SDSS IN THE MANAGEMENT OF FOREST RESOURCES

Alan T. Murray
Ohio State University, Columbus, Ohio, USA

Keywords: spatial decision support systems, geographic information systems, forest modeling and planning

Contents

Summary

Forest planning is a complex endeavor when political agendas, public demands, industry needs, and sustainability issues are thrown into the mix. Spatial decision support systems (SDSS) have evolved to address this complex planning situation. Considerable work on SDSS development has emanated from the field of forestry. This article reviews SDSS development and use in forest resource management. The unique concerns that bring about the need for SDSS in forest management are detailed. The ways in which GIS and SDSS are interrelated in forest planning are discussed. Forest management applications of SDSS are detailed, highlighting the application issues being addressed. Anticipated future trends in the application and development of SDSS for forest management are also given.

1. Introduction

Environmental consciousness is perhaps greater now than it has ever been. One way in which this is evident is through the compulsory evaluation of sustainability whenever the natural environment is altered, particularly in the case of forest timber production. The health and viability of forest resources has come under increasing scrutiny as a result of changing public attitudes and expectations. Both public and private lands have been subject to heightened governance. Although the private sector appears to be more constrained in the use of forestlands than ever before, laws and regulations are not new in forest management. The United States Department of Agriculture (USDA) Forest Service, for example, has long been mandated to use quantitative approaches in the management of public forests. Detailed analysis practices and regulatory oversight are seen to be important for ensuring that natural resources exist in the future.

Addressing issues of sustainability has become a primary challenge for forest managers. What is particularly difficult in the management of forest resources is balancing a wide range of desired uses. For example, the timber industry is dependent on access to sustained forest yields, but this use may not promote biodiversity, long-term sustainability, recreation, and so on. Recognized needs associated with the management of public forest resources include: basic understanding of forest ecosystems, ability to accommodate public input, industry sensitivity, accounting for uncertainty, detailed digital information on forest attributes, and approaches for developing management plans. As a result, a managing forest resource is very much an ill-structured problem, where associated valuation is difficult and usage trade-offs are paramount. It is no wonder that expectation for thorough analysis is greater, nor is it surprising that the public now demands the ability to provide input on proposed management plans. While initial attempts to address forestry planning problems relied primarily on optimization based modeling approaches, changing requirements of the management process have resulted in a greater reliance on spatially detailed information and interactive tools, such as geographic information systems (GIS) and SDSS.

This article reviews the use of SDSS in forest resource management. The next section establishes the context and definitions of GIS and SDSS. This is followed by a partial review of SDSS applications for forest resource management. The issues addressed using SDSS in forest modeling are then discussed. The article concludes with comments on anticipated future trends in forest management.

2. GIS and SDSS

Interactive tools for managing forest resources have largely been based upon the use of GIS and SDSS.

A GIS may be defined as a collection of hardware and software facilitating the following functions:

(a) creation/input of spatial information in a digital format
(b) management of spatial information
(c) manipulation of spatial information
(d) display and product output of spatial information
(e) analysis of spatial information

Elements (b) and (c) suggest that GIS is actually a type of database management system (DBMS), as they are common features of traditional DBMS. The distinguishing features of GIS are items (a), (d), and (e). Spatial information has numerous unique qualities and characteristics. For example, database entities are geographically located with an associated footprint on the surface of the earth. As a result there is an implicit notion of proximity, where relationships between spatial objects have meaning and may be interpreted. Distance and adjacency are important proximity features. Given the unique qualities of spatial information, there are implications for how data may be processed, presented, and analyzed. In particular, representing geographic information in a digital environment is complex, especially if it is done in an efficient and appropriate manner (see *Advanced Geographic Information Systems,* and *Spatial Data Quality)*. Clearly GIS serves a unique and important role in forest management, as the information of interest is spatial.

It is not be surprising that when GIS emerged, spatial information in a digital format was lacking. Thus, there has always been an emphasis on data collection in GIS development and application. While many functions required by forest planners can be fulfilled with simple database queries, many researchers and practitioners have found that more sophisticated spatial analysis functionality, component (e), is required than is currently available in GIS packages. This lack of functionality and the need for developing additional tools to work in conjunction with GIS have been discussed in the literature. Among the problems associated with the lack of GIS functionality are:

- Exploration of spatial relationships within data is limited,
- Ability to assign activities to entities is virtually impossible,
- Negotiation and interaction is not possible, and
- Complex assessment of management scenarios is difficult at best.

Additional GIS functionality may be provided through customized tool development. SDSS has emerged as the approach utilized for advancing spatial analysis and planning model functionality, with GIS continuing to be recognized as an important component of the overall management process (see *Introduction to Spatial Decision Support Systems)*. The implication of this view has been that enhanced analysis capabilities should compliment existing GIS functions. SDSS has tended to represent a framework within which the capabilities of GIS and application-specific analysis or modeling approaches are integrated for addressing unique spatial planning problems. The emergence of SDSS has led to a reassessment of the kind of GIS analysis capabilities that should be developed and provided. The strength of SDSS has been the ability to evaluate and develop forest-planning alternatives (management scenarios) through an interactive and highly visual interface. Addressing sustainability in the context of forest management necessitates the evaluation of multiple concerns and criteria, which requires an integrated framework for analyzing conflicting and competing objectives. Typically this cannot be done using GIS, so SDSS provides user interaction for addressing ill structured planning problems.

An SDSS typically enables the following needs to be addressed:

- Capture, input, and storage of geographic and attribute data;
- Represent complex geographic structures and relations associated with geographic data;
- Integrate external models and data;
- Flexible and adaptive architecture for application customization;
- User friendly interface that supports human–computer interaction; and
- Provide a range of outputs to support geographic decision making.

Clearly this represents an extension of GIS capabilities and attempts to address the recognized limitations of GIS for spatial planning applications. The major subelements of an SDSS, as suggested in the above definition, are illustrated in Figure 1. Shown in

Figure 1 are the five major components of an SDSS. One component is the interface, essential for user interaction with the system. A second component is a GIS, highlighting that an SDSS builds upon functionality provided by GIS. The third component is a module responsible for managing all necessary analytical techniques. A fourth component is the module handling non-spatial information display and reporting. Finally, the fifth component of the SDSS is the system linkage and management module.

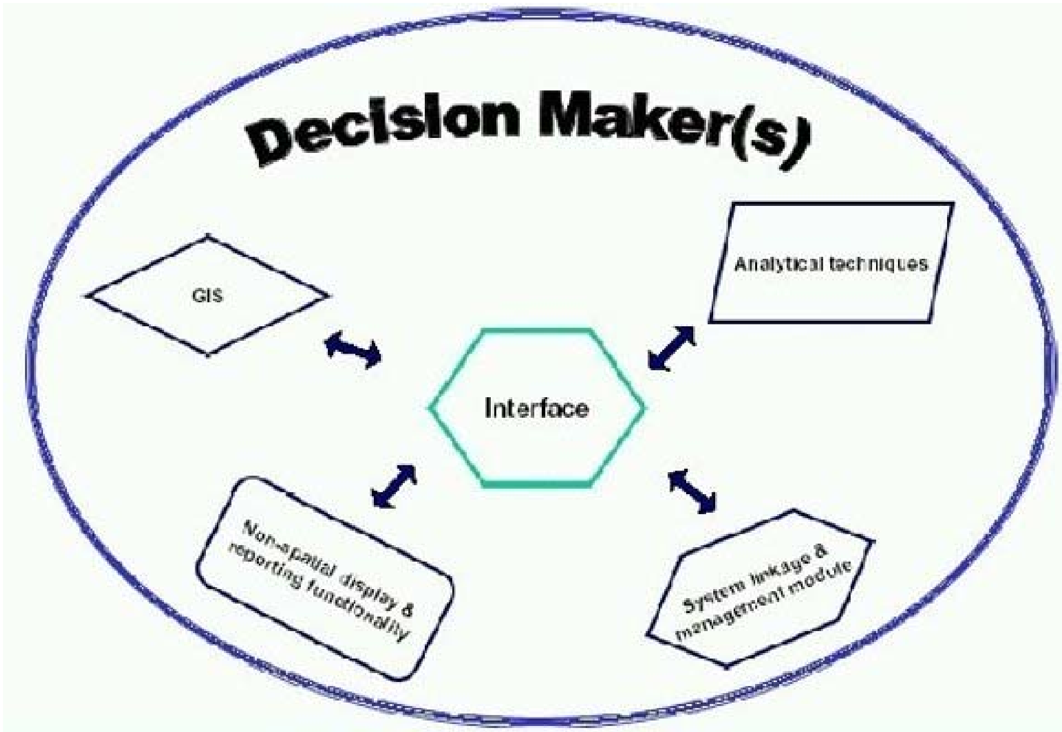

Figure 1. SDSS framework

SDSS is distinguished from GIS by its focus on supporting analytical modeling, customizing cartographic display for a specific application, tending to have a fixed scale of analysis (in contrast to the variable scale of analysis characteristic of GIS), providing flexibility to report and summarize data, and ensuring significant user interaction.

In addition to the characteristic features of SDSS, there are issues of how an SDSS should be structured. Since GIS is typically a major component of SDSS, much design effort involves how GIS functionality will be integrated in an SDSS. Four potential approaches exist. The first is to extend a GIS to carryout the needed analysis functionality of a SDSS. Traditionally this has been difficult to do given limitations in accessing internal GIS procedures, but the latest generation of object-oriented GIS software promises an improvement in customizing and extending GIS capabilities. A further issue with extending GIS capabilities is that it usually involves extensive programming, which may or may not be supported by a particular GIS. The second approach is to construct SDSS modules that link with GIS in order to take advantage of spatial information management and processing. This has been a popular approach for SDSS development. The third approach is to export information between a GIS and a developed SDSS as needed. This too has been a highly utilized approach for SDSS. The final approach is to begin from scratch and develop both GIS and other needed SDSS functionality in a new system. This is certainly the most costly approach and tends to be avoided if at all possible.

-
-
-

Bibliography

Covington W.W., Wood D.B., Young D.L., Dykstra D.P., and Garrett L.D. (1988). TEAMS: a decision support system for multiresource management. *Journal of Forestry* **86**(8), 25–33. [This article is among the first published SDSS applications in forestry.]

Church R.L., Murray A.T., Figueroa M.A., and Barber K.H. (2000). Support system development for forest ecosystem management. *European Journal of Operational Research* **121**, 247–258. [A recent article on the development, configuration and operational characteristics of an SDSS for forest management.]

Davis R.G. and Martell D.L. (1993). A decision support system that links short-term silvicultural operating plans with long-term forest-level strategic plans. *Canadian Journal of Forest Research* **23**, (1078), 1–95. [This article details an application of SDSS to hierarchical forest planning.]

Epstein R., Morales R., Seron J., and Weintraub A. (1999). Use of OR systems in the Chilean forest industries. *Interfaces* **29**(1), 7–29. [Details much of the planning model work being done in Chile for private forest management.]

Hasle G., Haavardtun J., Kloster O. and Lokketangen A. (2000). Interactive planning for sustainable forest management. *Annals of Operations Research* **95**, 19–40. [A recent article on the development of an SDSS for forest management.]

Kent B., Bare B.B., Field R.C., and Bradley G.A. (1991). Natural resource land management planning using large-scale linear programming: the USDA Forest Service experience with FORPLAN. *Operations Research* **39**, 13–27. [This article gives an insightful look into the evolution of mathematical modeling to support forest planning in the United States.]

Leung Y. (1997). *Intelligent Spatial Decision Support Systems*, 470 pp. Berlin: Springer Verlag. [The most recent text that details the various aspects of SDSS.]

Loh K.D. and Rykiel E.J. (1992). Integrated resource management systems: coupling expert systems with database management and geographical information systems. *Environmental Management* **16**, 167–177. [One of the initial articles detailing the use of GIS and SDSS for natural resource management.]

Naesset E. (1997). Geographical information systems in long-term forest management and planning with special reference to preservation of biological diversity: a review. *Forest Ecology and Management* **93**, 121–136. [This article discusses and reviews the use of GIS in forest management as well as SDSS use and application.]

Rauscher H.M. (1999). Ecosystem management decision support for federal forests in the United States: A review. *Forest Ecology and Management* **114**, 173–197. [This article gives an overview of ecosystem management in the US and the use of expert systems, DSS and SDSS in forestry]

Biographical Sketch

Alan Murray obtained a B.S. in mathematical sciences, an M.A. in statistics and applied probability, and a Ph.D. in geography, all from the University of California at Santa Barbara. Dr. Murray is currently an Assistant Professor in the Department of Geography at The Ohio State University. His research and teaching interests are in geographic information science, and urban, regional, and natural resource planning and development. In particular, he is interested in issues of sustainability and patterns of criminal activity. Professor Murray has published on a range of technical and application oriented topics in journals such as the *International Journal of Geographic Information Sciences*, *Geographical Analysis*, *Journal of Geographical Systems*, *Professional Geographer*, *Environment and Planning*, *Journal of Urban Planning and Development*, *British Journal of Criminology*, *Papers in Regional Science*, *Forest Science*, *Canadian Journal of Forest Research*, *European Journal of Operational Research*, *Annals of Operations Research*, *Computers and Operations Research*, *INFOR*, *OR Spektrum*, *Transportation Research*, *Location Science* and *Journal of Heuristics*.