Forest Visualization for Management and Planning in Wisconsin

"It is difficult to imagine any significant natural resource management activity that does not rely to some extent on visual representations."

—*W.B. White (1992)*

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ABSTRACT

Participation by the public in the management process of public forested lands has led to innovation in the visual simulation of management options. So far, visualization technology has largely been used by researchers and consultants, not by natural resource managers themselves. A three-dimensional forest visualization system, developed for use by the Wisconsin Department of Natural Resources, incorporates a library of photographs of trees, snags, and even logging debris in an effort to depict forest management activities realistically. Managers need only limited training to quickly generate visualizations depicting a specific stand or an entire landscape in its current and potential future states under a variety of silvicultural treatments. We describe the components of the system so that it can be recreated for other regions.

Keywords: inventory; mapping; silviculture

Growing participation by the general public in forest planning requires that management agencies convey information about natural resource management and planning in an easily understandable fashion. Humans recognize complex patterns in quantitative data best by viewing them graphically (e.g., Tufte 1983). This is why visualization tools evolved to create 3D, color graphics showing estimated extents, locations, and severities of environmental changes (Orland 1992). Throughout the 1990s, several forest visualization systems were designed to achieve this, including INFORMS (White 1992), FMIS (Marshall et al. 1997), the Landscape Management System (McCarter 1997), and the Stand Visualization System of the USDA Forest Service (McGaughey 1998). The strength of each of these simulators lies in the simulation of stand growth and development, not in the realism of the visualizations.

Concurrently, terrain-modeling software that could render landscapes in three dimensions became commercially available. The ability of software packages—examples include LandForm, TruFlite for Windows, Virtual Forest, and World Construction Set (WCS)—to use scanned photographs of trees and other objects to populate their 3D terrains added to their realism (Rowe 1997). The strengths of these packages are in their realistic depiction of landscapes and, especially in the case of WCS, the ability to incorporate data from GIS.

During the past decade, access to and use of visualization technology has been mostly limited to the academic community, consultants, and landscape architects, but not natural resource managers. Our objective was to construct a computer visualization tool for the main forest types of Wisconsin to demonstrate current conditions and management scenarios. It is essential that such a tool simulate specific forest conditions, including topography, species composition and density, coarse woody debris, and understory conditions. Such a tool can be applied for various purposes, including education, extension, and as an aid in forest man-

Table 1. Tree image library.

Hardwood species	Images in dbh class 0–9"	10–19"	20"+	Clump
Ash, white *(Fraxinus americana)*	7	4	—	2
Aspen, bigtooth *(Populus grandidentata)*	7	2	1	—
Aspen, quaking *(Populus deltoides)*	11	2	—	—
Basswood *(Tilia americana)*	5	6	—	3
Birch, white *(Betula papyrifera)*	7	7	—	—
Birch, Yellow *(Betula alleghaniensis)*	2	2	1	—
Cherry, black *(Prunus serotina)*	6	2	—	—
Elm, slippery *(Ulmus rubra)*	2	—	—	—
Hickory, shagbark *(Carya ovata)*	2	—	—	—
Maple, red *(Acer rubrum)*	8	6	—	—
Maple, sugar *(Acer saccharum)*	24	8	2	1
Oak, black *(Quercus velutina)*	11	10	1	—
Oak, bur *(Quercus macrocarpa)*	1	2	1	—
Oak, northern pin *(Quercus ellipsoidalis)*	—	3	1	1
Oak, red *(Quercus rubra)*	7	10	6	1
Oak, white *(Quercus alba)*	1	4	1	—
Serviceberry *(Amelanchier sp.)*	2	—	—	—
Walnut, black *(Juglans nigra)*	1	2	2	—
Total	104	71	16	8

Coniferous species	Images in dbh class 0–9"	10–19"	20"+	Clump
Balsam fir *(Abies balsamea)*	8	1	—	—
Cedar, red *(Juniperus virginiana)*	2	—	—	—
Cedar, white *(Thuja occidentalis)*	2	—	—	—
Hemlock *(Tsuga canadensis)*	2	9	4	
Pine, jack *(Pinus banksiana)*	13	12	—	1
Pine, red *(Pinus resinosa)*	6	11	3	—
Pine, white *(Pinus strobus)*	12	8	7	—
Spruce, black *(Picea mariana)*	2	1	—	—
Spruce, white *(Picea glauca)*	7	7	—	—
Tamarack *(Larix laricina)*	—	1	—	—
Total	54	49	14	1

Other images	
Snags	21
Stumps	13
Course woody debris	22
Total	56

agement planning.

In this article, we present a regionally specific forest visualization system, based on commonly available forest inventory data and visualization software, and discuss the steps involved in creating it.

Approach and Results

To create our visualization system and customize it for Wisconsin, several components were required. First, we chose WCS version 6.0 (3D Nature, LLC) as our visualization software because of its ability to create visualizations at many scales, its use of real tree imagery to create realistic images, and its ability to incorporate data from geographical information systems. Second, a library of images of representative tree species commonly found in Wisconsin needed to be compiled. These were essentially the building blocks of our visualizations. Third, a library containing templates of representative forest types for the state was required. This library, based on Forest Inventory and Analysis (FIA) data, provided us with templates representing average conditions for several forest types commonly occurring in Wisconsin. Finally, we visualized commonly used management tactics for each major forest type in Wisconsin. Based on these libraries, new visualizations depicting a specific stand in its current and potential future states can be generated quickly.

Tree image library. Tree images were obtained by taking high-quality 2-by-2-inch slide transparencies of 317 tree specimens throughout Wisconsin *(table 1).* For each species, images were collected for several size classes and forms *(fig. 1a–d),* including open-grown and stand-grown trees, healthy and damaged trees, and so forth. For the visualization of forest stands, images of open-grown trees were avoided because they tend to branch at low levels and "bush out," creating an unnatural look. Conversely, stand-grown trees would be inappropriate in a representation of a savannah. To create realistic images of forest stands and management tactics, images of other objects were also necessary. These include stumps, snags, rocks, logging slash, coarse woody debris, understory plants, and other objects that would be found in a forest setting *(fig. 1g–m).*

The slides were scanned at high resolution (2,000 dpi) and the backgrounds were removed using Adobe Photoshop (Adobe Systems, Inc.) *(fig. 1e–h).* Scanning at high resolution was necessary to erase the background around the branches and foliage, thus producing a sharp image of the specimen only. Images were resampled to 72 dpi with a maximum 7-inch height and saved as Amiga IFF files, optimum for usage in WCS.

We also used Tree Professional 5.0 (Onyx Computing, Inc.), a software package designed to build 3D tree imagery to create 22 (6 percent) of our tree images *(fig. 1i, j).* Trees created in Tree Professional were used when no suitable tree image was available for a given species and size class (e.g., small-size classes of aspen or large-diameter yellow birch). These images were also sized to 72 dpi with a maximum height of 7 inches.

Forest type library. Species composition data for the ecosystem library were derived from the USDA Forest Service's FIA database. The Forest Service periodically collects forest inventory data in fixed plots maintained across the entire United States at a sampling density of one plot per 6,000 acres of forested land (USDA-FS 2002). We used FIAMODEL to compile FIA data (Pugh et al. 2002). The outputs from FIAMODEL are stand tables of species and size classes on a per acre basis. Stand tables were compiled for each FIA forest type and 20-year age classes. These were entered into WCS, creating a series of templates to reflect the average conditions of each forest type and age.

A total of 38 forest type templates were created within WCS, including aspen, oak, scrub oak, northern hardwood, birch, red pine, white pine, jack pine, and fir-spruce *(table 2)*. Each forest type was constructed at several age classes for 20-year intervals to demonstrate the current age structures of the forests of Wisconsin. We created stand tables that represented the average conditions across northern Wisconsin by age and forest type. Each forest type was visualized at the stand scale *(fig. 2a, p. 10)*.

Creation of imagery of current forest management practices. Within WCS, simulations of several silvicultural systems and treatments were constructed to demonstrate the common forest management practices for a given forest type *(table 3, p. 11; fig. 2a–f)*. Visualizations of each treatment were based on the ecosystem library templates, and treatments applied were only those consistent with common silvicultural practices as described in the state's *Silviculture and Forest Aesthetics Handbook* (WiDNR 2003). Included were clearcuts, seed tree systems, shelterwood systems, single-tree and small group selection, and commercial and precommercial thinnings. In images of harvests, each tree harvested was replaced with a stump or snag.

Each silvicultural treatment was created such that it could be adapted to show different cutting intensities and shapes of treatment areas, as well as species to be cut or cultured. This allows for the exploration and demonstration of many multiples of treatments within a given forest type.

Case study: The Black River State Forest. We chose an area within the

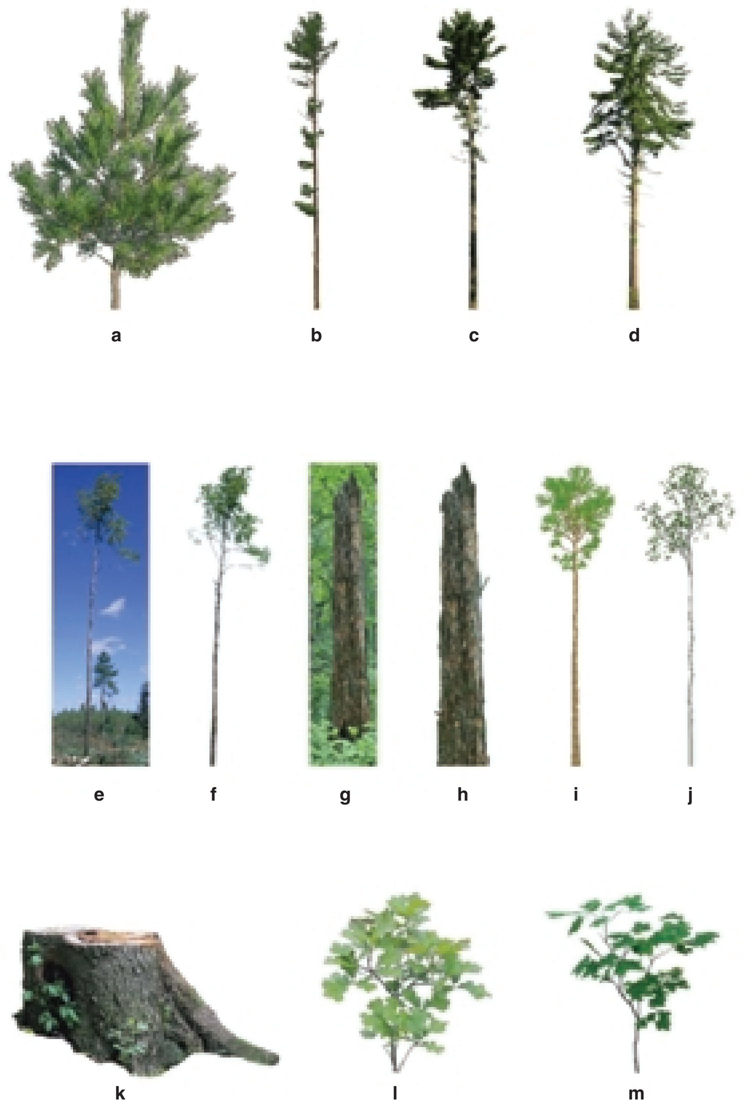

Figure 1. **Samples from the tree library: (a) eastern white pine *(Pinus strobus)* seedling; (b) 6 in. dbh by 60 ft; (c) 23 in. dbh by 86 ft; (d) 38 in. dbh by 108 ft; (e) quaking aspen *(Populus tremuloides)* isolated after logging; (f) same quaking aspen with background removed; (g) 20-foot snag; (h) same snag with background removed; (i) yellow birch *(Betula alleghaniensis)* 23 in. dbh by 82 ft created in Tree Pro™; (j) quaking aspen 1 in. dbh by 19 ft created in Tree Pro; (k) northern red oak *(Quercus rubra)* stump; (l) black oak *(Q. veluntina)* seedling; (m) sugar maple *(Acer saccharum)* seedling.**

Table 2. Forest type templates by age group (in years).

Forest types	0–20	21–40	41–60	61–80	81–100	101–120
Aspen	✓	✓	✓			
Paper birch	✓	✓	✓	✓		
Oak	✓	✓	✓	✓	✓	
Scrub oak	✓	✓	✓	✓		
Northern hardwood	✓	✓	✓	✓	✓	✓
White pine	✓	✓	✓	✓	✓	
Red pine	✓	✓	✓	✓		
Jack pine	✓	✓	✓			
Fir-spruce	✓	✓	✓	✓		

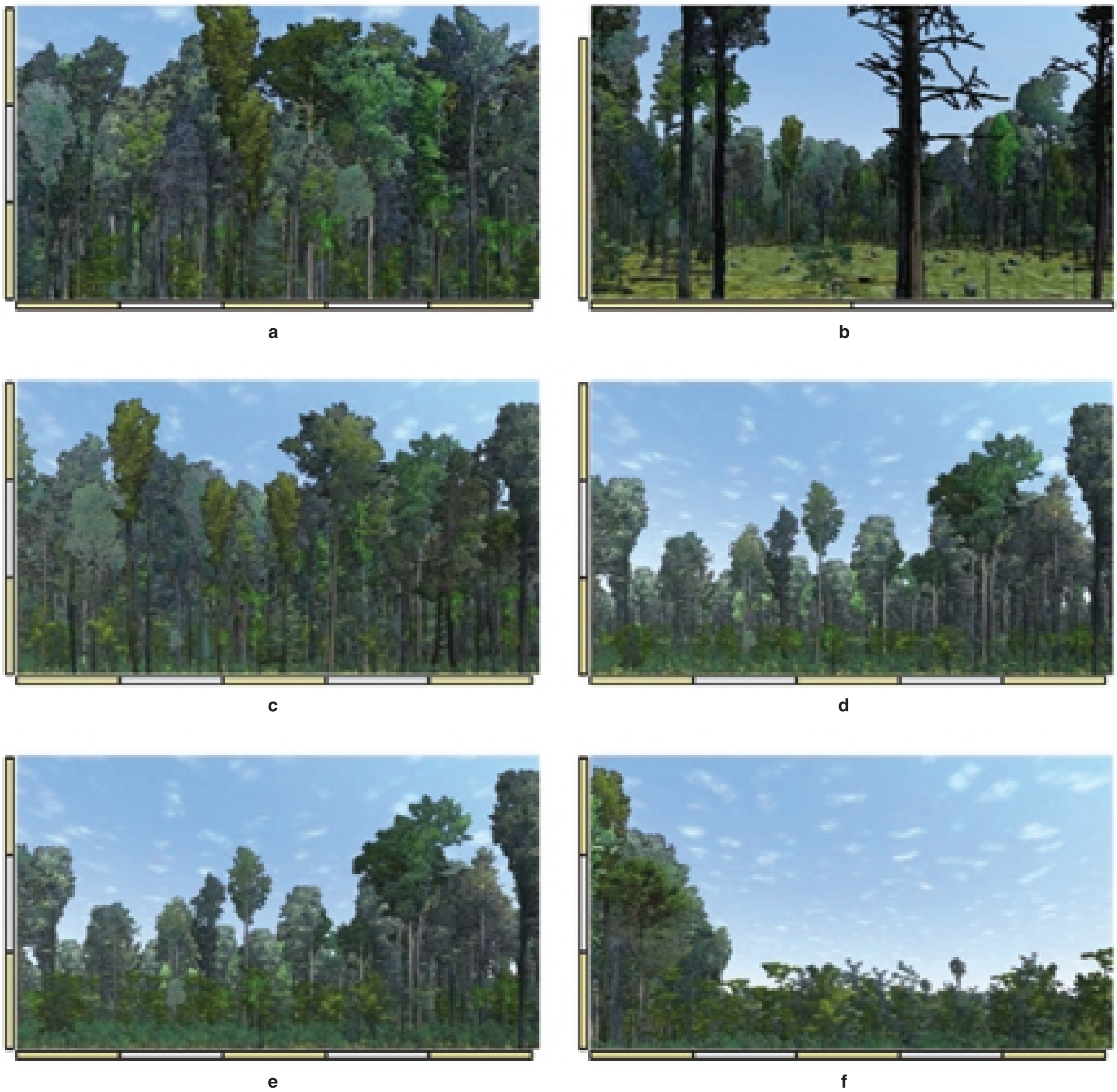

Figure 2. **Two northern hardwoods management scenarios: (a) 110-year-old northern hardwood stand; (b) 20 percent of basal area removed, in six to eight small patches per acre, each approximately 30 feet in diameter; (c) same stand from another angle; (d) 70 percent of basal area removed, leaving residual shelterwood overstory; (e) after five years of regeneration; (f) residual overstory removed. *Note:* Scale bars represent 10 meters each.**

Black River State Forest to demonstrate how our visualization system could be adapted to a specific location *(fig. 3).* We used forest inventory data supplied by the Wisconsin Department of Natural Resources as a GIS database that includes forest stand boundaries. This GIS dataset provided information on primary, secondary, and understory species, as well as age and height. It did not supply detailed stand information, so we also utilized FIA data from plots within Jackson County, where the forest is located. Using the methods described above, we created stand tables representing the average forest conditions by forest type for Jackson County and visualized the current condition. Visualizations of conditions after harvest were created based on current management guidelines.

Visualizations were created at the near-landscape scale for nine contiguous stands representing approximately 1 square kilometer. Typical silvicultural treatments were applied to those stands as recommended by the *Silviculture and Forest Aesthetics Handbook* (WiDNR 2003): Four of the 12 stands were harvested, and eight stands were left unchanged *(fig. 3).*

Discussion

We created a system that can demonstrate the visual impacts of forest management decisions at many different scales within Wisconsin. This system is user-friendly; managers without extensive computer knowledge can easily create their own imagery. The system is linked to a GIS so that the available forest survey data can be incorporated. And we provide a mechanism to augment those data from other sources (i.e., FIA) when necessary. Our visualization system was designed specifically for Wisconsin, but it would be relatively straightforward to develop similar systems for other regions. Here we discuss the issues involved with creating such a system.

The tree image library required the largest investment of time. We spent two summers gathering images and are still adding tree photos. To simulate a forest stand, it was necessary to obtain images of stand-grown trees and remove their backgrounds so that they could be rendered properly within WCS. This was a challenge: By definition, stand-grown trees are rarely isolated. We addressed this problem by taking images during harvests or thinnings, when single trees could be left standing until the image was taken *(fig. 1e, f)*. Additional images were obtained in areas harvested using shelterwood systems, seed tree, or clearcuts with reserves. After each photo was scanned, it took 30 to 60 minutes to remove the background. Images of snags and stumps were simpler to work with because the colors and mass of these objects made them generally easy to isolate from surrounding green foliage *(fig. 1g, h)*.

To obtain tree images, we worked with the Wisconsin Department of Natural Resources as well as private foresters to identify suitable forest stands that had been recently harvested. On a given day, we would spend on average three hours driving to and from suitable locations and four hours scouting suitable trees and photographing them. One day would yield an average of 20 usable images.

Partly cloudy skies provided the best light for photography. Bright sunlight illuminated the trees on one side, and when rendered in WCS, such images led to an unnatural appearance because the lighted side of neighboring trees might be different. Completely overcast skies produced images of trees that appeared flat and colorless. Windy conditions sometimes resulted in blurred images.

Images created with Tree Professional could be created in 10 to 20 minutes. Once an image was created in Tree Professional, it could be easily ma-

Table 3. Management applied to forest types.

Forest types	Clearcut	Clearcut with reserves	Group selection	Single-tree selection	Shelter-wood	Seed tree
Aspen	✓	✓				
Paper birch	✓				✓	
Oak	✓				✓	
Scrub oak	✓				✓	
Northern hardwood			✓	✓	✓	
White pine					✓	✓
Red pine	✓					
Jack pine	✓					✓
Fir-spruce	✓				✓	

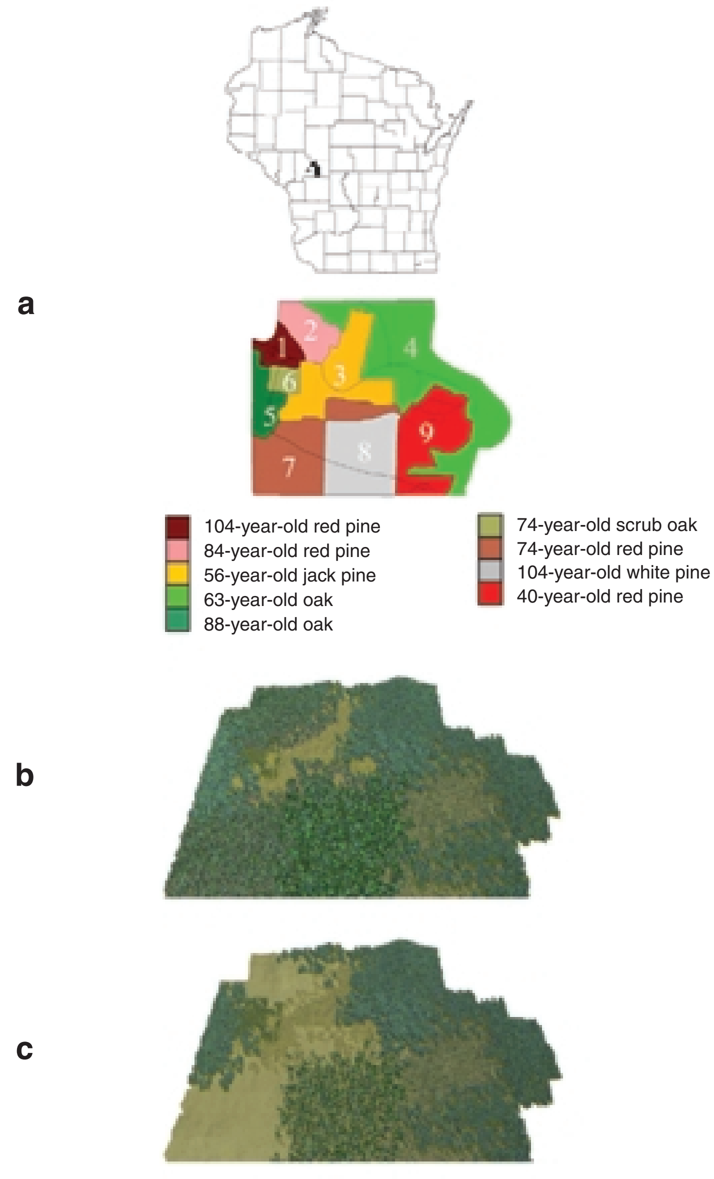

Figure 3. **Scenarios applied to Black River State Forest in Wisconsin: (a) portion of the forest with stand boundaries, approximately 1 square kilometer; (b) visualization of the nine stands as they currently exist; (c) management applied to four stands–stands 1, 2, and 7 are clearcut and stand 8 has undergone a shelterwood cut that removed 50 percent of crown cover.**

nipulated to create a version with different branch and leaf characteristics, as well as height, diameter, color, and other characteristics. However, images created with Tree Professional had less detail in leaf and bark texture and appeared less realistic. Tree Professional is also limited in the number of species templates available for creating tree imagery. Current templates include oaks, maples, birch, aspen, and pines but not basswood, hemlock, jack pine, black spruce, and other species native to Wisconsin.

For the forest type library, we created templates based on FIA data points throughout the entire northern portion of Wisconsin. This provides a starting point of average forest conditions for a given forest type and age. Using FIAMODEL, it took approximately four hours per template to summarize FIA data and enter it into WCS. This varied widely depending on the complexity of the forest type. Once these generic templates had been created, it took 15 to 60 minutes to modify the existing templates to represent a specific stand.

The visualization of management scenarios was relatively straightforward. Once a template had been developed for a forest type, prescribed portions of trees were simply replaced with images of stumps, snags, or slash, depending on the type of management practice. The ground layer was also modified to appear disturbed. The development of new management scenarios for addition to existing forest type templates can be accomplished in less than 60 minutes; the application of existing management for a forest type template can be completed in a few minutes.

The Black River State Forest simulations provided an example of near-landscape-level visualization. The GIS boundaries were imported into WCS, and appropriate forest type templates were applied to them. To simulate management, the management templates were applied where dictated. The time it took to accomplish this is the same as for applying management scenarios as described above, multiplied by the number of stands to be managed.

In total, establishing the framework for this type of system can be accomplished by one person in six to 12 months. The basic functions of this type of system can be learned by a person proficient in computer use in a matter of a several days to several weeks.

In addition to the technical issues, one must also consider the ethical issues involved in the use of visual simulation systems.

> When data visualization is crude, …appropriate skepticism is easily achieved because people are already wary of statistics,…but visualization techniques that approach the realism of photography or video imagery come much closer to making a promise, arousing a high level of expectation about what will actually be achieved…(McQuillan 1998)

This issue makes it important in visualization to include not only an accurate depiction of forest structure and composition but also such forest elements as snags, stumps, logging slash, logging roads, erosion, and other possible side effects of logging. For this reason, our system relies on FIA data and GIS data collected by the state Department of Natural Resources, including roads, watercourses, and others.

Conclusions

Computer visualization of forest management facilitates continued public involvement in the issues of forest management and emerging technologies. The key to this development is getting the system into the hands of the managers. To a certain degree, the development of forest visualization parallels the development of GIS. In its early stages, GIS was solely in the hands of a few computer-savvy consultants; now the technology is widely used by the broad scientific and natural resource management community. It is our expectation that visualization will follow a similar path. In this article, we have discussed the development and utility of a forest visualization system in Wisconsin that may further this development.

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