



ELSEVIER

Available online at www.sciencedirect.com

SCIENCE @ DIRECT®

Computers
and electronics
in agriculture

Computers and Electronics in Agriculture 43 (2004) 251–256

www.elsevier.com/locate/compag

Application note

Combining search techniques and stand visualization to explore and analyze forest inventory databases

Jeremy S. Wilson

Department of Forest Management, 5755 Nutting Hall, University of Maine, Orono, ME 044469-5755, USA

Received 16 March 2003; received in revised form 22 January 2004; accepted 6 February 2004

Abstract

Computer searching techniques used in combination with a three-dimensional forest visualization program provide an efficient method for exploring and analyzing large forest inventory databases. This paper describes and demonstrates a three-stage approach that combines visualization and searching tools. Using this technique, users can subset and rank stands according to filter and search criteria, refine and evaluate highly ranked stands using stand visualization, and finally evaluate summary statistics for the selected set of highly ranked stands. The approach can be used for objectives that range from facilitating basic exploration of inventory information to conducting analysis on forestry databases. Combining searching techniques and visualization places substantial responsibility for quality of the analysis on the user; however, the inherent transparency of the analysis makes it easy to judge whether the evaluation is applicable and meaningful to the questions being explored.

© 2004 Elsevier B.V. All rights reserved.

Keywords: Database exploration; Forest inventory; Forest visualization

1. Introduction

Increasingly, forest resource managers are being asked to consider multiple objectives across diverse spatial scales and over long-time horizons in their forest plans. For aspects of the planning process that rely on information from a contiguous area, such as aesthetics and habitat, forest landscapes are a logical unit for analysis or planning (Oliver, 1992; McCarter et al., 1998). Unfortunately, detailed inventory is not always available for every management

E-mail address: jeremy_wilson@umenfa.maine.edu (J.S. Wilson).

URL: <http://www.forest-resources.umaine.edu/wilson.htm>.

0168-1699/\$ – see front matter © 2004 Elsevier B.V. All rights reserved.

doi:10.1016/j.compag.2004.02.003

unit within a landscape. Nearest neighbor approaches have been proposed and are being used to fill information gaps common to landscape-scale studies (Moeur and Stage, 1995; Ek et al., 1997). The nearest neighbor technique has been utilized to provide data for areas in a landscape where inventory information is missing. Stands in which detailed inventory information has been collected are matched to those missing information according to criteria for more general information collected across the entire landscape.

The techniques for choosing the nearest neighbor range from relatively simple computerized ranking to more sophisticated use of canonical analysis to model relationships between general conditions with specific information from fully sampled areas (Moeur and Stage, 1995). In this paper, a relatively simple nearest neighbor approach based on ranking according to specified criteria is presented. For this application the nearest neighbor approach has been expanded to include multiple nearest neighbors combined with a three-dimensional visualization tool to help evaluate results and further refine stand selections.

Forest inventory databases can be quite large making exploration and analysis difficult. The searching technique described in this paper is designed to facilitate exploration and evaluation of large forest inventory databases and has uses ranging from finding nearest neighbors to fill information gaps through explorations of relationships in subsets of forestry databases.

2. The three-stage approach

A software application called Stand Search was developed in Microsoft AccessTM to implement the three-stage approach described in this paper (Wilson, 1999). In the first stage, investigators specify filter and search criteria to narrow down and then rank plots or stands within the database. In the second stage, investigators utilize three-dimensional stand visualization software to conduct detailed examinations, selections, and analyses on the remaining relatively highly ranked stands. In the final stage, investigators evaluate summary statistics for the subset of highest-ranking stands. The technique combines rapid exploration and analysis of large databases with detailed examination of specific stands or plots using graphical analysis.

2.1. First stage: filtering and ranking

The first stage combines the use of filter and search criteria to limit and rank plots. Filter criteria can be used to limit selected plots based on text or numeric fields. For example, filter criteria could restrict a search to inventory plots in which Douglas-fir (DF) (*Pseudotsuga menziesii* [Mirb.] Franco) dominates basal area and to plots where the elevation is less than 2000 feet (Fig. 1). Filter criteria eliminate inappropriate plots from consideration and can make the subsequent ranking process more efficient.

Search criteria are used to rank the subset of filtered plots based on how closely they match user targets for numeric fields. For example, search criteria could rank which plots are closest to having a dominant tree height of 80 feet, a stand density index of 500 (Reineke, 1933), a single canopy layer (Baker and Wilson, 1998), and an average canopy depth that is 30% of overall height (Fig. 1).

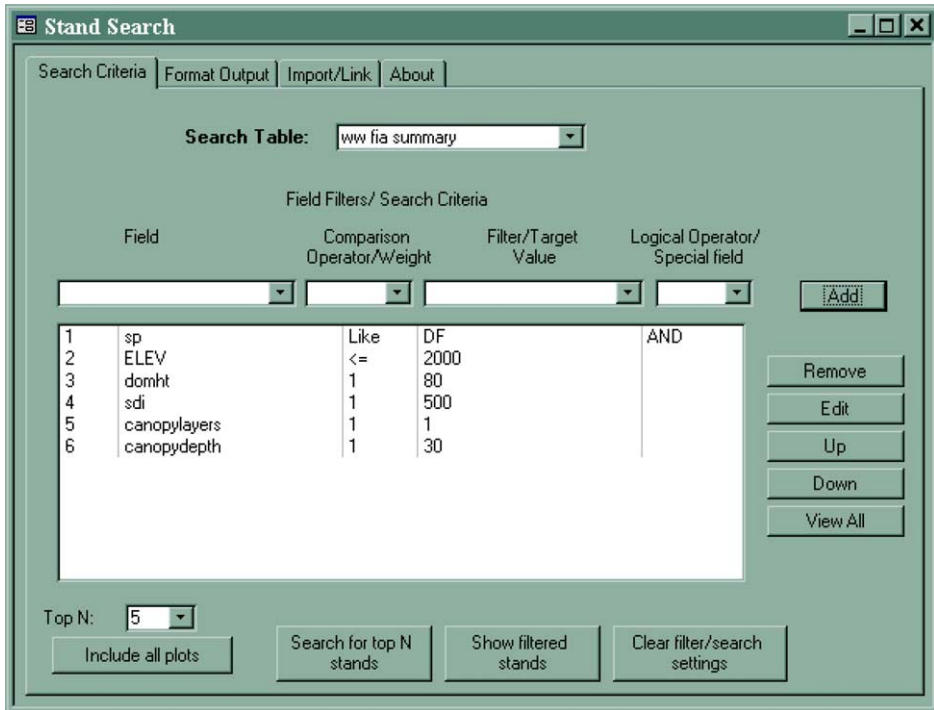


Fig. 1. Main window in Stand Search depicting filtering (1 and 2) and search (3–6) criteria for the Western Washington USDA Forest Service Forest Inventory and Analysis database.

The search-criteria ranking of plots is determined by minimizing the sum of relative deviations (SRD) between individual plot values and the numeric criteria specified:

$$SRD = \sum_{i=1}^n W_i \frac{|P_i - T_i|}{\text{Max}|P_i - T_i|} \tag{1}$$

where W_i is the weight assigned to i th criterion; P_i is plot value for i th criterion; T_i is target value for i th criterion; $\text{Max}|P_i - T_i|$ is maximum difference for i th criterion across all plots; n is the total number of criteria.

The absolute difference between a plot’s value and target value for a criterion are determined for every plot in the filtered database. Dividing by the maximum difference among all plots in the database provides a relative deviational value. Relative deviations can then be weighted by applying a designated weighting factor for that criterion. The weighted relative deviations are summed across all of the specified criteria for each plot. Plots are

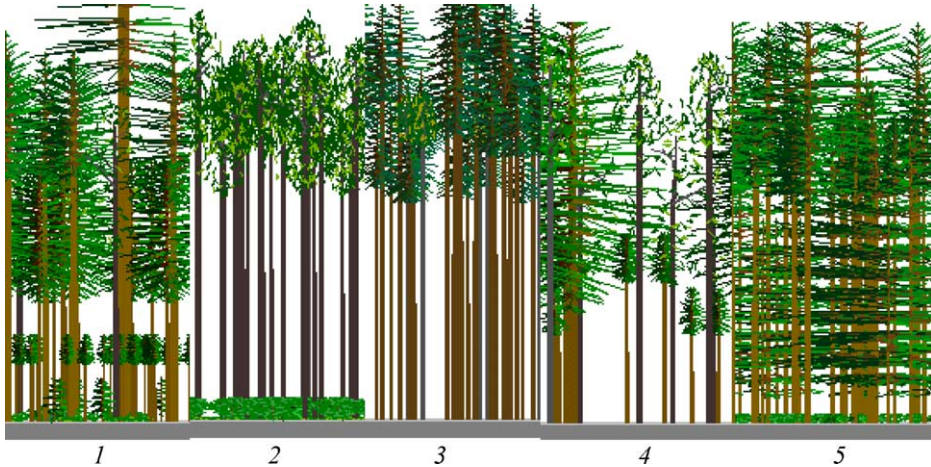


Fig. 2. The five highest-ranking subplots from a search for plots with an average dominant height of 80 feet and a stand density index of 500. Plot characteristics range widely, suggesting the need to further refine filter and search criteria. Images created using Winsvs (McGaughey, 1997).

tributes. Three-dimensional visualization tools such as the Stand Visualization System (SVS; McGaughey, 1997) are useful because they allow detailed information about individual trees and plants in an entire plot to be presented simultaneously with little or no summarization of the underlying data (Wilson and McGaughey, 2000). Summary statistics (i.e., average dbh, average height, Reineke Stand Density Index (SDI), can be misleading descriptors of stand characteristics, particularly when the shapes of the underlying distributions are unknown (Wilson, 1998).

The visual evaluation of plot details allows investigators to judge how effectively filter and search criteria are identifying similar plots (Fig. 2). If the detailed visual evaluation determines that highly ranked plots are frequently unacceptable, filter and search criteria may need to be added, removed, or modified to improve performance in an iterative fashion (Fig. 3). If the criteria appear to be working effectively for most plots, a peculiar plot can be removed manually. This allows the investigator to refine the selection of highest-ranking plots.

2.3. Third stage: results for the top-ranking plots

Once the top-ranking plots have been identified using filter and search criteria and iteratively refined through examination and visual evaluation, summary statistics for the highest-ranking plots can be examined. The type of summary statistics evaluated is limited only by the information that is available in the original database. Evaluations of these summary statistics may reveal relationships among the highest-ranking plots. For example, the average understory vegetation cover for the five plots pictured in Fig. 3 is 8% with a range from 0 to 20%. The limited range in understory cover values in this exam-

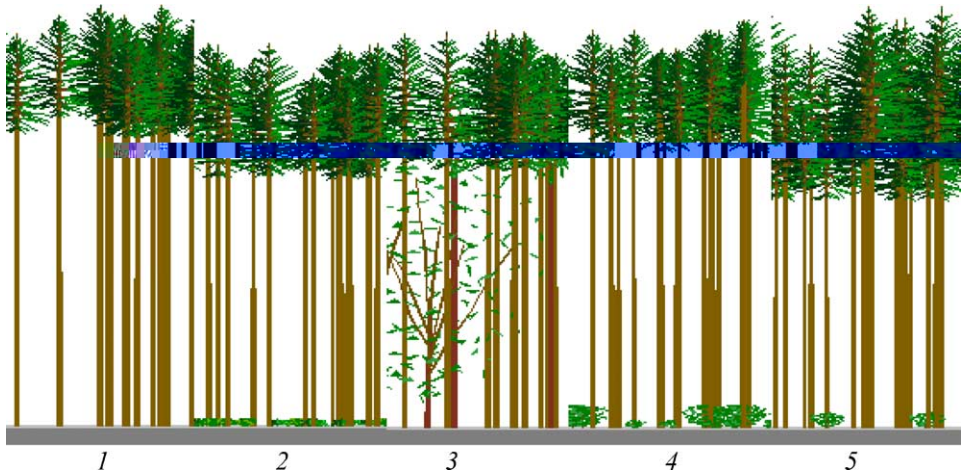


Fig. 3. Through an iterative process involving examination and visual evaluation of the highest-ranking plots the filter and search terms can be refined to capture desired stand characteristics more closely and consistently. The five highest-ranking subplots from a search for lower elevation plots dominated by Douglas-fir with an average dominant height of 80 feet, a stand density index of 500, one canopy layer, and an average canopy depth of 30%.

ple suggests that the characteristics used to select plots may influence understory development.

3. Conclusion

The combination of searching techniques and stand visualization described in this paper produces a transparent approach to analysis that exposes the strengths and weaknesses of the database and relationships being investigating. Users can concentrate the analysis on those stand conditions that are of special concern to the questions being asked. Similarities between high-ranking plots and specified criteria provide feedback on the appropriateness of the database for addressing specific questions. Residual variation among summary statistics for the highest-ranking plots presents the investigator with a clear sense for the strength of the relationship under investigation. Another advantage of this approach is that nearest neighbors are determined with each set of criteria; therefore, new data can be added to the database without having to update models developed using more static analysis techniques.

The transparent nature of three-stage approach described puts considerable responsibility upon the investigator for the quality of any analysis. Database suitability and search criteria must be carefully evaluated to determine if exposed relationships are meaningful. The use of three-dimensional stand visualization tools to facilitate exploration of the data and further refine the selection of highly ranked stands is a very powerful tool; however, it requires subjective evaluation of images and could lead to biased results if not used with considerable caution.

Acknowledgements

This research was supported by the USDA Forest Service Pacific Northwest Research Station Compatibility Initiative (Robert McGaughey and Steve Reutebuch, Principal Investigators).

References

- Baker, P.J., Wilson, J.S., 1998. A quantitative technique for the identification of canopy stratification in tropical and temperate forests. *Forest and Ecology Management* 127, 77–86.
- Ek, A.R., Robinson, A.P., Radtke, P.J., Walters, D.K., 1997. Development and testing of regeneration imputation models from forests in Minnesota. *Forest and Ecology Management* 94, 129–140.
- McCarter, J.B., Wilson, J.S., Baker, P.J., Moffett, J.L., Oliver, C.D., 1998. Landscape management through integration of existing tools and emerging technologies. *Journal of Forestry* 96 (6), 17–23.
- McGaughey, R.J., 1997. Visualizing forest stand dynamics using the stand visualization system. In: *Proceedings of ACSM/ASPRS*. vol. 4, no. 2, pp. 48–57.
- Moeur, M., Stage, A.R., 1995. Most similar neighbor: an improved sampling inference procedure for natural resource planning. *Forest Science* 41, 337–359.
- Oliver, C.D., 1992. A landscape approach: achieving and maintaining biodiversity and economic productivity. *Journal of Forestry* 90 (9), 20–25.
- Reineke, L.H., 1933. Perfecting a stand-density index for even-aged forests. *Journal of Agricultural Research* 46, 627–638.
- Wilson, J.S., McGaughey, R.J., 2000. Presenting landscape-scale forest information: what is sufficient and what is appropriate. *Journal of Forestry* 98 (12), 21–27.
- Wilson, J.S., 1998. Wind stability of naturally regenerated and planted Douglas-fir stands in coastal Washington, Oregon, and British Columbia. Ph.D. Dissertation, University of Washington, p. 160.
- Wilson, J.S., 1999. Stand Search User's Guide: A Tool for the Exploration and Analysis of Forestry Databases. USDA Forest Service, Pacific Northwest Research Station, Cooperative for Forest System Engineering, p. 29.