ECOSYSTEM MODELING USING SPECTRUM AND RELMDSS: ANALYZING VEGETATIVE SUCCESSION FOR FOREST PLAN REVISIONS

James Merzenich and Miles Hemstrom[1]

ABSTRACT.—This paper explains methods for scheduling management treatments using vegetative succession class acreage goals and the stratification of environmental variables as the guiding principles. The SPECTRUM linear programming model schedules treatments to meet vegetative goals while considering the risk of catastrophic loss due to fire and other causes. The RELMdss model allocates the SPECTRUM solution to subdrainage, where tradeoffs associated with meeting standards and guidelines or working within work force and budgetary limitations can be evaluated. This hierarchical planning approach is essential to ensure that goals are realistic and that the treatment levels called for can be achieved.

INTRODUCTION

Much of the forested area of the interior Columbia River Basin was historically dominated by open stands of ponderosa pine maintained by frequent ground fires. Many stands in these areas are now overstocked with grand fir, Douglas-fir, and small ponderosa pine. The composition of the remaining forested land has been substantially altered largely as a result of active fire suppression and timber harvests (Campbell and Leigel 1996). Recent drought and insect epidemics have caused substantial tree and stand mortality in many areas. Grassland and shrub habitat has also been significantly impacted by factors such as livestock grazing, juniper encroachment due to fire suppression, and the invasion of nonnative grasses and weeds (Keane et al. 1996). This results in vegetative conditions and hazards that are now well outside natural bounds.

One proposed goal of ecosystem management is to restore vegetative conditions to a more natural state. To accomplish this goal, it is often useful to compare existing vegetation or management alternatives to a historical range of variability (HRV) (USDA Forest Service 1992). For each vegetative type, or succession class, HRV is defined as the minimum and maximum acreage that should be maintained within each class through time. In theory, if vegetation is maintained within these historic bounds, the species and communities that evolved within them can persist. HRV depends on disturbance regimes, such as natural fire and insect outbreaks, which vary according to the environment. This conceptual framework is the basis of the Interior Columbia Basin Ecosystem Management Project (ICBEMP) effort.

This paper describes a methodology for modeling vegetative succession, using HRV and the stratification of environmental variables as the guiding principles. The SPECTRUM linear programming model linked with a RELMdss disaggregation model can be a useful tool for this analysis. The SPECTRUM model schedules treatments to meet HRV goals while considering the risk of catastrophic loss due to fire or other causes and maintaining essential habitat for all species. The RELMdss model allocates the SPECTRUM solution to subdrainages or other divisions of the forest where the trade offs associated with meeting standards and guidelines or working within work force and budgetary limitations can be evaluated (Church et al. 1995). This hierarchical planning approach is essential to ensure that the goals of the Forest plan are realistic and that the treatment levels called for in the plan can be achieved.

[1] Jim Merzenich is an analyst and Miles Hemstrom is an ecologist with the Pacific Northwest Region, USDA, Forest Service, P.O. Box 3623, Portland, Oregon 97208.

A primary objective of plan revisions is to determine the level of treatments necessary to move the existing vegetation towards a desired state in the coming decade. Treatments include prescribed and natural fire and commercial and noncommercial harvest activities. Long-range multidecade analysis is needed to ensure that improvements in ecosystem health are sustainable and that conflicts related to ecosystem management are resolved. The following sections discuss the basic information needed to support this modeling effort

A Classification of the Vegetation Based on Existing and Potential Conditions

The existing vegetation should be classified on the basis of cover type and structural stage using succession classes developed by the ICBEMP. Cover type is determined by the dominant species for range and forest types. Dominant species are calculated by canopy coverage for range types and by basal area for forest types (Keane et al. 1996). Structural stages define the physical condition of a stand at different states of development (Oliver and Larson 1990).

The potential vegetation type (PVT) is determined and mapped from biophysical characteristics of the site. PVT or environment maps are most useful at plant association group resolution. The classification of the potential and existing vegetation must be consistent across National Forests to ensure that data can be aggregated to support provincial and regional analysis.

Desired Future Conditions or Goals for the Vegetation

The acreage that should be in each succession class through time must be estimated. Acreage goals may be based on the HRV and other factors. HRV should be described by plant association group.

Management Prescriptions Designed to Manipulate Vegetation or to Manage Risk Due to Wildfire or Other Causes

Through partial cutting and other treatments one can shorten or prolong the time a given stand stays in one succession class. A stand may be driven towards an earlier or later class by removing selected species. Prescribed burning and other fuel management prescriptions may lessen the probability of a catastrophic wildfire. Economically efficient design of these prescriptions is essential to develop an overall strategy that can be implemented within budgetary constraints.

Successional Pathways Must be Described for Each PVT

These pathways are a temporal map of the succession classes contained in each PVT and include the probable effect of fire and other disturbances. The management of risk due to wildfire, insects and disease, and other factors must be an integral part of any model used to determine treatment needs. Pathways should be described between succession classes (cover type and structural stage) by plant association group.

The Vegetation Dynamics Development Tool (VDDT), developed for the ICBEMP effort, stochastically projects changes in vegetative composition over time as affected by natural and human-caused disturbances (Beukema and Kurz 1995). This tool is useful for building successional pathway diagrams and understanding the relationship between environmental variables. The sensitivity of the system to changes in alternative assumptions are also easily evaluated with VDDT. VDDT will be used in forest plan revisions to test assumptions prior to inclusion in other models. VDDT may also be used iteratively with SPECTRUM to evaluate the possible consequence of a large-scale stochastic disturbance on the selected treatment schedule.

A Methodology for Predicting Disturbance Rates at the Stand and Landscape Level

Disturbance probabilities and changes in succession that follow a disturbance have been estimated by the ICBEMP team for wildfire, insects and disease, and many other factors. These disturbance data are also loaded into VDDT models. One initial task is summary and aggregation of these data into a form useful for plan revisions.

The probability that a vegetative stand will burn (or be affected by any disturbance event) is a function of both the stand condition itself plus the condition of adjoining stands from which a fire may spread. In general, a stand's condition affects the probability of a fire start. The spatial configuration of stands and their associated fuels influence the expected size and intensity of a wildfire. A methodology is needed to make initial estimates of fire probabilities and to adjust these probabilities with time as landscape conditions change. Disturbance models should be stratified by succession class and plant association group.

MODELING TOOLS

The general purpose of vegetative modeling for plan revisions is to determine if and when ecosystem goals are attainable, and to develop reasonable treatment schedules to meet those goals. These models are *strategic* in scope and are not intended to identify actual stands where treatments will occur.

No single analytical model can develop a forest-wide management strategy that can be implemented on the ground. A hierarchical modeling approach, where each successive model provides input to the next model, is needed to achieve this task. The following sections describe the individual models.

VDDT

VDDT will be used to define successional pathways and examine the potential effects of disturbance agents on the vegetation. This model enables one to quickly analyze the sensitivity of the system to changes in disturbance assumptions, prior to running SPECTRUM.

SYSDYN

SYSDYN is a dynamic simulation model that has been developed for the Blue Mountains. It estimates the annual burned acres based on random fire events under variable weather conditions (Wiitala, Huff, and Schmidt 1994). The level of fuel treatments, such as prescribed burning, can be introduced into this model to estimate burned acres per decade. This or a similar model will be used to help generate expected burn probabilities for the SPECTRUM model.

SPECTRUM

The SPECTRUM model schedules the treatments necessary to achieve vegetative acreage goals, while considering the role of stochastic disturbance agents described in the VDDT and SYSDYN models. Two features of the SPECTRUM linear programming model enable this analysis: (1) a GOAL option allows one to easily set a target range for each succession class acreage objective; and (2) Model 2 capabilities allow direct modeling of fire mortality and other disturbance factors.

A prototype SPECTRUM model has been developed for the Ochoco National Forest to assess their viable ecosystem approach to management (Ochoco National Forest, 1994). This model schedules treatments to meet vegetative (HRV) goals while considering the risk of catastrophic loss due to fire or other causes. The model objective is to minimize the number of acres outside the historic range of variability. Weights are placed on goals for each plant association group and succession class based on relative importance. The effect of the nondeclining timber flow requirement and other legal requirements are also evaluated. Economic or treatment acreage limits are included to insure a realistic solution that can be implemented within budgetary and work force limits.

Two sample graphs, derived from a completed goal programming run for the North Fork Crooked river drainage of the Ochoco Forest, are shown here. The goal achievement for one succession class is displayed as Figure 1. The min and max lines on this graph represent the historic range of variability or goal for this class. The acres line represents the linear program solution for twenty periods. Note that the acreage within stage M3 initially exceeds the desired range. From the third to twentieth decade, the acreage fluctuates widely but stays within the desired range of 3 to 8 percent.

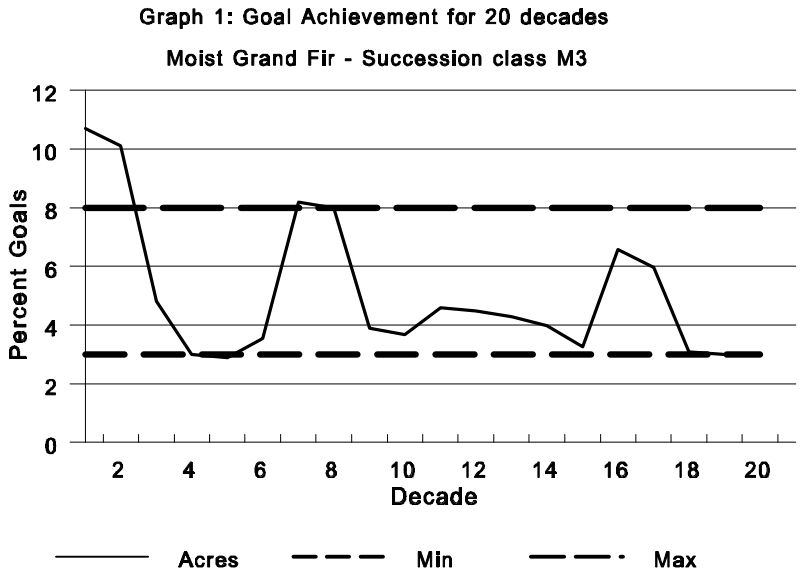
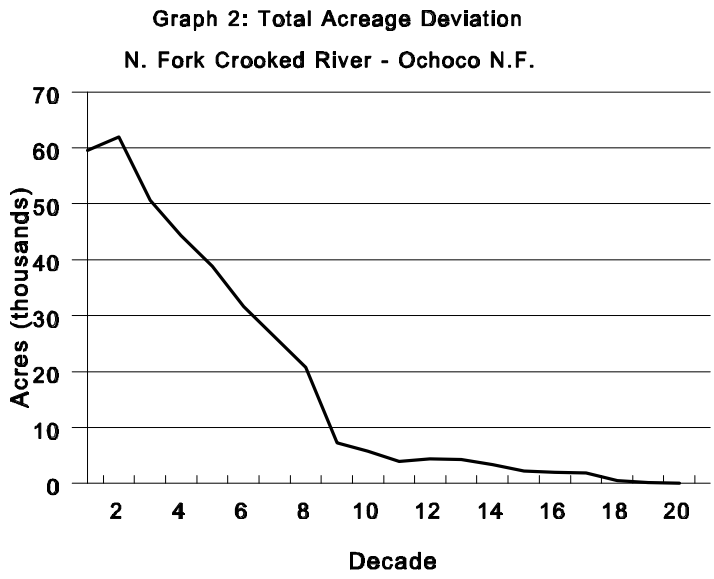


Figure 2 shows the acreage deviation for the entire drainage for 20 decades. This deviation is the sum of 45 separate goals applied to each combination of a plant association group and succession class. Initially 60,000 acres are outside the desired range. The deviations sharply decline in the succeeding decades as the model treats acres to meet the vegetative goals.



Automated procedures have been developed to build SPECTRUM models and interpret solutions. To build models, data are imported from GIS and other sources into relational data bases and are then automatically converted into the SPECTRUM format. The results of model runs are exported to data bases and spreadsheets where they can be viewed, summarized, and graphed.

SPECTRUM model results are nonspatial. Other tools are needed to estimate the location of proposed treatments. Linear programming models are also deterministic by design. That is, for each set of assumptions there is only one optimal solution. By making multiple runs with varying assumptions, the sensitivity of the solution to data changes can be evaluated.

RELMdss

The RELMdss model is a goal-based, visually interactive LP model. In this hierarchical approach, the RELMdss model is used to display the SPECTRUM solution and then redistribute the solution to meet standards and guidelines that apply to geographic subunits of the forest. For example, elk thermal cover requirements could be evaluated for winter ranges while equivalent clearcut limits are applied to watersheds. The main purpose of RELMdss is to fit the SPECTRUM solution to the scale at which each standard and guideline applies. This may result in a decline of treatment opportunities as compared to the SPECTRUM solution. The RELMdss model calculates and displays treatment opportunities for up to six decades.

The RELMdss model operates in real time and visually displays the results of each run on a computer screen map. In this way users can immediately identify the standard, guideline, or physical constraint that is most limiting in any area. With RELMdss users can also quickly enable or disable standards and guidelines. This allows quick sensitivity analysis of the factors that affect the available treatment acreage.

SUMMARY

No single analytical tool is capable of developing a treatment schedule for a National Forest that can be implemented on the ground. The authors propose a hierarchical approach that uses VDDT and other tools to assess the role of natural and human-caused disturbance agents; uses SPECTRUM to select treatments on the basis of

meeting vegetative goals; and uses RELMdss to distribute these treatments to subdrainages while complying with area-specific standards and guidelines.

LITERATURE CITED

BEUKEMA, S.J., AND W.A. KURZ. 1995. *Vegetation dynamics development tool user's guide*. Vancouver, BC: ESSA Technologies Ltd.

CAMPBELL, S., AND L. LIEGEL. 1996. *Disturbance and forest health in Oregon and Washington.* Gen. Tech.Rep. PNW-GTR-381. Portland, OR: U.S. Department of Agriculture, Forest Service.

CHURCH, R.L., MURRAY, A.T., BARBER, K.H., AND R. DYRLAND. 1995. A spatial decision support system for doing hierarchical habitat planning. In *Proceedings Analysis in Support of Ecosystem Management: Analysis workshop III*, 283-292. April 10-13, 1995, Fort Collins, CO: U.S. Department of Agriculture, Forest Service.

KEANE, ROBERT E., DONALD G. LONG, JAMES P. MENAKIS, WENDEL J. HANN, AND COLLIN B. BEVINS. 1996. *Simulating coarse-scale vegetation dynamics using the Columbia River Basin Succession Model—CRBSUM.* Gen. Tech. Rep. INT-GTR-340. Ogden, UT: U.S. Department of Agriculture, Forest Service.

MERZENICH, JAMES P. 1995. Seral stage modeling using SPECTRUM: Considering the risk of catastrophic loss. In *Proceedings Analysis in Support of Ecosystem Management: Analysis workshop III*, 251-257. April 10-13, 1995, Fort Collins, CO: U.S. Department of Agriculture, Forest Service.

OCHOCO NATIONAL FOREST. 1994. *Viable ecosystems management guide*. Prineville, OR.

OLIVER, CHADWICK D., AND BRUCE C. LARSON. 1990. *Forest stand dynamics*. New York: McGraw Hill Inc.

U.S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE. 1994. *Restoring ecosystems in the Blue Mountains: A report to the regional forester and forest supervisors of the Blue Mountain forests*. Portland, OR: U.S. Department of Agriculture, Forest Service.

WIITALA, M.R., M.H.HUFF, AND R.G. SCHMIDT. 1994. Modeling the response of ecosystems to random fire events using system dynamics. In *Proceedings 12th conference on Fire and Forest Meteorology, Society of American Foresters*, 291-298. Bethesda, MD.