MANAGING FOREST ECOSYSTEMS

Systems Analysis in Forest Resources

Edited by
Greg J. Arthaud and Tara M. Barrett

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Managing Forest Ecosystems

Volume 7

Aims & Scope:

Well-managed forests and woodlands are a renewable resource, producing essential raw material with minimum waste and energy use. Rich in habitat and species diversity, forests may contribute to increased ecosystem stability. They can absorb the effects of unwanted deposition and other disturbances and protect neighbouring ecosystems by maintaining stable nutrient and energy cycles and by preventing soil degradation and erosion. They provide much-needed recreation and their continued existence contributes to stabilizing rural communities.

Forests are managed for timber production and species, habitat and process conservation. A subtle shift from *multiple-use management* to *ecosystems management* is being observed and the new ecological perspective of *multi-functional forest management* is based on the principles of ecosystem diversity, stability and elasticity, and the dynamic equilibrium of primary and secondary production.

Making full use of new technology is one of the challenges facing forest management today. Resource information must be obtained with a limited budget. This requires better timing of resource assessment activities and improved use of multiple data sources. Sound ecosystems management, like any other management activity, relies on effective forecasting and operational control.

The aim of the book series ***Managing Forest Ecosystems*** is to present state-of-the-art research results relating to the practice of forest management. Contributions are solicited from prominent authors. Each reference book, monograph or proceedings volume will be focused to deal with a specific context. Typical issues of the series are: resource assessment techniques, evaluating sustainability for even-aged and uneven-aged forests, multi-objective management, predicting forest development, optimizing forest management, biodiversity management and monitoring, risk assessment and economic analysis.

The titles published in this series are listed at the end of this volume.

Systems Analysis in Forest Resources

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LINKING TEMPORAL-OPTIMIZATION AND SPATIAL-SIMULATION MODELS FOR FOREST PLANNING

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Key words: Landscape modeling, forest planning, simulation, optimization, HARVEST, Spectrum

Abstract: Increasingly, resource management agencies and researchers have turned their analysis and modeling efforts towards spatial and temporal information. This is driven by the need to address wildlife concerns, landscape issues, and social/economic questions. Historically, the USDA Forest Service has used optimization models (i.e., FORPLAN and Spectrum) for timber harvest scheduling in national forest planning. Spatial details often were based on geographic strata, model constraints and mapping. Recently, more spatial analyses have been used in forest plan revisions. But many spatial analyses are limited in their flexibility to address concerns about management standards and guidelines and relationships to non-agency lands. To address these limitations, we are linking two extant models, Spectrum and HARVEST, for forest plan revision on the Chequamegon-Nicolet National Forest in northern Wisconsin. Spectrum provides an initial optimal solution given standard linear programming inputs. Resulting vegetative treatments are filtered through an interface that distributes selected treatments to HARVEST's raster-based management areas over time. HARVEST's parameters adjust cut sizes, buffers and adjacency considerations. HARVEST is used to simulate implementation of Spectrum schedules in a spatial context. Spatial outputs such as area of closed forest and patchiness are calculated and displayed for the planning horizon. Unsatisfactory spatial patterns can be adjusted through subsequent

G.J. Arthaud and T.M. Barrett (eds.), Systems Analysis in Forest Resources, 165–173.

Spectrum/HARVEST runs. The Park Falls Ranger District (62,000 ha) and nearby private lands are used for this case study.

1. INTRODUCTION

Spatial analysis of management direction will be essential for U.S. national forests as they revise their forest plans over the next few years. The first round of forest plans, completed mostly in the late 1980s, relied on aspatial linear programming models to assess timber sustainability and species habitat requirements. Since then, many modeling efforts have been undertaken to deal with spatial concerns, such as patchiness, edge, and harvest adjacency. Some approaches are based on optimization (Hof and Bevers 2000), while others simulate change (Gustafson and Crow 1994). Optimization and simulation have inherent strengths and weaknesses. For example, most linear optimization models can handle and select among many harvesting options, but only coarsely address spatial details. Simulation models, on the other hand, may deal well with spatial considerations, but not as ably with potentially thousands of constrained harvest scheduling choices which are linked to policies such as non-declining timber production. We are capitalizing on the strengths of two models, HARVEST (for spatial simulation/analysis) and Spectrum (for optimizing harvest schedules), by linking them.

The Chequamegon-Nicolet National Forest (CNNF) is located in northern Wisconsin (figure 1). Currently, the 600,000 ha CNNF is undergoing forest plan revision and must consider ecological, economic and social sustainability (Committee of Scientists 1999). The revised forest plan will address many problems identified through public participation efforts; these include ecosystem restoration, landscape patterns, old growth, wildlife, and others. Composition and structure of forested ecosystems are integral to sustaining ecosystems and are influenced by various ecological processes (e.g., productivity, growth, nutrient cycling, energy flow, etc). Composition and structure are most often modeled in the planning context with less explicit treatment of functions/processes. In combination, HARVEST and Spectrum can provide ecological details on projected age-class structure of the forest, vegetative structure, species composition, land allocations, and landscape patterns. These data are needed to assess cumulative effects of forest management.

The purpose of this paper is to describe the modeling approach we devised for the 62,000 ha Park Falls Ranger District (figure 1) in north central Wisconsin. This portion of the forest is representative of the larger

CNNF area in terms of forest composition and structure as well as management goals. First, we discuss the models used and how they are linked. Then we identify additional modeling considerations and future work. Overall, we are attempting to create a generic modeling approach that is straightforward and adaptable across many national forest areas. Though not explicitly included in our current efforts, potential exists to examine the interaction of private and public lands management on the structure and composition of forested ecosystems.

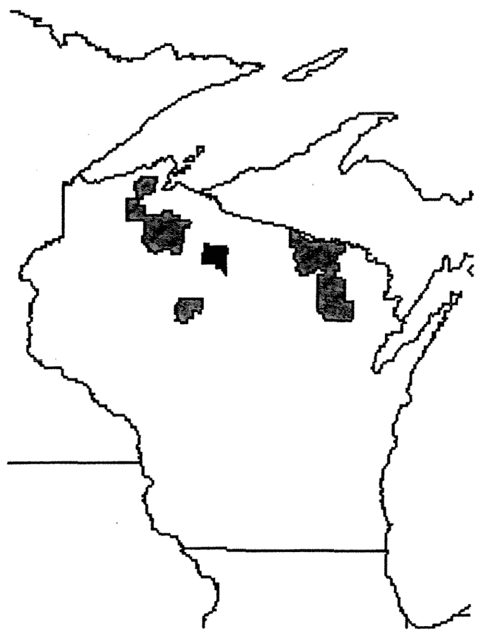

Figure 1. Location of Chequamegon-Nicolet National Forest (gray/black) and Park Falls Ranger District (black) in northern Wisconsin.

2. SPECTRUM

Spectrum and its predecessor, FORPLAN, have been used extensively in national forest planning. FORPLAN models were developed in the mid-1980s for the Chequamegon and Nicolet National Forests' land and resource management plans (before the forests were administratively combined). Due to periodic training programs, administrative support and organizational memory, Spectrum/FORPLAN is still widely recognized within the Forest

Service. As a result, the CNNF planning team decided to use Spectrum in its current plan revision efforts. As is often the case in forest planning, a prototype area was chosen to explore the capabilities and limitations of the model; the Park Falls Ranger District was chosen.

Several versions of Spectrum are available from the USDA Forest Service; we are using Version 1.5. This and other versions can be downloaded from the USDA Forest Service's Inventory and Monitoring Institute website. Spectrum is a fairly flexible resource-scheduling model that has evolved to provide extensive vegetation manipulation options (e.g., clearcutting, shelterwood sequences, etc.) within a constrained optimization framework. Our initial modeling has used a "maximize timber volume" objective function for a 15-decade planning horizon. This insures widespread harvesting that helps us test the utility of the spatial HARVEST model. Standard non-declining timber flow constraints are used to create period-by-period harvests. Given Committee of Scientists' concerns regarding species viability, we are particularly interested in developing a Spectrum model that can address wildlife habitat needs. This is approached in part by defining Spectrum "levels" related to habitat. While habitat needs may be approached with Spectrum alone (see Bevers et al., 1995 and Hof and Bevers, 2000), structuring the Spectrum to link with HARVEST provides a desired spatial dimension to the analysis.

Within Spectrum, "levels" or resource attributes are used to define analysis units—the levels are often land layers (e.g., vegetation type, site index, etc.). For our prototype Spectrum model, five land layers were chosen: forest type, forest-type age class, timber suitability, management area, and ranger district. Forest type and age class provide important characteristics that help define wildlife habitat. Forest type is an aggregation of dominant species used to classify timber stands. For example, we combine quaking aspen (*Populus tremuloides*) and bigtooth aspen (*Populus grandidentata*) into the aspen forest type. Ten forest types are used: aspen, balsam fir, hemlock, jack pine, northern hardwoods, oak, paper birch, red pine, upland spruce, and white pine. The age classes are 0-9 years old, 10-19 years old, and so on. Combined, forest types and age classes are associated with timber inventory and yield data and the economics of related silvicultural practices. Timber suitability segregates national forest lands into those that are available for silvicultural treatment and those that are not. Finally, management area (e.g., semi-primitive areas) and ranger district (e.g., Park Falls) are administrative subdivisions of the forest, though the former is often ecologically based and provides additional habitat insights. In total, the prototype Spectrum model has 204 analysis units defined using Spectrum levels. By changing model constraints and management area designations, Forest Service planners can develop alternative scenarios for public review.

Spectrum outputs and reports are numerous. Of particular interest to us is a report in comma-delimited format that provides the area of harvest treatments (human-caused disturbances) by analysis unit for each decade over the planning horizon. From this, harvesting activities can be disaggregated to ranger districts and management areas, but not specific stand-based locations on the landscape—HARVEST is necessary for that step.

3. HARVEST

HARVEST is a well-documented research model that has been applied to a number of spatial-temporal problems (Gustafson, 1996, 1998; Gustafson and Crow, 1994, 1996, 1999). The software (currently Version 6.0) and sample data sets can be downloaded from the USDA Forest Service North Central Research Station's website. HARVEST is an interactive simulation model that allows users to simulate effects of timber harvest on the structure of the forest. Using a random number seed, the model disperses harvests and harvest size stochastically across the landscape. HARVEST is a raster-based model and requires four input map files for forest type, forest age, management area, and stands. Hence, three of the maps match the Spectrum levels noted above, and timber suitability is reflected in "no harvest" treatments for certain analysis units. Since its inception, HARVEST has been based on the premise that public land agencies have stand-based data on forest attributes. This map allows stand-specific allocation of timber harvests consistent with agency data; our prototype model has 5,836 stands.

A GUI interface (figure 2) allows users to specify harvest parameters for each management area and forest type over each period over the planning horizon. Both even-aged and uneven-aged management can be simulated. Size of harvest and area harvested are user controlled. Our prototype model uses a 900 m^2 cell size, so that represents the smallest harvest size. It is equivalent to a group selection cut in northern Wisconsin. Different methods for dispersing the harvests across the landscape are also available. For example, harvests can be widely dispersed or clustered. In addition, harvest adjacency considerations (i.e., green-up intervals) and buffers can be included. As a group, these harvest parameters provide wide latitude for examining effects of standards and guidelines planners propose.

HARVEST provides several straightforward and essential outputs for contemporary forest planning. Specifically, it provides tabular summaries and maps related to patches and interior forest. Calculated measures of landscape patch structure include: age distribution, length of linear edge between patches (stands), average size of patches of a similar age, and distribution of patch size by age class. Interior and edge habitat are based on harvest activities and other forest openings and a user-specified buffer distance. In addition, the user indicates the duration of the temporary harvest opening before it reverts to a closed canopy condition. Age maps and forest interior maps can be saved for each period over the planning horizon. Figure 3 illustrates a comparison between openings, buffers, and closed forest for current and projected forest conditions—larger, more dispersed harvests are illustrated in the projected map (Note: the lower left portion of this 107,000 ha area is in private ownership and other private holdings are interspersed throughout the area; these are treated as closed canopy forest.).

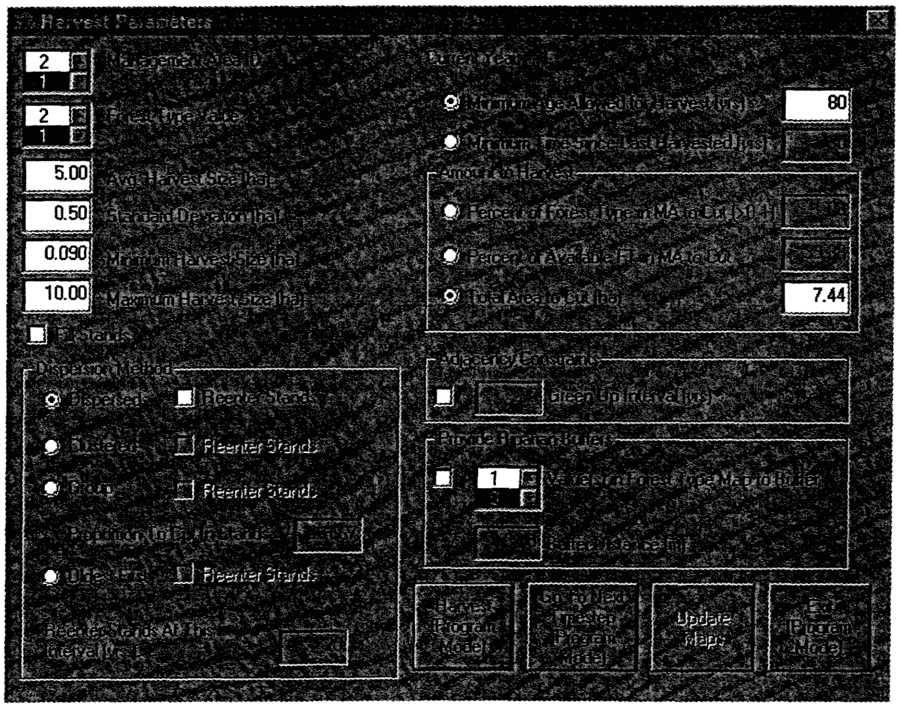

Figure 2. HARVEST parameters interface.

Thus, HARVEST provides useful data on forest conditions, but requires substantial, interactive user input. For national forest planning, efficient input is needed due to the large areas covered, complex harvest sequences, and numerous plan alternatives.

4. LINKING SPECTRUM AND HARVEST

By linking HARVEST with Spectrum, we are moving HARVEST from a research model to a strategic planning tool. The timing (i.e., decade) and general location (i.e., ranger district and management area) for various treatments by forest type are generated in Spectrum and linked (via additional software) to those attributes in HARVEST, by creating a HARVEST script file that provides needed inputs. These thousands of data inputs save users from the tedious task of entering data by management area, forest type, and time period. Other global parameters are also set in this process, including: saving age maps; creating a log file of harvests by management area, forest type and time period; selecting a random seed number related to dispersal of harvests; method of even-aged dispersion; and number of time periods. Management area parameters are addressed for adjacency constraints and riparian buffers. Finally, treatment type (e.g., group selection) parameters for mean harvest size, standard deviation, and minimum/maximum harvest size are set along with minimum age for harvesting by forest type.

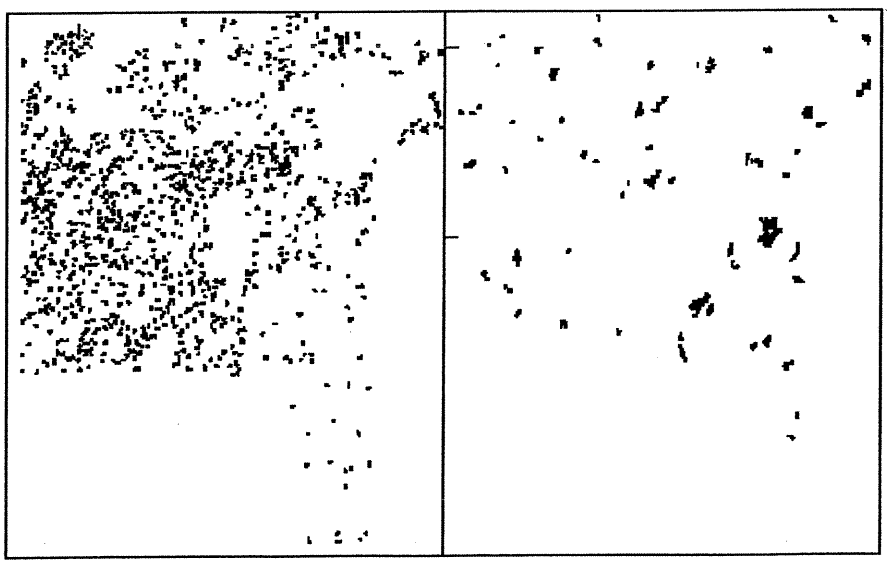

Figure 3. Current (left) and projected (right) openings/buffers (black) and closed (white) forest canopy conditions for the Park Falls Ranger District area.

In the end, a file is created and read into the HARVEST model that reflects Spectrum results and additional HARVEST inputs. Spatial results are then generated and evaluated relative to management goals, standards, and guidelines. At this juncture, some iteration may be needed if Spectrum results cannot be spatially confirmed, or if changes in HARVEST parameters (e.g., harvest size) are tested. Together, these models provide useful strategic planning results for forest plan revision.

5. FUTURE DIRECTIONS

We are currently in prototype evaluation. This process has provide insights regarding the relationship between optimization and simulatio modeling approaches in an applied case. Choices regarding HARVES parameters have been made at the forest, management area, and forest typ levels. An option was also created to recognize that some Spectrum mode include sub-forest areas (e.g., ranger districts) and that the results must t disaggregated to sub-forest HARVEST models. By providing a flexib interface between Spectrum and HARVEST, we are developing a generi stand-based modeling approach that can be applied to other national fores concerned with spatial analysis of harvest patterns. To a limited exte private forestland management can also be modeled by including the timi and location of private harvest patterns. Then an integrated public-priv analysis of landscape effects can be developed. Other models, such LANDIS (Gustafson et al. 2000), provide more detailed ecological modeli results by incorporating natural disturbance and successional change. T limited extent, these can be included in our approach. Nonetheless, Spectrum-HARVEST approach offers a more readily useable operatio modeling framework for forest plan revision.

6. ACKNOWLEDGMENT

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