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Visualizing forest landscapes using public data sources

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Abstract

Three-dimensional (3-D) visualizations of forest landscapes are quantitative ecological information-based techniques that can be used to visualize forest structure, dynamics, landscape transformations and regional plans. Visualizing forests and landscapes with limited ground observations are often the primary challenge for quality animations. Conducting stand-level field surveys over a large forest area is time consuming, labor-intensive and expensive. An alternative is to use existing public datasets. We used the Forest Inventory and Analysis (FIA) database and other existing vegetation data, classified Landsat TM imagery, measurements of tree architecture and Forest Vegetation Simulator (FVS) to visualize a forest landscape in the Washburn District of the Chequamegon National Forest (CNF) in northern Wisconsin to generate useful information for resource management at multiple scales. Realistic images for tree species were designed using the Tree Professional 5 software package. Empirical models were developed to calculate necessary information such as tree height and stand density from DBH, basal area and species composition. The 3-D visualizations were developed at stand and landscape levels within Visual Nature Studio 2.01. Different perspectives of the forest and landscape were visualized through zooming, variable latitudes and flying through. Potential applications of these animations are discussed within a context of alternative management of forests and landscapes (e.g., fire and harvesting), public education and decision-making processes. Results from our study demonstrate that public datasets are suitable for visualizing the dynamics of forests and landscapes, although precisely visualizing forest history is still challenging. It is appropriate to use FIA data for stand level visualization and existing vegetation data for landscape scale visualization. With these different public data sources, forests can be visualized at levels varying from a single stand to the landscape/regional level.

Keywords: Visualization; Stem density; Tree height; Public dataset; Landscape; Forest structure

1. Introduction

Over the past 30 years, advances in computer hardware and software have permitted scientists to simulate and visualize the complex forms, phenomena and dynamics of natural systems, such as plant growth and

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changes in atmospheric conditions (Cox, 1990; Faust, 1995; Ervin and Hasbrouck, 1999; Lim and Honjo, 2003). In landscape studies, geographic information systems (GIS) and remotely sensed data allow us to create necessary spatial data and develop alternative management options that managers often apply in decision-making processes. Consequently, visualizations have evolved as very useful tools for analysis of forest dynamics at stand and landscape levels to assess various management practices (Lange, 1994; Orland, 1994; McCarter, 1997; McGaughey, 1998). Finally, understanding of spatial patterns and temporal dynamics of forest ecosystems can be further advanced through three-dimensional (3-D) visualizations.

Data sources with high accuracy and resolution are essential to develop reliable landscape visualizations (Bergen et al., 1998; Appleton, 2003). Such data may include digital elevation models (DEMs), landcover maps, tree images, tree size (diameter and height), stand densities and species composition. Inclusion of other landscape features such as roads, streams, buildings and other artifacts enhances the quality of animations for users. For forested landscapes, the necessary stand level information (e.g., tree size and stand density) is not always available because conducting field surveys of stand level information over a large forest area is often impractical and expensive (Crow and Schlaegel, 1988). Therefore, visualizing forest dynamics using existing public datasets collected under similar environments of a given landscape (e.g., within the same climate zone) is preferred—suggesting that utilization of available public databases to generate accurate visualization is the primary challenge. We are aware of no published products addressing such needed research in landscape management.

The Forest Inventory and Analysis (FIA) data (Miles et al., 2001, http://www.fia.fs.fed.us/) and other existing vegetation data (Brohman and Bryant, 2003) for the National Forests are public domain databases and have been widely used in scientific investigations and resource management (Birdsey, 1992). Visualization systems based on these datasets are preferred because of their availability and accessibility. For example, numerous models and predictions have been used in stand dynamics models such as the Forest Vegetation Simulator (FVS, Crookston, 1997, 1999). The specific objectives of this study were to: (1) develop visualizations of a forested landscape in northern Wisconsin using existing datasets; (2) demonstrate how 3-D visualizations can help managers to understand ecosystem dynamics at various scales across the landscape; and (3) discuss the potential applications of visualizations to forest management issues (e.g., the impacts of fires and timber harvesting on landscape dynamics).

2. Methods

2.1. Study area

Our study area was a 386 km^2 landscape in the Washburn District of the Chequamegon National Forest (CNF) in northern Wisconsin, USA. Soils are deep (30–90 m), loamy, glacial outwash sands with little organic material. Topography in the area ranges from level terraces to pitted outwash plains (CNF, 1993; Albert, 1995). Elevation ranges from 256 to 439 m. The climate of the study area is characterized by long, cold winters with snow cover from November to April and short, mild summers. The four major forest types are dominated by quaking aspen (*Populus tremuloides* Michx.), red pine (*Pinus resinosa* Ait.), jack pine (*P. banksiana* Lamb.), and northern red oak (*Quercus rubra* L.), with land area of 20.7, 17.1, 13.9 and 11.9% of the total, respectively. Other land cover types include bigtooth aspen (*P. grandidentata* Michx., 4.7%) and paper birch (*Betula papyrifera* Marshall, 2.1%). Forest types such as white pine (*P. strobus* L.), mixed hardwoods, tamarack (*Larix laricina*), sugar maple (*Acer saccharum* Marsh.) and black ash-American elm-red maple (*Fraxinus nigra*, *Ulmus Americana* and *Acer rubrum* L., respectively) are less than 1.0% of the landscape. Non-forested land makes up 27.2% of the total area.

2.2. Creating tree images

Realistic tree images of species are the most critical components for quality visualizations. Tree images can be obtained from the field or designed on the computer. Because tree form varies greatly within and between species, we developed multiple images for each species so that variation within a species is represented. Preferred tree images are site-specific photographs taken in the field. However, taking such images is extremely difficult because of strict requirements such as uniform