Visualizing Tree Crowns for Forest Managers: Informatics Tools Enhance Natural Resource Management

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ABSTRACT
Ecologists aim to answer fundamental scientific questions regarding the natural world. Resource managers make practical decisions about natural resources, often with incomplete data. Our goal is to make research results more available to managers who decide which trees to leave when a forest stand is harvested. To that end, we work with Washington State resource managers and forest canopy researchers to: 1) determine what information technology might make new ecology research more applicable to managers, 2) articulate ecological values that dictate leave trees, 3) understand how those values are communicated. We have designed a catalog of tree crown structure with visualizations and metrics that help interpret complex research data for practitioners. This work extends prior NSF work to build research tools for ecologists, and addresses information technology issues of data presentation and data quality.

Categories and Subject Descriptors
H.2.8 [Database Applications]: Scientific Applications.

General Terms
Ecoinformatics, Data Integration, Data Quality, Decision Support.

Keywords
Scaling, Knowledge Representation, Data Visualization, Human-Computer Interaction, Forest Canopy Structure.

1. INTRODUCTION
Ecology researchers typically focus on scientific questions about the natural world, and sometimes humans’ effects on it. They publish data and report results, but are rarely involved in resource management. Natural resource managers, on the other hand, make practical decisions, often with incomplete data and while balancing conflicting goals. For example, a decision on which stand to harvest and which trees to leave there balances conflicting goals of producing revenue, preserving forests, and providing habitat. Current decision-support models help maximize timber production. However, the models rarely consider ecological values; even if they did, one could not readily derive information about the characteristics of an individual tree and its candidacy as a leave tree from stand-level models.

As the public increasingly appreciates ecological values, government agencies aim to incorporate those values into resource management decision processes. Translating ecological values into management procedures is difficult, however – not just because of a long tradition of revenue maximization, but also because it is not yet well understood how to manage resources for ecological values. Thus, managers of many kinds of resources, not only of forested lands, look to recent scientific ecology research. Unfortunately, as explained above, the goals and objectives of scientific researchers often differ from those of practitioners. The question we address is: how can recent research results be repurposed for resource management? Our work focuses on canopy research and forest management, but some of our results and methods are applicable to other digital government research involving natural resource management.

2. PRIOR RESEARCH
Prior NSF-funded ecology research by Nadkarni et al. established plots in eight forested sites, ranging from 50-950 years old [5]. Objectives were to measure canopy and stand structure, and test hypotheses relating structural complexity, function, and age. These data were used in our work with resource managers.

Complementary to the ecology research, Cushing et al. conducted computer science research on conceptual structures, software components for end users, and informatics to make field research more efficient and effective. The major contribution of that work was a database design tool where domain-specific components could be designed, used, stored and reused. These components enable use of productivity-enhancing databases and increase occurrences of overlapping data among research databases. The effectiveness of these components was demonstrated with visualization tools (Canopy DataBank, Canopy View) [3].

3. NATURAL RESOURCE MANAGEMENT
We conducted two intensive day-long interview sessions, on site at Washington State forested sites, with experienced resource managers, and three additional day-long sessions with canopy researchers. From these sessions we established short-, medium-, and long-term objectives for providing information technology that might render ecology research results more readily usable by resource managers. We learned that some managers do need help in making decisions, but their major bottlenecks lay in communicating (to the public, ecologists, and harvesters), documenting, validating, and following up on those decisions.
4. SUBSEQUENT RESEARCH
In this section, we articulate short-, medium- and long-term research objectives. We have nearly completed our short-term objectives, and begun the medium-term objective. Long-term ecology research objectives, which will likely require information technology innovation, constitute future research opportunities.

Short-term research activities included:

1. Modify our scientific visualization software and our metrics, previously developed for researchers, to serve practitioners as well. The resulting visualizations were run on an extensive ecology research data set, and gathered into a catalog for resource managers. Surprisingly, this repurposing took only about 20% of the time to develop them. Perhaps more surprising, several researchers found those enhancements useful as well. Figure 1 is a new visualization to help analyze crown shape, and estimate crown and crown-gap area and volume. Other visualizations and metrics can be seen at http://alala.evergreen.edu/catalog.

2. Mine current state policy statements and logging prescriptions to extract terms that describe leave trees. The results of this led us to conclude that forest canopy structure is a key indicator of ecological value, but that the terms to describe it (both by researchers and managers) are too vague to be used in data queries or even to generate visualizations of the desired crown structure.

3. With collaborating ecologists and managers, develop summaries of a database with nearly 1000 trees, of which 100 have detailed branch data; then use those summaries to survey ecologists and managers to refine terms gathered in (2). We aim to use the survey to refine descriptions of ecologically valuable leave trees and thus help managers give more explicit harvest directives and better document decisions. More precise terminology might also enable more informatics tools. Pattern recognition techniques to compare visualizations of crown characteristics in different trees, or in the same tree of different orientations, would have been helpful – but we could find no easy to use software for this.

Mid-term objectives involve 1) evaluating use of our crown summaries of individual trees to determine leave trees, and 2) the critical issue of how to scale up in space between relatively small research plots and large harvest sites. For the former, we envision a real or simulated comparison of leave tree selection by two groups of managers: one using traditional workflow and the other using our summaries. The scale issue is more difficult: how might research results from data on small plots apply to decisions on sites 20-30 times larger, or to landscapes hundreds of times larger? Since nearly all forested sites owned by Washington State will in the future have associated with them accurate and detailed 3-D spatial data thanks to new high-resolution, remote sensing technologies, in particular airborne laser scanning or LIDAR [1], we have launched a collaboration with scientists who infer forest structure from LIDAR data. Our detailed crown structure might help develop algorithms that infer individual crown shape, particularly in the lower canopy. If this succeeds, we will have made a small step towards spatial scaling, and our data, with LIDAR data might help look for stands with good leave trees.

Resource managers voiced a long-term need for two kinds of ecology research. 1) Precisely defining desirable leave trees is only the first step. They also need to know whether a candidate tree will likely develop into such a tree. Thus, studies on how particular “left” trees develop over 40-80 years are needed. 2) Because most research plots are small, managers need either more research at greater spatial scales (stand and landscape), or better ways of extrapolating results from plots to site, to landscape.

5. SUMMARY
The major result of our work – better characterization of canopy crowns – will serve both managers and researchers. Managers want to visualize (as in descriptions by Borchert, Hallé, et al. [2, 4]) crown characteristics that provide certain ecological values. Ecology researchers, on the other hand, are charged with describing the crown characteristics of valuable wildlife trees.

To characterize crowns, our informatics tools provide structure summaries that better enable humans to look at data and classify or cluster trees according to structural similarity. While these summaries and more precise terms clearly help, ecology research that yields results more easily applicable over time and space is also needed. We posit that new information technology features are likely required to accomplish that ecology research:

1. Interpolation and extrapolation of missing data on geographically complex topographies.
2. Better models and tools to develop complex simulations (e.g., that ‘grow’ trees both forward and backwards in time).
3. Better pattern recognition and visualization so data (actual and ideal, current and future trees) can be compared and contrasted.

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7. REFERENCES