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MODELING EFFECTS OF PRESCRIBED FIRE ON WILDLIFE HABITAT: STAND STRUCTURE, SNAG RECRUITMENT AND COARSE WOODY DEBRIS

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The essential role of fire in sustaining ecosystems has recently been formally recognized. It is specifically addressed in several new national policy documents. In the Federal Wildland Fire Policy and Program Review's Implementation Action Plan (U.S. Department of Interior and U.S. Department of Agriculture 1996), federal land managers expect to implement a several-fold increase in the use of prescribed fire to restore and maintain key ecosystems. In his February, 1997 speech addressing the need to "fight fire with fire," Interior Secretary Bruce Babbitt described the need to integrate fuels management with fire suppression funding. He challenged Congress to help "...escalate the restorative use of fire to make forests safer, healthier, and more resilient."[1]

Effective planning for, and implementation of, these new initiatives will depend on achieving significant improvements in our ability to predict mid- to long-term, site-specific effects of management actions involving fire. In particular, we need to be able to project and compare effects of alternatives — combinations of harvest and prescribed fire, fire suppression, wildfire, and salvage logging — on fuel dynamics and potential fire intensity over subsequent decades.

Recently, scientists at the Rocky Mountain Research Station, in cooperation with ESSA Technologies, Vancouver, B.C., have worked on linking existing models in order to provide predictions of stand development, including ladder and canopy fuels, snag dynamics, changes in surface fuel loads, and changes in potential fire behavior and effects. These linked models interact within the architecture of the *Forest Vegetation Simulator (FVS)*, or Prognosis Model (Wykoff et al. 1982).

Background

FVS and the Fire and Fuels Extension

FVS predicts stand development over a several hundred year time frame. Originally developed for the Interior West, variants are currently available for many parts of the U.S. The model allows the user to simulate management actions such as harvests, thinnings and plantings. It also has a number of sub-models, called extensions, to model effects of insects and diseases. Now, the addition of the *Fire and Fuels Extension* allows users to assess the impacts of management actions on fuels and fire potential.

[1] A coordinated campaign: fight fire with fire, Boise State University, February 11, 1997.

Fire behavior predictions from BEHAVE (Andrews 1986) are used to model surface fire behavior. Predictions of transitional behavior to crown fire, and crown fire behavior are also provided.[2]

Fire effects including fuel consumption, tree mortality, mineral soil exposure and smoke production are modeled using predictions from FOFEM (Reinhardt and others 1997). A new model of fuel dynamics provides the link that pulls together models of fire behavior, fire effects, and stand dynamics. We have had tools for some time that model short-term dynamics of activity fuels. For example, DEBMOD and HAZARD (Puckett et al. 1979) allow a user to project what fuels will be created by harvests of various specifications. What has not been previously available is a long-term model of fuel accumulation and decomposition. In the *Fire and Fuels Extension*, inputs to surface fuels include contributions from litterfall, activity fuels, and natural mortality. Fuels are reduced by decomposition, fire, or fuel treatment.

Management activities included in the new linked model allow the user to simulate harvests, planting, salvage logging, prescribed fire and wildfire, as well as fuel treatments such as piling and jackpot burning. The model requires stand exam data and initial fuel loads. Outputs include predictions over time of stand structure and composition, surface and crown fuel loads, snag dynamics, and potential fire behavior.

Wildlife Considerations

The *Fire and Fuels Extension* to *FVS* provides numerous outputs directly relevant to wildlife and wildlife habitat considerations. Snag dynamics for each species are tracked and reported at each cycle for each of up to six user-defined size classes. Reported snag characteristics include height, volume, and density (number of trees per acre) in each of two condition classes (hard and soft), year of death, and total density of all snags. An example of a snag report is shown in Table 1, which includes statistics for hard (hrd) and soft (sft) condition classes.

Another report tabulates biomass loadings (mass per unit area) and fuel consumption estimates for individual size classes of surface woody debris. Coarse woody debris is particularly relevant to wildlife habitat concerns, and the model addresses coarse woody debris parameters in several distinct size and condition classes.

The Tenderfoot Creek Case Study

Management Treatments in Lodgepole Pine

An array of management treatments is planned for the Tenderfoot Creek Experimental Forest (TCEF), a 9,125 acre experimental forest located in the western portion of the Little Belt Mountains of central Montana. The treatments include silviculture, prescribed fire, and silviculture-with-prescribed fire. The proposed treatments will provide new information on options available to regenerate and restore healthy lodgepole pine forests through emulation of natural processes while avoiding catastrophic scale disturbances. One of the silvicultural systems proposed is a two-aged system termed "shelterwood with reserves," retaining single or small groups of trees in an even spatial distribution.

[2] Scott, J.H., and E.D. Reinhardt. Linking models of surface and crown fire behavior: a method for assessing crown fire hazard. Manuscript in preparation. USDA Forest Service, Rocky Mountain Research Station, Missoula, MT 59807.

Table 1 — Example snag report for one reporting cycle

Year	Sp	DBH Cl	Died DBH	Curr.Ht Hrd	Curr.Ht Sft	Curr. Volume Hrd	Curr. Volume Sft	Curr. Volume Tot	Year died	Density (#/ac) Hrd	Density (#/ac) Sft	Density (#/ac) Tot
2010	LP	1	4.4	26.1	0.0	5	0	5	2009	0.7	.0	0.7
2010	LP	2	13.9	63.9	0.0	14	0	14	2009	0.4	.0	0.4
2010	LP	3	19.9	35.6	0.0	1	0	1	2009	0.1	.0	0.1
2010	S	1	1.2	8.8	0.0	1	0	1	2009	0.9	.0	0.9
2010	S	2	15.7	73.1	0.0	0	0	0	2009	0.0	.0	0.0
2010	S	3	18.6	82.4	0.0	0	0	0	2009	0.0	.0	0.0

Low intensity underburns will follow in 50 percent of the harvested units. In addition, several large blocks (35-100 acres) will be treated by mixed-severity underburning with no silvicultural treatments, and several no-treatment controls are also included in the plan.

Managers at TCEF will consider both direct and indirect effects of these proposed two-aged treatments with respect to the following wildlife species or habitats: elk, boreal owl, wolverine, lynx, pink agoseris, and old growth forest. Snag retention and/or recruitment objectives will be from 9-15 trees per acre of 9-10 inches minimum diameter breast height (dbh) in three age classes. Changes in coarse woody debris loadings will be assessed with respect to potential impacts on small mammal densities.

Modeling the Treatment Prescriptions

We used *FVS* and the *Fire and Fuels Extension* to explore the direct and indirect effects of the management treatments proposed for TCEF over the first 100 years following treatment. All treatments were scheduled in the model to occur in the year 2000. *FVS* was initialized to produce most reports on a ten year cycle, although some results were produced annually. Four treatments were used in the present case study:

1. **No treatment** — No treatment/ control unit(s);
2. **SE only** — Shelterwood with reserves; 40%-60% retention Evenly distributed; tops left on site; 9-15 snags per acre of 9-10 inch minimum dbh retained.
3. **SE and burn** — SE with low severity prescribed underburn following harvest.
4. **Burn only** — Prescribed burning only; mixed severity underburn.

Using a GIS, we chose a stand within TCEF that: 1. was within the proposed treatment sub-watersheds; and 2. was representative of the general lodgepole pine stands of TCEF. Stand examination data for the stand was converted to *FVS*-ready format, and was then input to *FVS* with the prescription parameters for each of the respective four treatments summarized above.

Results

Stand Characteristics

Summary statistics of stand characteristics at each of three model cycle-years are shown in Table 2. Data for 1990 represent pre-treatment conditions, so there is no difference among the four treatments. Tree density was 2627 stems per acre, for a total volume of 2925 cubic feet per acre. The immediate results are represented by the first model cycle-year following treatment (2010).

The contrasts between pre-treatment conditions and immediate post-treatment effects of the shelterwood with reserves silvicultural method are shown in Figure 1, which

Year	Treatment	Number of trees	Basal area	Quad. mean dia.	Total volume
			sq.ft.	inches	cu.ft
1990	No treatment	2627	116	2.8	2925
	SE only	2627	116	2.8	2925
	SE & burn	2627	116	2.8	2925
	Burn only	2627	116	2.8	2925
2010	No treatment	1796	129	3.6	3308
	SE only	1943	70	2.6	1743
	SE & burn	193	11	3.2	284
	Burn only	119	21	5.7	564
2090	No treatment	1138	175	5.3	4250
	SE only	1070	171	5.4	3506
	SE & burn	880	105	4.7	2031
	Burn only	1034	119	4.6	2275

Table 2 — Summary stand statistics for four treatments at three cycles

was rendered using the *Stand Visualization System (SVS)* (McGaughey 1997).

Snag Dynamics

We evaluated the effects of the treatments on snag densities at four 20-year reporting times: 2010, 2030, 2050, and 2070. The *Fire and Fuels Extension* reports snag statistics for all tree species and for several user-defined size classes. For wildlife implications, we only considered standing snags ^{3}12" dbh. In the TCEF case study, snag species reported include lodgepole pine, spruce, and subalpine fire. Figure 2 is a plot of accumulated snag densities by species, for each treatment, at four reporting times.

The most dramatic shifts in snag densities occur within the first ten years following treatment (all treatments occurred in year 2000). The **Burn only** treatment resulted in the largest recruitment of new snags through fire-caused mortality, with nearly twenty 12 inch and greater dbh snags/acre contrasting with only 2 snags/acre for the **No treatment** alternative. However, the relatively rapid fall-down rate for lodgepole pine snags is evident within the next ten year period, with a roughly two-thirds decline in the density of the fire-created snags. The **SE and burn** treatment experienced the most significant long-term reduction in snag densities.

Coarse Woody Debris

Coarse woody debris (CWD) includes all dead-and-down woody biomass with mean diameter greater than 3". For the TCEF case study, loadings for CWD are reported annually, as shown in Figure 3 for the period 1990-2090. Trends in CWD are most stable for **No treatment** and **SE only**, with **SE only** having the least overall CWD for the 100 year period. Both **SE & burn** and **Burn only** treatments result in the same post-treatment decreases in CWD due

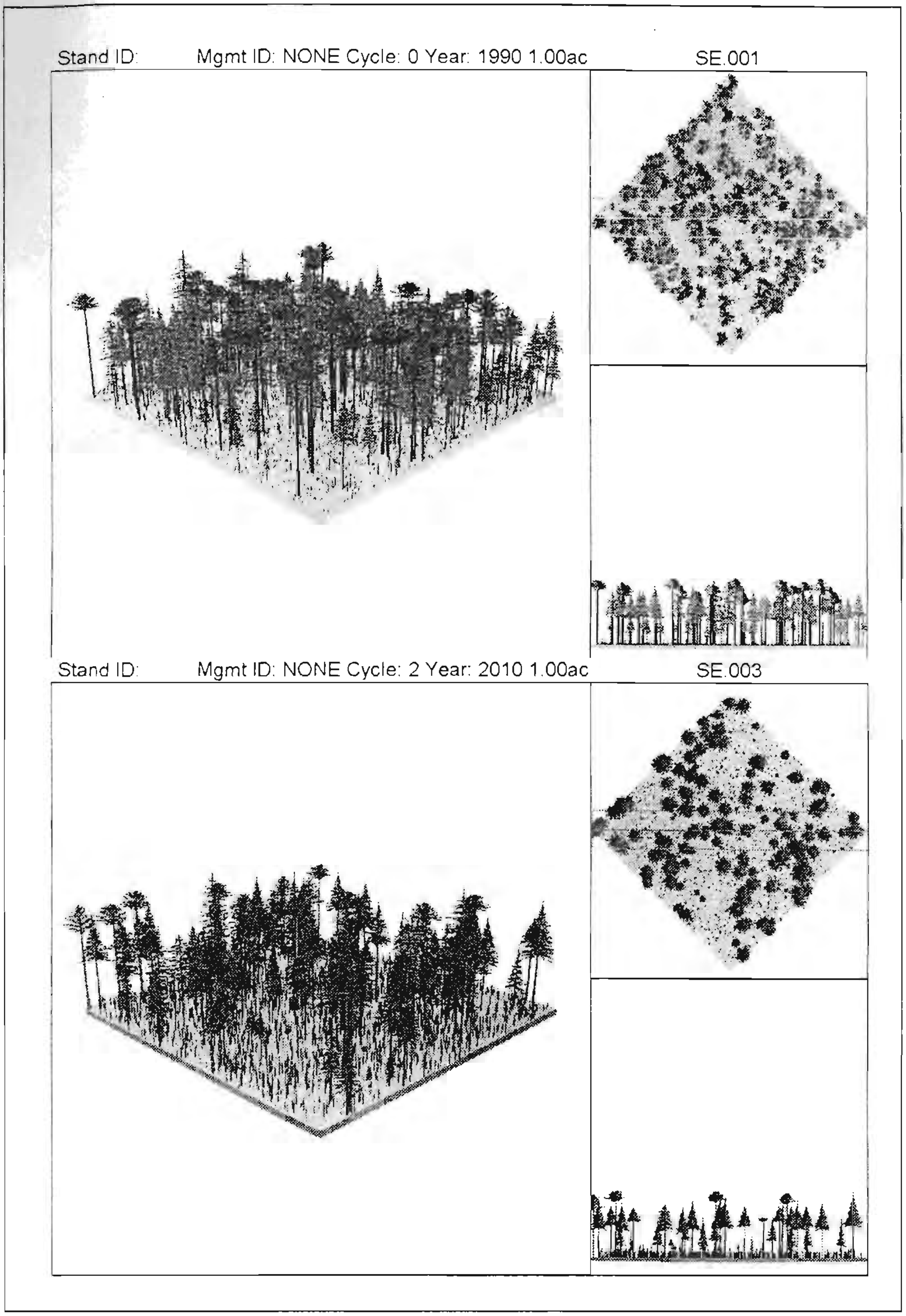


Figure 1 — SVS visualizations of pre-treatment (a) and immediate post-treatment (b) conditions.

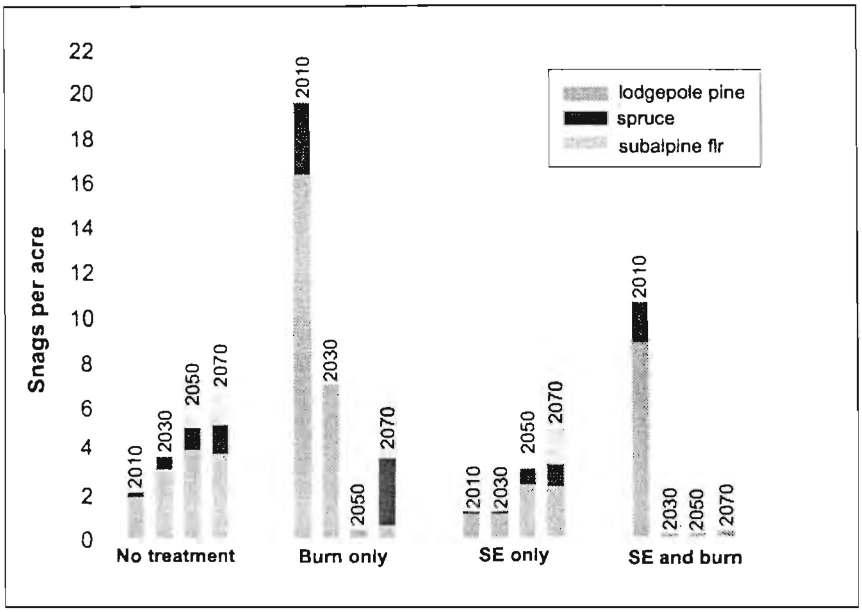


Figure 2 — Snag dynamics for the four treatments are shown for four reporting times. The three species are lodgepole pine, spruce, and subalpine fire.

to fuel consumption during the prescribed fire, but subsequent contributions to CWD from fire-caused mortality for the **SE & burn** treatment are significantly higher.

Potential Fire Behavior

One of the fire behavior-related indices calculated by the *Fire and Fuels Extension* is flame length (expressed in feet), which is a relatively intuitive indicator of fire potential. Flame length for the four treatments is plotted in Figure 4 for the 100-year period.

Potential flame length remains lowest for **No treatment** and **SE only**, while **SE & burn** and **Burn only** treatments nearly double the potential flame lengths for over five decades. The highest potential flame lengths are predicted for the SE/B treatment, due possibly to contributions to the fine fuel loading by crown-scorch and mortality.

Discussion

Management Implications

Development of this model extension is nearly complete, but without a thorough analysis and verification of model behavior, we are not yet prepared to interpret model predictions for application to actual planning efforts. The results predicted by the *Fire and Fuels Extension* to *FVS* for this case study are presented here to illustrate the potential power and usefulness of the model in assessments of proposed management activities. The *Fire and Fuels Extension* to *FVS* is clearly not intended to be used as a deterministic tool; rather, it is best used in contrasting the relative differences in predicted outcomes of various alternatives. This new extension provides the capability for multi-resource planning which integrates models for silviculture, fuels management, fire behavior, and fire effects.

The Future

Currently, the *Fire and Fuels Extension* has been linked to the north Idaho variant of FVS. A comprehensive behavior analysis and model documentation is planned for the near future. We also intend to link it to other geographic variants where fire has an ecological role, including those for California, Western Sierra Nevada, Klamath Mountains, and South Central Oregon/Northeast California. Additional work is continuing to link this new extension to the *FVS Parallel Processing Extension* (Crookston and Stage 1991) for a fully spatial implementation of the *Fire and Fuels Extension* to *FVS*. We hope it will be useful to wildlife managers as well as fire and fuels managers for planning, environmental assessment development, and communication.

Figure 3 — Coarse woody debris trends for the four treatments, 1990-2090.

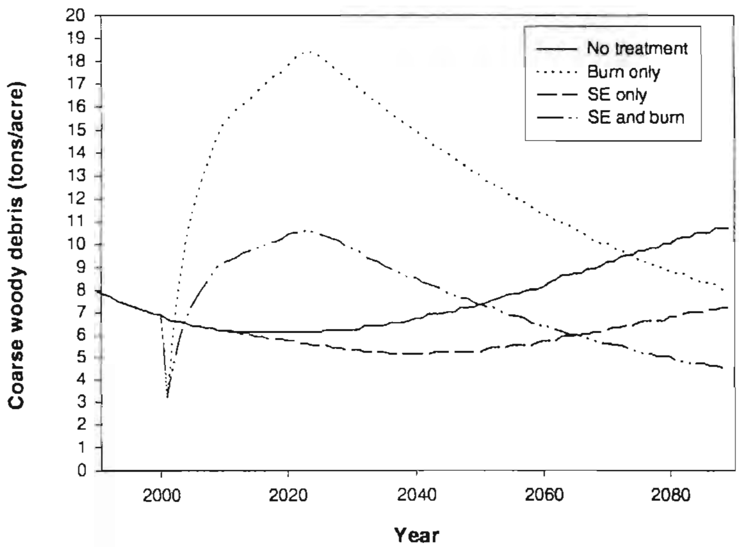
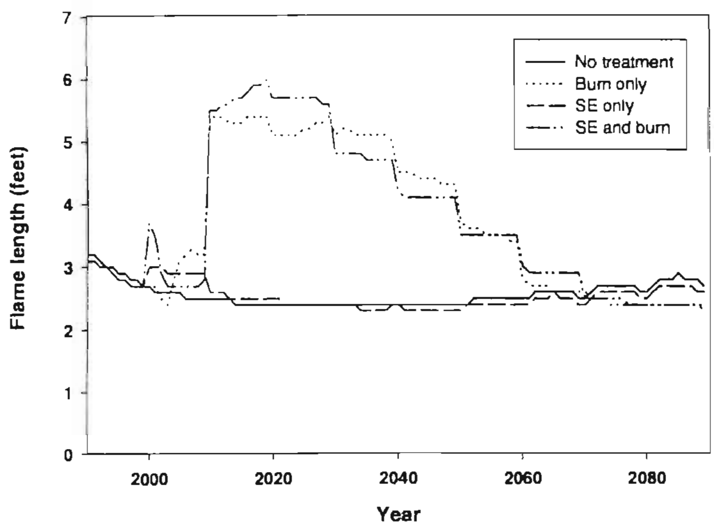


Figure 4 — Flame lengths predicted for each of the treatments, 1990-2090.



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