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Assessing Forest Scenic Beauty Impacts of Insects and Management

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Abstract

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Natural disturbances such as fire, insects, diseases, and severe weather can affect the perceived scenic beauty of forest landscapes. The impacts of disturbances may be reduced through management actions, although it is difficult to determine an appropriate level of mitigation. A better understanding of how the beauty of forests is affected by disturbance would enable more effective and efficient management of them; hence this assessment of the scientific knowledge concerning the impacts of forest insects on scenic beauty. This assessment defines management implications, including the degree to which forest insect impacts on scenic beauty may be partially mitigated through prevention of outbreaks, control of outbreaks, or other indirect methods such as stand and slash treatment.

The paper discusses relationships between scenic beauty perceptions and certain forest characteristics such as the presence and dominance of large trees, tree species composition, and stand age. Stand treatments such as burning, harvesting, treating slash, and regenerating harvested stands also affect scenic beauty. Stand treatment impacts on scenic beauty may be relatively large compared to the impacts caused by insects. A summary of scenic beauty estimation studies concerning forested landscapes is presented in tabular form as an appendix. This review is restricted to studies conducted on forests located in the U.S. about the perceptions of U.S. residents. Significant cultural differences may reduce the transferability of the studies' results to forests in other countries.

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Contents

I. Introduction

Numerous laws require implicit or explicit assessments of management impacts on all forest products and services. For example, the Multiple Use-Sustained Yield Act of 1960 and the National Environmental Policy Act of 1969 (NEPA) require consideration of all forest products in National Forest management decisions. In addition, the Forest and Rangeland Renewable Resources Planning Act of 1974 and the National Forest Management Act of 1976 specifically identify amenities, including aesthetics, wildlife, and recreation, that must be considered in a comprehensive assessment of planning and management. Public concern over these amenities of the natural environment have been expressed elsewhere such as in the Wild and Scenic Rivers Act of 1968.

These laws, however, provide no guidelines or standards to help define and measure potential trade-off impacts of management actions on forest amenities. One approach to evaluating management plans is to define alternative futures under different management scenarios. This approach often requires precision which is only available by quantifying impacts. Economics uses several methods for quantifying alternative futures to be used in economic evaluation of management plans. However, one of the amenities strongly affected by management decisions is the appearance, or visual quality, of a forest. The affect of management actions on the appearance of a forest can provide a foundation for public perceptions and approval/ disapproval of management actions (Hull 1988).

The appearance of a forest can have significant impacts on forest recreation. The President's Commission on Americans Outdoors identified natural beauty as the single most cited reason for choice of a recreation site (Market Opinion Research 1986). Sightseeing is one of the most frequent outdoor recreation activities enjoyed by most people (Cordell et al. 1990; Dwyer 1994). Also, it might be inferred that the appearance of the forest is an indicator of the quality and effectiveness of forest management.

Much research on quantifying landscape aesthetics has been undertaken over the past few decades. Zube et al. (1982) identified four different landscape perception research paradigms—expert, psychophysical, cognitive, and experiential.

- The expert paradigm “involves the evaluation of landscape quality by skilled and trained observers”.

- The psychophysical paradigm “involves assessment through testing general public or selected populations’ evaluations of landscape aesthetic qualities or of specific landscape properties”.

- The cognitive paradigm “involves a search for human meaning associated with landscapes or landscape properties”.

- The experiential paradigm "considers landscape value to be based on the experience of the human-landscape interaction, whereby both are shaping and being shaped in the interactive process" (Zube et al. 1982, p. 8).

In this paper we are concerned with the development and use of the psychophysical paradigm of landscape assessment, specifically, the Scenic Beauty Estimation (SBE) method developed by Daniel and Boster (1976).

The SBE method estimates standardized scores of preference judgments for various forest conditions exhibiting an array of visual quality levels. These scores are then statistically related to measurable forest characteristics through regression analysis. The relationship between manageable forest characteristics and perceived scenic beauty are used to predict or evaluate management alternatives for their impacts on scenic beauty.

The structure of this report is as follows. First the general results of SBE studies of forest insect impacts on perceived scenic beauty are presented. Next is a review of how management actions (stand treatments) impact public perceptions of scenic beauty. Third, the implications in managing for forest scenic beauty are reviewed, including generalized findings on the contributions of manageable forest attributes to the provision of scenic beauty. The conclusion contains a summary of results along with a discussion of implications for future research. There are two appendices. Appendix A presents, in tabular form, information on the SBE studies in this review. Appendix B discusses the use and implementation of the SBE method.

II. The Impact of Forest Insects on Perceived Scenic Beauty

Forest insects attack trees, leading to defoliation, discoloration of remaining foliage, and/or tree mortality. This can lead to, in the short term, standing defoliated trees, discolored foliage, and increased ground litter. In the long term, the effects can be standing dead trees, dead and downed trees, slash, open canopies which increase sunlight, understory growth, and/or visual penetration (reduced stand density). Not all of these impacts negatively influence scenic beauty judgments. The natural process of regeneration can lead to the mitigation of negative scenic beauty impacts over time.

Forest stand changes caused by insects can lead to preferred forest scenic qualities, such as open, parklike stands. Forest managers must trade short-term damages for long-term consequences in their decisions. Many insects are a natural and necessary part of, and play an important role in, sustained forest health (Averill et al., 1995). Introduced or exotic insects, however, may impact the natural landscape in non-historic ways, leading to devastating short-term damages. Although a forest may rebound from such damages in the long term, the magnitude of the damages and the nonnative status of the causal agent may require a different approach to mitigation of damages in the short term. Therefore, the forest manager's role in sustaining the health and beauty of a forest is not a straightforward decision; it requires many trade-offs between short-term changes and long-term consequences of natural disturbances such as pests and fires, and human-caused disturbances such as harvesting techniques, silvicultural treatments, and the treatment of slash. Additional difficulties arise when people either are unaware of the necessary trade-offs between short-term and long-term visual conditions or are unwilling to accept these trade-offs (i.e., the short-term damages seem more significant to them than the long-term benefits).

Several studies investigate the direct impact of forest insects on scenic beauty. Four studies were conducted on the direct impact of forest insects on scenic beauty, three of which were primarily concerned with the impact of beetles on coniferous forests, and the other with the impact of the gypsy moth on northern hardwood forests. Two of the studies were conducted in the West, one in the Southeast, and one in the Northeast. Table 1 lists the studies on forest insects' direct and indirect impacts on scenic beauty perceptions. No studies were found that investigated the scenic impacts of diseases and pathogens. However, general extensions of the insect results to diseases and pathogens should be relatively straightforward, since the general public may not be able to distinguish between insect and disease causal agents.

Table 1. Studies Quantifying the Impacts of Forest Insects on Scenic Beauty.

Southern Pine Beetle	Mountain Pine Beetle	Western Spruce Budworm	Gypsy Moth
Buhyoff & Leuschner (1978)	Buhyoff et al. (1982)	Buyoff et al. (1982)	Hollenhorst et al. (1993)
Buhyoff & Wellman (1980)	Hull et al. (1984)		
Buhyoff et al. (1980)	Schroeder & Daniel (1981)		
	Vining et al. (1984)		

Buhyoff and Leuschner (1978) estimated the impact of southern pine beetle on the scenic beauty of distant landscapes of an eastern coniferous forest along the Blue Ridge Parkway. This insect kills pines, often in large, contiguous patches. The effect is most visible when the needles have turned red on the dead trees. The exact impact of these beetles on the landscape was not described other than that the affected areas were concentrated as depicted in photos (presumably from group kills). This area was chosen because it best represented an intensively used (viewed) landscape in which management actions could have a substantial impact on protecting or restoring scenic beauty. Buhyoff et al. (1980) replicated the model in a later study with different observers.

Overall, this study showed beetle damage decreased the scenic beauty of the landscape. This effect was strongest up to 10 percent damage, then tapered off at a rapid rate for additional damage. The management implications are that a preventive stance would produce the greatest benefits, but that once the damage reached 10 percent, there would be little reason, from a scenic beauty standpoint, for aggressive management tactics. Other factors, however, may require aggressive management beyond this 10 percent threshold, such as increases in fire danger or concerns about providing critical habitat for threatened and endangered species.

Buhyoff et al. (1982) investigated the impact of mountain pine beetle and western spruce budworm on the scenic beauty of western coniferous (predominantly ponderosa pine) forest landscapes in the Colorado Front Range. The mountain pine beetle kills the pine trees it inhabits. Western spruce budworm defoliates conifers by eating the needles; although the trees often recover, they can die in severe outbreaks. The photo representations were of distant forest vistas with short-term insect damages such as fader (yellowish crown), black top (crown), and red top (crown) foliage discoloration. The damage was measured using a reliable damaged area identification rule as the percent of the total photo area exhibiting one or more of the above-listed damages.

They found that mid-view damages had a generally negative effect on perceived scenic beauty. Red tops in the distant view had a negative effect on scenic beauty perceptions for those observers told of its presence, but no significant impact for uninformed viewers. Overall, insect damages in the far-view had a negative effect on perceived scenic beauty. They also found level landscapes with homogeneous vegetative cover were more negatively impacted by insect damage, while perceived insect damage on landscapes with diverse forest structures and mountainous terrain had a minimal effect on scenic beauty.

Schroeder and Daniel (1981) investigated the near-view impacts of mountain pine beetle on scenic beauty judgments of western coniferous forests in the Colorado Front Range. For the in-stand analysis, the number per acre of dead ponderosa pine was used as the measure of insect damage. Other damages included defoliation and foliage discoloration. The measure of insect damage was chosen to aid the transfer of the ponderosa pine northern Arizona model to a ponderosa pine landscape in the Colorado Front Range where beetle-killed pine was visible in the latter region but not in the former. They found the inclusion of the insect damage measure accounted for approximately three percent of the 60 percent total variation explained by the scenic beauty model. This level of statistical explanatory power is consistent with the effect of a dead trees variable included in Ribe's (1990) general model for northern hardwood forests.

Hollenhorst et al. (1993) investigated the effects of gypsy moth in eastern hardwood (predominantly oak) forests on near-view scenic beauty judgments. Gypsy moth, like western spruce budworm, defoliates trees by eating leaves while in its larval stage. Trees can die from severe repeated defoliations. Their specific study area was Somerset County in southwestern Pennsylvania in the Central Appalachian Plateau. In the study area, sample plots were chosen for photographic representation, encompassing moth-caused tree mortality percentages ranging from six to 98 percent, with a mean mortality rate of 28 percent. Other damages included short-term effects of tree defoliation and nuisances such as the presence of caterpillars, leaf fragments, and frass.

They found scenic beauty actually increased with up to 30 to 40 percent tree mortality, but then rapidly dropped. This may have been the result of Eastern hardwood forests' more rapid decomposition of downed dead trees and vegetative understory regrowth. A reduction in forest density allows additional sunlight to penetrate the forest canopy, increasing understory growth such as flowering mountain laurel, and increasing visual penetration. They also estimated the impacts of damage on the likelihood of the same sample to recreate at a site similar to the one in the photos. They found that the desirability of a particular site for recreation was greatly influenced by the scenic quality of that site.

A direct comparison cannot be made across the different studies because of different observer vantage points (near-view versus far-view), and because of different forest types and geographic locations (coniferous versus deciduous, and Eastern versus Western). The Hollenhorst et al. study measures the impact of gypsy moth in the long term as tree mortality. In the moist climates of the East, the effect of slash and downed dead trees is negligible compared to the longer term impacts in the arid climates of the West, where dead timber and slash decompose more slowly. Therefore, management of these areas can be quite different. For instance, in Eastern forests, controlling moth populations may be the best management plan. In Western forests, the prevention of beetle outbreaks may produce the largest benefit, but once an outbreak exceeds 10 percent damage, intervention may not significantly contribute to perceived scenic beauty maintenance. Also, before any management decision is made, the area affected needs to be considered. The location of the area has important implications for the overall impact of insects on scenic beauty. More intensively used and viewed landscapes probably require more intensive management, since larger levels of benefits are at risk.

Forest insects and diseases can affect the perceived scenic beauty of a forest in many ways, several of which have been discussed. However, management actions can also impact scenic beauty, and these impacts may be relatively large compared to those of insects. The next section presents general findings on the impacts of different stand treatments on scenic beauty perceptions. In this way, both the direct impacts of forest insects on scenic beauty and the impacts of alternative management actions can be deduced.

III. Impacts of Stand Treatments on Scenic Beauty

Table 2 lists several studies investigating the impacts of stand treatments on scenic beauty, including burning, harvesting, slash, regeneration, and thinning. While the list is not exhaustive, it does support the general effects of these treatments on the visual quality of the stands. The general impacts of stand treatments as found in the studies of Table 2 are as follows.

Table 2. Studies Quantifying the Relationship between Scenic Beauty and Stand Treatment

Burning	Harvests	Slash	Regeneration	Thinning
Anderson et al. (1982)	Arthur (1977)	Anderson et al. (1982)	Arthur (1977)	Arthur (1977)
Patey & Evans (1979)	Benson & Ullrich (1981)	Arthur (1977)	Hull & Buhyoff (1986)	Hull et al. (1987)
Rudis et al. (1988)	Daniel & Boster (1976)	Benson & Ullrich (1981)	Rudis et al. (1988)	McCool et al. (1986)
Taylor & Daniel (1984)	Hull & Buhyoff (1986)	Brown & Daniel (1984, 1986)	Schroeder & Daniel (1981)	Patey & Evans (1979)
	McCool et al. (1986)	Daniel & Boster (1976)		Rudis et al. (1988)
	Vodak et al. (1985)	Daniel & Schroeder (1979)		Schroeder & Daniel (1981)
		Ribe (1990)		
		Ruddell et al. (1989)		
		Schroeder & Daniel (1981)		
		Vining et al. (1984)		
		Vodak et al. (1985)		

Fire damage to forest stands immediately reduces the scenic beauty of the area, the magnitude of the impact depending on the severity of the fire and the level and timing of recovery. Prescribed burns were found to negatively impact scenic beauty in the short term, but with ground vegetation recovery, prescribed burns can enhance scenic beauty after a few years. This is primarily due to the elimination of slash after harvest or increasing visual penetration through reducing understory density. More severe prescribed burns may decrease scenic beauty, since they may leave visible scars.

Harvesting probably has the greatest potential for negatively impacting scenic beauty in the short run, and may confound all other relationships between forest characteristics and scenic beauty. Uneven-aged stands have more structural diversity, thus partially mitigating the overall impacts of harvesting on scenic beauty. Clear-cutting of even-aged stands has the greatest negative impact on scenic beauty in the short run. Some shelterwood cuts reduce the overall impact of harvesting even-aged stands on scenic beauty, but are still preferred substantially to pre-harvest stands. This leads to the generalization that the more trees removed per acre, the lower the scenic quality of the stand.

Slash has a high negative impact on scenic beauty. The degree of this impact depends on the forest type, the size and amount of the slash, and the vertical height of the slash. Several management practices can significantly mitigate slash impacts on scenic beauty, including burning, removal, lopping, and chipping and spreading. In more humid climates, the presence of slash may have fairly short-term effects due to the more rapid natural decomposition of ground material.

Regeneration after stand harvest can have strong impacts on future scenic beauty. Planted stands are preferred over naturally regenerated stands. The duration of harvest activities' visual damage to a landscape depends greatly on the regenerative capabilities of specific forest types, climate, management techniques, and degree or severity of damages. Thinning of stands can both increase scenic beauty beyond that of naturally regenerated stands and decrease the duration of damages. This could be the result of increasing visual penetration through removal of understory slash and diseased or damaged trees, thus creating open parklike stands.

All of the above results and implications for insect damage control or prevention and management effects on scenic beauty are generalizations. Some of the variability among the different studies is probably due to different applications of the methodology, differences in the resources being valued, and differences in the samples.

IV. Management Implications

Table 3 lists several studies investigating the impact of management influenced stand variables on scenic beauty, including the presence of large trees, species composition of a forest, stand age, tree density, understory, and vegetative groundcover. This list is not exhaustive of studies on forest stand variables. It is only intended to provide information on what evidence has been found in this area. The presence and dominance of large trees (typically ³ 15 inches diameter at breast height1) in a forest stand has a strong, positive effect on scenic beauty. The presence of large trees is most important in stands with fewer trees per acre, and is positively correlated with stand age. Large tree size is a significant variable of scenic beauty explanation in most models, including Ribe's (1990) general model for various deciduous forest types.

[1]Diameter at breast height (dbh) is the diameter of a tree trunk measured 54 inches above the ground.

Table 3. Studies Quantifying the Impacts of Management Variables on Scenic Beauty

Presence of Large Trees	Species Composition	Stand Age	Tree Density	Understory	Vegetative Groundcover
Arthur (1977)	Brown & Daniel (1984)	Brown & Daniel (1984)	Arthur (1977)	Hollenhorst et al. (1993)	Arthur (1977)
Brown & Daniel (1984, 1986)	Daniel & Schroeder (1979)	Buhyoff et al. (1986)	Brown & Daniel (1984, 1986)	Hull et al. (1987)	Brown & Daniel (1984, 1986)
Buhyoff et al. (1986)	Ribe (1990)	Daniel & Boster (1976)	Buhyoff et al. (1982)	Patey & Evans (1979)	Daniel & Boster (1976)
Daniel & Boster (1976)	Schroeder & Daniel (1981)	Hollenhorst et al. (1993)	Buhyoff et al. (1986)	Ruddell et al. (1989)	Daniel & Schroeder (1979)
Daniel & Schroeder (1979)		Hull & Buyoff (1986)	Hollenhorst et al. (1993)	Rudis et al. (1988)	Hull et al. (1987)
Hull & Buhyoff (1986)		Hull et al. (1987)	Hull & Buyoff (1986)	Schroeder & Daniel (1981)	Ribe (1990)
Ribe (1990)		Shcroeder & Daniel (1981)	Ribe (1990)		Schroeder & Daneil (1981)
Ruddell et al. (1989)			Ruddell et al. (1989)		
Rudis et al. (1988)			Rudis et al. (1988)		
Schroeder & Daniel (1981)			Schroeder & Daniel (1981)		
Vodak et al. (1985)			Vodak et al. (1985)		

Species composition, the mix of dominant tree species with nondominant species, has a strong, positive effect on perceived scenic beauty. Several studies on ponderosa pine forests show improved scenic beauty when other species are present, including oaks, junipers, aspen, birch, and firs. The presence of flowering mountain laurel has a strong positive effect on scenic beauty of Northern hardwood forests. Species composition is also positive and significant in Ribe's (1990) general model, where white-barked birch and aspen added to perceived beauty in hardwood forests.

Stand age has a strong, positive effect on perceived scenic beauty. This is evident from and consistent with the positive effect of large trees, and the negative effect of dense, small trees (saplings and young poles) on scenic beauty. In some cases mature, even-aged stands are preferred over uneven-aged stands. However, in other cases vertical diversity in stands is preferred over homogeneous stands.

Tree density effects on scenic beauty are found to be more problematic in their modeling. For instance, the density of saplings has a negative effect, while with large trees, as tree density increases per acre, the effect grows more positive. Several studies adopt the use of a quadratic specification of this variable, allowing for too many or too few trees per acre, where an optimal density is identified. Any change from this optimal density results in a decrease in perceived scenic beauty. A more open and parklike stand is preferred over dense forest stands, whether the stand contains saplings and young trees or large trees. Forest density in the quadratic form noted above is also a strong indicator of scenic beauty in Ribe's (1990) general model.

Understory, including seedlings and shrubs, has a varied impact on perceived scenic beauty of forest stands. It has a negative effect on scenic beauty by reducing visual penetration, as would be expected when open, parklike stands are preferred. However, understory and the diversity of the understory improves the scenic beauty of Western forests. In several studies, understory is not significant in explaining scenic beauty.

Vegetative groundcover (grasses, forbs, and seedlings) has a positive effect on scenic beauty, especially in Western forests. Typically, the benefits of groundcover for scenic beauty are greatest with the first few increments of groundcover, with additional increments exhibiting diminishing marginal benefits. In Western forests, groundcover in open, parklike stands results in above-average scenic beauty. This variable also is significant in explaining scenic beauty in Ribe's (1990) general model.

All of the above relationships between perceived scenic beauty of forest stands and the forest stand variables have implications for forest management. Selective cutting would be preferred over clear-cutting, while use of herbicides would have different effects depending on the context of the application. Longer rotation periods would result in a greater flow of scenic beauty benefits.

The challenge of managing stands for desirable scenic beauty characteristics is, of course, that what looks good now may be at high risk for change in the future. In general, the types of characteristics preferred by those in the studies are not those which create a high risk for catastrophic change by fire or insects.

Decisions concerning the efficient provision of scenic beauty should take into account the costs of the provision. Different treatments may result in the same level of benefits but have different costs associated with them. One objective in forest management may be to maximize net benefits (total benefits less total costs) from a forest stand that includes multiple uses such as harvesting, recreation, and scenic quality. Another objective in forest management may be to minimize costs of specific production levels of one or more products or services from a forest. Scenic quality may be one of these products. The Scenic Beauty Estimation method is one way to quantify scenic quality of a landscape in order to compare the marginal costs of provision of scenic beauty with the marginal benefits derived from an incremental increase in management for scenic beauty. It also allows for trade-off identification with other forest products and services.

V. Discussion and Conclusions

The Scenic Beauty Estimation (SBE) method is a psychophysical approach to quantitatively measuring the scenic beauty, or visual quality, of landscapes. The SBE method conceptualizes the relationship between the observer and the landscape as interactive (for instance, beauty is neither solely "in the eye of the beholder" nor a property of the landscape). The SBE method uses both landscape properties and standardized observer ratings to determine quality scores. The estimation and subsequent predictive abilities of the method allows forest managers to gain an understanding of how their actions affect scenic beauty. From this knowledge, managers can design forest plans that are sensitive to jointly produced scenic beauty and secondary services (for example, increased recreational quality, improved property values) of forests.

The consistent application of research methods has been identified as an important responsibility of scenic beauty researchers. Comparisons of research results from different studies are difficult enough without compounding the problem with increased diversity of application. The fragmentation of studies limits the usefulness of the studies and makes application of the findings virtually nontransferable to other sites. Ribe (1990) identified the need for a generally valid model that exhibits greater applicability across different forests, potentially reducing time and effort requirements for future applications of the method by managers. An additional concern is the effect of different contexts on observer-judged scenic beauty. Different contexts surrounding the judgments can further compound the difficulties of information transfer and application of past research results to other areas and disturbance agents.

As is evident from the discussion of the impacts of forest insects on scenic beauty, these impacts have strong management implications. The prescription from the research is that forest scenic beauty of the interior West is affected for a longer period of time, due primarily to the relatively slow natural regeneration of the forests. The same impact in Eastern forests will probably be of a shorter duration because of the humid climate and the relatively more rapid regenerative abilities of these forests.

Three main factors that can affect scenic beauty include temporal, spatial, and structural components of forest dynamics. Forests are ever-changing products of natural processes that can be resilient to natural disturbances and human actions. Impacts on forest scenic beauty that are substantially negative in the short term, often can be naturally mitigated over time. Hull and Buhyoff (1986) develop the Scenic Beauty Temporal Distribution method that simulates and evaluates scenic beauty through time. Dynamic, or temporal, models are useful tools that provide valuable information to decision makers. The temporal span can cover the length of a management action, such as a harvest rotation period. It can also provide additional information on the implications of possible exchanges of scenic beauty for economic efficiency in stand rotations, including replanting of harvested sites, silvicultural treatments during stand regrowth such as thinning, and length of rotation. Ribe (1991) investigated the flow of scenic beauty over time for even-aged versus uneven-aged management of northern hardwood forests, finding uneven-aged management produces higher long-term scenic beauty values than even-aged management; and that naturally regenerated old-growth hardwood forests (>200 years.) in uneven-aged management produced the highest value of scenic beauty while clear-cutting in even-aged management produced the lowest scenic beauty value. These results may not transfer to different biological situations.

Spatial factors may slightly mitigate perceived scenic beauty impacts. For example, because Eastern deciduous forests are significantly different from Western coniferous forests the same level of disturbance results in vastly different impacts on scenic beauty. Also, structural components of landscapes such as the presence of mountains or water (lakes, rivers), forest type, and human structures (such as homes and developed recreation facilities), affect judgments of scenic beauty. Future research on the scenic beauty of natural landscapes needs to be concerned with these issues. A dynamic approach to forest scenic management is important. Visual, vegetation, and stand management systems are evolving in this direction.

Further standardization of the SBE method is needed before comparability of the models and their results can become a widely useful tool. Individuals involved in planning, management, and policy can greatly benefit from the information gained from SBE studies, which allows easier identification of the trade-offs and value conflicts in management alternatives. Knowledge of the scenic consequences of policies, along with other consequences of management decisions and actions, is valuable to the decision maker. Models need to be in a format that decision makers, managers, and stakeholders can readily use to compare management options so that they can make relevant trade-offs (see, for example, Orland 1994). The results from such models may be used for conflict resolution, decision making, and the development of new policy and regulation. Additionally, the results may provide an invaluable method for attaining public involvement, extension, and education activities. Many advances have been made toward attaining these goals (Daniel et al. 1992; Orland and LaFontaine 1991; Orland et al. 1993).

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Appendix A: Scenic Beauty Estimation Studies

Table A1. Scenic Beauty Estimation Studies

Researchers	Observer Group	Location	Forest Type	Visual Impact Agent	Visual Range	Key Point(s)
Anderson 1981	Psychology students	Northern Arizona	Conifer-ous	Labels: land use designations	Mid to far	Labels have significant impact.
Anderson et al. 1982	College students	Northern Arizona	Conifer-ous	Fire	Near	Estimates prescribed burning impacts.
Arthur 1977	Students; Forest Service landscape architects; residents	Northern Arizona	Conifer-ous	Manage-ment	Near	Develops 3 models—physical features, timber cruise, and design inventory—in which the timber cruise model is the most efficient predictive model.
Benson & Ullrich 1981	Students, teachers, research-ers	Montana, Idaho	Conifer-ous	Harvesting, season, time, roads, & trails	Near to mid	Natural and orderly scenes preferred; time improves scenic beauty.
Brown 1987	Student, church, civic	Northern Arizona	Conifer-ous	Harvest	Near	Estimates cost of scenic beauty.
Brown & Daniel 1984	Student, church, civic	Northern Arizona	Conifer-ous	Harvest	Near	Derives management implications.
Brown & Daniel 1986	Student, church, civic	Northern Arizona	Conifer-ous	Pre-harvest	Near	Cross-validation experiments, consistency across observer groups.
Brown & Daniel 1987	Students	Northern Arizona	Conifer-ous	Context effects: harvest	Near	Context has significant impact on SB judgements.
Brown et al. 1988	Onsite campers	Northern Arizona, camp-grounds	Conifer-ous	Direct vs. photo-based evaluations	Near	Onsite direct judgments of SB (and WTP) are higher than photo-based judgments.
Brown et al. 1990	Campers	Northern Arizona, developed campsites	Conifer-ous	Forest characteris-tics	Near	SBE and recreation value judgments are nearly identical.

Table A1. Scenic Beauty Estimation Studies (continued)

Researchers	Observer Group	Location	Forest Type	Visual Impact Agent	Visual Range	Key Point(s)
Buhyoff & Leuschner 1978	Students, foresters, nonforest- ers	Blue Ridge Parkway	Decidu- ous	Southern pine beetle	Mid to far	Paired comparisons; largest impact up to 10% damage; knowledge of pest damage decreases judgments; consistency across observer groups.
Buhyoff & Wellman 1980	Students	Blue Ridge Parkway	Decidu- ous	Southern pine beetle, snow, and mountains	Far	Law of Comparative Judgments. Includes three studies. Tests with and without pest information groupings. Discovers a comprehensive logarithmic stimulus- response function.
Buhyoff et al. 1980	Students	Blue Ridge Parkway	Decidu- ous	Southern pine beetle	Mid to far	Paired comparisons; finds Buhyoff & Leuschner 1978 is reliable and predictively valid.
Buhyoff et al. 1982	Students, church, PTA	Colorado Front Range	Conifer- ous	Mountain pine beetle, western spruce budworm	Far	No difference between observer group judgments; SBE and LCY yield similar metrics; information on pest damage impacts SB judgments.
Buhyoff et al. 1986	Students	North Carolina Piedmont	Conifer- ous	Forest conditions	Near	Evaluates SB of current and future forest stands by age class.
Daniel & Boster 1976	26 public groups; 6 categories	Northern Arizona	Conifer- ous	Harvest manage- ment	Near to mid	Similarities and differences across observer groups; photo validity.
Daniel & Schroeder 1979	Unidenti- fied	Northern Arizona	Conifer- ous	Forest composition and condition	Near	Identifies limitations of model.
Daniel et al. 1977	Students	Northern Arizona	Conifer- ous	Manage- ment	Near to mid	Describes development of SBE mapping technology.

Table A1. Scenic Beauty Estimation Studies (continued)

Researchers	Observer Group	Location	Forest Type	Visual Impact Agent	Visual Range	Key Point(s)
Daniel et al. 1989	Campers	Northern Arizona, camp-grounds	Conifer-ous	Management	Near	Comparison of WTP and SBE results in a strong linear relationship.
Hollenhorst et al. 1993	3 interest groups: preserva-tion, utilization, neutral	Central Appalachi-an Plateau	Decidu-ous	Gypsy moth	Near	Information on insect damage has minimal effect; SB estimates increase up to 30-40% damage; SBE and recreation value judgments are nearly identical.
Hull & Buhyoff 1986	Students	Virginia Piedmont and Coastal Plain; North Carolina Coastal Plain	Conifer-ous	Management	Near	Development of Scenic Beauty Temporal Distribution model to track SBEs across planning horizon. Identifies strengths and weaknesses.
Hull et al. 1984	Student, church, PTA	Colorado Front Range	Conifer-ous	Mountain pine beetle	Far	Finds SBE and Law of Comparative Judgment methods' results are similar. Tests for convergence validity.
Hull et al. 1987	Students	Virginia Piedmont and Coastal Plain; North Carolina Coastal Plain	Conifer-ous	Roadside stands	Near	Tests alternative functional forms; importance of documentation of empirical studies.
Hull & Stewart 1992`	Onsite hikers, up-and downhill; students	Colorado's White River NF trail	Conifer-ous	Context effects	Near to far	Investigates context effects on SB judgments; finds photo-based judgments may not be valid.

Table A1. Scenic Beauty Estimation Studies (continued)

Researchers	Observer Group	Location	Forest Type	Visual Impact Agent	Visual Range	Key Point(s)
McCool et al. 1986	18 professional and public-interest groups in western Montana	Montana and northern Idaho	Coniferous	USDA Forest Service Visual Management System Visual Quality Objective classifications	Mid	All groups have similar rank orderings but different absolute preference range.
Patey & Evans 1979	Eastern Tennessee residents	Eastern Tennessee	Deciduous /coniferous	Management	Near	Respondents prefer forest landscape to be open and parklike with low understory shrub density.
Ribe 1990	12 professional and public-interest groups in southern Wisconsin	Northern Wisconsin	Deciduous	Management	Near	Develops a regionally valid model for northern deciduous forests; extends knowledge toward more generally valid model for all forests.
Richards et al. 1990	Campers	Northern Arizona campgrounds	Coniferous	Management	Near	Finds photo-based WTP and onsite WTP are uncorrelated.
Ruddell et al. 1989	Students	Eastern Texas	Coniferous	Management	Near	Provides theoretical content by combining psychophysical and psychological methods through a visual penetration variable in the model. Visual penetration is important for SB valuations.

Table A1. Scenic Beauty Estimation Studies (continued)

Researchers	Observer Group	Location	Forest Type	Visual Impact Agent	Visual Range	Key Point(s)
Rudis et al. 1998	Students	Eastern Texas	Conifer-ous	Manage-ment	Near	Applications of timber management practices. Tests inter-seasonal differences.
Schroeder & Daniel 1980	Students	Northern Arizona	Conifer-ous	Road corridors	Near to mid	Use of SBE data for road corridor selection.
Taylor & Daniel 1984, 1985	Church, civic clubs, parent organiza-tions	Western United States	Conifer-ous	Fire (light vs. severe)	Near	Camping is impacted the most by all fires; SB judgments are negatively impacted by fire, but light burns improved SB.
Vining et al. 1984	Students	Colorado Front Range	Conifer-ous	Residential develop-ment; mountain pine beetle	Near to far	Develops a scenic quality prediction model for forested residential sites, distant views, and pine beetle infestations.
Vodak et al. 1985	Students, private land-owners	Western Virginia	Decidu-ous	Manage-ment	Near	Finds no forest management bias in a student panel divided into groups with and without information on harvesting practices. Discusses temporary negative impact of dead and downed wood in humid climates.

Appendix B
The Psychophysical Approach: The Scenic Beauty Estimation Method

A. The Psychophysical Approach

The Scenic Beauty Estimation (SBE) method arose out of the need to define and measure meaningful indicators of public preferences for forest landscape visual quality to be used in comprehensive forest planning and management (Daniel and Boster 1976). Daniel and Boster identify three main reasons for measuring relative visual preferences for forest landscapes: 1) "better integration with other resources and products"; 2) "better justification for land use decisions"; and 3) "restoration of the client-architect relationship" (p. 3). Because of the complexity of managing public lands, there is a need for a systematic method of assessing forest plans that integrates both commodity and amenity products and services. The quantification of management impacts on these products and services provides information on which the public land manager can base actions. The most direct and immediate source of information for the public regarding management actions is visual. Visual information is a major factor in public assessment of management actions (Hull 1988).

"Scenic beauty" is recommended as the term that best captures the meaning of a visually appreciated resource (Daniel and Boster 1976). Scenic beauty refers to the scenic, visual, or landscape quality, or the natural beauty of a landscape.

The conceptualization of scenic beauty in the psychophysical approach is that "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" (Brown and Daniel 1984, p. 2). Physical features of a landscape are assumed to have a stimulus-response relationship to the observer's evaluations of scenic beauty and behavior (Zube et al. 1982). This concept may be compared to the cognitive approach, wherein the information received from the landscape is assigned meaning by the observer conditional on the observer's experiences, knowledge about the environment, and expectations. In other words, the observer assigns meaning to the assessment of scenic beauty.

The cognitive approach, therefore, is an attempt to develop a psychological theory of landscape preference. The psychophysical approach has a more pragmatic goal of predicting scenic beauty based on the physical impacts of management on a forest landscape. Because of the pragmatic nature of the psychophysical approach, it has been critiqued as lacking strong aesthetic theoretic foundations and explanatory content (Ribe 1989).

The psychophysical approach quantifies relationships between perceptions or preferences for scenic beauty and measures of physical forest attributes. Brown and Daniel (1986) identify four psychophysical methods that have been used to characterize scenic beauty. These include: 1) summed rankings; 2) averaged ratings; 3) scaling of paired comparisons (Thurstone's Law of Comparative Judgment); and 4) SBEs. Benson and Ullrich (1981) state that average ratings and SBE scores are usually closely related for similar groups of observers, the only difference being the higher numeric quality of SBEs. Buhyoff et al. (1982) and Hull et al. (1984) found SBEs and scaled paired comparisons for the same scenes to be very similar, which is consistent with theoretical expectations. However, Buhyoff et al. conclude the SBE method is generally more efficient.

B. The Scenic Beauty Estimation Method

The SBE method considers the observer-observed relationship as interactive. That is, scenic beauty is neither "in the eye of the beholder", nor a property of the landscape. Scenic beauty is a stimulus-response judgment made by the observer based on perceived landscape attributes. The observer brings along certain criteria when judging the scenic beauty of a landscape—criteria which can be shaped by past experience, environmental conditioning, and future expectations.

Context may determine what criteria are used in judging scenic beauty. For example, the benefits derived from different recreation activities depend to varying degrees on the scenic quality of the surrounding landscape. More skilled recreation activities such as kayaking depend less on the scenic quality of the surrounding landscape for their overall appreciation or value than more passive activities such as sightseeing or camping (Brown et al. 1989). Other contextual effects include the level of information an observer brings to the judgment process, and specific reasons for judging scenic beauty (for instance, is the scenic judgment that of a landscape surrounding a new home or as a background for a once-in-a-lifetime vacation trip?).

When scenic beauty is being judged on a bounded point scale (for example, 0 to 9 where 0 represents low and 9 represents high scenic quality), different observers, due to different judgment criteria, may rate scenes differently. If these differences are consistent between observers, and each observer uses judgment criteria equally across different scenes, then different judgment criteria effects can be measured and controlled. This is essentially what the SBE procedure does. SBEs, or scenic beauty estimates, are measures of landscape beauty that are independent of individual judgment criteria from which a quantitative index of perceived scenic beauty is derived (Daniel and Boster 1976).

The standardization procedure is explained in detail in Daniel and Boster (1976). The conversion of observer ratings to standard normal deviates places all observer SBEs on the same scale. The distance of these deviates from a control (normally defined as the baseline in which scenic beauty estimates are zero) defines ratings relative to this origin. SBEs can then be averaged across all observers to represent a collective ranking of a landscape's scenic beauty. This procedure, in theory, provides measures of scenic beauty with interval scale quality. Interval scale measures include the mathematical properties of addition and subtraction, but have an arbitrarily determined zero point. Since the distance between the measures is known and unchanging, we know that not only is two greater than one, but that it is also one unit more than one. Interval scale quality, however, does not allow the judgment that two is exactly twice as much as one. For example, a scene with a SBE of 10 may not be twice as beautiful as a scene with a SBE of 5.

Ribe (1988) presents an alternative rating method in the SBE methodology that would result in ratio scale measures. Ratio scale measures include multiplication and division due to the non-arbitrary zero point in addition to the mathematical properties of interval scale measures.

This zero point is the switching point for the individual observer between "ugliness" and "beauty", representing the individual observer's indifference point. Ratio scale values are derived following the same technical steps as interval scale measures, with two exceptions. First, the rating scale used by observers to rate landscapes is changed from a bounded point scale to a symmetrical bipolar scale centered on a zero rating value. The criteria are to judge landscapes as to whether viewers like, dislike, or are indifferent to them (a zero value), and to determine the relative magnitude of each judgment. Second, the average cumulative probability statistic generated in the ratio scale method is the ratio scenic beauty estimate, whereas in the interval scale method, further computations are required to define the scenic beauty estimate. One major advantage of a ratio scale method is the explicit interpretive nature of the estimates. A negative scenic beauty estimate ($SBE<0$) in the ratio scale method directly refers to a disliked landscape. In the interval scale method, a negative SBE, due to an arbitrary zero point, may mean only that the judged landscape is relatively less appealing than one with a higher SBE, not that it is liked or disliked.

The application of the SBE method involves three steps: 1) representing the landscape to be judged; 2) presenting the landscape to the observers for judgment; and 3) evaluating the observer's judgments. In step one, it has to be determined whether the landscape will be presented directly or through photographic representations. Daniel and Boster (1976) have set the guidelines through which the landscape should be photographically represented to eliminate extraneous information which could bias the judgments of the observers (for example, the presence of clouds, the season in which photos are taken, or even the time of day).

C. Contextual Effects on Perceived Scenic Beauty

The context within which scenic beauty judgments are made can affect the perceptual process used in the judgment. There can be environmental context effects such as the recreation activity or the individual's home community type (e.g., urban versus rural). Context effects also may be experimental, such as the response format (paired comparison versus SBE), sample design, and presentation medium (photos versus on-site).

Brown and Daniel (1987) identified six areas of possible contextual effects in landscape research: (1) the sample selection used to represent a definable population (Brown and Daniel 1984; Daniel and Boster 1976); (2) the response format used such as paired comparisons, ratings, mean rankings, or SBE (Benson and Ullrich 1981; Buhyoff et al. 1982; Hull et al. 1984); (3) the amount of time the respondent took in evaluating the landscape (Wade 1982); (4) the effect of landscape presentation mediums, whether by slides, photos, or on-site; (5) the season in which the photo was taken versus the season of the year in which it was judged; and (6) the range or mixture of environmental conditions presented during the judgment session. An additional area that is relevant here is (7) information context. Several studies have investigated the effects of information provided in experiments on scenic beauty judgments, e.g., the presence of pest damage, landscape management labels, and identification of intended or actual recreation activity. The first three areas have been extensively investigated and found to have no appreciable effect. Therefore, only the latter four areas of context effects will be discussed.

Landscape Presentation Mediums: Photos versus On-Site

A major concern in using photographs and slides as representations of scenic quality is the validity of these presentation mediums. Several studies tested the validity of photo-based SBE judgments by comparing these judgments to on-site SBE judgments by the same observer groups (Daniel and Boster 1976). Photos are good representations of the scenic beauty of a site if proper photographic guidelines are followed (Bosselmann and Craik 1989; Zube et al. 1987). There was a high correlation between photo-based and on-site SBE judgments of the same landscape based on group average comparisons.

Hull and Stewart (1992) argued that the correct validity test of photo-based scenic beauty judgments is on the individual level, since it is at this level that judgments are being made. They found that a comparison of individual on-site scenic beauty ratings and photo-based scenic beauty ratings resulted in uncorrelated judgments, or that on-site and photo-based judgments were not similar. In fact, they also found on-site judgments to be consistently lower than photo-based judgments. However, when they compared group averages, they found a high correlation between the two judgments, implying no statistical difference. This suggests photo-representations of scenic beauty may be invalid measures in some situations due to the many different contexts involved in on-site landscape experiences. Several of these on-site contextual effects will be discussed in the following sections.

Temporal and Spatial Contexts of On-Site Experiences

Hull and Stewart (1992) found on-site and photo-based judgments of scenic beauty were different for some individuals. They stated that this may have been the result of the effects of mood, meaning, and novelty associated with the on-site experience of day hikers. On-site experiences included spatial and temporal views of landscapes as the observer moved through and interacted with the landscape, where the rate of travel through the landscape was controlled by the observer. Obviously, still photos cannot capture these elements of an on-site experience. Other contexts that may have had an influence on on-site judgments include stimuli such as fatigue, emotions, companionship, and the dynamic aspects of the landscape scene such as wind-caused movement and wildlife. Other experiences and perceptions that are coincident to scenic beauty judgments may have influenced or affected these judgments.

Scenic Beauty and the Camping Experience

Daniel et al. (1989) compared SBE judgments of the visual quality of forested campgrounds with contingent valuation derived economic measures of scenic beauty for the same areas. The preference orderings elicited by each method were statistically similar. This implies that photo-based SBE judgments and economic valuations of scenic beauty are equally good indicators of scenic quality. However, the authors did identify the possibility that other contexts in the camping experience, such as the quality of the facilities and the effects of crowding, would not be captured in photo-based SBE judgments as used, allowing for a divergence of economic and SBE indicators. SBE judgments are probably most closely related to economic measures when the recreation activity is fairly passive, such as sightseeing, where the scenic beauty of the surrounding landscape is a major determinant of satisfaction from the experience.

Brown et al. (1988) and Richards et al. (1990) compared photo-based SBE judgments and contingent valuation and travel cost derived economic measures of forested developed camping sites with on-site SBE and economic judgments. They found that campers consistently preferred the actual surrounding forested areas to the photo-representations of these same areas, whether the indicator of preference was in SBEs or dollars. Brown et al. identified four possible explanations for this observed difference. The first is that the photos did not represent the site adequately. However, based on other studies, they rejected this explanation. The second explanation is that the observers did not exclude extraneous information, such as lakes, vehicles, or facilities, in the on-site valuations, as they were instructed to do. The photos were taken in such a manner as to not include these objects, identifying only vegetative characteristics. A third explanation is that because the sample of campers was selected from on-site participants, the campers had already selected their campsites, implying they had already made judgments preferring one campsite to other available ones. The campers' desire to remain consistent may explain their continued preference for their chosen campsites from among the alternatives. And last, participation in outdoor recreation activities in a pleasant surrounding may enhance the preferences for these surroundings through mood, meaning, and sense of attachment.

A comparison of on-site SBEs and photo-based SBEs leads to the conclusion that there are significant contextual effects of direct observation that are not captured in photorepresentations of the same areas. Also, the camping experience comparisons where the onsite judgments are more positive than the photo-based judgments imply that the scenic beauty of the surrounding landscape as measured is not the dominant determinant of the camping experience. Other factors, such as companionship, recreational activity, and climate, that are not captured in an SBE evaluation, may be equally involved in determining the overall satisfaction derived from outdoor recreation.

Seasonality Effects

Buhyoff and Wellman (1979) tested the effect of seasonality on scenic judgments by comparing valuations between the season in which the photo was taken and the season in which it was evaluated. They found a significant relationship between the seasonal components. Green foliage was preferred more in the spring than in late summer, and fall foliage was preferred more in the late summer than in the spring. This may have been due, in part, to respondent expectations of changing seasonal landscapes.

Rudis et al. (1988) tested the effect of seasonal changes by using early summer (May) to late summer (October) photos in forest scenic beauty evaluations in Texas. They found that the photo samples taken in early summer were preferred over photo samples taken in late summer. They believe this was due to the differences in complexity and texture exhibited by a forest as it progresses through the summer, such as the relative shade of greenness and texture of leaves and groundcover vegetation. These contextual effects can be standardized through proper and consistent application of photo-sampling and presentation in experiment design.

Range and Relative Mixture of Environmental Conditions Presented

Brown and Daniel (1987) tested the effect on judgments when the photo-representations of the control photos were preceded by low scenic quality versus high scenic quality photos. The low scenic quality photos had obvious scenic impacts from recent harvests and had been rated low in previous studies. The high scenic quality photos had no obvious scenic impacts and had been rated high in previous studies. The control photos, presented to both observer groups, had no obvious scenic impacts and had been rated as of medium scenic quality in previous studies.

The researchers found that SBE judgments were influenced by previously viewed slides where the control photos were rated lower in the high-scenic-quality context than in the lowscenic- quality context. The importance of the experiment shows that external validity of SBE requires the assessment context be reflective of the "real world" as it is or is desired to be in a management context, i.e., photo-representations need to capture the true range of forest conditions for a stand. Also, SBE results should be interpreted within the scenic context/ range that generated them.

Experimental Information Effects

Information provided about the landscape during the experiment can influence scenic beauty judgments. Two information sources were tested: the labels used for different forested landscapes, and identification of the presence of insect damage. Buhyoff and Leuschner (1978), Buhyoff et al. (1982), and Hollenhorst et al. (1993) tested the effects on scenic beauty judgments by informing observers of the presence of insect damage in the observed landscape. This was accomplished by dividing the observer sample into two groups, one informed about the presence of insect damage, and the other uninformed. In these studies, the informed group had relatively lower scenic-beauty judgments for the overall stands. While insect damage had a predominantly negative impact on scenic beauty, the impact for the uninformed group was slightly mitigated by the presence of dense forests, long viewing distances, mountainous terrain in the distant landscape, or by the presence of flowering understory growth, increased sunlight, and visual penetration in the near view.

Anderson (1981) and Vodak et al. (1985) tested the effect of management labels on scenic beauty judgments. Anderson's informed group was presented with forested scenes carrying the land use designations "wilderness area", "National park", "recreation area", "leased grazing range", and "commercial timber stand". The uninformed observer group was presented the same forested scenes without the labels. Anderson found that the first two labels increased and the latter three labels decreased scenic beauty evaluations compared to the no label group. The labels, however, only accounted for approximately five percent of the variance in scenic beauty judgments.

The effect of land use designations was found to be compounded when the labels supported the forested scene. For example, when a highly scenic view was labeled "wilderness area" or "National Park" the evaluation was increased. But when the scene was relatively unscenic the label had little effect in raising judgments. The implication is that the value of recreation experiences is enhanced when the activity takes place in a "wilderness area" as compared to a "commercial timber stand".

The Vodak et al. (1985) study does not support these findings. It found forest management labels had no effect on scenic beauty judgments. The Vodak et al. (1985) labels included "natural or unmanaged", "light thin", "heavy thin", and "clear-cut". These labels were less emotive than the Anderson labels. The label correspondence to the scenic quality or visual impacts of forested stands was distinct enough so that the label had no impact on judgement. For example, "clear-cut" was highly visually evident in the forested scene, so the label was merely redundant.

D. SBE Prediction Methodology

The usefulness of the SBE method in evaluating alternative management proposals depends on the predictability of scenic beauty before the plan is undertaken. Therefore, SBEs need to be transformed into expected values of changes to the forest as a result of a management action. This is accomplished through the development of a statistical model that relates forest characteristics to perceived scenic beauty. The dependent variable is the scenic beauty measure, and the independent variables are measures of forest landscape features. Multivariate regression analysis is used to specify the prediction model and interpret the relationship between the dependent and independent variables. Most of the studies reviewed indicate that scenic judgments are consistently related to identifiable features of the forest landscape.

The applicability of SBE prediction models depends to a large extent on the type of independent variable measures used. A model that would be practical for use in forest management would predict changes in scenic beauty caused by management actions based on easily identifiable and manageable physical forest characteristics such as forest density, amount of slash, condition of ground vegetation, and the like. Therefore, the impacts of slash treatment on scenic beauty can be determined prior to the action. The expression of scenic beauty in terms of manageable forest characteristics allows examination of trade-offs, which in turn allows for the direct comparison of the effects on scenic beauty of management alternatives with those on other objectives, and to economic costs and benefits.

The coefficient on an independent variable in multivariate regression models shows the impact of a one-unit change in the independent variable (forest characteristic) on scenic beauty (dependent variable), holding all else constant. Therefore, the relative impact of a change in a forest landscape characteristic can be determined through the use of the model. A measure of the efficiency of the prediction model is the coefficient of variation, or R2, which is the proportion of the variance in the scenic beauty measure that is explained by the set of independent variables. Therefore, the more efficient a model is in predicting the dependent variable, the larger the R2. For the majority of the studies reviewed, R2 ranged from approximately 0.50 to 0.97, showing the overall efficiency of the models.

The statistical model is represented as:

$$SBE = f(X)$$

where SBE is the interval scale measure of the perceived scenic beauty for the site under investigation and X is a vector of the site's inventoried physical characteristics. The empirical model is represented by specifying the independent variables used. For example:

SBE = f (trees per acre of varying sizes, ground cover, understory, downed wood, tree grouping, etc.).

The overall ease of interpretation and usefulness of the empirical model to the manager or planner depends on the quality of the measures used to inventory the physical characteristics of the landscape. Time-cost savings are greatest if the inventory data used are the standard inventory data for the area. However, the inventory data may not fully represent the relevant characteristics of the landscape, in which case a special, separate inventory is needed.

Model functional form, whether linear, nonlinear, containing interaction terms, or the like, has been investigated. Hull et al. (1987) test several functional forms over models with and without interaction terms. Their recommendation is that empirical studies need to be explicit and comprehensive in presenting their models so that further examination of proper functional form can be tested, resulting in a consensus on what is "best" for SBE prediction models. This also allows for more informative comparisons of models across regions.

E. SBE Prediction Model Example

The easiest way to explain how these models work and the management implications that can be derived from them is to use an example. The model used in this example was taken from Brown and Daniel's (1984) study of the Woods/Bar-M Watershed areas of the Coconino National Forest in northern Arizona. There were 23 stands inventoried in 1979 prior to a timber harvest of the areas. The inventory of physical characteristics prior to harvest was conducted from late-May to mid-August. Four of the stands were reinventoried in 1980 and 1981 after the harvest. A full discussion of the inventory procedure is found in Brown and Daniel (1984). Inventory data was collected on seedlings and saplings by species, large trees by species, crown canopy, stumps, tree stories and tree groupings, herbage (as grasses, forbs, and shrubs) and ground cover (in gravel, cobble, stone, bare soil, litter, downed wood, herbage, and trees), and mechanical damage.

Photo-based scenic beauty estimates were elicited from groups of observers comprised of University of Arizona introductory psychology student volunteers and local church and civic group members. The study assumes that the groups are representative of the general public, as shown by Daniel and Boster (1976) and Buhyoff et al. (1982). Photographic-slide representations of the inventoried stands were taken between 8:00 a.m. and 4:00 p.m. following Daniel and Boster's (1976) guidelines, controlling for extraneous visual information, such as people, buildings, wildlife, or equipment, which did not represent instand, near-view scenes. The observer groups rated the slides on a 10 point scale, with each group rating the same subset of base area slides. Using a correlation test, they discovered no appreciable difference between observer groups, which supports the assumption that the groups mentioned above are representative of the general public.

A three-step procedure was used to estimate the coefficients of the prediction model. The first step was the selection of the inventory variables to be subjected to the regression procedure. The second step used a step-wise multiple regression technique to specify the model given the step one variables. The third step examined the residuals of the estimated model, depicting the variance in the SBE measures not explained by the included variables, for model bias and for the respecification of the model. Three pre-harvest, site-level models; three pre-harvest, stand-level models; and one post-harvest, site-level model were estimated. Only the pre-harvest, stand-level, detailed, downed-wood model will be presented here. A full discussion of all the models is presented in Brown and Daniel (1984).

The empirical pre-harvest, stand-level, detailed, downed-wood model estimated is:

$$SBE = 4.35 + 3.61PP24PL + 0.28PDTOT - 2.26DWV014$$

where:

SBE = scenic beauty estimate of the stand;

PP24PL = number of ponderosa pine ³ 24 inches diameter at breast height (dbh) per acre (mean value = 3.6 trees per acre);

PDTOT = total herbage weight in pounds per acre (mean value = 82.7 pounds per acre); and

DWV014 = cubic feet of 0-º inch diameter downed wood per acre (mean value = 10.8 cubic feet per acre).

The model has an R2 of 0.80, meaning it is a fairly efficient model in explaining the variation in SBE measures with the inventoried stand data. In general, the model shows that the presence of large trees and ground cover as herbage weight increases the scenic beauty of the stand, whereas the presence of downed wood detracts from the scenic beauty of the stand. For example, the predicted scenic beauty estimate of a representative stand can be calculated by entering the mean values of the variables in the equation above. This results in a predicted scenic beauty estimate of 16.1. Holding all else constant at its mean value except for the variable of interest, the impact on scenic beauty can be estimated from the model. With a 50 percent increase in the number of large ponderosa pine (from 3.6 to 5.4 trees >24 dbh per acre) in the representative sample, scenic beauty increases from 16.1 to 22.6. Similarly, a 50 percent increase in the volume of downed wood per acre (from 10.8 to 16.2 cubic feet per acre) results in a decrease of scenic beauty from 16.1 to 3.9. Given the model, it is concluded that an increase in downed-wood volume decreases the scenic beauty of the stand, while an increase in the number of large trees per acre increases the scenic beauty of the stand, all other forest characteristics discounted.

Results such as these can have important implications for different management plans. For instance, Brown and Daniel (1984) discuss the overall implications from the models estimated in the study for forest management, stand structure and density, harvest and slash cleanup, and grazing. The coefficients of the models suggest that large pine trees, presence of other tree species (Gambel oak), and herbage contribute to the scenic beauty of the study area. Smaller pine trees and downed wood detract from the scenic beauty of the area. Also, it is found that less dense pine stands of a northerly aspect are preferred. Unfortunately, because of the site-specific nature of the data, models estimated for one site may not be transferable to another site, especially if the forest structure (tree species, climate, past management practices, presence of fire or pest damage) is significantly different. Schroeder and Daniel (1981) found that some models of the northern Arizona forests are generalizable, with minor adjustments for pest damage, to Colorado forests. Ribe (1990) developed a regionally valid model for northern hardwood forests. The general hardwood model is constructed from testing the application of several models, resulting in what may be a more generally applicable model for deciduous forest types.