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ALTERNATIVE SILVICULTURAL PRACTICES AND DIVERSITY OF ANIMAL HABITAT IN WESTERN OREGON: A COMPUTER SIMULATION APPROACH

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ABSTRACT

We are developing a computer simulation approach to assist forest managers in western Oregon in evaluating trade-offs between timber production and animal-habitat diversity under different forest management scenarios. Our approach uses an existing forest succession model, ZELIG, which we modified to better simulate custom-designed silvicultural prescriptions and to evaluate suitability of animal habitat using empirically-derived statistical habitat models.

The purpose of this paper is to provide an overview of the design and use of this simulation approach. Preliminary results of a trade-off analysis under three silvicultural prescriptions are presented to demonstrate the utility of this simulation approach. Model improvements and future efforts are discussed.

INTRODUCTION

Managers of both federal and private forests in western Oregon are under increasing pressure to manage lands for ecological values such as animal-habitat diversity in addition to timber production. The primary management strategy over the past four decades has been clearcut logging where all standing and downed wood is removed during a harvest. Restocking clearcuts with monocultures of the commercially most important species, Douglas-fir, has been the protocol over the last 20 years. This coupled with decreasing rotation lengths (i.e., time between cutting) has substantially reduced the structural variability of forests across western Oregon. Recent awareness of the importance of structural heterogeneity and plant diversity throughout the rotation of a managed stand for many animal species has motivated the consideration of retaining live-standing trees of different species, snags (dead but standing trees), and logs on harvested sites. Retaining standing timber, however, results in reduction of harvested timber volume. Also, the growth rates of trees planted to reforest a site may be reduced owing to shading by taller trees retained on a site, potentially resulting in reduced wood volume at future harvests.

The amount of structural retention that reduces wood production the least but provides the greatest amount of animal-habitat diversity over the rotation of a stand is a topical issue for forest managers. Manipulative field studies are in place to examine trade-offs between timber production and animal-habitat diversity under different silvicultural prescriptions and rotation intervals but are limited in the number of treatments and are of short duration. Also, the lag time associated with synthesizing results of these studies and the fact that management decisions affecting future conditions of forested lands are being made today requires a more expedient approach to evaluate trade-offs.

To facilitate timely analyses of trade-offs, we are developing a computerized simulation approach to model forest and animal-habitat dynamics under a variety of silvicultural prescriptions. At the core of the approach is the forest succession model ZELIG, which we have parameterized for western Oregon. Modifications were added to this model to simulate the dynamics of dead wood and custom-designed harvest scenarios, and to evaluate suitability of modeled plots as habitat for individual animal species. Using this simulation approach, the dynamics of timber production and animal-habitat diversity under a variety of harvest scenarios can be rapidly assessed to determine those prescriptions that best meet specific short- and long-term resource management objectives.

THE ZELIG MODEL

ZELIG is one of many individual-based gap models derived from the FORET model of Shugart and West (1977), which in turn was derived from the JABOWA gap model (Botkin et al. 1972). ZELIG was selected for use in this system because; 1) it was designed as a generic gap model that could easily be parameterized for specific sites or regions without extensive code modifications, 2) its modular structure facilitated adding features specifically required for the types of analyses we needed to perform and, 3) initial model tests indicated that it was well suited to simulate mixed-species and mixed-aged forests of western Oregon. A summary of the model structure is presented here; model details are presented in Urban (1990).

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ZELIG simulates the annual establishment, diameter growth, and mortality of individual stems on a small model plot corresponding to the zone of influence of a canopy dominant tree (ca. .04-.1 ha). The basic approach used to model each of the demographic processes is to begin with maximum potential behavior (i.e., max. growth rates, inseeding rates) and subsequently constrain this potential by resource limitations. Constraints include available light and soil fertility. Soil moisture and temperature, which are derived from simulated weather conditions, are also used to constrain tree growth and establishment. Mortality is modeled as a probabilistic function, assuming that an individual has a 1% chance of reaching its maximum age (Shugart 1984). The probability of mortality increases if an individual experiences consecutive years of suppressed growth. Because ambient weather, mortality, and inseeding are modeled as stochastic processes, output from one model plot represents just one possible trajectory of forest dynamics. Numerous model plots (e.g., 30-50) are typically simulated during a model run and aggregated to represent the average trajectory of stand dynamics. Each plot in a simulation can be initiated without trees (i.e., bare ground) or with actual or hypothetical stand data.

Like other gap models, ZELIG was designed for ease of parameterization. Species-specific parameters can be derived simply from life-history descriptions found in silvics manuals, or from detailed field studies. Required parameters for each tree species include:

- Maximum values for age, diameter at breast height (dbh), height, and diameter growth.

- Seedling establishment rate.

- Relative tolerance to light, moisture and nutrient stress (rank values ranging from 1-5).

- Minimum and maximum temperature limits of the current geographical range.

Environmental parameters required to simulate ambient weather include monthly temperature and precipitation means and variances for the elevation of a simulation run. There is also consideration of monthly solar radiation levels which is generated for a given latitude using a support program provided with ZELIG.

A unique feature of ZELIG is that it can operate in either a non-spatial or spatial mode. In the non-spatial mode, there is no interaction between model plots: trees on a plot do not shade those on other plots. This mode is a carry over from the JABOWA and FORET models. This version of the model is used in our current simulation approach. The spatial mode is a tessellation of model plots where shading occurs across neighboring model plots, and direct and diffuse light are taken into account. This version is currently being tested for use in western Oregon.

ZELIG ENHANCEMENTS

Enhancements to the basic version of ZELIG were required to simulate the types of silvicultural prescriptions currently used and being considered by forest managers. Modifications were also implemented to facilitate performing simulation experiments, and data collection and analysis.

Routines to simulate snag and log dynamics were added to the generic version of ZELIG which lacked consideration of dead wood. When a tree dies, it is transferred to the snag pool or it becomes a log based on an estimated probability of windthrow. Probabilities derived from Graham (1982) were used to simulate formation of logs from snag breakage, and decay of snags and logs.

The ability to design and implement silvicultural prescriptions was also incorporated into ZELIG. Specific prescriptions were not hard-coded into the system. Instead, silvicultural options were implemented as a set of "tools" which are used in various combinations to design specific prescriptions (Table 1). Although only six main options are currently provided, the parameters associated with each provide for a wide variety of silvicultural prescriptions.

A queue-oriented interactive interface was implemented to integrate the silvicultural features with ZELIG. This interface provides the user with direct access to the silvicultural options as well as to the program control options which were developed to better regulate program execution and to control amounts and formats of data output. This interface provides, among other functions, the ability to pause program execution and evaluate stand conditions before implementing a management prescription, allowing for fine tuning of silvicultural prescriptions to specific stand conditions.

MODEL VERIFICATION

As an initial test of the performance of our modified version of ZELIG, we compared simulated stand dynamics at 1000-m elevation on the western slope of the Oregon Cascades over a 500-yr period with a chronosequence of field plots (i.e., time series of different-aged plots) located throughout the Oregon Cascades and at about 1000-m elevation. Only common tree species occurring in this area were considered in the simulation; species parameters were obtained from literature reports of life-histories and from detailed regional field studies. Environmental data used in the simulation were obtained from regression models developed by researchers at Oregon State University and EPA, Corvallis, Oregon. Each of the thirty model plots used in the simulation was initiated from bare ground and was .1 ha in size. Field data were from the USDA Forest Service Continuous Forest Inventory data base and the Oregon State University Forest Science Data Bank. Only those field plots we believed to have originated after natural disturbance and that had never been thinned were included.

The model was found to adequately simulate the live-tree component of stands over time (Figure 1). Predicted trends for snags and logs were not as clean, at least for the first 100 yrs. This may reflect, however, a problem in using field plots with somewhat unknown stand histories in such comparisons. Simulated plots were initiated without any structure. Actual stands initiated by natural disturbance could have a substantial snag and log component that extends over many years after disturbance. Resolving this issue will be required to fine tune the dead-wood component of the model. Overall, the model tends to simulate the structure of natural stands reasonably well.

ANIMAL-HABITAT ASSOCIATION MODELS

Because of the observed associations between animal occurrence and habitat structure, models of many types have been used to predict habitat suitability for a species (Capen, 1981). Any model form that associates the occurrence or density of animals with stand-level structural features modeled by ZELIG (e.g., density of snags and logs, basal area of tree species) can be used in this system. To date, we've primarily used multivariate statistical models such as discriminant function analysis (DFA) to relate animal occurrence (i.e., presence or absence) with structural characteristics based on field samples. Discriminant function analysis provides a predictive model of species occurrence using a linear combination of habitat variables as the independent variables. In deriving a discriminant model, a cross-validation procedure combined with a chance-corrected test of significance is used to determine classification efficiency of each discriminant model. Only models with classification efficiency better than chance are considered in the habitat classification process. At specified simulation intervals, the suitability of model plots as habitat is determined using species-specific DFA models and results are output for further processing.

SIMULATION EXPERIMENTS

As a preliminary demonstration of the utility of our approach for trade-off analyses we simulated and compared timber production and animal-habitat diversity under three contrasting silvicultural prescriptions. The first prescription represented intensive management for wood production. This consisted of clearcutting every 70 yrs without retaining any overstory or dead wood and planting 988 Douglas-fir per ha. Thinning to 543 Douglas-fir per ha was performed at 15 yrs post harvest. To evaluate the trade-offs of a longer rotation, the first prescription was duplicated but with clearcutting every 125 yrs. In the third simulated prescription, clearcutting was performed every 125 yrs, but 40 overstory trees per ha were retained without regard to species. Planting and thinning schedules were similar to the other prescriptions. All simulations were initiated with a simulated unmanaged 70-yr old forest and were run for 375 yrs. Runs were performed for 1000-m elevation for the western Oregon Cascades using tree species used in the verification analysis.

Habitat suitability of simulated plots were assessed for 14 species of birds. This list represented a cross-section of species associated with closed- and open-canopy conditions. Preliminary discriminant function models for these species were derived from local field studies. All models were based on density of conifer and hardwood tree species by four size classes. Snags and logs were not considered in these initial models.

As a measure of timber production, cumulative basal area of standing plus harvested trees > 11cm dbh was recorded at 10-yr intervals in each run. Suitability of each model plot as habitat for each bird species was classified and the number of bird species with suitable habitat was recorded at a similar frequency in each run.

Results

Simulation results demonstrate the reduction in timber production as rotation interval increases and with retention of live trees (Figure 2a). At year 375, for instance, basal area under the intensive management scenario was about twice that under the retention run. While trends in bird-species richness differed little between the wood production runs, retention of overstory trees resulted in habitat for more bird species, especially within 50 yrs after harvest (Figure 2b). In the first two scenarios, there was a gradual turn over of open-canopy to closed-canopy bird species with the development of the plantation. Retaining even a few overstory trees provided habitat for both groups of species, resulting in greater species richness. The reduced growth rate of plantation trees resulting from shading by the retained overstory appeared to maintain suitable habitat for open-canopy species for up to 50 years after harvest.

Although this initial application was relatively simplistic, it demonstrates the power of using a simulation approach to evaluate timber production and animal-habitat diversity under different forest management practices. Although the trend in wood production under the simulated scenarios revealed here could perhaps be surmized based on previous silvicultural research on maximum yields and shading effects on tree growth, the simulated output gives some indication of the magnitude of differences in production among the scenarios. Because of limited field data and the novelty of overstory retention on harvested sites, it would be difficult to estimate these differences otherwise. Having some handle on the relative amounts of wood production under different management scenarios is essential to determine costs associated with different strategies. Also, the benefits to animal-habitat diversity of different management prescriptions are made apparent using this simulation approach. Ideally, this system will provide managers with a tool by which silvicultural prescriptions can be refined in an iterative manner to determine the very best strategy that provides maximum desired levels of animal-habitat diversity over time with minimal loss in timber production.

FUTURE EFFORTS

Fine tuning and further validating ZELIG, specifically the snag and log dynamics, will be performed. Also, we recognize that there is a need to validate model performance under varying overstory retention levels to increase reliability of model estimates. Data sources are limited but are currently being pursued. Improving animal-habitat models and increasing the number of species considered is also necessary to provide a better understanding of management affects on animal-habitat diversity. Lastly, consideration of spatial variation in forest structure will add greater realism to model predictions. The spatial version of ZELIG offers the ability to do this and will likely be employed in future applications.

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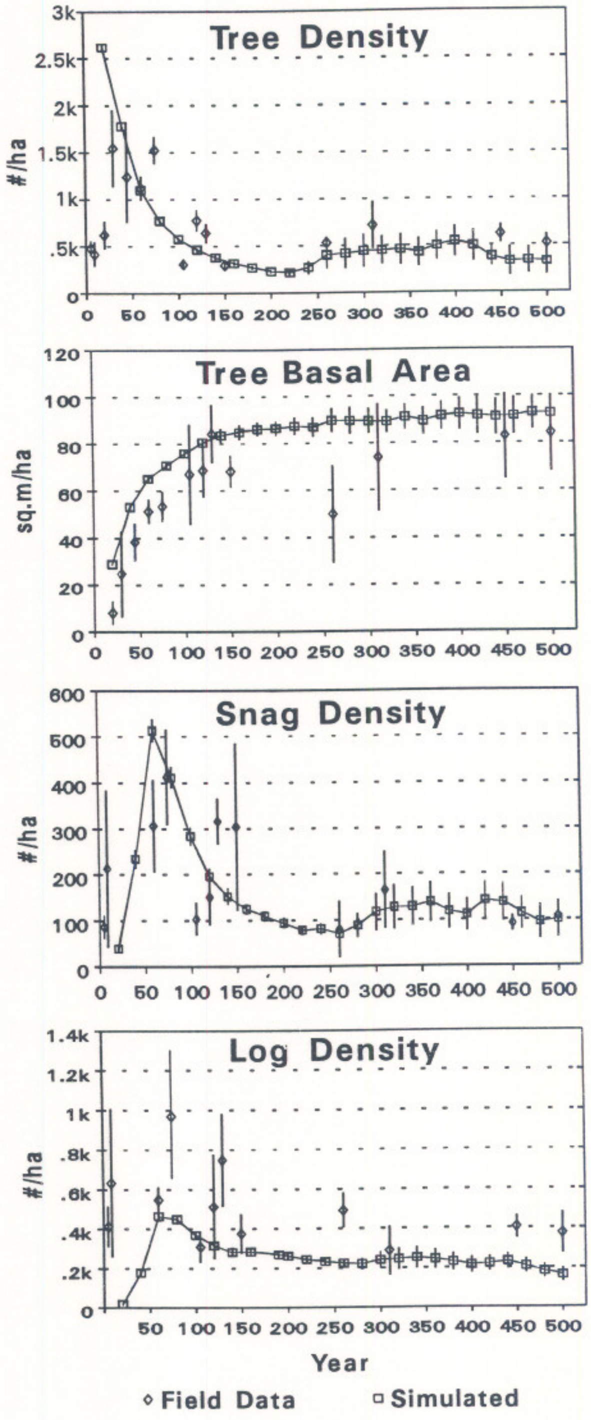

Figure 1. Means (2se) of simulated and actual field data at 1000-m elevation, western slope of Oregon Cascades. Simulated data based on thirty model plots. Sample sizes of field data varied from 5 to 42.

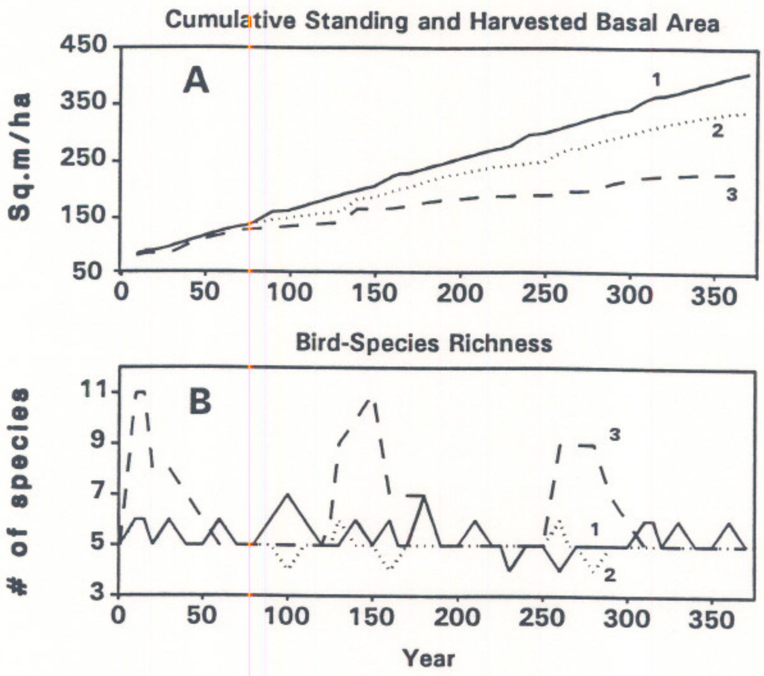

Figure 2. Comparison of simulated wood production (A) and bird species richness (B) under three silvicultural prescriptions. 1- 75 yr rotation, 2- 125 yr rotation, 3- overstory retention.

Table 1. Silvicultural options included in ZELIG.

Option	Parameters
1) Clearcut without retention of live trees	simulation year.
2) Harvest with retention of live trees	simulation year; retention level, min. size, canopy status, and species of retained trees.
3) Thin	simulation year; thinning level [based on basal area or density], min. size, canopy status, and species of trees removed.
4) Retention of snags	simulation year; min. size and density of snags retained, and method used to retain snags - select from existing snag pool, select from live trees, randomly select from live trees and snag pool, fixed proportion from live trees and existing snags, or all snags become trees (species of trees may be selected, but not required).
5) Retention of logs	as in 4, but for logs. Additionally, min. length of a retained log and total linear length of logs instead of density can be specified.
6) Establish Plantation	simulation year; stocking density and species composition.