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Production and Cost of Scenic Beauty: Examples for a Ponderosa Pine Forest

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ABSTRACT. Psychophysical models of scenic beauty for an all-aged ponderosa pine area were combined with estimates of management costs and physical output values to indicate more efficient input combinations for production of scenic beauty. Also, in combination with biophysical models, the scenic beauty models were used to examine tradeoffs between scenic beauty and net present worth from timber, forage, and water yields. These examples demonstrate the use, as well as important limitations, of scenic beauty models in a multiple use context. FOR. SCI. 33(2):394–410.

ADDITIONAL KEY WORDS. *Pinus ponderosa*, tradeoffs, multiple use, forest esthetics, landscape assessment.

MULTIPLE USE has long been a guiding principle in national forest management (Clawson 1978), and an economic approach to multiple use management has often been suggested (e.g., Gregory 1955, Convery 1977). Furthermore, an economic approach has been encouraged in recent legislation. The Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA), as amended by the National Forest Management Act of 1976 (NFMA), while not requiring formal cost-benefit analysis, places considerable emphasis on economic efficiency in the evaluation of tradeoffs among management alternatives.

The National Environmental Policy Act of 1969 was the first law affecting national forests to assure "productive and esthetically . . . pleasing surroundings" (42 U.S.C. 4331). The RPA and NFMA reinforced the mandate for consideration of amenity resources, specifically identifying esthetic along with wildlife, recreation, and wilderness resources. The visual quality, or scenic beauty, of forests is an important esthetic consideration in many forest locations.

Complete application of the modern microeconomic framework to multiple use management would require optimization given specification of multiproduct production or cost functions in light of the full set of prices for inputs and outputs. For scenic beauty, this would require measurement, incorporation into the multiproduct or cost functions, and monetary valuation. This approach is conceptually elegant, but requires much information about scenic beauty and other outputs that currently is not available. Thus, this paper takes a more modest approach. Monetary valuation of scenic beauty is not attempted, and multiproduct production functions are not derived. Rather, the paper specifies scenic beauty models and uses those models in the context of microeconomic theory and in combination with biological simulation models to estimate costs of providing scenic beauty. In place of optimization, discrete alternatives are compared and costs are depicted.

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The cost of something of course does not indicate its value. Rather, the cost should be compared with the value, or benefit, to indicate net value. Confidence in a benefit-cost comparison depends on confidence in the benefit and cost estimates. The purpose of this article is to demonstrate methods that can increase confidence in cost estimates for scenic beauty.

The paper first reviews recent literature that has examined the contribution of timber stands to noncommodity outputs such as scenic views. Next, models relating scenic beauty to scene features are presented. Those models are then used in two examples that depict costs of providing scenic beauty in terms of management outlays and foregone commodity products. Numerous assumptions of and qualifications on the approach are discussed. The paper concludes that the approach is a useful contribution to multiple use management.

Recent Literature

Four recent theoretical papers examined the effect of services rendered by standing timber on traditional timber management objectives. Both Hartman (1976) and Strang (1983) determined the optimal rotation length of an even-aged forest stand. Nguyen (1979) determined the optimal cutting cycle of a presumably all-aged forest stand given a residual stocking that was maintained because of the value of standing timber. Berck (1981) analyzed the problem of a resource stock that provides benefits to society not captured by the resource owner, such as a forest that provides both harvestable timber and "pretty views" (p. 113). Although he did not distinguish between even-aged and all-aged management, he concluded that "failure to account for . . . an externality . . . result(s) in too low a plan for the resource stock" (p. 116). All four papers assume that standing timber has value for recreation purposes and show that consideration of such value will often affect optimum timber management objectives. To reach this conclusion, Hartman and Strang explicitly, and Berck implicitly, also assume that the external (nonharvest) marginal benefit of the stand is positive over the relevant range in timber density. However, while this latter assumption seems reasonable, it is not necessarily so for selective harvest of an all-aged forest. As demonstrated below using empirically estimated scenic beauty models, increasing timber density, as would naturally result from a lack of harvest, does not necessarily improve scenic beauty.

Several empirical studies have estimated relationships between scenic beauty and physical forest characteristics (e.g., Arthur 1977, Schroeder and Daniel 1981, Buhyoff et al. 1982), but have not extended their methodology to cost or tradeoff estimation. Also, two recent studies estimated the cost of forest scenic beauty, but neither were based on quantitative relationships between scenic beauty and forest features. First, Fight and Randall (1980) estimated the increase in cost of producing and harvesting a specified timber quantity while meeting a midrange visual quality constraint in Oregon. They considered only two levels of visual quality (with and without the constraint) and did not directly relate the physical features of the scene to the visual quality. Second, Calish, Fight, and Teeguarden (1978) estimated the effect of nontimber outputs, including visual quality, on rotation in Douglas-fir. The relationship between visual quality and rotation length was represented by a freehand curve of continually increasing value from 0, at a rotation of 1 year, to 1.0, at a rotation of 100 years. Because precise relationships between scenic beauty and multiple forest characteristics were not developed in these two studies, only limited tradeoff evaluation was possible.

Earlier papers have taken initial steps toward incorporating scenic beauty into the multiple use management process, but much remains to be done. The purpose of this paper is to demonstrate an approach for estimating the cost of providing scenic beauty on multiple use lands using an empirically derived interval-scale measure of near-view scenic beauty for an all-aged ponderosa pine forest. This paper draws on previous efforts to specify models expressing scenic beauty as a function of physical site characteristics, but goes further than previous attempts to incorporate scenic beauty into multiple use management.

Scenic Beauty Models

The general procedure used in this study to develop scenic beauty models has been described elsewhere (e.g., Schroeder and Daniel 1981, Buyhoff et al. 1982, Brown and Daniel 1984), and is only summarized here. The models express scenic beauty as a function of physical and biological scene features. The case for modeling is a forest site, which is represented by one or more scenes. A panel of observers views and judges each scene, and the responses are scaled to yield an interval scale measure of scenic beauty for each scene. Where more than one scene represents a forest site, the scenic beauty values of the scenes are averaged for the site to form the dependent variable. The observers are chosen randomly from the population of interest, and observer differences are given up in the scaling procedure, such that the dependent variable represents the population, but not necessarily any specific individual. The independent variables are obtained from measurements of visible features at the sites. Regressing the scenic beauty values on the measures of site features yields a quantified relationship of the population's relative scenic beauty judgments to site characteristics. This relationship is a production function in that it gives output for specified inputs.[1]

Arthur (1977) found that perceived and rated scenic beauty of ponderosa pine stands could be predicted as a function of either formal design features, such as contrast and vividness, or common measures of biological features, such as trees per acre by diameter size class and amount of downed wood. Characterizing scenes in terms of biological rather than design features has the advantage of expressing scenic beauty in terms of the components that are directly affected by management practices. And, of principal interest here, expressing scenic beauty in terms of manageable features allows direct examination of at least some of the tradeoffs to be considered in forest management.

Randomly located sites within specified timber stands were each represented by 4 color slides that did not include bodies of water, constructed features (e.g., fences or buildings), people, or livestock. The slides were shown in sets to panels of observers who rated the slides for "scenic beauty" on a 10-point scale. Based on results from several studies, including Daniel and Boster (1976), Shuttleworth (1980), and Kellomaki and Savolainen (1984), the scenic beauty judgments from color slides were assumed to represent on-site judgments. All panels saw about 130 slides, including a common set of 25 baseline slides. The ratings of each panel were scaled using the "by-slide" *SBE* procedure (Daniel and Boster 1976, Hull et al. 1984). Responses to the baseline slides determined the origin of the scale,

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[1] It is beyond the scope of this paper to compare and contrast the scenic beauty model to the standard notion of a production function in production economics (Georgescu-Rogen 1970) or to the notion of a household production function (Becker 1965).

providing a standardized difference score called a "scenic beauty estimate" or *SBE*. The 4 *SBE*'s representing the 4 slides taken at each site were then averaged to yield one *SBE* per site.

The slides were rated for scenic beauty by randomly selected panels of at least 25 people. The observer panels were recruited from university classes and student organizations, church groups, and civic groups. They did not represent any particular land management orientation, and thus were considered to represent the general public. Group-to-group reliability statistics (Ebel 1951) showed that the groups were sufficiently similar to allow combining their *SBE*s into the same analysis (Brown and Daniel 1984, 1986).

The sites inventoried for this study are in the ponderosa pine type on the Coconino National Forest of north central Arizona (Brown and Daniel 1984). They are on the relatively flat plateau above the Mogollon Rim at elevations of from 6,400 to 7,700 feet. The views are characterized as near-view. Near-view distance ranges from only a few yards in a very dense forest, to approximately 100 yards. One cannot see farther, except for sky or clouds, in a near-view scene because of the vegetation. Typical near-view situations are walking through a forest or driving along a road through a forest. If one can see distant slopes or peaks over the tree tops, the scene is a midrange or vista view, although the foreground is probably within the near-view range.

The sites were inventoried using standard forest and range inventory techniques (Brown and Daniel 1986). For example, overstory trees were tallied using a ten-factor prism, and down wood volume was measured following Brown's (1974) line intercept (transect) method. Timber was inventoried for the full 360° around the site center. Herbage was inventoried in eight small plots, and downed wood was inventoried along eight transects, with two of each in the view of each of the four photos taken at the site.

Two preharvest models and one postharvest model are presented here. The preharvest models were developed from data for 333 sites. Most of those sites had been selectively harvested about 30 years before the inventory, but few signs of that harvest remained, giving the area a generally unmanaged appearance. Most sites contained trees of two or more age classes, and the stands in general had an all-aged appearance. The postharvest model was developed from data for 123 sites found in recently harvested ponderosa pine stands in the same geographical area. Signs of the recent harvest were abundant and obvious at many of the sites. The preharvest and postharvest sites averaged 125 ft^2 and 73 ft^2 of pine basal area, respectively.

The models were developed by considering many candidate models that included linear, quadradic, and interaction terms. The final models were selected based on statistical measures of fit (coefficient of determination, mean square error, standard error, and examination of residuals), on results of modeling efforts in other pine areas, on statistical significance of the individual parameters, and on intuitive appeal. The first one was restricted to noninteraction terms:

$$\begin{aligned} SBE = {} & -3.99 - \underset{(-2.04)}{.0087PPSAP} - \underset{(-1.98)}{.0238PPULP} + \underset{(2.18)}{.8169PPLG} - \underset{(-3.44)}{.3062HERB} \\ & + \underset{(5.63)}{2.3845HERB^{0.75}} - \underset{(-3.64)}{0.9650DWSM} - \underset{(-2.31)}{.0035DWLG} \end{aligned} \tag{1}$$

This model accounts for 51% of the variance in *SBE*, has a standard error of

25.6 *SBE* units, and is highly significant, with $F(7,325) = 48.87$. All independent variables are significant ($P \leqq 0.05$); t-statistics are shown in parentheses.

The variables of Equation (1) are described in Table 1. The model includes measures of the pine overstory, herbage, and downed wood except for pine from 12 to 24 in. dbh. Inclusion of variables for these small and intermediate-sized sawtimber trees did not improve model prediction and had a trivial effect on the coefficients of the remaining variables. Overstory summary variables, such as square feet of basal area or cubic feet of volume, did not improve model prediction, and apparently were unable to characterize the nature of the all-aged stands [Hull and Buhyoff (1986) reached a different conclusion in loblolly pine stands in the Southeast]. The two herbage terms indicate the decreasing marginal contribution of herbage to scenic beauty. Other features did not exhibit this diminishing marginal effect, at least within the range of features measured in the study area.

The other preharvest model was estimated with the availability of interaction terms:

$$\begin{aligned} \mathit{SBE} = {} & -\ \underset{(-1.80)}{10.75} - \underset{(-2.57)}{0.000117}\mathit{PPSAP} \cdot \mathit{HERB} - \underset{(-3.28)}{0.000015}\mathit{PPULP} \cdot \mathit{DWLG} \\ & + \underset{(2.44)}{0.8954}\mathit{PPLG} - \underset{(-3.71)}{0.3299}\mathit{HERB} + \underset{(6.04)}{2.5685}\mathit{HERB}^{-.75} - \underset{(-3.77)}{0.9880}\mathit{DWSM} \end{aligned} \tag{2}$$

This model has an R^2 of 0.51, a standard error of 25.6, and is highly significant with $F(6,326) = 57.25$. All independent variables are significant at 0.02; t-statistics are given in parantheses. The model increases model R^2, over

TABLE 1. Information on selected variables.

Variable Description	Name	Mean	SD[a]	Range Min	 Max	R[b] with *SBE*
Preharvest sites ($n = 333$)						
Scenic beauty estimate	*SBE*	16.3	36.3	−83	122	1.0
Pine saplings (no./ac)	*PPSAP*	179.3	341.4	0	2600	−0.15
Pine trees 5 to 12 in. dbh (no./ac)	*PPULP*	137.0	134.4	0	727	−0.37
Pine trees ≧24 in. dbh (no./ac)	*PPLG*	3.5	4.0	0	18	0.24
Herbage[c] weight (lb/ac)	*HERB*	86.6	90.5	1	1025	0.58
Downed wood <¼ in. diameter (ft^3/ac)	*DWSM*	10.7	6.0	1	37	−0.44
Downed wood ≥¼ in. diameter (ft^3/ac)	*DWLG*	1209.9	994.6	33	6426	−0.25
Postharvest sites ($n = 123$)						
Scenic beauty estimate	*SBE*	8.6	31.4	−48	93	1.0
Pine saplings (no./ac)	*PPSAP*	114.2	228.7	0	1300	−0.19
Herbage weight (lb/ac)	*HERB*	135.1	104.9	1	795	0.23
Downed wood <¼ in. diameter (ft^3/ac)	*DWSM*	7.5	4.8	1	29	−0.27
Downed wood percent slash	*PCTSL*	54.5	25.4	0	100	−0.47

[a] Standard deviation.

[b] Pearson's correlation coefficient.

[c] Herbage includes grasses, forbs, and shrubs.

Equation (1), by only a trivial amount. However, it demonstrates the intuitively reasonable notion that physical features interact in their impact on perceived scenic beauty. The interaction between *PPULP* and *DWLG* indicates that the negative impact of each on scenic beauty is greater the more of the other that is present. The interaction between *PPSAP* and *HERB* can be interpreted to indicate that the positive contribution of herbage to scenic beauty is reduced the more saplings that are present.

The postharvest model, previously reported by Brown and Daniel (1984), accounted for 41% of the variance in *SBE* with a standard error of 24.5 *SBE* units:

$$\begin{aligned} SBE = {} & \underset{(6.82)}{46.84} - \underset{(-2.45)}{0.0243PPSAP} + \underset{(2.72)}{0.0652HERB} - \underset{(-3.93)}{1.8871DWSM} \\ & - \underset{(-7.88)}{0.6448PCTSL}. \end{aligned} \quad (3)$$

The model was significant, with $F(4,118) = 20.91$. All independent variables were significant at <0.02. The variables are described in Table 1. Neither quadradic nor interaction terms significantly improved the fit of the model. The lower R^2 of this model, compared with the preharvest models, suggests that the field measurements used are less able to represent the scenic dimension of such recently harvested stands.

The independent variables of the models are not highly correlated (except for the correlation of the linear herbage term with its exponential, the highest intercorrelation was 0.32, between *PPULP* and *DWSM* in the preharvest situation), suggesting that multicolinearity was not a problem. Further, plots of the residuals versus the independent variables of the models, and versus a single variable measuring stand density, indicated that heteroskedasticity was not a problem.

Because the intended use of Equation (1) was not only to obtain overall predictions of *SBE*, but also to evaluate the contributions to *SBE* of individual independent variables, effects of collinearity on model coefficients were carefully examined using the "singular-value decomposition" method of Belsley et al. (1980). With the exception of the coefficients for *HERB* and $HERB^{0.75}$, which are obviously related and must be combined to indicate the contribution of herbage to *SBE*, no indication of degrading collinearity was found. To the contrary, decomposition of the variance of the individual coefficients of Equation (1) showed that, with the herbage exception just mentioned, the coefficients are each almost wholly determined by one unique variable. Thus, Equation (1) was assumed to be sufficiently orthogonal to allow examination and use of the individual model coefficients.

In relation to harvest activities, Equation (3) predicts relative scenic beauty for those few years following a partial harvest when the signs of the harvest, including slash, are still obvious. Correspondingly, Equations (1) and (2) predict the relative scenic beauty several years following harvest, when the scars of harvest have largely healed.

In all three models, scenic beauty increases with increases in herbage and with decreases in pine saplings and small-diameter downed wood. The importance of small-diameter downed wood in the postharvest model apparently derives from its high visibility when suspended above the ground on larger diameter fallen branches. Postharvest scenic beauty is also sensitive to the percentage of downed wood that is slash. In the preharvest models, where the downed wood tends not to be suspended, small-diameter downed wood generally indicates the presence of litter, and the natural downed wood/slash distinction is not important. Preharvest *SBE* is also increased by increases in large pine trees and decreases in pulp-sized pine and large downed wood. These relationships agree with the simple correlations between *SBE* and the predictor variables.

How does one interpret an *SBE* scale? For example, how good is an improvment of 29 *SBE* units? One aid to interpretation is the range in *SBE* for a relevant geographical area (the range for the sample is given in Table 1). Comparing the 29 *SBE* unit change to such a range, and noting where along the range the change occurred, would be of some help. And, the range might be accompanied by a set of photos showing typical scenes for each of several intervals along the range, such as those presented in Brown and Daniel (1984). More useful than a simple range would be a distribution of *SBE*s for a relevant geographical area. The sample from which the distribution were developed might reflect random sampling from anywhere in the geographical area, or a stratified sample based on the likelihood that sections of the geographical area would be visited. Then a change in *SBE* could be interpreted as a change from one percentile to another along the distribution.

Application of the scenic beauty models is limited by four concerns. First, the models ignore the effect of time on scenic beauty.[2] Second, the "by-slide" *SBE* procedure gives group *SBE*s, and thus the models do not provide information about individual observer differences. Third, the scenic beauty judgments were obtained without reference to any specific activity, such as camping or sightseeing. Respondents were simply asked to rate the scenes for scenic beauty, without mention of recreation activities. If participation in some activities affects scenic beauty judgments (a possibility that was not investigated), the applicability of the models may be limited.

The fourth limitation is that the area of application of the models must be represented by the data from which the models were developed. This is, of course, a limitation of any empirical model. However, in this case the limitation includes two concerns that are not important for all empirical models. First, the spatial distribution of the independent variables is important. For example, the models are limited to use in predicting *SBE* for the types of uneven-aged stands encountered in the sample. Even-aged stands, some of which could be described by the same variables as those in the models, cannot be properly represented by the models.

The second concern is that the mixture of scenes of different types included in the set of rated scenes is important. Mixtures may vary, for example, in terms of the proportion of the scenes that depict recent harvest effects, or in terms of the distribution of overstory density depicted. If, as recent research indicates, the rating of a given scene depends in part on the other scenes rated in a slide presentation, a model does not apply to mixes of scenes that differ markedly from the one upon which the model was

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[2] With time, both the scene and the viewer, the latter perhaps via familiarity with the scene, may change. Empirical scenic beauty models have so far ignored the dynamics of scenic beauty, in part because there is some evidence that time is not a major concern. Wade (1983) found that viewing time of slides did not significantly affect viewer preference. Furthermore, Daniel and Boster (1976) and Buhyoff et al. (1982) suggest that most public groups agree closely in their scenic preferences even though they differ in their familiarity with given types of landscapes, and Hull and Buhyoff (1986) indicate that individuals' scenic preferences change very little over time. However, additional research is needed on the time element in scenic beauty production.

based.[3] The models presented above represent two distinct scene mixtures. One included only preharvest scenes, while the other included mainly recently harvested scenes. Separate models were developed because the slides, for logistical reasons, had been rated in the two distinct mixtures, and because some variables, such as described above for small-diameter downed wood (*DWSM*), do not necessarily represent the same visual effect in the preharvest and postharvest conditions. The models are appropriately used only when generalized to their respective scene mixtures.

Cost of Scenic Beauty

Models like those presented above, describing scenic beauty in terms of manageable scene features, can be used to examine the cost of scenic beauty. There are two basic possibilities. First, if a feature has a positive coefficient, its removal, all else equal, lowers scenic beauty. For such a feature, the cost of maintaining scenic beauty equals the foregone off-site economic value less its removal (e.g., harvest) cost. Large commercial trees are an example where this cost is often positive. Second, if a feature has a negative coefficient, its removal, all else equal, enhances scenic beauty. For such a feature, the cost of enhancing scenic beauty equals the removal cost less any off-site economic value. Slash is an example where this cost is positive. Of course, where this cost is negative, such as it may be for pulp-sized trees, there is no tradeoff, as it is possible to enhance scenic beauty and reap income from harvest.

The scenic beauty models are static models, giving *SBE* for distinct combinations of scene variables. They can easily be used to compare the effect of discrete forest conditions, such as alternative downed wood volumes, on *SBE*. Such comparisons may be of practical importance in decision making, but most forest management decisions have long-range implications and require explicit consideration of forest dynamics. Coupling the scenic beauty models with models of forest growth, for example, allows comparison of alternative overstory stocking levels for a selective harvest system, in terms of scenic quality and of timber harvest. Two examples of use of the scenic beauty models to estimate costs of providing scenic beauty are presented here. The first example compares discrete forest conditions and examines the costs of substitutable inputs in the production of scenic beauty. The second example compares management regimes of different stocking levels and examines the cost of scenic beauty in terms of management inputs and foregone outputs. Both examples are for forest conditions that were represented in the data set upon which the scenic beauty models were based.

HERBAGE, LARGE PINE, AND SCENIC BEAUTY

Both herbage (*HERB*) and large pine (*PPLG*) contribute to increased scenic beauty, but compete for space, nutrients, light, and moisture. Borrowing methodology from the theory of the firm in neoclassical economics, Figure 1 shows isoquants, based on the preharvest model [Equation (1)], expressing the substitution of herbage for large pine, and vice versa, for realistic combinations of site characteristics.[4] Other variables in the model are fixed at quantities representing a site of medium overstory density and downed wood volume (see note to Figure 1).

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[3] Manuscript by T. C. Brown and T. C. Daniel, "Context Effects in Perceived Environmental Quality Assessment: Scene Selection and Landscape Quality Ratings."

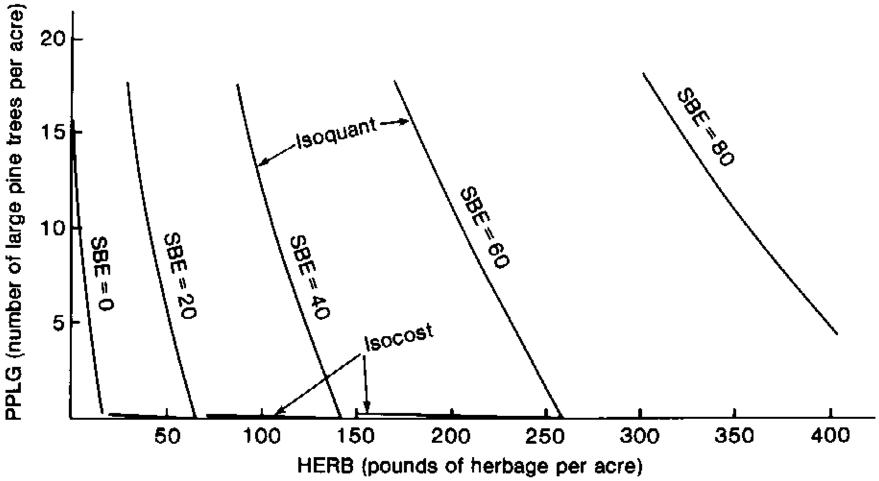

FIGURE 1. Production and cost of scenic beauty given alternative combinations of large ponderosa pine (*PPLG*) and herbage (*HERB*).

Isoquants are based on the preharvest scenic beauty model [Equation (1)]. They assume 110 *PPSAP*, 80 *PPMED*, 6 *DWSM*, and 600 *DWLG*, and are limited to herbage amounts obtainable on a site with 27 in. of annual precipitation, 6 in. of volcanic-derived soil above clay, and an average temperature of 47°F (see Clary). Overstory density ranges from 55 to 85 ft^2 of basal area as *PPLG* increase in number from 0 to 17.

Isocost curves assume 1300 bd ft per *PPLG* with a value of $100 per mbf (Brown 1982), 0.65 pound of forage per pound of herbage, 750 pounds of forage per *AUM*, and a value of $2 per *AUM*.

Because of the lack of interaction terms in the model, the curves would have the same shape, but different *SBE* values, for each herbage and large pine combination if other quantities of the fixed variables were assumed. Because of the decreasing marginal contribution of *HERB* to *SBE*, the model is nonhomogeneous, and the isoquants in Figure 1 are (1) slightly convex to the origin, indicating a diminishing marginal rate of technical substitution or *RTS*;[5] (2) further apart as *SBE* increases (i.e., there are decreasing returns as more *HERB* is added); and (3) flatter as *SBE* increases. At an *SBE* of 0, 1 pound of herbage can be traded for about 1 large pine tree ($RTS \simeq 1.0$), while at an *SBE* of 80, about 7.5 pounds can be traded per large pine tree ($RTS \simeq 0.13$).

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[4] The data set from which the preharvest model was developed contained sites with no large pine (*PPLG*) and 1 pound of herbage per acre (*HERB*). Numbers of large pine are limited in Figure 1 to 17, the maximum for *PPLG* in the data set from which the preharvest model was developed. Although several sites of much heavier herbage quantities were included in the data set, *HERB* is limited in Figure 1 to 400 lb/ac, the maximum potential herbage that would be found at an average northern Arizona ponderosa pine site on volcanic-derived soils with medium overstory density.

[5] The *RTS* is the negative of the slope of an isoquant (Henderson and Quandt 1980). The diminishing *RTS* of Figure 1 indicates that, at a given scenic beauty level, the number of large pine trees that can be given up as additional units of herbage are available drops as more herbage is substituted for large pine.

While large pine and herbage contribute to scenic beauty, the trees could be harvested for lumber, and the herbage could be grazed by livestock (wildlife grazing is ignored in this analysis). Thus, opportunities are foregone when large pine and herbage are left on site. The opportunities foregone by leaving large pine trees or herbage on site are depicted by isocost curves in Figure 1.[6] The isocost curves assume that one large pine tree yields 1.3 mbf at harvest, that 65% of the herbage is forage palatable to livestock, that all forage is consumed by beef cattle, and that 750 pounds of forage produce one animal unit month (*AUM*). Assuming 1977 values of $100 per mbf of stumpage and $2 per *AUM* (Brown 1982), and assuming that herbage can be harvested forever, with returns discounted at 4%, one harvested large pine tree is equivalent in monetary value to 3,000 pounds of herbage per year consumed by livestock.[7] Given this situation, the isocost curves are nearly parallel to the horizontal axis.

The situation is essentially the same even if a much higher herbage value of $10 per *AUM* (Gee 1981) is used along with a much lower stumpage value of $25 per mbf (timber values have fallen considerably since 1977). Here one large pine tree is worth as much as 150 pounds of annual available herbage, but the isocost curves would still be nearly horizontal in Figure 1.

Tangency of isocost and isoquant curves indicates, from an economic efficiency standpoint, the least cost resource allocations to maintain specified levels of output. The isocost curves of Figure 1 are flatter than any of the isoquants, yielding a corner solution on the herbage axis. Thus, a given level of scenic beauty is more efficiently produced by substituting herbage for large pine, which implies a strategy of harvesting the large trees and restricting grazing.

The analysis depicted in Figure 1 provides specific management guidance where output of scenic beauty is of interest, but not without numerous underlying assumptions, including (1) that Equation (1) accurately depicts the relationship of *SBE* to scene features (this assumption, of course, does not hold during the period just following selective harvest, when harvest effects such as slash are obvious); (2) that the economic efficiency framework accurately reflects management objectives, and thus, for example, that the equity consequences of the suggested reallocations are inconsequential or not important [see McKean (1958), Mishan (1976), and Randall (1981), for more on the assumptions of the economic efficiency paradigm]; and (3) that herbage and large pine are important only for production of scenic beauty, lumber, and livestock grazing, and thus, for example, that wildlife grazing is unimportant.

Figure 1 depicts a static analysis in that (1) quantities of all other inputs are held constant and (2) interactions between large pine and herbage, such as the effect on herbage quantity of removing large pine, are ignored. However, removing these limitations appears to have little effect on the principal

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[6] Controlled before-and-after experiments of the effect of timber harvest on "preharvest" (i.e., once the visual impacts of harvest are no longer obvious) scenic beauty or of grazing on scenic beauty have not been carried out. The isocost curves are entered in Figure 1 under the assumption that the effects of harvest and grazing on scenic beauty are captured by changes in numbers of trees and herbage weight, respectively.

[7] Assuming perpetual returns from grazing technically expands the analysis beyond the short run. If some shorter time period for grazing returns were assumed, the slope of the isocost curves would be even flatter, and the conclusion would therefore remain the same.

conclusion of Figure 1. First, allowing quantities of other inputs, such as number of saplings (*PPSAP*), to vary would affect the *SBE* values of Figure 1, but it would not affect the corner solution along the horizontal axis. Even if the figure were based on Equation (2), which includes interaction terms, the conclusion would hold, although herbage would contribute less the more saplings there were. Second, considering interactions between large pine and herbage appears to reinforce the conclusion drawn from Figure 1. In the near term, removing large trees would tend to increase herbage production by removing competition for light, moisture, and nutrients.[8] Because this additional herbage could be grazed, the net effect of the herbage response would be to increase the cost of leaving large pine on the site, and thus to flatten the slope of the isocost line in Figure 1. In the longer term, removing large trees might increase the timber growth rate, which would lower herbage production but also enhance harvest opportunities, all else equal. Detailed simulation would be needed to determine the relative weight of these two effects, but the net effect is likely to further flatten the slope of the isocost line. Thus, it appears that a corner colution would also result if Figure 1 reflected a dynamic comparison of large pine and herbage inputs to scenic beauty production.

STOCKING LEVELS OF AN ALL-AGED STAND

The choice of overstory stocking level is a major multiresource decision for all-aged management. As an example of relevant input to this decision where scenic beauty is important, scenic beauty, timber, downed wood, herbage, and water yields, and associated management costs, were estimated for a typical northern Arizona ponderosa pine site with an all-aged stand. Quantities were estimated for each of a set of alternative stocking levels. For each alternative, the stand was, over a 120-year period, periodically thinned to the desired stocking. Furthermore, for each alternative stocking, two slash disposal levels were evaluated. Average scenic beauty was then compared with the net monetary value of the yields and costs at each stocking and slash disposal level. A site of site index 75 (Minor 1984) was chosen, with an average annual temperature of 47°F and average annual precipitation of 27 in. The stand structure was defined in terms of di Liocourt's rule, $X_{d-1} = QX_d$ for $d = 1, \ldots, m$, where X_d is the number of trees in 1-in. diameter class d, m is the maximum diameter class (43 in. dbh), and Q is 1.217.

Following common practice, harvests were assumed to take place every 20 years, beginning in year 1. Each harvest returned the stand to a specified stocking level and all-aged stand structure. The conditions of the original stands before harvest in year 1 reflected harvest to the desired level 20 years earlier. Scenic beauty was estimated by the postharvest model [Equation (3)] for the first 10 years following a harvest and by the preharvest model [Equation (1)] for the second 10 years following a harvest.[9] As is common

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[8] The herbage response to overstory reduction is well documented (e.g., Jameson 1967, Clary 1975), and also suggested by the data used to develop the preharvest model (on preharvest sites *HERB* correlated -0.23 with overstory basal area). However, it should be noted that *PPLG* and *HERB* were not strongly correlated (the correlation for preharvest sites was 0.09).

[9] The assignment of the postharvest model to the first 10 years following harvest was based on the author's judgment and one unpublished study for a ponderosa pine area similar to the one sampled for this study. Followup postharvest inventories, now in progress, should improve understanding of the harvest recovery process.

for Southwestern ponderosa pine, logs of from 5 to 12 in. dbh were considered pulpwood, and larger logs were sawtimber. The maximum tree size was limited via harvest to 43 in. dbh.

Timber, herbage, water, and downed wood quantities, and scenic beauty levels, were simulated using individual resource models linked via a computer simulation package (Rogers et al. 1984). Timber yields were calculated based on a calibration for Coconino National Forest conditions of a model developed by Belcher et al. (1983), with volume equations from Hann and Bare (1978). Downed wood quantities were estimated from Brown et al. (1977), Brown (1978), and Puckett et al. (1979). Herbage yields were calculated using Clary's (1978) equation and assuming that cattle eat 30% of the available herbage. Water yields were calculated using the Baker-Kovner equation assuming that 90% of the runoff differences reach points of use downstream (Brown et al. 1974). Predicted timber, livestock grazing, and water yields for alternative stocking levels are listed in Table 2.

Timber, grazing, and water yields were assigned monetary values, as were management costs. The following benefit estimates (1977 dollars) were taken from Brown (1982): \$100 per mbf of sawtimber, \$6 per cord of pulpwood, \$2 per *AUM*, and \$24 per ac-ft. The real values of lumber yields were assumed to increase in the future as they have in the past, at about 2% per year. Real livestock forage values were assumed to remain constant (Manthy 1978). The following cost estimates (1977 dollars) were obtained from USDA Forest Service records and Turner and Larson (1974): timber sale preparation at \$5 per acre, sale administration at \$4 per acre, road construction and maintenance at \$14.50 per acre, precommercial thinning at \$1.38 per square foot of basal area removed, and slash pile burning cost at \$3.40 per acre. Slash piling cost was estimated at \$8 per acre plus \$0.50 per square foot of basal area removed per acre. All costs and returns were discounted at 4% to give a net present worth for those costs and returns for each overstory stocking and slash disposal level.

Feasible combinations of scenic beauty and net present worth are depicted for the various stocking and two slash disposal levels in Figure 2. Both curves of Figure 2 show a loss in scenic beauty and gain in net present worth as stocking level increases to about 120 ft^2 of basal area. The benefit from increasing timber yield outweighs the loss in benefit from declining

TABLE 2. An example of average annual per acre stocking levels and yields for an all-aged ponderosa pine site.[a]

Stocking (ft^2 of basal area)	Timber (bd ft[b])	Timber (cd)	Livestock grazing (*AUMs*)	Runoff (ac-in.)
39	113	0.089	0.098	4.40
61	175	0.124	0.073	4.01
84	222	0.176	0.059	3.80
106	249	0.206	0.052	3.73
123	257	0.210	0.048	3.72
145	264	0.153	0.047	3.72
160	254	0.132	0.045	3.72

[a] These data accompany Figure 2.

[b] Alexander and Edminster (1980) also show bd ft volume increment leveling off at about 140 ft^2 of basal area for a southwestern ponderosa pine site of site index 70. Their analysis was of an even-aged stand.

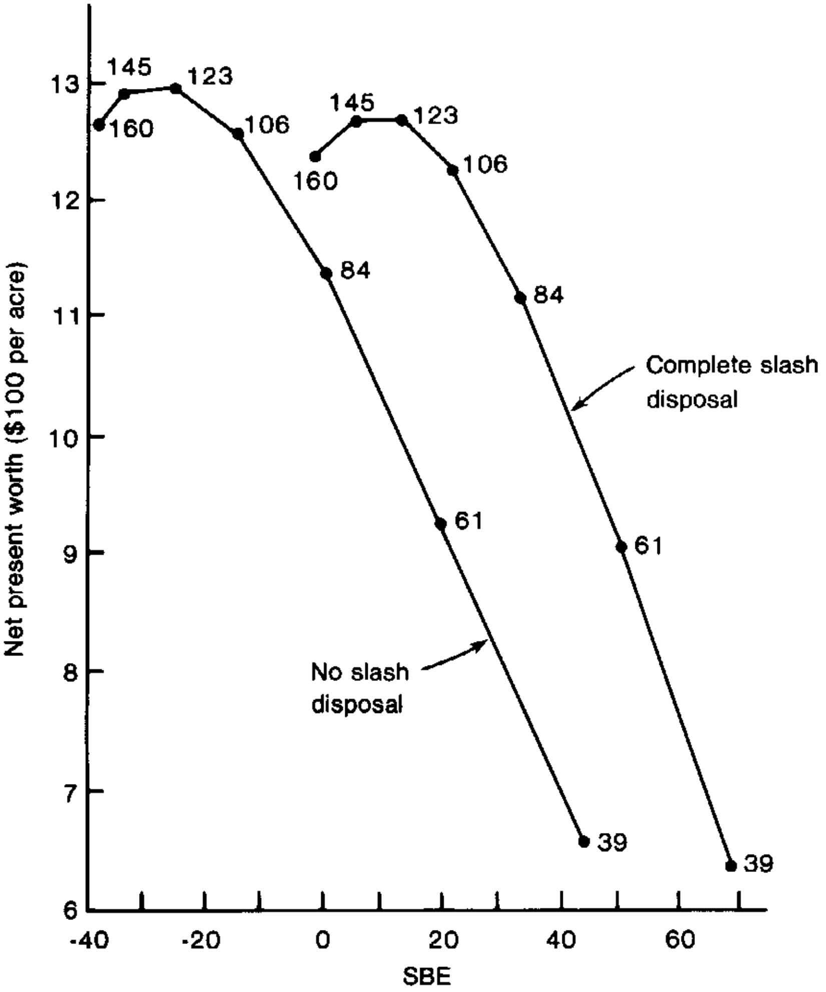

FIGURE 2. Relationship between average annual scenic beauty (*SBE*) and net present worth from timber, forage, and water yields minus management costs, for two slash removal levels and a range of stocking levels.

Numbers along curves indicate average annual stocking level in square feet of basal area per acre. Net present worth is based on a 4% discount rate.

forage and water yields as stocking increases to that level. From stocking levels of about 120 to 145 ft^2 of basal area, scenic beauty declines and net present worth levels off. Beyond about 145 ft^2 of basal area, both net present worth and scenic beauty decline.

As expected, given the negative coefficients for downed wood in the models, comparison of the two curves in Figure 2 shows that scenic beauty improves with slash disposal. At average annual stocking levels of from 39 to 160 ft^2 of basal area, scenic beauty is improved with slash disposal by from 30 to 35 *SBE* units at a cost of approximately $30 per acre in net present value. Furthermore, at stocking levels below about 106 ft^2 of basal area, increases in *SBE* or net present worth, or both, can be obtained, above the no-slash disposal option, by increasing the density level and disposing of slash. For example, at a net present value of $920 per acre, an *SBE* of 20 would be obtained without slash disposal at a stocking level of 61 ft^2/ac of basal area. At the same net present value, an *SBE* of 49 could be obtained with slash disposal if stocking were increased to about 64 ft^2/ac. At stocking levels above about 106 ft^2 of basal area, slash disposal will increase *SBE*, but only at a sacrifice in net present worth.

The slopes of the two curves in Figure 2 are similar at each basal area level. Averaging across the two slash disposal options (i.e., averaging the slopes of the two curves at each basal area level), the cost of a unit gain in *SBE* is $4.50 in net present worth as stocking level decreases from 123 to 106 ft^2 of basal area. This cost increases to $9 as stocking level decreases from 106 to 84 ft^2, and to $12 as stocking level decreases from 84 to 39 ft^2.

Use of Figure 2 to help choose stocking or slash cleanup levels is subject to the same assumptions as Figure 1, and requires three additional qualifications. The first is that it assumes that Equation (3) depicts scenic beauty during the first 10 years following a harvest, and that Equation (1) depicts scenic beauty thereafter. The second is that the figure summarizes an analysis that required the combined use of several models. While the combination is quite powerful, allowing multiresource projections, the complexity of the system of models compounds possibilities for error and difficulties of understanding the implications of the assumptions.

The third qualification concerns limits of applicability of the results. Figure 2 depicts, within the range of stocking levels represented, a clear scenic preference for less dense ponderosa pine stands. This preference reflects, to some unknown degree, the particular mix of overstory densities shown in the color slides presented to observers for scenic beauty judgments. Slides used for this study depicted the rather dense nature of the stands in the study area (pine basal area averaged 125 ft^2 before harvest), and the paucity of stands of less than about 30 ft^2 of basal area. The preference for less dense sites may not hold for a markedly different scene mixture, such as one of many sparse and few dense sites. Thus, even if scenic beauty were determined to be worth the cost shown in Figure 2, the figure does not support major reductions in density of rather dense areas. At some point, density reduction may change scene mixture so much that the scenic beauty models no longer apply to the area. However, while the scene mixture inherent in the models limits the degree of harvest of an area that Figure 2 can support, it should be mentioned that the scene mixture represents extensive areas of ponderosa pine in the Southwest.

Conclusions

Models relating scenic beauty to biophysical site features enable estimation of the cost of preserving or enhancing scenic beauty in terms of management inputs and/or foregone production of competing forest products. Such models developed from data for an Arizona ponderosa pine area indicate that a given level of scenic beauty can under certain conditions be more efficiently obtained by restricting grazing to maintain a dense herbage cover than by leaving mature harvestable trees. They also indicate that scenic beauty can always be increased with downed wood removal. Furthermore, the models indicate that scenic beauty decreases with increases in overstory stocking of all-aged stands; the increase in scenic beauty with more mature pine trees is outweighed by the decrease in scenic beauty with decreases in herbage and increases in small- and medium-sized pine trees as density increases.

Given a selective harvest system, and given the context of a rather dense forest, lower timber densities are preferred for scenic quality than those that maximize net present worth from lumber production. This remains true even when marginal values of herbage and water yields, which favor less dense stands, are also included. This is contrary to Berck's (1981) conclusion that the presence of valuable environmental services, such as pretty views, requires a greater stock than would be optimal in the absence of such services, and suggests that his conclusion may not apply to a selective harvest system.

Psychophysical scenic beauty models are well suited to quantitative estimation of the tradeoffs between scenic beauty and other forest products. Given necessary assumptions, they allow more precise evaluation of tradeoffs between scenic beauty and other forest outputs than has been possible heretofore. Furthermore, measures of the cost of providing scenic beauty could be compared with estimates of the value of scenic beauty to indicate efficient management direction. The approach outlined here should increase confidence in cost estimates. The greater the confidence in cost estimates, the less a benefit-cost difference needs to be before it lends clear support for a decision about provision of scenic beauty.

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