Michael J. Meitner
Terry C. Daniel

# Vista Scenic Beauty Estimation Modeling: A GIS Approach

Abstract:

"Natural scenic beauty" is a concept that National Forest Managers must grapple with continuously when it comes to planning and decision making for the future of our forests. This resource has been difficult to define and has been the subject of over twenty years of research and development effort. Even more complex, are the vista perspectives, where in the viewer is typically elevated above the forest canopy and the view extends over relatively large expanses of forest landscape. This special case requires sophisticated techniques that take into account the levels of precision, reliability, and validity necessary to support public land management decisions. This paper discusses the components required for a GIS-based, "3-dimensional" prediction model for vista scenic beauty, including, 1) determination of significant viewpoints, 2) procedures for viewshed area specification and analysis, 3) defining the locus of vista scenic beauty (landscape or viewpoint), 4) the definition and computational methodology of relevant georelational landscape features, and 5) the statistical model used to generate predicted values.

## Introduction:

This paper details one component, the *vista scenic beauty estimation modeling* of the Scenic Beauty Management System, a conceptual model for a system to support planning and management of scenic beauty on National Forest lands. The primary role of the scenic beauty model is to translate forest conditions, existing and projected, into precise and reliable quantitative indices of scenic beauty. In addition, the system would provide guidelines for and assessments of alternative management designs for achieving specified forest scenic beauty objectives. Quantitative models and calibrated visual representations will be provided for communicating projected forest conditions within the multi-resource, interdisciplinary planning context, and with concerned publics/stakeholders, (Daniel, 1996) .

The term scenic beauty is intended to capture the central aspects of what has been labeled as *visual quality*, *scenic quality*, or *visual aesthetic value* (*-resource*, *-quality*). By whatever name, scenic beauty has long and consistently been recognized as an important resource of the National Forests. NEPA and NFMA both require the USDA Forest Service to incorporate "natural scenic beauty" in the management of public lands. Moreover, any broad survey of the American public will invariably identify scenic beauty as among the most important desires and concerns regarding the National Forests. Thus, a system for managing scenic beauty--i.e., for identifying, assessing, evaluating, projecting, manipulating and monitoring scenic beauty--must be a key component of any responsible forest planning and management system.

While scenic beauty in general is of interest, this paper will focus on outlining the procedure for the quantification of scenic beauty from a vista perspective. Vista perspectives are characterized by scenic overlooks, locations that offer relatively extensive views, as across a valley or over a river, lake or meadow. The viewer is typically outside the canopy of the forest and the depth of view may be measured in hundreds of meters. Breadth of views may extend up to 360-degrees, with both landforms and vegetation cover (especially when near the viewer) potentially restricting the view. Some parts of the viewshed (visible area) of a vista may be substantially below the height of the viewer and other parts may be well above the viewer. All of these characteristics of the vista are issues that must be dealt with if a predictive model is to be successful.

Modeling vista scenic beauty has typically focused on individual scenes, such as the view captured by a camera with somewhere between a 35 and a 55 mm lens (Buhyoff, et al, 1982; Shafer, 1964; Shafer & Richards, 1974; Vining, et al ,1984). These types of models are typically referred to as *picture plane* models. Originally, the unit of analysis for this project was going to be the vista as a point location, but because of the inability to validate this approach due to funding limitations we will define the vista as limited by view angle similar to a picture. Therefore, at any one vista point there will invariably be multiple vista viewsheds for which the model will attempt to predict a value. Variables found important in the picture plane models include presence and height of mountains, percentage of the scene that is covered by forest canopy, presence and size of water features (lakes or streams) and other relatively large scale land cover variables. These factors are commonly determined by placing a grid over the picture and manually counting the number of cells that contain the attribute of interest. The effects of all of these land cover variables differ depending upon the distance from the viewer (foreground, midground, background) and probably upon the visual aspect (angle of intercept of the line of sight with the main axis of the feature). Vista scenic beauty, then, has been found to depend upon the particular features present in the view, the pattern and inter-relationships among those features and whether these features and patterns occur close to or distant from the viewer (i.e., in the for-, mid- or back-ground of the scene).

Thus, vista scenic beauty is tied to the features of the landscape and to the particular location (the viewpoint) from which that landscape is viewed. It is impossible to refer to the "inherent" vista scenic beauty of any given landscape feature without specific reference to the viewpoint(s) from which it is viewed. Features that make an important positive contribution to scenic beauty from one view point may not be visible at all from another viewpoint, or may even have a negative effect on other views. Thus, the "scenic beauty" of a given landscape feature is conditional upon the viewpoint(s) from which that feature can be viewed. In some contexts it may be meaningful to refer to the scenic beauty of a feature, based on its contributions to the multiple viewpoints from which that feature can or might be seen, but for the purposes of this project the I will not attempt to present how that would be done. Suffice to say that once the viewsheds are quantified in terms of scenic beauty, it would be relatively easy to reverse one's thinking and predict values for objects.

These concerns offer an additional layer of complexity that differs from the typical near-view perspective of scenic beauty from which vista modeling draws much of it initial framework, but the underlying concepts and some of the procedures are the same. The most successful approaches to assessing and projecting near-view scenic beauty have been based on the public perception or "psychophysical" model. This technology has been well tested and its reliability, validity and utility confirmed in numerous studies (Brown & Daniel, 1986; Buhyoff, et al , 1986; Daniel, et al, 1977; Daniel & Schroeder, 1980; Zube, et al, 1975). Scenic Beauty Estimates are obtained by presenting representative samples of individuals with color slides of the forest in question and asking them to rate those slides according to their "natural scenic beauty" on a ten point scale. These raw scores are then transformed by statistical procedures, outside the scope of this paper, into Scenic Beauty Estimates. Those estimates will then be related through multivariate statistical techniques to inventoried or estimated forest features (numbers, sizes and species of trees, volumes of downed wood, shrubs, grasses, etc.) to create quantitative scenic beauty prediction models. By design, these quantitative models will take as input the biological and physical forest features. Thus, as future conditions of the forest are projected by the biological models, estimates were provided of the associated changes to be expected in perceived scenic beauty indices (Brown & Daniel, 1984; Daniel & Boster, 1976).

The goal of this paper is to specify in detail the explicit structure of a model that is capable of predicting scenic beauty values based on data associated with a view from a particular vista location. Specifically, to develop and test statistically-based *vista scenic beauty estimation*assessment methods and prediction models for restricted (mid-range) and panoramic views characteristic of forest landscapes in visually sensitive areas of the Dixie National Forest. While much research has been undertaken over the last 15 years in the development, validation and subsequent refinement of the SBE models for the nearview perspective, very little effort has been expended on modeling vista perspectives, and no adequate models exist.

Opportunities for vista scenic beauty modeling efforts are greatly enhanced by modern Geographic Information Systems technology. In particular, GIS overlay and spatial modeling techniques can be combined with viewshed analysis functions to develop bio-physically based models. As discussed previously, vista scenic beauty estimations must be modeled on a viewpoint basis. Thus, the area that is visible from a viewpoint must be made explicit and a viewshed must be specified. Furthermore, changes in the bio-physical landscape features, such as; topography, vegetation cover, streams and lakes that fall within the viewshed of a designated viewpoint, along with contrasts, shapes and patterns of these features, within the visible area (viewshed) for a given viewpoint would serve as the independent variables in quantitative models of vista scenic beauty. Relevant landscape features will have to be geo-spatially referenced both in terms of their distance and azimuth relative to the viewer (viewpoint), as well as their extents, distributions and interrelationships within the viewshed. Because detailed three-dimensional, geographically distributed landscape features are the logical input parameters for such a model, a GIS platform is necessary for the adequate spatial analysis of such complex variables.

A great deal of thought must be put into the creation of such a vista model. Independent variables must be chosen from the multitude of possibilities to serve as predictive parameters in our statistical model and as with any statistical model one runs the risk of including too many variables and ending up with a model that merely capitalizes on chance. Therefore we must seek to discover a more parsimonious subset of the larger set of possible variables that we hypothesis to explain our dependent variable of interest, *vista scenic beauty estimations* This paper serves the purpose of delimiting a concrete target model through which the process of hypothesis testing can begin and eventually by the process of model refinement, the solidification of a final product for decision management will emerge.

## Methodology:

A stratified sample of 24 viewpoints were selected from the possible set of 70 total viewpoints in the Dixie National Forest based primarily on the availability of data for surrounding forest stands. A stand is loosely defined by the Forest Service as a predominantly homogeneous, polygonal area of vegetation. At each viewpoint a series of sixteen photographs were taken, (image 1) in order to accurately represent a 360-degree panorama view of the location. The photographs from the sampled vista viewpoints were shown to representative volunteers, ratings were collected and scenic beauty indices were computed for each view from a vista. Reliability measures indicate a high level of agreement among observers and the viewsheds selected represent a significant proportion of the range of scenic beauty values.


Image 1: A typical mid-range vista

For the sake of simplicity in this preliminary analysis only one of the 16 views from each of the 24 vista points were included. The orientation of these views were systematically selected so that the resulting viewshed was one that contained reliable stand-level data. Each view was defined by its point location, (X, Y, and 1.68 meter offset from the extrapolated surface location) and orientation information, defined by two angles of azimuth and two vertical angles. Since a 50mm lenses was used to take the photographs the view was defined as 40 degrees of visual angle horizontally by 27 degrees vertically, therefore a picture taken pointing due north would be defined in the visibility command by the following parameters: offsetA = 1.68, azimuthA = 340, azimuthB = 20, vert1 = 14, and vert2= -13. The parameters offsetB, radius1, and radius2 were left set to their defaults. Visibility coverages were then calculated for all the views using 30 meter USGS DEM data concatenated with the stand height data derived by the forest service to produce a DEM representing the canopy of the forest, as the *in lattice*. "Projectcompare" was set to full so that the curvature of the earth and atmospheric distortions were taken into account in the calculation. The output coverages were polygonal with the frequency of observation specified as the visible-code of the polygons. These were then unioned with the original polygonal stand coverage in order to determine the underlying distribution of stands that made up the viewshed. A frequency table was then created so that the area represented by each of the stands in the viewshed could be totaled and converted to percentages of the total area of the viewshed.

The percentage of area was the variable used to relate the viewsheds back to the bio-physical stand data collected by the Forest Service. Each viewshed was then described by the weighted average of stand information visible to the observer from the point and orientation specified. In other words, viewshed 1, which is comprised of 30% stand A and 70% stand B, would be represented by .3 * (# of aspen, # of spruce/fir, etc.) + .7 * ( stand B's data). These weighted sums would then be used to calculate average percentages of tree type represented. This allowed us to begin to build multiple regression models to predict the scenic beauty estimates of the commensurate viewsheds.

# Conclusions:

The preliminary model, SBE = 6.025892 + 1.06729e-05 (Total Area Seen) + -.014715 (%Spruce/Fir) + .010804 (%Aspen) - .007154 (%Dead Trees) - .012179 (%Meadow) + .070320 (# of Stands in the view), yields a R squared of .34, which unfortunately is not significant. As the modeling effort continues we expect to see this increase and move beyond significance, but there are many problems that still need to be overcome. The greatest of which is the fact that the calculation of viewshed areas is somewhat dependant upon chance. The 30 meter resolution of the input lattice causes the creation of sliver polygons when this layer is unioned with the polygonal stands layer. This leads to a situation where the areas of stands in a particular viewshed are arbitrarily specified based on the view point's location along with the stand boundaries, in reference to the cells of the grid used. One possible solution to this problem that we are presently pursuing is the idea of the percentage of the stand seen as being represented by the length of the arc of the leading edge of the stand bounded by the viewshed. This would eliminate a great deal of measurement error in the calculation of the percentages of represented stands, which in turn degrades the data driving the modeling procedure, causing the relationships to be muddied.

Ultimately, we would like to take into consideration the relative densities of the stands, but because approximately half of our stands currently depend on coarse GAP data it is impossible to compute average viewshed tree densities. As more cases are introduced it will be possible to minimize the number of viewsheds dependant on the GAP data, therefore increasing the resolution of the underlying data. This information is also crucial to the approximation of textural information contained in the view which may also be of importance. The incorporation of a distance weighting scheme in order to account for inevitable visual differences of near and far objects is also a variable we would ulitimately like to include. As this ongoing process continues to evolve a more significant and robust model will emerge to fullfull the needs of Forest and other land managers so that they may better administer the duties with which they are charged.

# References

Brown, T.C., & Daniel, T.C. (1984). *Modeling forest scenic beauty: concepts and application to ponderosa pine*. USDA Forest Service Research Paper RM-256. Fort Collins, CO: Rocky Mountain Forest and Range Experiment Station. 35p.

Brown, T.C., & Daniel, T.C. (1986). Predicting scenic beauty of forest timber stands. Forest Science, *32*, 471-487.

Buhyoff, G.J., & Wellman, J. (1980). The specification of non-linear psychophysical function for visual landscape dimensions. Journal of Leisure Research, *12*, 257-272.

Buhyoff, G.J., Hull, R.B., Lien, J.N. & Cordell, H.K. (1986) Prediction of scenic beauty for southern pine stands. Forest Science, 32:769-778.

Buhyoff, G.J., Wellman, J.D., & Daniel, T.C. (1982). Predicting scenic quality for mountain pine beetle and western spruce budworm damaged forest vistas. Forest Science, *28*, 827-838.

Daniel, T.C. (1996). The scenic beauty management system: a decision support tool for forest ecosystem management. Unpublished Manuscript.

Daniel, T.C., Anderson, L. M., Schroeder, H. W., & Wheeler, L. W., III. Mapping the scenic beauty of forests. Leisure Sciences, 1977, 1, 35-51.

Daniel, T.C. & Boster, R.S. (1976). *Measuring landscape aesthetics: the scenic beauty estimation method.* USDA Forest Service Research Paper RM-167. Fort Collins, CO: Rocky Mountain Forest and Range Experiment Station.

Daniel, T.C., & Schroeder, H.S. Predicting the scenic beauty of forest landscapes: The scenic beauty estimation model. In G. Elsner & R. Smarden (Eds.) *Our National Landscape*, USDA, Forest Service, 1980.

Shafer, E.L. (1964). *The photo-choice method for recreation research.* USDA Forest Service Research Paper NE-29. Upper Darby, PA: Northeastern Forest Experiment Station.

Shafer, E.L., Hamilton, J.F., & Schmidt, E.A. (1969). Natural landscape preferences: A predictive model. Journal of Leisure Research, *1*, 1-19.

Shafer, E.L., & Richards, T.A. (1974). *A comparison of viewer reactions to outdoor scenes and photographs of those scenes.* USDA Forest Service Research Paper NE-302. Upper Darby, PA: Northeastern Forest Experiment Station.

Vining, J., Daniel, T. C., & Schroeder, H. W. Predicting scenic quality in forested residential landscapes. Journal of Leisure Research, 1984, 16(2), 124-135.

Zube, E.H., Pitt, D.G., & Anderson, T.W. (1975). Perception and prediction of scenic resource values of the Northeast. In E. Zube, R. Brush, & J. Fabos (Eds.) *Landscape assessment: values, perceptions, and resources*, pp. 151-167. Stroudsburg, PA: Dowden, Hutchinson, & Ross, Inc.

Michael J. Meitner
Graduate Student
Environmental Perception Laboritory
Department of Psychology
University of Arizona
Tucson, AZ 85721
E-Mail: Meitner@U.Arizona.edu
Phone: (520) 621-9263
Fax: (520) 621-9306

Terry C. Daniel
Professor of Psychology and Renewable Natural Resources
Environmental Perception Laboritory
Department of Psychology
University of Arizona
Tucson, AZ 85721
E-Mail: Danieltc@ccit.arizona.edu
Phone: (520) 621-7453
Fax: (520) 621-9306