Appendix 3

Envision Model Overview, Design Concepts, and Details (ODD)

1. Purpose

The model has at least two purposes: 1) to advance scientific understanding of the dynamics and interactions of forest management, fire, and vegetation across landscapes characterized by multiple owners; and 2) contribute to management and collaborative restoration of fire-prone landscapes by serving as a tool for managers and stakeholders to evaluate ecological and social outcomes of different management, policy and climate scenarios.

2. Entities, state variables, and scales

The spatial entities are individual decision units (IDU) that have a mean size of 3.15 ha and range from 0.06 to 8.5 ha. They are defined by the intersection of vegetation type, topography and ownership. The study area used in this paper contains 397,041 IDUs. Vegetation is classified into structure classes based on cover classes (%) (4), tree size classes (cm) (7), and number of canopy layers (single or multiple) (2), and time since last disturbance in years Six main classes of forest owner (federal, state, corporate, tribal, family and homeowner) are recognized with potential to subdivide within those main groups (e.g. forest districts or individual corporate owners). IDUs are also characterized in terms of: topography, land management zones, fuel models, potential vegetation zones, housing density, and distance to roads. The model is run at annual time steps for 50 years.

3. Process overview and scheduling

Within a single year the order of processes and state variable change is: 1) vegetation succession; 2) identify possible areas for treatment given constraints and preferences; 3) implement management actions to meet targets or other satisfy equations (family forest owners) management actions; 4) ignite and spread fires; 5) change vegetation and fuel models.

4. Design concepts

The model is based on existing theories models of fire behavior and spread, forest and fuel succession, and empirically-based knowledge of forest management goals, objectives and silvicultural effects, and human development. For the most part the submodels, fire, vegetation, management and development are well developed and established in various forms. However, few models have put all of these submodels together in a single framework (but see Landis, Scheller et. al. 2007). The model also has capability to evaluate climate change effects on fire and how it might in turn affect vegetation dynamics. The model is especially designed to explore landscape-scale interactions of four processes: 1) wildfire occurrence, spread and severity, 2) succession in vegetation structure and composition and fuels, 3) forest management treatment type, pattern and rate; and 4) increases in housing density in forest environments. While vegetation succession is modeled using relatively simple state and transition models which limits evaluation of fine-scale vegetation processes (e.g. dispersal, regeneration, competition, and changing interactions of biotic processes and climate), the vegetation model includes hundreds of states, thousands of possible pathways and probabilistic transitions for a diverse set of forest environments and community types. The model can produce emergent behavior that is difficult to predict over time and space from general knowledge of rates and patterns of fire, succession, and vegetation management across ownerships. Given the fundamental state variables, metrics of timber volume, carbon, biomass and wildlife habitat can be calculated and evaluated. The model is parameterized for a large existing landscape based on spatial models of current vegetation and fuel conditions, topography and knowledge of landowner management objectives and vegetation treatment approaches. It uses many of the component models that federal managers currently use individually but not together in an integrated framework. Consequently, the model has great potential for real-world applications, in addition to its capabilities to evaluate current scientific questions of how fire, vegetation and management interactions scale-up from stand to landscape levels.

Emergence

The landscape-scale pattern and dynamics of fire (size, severity, and area), vegetation states and vegetation treatments emerge from the stand or patch-level dynamics and management rules that affect almost 400,000 spatial units covering multiple ownerships over a 50-year time horizon. State variables can be used to calculate additional landscape-scale effects of fire-succession-management interactions on fire occurrence, fire exposure, smoke, timber volume production, carbon, and wildlife habitat. Large landowner objectives are focused on achieving ownership-scale timber volume or area treatment targets under constraints and preferences for certain vegetation types or management zones. In some cases fire and landowners "compete" for timber volume. For example, if wildfires kill merchantable trees some landowners will be forced to harvest those trees within a year or two and reduce timber harvest and fuel treatments by equivalent amounts in unburned areas. This rule acts as a budget constraint on forest management. The landscape scale effects of these objectives and rules on outputs including fire occurrence and severity, carbon, wildlife habitat and other metrics are not easily predictable, especially with large wildfires occurring stochastically in response to climate variation and dynamics in vegetation structure and composition. For example, managers may not be able to reach their volume or area targets over 50 years if fire and high rates of cutting have reduced available volumes or suitable acres.

Adaptation

Major landowner agents have targets (volume or area treated goals) and general rules (constraints on actions, and preferences within constraints) that guide location and timing of management actions; agents shift location and area of activities based on highest volume and suitability of vegetation structure according to constraints and preferences. Past management actions or fire effects, growth and succession in vegetation or changes in wildlife habitat can alter location and amount of management actions. Family forest owners can adapt (increase fuel treatments) if fire has occurred recently in surrounding lands or if vegetation becomes denser and they perceive increased fire hazard.

Objectives

For large landowners the objectives are framed in terms of targets of volume production or area treated. IDU's are screened by constraints that eliminate IDUs from treatment consideration based on volume, forest age, time since last treatment, land allocation, vegetation type and other characteristics. IDUs that are not eliminated by constraints, are scored based on characteristics such as timber volume, vegetation type, proximity to other IDUs with similar volumes, and wildlife habitat. The aggregate scores are then used to determine the probability that an IDU will be selected for treatment during a year. For family forest owners, objectives are determined by empirical equations that set the probability of forest management (timber removal or fuel reduction treatment) in an IDU based on conditions in the IDU, history of occurrence of wildfire in nearby areas and perception of fire hazard in IDUs surrounding the family forest IDU.

Sensing

Family forest owners harvest and reduce fuels based on perception of forest fire hazard in the surrounding landscape and based on past occurrence of wildfire in areas around their IDU.

Interaction

Interactions among landowners and IDUs are indirect and mediated by fire spread. For example, if management on one ownership affects fire occurrence and spread it may alter how fire spreads and burns on adjacent ownerships. Of course, fire itself interacts spatially with vegetation and conditions of IDUs. IDUs surrounded by vegetation that is resistant to spread of fire, will burn less frequently than those that are contiguous with IDUs have high fuel loads.

Stochasticity

Fire ignition and weather (spread and severity potential) are stochastic. Factors driving fire ignition probabilities and weather not modeled. Some successional transitions are probabilistic; selection of IDUs for management actions is random given equal constraints and preference scores.

Observation

Data collected for testing, understanding and analyzing model results are termed evaluative models. The list of these is quite long and includes measures of fire occurrence, severity, potential and exposure, wood volume, biomass, smoke, housing density, carbon, and habitat scores for several species of wildlife.

5. Initialization

The landscape conditions including vegetation structure and composition, fuel models, history of disturbance are initialized for 2012. The initial conditions were characterized from satellite imagery and forest inventory plots and other GIS layers. It is important to have a realistic representation of the initial state of the landscapes since it will be used by managers and stakeholders to evaluate alternative strategies for managing this area.

6. Input data

Time series of weather influence fire behavior. Annual volume and treatment area targets are preset based on interviews with land owners.

7. Submodels

Three major submodels operate in Envision: 1) fire; 2) vegetation succession; and 3) management. A fourth submodel population operates to populate people and homes in IDUs. The fire submodel is based on Flammap and is described in detail in Ager et al. unpublished manuscript. The vegetation succession model is based on a state and transition model of vegetation structure and composition classes and fuel models. The vegetation submodel is described in Spies et al. this issue. The management submodel uses empirically generated rules to schedule vegetation management activities according to the constraints and preferences of the different owners. Those models are described in the main body of this paper and in the appendices. The development submodel uses projected rates of increase in human population and semi-randomly populates IDUs according to distance from cities and state of Oregon landuse planning zones.

Literature cited:

Scheller, R. M., J. B. Domingo, B. R. Sturtevant, J. S. Williams, A. Rudy, A., E. J. Gustafson, and D. J. Mladenoff. 2007. Design, development, and application of LANDIS-II, a spatial landscape simulation model with flexible temporal and spatial resolution. *Ecological Modelling* 201(3):409-419.