may often be restricted for women and young people, for older and disabled people, for those from ethnic-minority groups, and for socially disadvantaged groups. Amenity planning is increasingly required to take an inclusive approach which addresses these issues, although planning procedures which do so in practice are rare.

Conclusion

European traditions in forestry continue to provide a far-sighted model for the development of integrated amenity planning tools and multiple-use forest planning. Recent areas of interest in amenity planning in the UK include tranquillity mapping (mapping areas of countryside away from noise and visual intrusion) and mapping of areas free from light pollution, as well as focusing attention on the physical, mental, and social health benefits of living near woodlands, recognizing the potential for forests to improve people's quality of life. Nordic European countries such as Finland, with a different and more continuous tradition of living in and enjoyment of forest landscapes, have contributed to planning models which place an emphasis on the cultural landscape of forests. Early holistic approaches to forest planning in New Zealand have been matched by more recent innovative community-planning models in Australia. Worldwide, with the advancing urbanization of most nations and lifestyles, forest amenity planning has turned its focus increasingly on urban and urban periphery woodlands. For less developed countries, amenity planning for ecotourism is seen as a way to conserve forests while benefiting the local economy but requires strategies that are also compatible with the traditional dependence of local communities on forest resources for their way of life. This calls for integrated and holistic approaches to planning for multiple use that place a high value on social benefits, cultural contexts, and engagement of the community in the planning process.

See also: **Landscape and Planning**: Perceptions of Nature by Indigenous Communities; Urban Forestry; Visual Analysis of Forest Landscapes; Visual Resource Management Approaches. **Recreation**: User Needs and Preferences. **Social and Collaborative Forestry**: Joint and Collaborative Forest Management; Social and Community Forestry; Social Values of Forests.

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The Role of Visualization in Forest Planning

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Introduction

Modern techniques of computer visualization, involving three-dimensional (3D) modeling, computer animation, and virtual reality (VR), are taking their place among decision-support tools for forestry. This article focuses on the emerging role of visualization techniques that simulate the appearance of forested landscapes in forest resource planning, design, and management.

The Forest Planning Context for Visualization

It is increasingly recognized that sustainable management of forests cannot be effective without the integration of biophysical, socioeconomic, and cultural factors into the decision-making process. Public pressure for good stewardship of multiple forest resources requires more comprehensive and inclusive processes for decision-making. It is important that forest managers communicate with many stakeholder groups, with varying needs and degrees of knowledge on forest sciences. The complexity of these multiple demands on forest planning and management requires sophisticated decision-support techniques; this favors the use of visual communication techniques that can potentially simplify and explain complex information and improve the process of decision-making.

It is widely recognized that pictures can convey more information, more meaningful information, and more memorable information than other forms of communication. Visual information can also be interpreted by people from many walks of life. The general function of communicating scientific information can be achieved by what is called 'data visualization,' which comes in forms such as charts, diagrams, maps, graphics, models, etc. This can be helpful in explaining concepts, ecological processes, overall conditions, etc., which are not well expressed verbally, in text, or as data tables.

More specific forms of visualization, called visual simulation or landscape visualization, attempt to represent actual places and on-the-ground conditions in 3D perspective views, with varying degrees of realism (**Figure 1**). These convey detailed information on the expected future appearance of the landscape under certain forest conditions. Landscape visualizations offer potential to address social implications of site-specific management actions or scenarios, such as impacts on scenic quality, recreation, spiritual/cultural values, general quality of life, and property values. Furthermore, the general health of the forest is often judged by the public (and even experts such as forest certification panels) in part by what they see on the ground.

The two forms of visualization described above, data visualization and landscape visualization, can be combined in various ways. Showing spatial relationships (e.g., by mapping geographic information systems (GIS) data on to a landscape visualization) in the context of a recognizable place to which people can relate (**Figure 2**), can communicate complex information on ecosystem processes and patterns of resource values. This article will focus mostly on landscape visualization alone or in combination with data visualization.

It is widely believed within the forestry profession that the public often has little awareness of long-term landscape changes such as tree growth and death, and of temporal concepts such as succession and harvest rotations. Landscape visualization can depict both spatial and temporal variations in ecosystem conditions. It therefore offers the possibility of improving public knowledge regarding ecosystem management, and may perhaps help the public to strike a balance or trade-off in their own minds between short-term adverse effects on some values in return for long-term benefits to the ecosystem.

History of Landscape Visualization

Visual representations of existing landscapes and objects have occurred as art forms for millennia, with

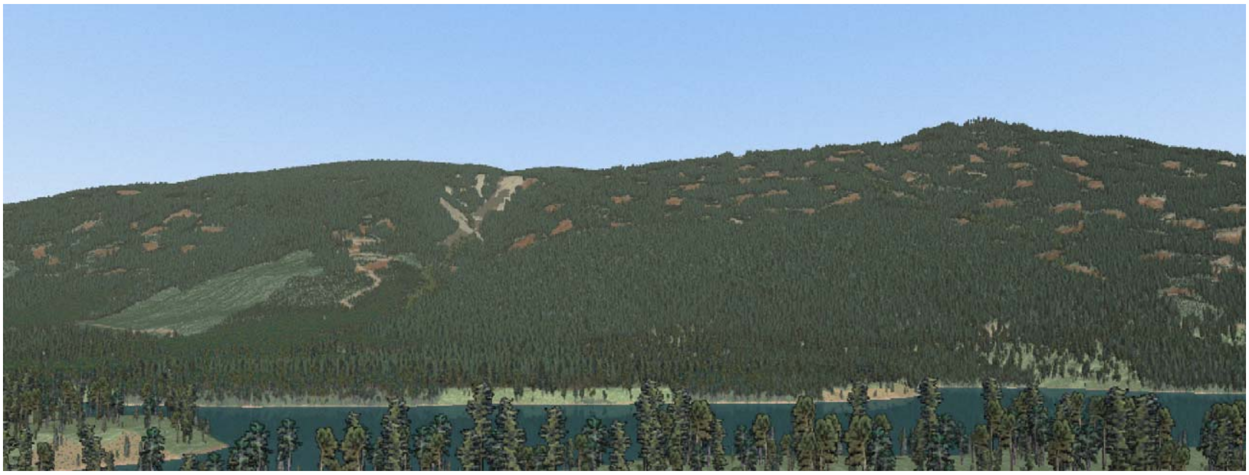

Figure 1 A fairly realistic computer-generated landscape visualization of a conceptual forest planning scenario in the Slocan Valley of British Columbia. Image by Jon Salter and Duncan Cavens, Collaborative for Advanced Landscape Planning (CALP).

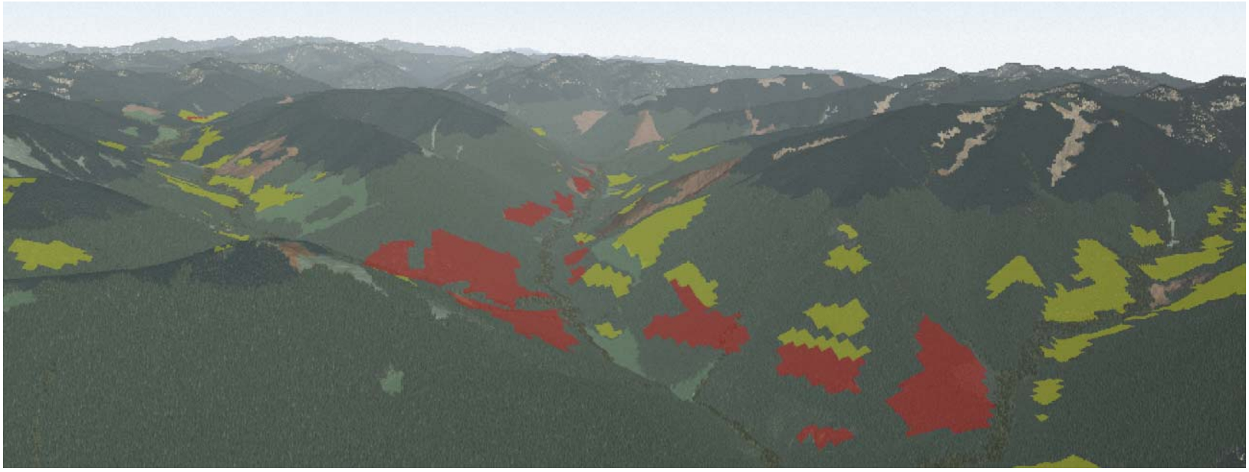

Figure 2 Overlay of habitat modeling results on to a landscape visualization of forest plans: red indicates high habitat value and green indicates moderate habitat value for a forest bird species. Image by Jon Salter, CALP and Ralph Wells, University of British Columbia.

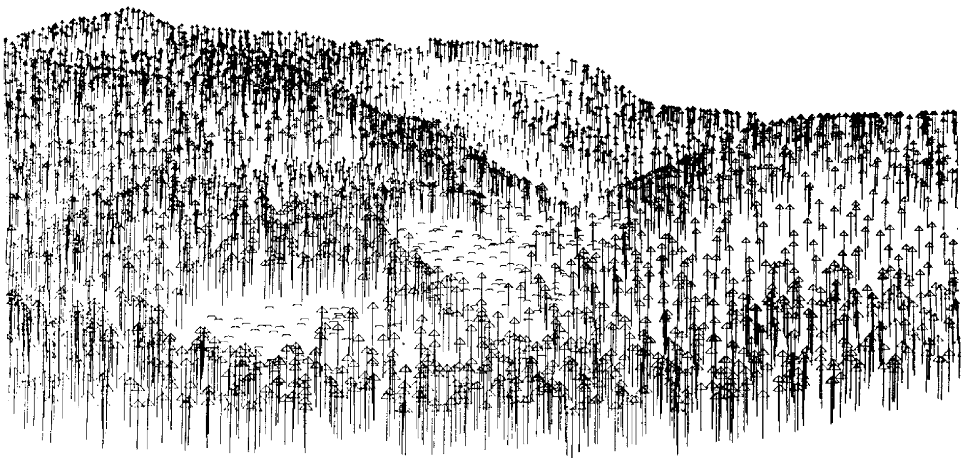

Figure 3 Example of a 3D modeling system used in the 1980s: 'wireframe' simulations from the PREVIEW program. Image by JA Wagar.

the rules of visual perspective developing during the Renaissance. Portrayals of future conditions or design proposals in perspective took a major step forward with the work of English landscape architect Humphry Repton, who presented his landscape design proposals in the form of 'before: after' paintings in the late eighteenth century. In the twentieth century, the emergence of land use planning and the design professions of architecture and landscape architecture led to standardized perspective simulations of proposed designs, initially in the form of scale models, line drawings, and color renderings. The availability of quality color photography led to techniques of photosimulation (i.e., photomontage and photoretouching), which were capable of delivering highly photorealistic landscape images many years before computers came into widespread use.

Beginning in the 1970s and 1980s, early computer-assisted or computer-generated visualization techniques were developed, initially for architectural projects, but these were soon expanded to engineering and forestry applications. Various software packages were developed in the 1970s and 1980s to model the appearance of changing landscape conditions. These 3D modelling systems used digital elevation models, building masses, and tree symbols to develop quantitatively accurate but rather abstract computer perspectives (e.g., 'wireframe' models) (**Figure 3**). These could be combined with traditional hand-rendering or photosimulation techniques to produce more realistic finished products. In the 1980s, the first image-processing techniques also emerged, allowing digital enhancement of scanned photographic images.

At the same time, the military and entertainment industries were developing more sophisticated computer-imaging techniques for modeling real or imagined landscapes. Some of these technological advances eventually contributed to the computer-based landscape visualization tools currently available commercially, including two-dimensional (2D) and 3D computer programs with a range of both abstract and highly realistic landscape imagery (see below).

Much of the visualization use in forestry has been associated with visual resource management (VRM) in Western nations, notably in North America (*see* **Landscape and Planning**: Visual Resource Management Approaches). The US Forest Service and other agencies have applied various visual simulation techniques since the early 1970s when the National Environmental Protection Act first mandated protection of aesthetic resources on public lands. These visualization techniques have been used mainly to support visual assessments and forest design, and are quite widely used for this purpose in several countries, such as the USA, Canada, New Zealand, Britain, and Finland.

In the 1990s, the development of spatially explicit stand modeling systems for mainly silvicultural purposes, such as the Stand Visualization System (SVS) at the University of Washington (**Figure 4**), SMARTFOREST at the University of Illinois, and MONSU in Finland, led to 3D visualizations of stand composition and structure, using increasingly detailed tree models. Developments in integrated decision-support systems using spatially explicit ecosystem modeling with multiple indicators are also beginning to link directly with visualization capabilities. Highly realistic viewers are also available to 'bolt on' to the outputs of various forest modeling systems.

Current uses of visualization in forestry can be broadly categorized as shown in **Figure 5**. This hierarchy illustrates the broader range of applications of visualization to research and education/professional extension activities, but consideration here is focused primarily upon practical use in decision-making where social values need to be integrated into the process. Because many forest management models and systems do not as yet explicitly incorporate social values into the process in a participatory way, the use of visualization in this context has not yet become commonplace.

Types of Visualization

This section presents a typology of landscape visualization techniques in current and emerging applications. Any typology in such a rapidly changing field cannot be all-encompassing or rigid in its definitions. It is important, however, to distinguish between the types of visualization models becoming available to generate visualization imagery, and the types of presentation formats through which the visualization products are delivered to their intended audience.

Visualization Models: Image Production

The following approaches to producing forest visualization imagery can be identified:

Geometric modeling This technique uses volumetric data (either from real-world inventory data or

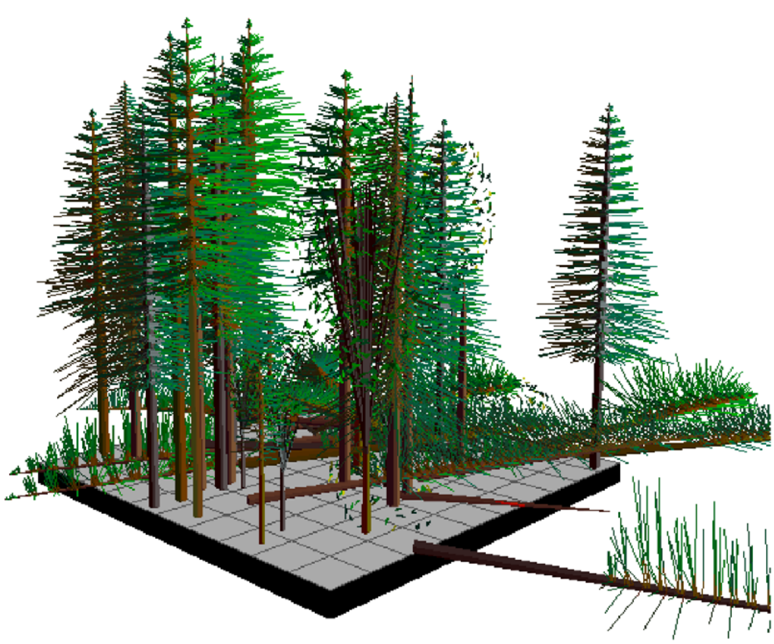

Figure 4 Example of a geometrically modeled stand with a moderate level of realism, from the Stand Visualization System (SVS). Reproduced from the SVS website. Image by Robert J McGaughey, USDA Forest Service.

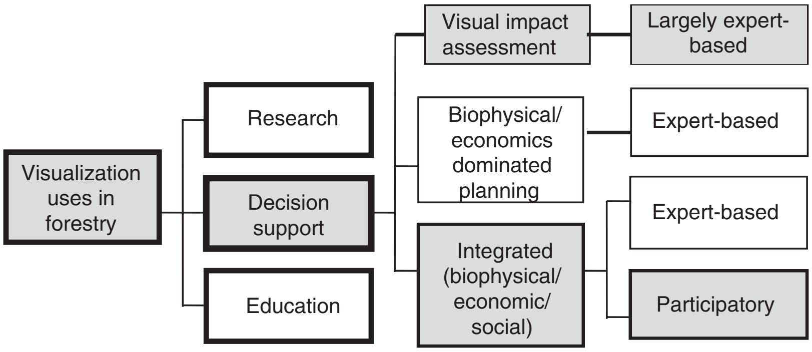

Figure 5 Hierarchy of visualization uses in forest ecosystem management. Shading indicates areas of concentration in this article. Reproduced with permission from Sheppard SRJ (2000) *The Compiler* 16(1): 25–40.

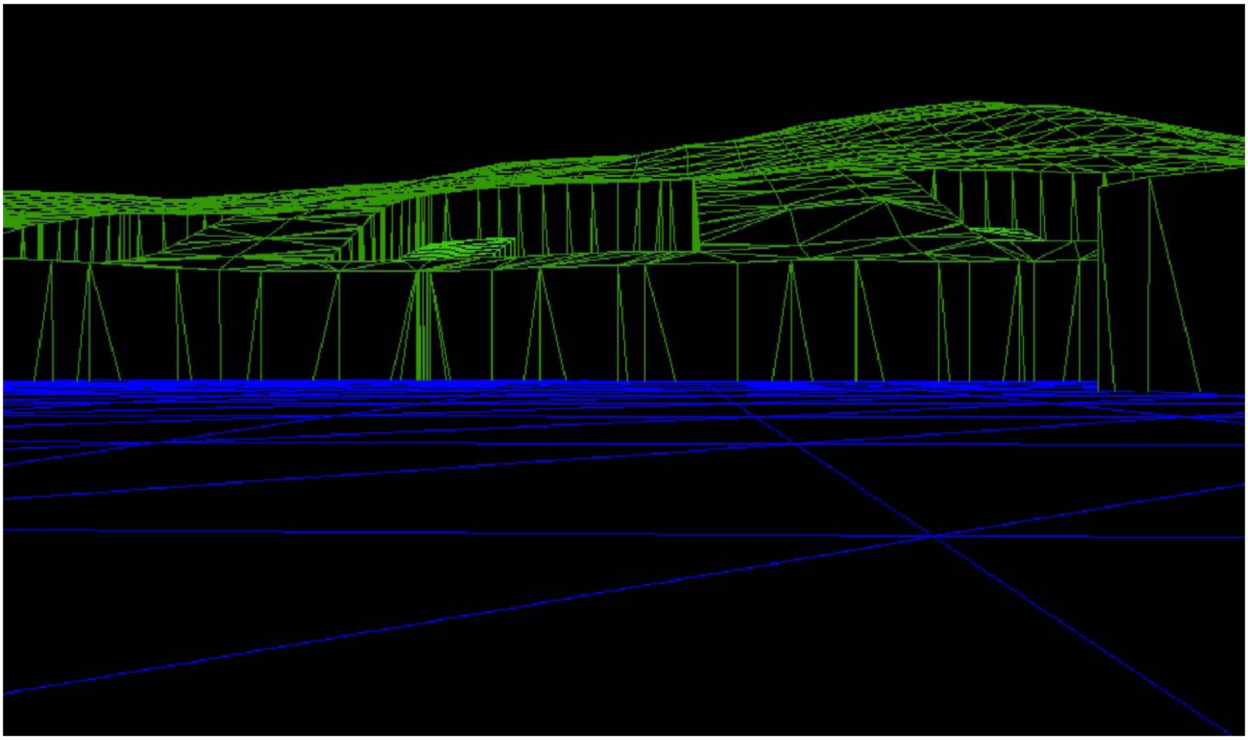

Figure 6 CAD-based 'wireframe' simulation of tree canopy and landform, showing proposed shelterwood harvesting at the Alex Fraser Research Forest, British Columbia. Image by John Lewis, CALP; Reproduced with permission from Sheppard SRJ and Harshaw HJ (eds) (2001) *Forests and Landscapes: Linking, Ecology, Sustainability, and Aesthetics*. Courtesy of CAB International, Wallingford, UK.

generated by predictive mathematical models) to construct digital 3D models of landscape forms. Ground surfaces or landforms can be constructed from surveyed elevation points or contour lines in computer-aided drafting (CAD) or GIS programs; vegetation can be generated from cruise data or ecological/growth models at the individual plant or stand level; and proposed roads or structures can be created from development plans. These models can range from simple wireframes (**Figure 6**) to more sophisticated solid models with synthetic textures and light sources (**Figures 4 and 7**). Geometric models may allow animation (dynamic motion or change over time). They can be considered as synthetic analogs of real world landscapes.

Photo-imaging (2D) The application of computer 'paint' programs to manipulate the pixel colors in digital 2D static photographs (**Figure 8**) is essentially artist-driven, but can be augmented by such tools as image element libraries (e.g., tree types, textures, etc.), 3D modeled perspectives to aid in element placement, and mathematical and/or survey techniques to improve image accuracy. Photorealistic images generally require skilled operators, and are too time-consuming for generation of large numbers of images, e.g., to show changing or alternative conditions over many time periods.

Hybrid geometric/photo-imaging Several techniques combine elements of the first two approaches to merge the synthetic elements of geometric models with photographic elements from photo-imaging. These fall into three main categories:

- 2D blend: views of 3D geometric models representing proposed management activities are placed into 2D static site photographs (**Figure 9**), precluding animation.
- Image draping/texture mapping: a 2D image or scanned texture map is draped on to a 3D model to represent surface features. This can be an aerial photo or satellite image draped on 3D terrain, or a texture image (such as grass or asphalt) mapped on to a landscape element. This technique is computationally efficient, and therefore is commonly used for animation and real-time applications. Its main drawback for forestry is that 2D image elements (e.g., an air photo) do not convey the 3D height effects of the trees (**Figure 10**).
- Photo-based objects: an extension of the draped texture map is the creation of discrete 3D objects which can be located with x, y, and z coordinates on a digital terrain surface, and upon which can be pasted individual photographic texture maps. For example, 2D or simple 3D tree models can be created and photographs of actual trees pasted on as 'billboards.' This technique can appear very lifelike, and allows animated travel through the forest model, though it is computationally very demanding because of the countless number of tree objects that need to be rendered (**Figure 11**).

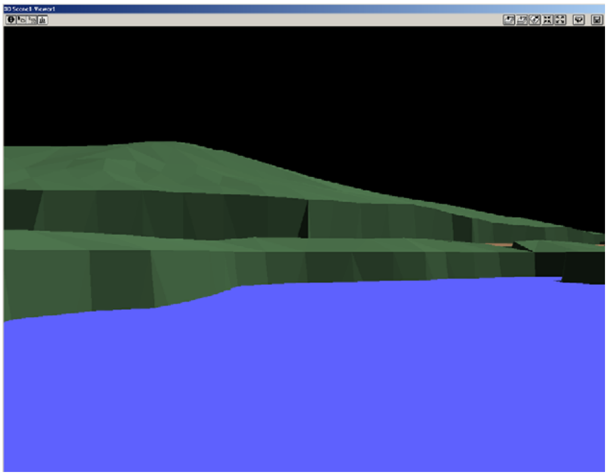

Figure 7 A digital solid model of proposed shelterwood harvesting at the Alex Fraser Research Forest, British Columbia; this model was constructed using ArcView 3D by ESRI. Image by John Lewis, CALP.

Viewing Formats: Image Presentation

Presentation formats for visualization can be classified by the degree of dynamism allowed in the delivery system, as follows:

- Static 2D images: hardcopy prints, on-screen images, or projected flat single images.
- Immersive static imagery: static images presented or projected in a 3D display, e.g., 'wraparound' projection screens or simulation booths which increase the viewer's sense of involvement in the simulated scene (**Figure 12**).
- Limited animation: allowing movement of the whole image to simulate changes in view direction or viewpoint, permitting the viewer to select different pre-prepared views of static digital

Figure 8 Photosimulation, created by 2D digital image manipulation using Adobe PhotoShop, of proposed shelterwood harvesting at the Alex Fraser Research Forest, British Columbia. Image by John Lewis, CALP, reproduced with permission from Sheppard SRJ and Harshaw HJ (eds) (2001) *Forests and Landscapes: Linking, Ecology, Sustainability, and Aesthetics*. Courtesy of CAB International, Wallingford, UK.

Figure 9 Hybrid image combining photographic elements with a geometrically modeled riparian corridor. Image by John Lewis, CALP.

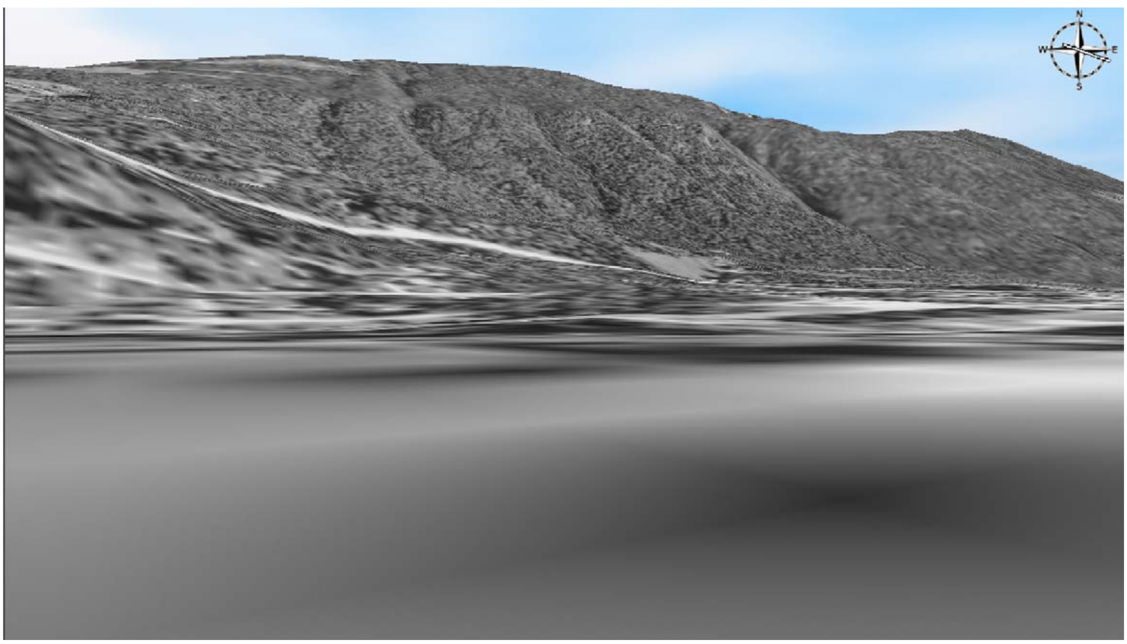

Figure 10 An orthophoto draped on a 3D model of a hillside in the Slocan Valley, British Columbia. Image by Jon Salter, CALP.

scenes arranged in viewing sequences or wrap-around panoramas.

- Animated viewpoints: allowing true dynamic simulation of continuous movement through a 3D model, along pre-prepared animation paths (i.e., the typical 'walk-through' or 'fly-through').
- Animated conditions: allowing pre-programmed continuous temporal/spatial change in simulated landscape conditions, e.g., trees growing (**Figure 13**) or a fire spreading.
- Real-time interactivity: allowing fuller interactivity between the viewer and the visualization system, whereby viewpoints, travel speeds, certain landscape conditions, etc., can be modified at will and in real time by user commands. Immersive VR systems allow the observer to experience virtual landscapes interactively as though they were within it, using headset systems or sophisticated forms of computer projection.

Assessing the Benefits and Limitations of Visualization in Forest Planning

Do these increasingly sophisticated and powerful visualizations live up to their promise? This section considers the advantages and disadvantages of established and emerging forms of landscape visualization in forest planning, based on research findings, current theory, and practice.

A limited amount of research on visualization methods in planning has been conducted since the

Figure 11 Hybrid image of proposed shelterwood harvesting on the Alex Fraser Research Forest, British Columbia, created with World Construction Set software and using 'billboard' 2D photographs of individual trees inserted into a digital 3D model. Image by John Lewis, CALP, University of British Columbia; reproduced by permission of Garten & Landschaft and CAB International, Wallingford, UK.

1970s, much of it grounded in the pioneering work of Donald Appleyard and colleagues at the University of California–Berkeley. The research comes from various disciplines, including urban and environmental planning, landscape architecture, computer science, graphic arts, information sciences, environmental psychology, social sciences, forestry, geography, and civil engineering. Implications for visualization in forestry have to be interpreted from the full range of applications. Some studies have evaluated the effectiveness of visualization media, but there have been few comprehensive experiments to assess the quality or validity of visualizations across multiple media or forest modeling contexts, and even fewer longitudinal studies relating predictive visualizations to actual landscape changes. The theoretical framework for landscape visualization is also very incomplete: the most cogent theories include communications theory, addressing the process of communications from source to receptor via certain channels; and various environmental psychology and aesthetic theories on human responses to the visual environment (*see* **Landscape and Planning**: Perceptions of Forest Landscapes). There is much anecdotal evidence to support the usefulness of landscape visualization in project-based decision support for forestry, but very little scientific documentation of real-world applications.

There is therefore considerable reliance on theoretical concepts and anecdotal evidence. The following sections summarize some key aspects of what is known and anticipated about visualization performance, and present a conceptual set of criteria for determining appropriate use of visualizations in the forestry context.

Performance of Landscape Visualization

The performance of visualizations can be thought of in terms of utility (practical usefulness or effectiveness) and quality (validity, reliability, realism, acceptability, etc.). The primary emphasis here is placed on the latter. Aspects of quality relate to the use of visualization to test observer reactions on the social acceptability of proposed forestry alternatives as well as on the acceptability of the visualizations themselves. Social responses can be obtained informally, through structured surveys of attitudes or judgments, or even through physiological measurements of pupillary excitation or stress levels. A variety of response types can be measured: responses can be categorized as cognitive (related to knowledge and

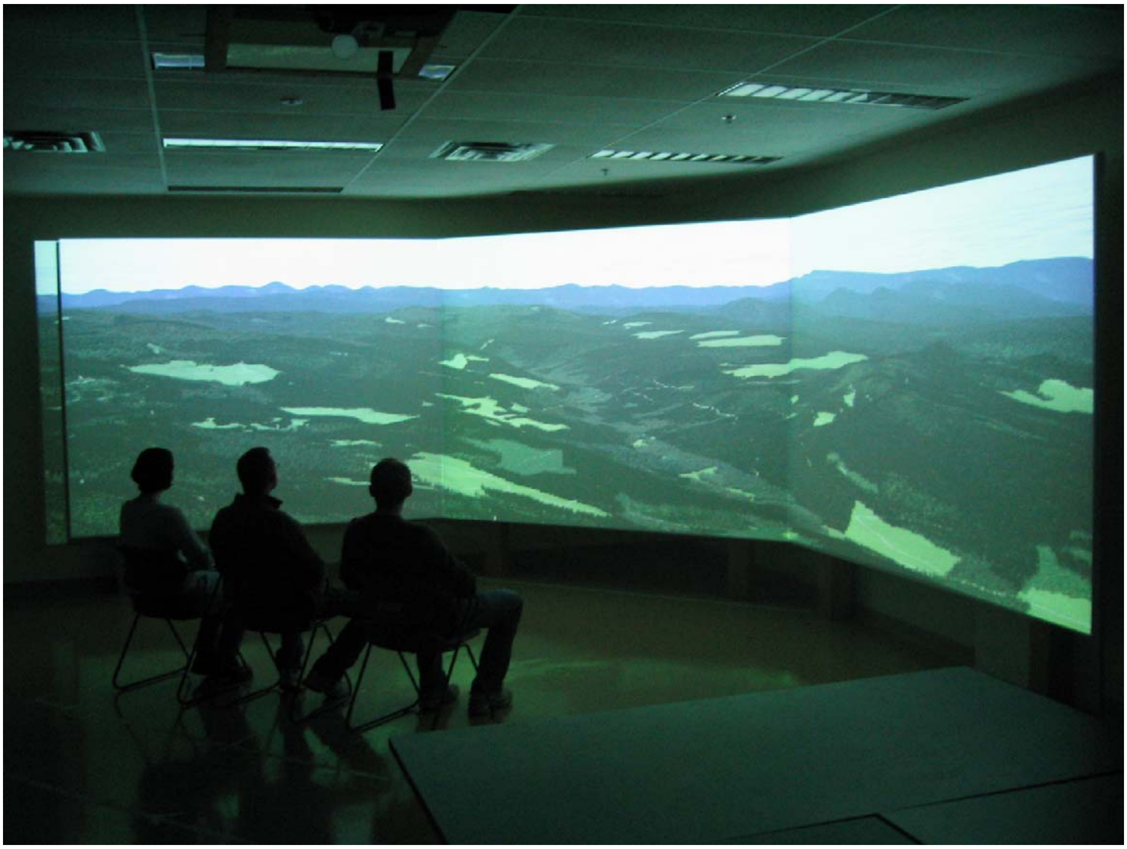

Figure 12 Immersive static image presented on three wraparound screens in the Landscape Immersion Laboratory of the Collaborative for Advanced Landscape Planning (CALP) at the University of British Columbia's Faculty of Forestry. Image by Jon Salter, CALP.

Figure 13 Visualization imagery showing ecological model-driven tree growth over three time periods, using CALP Forester experimental software. Image by Duncan Cavens and Jon Salter, CALP.

understanding), affective (related to feelings, perceptions, and emotions), and behavioral (related to changes in behavior of the viewer). Of these response types, little or nothing is documented scientifically on the effects of visualization on postexperiment behavior relevant to landscape management or forestry.

Specific advantages in utility believed to result from using landscape visualizations in a project planning context include: more meaningful participation of nonexperts in considering alternatives; more certainty for the project applicant and the affected community during the process; faster decisions as a result; better design of projects; less shock on the part of the public when visually disruptive changes occur on the landscape as a result of management; and in some cases an improved public image for the management agency. In theory, social response information can be fed back into the decision-support process to improve the basis of those decisions.

However, many visualization systems, and particularly the newer technologies such as animation and interactive VR, have very practical limitations associated with cost, availability of sufficiently powerful equipment, lack of appropriate data, availability of trained and experienced staff, and operational complexity.

Many of these factors are also believed to influence the quality of visualization. Quality also varies with the type of use or response sought from a given visualization set. With cognitive responses, adequate visualizations are generally understood to accelerate the mental processing of information, improve understanding, and place information in a context or perspective that allows broader interpretation of possible consequences. In practice, with site-specific landscape visualization, it is common that the process leads to new or modified conclusions on a project design or management action. Practitioners can often identify anomalies and errors in their data more quickly than in other ways. These cognitive benefits may be associated with abstract or conceptual (diagrammatic) data visualizations, realistic landscape visualizations, or hybrids of the two. However, there is a strong risk that visualizations may be cognitively misleading if they imply greater certainty than exists in future predictions of forest conditions.

Realistic ground-level views are often necessary for laypeople's fuller understanding of maps and plans. The more realistic visualizations also tend to evoke more affective reactions from viewers. Research shows that more abstract imagery (such as maps and simple computer modeling) provides less opportunity for people to respond to place-based cultural or quality of life issues such as aesthetics or acceptability of forest practices. Photographs and some forms of photorealistic visualization have been shown to replicate people's actual responses to real-world environments, which is the ultimate test of visualization validity (known as response equivalence). Most forestry studies with visualizations have tested responses on scenic beauty and/or acceptability of forest management; less is understood about validity on other questions.

However, visualizations have been criticized in terms of the following quality issues:

- Poor clarity of communication, leading to confusion and misinterpretation by viewers; this is understood to result from poor graphic presentation, too rapid animation speeds, overly complex information displays, etc.
- Low credibility of the visualizations to the audience; this can result from obvious errors, sloppy procedures, low realism, apparent bias in motivation of the preparer, etc.
- Actual bias (lack of response equivalence) in the responses arising from the use of the visualizations, as compared with the responses which would be expected from the corresponding real-world conditions if they were to be experienced. There is anecdotal evidence of misleading visualizations in practice, and some research measuring bias, though the causes are not fully understood.

Bias in responses to visualization can, in theory, be caused by deliberate manipulation (e.g., selective omission of landscape features), or unintentional inaccuracy. There is as yet no comprehensive evidence relating bias in responses to accuracy of the visualization. There is however a strong precautionary principle reflected in the literature, to the effect that, while accuracy may not be absolute or enough by itself to assure validity, it is risky to permit major inaccuracies in visualization content. Researchers such as Orland, Sheppard, and McQuillan have reinforced this view through their concerns about the ease with which realistic-appearing images can be created with today's technology, regardless of the accuracy of underlying data.

It is, however, known that responses to visualizations can be affected by factors other than image accuracy, such as the viewing locations chosen, accompanying information (e.g., verbal delivery or nonvisual data), and possibly the presentation format. Various studies have demonstrated the effects of using certain visualization media. Static imagery showing one or two 'snapshots' in time (e.g. 'before and after' an activity takes place) has been the predominant display technique for landscape visualization in forestry. Such methods offer a very limited window or slice of the information available: this places considerable reliance on the visualization preparer to select the appropriate view and conditions, in order to represent the universe of possibilities that exist over a long period of time, such as a forest rotation.

The general trend in emerging visualization methods appears to be towards more powerful and sophisticated animated graphics and VR displays, more realistic synthetic landscape models, more intuitive graphical user interfaces (GUIs), and wider access to these systems through means such as the Internet. However, the consequences of using this type of information have been tested in very few experiments. Even less information is available on the consequences of using VR techniques in practical resource management. Advanced techniques such as animation and interactive VR programs provide substantially more visual information and flexibility in viewing, and offer to overcome some of the limitations of previous methods. Much of this available visual information can of course be redundant, but there is also considerable potential for animation to provide new information through change of perspective. The ability for the user to control more aspects of the visualization also promises to reduce risks of bias from more limited or selective presentations.

Possible disadvantages associated particularly with newer methods of visualization include:

- The increased risk of raising unrealistic expectations of visualization accuracy, again because of its apparent realism.
- The risk of the novelty factor of dramatic visualizations overshadowing the content of the visualization message.
- The risk that the very sophistication, perceived expense, and 'high-tech' image of the emerging visualization media may cause a negative backlash in the public's mind, leading to rejection of the message regardless of its accuracy.
- The risk of excluding noncomputer-literate sectors of society from the decision-making process, through overreliance on digital media and access to online computer visualization techniques.

Indicators for Appropriate Use of Visualization

Given the incomplete state of our knowledge on visualization benefits and limitations, and the rapidly changing nature of visualization technologies, what guidance exists on the appropriate use of visualization for forest planning?

Previously elaborated principles and guidelines for valid and effective visualization can be used as a starting point, but needs to be extended and re-evaluated in the context of new techniques and modern demands on forest management. The following are principles for project-level landscape visualization where public (laypeople) responses may be expected:

- Representativeness: visualizations should represent typical or important views of the landscape.
- Accuracy: visualizations should simulate the actual appearance of the landscape (at least for those landscape factors being judged) (*see* **Landscape and Planning**: Visual Analysis of Forest Landscapes).
- Visual clarity: the details, components, and overall content of the visualization should be clearly distinguishable.
- Interest: the visualization should engage and hold the interest of the audience.
- Legitimacy: the visualization should be defensible and its correctness demonstrable; visualizations used should be driven by data, not by artistic license.
- Access to visual information: visualizations (and associated information) that are consistent with the above principles should be made readily accessible to the public via a variety of formats and communication channels.

These precautionary principles can be used to guide the ethical preparation and use of visualizations, the validity of which can ultimately be established only after the forest management actions have been implemented. It is therefore important to record

Figure 14 An interactive visualization system prototype (CALP Forester) that allows the user to prescribe management actions through a laser pointer interface and query the underlying model data. Image by Duncan Cavens, CALP.

and monitor the performance of the visualizations over time, so that the guidelines can be adapted as more hard information becomes available.

The current trend towards more public participation in forest management, and specifically toward the inclusion of social values in modern forest ecosystem management, calls for decision-support systems with more stakeholder involvement in and control over the development and evaluation of forest landscape choices. This can be translated into demands on visualization systems for:

- More intuitively understandable visualization methods.
- More transparent and accountable visualization processes/products.
- More involvement of the public in interrogating, interpreting, and even preparing visualizations which allow some user control over factors such as tree growth and management activities reflected in the visualization images (**Figure 14**).
- More choices of views, conditions, and alternatives visualized.

Conclusions

The science of landscape visualization is still young and evolving. There is much that we need to learn about how visualizations work in practice, and how emerging techniques will affect forest decision-making. While much more research is needed, the speed with which new visualization technologies are becoming available means that practicing forest managers cannot wait for research results, but must proceed under interim precautionary principles.

The power of the visual medium means that the preparer of visualizations carries a heavy responsibility to use that power appropriately. It must be recognized that all visualizations carry some inaccuracy, some bias in responses, and considerable uncertainty. This requires expectation management among users, and suggests that visualizations should not simply be plugged in and played without considerable planning and appropriate training for users. Updated guidelines and a code of ethics will be needed. Where possible, computer interfaces which provide access to nonvisual information about forest conditions should be provided, with built-in limitations on potential misrepresentation of data.

We can expect a new class of exploratory visualization tools to emerge that are more user-friendly, interactive, dynamic, and allow the user to navigate through the available 3D data to see forest conditions across space and time. Visualizations may move from being an end-product of planning activities or stand modeling exercises, to acting as a gateway to the planning or modeling process, through which new model runs or 'what-if' scenarios can be triggered directly and results browsed. The potential benefits are that it promises to provide easier and wider public access to the issues of forest management than has ever before been possible. The policy implications and procedural mechanisms to accommodate such public demands have yet to be thought through, however. It is also not clear whether the increasing choice and control by the viewer necessarily leads to greater validity and better decision-making.

In the long term, accumulating research and practice with visualization should fill out the theoretical framework for landscape visualization. Priorities for research include systematic evaluation of existing and experimental visualization techniques in laboratory conditions, and monitoring and evaluation of visualization techniques and effects in practical forestry applications.

Most forest managers are not well trained in methods of collaborating with the public, and often lack needed skills when dealing with affected communities. The use of credible visualization methods may ultimately help them to overcome these shortcomings, transform forest planning, and perhaps increase public understanding of forest sciences in management.

See also: **Landscape and Planning**: Forest Amenity Planning Approaches; Perceptions of Forest Landscapes; Perceptions of Nature by Indigenous Communities; Visual Analysis of Forest Landscapes; Visual Resource Management Approaches.

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Landscape Ecology, Use and Application in Forestry

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Introduction

Many ecological processes result in or are affected by spatial patterns. However, the relative importance of different processes is very sensitive to the scale of analysis. For example, at a very local scale, species diversity is often strongly affected by competition and trophic interactions between species. In contrast, at the regional scale species diversity is more strongly influenced by habitat dynamics and biogeography. The majority of ecological studies in the past has focused on local level processes, probably because they are less daunting to measure and are more amenable to experimental manipulation. The recognition that the important processes acting at a landscape level are often different from those at a local level has led to the development of landscape ecology as a distinct approach with its own paradigms and methodologies.

Ecologists have traditionally been interested in the spatial patterns of organisms. Charles Darwin's *On The Origin of Species* contains an entire chapter discussing the geographical distribution of species. However, the focus of his chapter, like much of the ecological literature since, is on the processes that create spatial patterns or biogeography. In contrast, an area of prime interest in landscape ecology is the way that spatial patterns affect ecological processes. This article reviews some of the ideas that this perspective has generated and looks at their relevance to forestry.

Why Landscape Scale?

The question of which is the appropriate scale for a particular analysis will largely depend on its objectives. Many issues in applied ecology and particularly those concerning environmental management are most appropriately addressed at a landscape scale. This is certainly true of forestry where many of the key management issues concern processes that operate over large areas. Environmental change, conservation, sustainability concerns, recreation, and public participation all involve considering forests in their landscape context.

The term 'landscape' has no precise definition. It implies an area that is perceived to have some coherence of natural or cultural entities. In practice the lack of a formal description of what constitutes a landscape is no more problematic than the similarly vague definition of the term 'population' in ecology. Both are useful because they demarcate biologically meaningful groups. Just like landscapes, populations can be identified at a scale that is appropriate to the objectives of the study.

The need for a large-scale perspective is not a new one but it is only recently that ecologists have acquired the tools that permit them to carry out this type of analysis efficiently. Remote sensing and geographic information systems (GIS) have permitted the collection and analysis of large quantities of spatial data. Although ecologists use experimental approaches more frequently than many environmental scientists, the possibilities for experimental landscape ecology research are severely limited. It is usually impractical to deliberately manipulate landscapes for experimental purposes and even in those situations where a treatment occurs as a consequence of other action it is usually impossible to replicate or control. Hence landscape ecologists typically measure rather than manipulate; patterns and processes are described rather than being experimentally controlled. Although purely descriptive studies in ecology are often criticized it is only by having accurate quantitative descriptions of landscape patterns that testable hypotheses can subsequently be developed.

Simulation modeling can be used as an alternative to the descriptive–inductive approach to landscape ecology. Aided by huge advances in computing, simulation modeling has permitted landscape ecology to throw off some of the constraints of studying region-specific, observable phenomena. Modeling has been used to identify the ecological implications of changing landscape patterns and of alternative management regimes applied to existing land use configurations. The combination of ecological models