THE SCENIC IMPACT OF KEY FOREST ATTRIBUTES AND LONG-TERM MANAGEMENT ALTERNATIVES FOR HARDWOOD FORESTS[1]

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Abstract: The problem of identifying the scenic value of forest attributes and management plans is empirically explored. A sample of hardwood forests in Wisconsin, representing a diversity of management histories, is analyzed through photographs and field inventories. Scenic beauty judgements of the photographs by a diversity of respondents yield general scenic beauty estimates for the sampled forests. A general model is reported for predicting these estimates from forests' structural attributes. This model is then used to isolate and identify the marginal scenic impacts of single critical forest attributes with the effects of other attributes discounted. These are interpreted for their relative scenic value. In addition, rough estimations of scenic beauty flows for each of several basic long-term hardwood management alternatives are identified. These scenic flows are compared for their average scenic beauty "output". The results provide guidance to hardwood forest managers in selecting overall management plans and management prescriptions for forests where scenic beauty is an important goal.

INTRODUCTION

Scenic values are an important factor in management decisions for many public hardwood forests. Where these are popular for recreation or highly visible examples of public land management, foresters must often consider the scenic merit of their decisions to meet the needs of visitors and retain the confidence of the constituents who must support those decisions. For example, the U.S. Forest Service now classifies portions of forest landscapes according to the visual quality objectives that must be sought there (USDA 1974), including those for scenic corridors along highways and trails. That agency often also identifies recreation opportunity spectrum classes for areas according to the nature of the settings to be provided in each with attendant visual quality objectives (USDA 1986).

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To work toward providing scenically satisfying forest landscapes, managers can rely to some extent on their intuitive sensibilities about the relative beauty of alternative forest conditions, or upon landscape designers to suggest preferable spatial arrangements and vegetation structures for forests. To make decisions, especially among alternatives with intuitively similar scenic merit, with more confidence and administrative defensibility, foresters must turn to empirical research investigating the scenic preferences of the public for forest landscapes. In response to this need a considerable body of research has been reported about public perceptions of scenic beauty within forests (Ribe 1989).

Information Problems

The information yielded to hardwood forest managers by empirical scenic preference studies is of limited value for practical decision making. Most studies either report a few odd findings or report a forest-structure-based model for predicting the scenic beauty of one particular forest type. In the first case, the findings are often limited to answering a few questions and the answers may be specific to particular scenic comparisons or contexts such that they can vary from one study to another either in direction or magnitude. In the second case, particular relationships that may inform decisions can be buried within a scenic beauty prediction model or have been selected against in model development in favor of a related but more powerful variable. As a result, these models do not readily answer questions for foresters who do not wish to fully study and interpret such research reports. In addition, the hardwood forest manager will find that only one such study investigated hardwood forests and then only included basal area and slash volume as scenic beauty predictors (Vodak and others 1985). Many reported findings between forests' structures and their perceived scenic beauty tend mainly to confirm the obvious. Where more subtle relationships are reported, or obvious relationships are studied as to their magnitude, the different studies' results tend to diverge. This yields little clear support for decisions about subtly different managements or the complex trade-offs among forest attributes and their scenic and other resource consequences. Indeed, research methods and results to date yield little to compare the magnitude of scenic results among alternative forest management decisions.

There are two types of things that foresters most need to know to determine the near-view, within-stand scenic beauty of alternative future hardwood forest conditions. The first is the relative scenic worth of changing incrementally any single important forest attribute independent of the many possible overall states of the forest in question. (This is called the "marginal value" of that attribute.) For example, foresters often ask just how much is it worth to the passing recreator to retain the extra two big trees per acre in a forest compared to cleaning up down wood or thinning, irrespective of exactly how many other big trees are already there or whether the forest contains many saplings or has an open floor. The second kind of information most often needed is the relative scenic merit of alternative general forest management programs that might be pursued in areas with different scenic requirements. These choices are not always obvious, as several alternatives may yield intuitively, equally-meritorious scenic values. For example, foresters may ask whether an even-aged rotation might actually yield more total scenic beauty over time than an uneven-aged one.

This could be true in spite of the initial scenic impact of harvesting if the even-aged rotation yielded much higher scenic beauty during its period of forest maturity. More empirical and valid information must be sought to answer such questions.

Research Design

The research reported here sought to provide hardwood forest managers with the two kinds of practical information needs described above. It began in the same manner as have the many reported scenic beauty modeling studies, and then added further analysis aimed at answering the two key kinds of questions. A sample of such forests was inventoried and photographed and then judged for scenic beauty by a sample of public respondents. A model was then developed to predict average scenic beauty values for forests using many of their structural attributes. This model was then used to account for the observed scenic beauty of forests as much as possible by the scenic effects of all but one variable at a time. This allowed the identification of marginal relationships between each of several critical forest attributes and their singular effect on scenic beauty, all other scenic factors being accounted for. In each case, the marginal variable analyzed was chosen for its practical value in informing forestry decisions. (Consequently, the variables analyzed for their marginal scenic values were sometimes slightly different from those optimally included in the more general scenic beauty model.) This permitted the identification of simple and informative relationships between manageable attributes of hardwood forests and their scenic effects. And, those relative effects are all measured on the same ratio scale of scenic beauty for ready comparison in selecting future forest conditions to maximize scenic beauty goals.

To answer the second kind of question regarding the scenic merit of alternative general hardwood forest managements, a simpler research design was employed. A few forests representing different stages of forest development under several management alternatives were sampled. A curve was then fitted through the observed scenic beauty of these forests plotted against time to indicate the general flow of scenic beauty that might be expected from each management alternative. The resulting general scenic flow patterns could then be compared in roughly estimating the relative scenic merit of general management alternatives.

METHODS

The development of the scenic beauty prediction model is explained in greater detail in Ribe (1990). The process involved field-sampling a diverse set of predominantly hardwood forests, having a variety of respondents judge scenes from the forests for scenic beauty, standardizing and then averaging the respondents judgements by forest, and then finding a linear regression model that used forest structure attributes to predict these average scenic beauty values across the forests.

Stand Sample

A sample of 31 dominantly hardwood forests were selected to include a variety of ages, dominant species, management histories- including experimental stands, structures, site qualities and slash treatments. The average site index was 50 for Sugar Maple (*Acer saccharum*), base age 50. They ranged from 10 to 180 acres, and their interior floors were flat and free of artifacts.

The stands were sampled during mid-day in July 1987- mid way through the seasonal decline in perceived scenic beauty due to progressive dulling of foliage color (Buhyoff and Wellman 1980, Rudis and others 1988). Each stand was sampled around two randomly selected points. At each, three photographs were taken in different directions away from the sun with a 35 mm lens. The stands structure was then measured within a 1/10 acre plot surrounding each sample point in a manner like that of Brown and Daniel (1986). The diameter distribution was counted for trees exceeding 2 inches dbh in 5 inch categories, and a count of all saplings at least 5 feet tall but less than 2 inches dbh was made. Transects were measured for percent canopy in shrubs and seedlings less than 5 feet tall (Canfield 1941), and cubic feet of sound slash per acre (Brown 1974). Rectangular plots served to measure percent canopy coverage in live ground vegetation (Daubenmire 1959). The two sample point values for these structural attributes were averaged to yield single values for each stand. These attributes exhibited a broad range of values and a variety of value combinations due to the diversity of the stand sample.

Scenic Beauty Measurement

Three slides were selected from each stand's sample for photographic quality and range of scenery represented. The slides from all the stands were then shown in random orders to 139 judges. These were from 12 diverse but dominantly white public groups from Wisconsin. Only one group, consisting of Wisconsin Department of Natural Resources staff members, included a significant representation of people familiar with forest management. The judges rated every slide for scenic beauty on a scale from -5 to +5, corresponding to a range from ugly to beautiful perceptions. These ratings were then standardized and averaged for each stand across all judges using the ratio scenic beauty estimate (RSBE) method (Ribe 1988), modified from the scenic beauty estimation method (Daniel and Boster 1976). Scenic beauty estimates on a ratio scale take on positive and negative values that correspondingly indicate the relative beauty or ugliness of landscapes, as opposed to those on an interval scale that take on relative values around an arbitrary zero value.

Model Development

An optimal linear regression model was sought using measures of forest structure derived from the stands' inventory data as independent variables to predict the RSBE's of the stands. Independent variables were selected to be intuitively reasonable as scenic beauty predictors, by reference to past research (Ribe 1989) and by replication of other models with the new hardwood data set (Ribe 1990). A large number of independent variables were included in the model to capture many of the important scenic attributes of forests and to minimize bias in all variables' estimated coefficients. To be included in the model, a variable had to have the expected direction of effect upon scenic beauty, a statistically significant coefficient at the P=.05 level, and pass further statistical tests described in Ribe (1990). In selecting from among alternative models including variables that met these criteria, a final model was chosen that maximized the F statistic and the model's explanation of variance in RSBE's.

Data Analysis

The marginal impact of each critical forest attribute upon perceived scenic beauty was analyzed through its own separate analysis, albeit one very similar to that for the other attributes. Each such analysis began by discounting each forest's observed scenic beauty for the scenic-beauty-producing effects of all forest attributes in the regression model other than the one being analyzed. This was achieved simply by performing algebra upon the regression equation with the observed rather than predicted RSBE value for each forest included as the dependent variable value. Each forest's observed values for all independent variables being discounted from scenic beauty were multiplied by their regression coefficient and then subtracted from the forest's observed RSBE. The result was a residual RSBE value for each forest that can only be explained by the remaining undiscounted forest attribute being analyzed for its scenic impact, as well as all other scenically affective attributes not included in the regression model.

The relationship between each critical forest attribute and the residual scenic beauty it might serve to explain was then analyzed. This was done by plotting the two variables across all 31 forests on a graph and fitting a least squares function through the points. The resulting relationship was then analyzed by an F test for statistical significance and an R^2 test for explanation of variance in residual RSBE's across all forests. The forest attribute measurement variable plotted against residual RSBE's at this point needed not be exactly the same as that included in the regression model. Instead, a more informative measure of the forest attribute in question was often plotted against the residual RSBE's largely attributable to that aspect of hardwood forests' structure.

The nature of perceived scenic beauty flows from alternative long-term forest managements was plotted through a rough application of the Scenic Beauty Temporal Distribution method (Hull and Buhyoff 1986). This involved a separate and much simpler analysis than that described above for the critical forest attributes. It involved taking forests from the sample which represented different conditions over time within a management program and plotting their observed RSBE's against forest age. A curve was then plotted through each program's plot of points to roughly approximate the flow of scenic beauty from that program. This was done by eye. Where a long time gap occurred between two sample forests within a management program it was done with educated guessing about the development of forests under different managements. This simple method served as a first approximation of scenic flows using the relatively few forests that could be sampled to represent different management programs.

RESULTS

The sample of hardwood forests exhibited a wide range of RSBE values, making possible some informative analysis of the contribution of forest attributes to scenic beauty and the flow of beauty from alternative management programs. Fortuitously, the range of observed RSBE values took on a property that aids the interpretation of their numeric intervals. Namely, the old-growth forest received an RSBE of close to +100 and the recent clear-cut forest a value of just over -100. Consequently, this range of RSBE values can be viewed as the range of scenic beauty possible from hardwood forests. The zero RSBE value halfway in-between corresponds to forests of "neutral" or aesthetically indifferent scenic value just between those which respondents liked and disliked.

General Scenic Beauty Model

The best linear regression model for predicting RSBE's from hardwood forest's structural attributes is reported in Table 1. The importance of the variables in this model in predicting RSBE's, by virtue of their stepwise contribution to R^2, corresponds to their order from top to bottom in that table. All intercorrelations among the independent variables were less than 0.50 indicating an absence of multicollinearity. The unusually high R^2 and F statistic values for this model indicate that it can serve well the marginal scenic impact analyses of the research. This is because any residual variance in discounted RSBE's will be largely explained by a remaining undiscounted scenic factor. The ability to isolate the scenic impact of one variable at a time is further enhanced by the inclusion of many forest attributes as variables in the model that can all be clearly discounted from RSBE's. And, such discounting is also more accurate because all the regression coefficient estimates are minimally biased by including all relevant and evidently valid variables in the model.

All the independent variables in the model are statistically significant in their relations to scenic beauty at the $P=.05$ level. They are intuitively reasonable, although some take on nonlinear functional forms through special functional specifications and interaction terms: Aspen and birch trees are together positively related to RSBE's but with a nonlinear asymptotic relation expressed by the negative coefficient for the reciprocal of this variable. The number of trees per acre greater than 2 inches dbh appears in two variables as a

Table 1.--Hardwood Forests Scenic Beauty Model

Dependent Variable: Ratio Scenic Beauty Estimate (RSBE)

Independent Variables:

	Estim. Coeff.	Beta	Stand. Error	t Value
Slash >3" (cu.ft./acre)	-.034	-.701	.003	10.958*
Number of trees >2"/acre	.093	.162	.040	2.353*
[Trees & saplings/acre]^2	-9×10^{-8}	-.187	3×10^{-8}	-3.053*
Number of trees >15"/acre	.670	.207	.198	3.382*
Ground vegetation (% cover)	.437	.209	.130	3.364*
1/[% trees aspen/birch]	-63.465	-.124	27.854	-2.278*
[Standing slash >18" tall/ acre rescaled to 0-100] X [Percent trees dead] X [Bare ground (% cover)]	-.0002	-.159	.0001	-2.422*
Constant	14.433			

Regression Statistics:

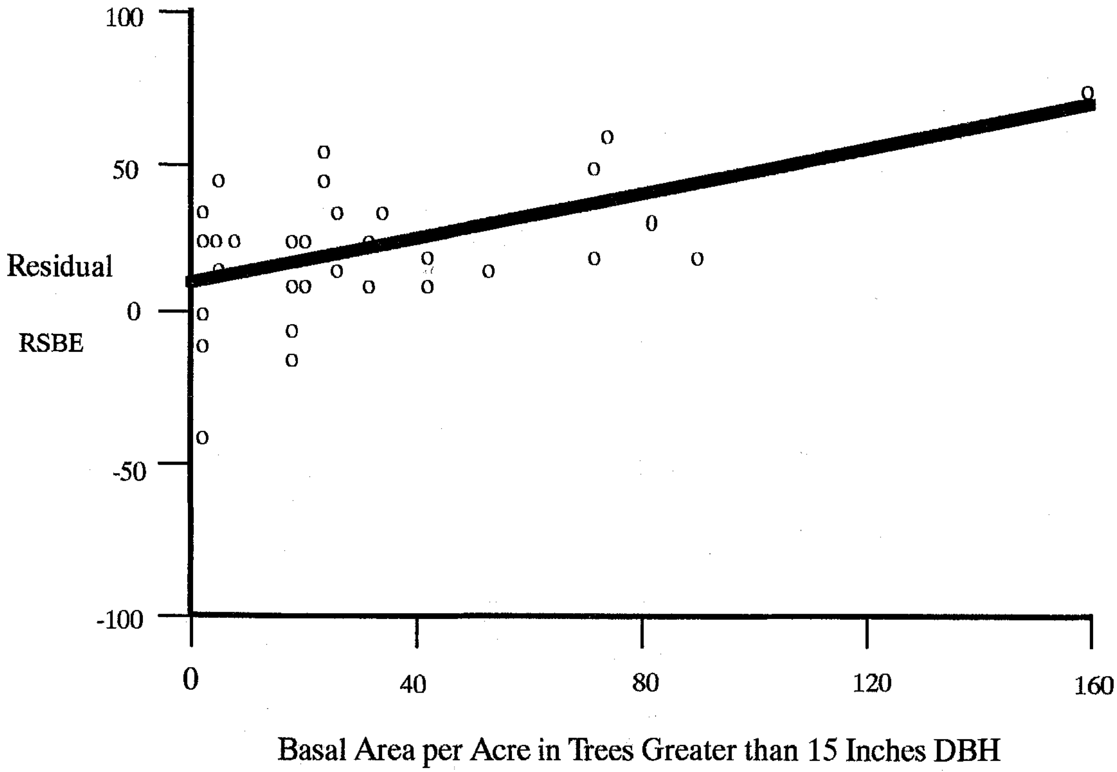
R^2 = .967 Adjusted R^2 = .934 F= 46.829

* Indicates statistical significance at alpha =.05 level.

quadratic specification defining a curve like that in Figure 3. Finally, the last variable multiplies three similarly scaled factors which together produce the appearance of death or sterility in the forest. The other variables are self explanatory.

Big Trees

The marginal impact of big trees upon perceived scenic beauty was isolated by discounting each forest's observed RSBE's by the scenic effects of all variables in the model except for the number of trees bigger than 15 inches dbh per acre. The resulting residual RSBE's are plotted in Figure 1 against the basal area per acre of such trees. This is a more interesting



Residual RSBE = 12.66 + .36(Basal Area in Big Trees)

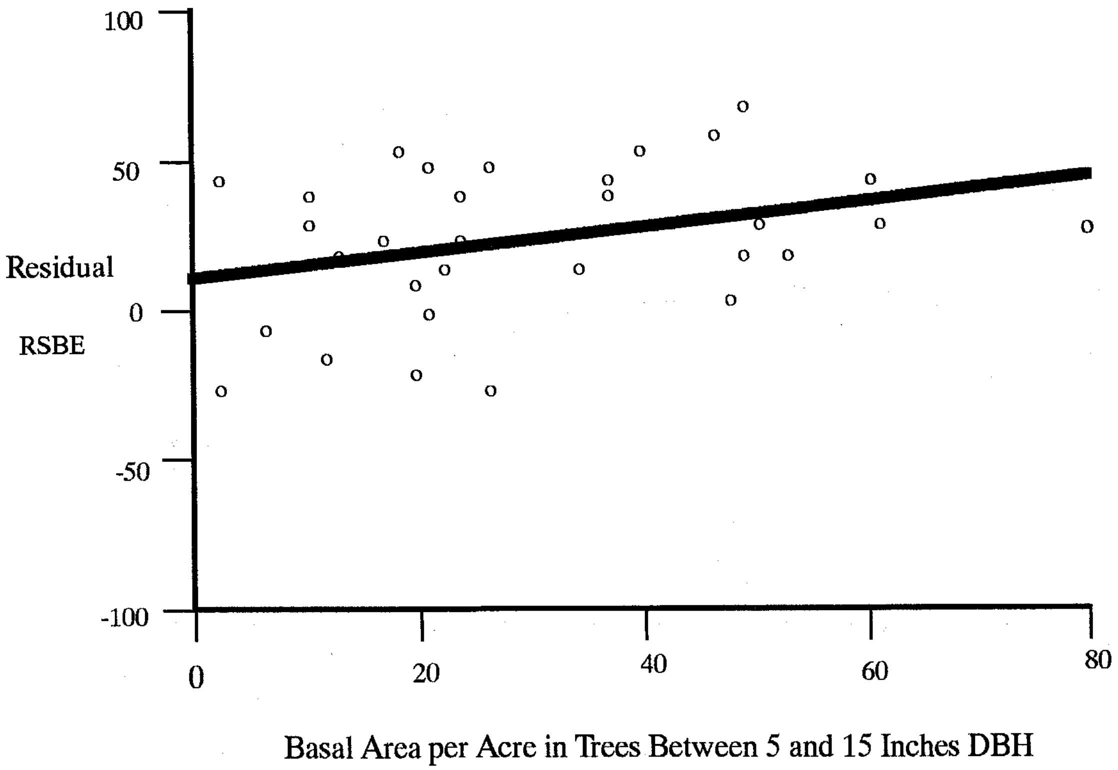
P = .0002 R^2 = .62

Figure 1. Relation between big trees and scenic beauty.

variable for detailed analysis because it indicates more about how scenically valuable it is to retain the largest trees in a stand rather than simply maximizing the number greater than 15 inches dbh. These results indicate that the basal area of large trees more than their numbers (a less beautiful forest could have many 15 inch dbh trees and none larger) is strongly related to forests' scenic beauty. Each 15 square feet of basal area in trees exceeding 15 inches dbh adds to scenic beauty by about 10 percent of the possible range of positive beauty from an aesthetically neutral landscape to an old-growth forest, all other factors being equal. This relationship is strongly supported by its statistical significance and the strong explanation of variance in residual RSBE's by basal area in big trees (Figure 1).

Pole Sized Trees

The result reported above for big trees might apply equally to pole sized trees if observers simply judged the beauty of forests by the presence of any and all full-grown trees. This possibility was tested by isolating the marginal impact of trees between 5 and 15 inches dbh upon perceived scenic beauty. This was done by discounting each forest's observed RSBE by all variables in the model except for the number of trees per acre exceeding 2 inches dbh and



Residual RSBE = 13.22 + .42(Basal Area in Poles)

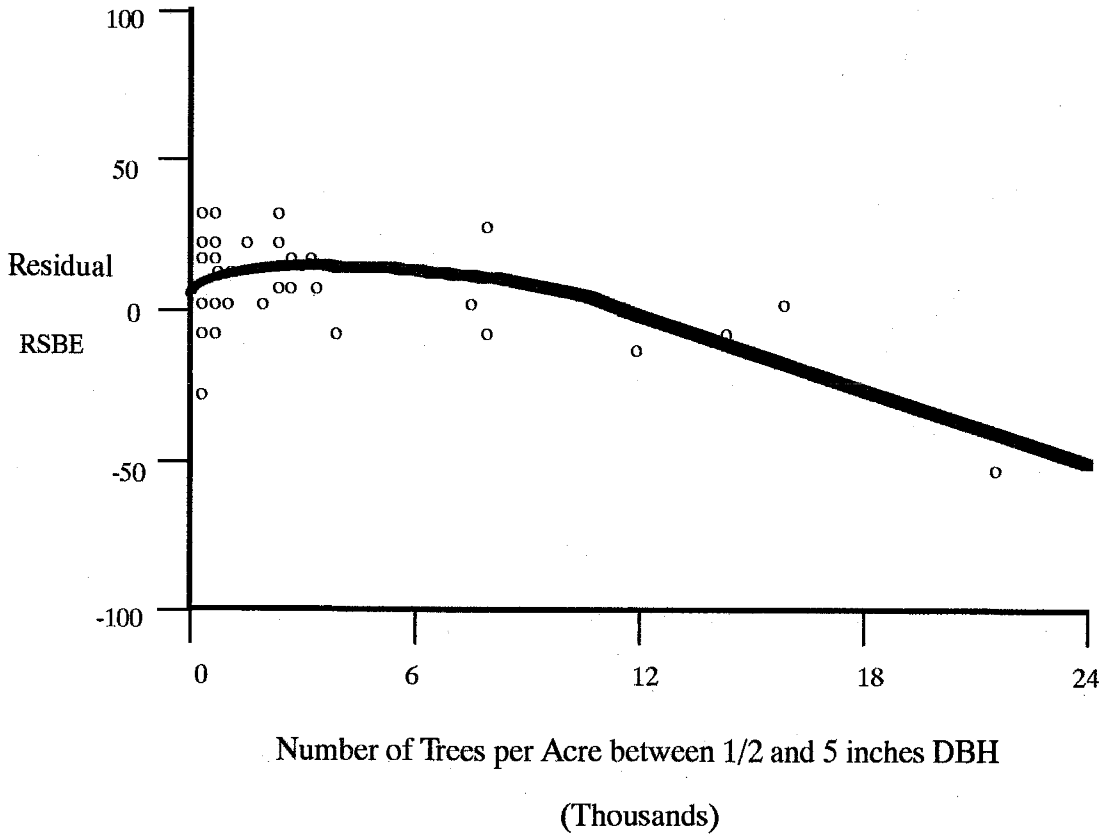
$P = .0042 \quad R^2 = .50$

Figure 2. Relation between pole sized trees and scenic beauty.

plotting these residual RSBE's against basal area in pole sized trees. The results appear in Figure 2. They indicate that basal area in pole sized trees is positively related to scenic beauty, but not as strongly as that for big trees. The scatter plot is less clearly linear and the explanation of variance and statistical significance are lower. Most importantly, the contribution of basal area in pole sized trees to scenic beauty is half that for big trees. Each 30 square feet of basal area in trees between 5 and 15 inches dbh adds to scenic beauty only about 10 percent of the possible range of positive beauty, all other factors being equal. This is twice the basal area requirement to achieve a 10 RSBE point increase than that needed in trees greater than 15 inches dbh to achieve the same scenic beauty result. This confirms the relative importance of big versus pole sized trees in producing forests that the public finds attractive.

Small Trees

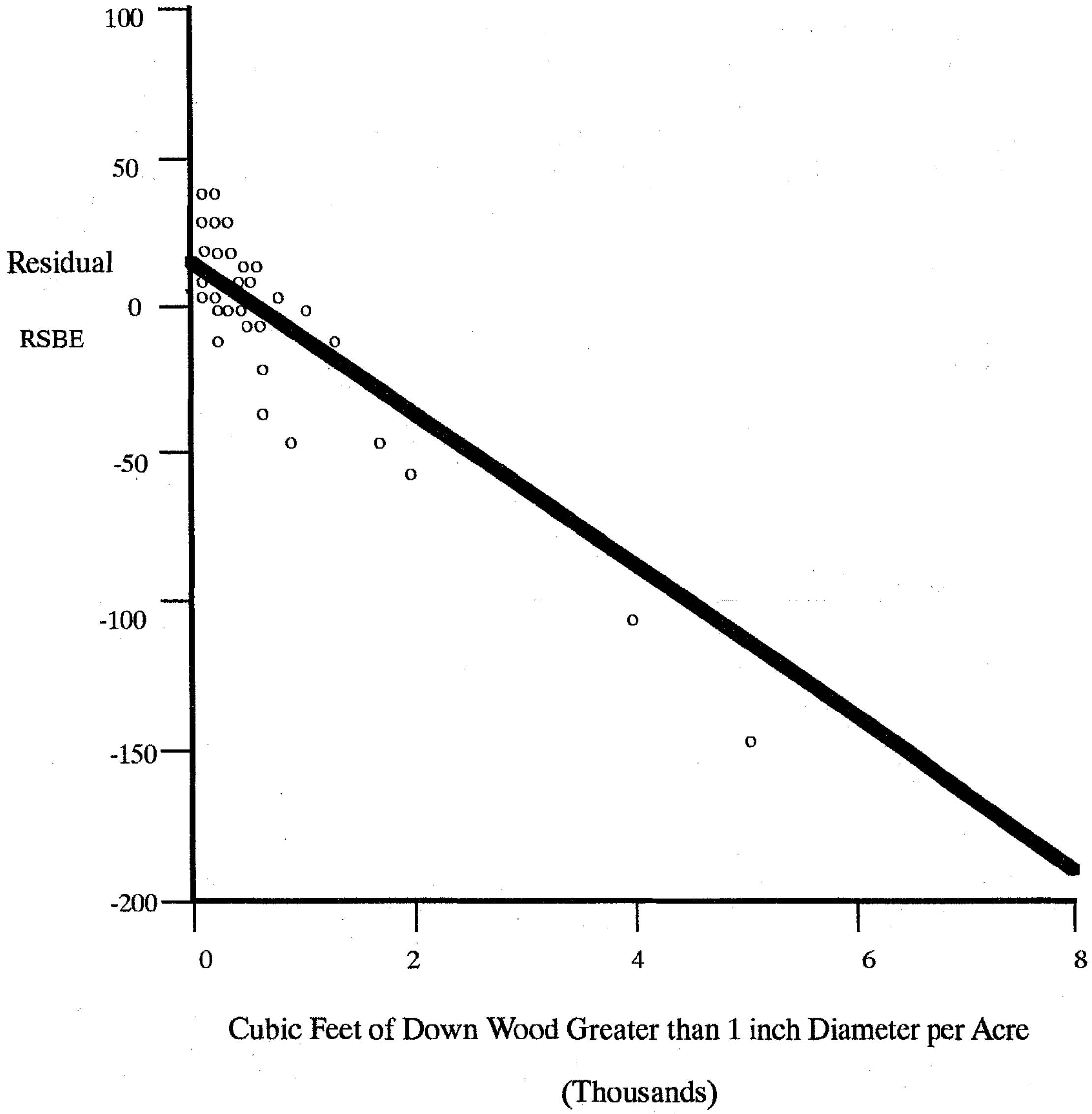
The marginal impact of small trees upon perceived scenic beauty was isolated by discounting each forest's observed RSBE's by the scenic effects of all variables in the model except for the number of trees and saplings per acre squared. The resulting residual RSBE's are plotted



Residual RSBE = 11.44 + .0009(Number Saplings) - .0000001(Number Saplings)
$P = .0009 \quad R^2 = .63$

Figure 3. Relation between saplings and scenic beauty.

in Figure 3 against the number of trees per acre at least 5 feet tall and less than 5 inches dbh. The best least squares functional fit through this scatter plot proved to be a quadratic specification, which is consistent with that found in the general regression model for tree numbers. This curve indicates that up to 4 thousand small trees per acre have a negligible marginal impact upon perceived scenic beauty. With more small trees than that, their marginal negative impact upon scenic beauty becomes increasingly pronounced. For example, beyond 10 thousand small trees per acre, each thousand small trees reduces scenic beauty by about 10 percent of the possible negative range of scenic beauty from an aesthetically neutral landscape to a fresh clear-cut, all other factors equal. This relationship is strongly supported by its statistical significance and explanation of variance in residual RSBE's.



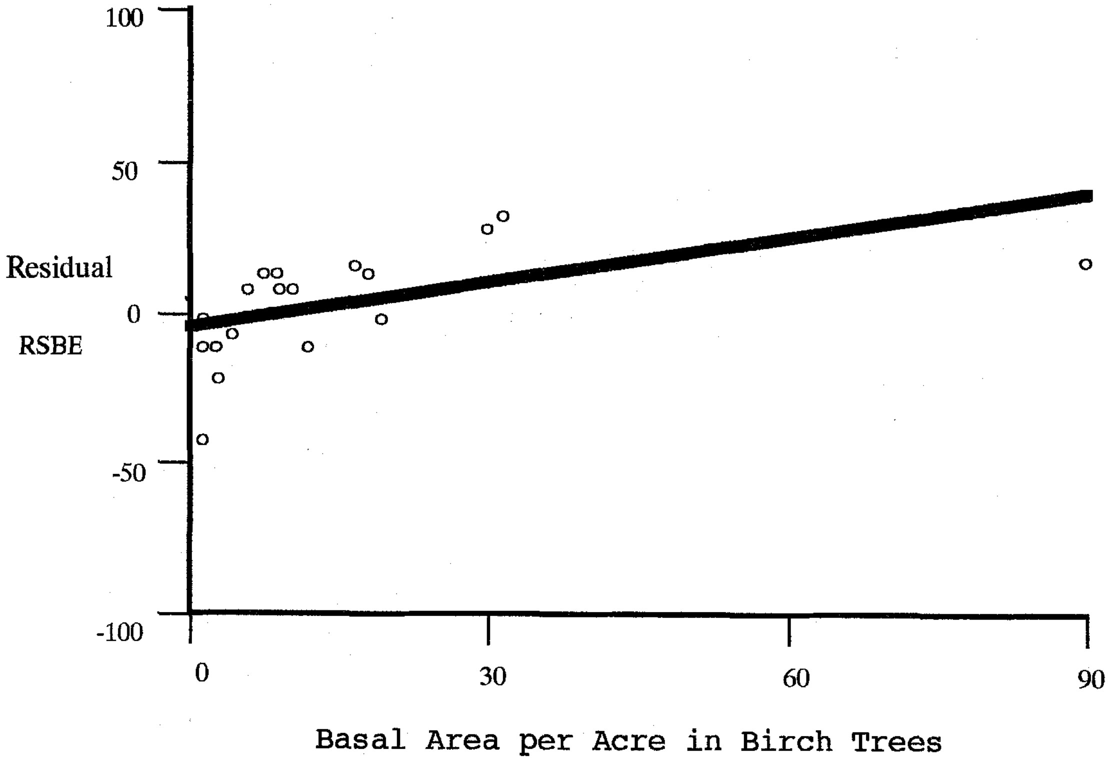
Residual RSBE = 14.86 - .02(Cubic Feet Down Wood)

P = .00001 R^2 = .93

Figure 4. Relation between down wood and scenic beauty.

Down Wood

The negative scenic effect of down wood proved to be the most powerful single predictor of variance in RSBE's in the general regression model. To single out the marginal impact of down wood on scenic beauty each forest's observed RSBE was discounted by the scenic effects of all variables in the model except for cubic feet per acre of "slash" greater than 3 inches in diameter. This variable includes all down wood whether from natural or harvesting sources. The resulting residual RSBE's are plotted in Figure 4 against a slightly different more inclusive measure of down wood- namely cubic feet per acre greater than 1 inch in diameter. As the general model suggests, the resulting relationship is strongly negative, linear, and of very strong statistical significance and capacity to explain variance in residual RSBE's. Each thousand cubic feet per acre of down wood reduces perceived scenic beauty by about 10 percent of the possible range of negative scenic beauty, all other factors being equal.



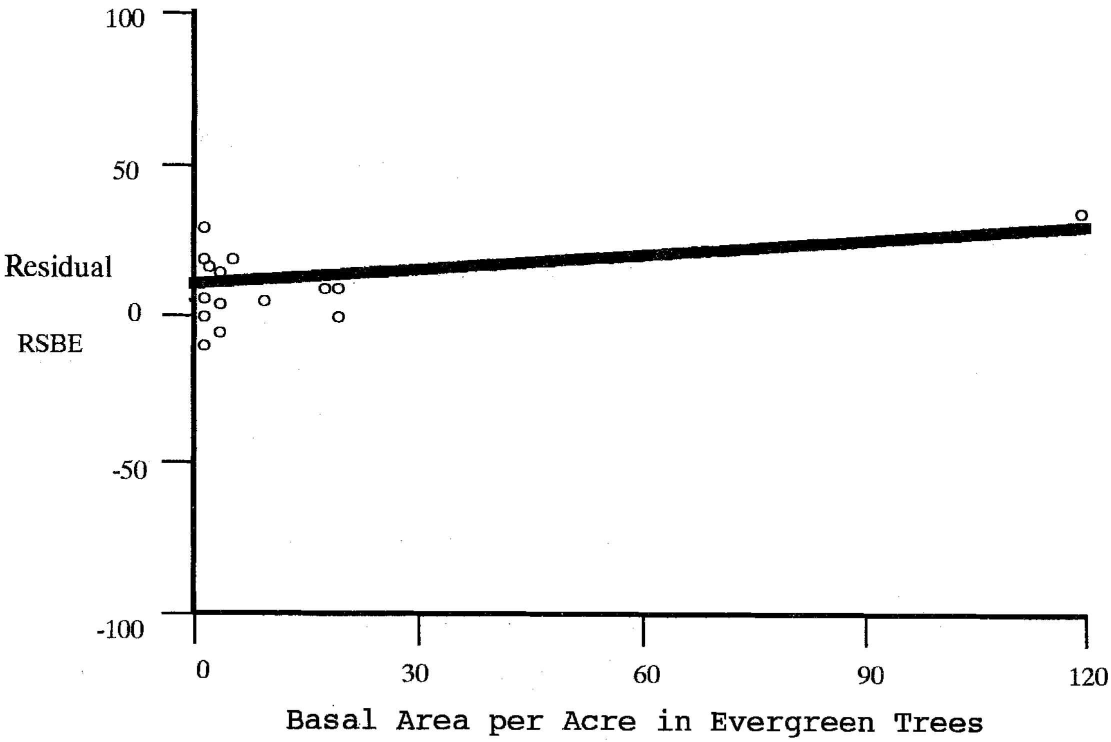
Residual RSBE = -2.35 + .44(Basal Area Birches)

P = ..012 R^2 = .58

Figure 5. Relation between birch trees and scenic beauty.

Birch Trees

To investigate the marginal scenic impact of contrasting tree types, such impacts were investigated for both birch (Betula alleghaniensis or papyrifera) and evergreen trees, which are most frequently of interest to managers of hardwood forests. The general regression model worked best by combining both birch and aspen trees in one variable because a number of aspen stands were sampled to enable an investigation of scenic flows from clear-cut even aged rotations dominated by aspens. To investigate the marginal impact of only birch trees, which more frequently occur in dominantly hardwood forests in northern zones, the observed RSBE's were discounted by all independent variables in the model except for the reciprocal of the percent of trees aspen or birch variable. The resulting residual RSBE's were plotted against the basal area per acre in birch trees, ignoring stands that had no basal area in such trees. It was assumed that the scenic affect of contrasting trees would only play upon perceptions when such trees are at least minimally evident. The results appear in Figure 5. Each 20 square feet of basal area per acre in birches increases scenic beauty by about 10 percent of the possible range of positive scenic beauty. This relationship is supported by its statistical significance at the P = .02 level and by an explanation of 58 percent of the variance in residual RSBE's.



Residual RSBE = 10.58 + .15(Basal Area Evergreens)

P = ..19 R^2 = .35

Figure 6. Relation between evergreen trees and scenic beauty.

Evergreen Trees

The other contrasting tree type that can occur in hardwood forests are evergreens. These did not succeed in contributing to RSBE prediction for inclusion in the general regression model. This may be because most of the hardwood forests sampled had no or very few evergreen trees and only one had a basal area in such trees exceeding 20 square feet per acre, and perhaps also because the forests were sampled in the summer when evergreen trees may have less scenic impact. For the sake of exploration, a marginal scenic impact analysis for evergreen trees was still performed. Because such trees do not appear as a variable in the general model, the forests' observed RSBE's were discounted by the scenic effects of all the independent variables in the model. The resulting residual RSBE's not explained by the model were then plotted against the basal area per acre in evergreen trees. The results appear in Figure 6. As in the analysis for birch trees, forests with no evergreen trees were left out of the analysis. The least squares function through the points is positive, suggesting evergreen trees do have a positive marginal impact upon scenic beauty. But, consistent with the results of the general model, this relationship is not supported by statistical significance or a high R^2. It suggests that each 10 square feet of basal area in evergreen trees may contribute to scenic beauty by about 2 percent of its possible positive range, but an analysis of forests with more such trees would be more conclusive.

Even-aged Managements

Shelterwood harvest rotations are the even-aged management of choice among the hardwood forests sampled in this study To estimate the flow of scenic beauty from such rotations, forests were sampled from several points in time along this management program. Naturally, these forests varied a bit in site quality, species composition and exact historical development. The intent was to obtain a sample of the general appearance of forests throughout such rotations for the respondents to judge for scenic beauty. The resulting RSBE's are plotted against forest age in Figure 7 either as small circles or with the "S" symbol. A 110 year rotation is illustrated because that is the average time to culmination of mean annual increment among the forests sampled in this study. A solid-line curve is fitted through the sample points along this rotation to roughly estimate the scenic flow from it. While the methods employed here do not permit a calculation of average or total scenic beauty flow from this rotation, the results do indicate the degree to which a shelterwood harvest impacts scenic beauty, the rate at which perceived attractiveness recovers, and the portion of the forest's life with relatively high (RSBE > 70) scenic beauty.

Two forests were also sampled from an even-aged shelterwood rotation that had been pre-commercially thinned at around age 50. These are also plotted in Figure 7 with the symbol "T" and the scenic beauty flow from them estimated with the broken line. Based upon this limited evidence, as well as that regarding numbers of small and big trees in the general scenic beauty model, these thinnings increase the scenic beauty flow from such forests slightly after they are made until harvest.

The other even-aged management option commonly pursued on the hardwood sites sampled in this study is clear-cutting with the resulting establishment of aspen (*Populus tremuloides* or *grandidentata*) species. Six forests from this management program were sampled and these are plotted with an estimated scenic flow in Figure 8 for a 40 year rotation. The form of the solid-line curve for this rotation is similar to that in Figure 7 for an even-aged hardwood rotation. However, the frequency of harvests and their scenic impact are both greater, the recovery of scenic beauty after harvests may be slower, and the highest scenic beauty achieved is a lower. While the methods used to plot this flow also do not permit quantitative

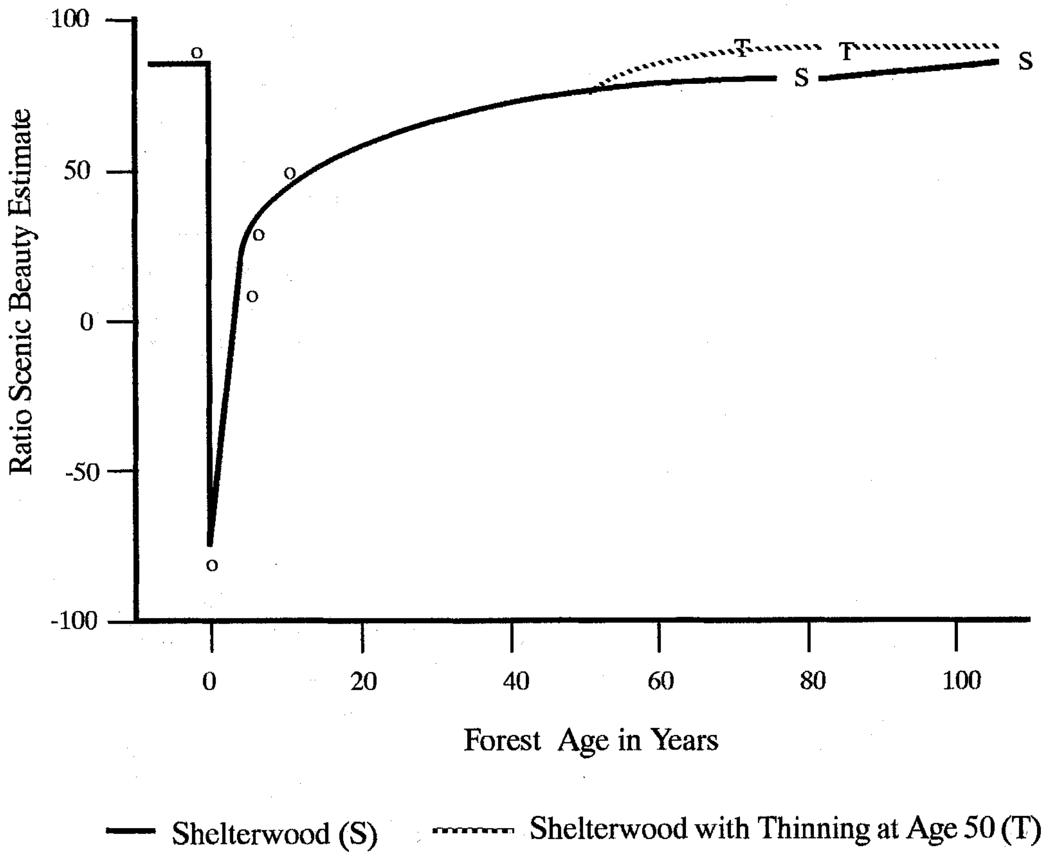


Figure 7. Scenic flows from even-aged hardwood rotations.

estimates of relative scenic flows from this management program, it seems safe to assert that it yields less scenic beauty over time than the shelterwood hardwood rotation.

There is a forest management option that might mitigate the low scenic flow from even-aged clear-cut aspen dominated rotations. This would be to allow shade tolerant fir trees to grow within the aspen forest to replace the aspen trees as they die or are selectively harvested. Forests which represented the deliberate execution of this management option were not found. However, two forests were sampled that had developed as aspen stands from clear-cuts- and in one case with some birch trees- which had been allowed to mature to the point that they were dominated by young to middle aged fir trees. The RSBE's for these are also plotted in Figure 8 with the "F" symbols and an estimated scenic flow from this management option plotted with the broken line. These rough results suggest that the conversion of aspen stands to fir dominated forests will yield greater scenic beauty flow over time than if such stands are clear-cut to begin a new aspen rotation. The results account for the perceived scenic beauty of forests containing a mix of mature aspen and young fir trees. They do not incorporate the effects of selectively harvesting the aspen trees while leaving the firs. They also do not reflect the long-term scenic flow from allowing the fir dominated forest to mature because this research did not explore the scenic beauty of non-hardwood fir or pine dominated forests.

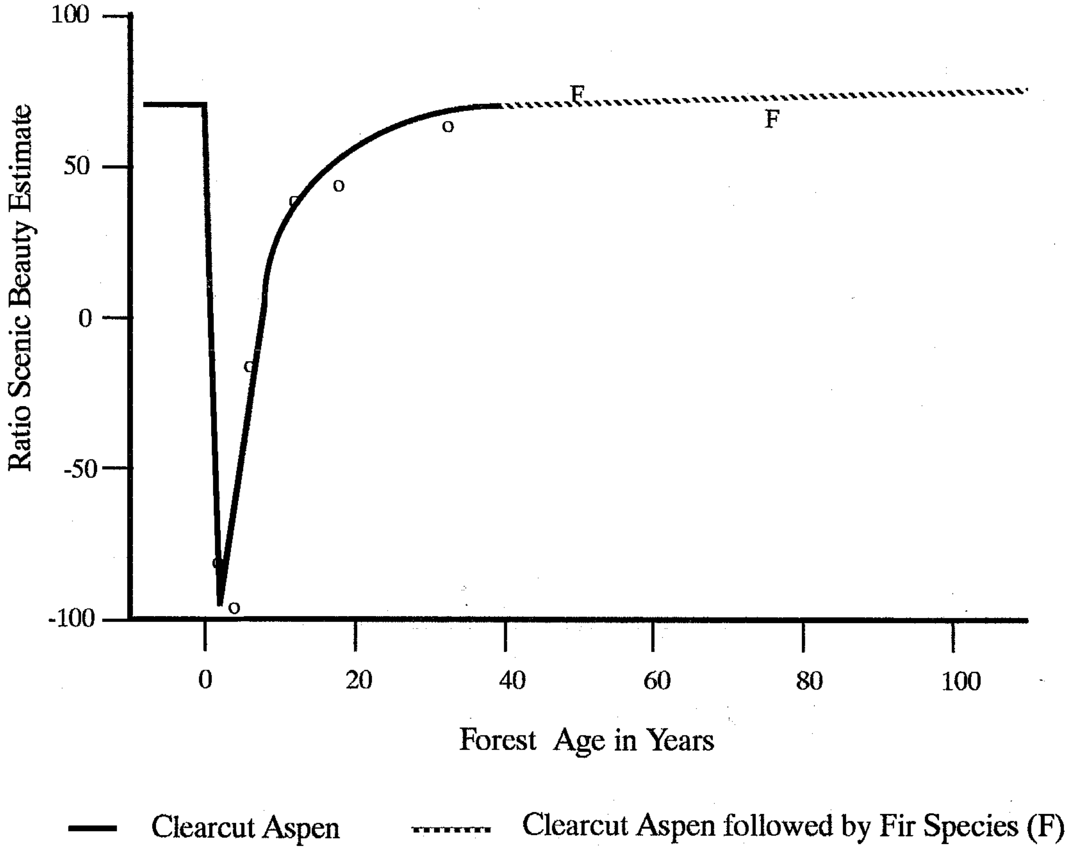


Figure 8. Scenic flows from even-aged softwood rotations.

Uneven-aged Managements

Uneven-aged forest managements are generally believed to be preferable in their scenic beauty yields due to the elimination of major harvests and the maintenance of a forest that more nearly simulates natural conditions. Old-growth forests are similarly viewed as aesthetically preferable and are often left or allowed to develop in areas where recreation is the dominant use. Consequently, forests were included in the sample to allow rough estimations of the scenic beauty flows from these management options. A beginning point forest was chosen to represent a 40 year old even-aged stand of average site index and species composition for northern Wisconsin hardwood forests.

Three experimental forests were then sampled to represent stages of successful conversion to an optimal growth-rate uneven-aged condition (Erdmann 1986). A 40 year old forest was chosen as the starting point for this analysis because that was the age when these sampled experimental forests began this conversion. One forest was also sampled that represented an established optimal uneven-aged forest that was assumed to be in a long-term stable appearing condition under selective harvesting (Arbogast 1957, Crow and others 1981). These forests RSBE's are plotted in Figure 9 with the "M" symbols, and an estimated scenic beauty flow

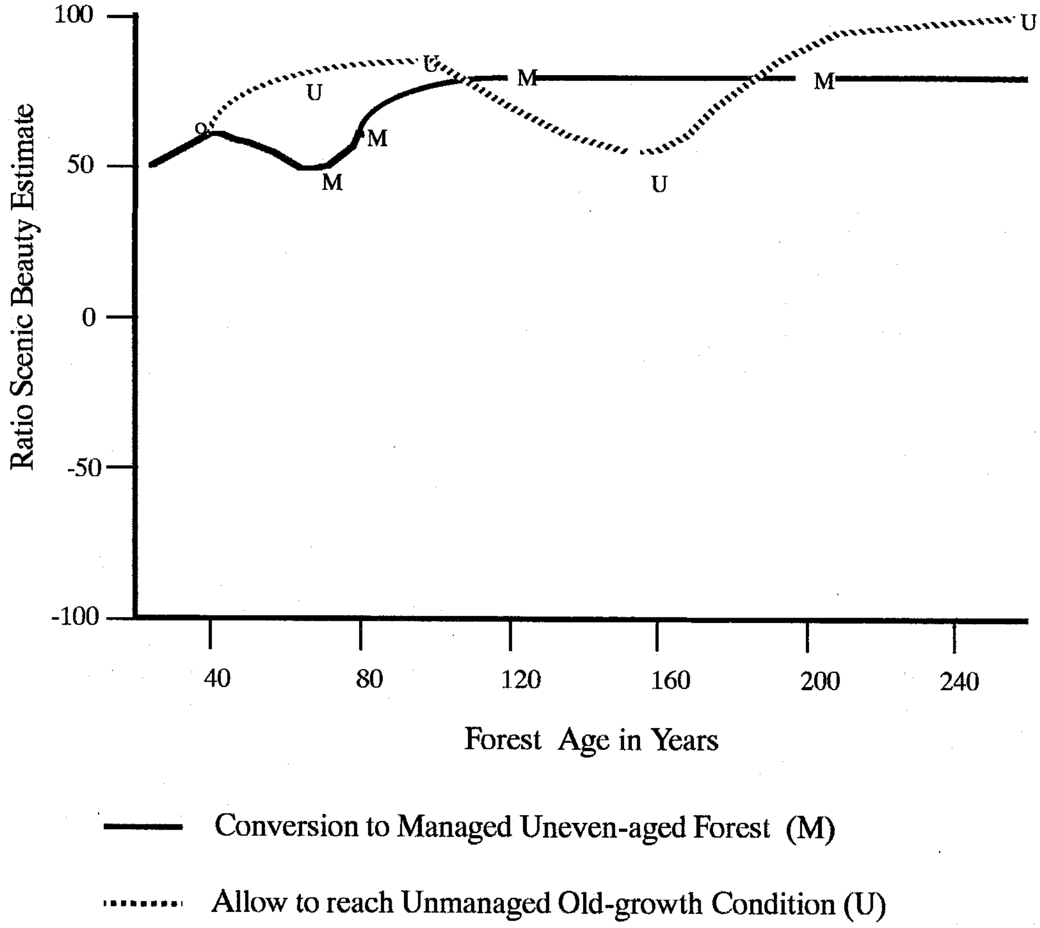


Figure 9. Scenic flows from uneven-aged hardwood forests.

from them is plotted as the solid line. The resulting flow pattern indicates a period of about 20 years after thinnings to 75 square feet of residual basal area per acre when scenic beauty declines due to increased sapling and reduced pole sized tree numbers. After that time the forest grows in beauty to reach a long-term scenic beauty level comparable to that of a mature even-aged hardwood forest.

The same kind of analysis was done to roughly estimate the scenic flow from allowing a forest to attain an uneven aged condition through aging to an old-growth condition. The results appear in Figure 9 as "U" symbols for the sampled forests and the broken line for the flow of scenic beauty from this management option. The general pattern is the same as for a managed conversion to an uneven-aged condition. The differences are as might be expected. The final long-term level of scenic beauty achieved is considerably higher due to more large trees and fewer small ones. The time it takes for conversion to uneven ages through natural mortality is much longer and also produces a temporary decline in perceived scenic beauty. And, there is an early increase in scenic beauty with the maturation of the even-aged forest before natural conversion to uneven ages begins.

DISCUSSION

Critical Forest Attributes

The key finding in the analysis of critical forest attributes' relation to scenic beauty lies in the interpretation of the functional slopes found in Figures 1 through 6. All these slopes relate the value of their respective forest attributes to the same ratio scale of scenic beauty. Consequently, a decision maker can readily compare the scenic returns from changes in sets of forest conditions to be created or promoted through management. These relationships have each been carefully isolated as marginal relationships that apply after the effects of other forest attributes upon scenic beauty have been discounted. As a result, they can be applied with confidence that they are not likely to change from one forest context to another because the effect of each factor has not been commingled and confused with that of other forest attributes. Above all, by knowing the independent, stable, and commensurable magnitude of each forest attributes relation to perceived scenic beauty, managers can have a grasp of the subtleties of how forests take on scenic beauty rather than relying upon their general intuitive sensibilities that these relationships do exist in some rough and complex way.

The interpretation of these marginal impacts of forest attributes upon scenic beauty is dependent upon the set of choices for modifying forest conditions available to the forester in each situation. Consequently, it is difficult to make any generalizations about the scenic value of different attributes, particularly without accounting for the relative financial and resource costs that might be incurred in producing them in different forests. What can be summarized from these findings is that the following changes in the state of a forest all produce about the same marginal impact upon scenic beauty equal to 10 RSBE points, or 5 percent of the total possible range of hardwood forest beauty: 15 square feet basal area per acre in big trees, 30 square feet basal area in pole sized trees, 20 square feet basal area in birch trees, 50 square feet basal area in evergreen trees, a reduction of down wood by 1,000 cubic feet per acre, and a reduction of 1000 saplings per acre. To the extent that these variables' stepwise explanation of variance in the general regression model indicates their relative importance in producing summer scenic beauty, the removal of down wood is the most valuable scenic management, followed by the avoidance of many saplings, and then the retention of big trees. For managers seeking to maximize the scenic beauty of important recreational forests, all these variables (with the possible exception of more evergreen trees) should be maximized within silvicultural constraints.

Management Programs

The results found in Figures 7 through 9 showing flows of scenic beauty from alternative long-term management programs are of critical interest to hardwood forest managers. They are useful in the same way that other informed long-term expectation for forest products are, such as those for expected wildlife habitat values. They show estimated flows that can be generally anticipated, and as such are only approximate. This is because they are based upon only a few representative forests from a management program over time and upon only a rough fitting of curves through these few points. Further research can yield more accurate estimates of scenic beauty flows from hardwood forest management programs by simulating the development of forests with computer programs such as STEMS (Belcher 1981) and applying the general scenic beauty model shown in Table 1 to the resulting simulated forest conditions to identify flows of scenic beauty over time.

Within the limitations of the accuracy of these scenic beauty flow estimates, several expected findings can be summarized. Uneven-aged managements do yield higher long-term average scenic beauty values, and, among these, old-growth hardwood forests evidently yield the most beauty beyond the age of 200 years. Among even-aged managements, those that involve longer rotations yield the highest long-term average scenic beauty values, including successional management programs such as allowing fir trees to replace aspens. The evidence also suggests, and is corroborated by the general model, that management programs that reduce numbers of small trees and increase basal area in large trees over some of the forest's life yield greater long-term flows of scenic beauty. Because the flow curves in Figures 7 through 9 were fitted in places by eye with these kind of expectations in mind, these results should be interpreted with some caution. Only further research simulating forests' growth or with more sample forests for each program can assure the validity of these and more specific findings.

CONCLUSIONS

Foresters have come to rely on scientific information to aid them in gaining the production of a variety of resource values from the forests they manage. The results of this study should aid those working with hardwood forests to do so also for the production of scenic beauty. They provide the kind of simple relationships and general expectations of future forest production rates that can be most useful in making decisions to enhance the scenic beauty of hardwood forests. Two kinds of information have been produced for the first time. First, the relative marginal scenic effects of key forest attributes have been isolated by discounting for the effects of other attributes across a sample of forests. These key positive scenic attributes are the basal area of large trees, a reduced quantity of down wood, the number of pole sized or birch trees, and a reduced number of small trees. Second, the scenic flow of alternative general forest management programs have been roughly estimated for comparison of even-aged, uneven-aged and alternative managements for hardwood sites. These rough estimates suggest that the greatest long-term scenic beauty flow may be obtained from allowing forests to reach an old-growth condition, followed by an uneven-aged management program, a shelterwood management with thinning, and then the same without thinning. Lower scenic beauty flows might be expected from a clear-cut aspen rotation allowed to progress into a successional fir forest or a much lower flow from a simple clear-cut aspen rotation. With this information, and that produced by further research improving the scenic flow results, the scenic impact of management choices in multiple-use hardwood forests need not be left to guess-work. Decisions can be better substantiated and documented to assure the continuous provision of enjoyable landscape experiences in hardwood forests.

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