next set of slides. You should assign one rating number from one to ten to each slide. Your rating should indicate your judgment of the scenic beauty represented by the slide. Please use the full range of numbers if you possibly can and please respond to each slide. Are there any questions? (Answer any questions by repeating instructions, or deferring them until after the experiment is over.)

These are the preview slides—do not rate these slides, just use them to get an idea of the range of areas you will see. (Show the preview slides.)

Now, rate the following slides, using the one to ten rating scale. A number will appear where the X is now to help you keep track of which slide is being shown. (Show tray one, at 8 seconds per slide.)

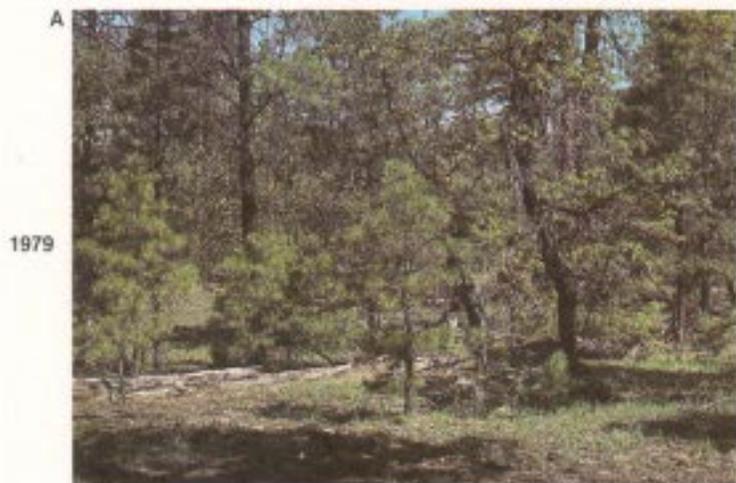
I am going to change slide trays now—these slides will be shown at a slightly faster rate so that we can finish sooner. (Show tray two at 5 seconds per slide.)

That is all of the slides.

Figure 3.—Instructions to subjects for rating slides.

View 1

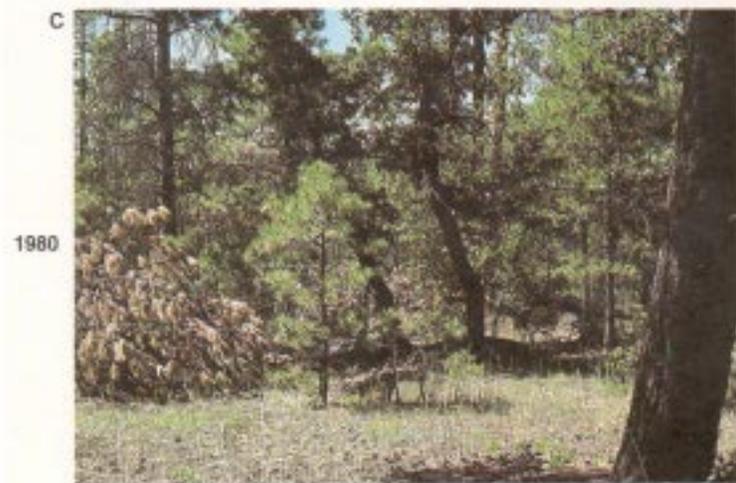
View 2



SBE = 47



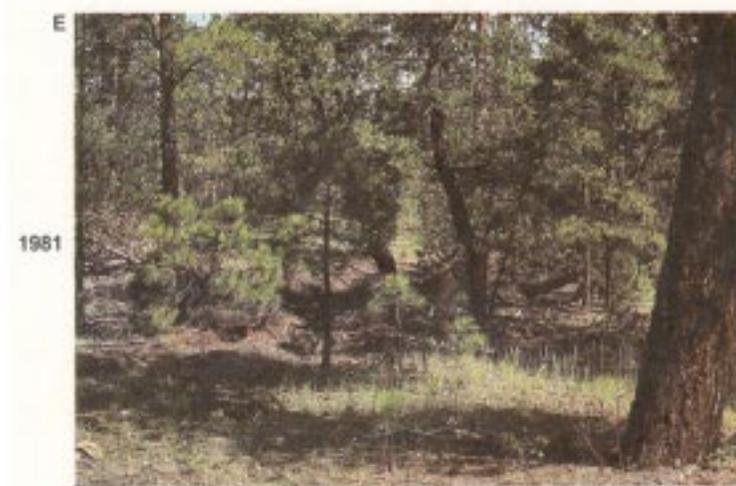
SBE = 33



SBE = 1



SBE = -40



SBE = 30



SBE = 14

Figure 4.—Changes with harvest and slash cleanup activities for two views.

variables that explained the major portion of the variance in SBE. For additional models, see Brown (1983).

Examination of the correlations between SBE and measures of overstory, understory, and downed wood showed obvious differences between slides shown in the preharvest context and slides shown in mixed preharvest and postharvest context. For example, the site-level correlations of SBE to measures of total basal area, degree of tree grouping, herbage weight, and percent slash change from -0.26, 0.44, 0.58, and -0.11 for the slides shown in the preharvest context to 0.07, -0.07, 0.23, and -0.47, respectively, for the slides shown in the postharvest context. It is not known whether these relationships would change if the slides were shown in other slide presentation contexts. Because of the possibility of a significant slide presentation context effect on the relationship of SBE to measures of physical features, separate preharvest and postharvest models were developed.

The coefficients of the models presented were estimated using least squares regression. A three-step procedure was followed to develop the models. The first step was the selection of the variables to be subjected to the regression procedure. Initially, very detailed independent variables, such as the volume of sound natural downed wood from 6 to 9 inches in diameter, were examined. In some cases, variables that contributed very little to the prediction of SBE, such as the stump variables and most of the oak variables, were deleted. In other cases, where two variables were strongly intercorrelated and contributed similarly to the prediction of SBE (such that they did not each make an independent contribution to explanation of SBE), the variable of the pair that was less likely to be available to managers was deleted. For example, the percentage of ground cover in herbage was dropped because it served as a surrogate for herbage weight, a more frequently available measure. In still other cases, detailed variables were combined across species, size, and condition distinctions into more comprehensive variables. Combinations were based on factor analysis results and practical considerations, such as similarity of the variables from an ecological standpoint. For example, grass, forb, and shrub weights were combined to form the variable PDTOT (total herbage weight in pounds), and numerous downed wood size and condition classes were combined to form the variable DWVTOT (total downed wood volume). Finally, the remaining variables were arranged into groups for submission to regression procedures. Nonlinear terms were added to the groups for those variables that showed any nonlinear relationship with SBE. Interaction terms, however, contributed little and were not included.

The second step was the use of stepwise multiple regression to specify the models given the groups of available independent variables. All variables in the final models have an F-level of at least 4.0, a rather restrictive procedure designed to limit the number of included variables in the final models. The fact that an available variable was not included, given the entry criterion, does not imply that it is useless in predicting SBE. It only indicates that, given the F-level for inclusion/deletion, the set of included variables

does a better job of accounting for the variance in SBE than any other set from the same group.

The third step was the examination of residuals depicting the variance in SBE not explained by the included variables, for model bias, and the respecification of the models where necessary.

Regression is useful for specifying prediction models and for interpreting the relationship between the dependent and independent variables. The coefficients of the independent variables in a regression model indicate the contribution of that variable to changes in the dependent variable, given that the other independent variables in the equation are controlled for, in effect by being held constant. If a variable is not included, either because it was not available or because it did not meet a stepwise entry/deletion criterion, its effects on the included variables are not controlled for, and the coefficients of the included variables reflect both their individual effects on the dependent variable and the effect of the omitted variable on the dependent variable via the intercorrelation of the included and omitted variables. Generally, stepwise regression models based on relatively restrictive entry/deletion criteria, such as those presented here, are efficient in terms of data requirements, because they avoid inclusion of highly intercorrelated variables; but such coefficients must be interpreted with caution because of the effects on those coefficients of omitted variables. However, for the Woods/Bar-M area, models not restricted by the entry/deletion criterion, such that more variables entered the equation, accounted for little additional variance (about 0.05 in terms of R^2), and had little effect on the coefficients of the variables in the more data-efficient models.

Preharvest Site-Level Models

Three preharvest models based on site-level data are presented here—the basic model, the detailed downed wood model, and the summary variable model (table 1). The basic model resulted from a stepwise regression with the following independent variables available: numbers 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 downed wood volume per acre (DWVTOT), plus nonlinear terms for each of these. The nonlinear terms were chosen from a set of several tested with bivariate regression. For example, herbage weight was taken to the 0.75 power (PDTOT75). The solution included all linear terms except PP1624, plus one nonlinear term:

$$\begin{aligned} \text{SBE} = & -16.34 - 0.0087\text{PPSAP} - 0.0281\text{PP516} \\ & + 0.9246\text{PP24PL} - 0.3546\text{PDTOT} + 2.6896 \quad [1] \\ & \text{PDTOT75} - 0.0036\text{DWVTOT}. \end{aligned}$$

The coefficients of the model are listed in table 1 along with (1) statistics describing, for the data set, the independent variables in the equation and (2) summary

Table 1—Preharvest site-level scenic beauty models.^a

Terms in the equations						Models ^b							
Description	Name	Mean	SD ^c	Range		R ^d with SBE	Basic		Detailed downed wood		Summary variable		
				Min	Max		Coef ^e	Beta ^f	Coef	Beta	Coef	Beta	
Ponderosa pine (trees/acre)													
Saplings	PPSAP	179.3	341.4	0	2600	-0.15	-0.0087	-0.08	-0.0094	-0.09			
5–15.9 inches d.b.h.	PP516	167.6	145.8	0	739	-0.39	-0.0281	-0.11	-0.0197	-0.08			
≥24 inches d.b.h.	PP24PL	3.5	4.0	0	18	0.24	0.9246	0.10	0.7879	0.09			
Herbage weight (lb/acre)													
Total	PDTOT	86.6	90.5	1	1025	0.58	-0.3546	-0.89	-0.3025	-0.76			
(Total) ^{0.75}	PDTOT75	26.3	19.3	1	181	0.63	2.6896	1.43	2.3635	1.26			
Downed wood (ft ² /acre)													
Total	DWVTOT	1277.3	1001.4	57	6582	-0.25	-0.0036	-0.10					
0–¼ inch diameter	DWV014	10.7	6.0	1	37	-0.44			-0.0639	-0.16			
>3 inch diameter	DWV3PL	1086.7	971.6	0	6301	-0.24			-0.0036	-0.10			
Basal area (ft ² /acre)													
Pine	PPBA	124.9	63.3	20	322	-0.37					-0.1117	-0.20	
Oak	GOBA	18.8	25.9	0	187	0.17					0.2288	0.16	
Tree grouping ^g													
	TG	2.2	0.9	1	4	0.44					11.7268	0.31	
Aspect ^h													
	ASPECT	5.0	2.3	1	9	-0.38					-3.9753	-0.26	
Constant							-16.34		-3.46		-18.01		
Model summary statistics													
R ² ⁱ							0.49		0.51		0.33		
Adjusted R ²							0.48		0.50		0.32		
F-level ^j							52.42		48.52		40.86		
Standard error							26.10		25.62		29.79		

^aBased on 333 cases.

^bAll variables have an F-level ≥ 4.00 and are significant at the 0.01 probability level.

^cStandard deviation.

^dPearson's correlation coefficient.

^eRegression coefficient.

^fStandardized regression coefficient, or beta weights, result when the quantities for the variables are expressed in standard deviations from the mean of the variables. A high absolute value for a beta indicates that scenic beauty is relatively sensitive to changes in that variable within the range of the variable for the data set.

^gAn ordinal variable with a range from 1 to 4 (1 = trees in groups with many interlocking crowns, 2 = some tree grouping but little interlocking of crowns, 3 = very little tree grouping, 4 = no tree grouping, trees evenly spaced, see Patton 1977).

^hAn ordinal variable having a range from 1 to 9 (1 = flat, 2 = N, 3 = NW, 4 = NE, 5 = W, 6 = E, 7 = SW, 8 = SE, 9 = S) whereby SBE decreases as aspect increases.

ⁱCoefficient of determination. An R² of 1.0 indicates that the model accounts for all of the variance in SBE.

^jAll three models are highly significant (P < 0.001).

statistics about the overall model. The absence of intermediate sawtimber-sized pine (PP1624) from the equation should not necessarily suggest that pine trees in this size range are unimportant for predicting scenic beauty. Rather, they are relatively unimportant, and add so little to the prediction, once the other tree, herbage, and downed wood variables are in the equation, as to make the inclusion of PP1624 of little consequence for this data set.

The SBE for any specific forest location similar to those in the data set used to build the model can be estimated by simply adding the constant and the products of the coefficients multiplied by the quantities for the corresponding variables. For example, if the location for which an SBE were desired contained 100 ponderosa pine trees per acre from 5 to 16 inches d.b.h., that term would contribute -2.81 (-0.0281 x 100) to the summation. The separate coefficients indicate the change in SBE caused by a one-unit

change in corresponding independent variables. For example, the addition of one 24-inch pine tree per acre would add 0.92 SBE unit.

The basic model accounts for about one-half of the variation in SBE (R² is 0.49, table 1) and is significant (p < 0.001). The adjusted R², which takes into account the loss in statistical degrees of freedom as more variables are added to the equation, is nearly as high, at 0.48. (Hereafter, only unadjusted R²s are reported in the text. The unadjusted R²s are very similar to the adjusted R²s, which are presented in the tables.) The standard error of the estimate (i.e., the standard deviation of the actual SBE values from the predicted SBE values) is 26.1 SBE units. If the actual SBE values are assumed to be normally distributed about the predicted values, then about 68% of the actual SBEs would fall within ± 26 SBE units of the predicted SBE.

The changes in SBE with changes in the independent variables are plotted for the basic model in figure 5. The horizontal axis in figure 5 measures changes in the independent variables, which vary over their full range in the data set (table 1). For example, the number of ponderosa pine saplings (PPSAP) ranges from 0 to 2,600. Thus, keeping within that range, the most PPSAP could detract from SBE is 23 units (2600 x -0.0087). Similarly, PP516 and DWVTOT can detract at most 21 and 24 SBE units, respectively, and PP24PL can enhance SBE by at most 17 units. The most that herbage weight can enhance SBE is about 124 units, which occurs both at 1,025 pounds per acre, the maximum case for the data set, and at 1,047 pounds per acre, the point at which the herbage curve (fig. 5) reaches a maximum.

The detailed downed wood model resulted from a stepwise solution, given an available set of independent variables identical to that for the basic model, except that total downed wood volume (DWVTOT) was replaced by variables describing downed wood volume in the less than 1/4-inch (DWV014), 1/4- to 1-inch, 1- to 3-inch, and greater than 3-inch (DWWW3PL) diameter classes, and the percentage of downed wood which harvest created. The resulting equation includes seven independent variables (table 1):

$$\begin{aligned} \text{SBE} = & -3.46 - 0.0094\text{PPSAP} - 0.0197\text{PP516} \\ & + 0.7879\text{PP24PL} - 0.3025\text{PDTOT} + 2.3635 \quad [2] \\ & \text{PDTOT75} - 0.9639\text{DWV014} - 0.0036 \\ & \text{DWV3PL}. \end{aligned}$$

In the model, downed wood and small ponderosa pine variables detract from scenic beauty, while large pine and herbage variables contribute to scenic beauty. The substitution of DWV014 and DWV3PL for DWVTOT in the model improves the overall predictive capability of the model somewhat, signified by the increase in R² (to 0.51) and decrease in standard error (to 25.4), compared with the basic model. The substitution also indicates the importance to scenic beauty of small diameter downed wood. Scenic beauty is more sensitive to volume of small diameter downed wood (DWV014) than to the volume of larger diameter downed wood (DWV3PL). Again,

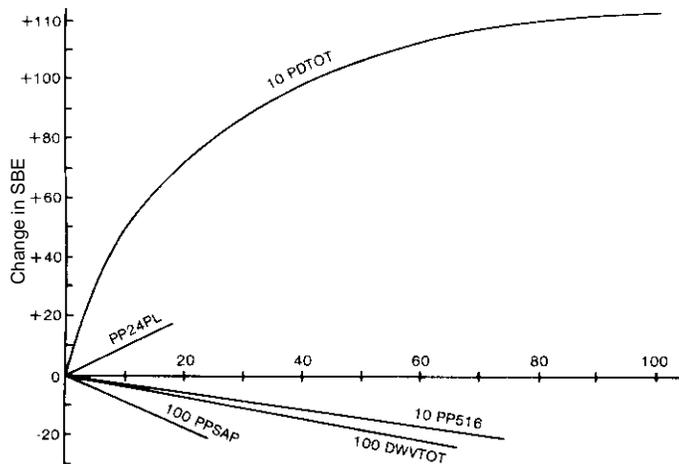


Figure 5.—Change in SBE with change in independent variable for preharvest basic model.

however, scenic beauty is far more sensitive to changes in herbage weight than to changes in the overstory and downed wood variables.

The summary variable model resulted from a stepwise solution, given a set of available independent variables including slope, aspect (ASPECT), site index, tree grouping (TG), tree stories, crown canopy, ponderosa pine basal area (PPBA), and Gambel oak basal area (GOBA). The resulting equation contains four independent variables (table 1):

$$\begin{aligned} \text{SBE} = & -8.01 - 0.1117\text{PPBA} + 0.2288 \\ & \text{GOBA} + 11.7268\text{TG} - 3.9753\text{ASPECT}. \quad [3] \end{aligned}$$

In this model, oak basal area contributes to scenic beauty; pine basal area detracts. This follows from the fact that numbers of oak of all sizes are positively correlated with SBE, while numbers of pine smaller than about 20 inches d.b.h., which make up the majority of pine based area, are negatively correlated with SBE. Movement from a south to north aspect improves scenic beauty. And, a decrease in degree of tree grouping and interlocking of crowns, and corresponding increase in evenness of tree spacing, contributes to scenic beauty. Scenic beauty is most sensitive to changes in the tree grouping and aspect variables. The model is highly significant, but accounts for only 33% of the variance in SBE.

The summary variable model contains no variables directly measuring herbage or downed wood. The intercorrelations, however, suggest that herbage at least is represented indirectly, via the relationship of herbage to the summary variables. The correlations of PDTOT to PPBA, GOBA, TG, and ASPECT are -0.36, 0.26, 0.39, and -0.27, respectively, indicating that more herbage is found in less dense pine areas, in areas of more oak, in areas of less tree grouping, and on the wetter, north-facing slopes.

In both the basic and detailed downed wood models, large pine (PP24PL) and herbage contribute to increased scenic beauty. In practice, an increase in overstory will reduce potential herbage production. Thus, there is a tradeoff between these two characteristics. Figure 6 shows isoquants expressing this tradeoff, assuming mean quantities (table 1) of the other variables for the basic model. The curves are slightly convex to the origin, as a result of the decreasing marginal contribution to scenic beauty of increasing amounts of herbage. However, because the model contains no interaction terms, the isoquants would have the same shape no matter what quantities of the other variables were assumed. Only the SBE values of figure 6 would change if different quantities of the other variables were assumed.

The dotted isoquants of figure 6 assume very little herbage. Given this situation, one mature pine tree contributes about the same to pre-harvest scenic beauty as 1 pound of herbage. For example, 17 large pine trees, 5 large pine trees and 10 pounds of herbage, or 16 pounds of herbage, would result in an SBE of -11. The solid isoquants of figure 6 assume at least 300 pounds of herbage, plus mean quantities of smaller pine and downed

wood variables. Given this situation, one large pine tree contributes about the same to scenic beauty as 8 pounds of herbage. For example, given an initial endowment of no mature pine and 300 pounds of herbage plus mean quantities of the other variables, the addition of 5.4 mature pine trees or 42 pounds of grasses and forbs would result in an SBE of 65. The slopes of the isoquants continue to flatten as more herbage is initially assumed, and as more is added.

Similar isoquants could be drawn involving other variables. For example, there is a tradeoff between additional pine saplings (PPSAP) and additional pulp and small sawtimber pine trees (PP516), given some initial quantities of all variables. However, care must be used in interpreting such relationships. For example, consider the dotted isoquants in figure 6. They suggest, as stated, that about one mature pine tree can be traded for 1 pound of herbage, given that very little herbage is present. However, it is doubtful that 1 pound of herbage per acre would even be noticed. The data upon which the models were based show large variation in SBE for sites with very little herbage. The rather strong overall relationship between herbage weight and SBE ($R = 0.58$) is heavily influenced by the very clear relationship for sites with greater quantities of herbage. Thus, there should be greater confidence in tradeoffs based on a greater initial endowment of herbage, such as those demonstrated by the solid isoquants of figure 6. There, greater changes in herbage weight per large pine tree are involved, and the relationship between herbage and scenic beauty is quite clear given the data.

For both the basic model and detailed downed wood model, the effect of herbage on scenic beauty is far greater than the effect of the other independent variables. In fact, for the basic model, within the bounds of the data, only PDTOT can have a greater effect on SBE than the standard error of the model of 26 SBE units. Similarly, for the detailed downed wood model, only PDTOT and DWV014 can have a greater effect on SBE than the standard error for that model of 25 SBE units. These relationships apply, of course, only to areas depicted by the Woods/Bar-M preharvest data set, which include only treed sites and a preponderance of quite dense stands (basal area averaged 149 square

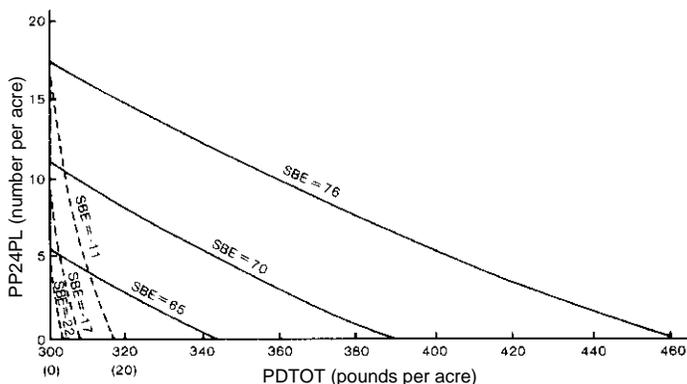


Figure 6.—Isoquants of mature ponderosa pine (PP24PL) and herbage (PDTOT) given fixed quantities of smaller pine and downed wood, preharvest basic model.

feet per acre in pine and Gambel oak). The models imply that nonherbage variables are relatively unimportant and that the key to high scenic beauty is to plant grasses and forbs and restrict grazing. However, while such efforts would certainly contribute to higher scenic beauty, the practical relationship between herbage and overstory must not be ignored. Beyond direct range management actions such as fertilizing and planting grass and forbs or restricting grazing, herbage can only be increased by removing overstory.

A related apparent implication of these two models is that additional large ponderosa pine and herbage can compensate for the deleterious effect of smaller pine trees and downed wood on scenic beauty. However, in practice, increasing amounts of positive variables cannot be continually added to compensate for increasing amounts of the negative variables. In general, increasing numbers of immature pine trees reduces herbage quantity and, at higher stand densities, can only be obtained at the cost of fewer mature trees. The limitations of static, linear models such as these must be recognized.

While overstory and understory are unavoidably linked, downed wood quantity is independently under the control of managers. When downed wood is characterized only by total volume, as in the basic model, only small changes in SBE can be caused by manipulating downed wood quantities. Again within the bounds of the original data, the basic model suggests that a change of only 24 SBE units could be caused by removing all downed wood from the most heavily burdened site. However, when downed wood is characterized, as in the detailed downed wood model, by two separate size classes (DWV014 and DWV3PL), the maximum improvement in scenic beauty is 59 SBE units, 36 attributed to the removal of the small diameter downed wood and 23 attributed to the removal of downed wood 3 inches in diameter and greater.

In addition to the models presented, stepwise solutions given other groups of available independent variables also were obtained. Some of these groups of variables contained the variables of the basic model, plus sets of variables that showed some promise of accounting for variance in scenic beauty in bivariate comparisons. However, addition of these variables produced only moderate improvements in model R^2 and significance. For example, when percentage of ground cover (eight categories), number of stumps (four size classes), percentage of mechanical disturbance, and number of brush piles were available along with the basic variables, seven independent variables were included (PP516, PP24PL, PDTOT, three ground cover variables, and number of brush piles) in an equation accounting for 51 percent of the variance in SBE. And, when the eight summary variables (available to the summary variable model described above), number of Gambel oak larger than 5 inches d.b.h., fuel depth, percentage of downed wood in slash, number of brush piles, and percentage of mechanical disturbance also were available, 10 independent variables were included (PP516, PP24PL, PDTOT, PDTOT75, DWVTOT, TG, ASPECT, site index, number of oak, and number of brush piles) in an equation accounting for 55% of the variance

in SBE. Thus, the availability of additional variables improved model R^2 by at most 6 points (from 0.49 to 0.55). This modest improvement perhaps would not justify the effort required to obtain measurements of the additional variables.

A stepwise solution also was obtained for a set of independent variables identical to those available to the basic model, except that herbage canopy and height were substituted for herbage weight. The resulting equation included six independent variables (PP516, PP24PL, herbage canopy and height, and nonlinear terms for herbage canopy and height) and accounted for 54% of the variance in SBE. Thus, substitution of more visually descriptive measures of herbage for the weight measure improved R^2 by 5 points, even without a downed wood variable. Because herbage canopy and height measurements are less costly than weight measurements (the former do not require clipping and weighing of herbage to adjust for moisture content), the substitution is perhaps warranted for future scenic beauty modeling efforts. Finally, when numerous additional variables were available, an herbage canopy and height model of nine variables accounted for 60% of the variance in SBE.

Postharvest Site-Level Model

Postharvest models were developed from data collected at sites in stands that had recently been harvested. Most of the 120 sites used in the stepwise regressions contained harvest effects. Some of the 1980 slides contained scattered slash and some of the 1981 slides contained piled slash. Most postharvest slides showed considerable mechanical ground disturbance.

Variable sets containing detailed measures of downed wood yielded the most promising models. The following model

resulted from availability of the same variable set as that which yielded the preharvest detailed downed wood model:

$$\text{SBE} = 46.84 - 0.0243 \text{ PPSAP} + 0.0652 \text{ PDTOT} - 1.8871 \text{ DWV014} - 0.6448 \text{ PCTSL} \quad [4]$$

Herbage weight contributes to scenic beauty, while pine saplings, small diameter downed wood, and percent of downed wood as slash (PCTSL) detract from scenic beauty. Scenic beauty in this model is much more sensitive to changes in downed wood than to changes in overstory and herbage quantities. The model accounts for only 41% of the variance in SBE (table 2). Apparently, the physical variables measured are not as useful in predicting scenic beauty for postharvest scenes as they are for the less complex preharvest scenes.

Limitations of Site-Level Models

Stepwise models, requiring an F-level of 4.0 for an individual variable to be included, accounted for at most 60% and 48% of the variance in SBE for the preharvest and postharvest sites, respectively. The variance in SBE not accounted for by these models probably can be attributed to numerous factors, aside from omitted forest- and range-related physical variables and data collection and manipulation errors.

First, physical, mensurational variables may not fully explain responses about scenic beauty, which incorporate human perception and judgment. Many landscape assessment techniques rely totally on design variables such as color, texture, form, and variety. Arthur (1977) showed that most of the variance in SBE can be accounted for by estimates of design variables for slides shown in a setting similar to that used for this study. In addition, this study did

Table 2.—Postharvest site-level detailed downed wood scenic beauty model.^a

Description	Terms in the equation			Range		R^d with SBE	Model ^b	
	Name	Mean	SD ^c	Min	Max		Coef	Beta
Number of pine saplings	PPSAP	114.2	228.7	0	1300	-0.19	-0.0243	-0.18
Total herbage weight (lb/acre)	PDTOT	135.1	104.9	1	795	0.23	0.0652	0.20
Volume of small diameter downed wood	DWV014	7.5	4.8	1	29	-0.27	-1.8871	-0.29
Downed wood percent slash	PCTSL	54.5	25.4	0	100	-0.47	-0.6448	-0.57
Constant							46.84	
Model summary statistics								
R^2							0.41	
Adjusted R^2							0.39	
F-level ^e							20.91	
Standard error							24.50	

^aBased on 120 cases.

^bAll variables have an F-level ≥ 4.0 and are significant at the 0.05 level.

^cStandard deviation.

^dPearson's correlation coefficient.

^eModel significant at the 0.001 probability level.

not include other variables measurable on-site, such as lighting or sky characteristics.

Second, field measurement of the physical characteristics did not perfectly describe those characteristics. On the one hand, physical variables were only sampled at the inventory points (fig. 2). For example, trees of at least 5 inches d.b.h. were tallied using a 10-factor prism, herbage was sampled in eight 9.6 square foot plots per site, and downed wood was sampled along eight 40-foot transects per site. On the other hand, a mismatch occurred between what the four photographs per site recorded, and how the physical variables were measured. For example, trees were sampled for the full 360° around the inventory center point, while the four photographs taken at the point encompassed only 128°. Also, the depth of view in the photographs did not always correspond well with the location of the physical measurements. At very densely treed sites, some physical features were measured beyond the photographic depth of view, while at sparse sites, considerable areas of the forest seen in the photographs were beyond the distance of the physical measurements.

Third, the equation form used may be less than the best-fit form. Fourth, the photographic quality of the slides differed. Finally, scenic beauty judgments of the slides may be subject to order effects and person-to-person (and group-to-group) differences that are not adjusted for in the SBE scaling procedure.

Stand-Level Models

Aggregating site-level data to the timber stand level alleviated some of the sampling problems associated with site-level models. The site-level estimates in each

preharvest stand were averaged to yield 23 stand-level cases. In addition, the averages for the ordinal variables (e.g., TG) were rounded to the nearest whole number to maintain the nominal characteristics of those variables. Stand average SBE ranged from -32 to 64, and averaged 16 with a standard deviation of 25.

A stepwise solution given the basic variables (PPSAP, PP516, PP1624, PP24PL, PDTOT, DWVTOT), plus nonlinear terms for these variables, resulted in a model of two terms (PP24PL and PDTOT) accounting for 70% of the variance in SBE (table 3):

$$SBE = -32.47 + 4.6999 \text{ PP24PL} + 0.3806 \text{ PDTOT}. \quad [5]$$

The standard error of the estimate for this model is only 14, or about one-half as large as for the comparable point-level model (table 1). However, the range in SBE for the stand-level data is only 47% of that for the site-level data.

Stepwise solution with detailed downed wood variables substituted for DWVTOT in the above variable set yields a model of three terms that accounts for 80% of the variance in SBE (table 3):

$$SBE = 4.35 + 3.6079 \text{ PP24PL} + 0.2788 \text{ PDTOT} - 2.2606 \text{ DWV014}. \quad [6]$$

Both this and the basic stand-level model are highly significant, and account for much more of the variance in SBE than do the site-level models.

A third stand-level model, resulting from the availability of only overstory variables (trees per acre by size class plus summary variables) yielded a model of two terms accounting for 55% of the variance in SBE (table 3):

$$SBE = -41.17 + 5.5076 \text{ PP24PL} + 22.5761 \text{ TG}. \quad [7]$$

Table 3.—Preharvest stand-level scenic beauty models.^a

Description	Terms in the equations					Models ^b						
	Name	Mean	SD ^c	Range		R ^d with SBE	Basic		Detailed downed wood		Summary variable	
				Min	Max		Coef ^e	Beta ^f	Coef	Beta	Coef	Beta
Mature pine (trees/acre)	PP24PL	3.6	1.7	1	8	0.35	4.6999	0.32	3.6079	0.24	5.5076	0.37
Total herbage weight (lb/acre)	PDTOT	82.7	49.4	15	233	0.72	0.3806	0.76	0.2788	0.56		
Small diameter downed wood volume (ft ³ /acre)	DWV014	10.8	4.2	5	22	-0.73			-2.2606	-0.38		
Tree grouping	TG	1.7	0.7	1	3	0.64					22.5761	0.65
Constant							32.47		4.35		-41.17	
Model summary statistics												
R ²							0.70		0.80		0.55	
Adjusted R ²							0.67		0.76		0.50	
F-level ^g							23.06		24.81		12.05	
Standard error							14.29		12.02		17.50	

^aBased on 23 cases.

^bAll variables have an F-level ≥ 4.0 and are significant at the 0.05 probability level.

^cStandard deviation.

^dPearson's correlation coefficient.

^eAll models are significant at the 0.001 probability level.

At the timber stand level, one can account for much of the variance in scenic beauty of the preharvest Woods/Bar-M stands by knowing only the number of mature ponderosa pine trees per acre and the tree grouping category.

As stated, the data used to build the stand-level models were obtained by averaging site-level data. The site-level SBEs were obtained from judgments of slides that were presented in a random order, rather than being presented in groups by stand. However, tests reported by Boster and Daniel (1972) and Daniel and Boster (1976) showed high correspondence between onsite judgments obtained once the observers had viewed a forest area and the mean of single slide judgments for slides taken in the same area.

Tests of Site-Level Models

The site-level models were tested on the Coconino National Forest and Colorado Front Range data sets used by Schroeder and Daniel (1981). Because the Woods Canyon and Bar-M sites were almost entirely free of insect and disease damage and were forested almost entirely with ponderosa pine, only those sites of the Coconino and Colorado data sets without damage and with overstories of at least 90% ponderosa pine were used. In addition, only those points with less than 10% of the downed wood in sound slash were selected, resulting in data subsets of 31 and 29 cases for the Coconino and Colorado areas, respectively.

Both the basic and detailed downed wood preharvest models (table 1) accounted for about 34% of the variance in SBE of the Coconino points. But they performed poorly on the Colorado points, each accounting for only about 10% of the variance in SBE. However, new models, restricted to the variables in the Woods/Bar-M models (table 1), accounted for about 43% and 40% of the variance in SBE for the Coconino and Colorado areas, respectively. This suggests that while the same variables are rather important in the three areas, their relative weight differs among the areas.

Removing the restriction on the proportion of downed wood that is sound slash increased the Colorado data subset to 60 points. The postharvest detailed downed wood model (table 2) performed poorly on this Colorado data set, accounting for only 10% of variance in SBE (the model could not be used on the Coconino data, because PCTSL was not measured for that study). When the model was free to choose the coefficients, yet restricted to the four variables of the Woods/Bar-M model (table 2), it accounted for only 17% of the variance in SBE.

In general, the stepwise models derived from the Woods/Bar-M area apply reasonably well to the Coconino ponderosa pine sites, but quite poorly to the Colorado Front Range. Schroeder and Daniel (1981) reported considerably higher R^2 s for the models they developed from the Coconino and Colorado data sets than were obtained using the variables of the Woods/Bar-M models. Schroeder and Daniel's (1981)

models separate shrubs from grasses and forbs, combine timber sizes differently, and include only the slash portion of downed wood. Furthermore, their Colorado model contains variables representing other overstory species. On the Woods/Bar-M area, large pine (PP24PL) is the most important pine size category for scenic beauty, and shrubs contribute to scenic beauty. On the Colorado Front Range, few pine greater than 24 inches d.b.h., are found, and shrubs detract from scenic beauty.

Nevertheless, while areas differ, these relationships between scenic beauty and physical characteristics hold for all three areas: large pine trees, grasses, and forbs enhance scenic beauty, while downed wood and small trees in sufficient numbers detract from scenic beauty.

INTERPRETATION OF SCENIC BEAUTY ESTIMATES

What does an SBE of -27 mean? How good is an improvement of 19 SBE units? Merely knowing that an area is judged 27 SBE units lower than the base area, or that one management alternative results in scenic beauty being 19 units better than an other alternative, is inadequate. Some way to interpret the magnitude of an SBE is necessary. Two approaches to interpretation are presented here. The first relies on photographs depicting points along the range of scenic beauty. The other utilizes a scenic beauty distribution.

Representative Scenes

The scenic beauty values predicted by the models are statistical estimates of public evaluations of forest landscapes. Each estimate reflects a set of physical characteristics. To help visualize what the scenic beauty values mean, sites representing low, medium, and high scenic beauty have been selected from those used to build the basic preharvest model and the detailed downed wood postharvest model. With each set of representative scenes, the actual SBE and physical feature data at the site where the photos were taken, and the predicted SBE based on these data, are presented. Figures 7, 8, and 9 depict scenes used to build the preharvest scenic beauty models; figures 10, 11, and 12 depict scenes used to build the postharvest scenic beauty model. Note that the high scenic beauty site shown for the postharvest model (fig. 12) contains almost no harvest effects (the upper right photo shows some slash in the background). Although the site is in a harvested stand, the area near the point was essentially undisturbed.

As figures 7 through 12 help depict, high or low levels of scenic beauty may result from different combinations of physical features. For example, low scenic beauty may occur where there are large amounts of visible slash (fig. 10), or in a dense pole stand with some downed wood but no slash (fig. 7). Or, high scenic beauty



A

SBE = -42



B

SBE = -82



C

SBE = -104

Pine saplings (no./acre): 200
 PP d.b.h. 5-16 (no./acre): 392
 PP d.b.h. ≥ 24 (no./acre): 12



D

SBE = -16

Herbage (lb/acre): 5
 Downed wood (ft³/acre): 1259

Actual SBE: -53
 Predicted (basic preharvest model) SBE: -25

Figure 7.—A preharvest site of low scenic beauty.



A

SBE = 50



B

SBE = -31



C

SBE = 41

PP saplings (no./acre): 200
 PP d.b.h. 5-16 (no./acre): 27
 PP d.b.h. ≥ 24 (no./acre): 7.1

Actual SBE: 23
 Predicted (basic preharvest model) SBE: 14



D

SBE = 24

Herbage (lb/acre): 45
 Downed wood (ft³/acre): 1397

Figure 8.—A preharvest site of medium scenic beauty.



A

SBE = 84



B

SBE = 155



C

SBE = 59

PP saplings (no./acre): 150
 PP d.b.h. 5-16 (no./acre): 5
 PP d.b.h. > 24 (no./acre): 10

Actual SBE: 89
 Predicted (basic preharvest model) SBE: 86



D

SBE = 56

Herbage (lb/acre): 390
 Downed wood (ft³/acre): 749

Figure 9.—A preharvest site of high scenic beauty.



A

SBE = -56



B

SBE = -24



C

SBE = -11



D

SBE = -12

PP saplings (no./acre): 0
Herbage (lb/acre): 44

Downed wood < 1/4-inch diameter (ft³/acre): 8
Percent slash: 95

Actual SBE: -26

Predicted (detailed downed wood postharvest model) SBE: -20

Figure 10.—A postharvest site of low scenic beauty.



A

SBE = 31



C

SBE = 0

PP saplings (no./acre): 0
Herbage (lb/acre): 119

Actual SBE: 11
Predicted (detailed downed wood postharvest model) SBE: 8



B

SBE = 10



D

SBE = 1

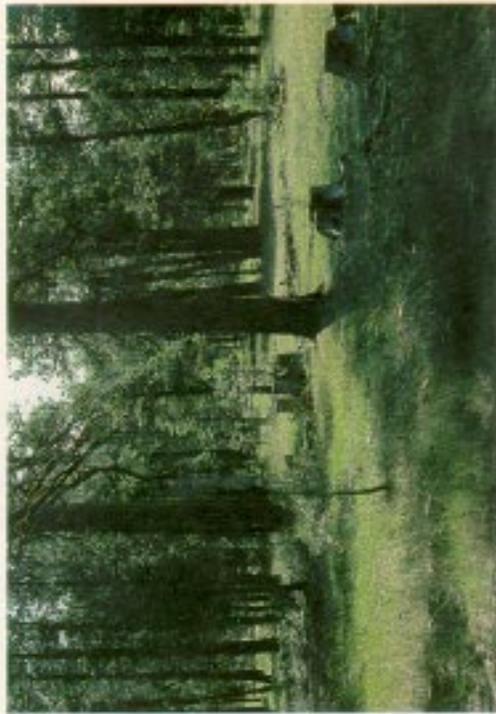
Downed wood < 1/4-inch diameter (ft²/acre): 16
Percent slash: 34

Figure 11.—A postharvest site of medium scenic beauty.



A

SBE = 57



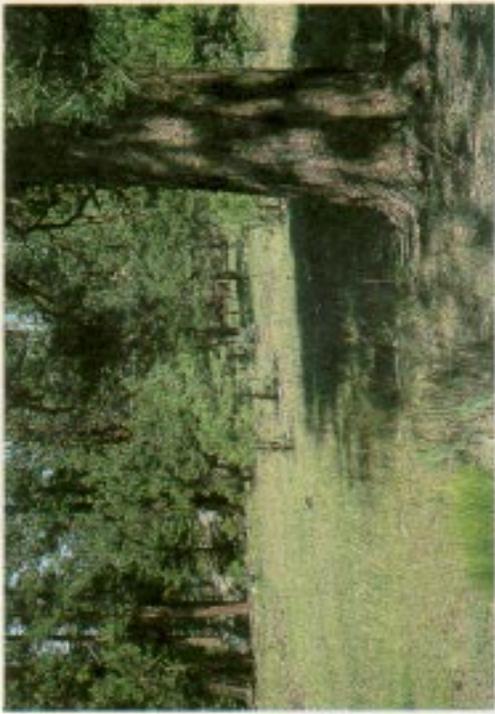
B

SBE = 49



C

SBE = 124



D

SBE = 96

PP saplings (no./acre): 0
Herbage (lb/acre): 293

Actual SBE: 82

Predicted (detailed downed wood postharvest model) SBE: 51

(Note: This site was not harvested. However, it is in a stand that was largely harvested, and was included in the postharvest data.)

Downed wood < 1/4-inch diameter (ft³/acre): 1
Percent slash: 20

Figure 12.—A postharvest site of high scenic beauty.

may occur in relatively open areas having large pine trees and moderate herbage amounts (fig. 12), or in areas of medium density having some large pine trees and heavy herbage amounts (fig. 9).

Individual scenes may deviate somewhat from the values predicted for them by the model. This is to be expected, because the predicted value is the expected average for the entire site. For example, the SBEs for the four photos in figure 7 range from -104 to 16. Any site potentially offers a great many individual views, each differing from the average. Some types of forest sites (or stands) may be more variable in this respect than others. Special features, such as occasional meadows or dense “dog hair” thickets, are especially likely to produce deviations from the average value, especially if they are beyond the range of the physical inventory but captured in the photos.

Scenic Beauty Distribution

Perhaps the best aid to interpretation of SBEs is a distribution of SBEs for some meaningful geographical area. Such a distribution would allow calculation of the percentage of the sites in the overall area that is more, or less, preferred than the one in question. Furthermore, a change in SBE for a site could be interpreted as a change from one percentile to another.

As an example, consider the distribution of scenic beauty for the Woods/Bar-M area. To determine this distribution, the timber stands in the area were delineated and categorized by stand type. Sixteen percent of the 504 delineated stands were selected for inventory based on the distribution of stand types within the overall area, and photographs were taken at 15 sites per stand according to the procedure described above for the modeling data. The SBEs on the 1,204 usable sites range from -84 to 122 and average 18 SBE units. As seen in figure 13, they are approximately normally distributed.

The preharvest Woods/Bar-M scenic beauty distribution in figure 13 is depicted in figure 14 as a cumulative frequency distribution. With figure 14, any specific site or stand SBE can be put in perspective relative to the Woods/Bar-M area. For example, a site of -20 SBE units has higher scenic beauty than only 13% of the Woods/Bar-M area, and an improvement in scenic quality of that site to an SBE of 40 signifies an improvement to the 74th percentile.

The Woods/Bar-M scenic beauty distribution is adequate for illustrative purposes; but, it lacks operational practicality for two reasons. First, the geographical area encompassed by the Woods Canyon and Bar-M Watersheds is small and its vegetation is rather homogeneous. Second, all photographs reflect preharvest conditions, which is unrealistic for timber lands managed under multiple use concepts.

The geographical area included in an operational SBE distribution probably should encompass an important administrative area, such as a national forest. If two or more forests contained similar forest characteristics, the SBE distribution could include those forests, thereby reducing overall sampling cost.

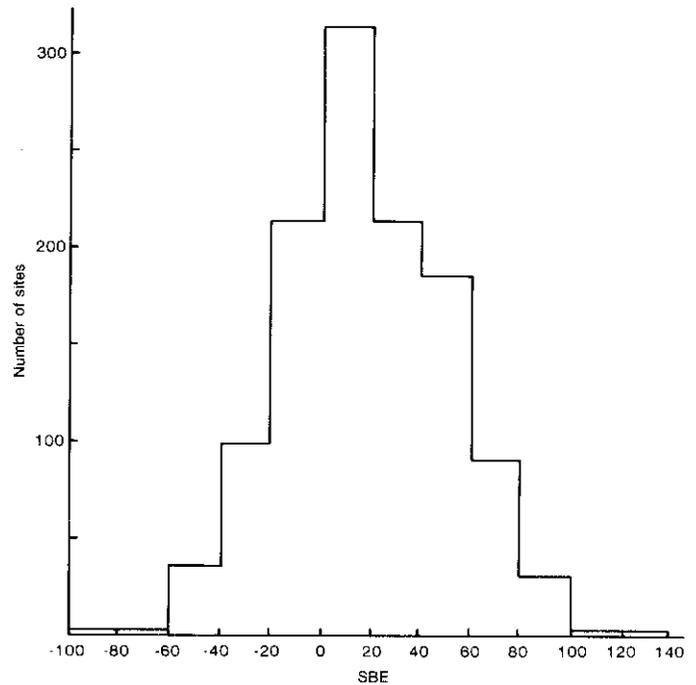


Figure 13.—Distribution of scenic beauty (SBE) for Woods Canyon and Bar-M Watersheds before harvest (based on 1,204 sites with a mean SBE of 18).

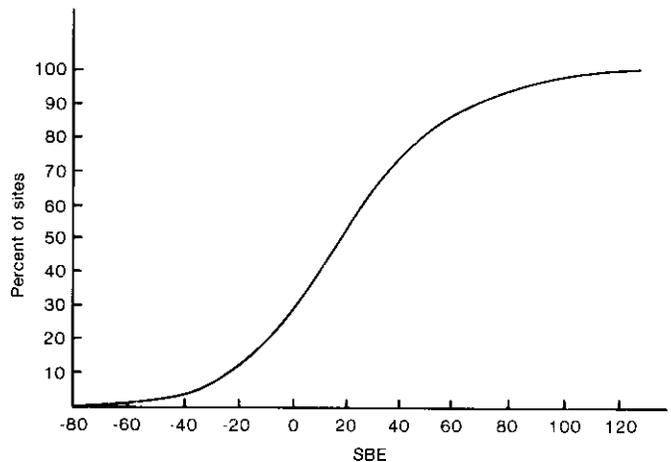


Figure 14.—Cumulative frequency distribution of scenic beauty (SBE) for Woods Canyon and Bar-M Watersheds before harvest.

The mix of the conditions to be represented in an SBE distribution is largely characterized by the proportion of the slides that contain harvest effects, disease or insect damage, specific stand types, and specific tree species. The most appropriate mix, or set of mixes, to use in building SBE distributions should reflect realistic conditions for usual forest visitors. If visitors are likely to see a proportional cross section of the entire administrative area, then a mix reflecting the distribution of conditions within the entire area is warranted. However, if visitors typically see only a portion of the administrative area, the mix should probably reflect the distribution of conditions in that portion. Or, if one group of visitors generally sees

one portion of the area, while another group sees a different portion, perhaps two mixes and associated distributions are warranted. In any case, the slide presentation context used to obtain SBEs for a given mix should reflect the proportion of different conditions in the mix.

Within each mix, a tradeoff between model precision and model generality is encountered. More precise models, accounting for greater portions of the variance in SBE, more often can be obtained if they are built upon subsets of the data reflecting specific overstory species or stand characteristics, than if they are built upon the entire data set for the mix. For example, individual models for preharvest single- and two-storied sites have higher R^2 s than the model for both one- and two-storied sites. However, such stratification increases the complexity of the modeling effort and makes use of the models more cumbersome.

USE OF SCENIC BEAUTY MODELS

The scenic beauty models provide many insights into the nature of near-view ponderosa pine scenic beauty that have implications for forest management. Furthermore, they provide new opportunities for enhancing forest landscape assessment procedures.

Forest Management

The coefficients of the models presented here suggest that, for the study area, large pine trees, Gambel oak, and herbage contribute to scenic beauty, while smaller pine trees and downed wood detract from scenic beauty. Furthermore, less dense pine stands of less tree grouping and stands of a northerly aspect are preferred. In addition to these rather general statements, use of the models allows comparison of numerous stand conditions. The implications of the models for questions of stand structure and density, slash treatment, and grazing follow.

Stand Structure and Density

Based on criteria adapted from Meyer's (1938) description of even-aged ponderosa pine stands, 58% of the sites used to build the preharvest models and 66% of the sites used to build the postharvest models were characterized as even-aged. Thus, the models were built with a set of data representing a good mix of even- and uneven-aged sites. Assuming constant herbage and downed wood amounts, the preharvest basic model predicted SBEs for even-aged stands ranging about 30 SBE units from most preferred (mature sawtimber) to least preferred (sapling) stands. Predicted SBE for an all-aged stand fell close to the mid-point of the 30-point range for even-aged stands. Thus, even-aged mature sawtimber stands were preferred to all-aged stands, which, in turn, were preferred to even-aged sapling stands, all else being equal. However, because the

standard error of the estimate for the model is about 27 SBE units, this analysis is less than conclusive.

Predicted SBEs of the preharvest basic and detailed downed wood models (table 1) and the postharvest detailed downed wood model (table 2) were compared for six hypothetical ponderosa pine stands. The six stands, which range from 20 to 120 square feet of basal area per acre, are all-aged stands, each containing trees from 1 to 30 inches d.b.h. (table 4). For each stand, the number of trees in any 1-inch diameter class is 1.2 times the number in the next larger 1-inch class. Herbage weight increases as overstory density decreases. The herbage estimates were obtained using an equation developed from data for pine stands on the Coconino National Forest (table 4). These estimates of potential ground cover assume the absence of grazing. Livestock or wildlife grazing would reduce the herbage estimates.

SBEs predicted using each of the three models, for each of the six timber stands, assuming no downed wood, are listed in table 4 and graphed in figure 15. The models predicted very similar estimates of SBE, differing at most by 16 SBE units at 20 square feet of basal area. The preharvest context models show SBE decreasing by more than 40 SBE units as density increases from 20 to 120 square feet of basal area. The postharvest model is less sensitive to this density change, showing a decrease in SBE of 30 units.

The relationship between scenic beauty and stand density depicted in figure 15 shows a clear preference for stands of only 20 square feet of basal area. However, because of the data upon which the models are based, one cannot conclude that large areas of such sparse stands are preferable to areas of a mixture of stand densities. First of all, most sparsely treed inventory sites were surrounded by areas of greater density. Because it is easier to see surrounding, untallied, trees when one is in a sparse stand, it is likely that many photographs taken in sparse stands showed denser areas in the distance. More important, 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 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 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.

Harvest and Slash Cleanup

The detailed downed wood models are more sensitive than the basic models to downed wood changes. The postharvest model is most appropriate for estimating the initial effect of harvest on scenic beauty, and the preharvest model is more appropriate for estimating the long-run effect.

Consider an all-aged stand of 120 square feet of basal area that could be harvested selectively to various density

Table 4.—All-aged stands of differing density.

	Basal area (ft ² /acre)					
	20	40	60	80	100	120
Ponderosa pine (trees/acre) ^a						
0.1–4.9 inches d.b.h.	30	59	86	118	149	183
5–15.9 inches d.b.h.	24	48	69	95	119	145
16–23.9 inches d.b.h.	2.9	5.6	8.2	11.4	14.3	17.3
≥24 inches d.b.h.	0.6	1.3	1.8	2.5	3.2	3.8
Herbage (lb/acre) ^b	617	420	313	254	222	204
Predicted SBE						
Preharvest site-level						
Basic model	98	84	72	63	58	54
Detailed downed wood model	102	88	77	69	64	61
Postharvest site-level						
Detailed downed wood model	86	73	65	61	58	56

^aBased on a Q-value of 1.2.

^bBased on the following equation:

$$PDGFS = 18313 + (22.45ANNPRE + 58.52SOIL - 1.36ANNTEMP) (e^{-0.0084GSL})^3$$

The equation form is a modification of Clary (1978). The equation was calibrated with data for 9,151 plots collected for 20 years on Beaver Creek watershed (H. Brown et al. 1974) and on Wild Bill Experiment Range (Pearson and Jameson 1967). Average Woods Canyon amounts of 26, 43, and 4.5 were used for ANNPRES (annual precipitation), ANNTEMP (annual average temperature), and SOIL (average soil depth), respectively.

levels (table 5). If all slash were removed following harvest, the preharvest and postharvest models would both predict higher scenic beauty at each heavier harvest (fig. 16). Furthermore, the two models yield quite similar predictions, suggesting that short- and long-term scenic beauty would be similar.

However, if some or all of the slash is left on-site, short-term scenic beauty may be greatly affected. As seen in figure 16, the postharvest model shows SBE dropping

dramatically with even a moderate harvest if some slash is left. The model is very sensitive to slash percentage (PCTSL) and small diameter downed wood (DWV014). In the example, all downed wood is slash, and much of it is of small diameter, because it consists of only branches and tops of less than 5 inches in diameter (all other wood is assumed to be harvested).

In the long run, as predicted by the preharvest model, the effect on SBE of leaving some or all the slash, as was done in the actual harvests on the Woods/Bar-M area more than 30 years ago, is moderately negative.

Unfortunately, as shown by the dotted lines in figure 16, most of the predicted SBEs for the no-slash-removal option, and some of the SBEs for the one-half-slash-removal option, are based on estimates of small diameter downed wood (DWV014) which outstep the bounds of the original data. The recently harvested Woods/Bar-M sites did not include sites of such a drastic harvest level as the heavier harvests considered here.

Grazing

Of the physical variables measured for this study, herbage has by far the largest effect on scenic beauty of preharvest conditions and the greatest positive effect on scenic beauty of either preharvest or postharvest conditions (see, for example, the beta coefficients of tables 1, 2, and 3). This has obvious implications for range management, for (with the exception of any increase in scenic beauty from increases in sightings of grazing animals) scenic beauty and grazed animals are competing products. Furthermore, changes in overstory that benefit scenic beauty may create conflicts with grazing interests. Consider that, for areas of overstory density similar to the

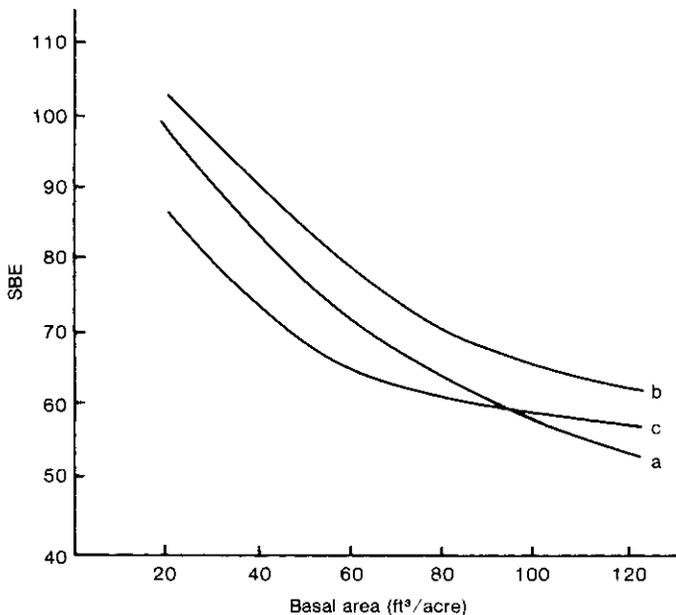


Figure 15.—Change in SBE with basal area for three site-level models: a—preharvest basic model, b—preharvest detailed downed wood model, c—postharvest detailed downed wood model.

Table 5.—Effect of harvest of an all-aged stand of 120 square feet of basal area per acre.

	Basal area (ft ² /acre)								
	120	115	110	105	100	90	80	60	40
Ponderosa pine (trees/acre)									
0.1–4.9 inches d.b.h.	183	175	166	158	149	134	118	86	59
5–15.9 inches d.b.h.	145	139	132	126	119	107	95	69	48
16–23.9 inches d.b.h.	17.3	16.5	15.8	15.1	14.3	12.8	11.4	8.2	5.6
≥24 inches d.b.h.	3.8	3.7	3.5	3.4	3.2	2.9	2.5	1.8	1.3
Herbage (lb/acre)	204	207	211	215	222	235	254	313	420
Downed wood (ft ³ /acre) ^a									
Total	0	41	81	122	162	220	277	408	523
<1/4 inch diameter	0	8	15	23	30	34	38	54	61
>3 inch diameter	0	6	12	17	23	34	46	69	85

^aDowned wood created with harvest.

Woods/Bar-M area before harvest, which averaged 145 square feet of basal area, scenic beauty and herbage for livestock and wildlife can both be increased by harvest of part of the overstory, once the scars of harvest have healed. That is, decreasing overstory density can improve both scenic beauty and grazing potential. However, increases in grazing in response to the increased herbage supply will lower scenic beauty of ponderosa pine areas similar to those of the study area. The grazing/scenic beauty tradeoff thus may be a concern, particularly in areas frequented by recreationists.

Landscape Assessment

In current national forest management, integration of scenic quality with other resources and concerns is crucial. Therefore, it is important to consider the potential contribution of scenic beauty modeling efforts to forest scenic quality management capabilities.

Daniel and Boster (1976) listed three potential contributions of quantitative assessments of perceived scenic beauty to forest management:

1. Better integration with other resources and products.
2. Better justification for land-use decisions.
3. Restoration of the client-architect relationship.

Integration

“Integration” may once have involved largely informal processes, where managers or planning teams attempted intuitively to balance the mixture of forest effects and products. Increasingly, however, this process has become more formal and systematic. Quantitative models project management-induced changes in forest characteristics with considerable precision, and complex linear programs are employed to allocate management resources so as to achieve multiple-use goals efficiently. Integration of scenic resources in this context can be greatly facilitated by the quantitative precision of psychophysical assessments of forest scenic quality and by the explicit relationships between scenic beauty and other measurable, manageable features of the forest provided by the scenic beauty models. Scenic beauty models make it possible to project the scenic consequences of management actions with specified levels of accuracy. Thus, tradeoffs between scenic and other objectives can be evaluated and negotiated with greater precision and confidence. For example, the impact on scenic beauty of typical overstory management can be assessed, facilitating quantification of tradeoffs between net return from marketed products, such as stumpage, and relative scenic beauty. Furthermore, treatments can be designed to maximize scenic beauty in high-use areas, given the existing stand characteristics.

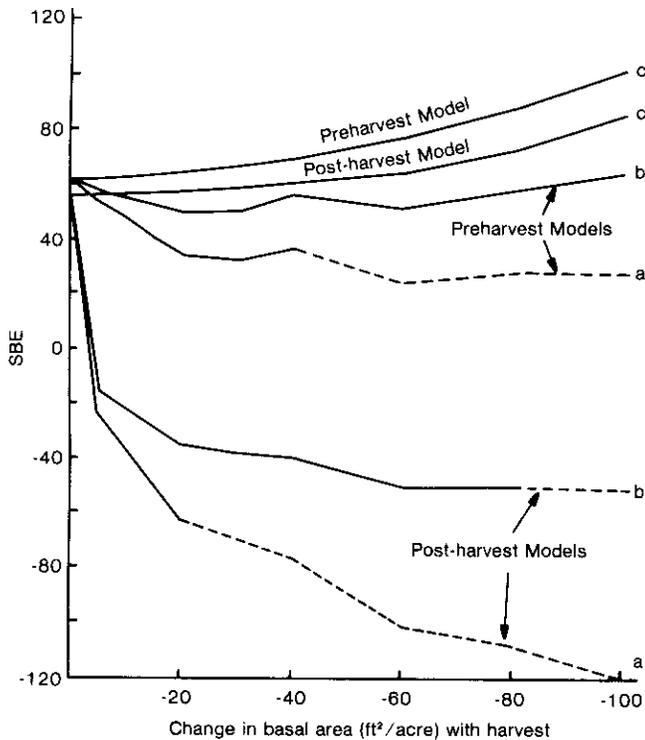


Figure 16.—Change in SBE with harvest of a stand of 120 square feet of basal area as predicted by detailed downed wood site-level models (dotted lines indicate that model is being used outside the range of the original data) (a—no downed wood removal, b—removal of one-half of downed wood, c—complete removal of downed wood).

Justification

Justification of management actions generally involves two major components, a traceable objective decisionmaking process, and documented evidence of public participation. The scenic beauty estimation method makes the assessment process explicit and objective. The procedures are standard, and the outcome does not depend on the judgment or biases of the individual applying the method. Further, projections of the expected scenic consequences of management alternatives are made with explicit models and with specified levels of reliability.

The public participation requirement is met directly when public perceptual judgments are used to assess scenic quality. While most research has found a high degree of consensus in scenic preferences across many segments of the public, it is possible, and may be advisable in some situations, to make separate assessments for important groups that are suspected to have divergent perceptions of forest scenic quality. By using scenic beauty prediction models to project scenic impacts, public judgments are indirectly used to evaluate management alternatives. Thus, public participation is provided at several levels of landscape management.

Client-Architect Relationship

The client-architect relationship is an important element of most architect's work. Reliance on individual, and perhaps idiosyncratic, judgments can be advantageous for landscape designers working for individual private clients. The intensive interaction between the skilled and sensitive designer and an individual client provides an opportunity for the emergence of a highly creative design that uniquely meets the client's needs and wishes. The forest landscape architect, however, designs for a large and somewhat diverse public. There is little opportunity for intensive interaction. The public client does not have the privilege of selecting a designer with a specific style and approach, and the public does not respond to and influence, on a direct and regular basis, the products of the various stages of design development. Thus, some essential elements of an effective client-architect relationship are not available to the public landscape designer. The scenic beauty models can help to restore the client interaction for the forest landscape architect. They provide explicit input about public preferences.

Scenic Beauty Models and the Visual Management System

The Visual Management System (VMS) was developed and implemented on all national forests to guide and assist landscape architects in scenic quality management. The VMS provides an explicit, standardized procedure based on widely accepted design principles and intuitively

reasonable assumptions about viewer sensitivity to scenic beauty and scenic impacts.

Scenic beauty models, such as those presented here, also can be useful tools for the landscape architect. The models complement the VMS system in several ways. First, they provide easily used, quantitative tools that express scenic beauty in terms of other forest resources. Use of scenic beauty models can be facilitated by programming them in hand-held calculators, or providing them as interactive computer programs. Their use should help the landscape architect to function as a full partner in the multidisciplinary team. Integration of scenic resources with other forest products and management concerns is difficult using only the VMS because of the categorical nature of Visual Quality Objectives and the abstract nature of the VMS characterization of the landscape (Daniel and Vining 1983). For example, it is not possible to determine tradeoffs between Visual Quality Objectives and timber volume production except in very gross terms. The relationship between specific harvest-related changes in forest characteristics (e.g., changes in stand density and size distributions or slash accumulations) and formal esthetic features (e.g., variety) is not explicit. Also, the VMS categories often combine large areas that differ in terms of manageable stand characteristics. The scenic beauty models could help provide the degree of quantitative precision at the near-view level necessary to adequately evaluate important tradeoffs.

Second, the scenic beauty models can enhance the landscape architect's credibility among other land management professionals and provide additional justification for the architect's suggestions. Feimer et al. (1981) found very low agreement between individual landscape architects in their judgments of scenic quality and of scenic impacts of various changes in the landscape. Further, judgments of VMS-type landscape features (color, line, texture, etc.) showed inconsistent relationships to global judgments of scenic quality. Because the scenic beauty models rely on public preference, they can supplement the VMS system.

Third, the scenic beauty models can clearly augment the client-architect relationship. The VMS approach alone provides for no direct client-architect interaction. The scenic beauty models provide an easily accessed source of client input that the architect can use in reaching Visual Quality Objectives.

While the scenic beauty models help to quantify scenic beauty, they do not usurp the landscape architect's design prerogative, for they do not prescribe any particular forest treatments. As the models show, a given level of scenic beauty can be achieved with numerous combinations of physical characteristics. Many different combinations of large and small trees, downed wood, and vegetative ground cover will all produce the same SBE in ponderosa pine forests. For any particular combination of features, however, a unique SBE value will be determined—a value that is a reliable estimate of a broad cross section of the public's perception of the scenic quality of the forest.

As the landscape architect works with principles of design and translates them into changes in the visual

appearance of the forest landscape by manipulating biological features, SBE models can be used to provide essential feedback regarding the expected perceptions of the public. That is, the models serve as a surrogate for the public client, providing one source of interaction between public client and forest landscape architect throughout the design process. The landscape architect, combining the features of the VMS and scenic beauty models, and consulting with other resource professionals, could design the combination of landscape features that best meets the needs of the clientele.

SUMMARY AND CONCLUSIONS

The scenic beauty models show that, for the Woods/Bar-M area, observers' verbal judgments of relative scenic beauty of near-view forest scenes can largely be explained in terms of physical characteristics measured on-site using widely accepted forest inventory procedures. Among sites that showed no signs of recent harvest, up to 60% of the variance in perceived scenic beauty can be explained by field measurements of physical characteristics. When site-level data are aggregated to the timber stand level, the variance accounted for is more than 80%. For recently harvested sites, the amount of the variance in perceived scenic beauty explained by site-level measures of physical characteristics drops to at most 50%.

In the Woods/Bar-M area, of all the physical characteristics, herbage had by far the greatest effect on preharvest scenic beauty. The most visually important measure of herbage, combined herbage canopy of grasses, forbs, and shrubs, accounted for 48% of the variance in scenic beauty of preharvest sites and for 79% in preharvest stands. Large ponderosa pine trees and Gambel oak of all sizes also enhanced scenic beauty. Downed wood consistently lowered scenic beauty, especially as slash. In addition, pine saplings and poles detracted from scenic beauty when they were present in large quantities.

The basic stand table, herbage weight, and total downed wood volume variables used in previous studies proved to be the most important for predicting preharvest site-level SBE, accounting for 49% of the variance in SBE. The greatest improvements, over the basic variables, occurred when volume of very fine downed wood, aspect, and a measure of the degree of tree grouping were additionally available, and when herbage canopy and height were available in place of herbage weight. The most effective combination of variables increased the percentage of the variance accounted for by about 10 points above that possible with the basic variables only. The basic variables were of limited utility in predicting SBE for recent postharvest sites; but, when very fine downed wood volume and percentage of the small downed wood in slash were additionally available, prediction improved considerably.

Stand-level models accounted for up to 87% of the variance in preharvest scenic beauty, considerably more than comparable site-level models. The increase in model precision caused by averaging values for the sites within a

stand is attributable to a reduction in variability in the data, which, in part, results from amelioration of the problems with the site sampling procedure. The stand models are very promising, because they account for much of the variance in scenic beauty with so few independent variables. A model of only two independent variables (number of large ponderosa pine and herbage weight) explained 70% of the variance in preharvest stand scenic beauty. While such a model, because it includes so few variables, does not allow some of the finer distinctions between sites that can be made with site-level models, the stand-level models should be well suited to decisionmaking at the timber stand level. Testing of these models on another data base, however, would be very important before they were used outside of the study area.

Often downed wood and herbage estimates are not available, and predictions have to be made on overstory data alone. Site-level models do not show great promise here, explaining at most only 30% of the variance in perceived scenic beauty. However, the preharvest stand-level overstory model accounted for 55%, lending additional support to further development of stand-level models.

Respondents generally preferred less dense, less horizontally complex pine stands. Less dense stands generally have more herbage and fewer small- and intermediate-sized trees than denser stands. Less horizontally complex stands are characterized by stands with less tree clumping. Respondents, however, had no clear preferences regarding vertical diversity (number of tree stories) and preferred mature even-aged stands over all-aged stands, but all-aged stands over young even-aged stands. Comparison of the preharvest and postharvest models suggests that moderate harvest of the Woods/Bar-M area would improve scenic beauty once the stand has recovered from obvious harvest effects and that the recovery period can be greatly reduced with slash cleanup.

An important aspect of the context in which the respondents provided their scenic beauty judgments is the mix of overstory densities in the slides. The slide presentation context contained a clear majority of rather dense sites. The observers' preference for less dense sites of more herbage and large trees may not hold in a context of many sparse and few dense sites. The importance of the mix of conditions depicted in the slides must be understood before the results presented here can be applied to estimate the effect of other than marginal changes in conditions similar to those at Woods/Bar-M.

Selected models developed from the Woods/Bar-M site-level data were tested on data representing ponderosa pine sites throughout the Coconino National Forest and on data representing the Colorado Front Range. The models generally did not perform as well for these areas as they did for the Woods/Bar-M area, both because the contexts of the slide presentations for the other areas differed from that of the Woods/Bar-M slides and because of physical differences between the areas. Calibration of the Woods/Bar-M models increased predictability somewhat. Predictability could be further improved by

changes among the models' independent variables, principally separating shrub weight from grass and forb weight and including a variable for intermediate-sized pine sawtimber.

The direction of the effect on perceived scenic beauty of most physical characteristics that are measurable onsite appears to be stable regardless of the mix of physical features of the site or the context of the scenes viewed by respondents. Regardless of the area or context, large pine trees, grasses, and forbs enhance scenic beauty, while downed wood and small pine trees in sufficient quantities detract from scenic beauty. However, the relative contribution of any variable to scenic beauty appears to vary among forests and depends, even within relatively small areas, on the mix of conditions depicted in the scenes viewed.

A general model, complete with coefficients, for all southwestern ponderosa pine probably would be inadequate for most areas. However, it seems reasonable to suggest that the following physical variables should be included in a model to be calibrated for individual, relatively damage-free pine sites: numbers of ponderosa pine saplings, pulp and small sawtimber, intermediate sawtimber, and mature sawtimber; weight, canopy, and/or height of grasses plus forbs and of shrubs, plus nonlinear terms of these variables; volume or weight of downed wood in diameter size classes of less than 1/4-inch and greater than 1/4-inch; tree grouping; and aspect.

Preharvest models reflect stand conditions after the scars of selection harvest have largely healed, while the postharvest model reflects very short-term postharvest stand conditions, with slash and other harvest effects quite obvious at harvested sites. An operational model probably should reflect not just these two situations, but the full range of nonharvest and harvest recovery conditions in proportion to those likely to be encountered by forest visitors.

This study suggests that people's scenic beauty judgments are consistent and intuitively logical. It also supports the psychophysical approach to understanding esthetic preference for near-view forest scenes. Not only can the psychophysical model be used to explain a large percentage of the variance in perceived scenic beauty, but that percentage drops, as would be expected, when scenes become more complex, and correspondingly more difficult to characterize with physical variables measured on-site. However, because the southwestern ponderosa pine ecosystem is relatively simple in terms of species diversity and seasonal color changes, and because the topography of the Woods/Bar-M area is relatively flat, the modeling success reported here may be exceptional. The psychophysical approach for modeling scenic beauty must be tested in other ecosystems and topographical situations in order to determine its forest-wide applicability.

The scenic beauty models are well suited to use in forest planning. They could be easily linked to physical simulation models, allowing prediction of near-view scenic effects along with more traditionally quantified forest characteristics. The models allow calculation of the change in

scenic beauty with harvest, grazing, and slash cleanup, and suggest that moderate harvest can improve scenic beauty if slash is cleaned up, that grazing can reduce scenic beauty, and that slash cleanup dramatically increases scenic beauty. The models should complement use of the Visual Management System and enhance the landscape architect's ability to manage scenic resources.

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APPENDIX

BIVARIATE RELATIONSHIPS AMONG THE VARIABLES

The independent variables of this study are of a biological or physical nature. All were measured on-site using generally accepted forest and rangeland inventory procedures. In all, 82 physical variables, which fall into seven groups, were considered: (1) 4 land variables (e.g., slope); (2) 7 overstory summary variables (e.g., ponderosa pine basal area per acre); (3) 23 variables listing numbers of trees per acre by species and size class; (4) 10 variables listing grass, forb, and shrub weight, canopy, or height; (5) 9 describing percent ground cover; (6) 4 listing number of stumps per acre by size class; and (7) 25 describing downed wood volume by size and condition class plus downed wood depth, dispersion, and percent slash (see Brown (1983) for a complete description of all 82 variables). This appendix presents more detailed information about relationships among these variables. All measures describe site-level data.

Linear Relationships

Relationships between the variables for site-level data are described based on Pearson correlations significant at the 5% probability level. These correlations indicate the strength of the linear relationship between pairs of variables. The more closely a two-dimensional plot of the site-level values for any two variables fits a straight line, the closer the absolute value of the correlation coefficient is to 1.0.

Land Variables

The inventoried Woods/Bar-M sites range up to a 40% slope. Site index (Minor 1964) ranges from 64 to 89 and averages 78. Increases in both slope and site index were associated with decreasing scenic beauty. Slope and site index were positively intercorrelated, and were positively correlated with the following features, which were all associated with decreasing scenic beauty: number of ponderosa pine in the pulp (5 to 12 inches d.b.h.), small sawtimber (12 to 16 inches d.b.h.), and intermediate sawtimber (16 to 24 inches d.b.h.) size classes, pine basal area, overstory crown canopy, and small diameter downed wood. In addition, slope and site index were negatively correlated with number of large (greater than 24 inches d.b.h.) ponderosa pine, which was positively correlated with scenic beauty (perhaps past harvests of large diameter pine on the better sites contributed to this situation). In other words, more rapid tree height growth was generally found on steeper slopes where stands were denser because of an abundance of pulp- and small and intermediate sawtimber-sized trees. These stands tended to have more small

diameter downed wood, fewer large pine trees, and lower scenic beauty.

Movement from a south to north aspect was associated with increasing scenic beauty as well as increases in herbage weight, canopy, and height and with decreases in number of pine of the pulp to intermediate sawtimber sizes, pine basal area, crown canopy, and volume of small diameter downed wood.

Overstory Summary Variables

Preharvest sites ranged from 20 to 320 square feet per acre of pine basal area, from 260 to 8,800 cubic feet of pine per acre, and from 2% to 98% overstory crown canopy. Basal area averaged 125 and 19 square feet per acre in pine and Gambel oak, respectively. For preharvest sites, increases in scenic beauty were associated with increases in Gambel oak basal area, and with decreases in pine basal area, cubic feet of timber, overstory crown canopy, and degree of tree grouping. Pine basal area, crown canopy, and tree grouping were all positively correlated with number of pine in the pulp, small sawtimber, and intermediate sawtimber size classes, and with volume of small diameter downed wood, and were negatively correlated with herbage amounts and heights and with number of large pine trees. In general, as Rutherford and Shafer (1969) and Daniel and Boster (1976) found, less dense sites had less tree grouping, more herbage, and higher scenic beauty. The increase in scenic beauty as pine basal area decreased was probably enhanced by the corresponding increase in visibility of herbage, mature pine, and oak.

Pine basal area of postharvest sites ranged from 5 to 183 square feet per acre, while timber volume ranged from 140 to 3,000 cubic feet. The strong correlations between scenic beauty and overstory summary variables found for preharvest sites generally were absent for the postharvest sites. Only oak basal area was clearly, positively, associated with scenic beauty among the postharvest sites. The lack of a strong negative correlation between scenic beauty and variables describing pine stand density and grouping probably reflects the generally lower stand densities of the postharvest sites, and perhaps the more obvious harvest effects at some of the least dense sites.

Twenty-nine percent of the preharvest sites had less than 100 square feet of total basal area, 51% had from 100 to 200 square feet of basal area, and the remaining 20% had more than 200 square feet of basal area. The denser sites generally had more pulp- and immature sawtimber-sized pine trees, fewer large pine, less herbage, and lower SBE (table A-1). Increasing ponderosa pine stand density was negatively associated with scenic beauty for all three subsets. The simple correlation between SBE and pine basal area was -0.17 , -0.32 , and -0.37 for the three subsets in order of increasing total basal area.

Table A1.—Means for selected variables for subsets of the preharvest sites based on total basal area, number of tree stories, and tree grouping.

Variable	Total basal area ^a			Tree stories ^b				Tree grouping ^c			
	<100 (96) ^d	100–200 (171)	>200 (66)	1 (29)	2 (103)	3 (162)	4 (39)	1 (79)	2 (159)	3 (51)	4 (44)
SBE	28	15	2	33	15	12	24	1	10	27	53
Ponderosa pine (trees/acre) saplings	115	230	142	59	111	233	226	239	214	84	55
5–15.9 inches d.b.h.	56	162	343	165	180	177	99	246	158	138	94
16–23.9 inches d.b.h.	7	13	18	10	13	12	15	13	12	11	12
>24 inches d.b.h.	4.6	3.5	2.1	3.4	2.4	3.8	5.4	2.8	3.6	4.1	3.9
Herbage weight (lb/acre)	98	93	52	100	85	85	87	54	76	113	154
Downed wood (ft ³ /acre)	1005	1399	1359	1004	1390	1299	1094	1346	1310	1300	1007
Basal area (ft ² /acre)											
Pine	64	123	218	122	134	125	101	158	121	114	92
Oak	8	19	32	24	20	19	13	22	16	14	30
Total	73	144	251	146	155	145	114	181	137	130	123
Tree grouping ^c	2.4	2.2	1.7	2.7	2.5	2.0	2.0	1.0	2.0	3.0	4.0
Tree stories ^b	2.7	2.7	2.4	1.0	2.0	3.0	4.0	2.6	2.9	2.4	2.0
Crown canopy (percent)	42	59	73	56	62	56	49	65	54	56	54
Site index	75	78	82	78	79	79	75	81	77	76	78

^aSquare feet per acre.

^b1 = one, 2 = one but some two, 3 = two but some three, 4 = generally three.

^c1 = trees in groups with many interlocking crowns, 2 = some tree grouping but little interlocking of crowns, 3 = very little grouping, 4 = no tree grouping—trees evenly spaced.

^dNumber of cases in parentheses. The sum of the cases for each of the 3 groups is 333.

Each inventory site was categorized on-site into one of four tree story classes: (1) one-storied; (2) generally one-storied, but partially two-storied; (3) generally two-storied, but partially three-storied; and (4) generally three-storied. Of the 333 preharvest sites, 9%, 31%, 49%, and 12%, respectively, were assigned to the four classes. Note that sites assigned to each class may contain cases representing a variety of age classes. For example, single-storied stands of any age class may be included in the first class. The four data subsets are not easily distinguished in terms of most measured variables. For example, total basal area ranges from 114 square feet per acre for tree story class 4 to 155 for class 2 (table A-1). The range from 12 SBE units for class 3 to 33 SBE units for class 1 is small; therefore, firm conclusions about the preference for one class above another are risky.

Sites were also categorized during field inspection into four tree grouping classes: (1) trees in groups with many interlocking crowns; (2) some tree grouping, but little interlocking of crowns; (3) very little tree grouping; and (4) no tree grouping—trees evenly spaced. Twenty-four percent, 48%, 15%, and 13% of the preharvest sites were assigned to the four tree grouping classes, respectively (table A-1). Note that sites assigned to each class may contain sites representing a variety of tree story and age classes. In contrast to the tree story distinction, the four data subsets are distinct in terms of several measured variables. An increase in grouping is associated with increasing stand basal area, increasing numbers of pine saplings, pulp, and small sawtimber trees, and decreasing

herbage (table A-1). Thus, increased grouping is generally more common in denser stands crowded with smaller trees. In concert with these characteristics of increased tree grouping, scenic beauty (SBE) decreases as grouping increases. Mean SBE drops from 53 for the sites of no grouping to 1 for the sites of trees in groups with many interlocking crowns (table A-1).

Trees

The preharvest sites averaged 180 pine saplings and 184 larger pine trees per acre, plus 36 Gambel oak saplings and 24 larger oak trees per acre. Increasing numbers of pine trees up to 20 inches d.b.h. for preharvest sites, and of up to 16 inches d.b.h. for postharvest sites, were associated with decreasing scenic beauty. However, because nearly all sites had some pine trees in these size ranges present, it cannot be concluded that the complete lack of such pine trees is preferable to a small number of such trees. Furthermore, increasing numbers of oak and large pine trees were associated with increasing scenic beauty. These findings reinforce those of Klukas and Duncan (1967) about the preference for mature pine stands with clear understory, the conclusions of Arthur (1977), Brush (1979), and Schroeder and Daniel (1981) about the preference for large trees and negative effect of increasing numbers of small trees, and the finding of Schroeder and Daniel (1981) about the positive correlation between Gambel oak and scenic beauty.

Herbage

Preharvest herbage weight of grasses, forbs, and shrubs, respectively, ranged to 330, 680, and 200 pounds per acre, and averaged 22, 51, and 14 pounds per acre. Total weight averaged 87 pounds per acre, while combined herbage canopy averaged 16% and maximum herbage height averaged 10 inches. Herbage quantities on postharvest sites averaged slightly higher than on the preharvest sites.

All weight, canopy, and height measures of grasses, forbs, and shrubs were strongly, positively correlated with scenic beauty for both contexts, with the exception of low positive correlations between scenic beauty and forb weight and height for the postharvest sites. Correlations of canopy and height variables to SBE were generally somewhat higher than corresponding correlations of weight to SBE. For example, the correlations of herbage weight, herbage canopy, and maximum herbage height to SBE for preharvest sites were 0.58, 0.65, and 0.62, respectively. Herbage amounts were generally lower in the denser timber stands, principally because of competition for light and moisture. Both Arthur (1977) and Schroeder and Daniel (1981) reported positive contributions of herbage weight to scenic beauty.

Ground Cover

Preharvest ground cover averaged 77% litter, 6% downed wood, 10% rock, 3.5% bare soil, and 2.5% herbage. Obvious signs of mechanical ground disturbance covered only 3% of the inventoried area.

Percentage of bare soil and percentage of herbage were positively correlated to scenic beauty, while percentage of litter was negatively correlated to scenic beauty. Percentage of ground cover in herbage was closely related to other herbage measures. However, it is not intuitively obvious why bare soil was positively associated with scenic beauty. Perhaps the answer lies in the fact that percentage of bare soil was positively correlated with grass amount and negatively correlated with number of pulp- and intermediate sawtimber-sized pine, pine basal area, and numerous downed wood variables. Similarly, percentage of litter cover, which is probably not inherently displeasing, was positively correlated with number of pine in the pulp, small sawtimber, and intermediate sawtimber-size classes, pine basal area, crown canopy, and small downed wood.

For postharvest sites, average proportion of bare soil increased to 11%, at the expense of slight reductions in all other categories. Furthermore, about 30% of the inventoried area showed obvious signs of mechanical disturbance. Percentage of ground cover in herbage again was positively correlated with scenic beauty. However, the relationships of percentage of bare soil and litter to scenic beauty were reversed from the preharvest context. The negative correlation of percentage of bare soil to scenic beauty for postharvest sites is probably related to the strong positive relationships of bare soil to mechanical ground disturbance and to the percentage of the small

downed wood that is slash, both of which are strongly negatively correlated to scenic beauty. Harvest and slash piling both involve mechanical scraping of the ground and an increase in the amount of exposed soil.

Stumps

Preharvest sites averaged about 30 stumps per acre, while postharvest sites averaged about 42 stumps per acre. The recently created stumps were generally less than 6 inches high, considerably lower than the stumps on preharvest sites. Stumps were negatively but weakly correlated with scenic beauty on preharvest sites. For postharvest sites, stumps were negatively correlated with scenic beauty, which was partially the result of the association of number of stumps with other harvest-related effects, such as increased amounts of downed wood and mechanical disturbance.

Downed Wood

Total downed wood volumes for both preharvest and postharvest sites averaged about 1,200 cubic feet per acre. This happened for two reasons. First, the sites that were inventoried after harvest had less than average downed wood before the harvest. Second, some of the large downed logs that were on-site before harvest were skidded to landings during harvest. Sixteen percent of the small diameter downed wood on preharvest sites was estimated on-site to have originated from harvests, which occurred many years prior to the inventory. For postharvest sites, this rose to close to 60%.

Downed wood volumes of all categories were negatively correlated with scenic beauty for both preharvest and postharvest sites. Percentage of the small downed wood that is slash also was negatively correlated with scenic beauty, especially for the postharvest sites. A measure of the distribution of downed wood was not significantly correlated to scenic beauty; but, number of brush piles were clearly negatively correlated to scenic beauty. These findings corroborate those of Daniel and Boster (1976), Arthur (1977), and Schroeder and Daniel (1981) that increasing downed wood amounts and piling of downed wood detract from scenic beauty.

Nonlinear Relationships Between SBE and Physical Variables

Cohen and Cohen (1975) stated "... it is a fundamental law of psychophysics that constant increases in the size of a physical stimulus are not associated with constant increases in subjective sensation." Fechner suggested that a logarithmic function best measures this relationship (see Guilford 1954), while Stevens (1975) suggested a power function. Buyhoff and Wellman (1980) tested these functions, plus an exponential function, for vista scenes, and

found that the log function gave the best fit for regression of the proportion of visible area of color photographs in specific landscape dimensions on perceived scenic quality.

Alternative functional forms were compared for five variables (pine basal area, herbage weight, herbage canopy, herbage height, and downed wood volume) that exhibited some degree of nonlinear relationship with scenic beauty (SBE) for preharvest sites. The exponential ($SBE = b_0 e^{b_1 X}$) and power ($SBE = b_0 X^{b_1}$) forms gave a poorer fit to the data based on R^2 and F-ratio, for all five variables, than did the linear form (table A-2). However, an improvement in fit, over the linear form, was obtained with the log form ($SBE = b_0 + b_1 \log X$) for four of the five variables. While this suggests that Fechner's claim (Guilford 1954) is superior to Stevens' (1975) for scenic beauty judgments of timber stands, the evidence is weak. The largest increase in R^2 of the log form over the linear form was only from 0.34 to 0.38 for total herbage weight. Buyhoff and Wellman (1980) showed much larger increases for vista scenes.

The quadratic form $SBE = b_0 b_1 + b_2 X^2$ is compared with the other forms in table A-2. Given the nature of the curves, the quadratic form described the relationships about as well as possible. The biggest improvement in R^2 was from 0.42 to 0.48 for herbage canopy. Figure A-1 is similar to the quadratic curves for all herbage variables, but obtains a slightly better fit of the data, because an exponent of 0.75 was used instead of 2.0. It depicts the following relationship of SBE and herbage canopy (CCTOT):

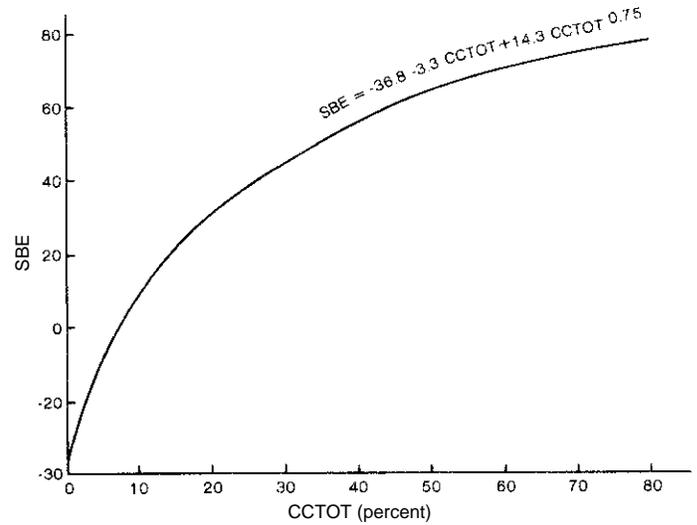


Figure 1A.—Relationship of scenic beauty (SBE) to herbage canopy (CCTOT).

$$SBE = 36.82 - 3.34 CCTOT + 14.31 CCTOT^{0.75}.$$

The curve depicted in figure A-1 ends at an SBE of 79 where CCTOT is 81, the maximum value for CCTOT in the data set. The curve eventually peaks at an SBE of 82 where CCTOT is 110.

Table A2.—Four functional forms of the relationship between SBE and selected biological variables for 333 preharvest cases.

Variable	Functional form ^a	Equation (SBE =) ^b	R ² ^c	F-ratio
Pine basal area	linear	42.62 - 0.21X	0.14	52
	log	132.60 - 24.81 logX	.14	56
	exponential	22.87 e ^{-0.0083X}	.09	32
	power	844.72X ^{-0.99}	.10	35
	quadratic	51.46 - 0.36X + 0.005X ²	.14	27
Herbage weight	linear	-7.63 + 0.29X	.34	174
	log	-67.55 + 21.001 logX	.38	205
	exponential	2.81 e ^{0.01X}	.28	132
	power	0.2X ^{0.93}	.31	151
	quadratic	- 18.17 + 0.54X - 0.0009X ²	.39	104
Herbage canopy	linear	- 8.83 + 1.57X	.42	240
	log	- 38.39 + 23.38 logX	.44	262
	exponential	2.70 e ^{0.07X}	.34	169
	power	0.71X ^{1.04}	.37	194
	quadratic	- 21.47 + 3.16X - 0.03C ²	.48	151
Herbage height	linear	- 19.66 + 3.58X	.38	202
	log	- 53.99 + 33.31 logX	.40	2.16
	exponential	1.69 e ^{0.16X}	.30	143
	power	0.37X ^{1.47}	.32	157
	quadratic	- 37.19 + 6.73X - 0.10X ²	.43	123
Total downed wood volume	linear	27.78 - 90.29X	.06	22
	log	72.49 - 8.22 logX	.04	13
	exponential	13.73 e ^{-0.00041X}	.05	19
	power	70.73X ^{-0.32}	.02	8
	quadratic	26.40 - 0.007X + 0.0000005X ²	.06	11

^aLog signifies natural logs.

^bX signifies the independent variable.

^cCoefficient of determination.

In all cases where a nonlinear functional form provided a better fit than the linear form, the equations indicated a decreasing marginal contribution of the physical stimulus to scenic beauty. Equal increases in pine basal area and downed wood volume were associated with decreasing marginal reductions in scenic beauty; and equal increases in herbage quantities or heights were associated with decreasing marginal increases in scenic beauty.

It is of considerable interest that 48% of the variance in SBE of the preharvest sites can be explained by knowing

only the combined canopy of grasses, forbs, and shrubs, and that 43% of said variance can be explained by merely knowing the maximum herbage height (table A-2). When sample point estimates are averaged per stand, providing 23 stand-level cases, these percentages increase to 67% and 79%, respectively. However, while it can be inferred from this that herbage makes an important contribution to preharvest scenic beauty, it cannot be concluded that large quantities of herbage are essential to high scenic beauty.

Brown, Thomas C. and Terry C. Daniel. 1984. Modeling forest scenic beauty: Concepts and application to ponderosa pine. USDA Forest Service Research Paper RM-256, 35 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Statistical models are presented which relate near-view scenic beauty of ponderosa pine stands in the Southwest to variables describing physical characteristics. The models suggest that herbage and large ponderosa pine contribute to scenic beauty, while numbers of small and intermediate-sized pine trees and downed wood, especially as slash, detract from scenic beauty. Areas of lower overstory density and less tree clumping were preferred. Moderate harvest of relatively dense stands tends to improve scenic beauty once the stand has recovered from obvious harvest effects. The recovery period can be greatly reduced by slash cleanup.

Keywords: Scenic beauty, landscape assessment, forest esthetics, *Pinus ponderosa*



Rocky
Mountains

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Southwest

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