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Exploring, forecasting and visualizing alternative ecosystem management scenarios

Over the last decade we have seen considerable change in social values and forest ecosystem knowledge triggering a plethora of complex forest management alternatives. Planning and forecasting the economic, social and environmental consequences of these options requires sophisticated computer models, which are seldom easy to understand. This paper describes how an interdisciplinary team integrated various forest modeling efforts with advanced environmental and data visualization techniques aimed at improving our ability to communicate the resulting spatio-temporal data. Ultimately, the goal of this work was to expand the ability for the public to explore, critique, and improve proposed management alternatives.

INTRODUCTION

Modern-day sustainable forest management requires a great deal of high quality spatial and temporal data related to evaluating proposed management alternatives. Additionally methods for displaying, interpreting and simplifying that data as well as mechanisms and standards for interacting with a variety of consumers of that information - including professional forest managers, conservation groups as well as the general public (both urban and rural) are also essential. This is particularly true in today's climate of increased public scrutiny and the continued shift towards external methods of certification of forest products. Currently in the province of British Columbia, certification bodies such as the Canadian Standards Association (CSA), the Forest Stewardship Council (FSC) and others typically require the inclusion of public values through a variety of mechanisms such as public advisory committees, town hall meetings, etc. In regard to these public forums, it is often the case that forest industry representatives arrive bearing a plethora of spatial information related to the temporal dynamics of the forest ecosystems for which they are proposing a variety of alternative management scenarios. Needless to say this can be quite complex indeed. This information is generally communicated through a number of traditional means such as maps, graphs/charts and text. Unfortunately the sheer bulk of information, when coupled with tight time schedules, limited attention spans and post dinner-hour lethargy tends, to conspire against any truly meaningful discourse between the public and forest managers. As a partial solution to this conundrum, members of the Collaborative for Advanced Landscape Planning (CALP) have sought to streamline the translation of this complex data set into a more intuitively legible form by developing, testing and refining methods for increasingly automating the production of visualizations of alternative forest futures.

While far from a complete solution to the problem of communicating (as well as understanding) complex spatio-temporal forest information, visualization does offer a number of distinct advantages over its more traditional counter-parts. One such advantage is that individuals generally do not need to be told how to process, frame or interpret a "picture" of a proposed future condition. Additionally, we are routinely exposed to immense quantities of information via our visual perceptual systems and are rarely overwhelmed by this complexity. Instead we are immediately drawn to that which is most salient to us and progressively scan the visual array for additional information, as we are able to process it. All of this happens with very little effort on our part, as opposed to when we are reading a technical report, where copious amounts of cognitive energy must be expended to identify, let alone comprehend, the information with which we are most concerned. For that reason, visualizing this complex set of information allows us to capitalize on our evolutionary predispositions to filter visual information automatically. Due to the relative ease with which visual information is absorbed, participants involved in public advisory groups will have a less steep information curve to climb before they can participate meaningfully and with confidence, and as a result are more likely to become engaged in the process.

However a number of limitations related to relying too heavily on visual representations of forestry data have become apparent in recent years. Most obvious of these limitations would be that not all data lends itself to near-photorealistic environmental visualization. Additionally, even information that does lend itself to visualization might not always be best represented or communicated by this method. For example, even though information such as the average crown height of trees in a set of stands is a predominantly visual statistic, one would not want to create a visualization in an attempt to communicate the distribution of this statistic across the land base, since stands of trees located in front of others will occlude those behind them. Another concern generally raised, is that this form of representation may serve to overemphasize the aesthetic dimension of the forest when other dimensions may be more critical in relation to a particular planning concern (e.g. water quality). While in some regards this might be seen as a limitation, it can also be a great strength, as the aesthetic dimensions of our forests have historically been quite important in our forest management and have generally been quite difficult to quantify in discussions related to forest management.

METHODS

To facilitate the construction of near photorealistic environmental visualizations, we at CALP have focused our recent efforts on more fully integrating state-of-the-art forest modeling programs and off-the-shelf rendering platforms, in order to explore these challenges and create tools and imagery for further testing in applied and experimental settings. In this section of the paper, we outline the visualization system as a whole in relationship to the contributions of our multi-disciplinary colleagues in two multi-year research projects, and begin with a brief discussion of the system components represented in Figure 1.

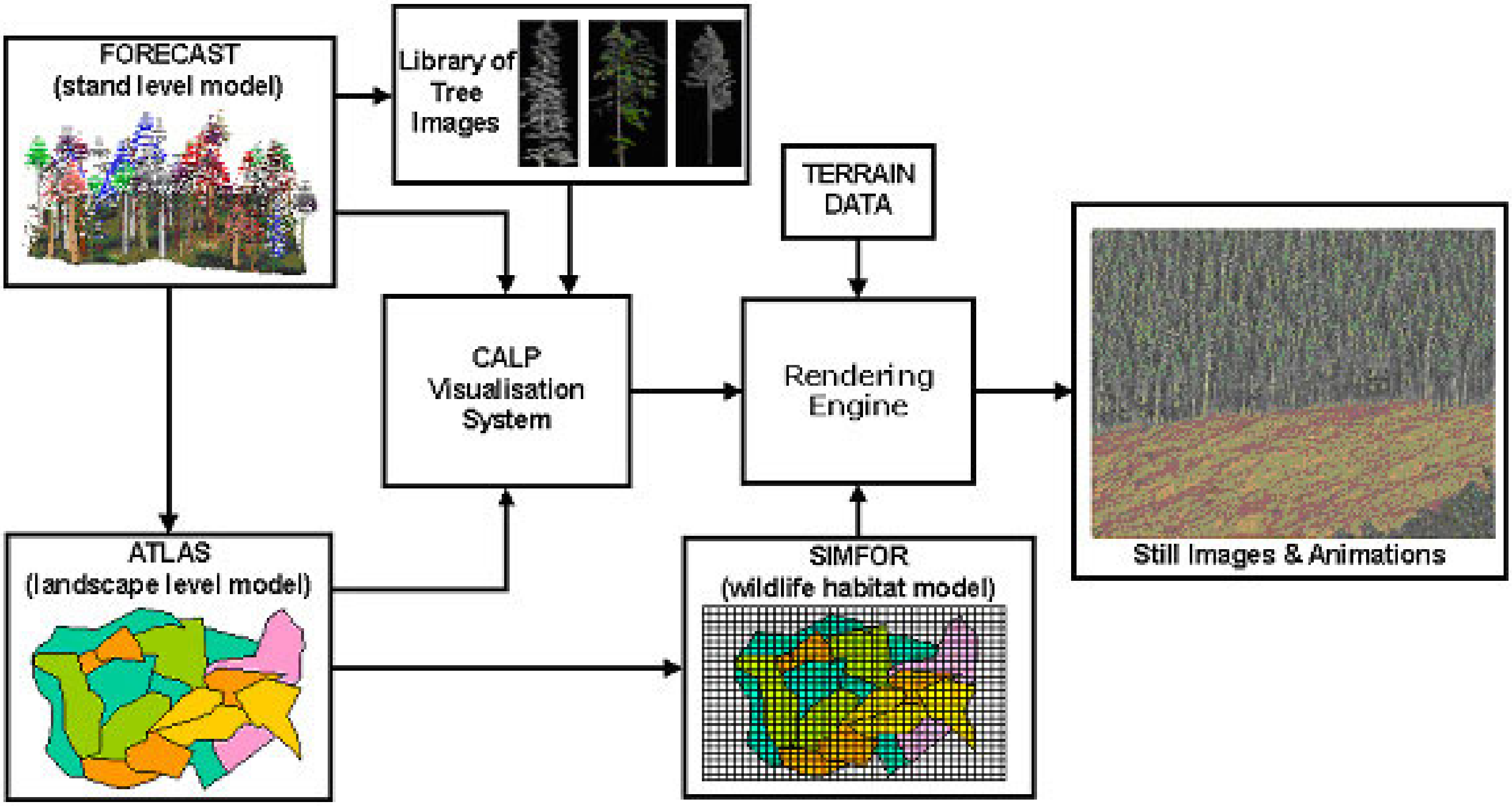

Figure 1: Flow chart showing the overall visualization process used

The CALP Visualization System was created to address some of the goals of a more widely usable visualization system and most simply is a computer program that links a number of forestry modeling programs. While any number of modeling programs could be linked to this system we have focused our initial efforts on FORECAST (an ecosystem-based, stand-level, forest growth simulator), FPS-ATLAS (a forest-level harvest simulation model) and SIMFOR (a decision support tool designed to help managers and researchers evaluate the impacts of forest harvesting scenarios against landscape and habitat indicators). Projected stand data, management actions and various evaluative measures such as wildlife habitat are synthesized by this visualization system and are reformatted to provide a given rendering engine the information needed to create the required visualizations. The strength of this approach is that the resulting system is quite flexible and is able to accept a wide variety of inputs as well as produce output for many different rendering engines. However in this specific case World Construction Set (WCS) was used as the rendering engine and the aforementioned modeling programs were used on the input side.

Because this work has been predominately focused on aspects of forest management within a sub-regional context in British Columbia, and because of the importance of the temporal dimension to forest management decisions, tools were needed to model both stand dynamics and landscape level change. FORECAST was used to provide our visualization system with the necessary parameters for defining species composition, stand densities, tree height, and crown ratios. This model, developed by Hamish Kimmins and the Forest Ecosystem Management Simulation Group at the University of British Columbia (www.forestry.ubc.ca/forestmodels/), was designed to accommodate a wide variety of harvesting and silvicultural systems in order to compare and contrast their effect upon forest productivity, stand dynamics, and various biophysical indicators of non-timber values. The model uses a hybrid approach whereby local growth and yield data are combined with other data to derive estimates of the rates of key ecosystem processes related to the productivity and resource requirements of selected species. *For a more detailed discussion of FORECAST see Kimmins et al., 1999 and Seely et al., 1999.*

For the landscape level modeling, FPS-ATLAS was used to provide the visualization system with information about where and when management activities would occur in the area being modeled. FPS-ATLAS is designed to schedule management activities according to a range of spatial and temporal objectives and forms the basis of our ability to visualize a range of desired forest futures. A number of possible policy dimensions can be explored using this tool such as the rate of harvest flows, the opening size of a block to harvest, targets for seral stage distributions, etc. *For a more detailed discussion of FPS-ATLAS see Nelson & Wells, 1996 or Nelson, 2001.*

These two programs work in concert with one another, FORECAST providing FPS-ATLAS with appropriate growth and yield information based on the harvest and silvicultural information provided by FPS-ATLAS. The CALP visualization system takes output from both of these programs, concatenates, parses and reinterprets this data by means of a Perl script, and generates text files to automate the set up of World Construction Set (WCS) "ecosystems" (a term used by WCS to denote a contiguous and homogeneous vegetation polygon) that in turn allow us to visualize the area being modeled.

Information regarding species composition within the stands is used to select appropriate tree images from the CALP Tree Library. This library of tree images has been amassed over the last five years and includes nearly 200 images of tree species by age and condition common to the province of British Columbia and the Pacific Northwest. Once the appropriate images are selected, they are arranged within the boundaries of the stand according to species density information. Once the basic modeling of a given forest management scenario was accomplished and before visualizations were created, the scenarios were typically handed over to a number of evaluative models (represented in Figure 1 by the SIMFOR box) that would help us to estimate the impacts of the scenario along a number of socially relevant dimensions. One of these dimensions of great importance has traditionally been wildlife habitat and to address this concern SIMFOR was brought to bear on the problem. SIMFOR is a decision support tool designed to help managers and researchers evaluate the impacts of forest harvesting scenarios against landscape and habitat indicators and was originally developed by a team of researchers led by Dr. Fred Bunnell at the Centre for Applied Conservation Research within the University of British Columbia. This program reports on general trends in selected indicators of forest structure and function through space and time, which can then be spatially draped over the environmental visualizations as a color map allowing for the visualization of selected non-visual information as seen in Figure 2. *For more information on SIMFOR see Wells et al., 1999.*

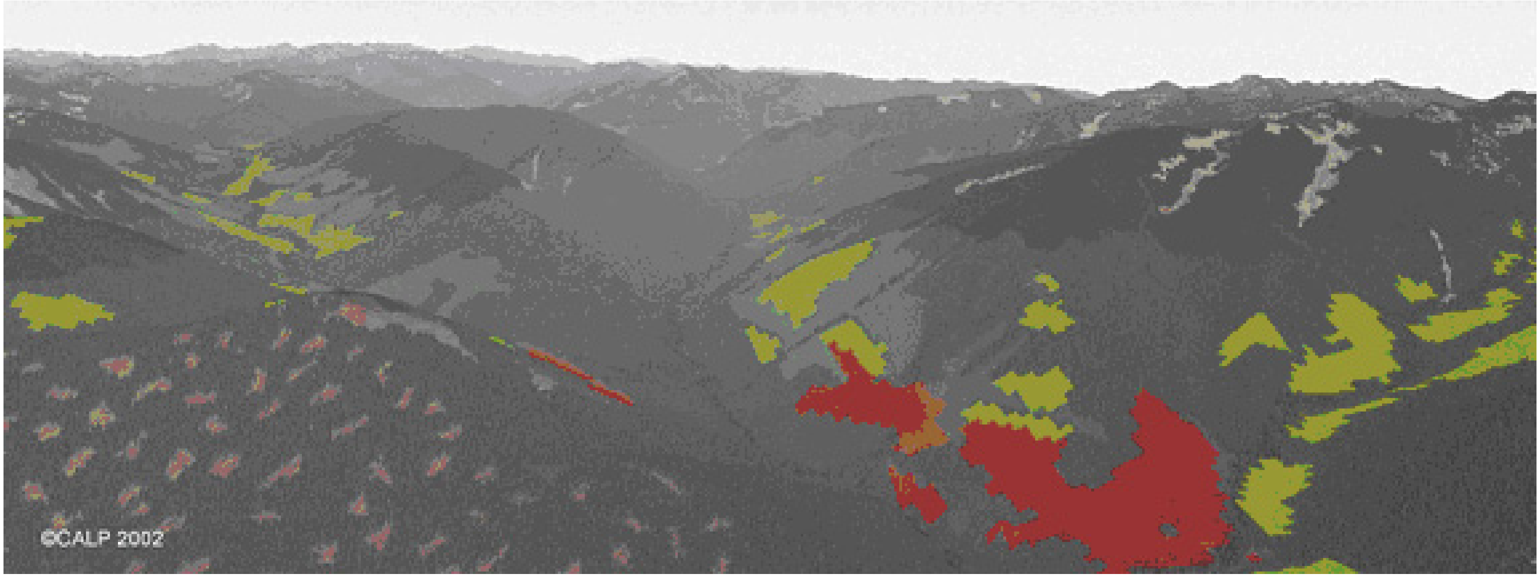

Figure 2: An example of habitat quality information draped over a typical environmental visualization.

RESULTS/DISCUSSION

Numerous visualization sequences, both animation and stills, were created to communicate model outputs. These generally fell into the classes (adapted from Danahy, 1999):

1. strategic overview images
2. visualizations that attempt to communicate spatial patterns or arrangements and
3. visualizations that endeavor to convey some sense of presence or "sense of place".

Examples of these three types of visualizations can be seen below in Figure 3.

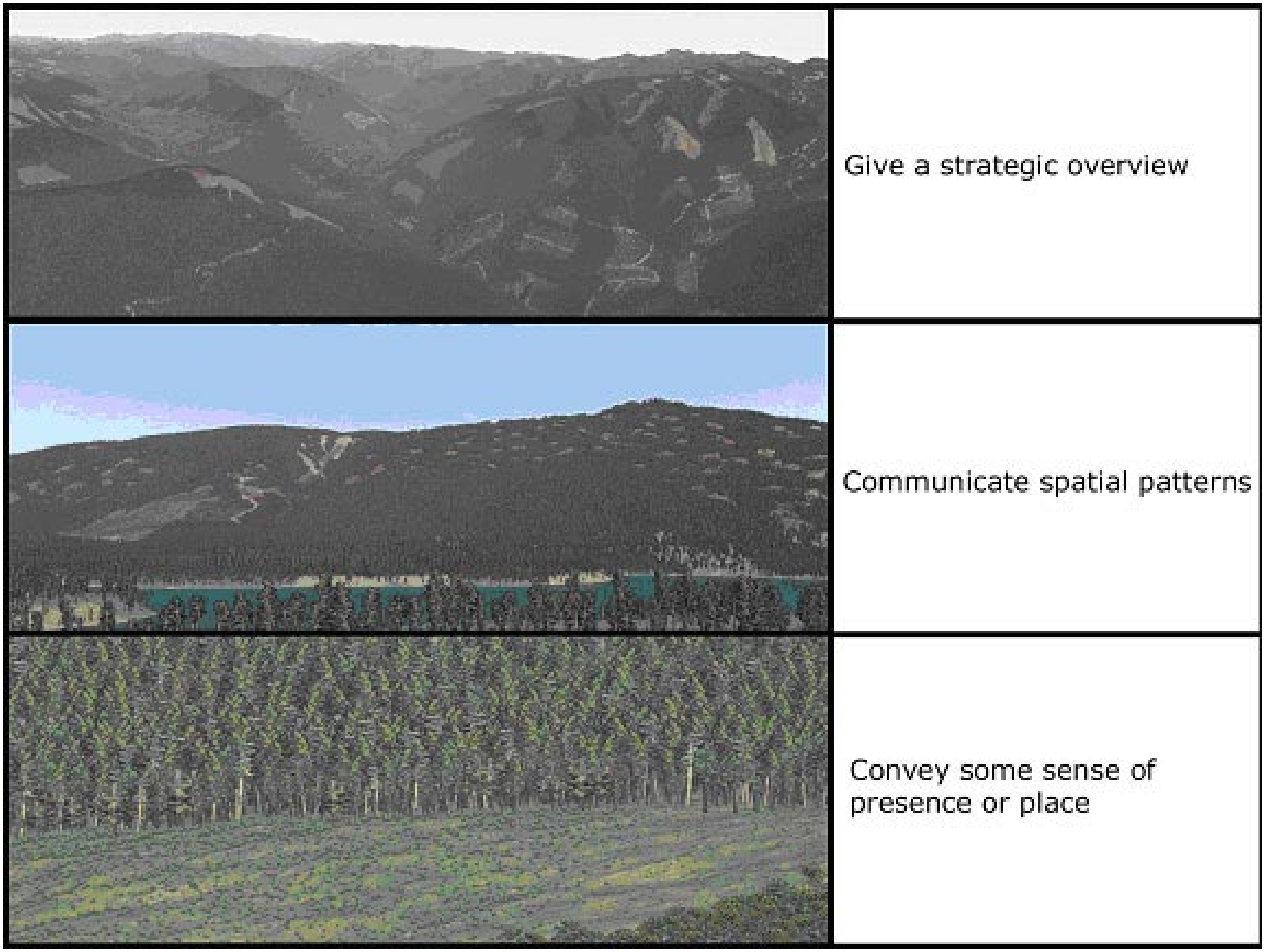

Figure 3: Examples of three distinct types of environmental visualization outputs.

In general, we have found that these visualizations have been useful in a number of ways. Our initial goal was to allow for various forest planning scenarios to be both represented and compared to one another. Preliminary results, based on our usage of these visualizations in this capacity with a variety of public groups, show that, while these visualizations offer a great deal of promise, there are still a great number of issues to be resolved. For example, answering the question as to how to best represent the vast quantities of non-visual data associated with a given scenario to be on a similar footing to the overwhelmingly powerful visual representations presented, has proven to be exceedingly difficult (see Figure 4).

Figure 4: Presenting associated data along side visual representations of that data.

While this problem still requires additional research it should be noted that the spatio-temporal environmental visualization sequences have proven quite useful in simplifying a number of complex spatial and temporal concepts such as stand regeneration, changes in species composition, etc.

In addition to the generally anticipated results above, we have found that these environmental visualizations played a critical role within our group as sources of model validation as well as enabling the discovery of possible errors in the modeling process. At times these errors were both banal and routine, such as spurious elevation values in a digital elevation model, but in other cases, could have been much harder to track down given traditional means of error-checking. Examples of this might range from systematic errors in the assignment of stand attribute information to a failure to realize areas either excluded from or outside the bounds of the modeled area (See Figure 5).

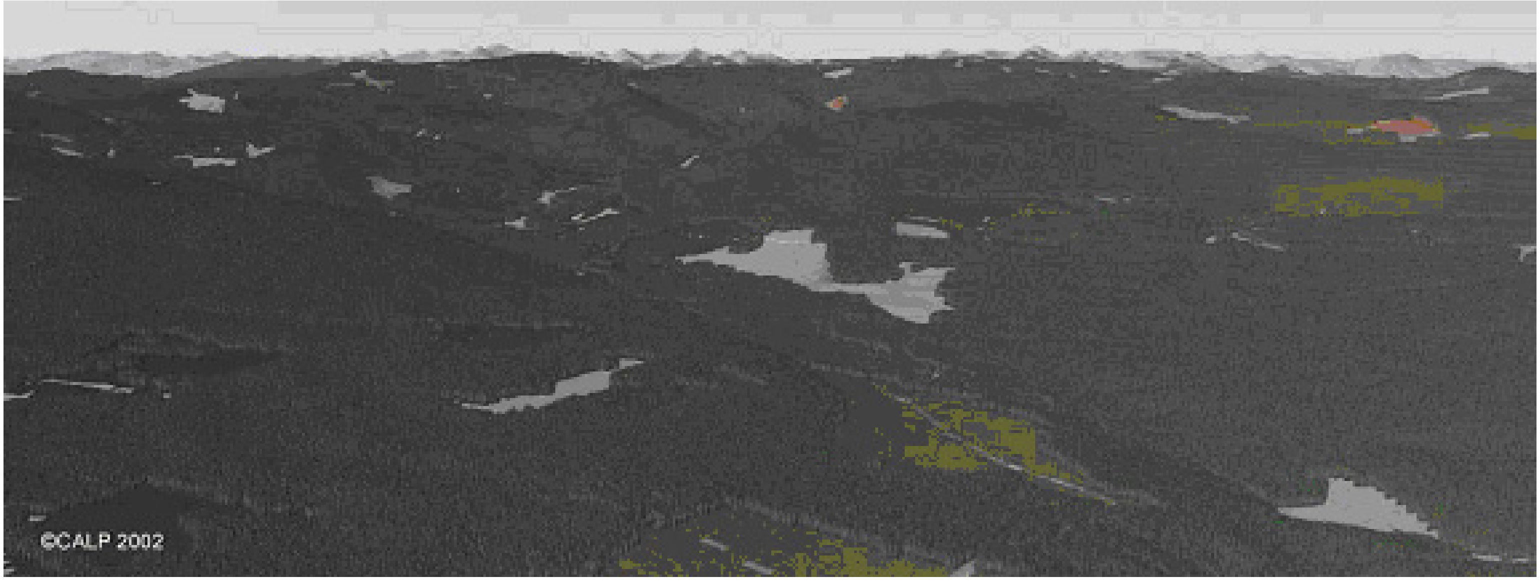

Figure 5: Interim visualization showing missing data in gray

Additionally, these visualizations offer possibilities for innovation, insight and discovery that may very well not occur in the absence of researchers being able to "see" the results of various modeling assumptions. Also, near-photorealistic environmental visualizations and their scientific visualization counterparts offer the ability for scientists to quickly and easily check the face validity of modeled outcomes. Lastly these visual representations are extremely useful in the communication of research outcomes to a variety of groups including but not limited to, public stakeholder groups, environmental non-governmental organizations and forest industry representatives.

CONCLUSIONS

Even though much progress has been made on a number of visualization issues identified as a result of this research, there remains a great deal of improvement to be made in these areas. Visualizations offer distinct advantages in their ability to communicate complex information and to foster understanding amongst a wide diversity of social groups. To this end, it is the opinion of the researchers involved in this work that the development of a targeted suite of communications tools based on these environmental visualization technologies would prove to be immeasurably helpful. This would allow us to elucidate a greater range of complex topics germane to forest management, so that high-level policy makers, forest managers and the general public, might have a greater commonality in the understanding of a variety of issues important in the land management decision-making process.

In addition, work must be done to develop methods for dealing with the communication of the uncertainty in modeling outcomes beyond simply stating confidence intervals about numeric predictions. This is increasingly important when presenting near-photorealistic environmental visualizations, as the tendency of the viewer is to take them at face value. While this certainly applies to more abstract scientific visualizations based on modeled predictions of future outcomes, it is of the even more importance as the realism of the given visualization increases.

Currently, we at the Collaborative for Advanced Landscape Planning are working on the development of a code of ethics for landscape visualization to address these and other concerns (Sheppard, 2001). As the frequency of use of these environmental visualization tools grows, it becomes progressively more important that practitioners in this area are able to turn to a set of standards aimed at increasing the legitimacy of the visualization process. While a complete discussion of this topic area lies outside the scope of this paper, we would invite you to review and comment on a proposed, interim code of ethics for landscape visualization by visiting our website at http://www.calp.forestry.ubc.ca/.

In conclusion, we see a number of advantages, as well as pitfalls, related to the increased utilization of these technologies and clearly hope to advance our understanding of how they relate to the forest planning process. Opportunities undoubtedly exist for further research in this area and it is our intent to move forward in this area, not only through direct research but also through urging the scientific community to focus on research questions that shed light on a number of the issues surrounding the multitude of uses for environmental visualization in improving the management of our increasingly scarce natural resources.

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