Using Computer Visualizations to Help Understand How Forests Change and Develop

Brian Orland and Cenk Ursavas
Penn State University, State College, PA (boo1@psu.edu)

Introduction

Trying to understand the effects of alternative management practices over long periods puts an enormous burden on decisionmakers or the public when making decisions. One means of easing the burden is to develop a range of precise, carefully developed illustrations of the important characteristics of the anticipated changes. Computer visualizations can be a powerful tool for such illustrations. The significant advantage of the computer image is that it is readily manipulated to represent the impact of management activities on forest growth.

The work described in this paper offers some guidance toward making the power of the visual world a valid and reliable surrogate for the real world that we manage. As part of a larger study (see Daniel and Vining chapters for other aspects), computer visualizations were developed—using the kind of data a forest manager will typically be able to access—to clearly show the development of the forest over time and in response to different management actions. This paper will discuss four aspects of the process managers need to consider in using visualizations and then provide a specific example of how these issues were addressed in our study.

Key Findings: Making Visualizations Useful to Forest Managers

Managers need to consider four issues when using visualizations:

- **Visual realism:** To what degree does the image match the real world?
- **Information-driven visualization**: Can it be shown that the image is an accurate representation of forest conditions?
- **Change over time:** Can it show an essential component of forest landscape management, change over time?
- **Challenges in using visualizations**:
    - Using sampled data
    - Data availability and quality

Visual Realism

Using digital or scanned photographs, it is feasible, and quite easy, to use image editing tools such as Adobe Photoshop® to create highly realistic images of landscapes modified by management and changing over time. Figure 1 provides an example from a study of forest harvest practices (Orland *et al*. 1994). The visualizations were created by referencing a large library of photographs of known ground conditions that provided visual templates, but most projects do not have the luxury of such libraries. While the images themselves are convincing representations, the visual changes are not necessarily connected to any underlying information such as forest density, species mix, diameter, or terrain.

Figure 1.—Images representing attribute levels for variable "residuals in cut area"

Information-Driven Visualization

Generally, investigation of such complex issues as forest management requires that images accurately represent measured or predicted ground conditions. Some software developers have created tools that provide visual representations of forest inventory data. The Stand Visualization System (SVS) and Envision, a landscape-scale visualization tool, were developed by Robert McGaughey and his colleagues (McGaughey 2003), and SmartForest was developed by the author and his collaborators (Orland 2003). Both use USDA Forest Service forest inventory data to create visual representations of forest stands. In the former case, this is done at the scale of a 1- to 4-acre plot with no reference to the landscape context; in the latter case, this is done at landscape scale in the context of other stands and including the representation of topography.

Another necessity is a dataset with sufficient detail to show noncommercial or less important species beside the dominant forest types and including details of the shrub and herbaceous components of the forest. Each of these has significant visual impact, but requires that sufficiently detailed data are available. Such information is particularly important when discussing treatments to decrease fuel loads; studies have found that understory vegetation is an important component of scenic beauty ratings (Ryan 2005).

Change Over Time

As Figure 2 demonstrates, the necessity to consider change over time is a central aspect of forest management. To project the changes in biophysical components of the forest, the Forest Vegetation Simulator (FVS) (Dixon 2003) is one of a family of tools developed to enable forest managers to project future forest conditions. In wide use by forest management agencies, FVS and its derivatives are capable of modeling very complex growth processes. In the context of silvicultural and harvest operations, users can specify parameters for a range of forest operations including thinning and planting as well as major treatments anticipated for the study sites. The growth model takes into account overperforming and underperforming trees, as well as mortality among outcompeted or senescent trees, and includes natural regeneration of both commercial and noncommercial species.

Output data from FVS can be used by each of the visualization tools identified earlier to create images of the forest under a range of management scenarios and at time-steps into the future as specified in creating the FVS projections. The resultant images are a powerful tool for communicating the implications of management programs, especially to groups from multidisciplinary backgrounds where the visualization serves as a common meeting ground for their different understandings.

Figure 2.—Actual site conditions photographed in 2001 and 2003

Challenges in Using Visualizations

Visualization is especially challenging where trees and shrubs are recognizable as individuals of different species and are clumped or dispersed with respect to one another, yet the information gathered and projected about their growth and change is based on sampled data and statistically summarized. In foresters' terms the "stand" or "block" is a fundamental unit of forest management, each being defined as an area of relatively homogeneous forest of consistent topographical characteristics such as slope and aspect. The same conditions apply to urban and recreational forest, where management actions are taken on individual and recognizable trees, yet information about the forest is maintained as numbers of trees per acre, with little or no spatial information maintained at the tree-by-tree level.

One critical necessity at the heart of using such visualizations is to accept that the image is from sampled data and does not represent a real location—even though the visualization is sufficiently realistic to create a plausible sense of place. Users must accept that scenes are no more than surrogates for "the real world" and that all that is necessary in the context of a project such as this one is to ensure that the landscape behaves plausibly. Managers will need to constantly remind people to separate themselves from considering each location as "real."

The other closely related fundamental considerations are the availability and quality of the data used to develop the visualizations. FVS is a highly developed tool, but its capabilities are dictated by the completeness and accuracy of the input data. One thing that visualization is especially useful for is to show the errors and omissions in available data; in other scientific fields a principal use of visualization is in data verification. FVS is also a statistically derived numerical modeling tool—thus its projections have uncertainties associated with them. That uncertainty, while challenging to visualize, is nevertheless an important issue to consider when using visualization in decisionmaking. The realism of the visual imagery may create a false sense of confidence in what are, in fact, best approximations of what the future will bring (Orland *et al.* 2001).

Visual Case Study

On July 4, 1999, a powerful windstorm affecting the Boundary Waters Canoe Area Wilderness resulted in widespread forest blowdowns—areas of completely uprooted or snapped-off conifer and deciduous trees (USDA Forest Service 2000). The blowdown area is in northern Minnesota and across the Canadian border in western Ontario. The opportunity to monitor the recovery of this important area has resulted in forest inventory data of high quality, collected as part of an intensive inventory for ecological modeling (Gilmore *et al*. 2003). The data included the species and size of each stem more than 6 mm in diameter.

Using that data alone, it was possible to create very convincing images using SmartForest (http://www.imlab.psu.edu/smartforest)—a tool developed as a landscape-scale visualization tool capable of distributing forest stand data according to stand boundaries defined via the ArcGIS® Geographic Information System and over terrain derived from a USGS Digital Elevation Model. We will use SmartForest images as the basis for our discussion here, but the principles apply to images created using other visualization tools.

Figure 3.—In-stand photos and visualization: salvage area residuals

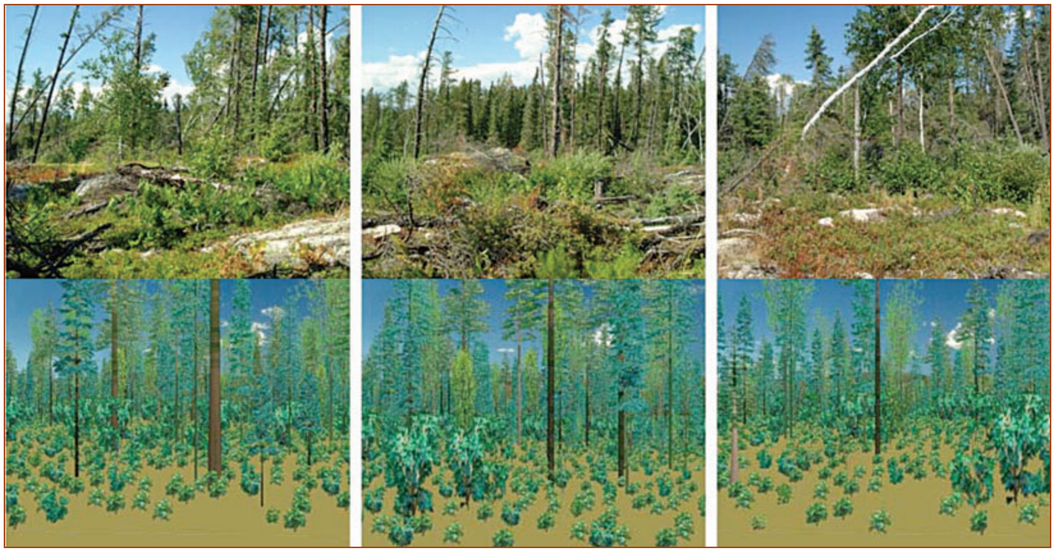


Figure 4.—In-stand photos and visualization: undisturbed, mature forest area

Figures 3 and 4 represent different forest conditions. It is evident that the computer-generated images lack the realism of the photographs. However, it is also evident that the distribution of large woody material within the immediate forest stand is similar in numbers, species, and sizes of trees—the component of forest management most likely to be impacted by policy changes.

Figure 5.—Tree component; with grass and half-density shrubs; and with full shrubs

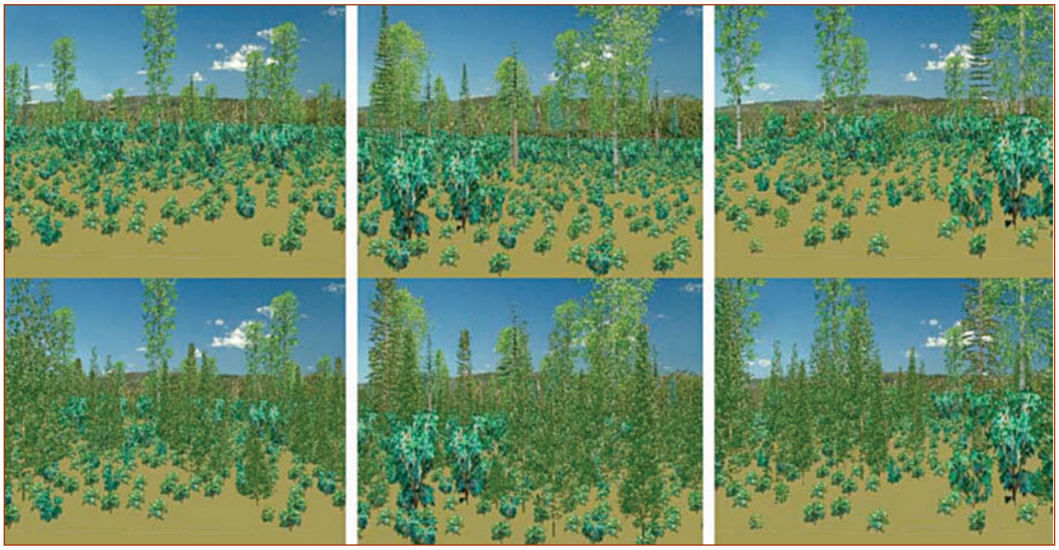
Much realism can be achieved with full representation of shrubs and grasses. Figure 5 illustrates the effects of adding those components to the scene. Just as in photographs of the real landscape, the addition of a vigorous shrub component to the visualization can be as visually devastating as it is in the real world.

The images in figure 6 show the early stages of recovery from a salvage operation in an area heavily impacted by the blowdown. The top images show the regeneration from natural seed sources; the lower images show the effect of deliberately planting a mix of red and white pines. Figure 7 shows representations (in years 2022 and 2052) of the planted forest conditions in figure 6. When we look at the first set of images, the impact of the pine planting is very clear and seen in the context of the residual hardwoods. In the "growth" images, individual trees can be tracked between the time-steps, although the major visual change is the density of the youthful growth.

In the instances visualized in figures 6 and 7, base data were available for those shrubs and forbs present in 2001, but growth and development data for groundcover and shrub species are generally not a component of the growth models. Although the resulting images of those components were thus not accurate to the anticipated conditions, if such detailed information had been available the improved validity of that aspect of the visualization might well mask changes in the major vegetative component—the trees—just as in the photographs of the real location. Figure 4 indicated the technical feasibility of creating accurate images of groundcover, given adequate data.

The resultant images were used in a survey (fig. 8) (Daniel, this volume) that was used to solicit public input on desirable management scenarios for a much-impacted forest in more than 200 face-to-face interviews. To express the passage of time represented in the image sets, they were shown as animations stepping viewers through five time-steps. They were also used by Merrick and Vining (this volume) to investigate what forest elements people pay attention to when determining visual preferences.

Figure 6.—Recovery from salvage: natural regeneration (top) vs. planting with pines



Note: Images show 2002 conditions.

Figure 7.—Growth: 2022 (top) and 2052 visualizations of the planting scenarios in figure 6

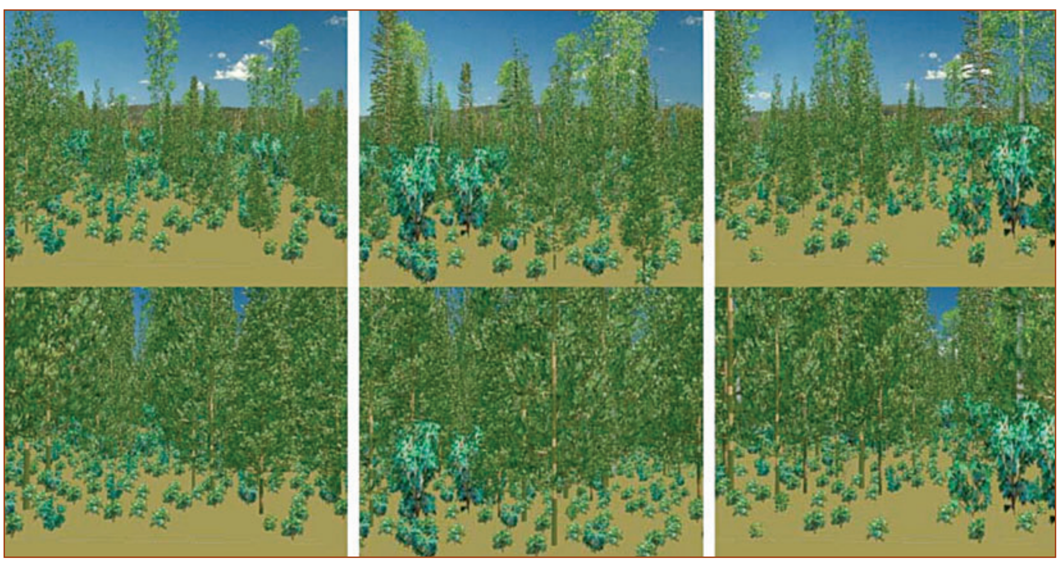
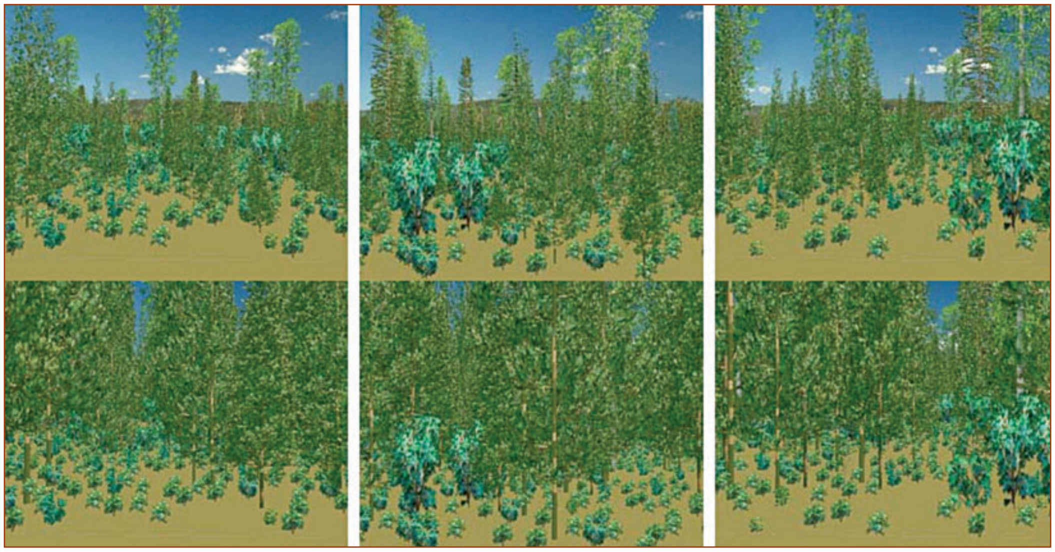


Figure 8.—Typical survey page



References

Dixon, G.S., comp. 2003. Essential FVS: a user's guide to the Forest Vegetation Simulator. Internal report. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Forest Management Center. 193 p.

Gilmore, D.W.; Kastendick, D.N.; Zasada, J.C.; Anderson, P.J. 2003. Alternative fuel reduction treatments in the Gunflint Corridor of the Superior National Forest: second year results and sampling recommendations. Res. Note NC-381. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. 8 p.

McGaughey, R. 2003. SVS—The Stand Visualization System. Portland, OR: U.S. Department of Agriculture, Pacific Northwest Research Station. [Available on line: http://forsys.cfr.washington.edu/ svs.html].

Orland, B., 2003. SmartForest—Interactive Forest Visualization. State College, PA: Penn State University, Department of Landscape Architecture. http://www.imlab.psu.edu/smartforest

Orland, B.; Budthimedhee, K.; Uusitalo, J. 2001. Considering virtual worlds as representations of landscape realities. Landscape and Urban Planning. 54: 139-148.

Orland, B.; Daniel, T.C.; Haider, W. 1994. Calibrated images: landscape visualizations to meet rigorous experimental design specification. In: Proceedings, Decision support 2001—resource technology 94; 1994 September 12-16; Toronto, ON. Bethesda, MD: American Society for Photogrammetry and Remote Sensing: 919-926.

Ryan, R.L. 2005. Social science to improve fuels management: a synthesis of research on aesthetics and fuels management. Gen. Tech. Rep. NC-261. St Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. 58 p.

U.S. Department of Agriculture, Forest Service. 2000. Gunflint Corridor fuel reduction: final environmental impact statement. Gunflint Ranger District. Grand Marais, MN: U.S. Department of Agriculture, Forest Service, Superior National Forest. 294 p. [Available on line: http://www.fs.fed.us/r9/forests/superior/storm_recovery/documents/Final%20Master%20Document%FEIS1.doc].