Challenges in Visualizing Forests and Landscapes

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Landscape visualization is a useful tool in understanding forest dynamics and in assessing various management practices. However, the application of this technology remains very challenging. We propose criteria for landscape visualization so that users can judge the quality of the visualization. We also identify the challenges in developing visualizations and discuss the limitations and advantages of visualizations for basic and applied science in natural resource management. We believe that the combination of visualizations with traditional research methods will enable the decision-making process to become more convincing and reliable.

Keywords: landscape visualization, forest landscape, criteria of visualization

Over the past 30 years, three-dimensional (3D) visualization of the forest and landscape has proven to be a very useful tool in understanding forest dynamics at stand and landscape scales for assessing various management practices and planning (Sheppard et al. 2004). With rapid development of computer technology and increasing use of geographic information systems and remotely sensed products, visualizing complex ecosystems at multiple spatial and temporal scales is possible in many scientific disciplines (Lim and Honjo 2003). Although there is no doubt that visualizations can help improve forest research and management, there remain serious challenges for developing visualizations and applying them properly.

Visualization (i.e., a graphic) refers to any technique for creating images, diagrams, or animations to communicate a message. It offers a method for seeing complex ecological processes that one cannot comprehend. It enriches the process of scientific discovery and creates a way for viewing the material, unavailable until recently, which can lead to profound and unexpected insights (Mc Cormick et al. 1987). The value of visualization may be best summarized by ancient proverb, “A picture is worth a thousand words.” Compared with the verbal or numeric communication formats and data visualization, landscape visualization is a much more powerful and efficient tool to facilitate better understanding of complex systems. Our objectives were to (1) evaluate and develop criteria for visualization of forests and landscapes; (2) identify the challenges of visualization from three perspectives—computer technology, insufficient scientific knowledge, and the application of the visualizations; and (3) discuss the limitations and advantages of visualization in basic and applied ecological research.

Criteria

The purpose of visualization is to provide users with an improved insight into complex systems. The strength of quality visualization lies in its ability to reveal the underlying mechanisms and phenomena with useful outputs. Depending on the model it is used with, it may predict the future state of the ecosystem or restore the history of the forest or landscape (Wang et al. 2005). We propose the following criteria for evaluating visualization quality.

Clear Objective. A clear objective should be defined before creating a visualization, including the methods to be used because the quality of a visualization is related closely to the objective and the methods used to create it. For example, a 2D map of a large region to show the landscape components has a different objective and method than if one’s objective is to represent the vertical structure of a forest stand effectively, where individual tree images are necessary to show the differences between species, age, or condition class.

Reliability. The following four features for landscape visualization evaluation have been proposed here (see also Sheppard and Salter [2004]).

Legitimacy. Visualization should be defensible; visualizations used should be driven by data, not by artistic license.

Accuracy. Visualizations should represent the actual appearance of the landscape, at least for those factors being judged. However, accuracy is scale dependent, and the proper resolution and extent need to be carefully determined with trial simulations (Wang et al. 2005).

Representativeness. Visualizations should be adequate enough to represent the dependent variable in question. The dominant vegetation or tree species in a stand or in ecosystems across the landscape is a good place to start to see if it represents our forest stands. Then, we can ask, are there any features or processes that are not included that would help us better represent the phenomena we wish to study?
Challenges

Computer Technology. A 3D visualization is dependent on computer hardware and software. Ten years ago, the most important challenges to visualization technology were the development of hardware and software capable of rendering ecological data (Helley et al. 1995). Today, computer technology is much more advanced and is constantly getting better. Consequently, frequent updating and revising are required, as with all computer applications, to ensure that they are fully updated, free from bugs, and operating properly.

Data Linkage. The 3D visualization usually involves large data sets and requires cohesive linkages among different types of data (e.g., external and internal data). Because of these linkages, each animation frame has to be rerendered if additional modifications or updates are made for most of the visualization tools (Figure 1).

This challenge is not only related to hardware, but also relevant to the software. Some currently available visualization software includes Landscape Management System by the University of Washington (Seattle, WA) and FORESTY APPLICATIONS by Facet Decision Systems, Inc. (Morrison, CO). Most of these packages were designed for use at specific spatial scales and are not readily adaptable at other scales. For example, Stand Visualization System by the USDA Forest Service Pacific Northwest Research Station can be used at the stand scale, and SmartForest by the University of Illinois at Champaign–Urbana is more appropriate at landscape scale. Visual Nature Studio by 3D Nature (Vancouver, Canada) is among the best for use at multiple scales while using real spatial information. The disadvantages, however, include high demands for computing resources.

Real Time Interactions. Visualizations provide assistance when assessing dynamics of stands and landscapes over time resulted from different input variables, both natural, (i.e., succession and fire) and human induced (e.g., building roads). Users need to have the option to replay alternative management activities (e.g., harvesting and planting) with respect to both spatial location and timing of events. That is what separates a policy evaluation model rendered with 3D visualization from a picture or a movie. There are several software products available that are working toward better enhancing this feature so that modeled results can be used to predict outcomes and allow decisionmakers to explore the possible responses of the ecosystems to the management actions. For example, Ecomodeler/ Ecoviewer, by Viewscape3D Graphics, Ltd. (100 Mile House, British Columbia, Canada), displays the visualizations with point-of-view and flyover capabilities in real time. Users can add management activities (e.g., clearcutting a patch of forest) and have free navigation on the visualized landscape. Indeed, more advanced visualization technologies have been developed for computer games, which achieve instantaneous interactions by the players. We foresee these kinds of interactions in future forest and landscape computer software.

Scientific Research. Data Availability. A major obstacle in developing quality visualizations is related to the availability of appropriate information. When developing 3D visualizations, input data may include digital elevation models, land cover maps, tree images, tree size (diameter and height), stand densities, and species composition (Orland and Uusitalo 2001). Often, available data do not meet the requirement for developing quality visualizations. For example, most current forest inventory and vegetation data are maintained at abstract levels with focus on mean volumes, diameters, and ages. However, the primary variables required by most of the visualization programs such as tree height and location, stem density, and species composition are not included. Because visualizations are for current forests and landscapes, the continuous change of forests, because of diverse management activities, and succession or natural disturbances that baseline data inputs need to be frequently updated. Other databases (e.g., the tree image library) required in the visualizations also need a great deal of fundamental work. Because of the lack of data, being forced to continuously update data, and the maintenance of parallel databases, a strong emphasis is placed on ecosystem models to simulate natural disturbances (e.g., fire). Some forest inventory and analysis (FIA) data (Miles et al. 2001), but the accurate spatial locations are not always available.

Data Quality. Constructing a virtual forest requires integrating information from various sources (Orland and Uusitalo 2001); inaccurate information creates errors. An issue related to input data is their quality be-

Figure 1. Fly through visualization of Chequamegon National Forest (CNF) based on existing vegetation stand data from 1999.

Realism and Visual Clarity. The details (e.g., composition) of the visualization should be clearly distinguishable. When visualizing a forest landscape, the following parameters should be used as indicators of its clarity. Those measurements that can be used to describe a real forest, such as tree heights, stem density, dbh, and crown density also should describe a virtual forest. Measures unique to computer representation such as being able to distinguish colors and shapes of the plants and physiographic features of the land also are important for visual clarity (e.g., Figure 1).

Presentation. The best way to make visualization a useful tool is to have a presentation format that allows the users to manipulate the visualization products (Uusitalo and Orland 2001). This allows for full use of the products by being able to switch between alternative scenarios, compare end point goals, and fine tune inputs to better fit their real forests. Ease of use and strength of outputs are marks of a powerful tool and are the effective ways to ensure that busy users actually will integrate new tools into their daily lives.
cause of its direct linkage to visualization quality. An input variable such as stem density is extremely important to accurately simulate ecosystem processes. Data quality also depends on the objectives and scale of the visualization. When visualizing tree growth in a forest, it requires more accurate data on tree height and stem density, vertical structure, and species composition (Wang et al. 2005). Visualization of a multiecosystem landscape, meanwhile, will require more accurate data on management boundaries. Therefore, objective of visualization determines the data inputs needed.

Applications. Landscape management with careful consideration for aesthetics is becoming increasingly important (Sheppard 2001, Luymes 2001). In North America, aesthetics has been included in some classic visual resource management programs such as the Scenery Management System of the USDA Forest Service (1995). Another contribution of 3D visualization is to be able to view the forests, including its status and future conditions. Public aesthetic preferences come from people’s culture, personal experiences, profession, education, and understanding of the objects. To balance sustainable development and public aesthetic preference, managers and policymakers should be familiar with or have access to diverse stakeholders with knowledge in the subject areas of forestry, ecology, socioeconomics, philosophy, psychology, landscape architecture, and computer science (Sheppard and Harshaw 2001). However, such a balance is case sensitive and dependent on other variables such as management objectives. Because of the complexities in landscape management, developing 3D visualizations to evaluate the forest management aesthetic alternatives is important. Public involvements in the forest and landscape planning process and their acceptance of management plans based on sound ecological concepts and their aesthetics are essential to a successful plan.

In regards to different management scenarios, a 3D visualization is based on qualitative data and the final products are photographic, suggesting that numeric data, tables, or graphs are needed to describe precisely the quantitative differences between management plans to users. The combination of these different communication methods as outputs would ensure its usefulness. A 3D visualization can be very realistic, but only if its actual or simulated data are readily accessible at the same time. The public in general is interested in a workable plan they can live with and is result oriented while experts who are also familiar with ecological theories, would like to know how and why a plan is sustainable. The ability to integrate these two different needs is important. One way of achieving this would be to create dynamic links between the landscape visualization and the supporting data, which would allow different users to explore the information as needed. However, this also is highly dependent on the present capabilities of the technology.

Discussion

Currently, the role that 3D visualization plays in forest research is limited, even though 3D visualization is recognized as an asset to forest management plans and other activities (Sheppard et al. 2004). It is obvious that 3D visualization can effectively enhance both applied and basic research because it adds a visual dimension to our interpretation of scientific data. The combination of visualization with traditional research methods gives more power to the users to address visual and spatial questions at multiple scales from the data available. This is very helpful, especially when combined with ecosystem models. For example, with fire studies, models such as FARSITE (Finney 1998) and FireStem (Missoula Fire Sciences Lab, available online at www.firelab.org; last accessed Apr. 9, 2006) were used with visualization to show heights of tree scaring or damage to trees or stands from a fire or the spatial locations within a stand of incidence versus refugia of the event (Wang et al. 2005). This also can work in reverse, e.g., forensically, from actual field evidence, helping investigators to determine the cause of a fire, its starting point, or other movements and behaviors. The 3D visualization when combined with simulation models may show us unforeseen consequences of our activities when multiple ecological processes interact in space and time. In addition, visualization can help us choose between alternative strategies for a landscape plan. The 3D visualization provides managers and scientists with an opportunity to envision management options before the activity is executed. Clearly, visualization is a good way to display complex ecological interactions to users without a scientific background. The role that scientists play, using visualization, is to help laypersons, in stakeholder roles, understand more about ecosystems, how to apply this knowledge in multiple use landscapes, and, finally, show the accepted plan or design options before they are implemented (Sheppard 2001). Realistic visualizations may help us notice overlooked possibilities that might be very important in practice.

Literature Cited


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