ANALYZING EFFECTS OF MANAGEMENT ACTIONS INCLUDING SALVAGE, FUEL TREATMENT, AND PRESCRIBED FIRE ON FUEL DYNAMICS AND FIRE POTENTIAL

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ABSTRACT

This paper summarizes methods available to help managers evaluate fuels and fire potential as they may be expected to change over time within a forest stand. We use a case study to compare alternative management scenarios including thinning from below, prescribed underburning, and no treatment. Fire behavior, fuel consumption, and tree mortality models are used to contrast stand dynamics following prescribed fire versus wildfire. Fuel accumulation and decomposition are modeled to contrast fuel dynamics in salvaged versus nonsalvaged stands. Linking existing modeling tools provides a method that expands our ability to provide long-term, site-specific evaluations of management actions on fuels and potential fire intensity.

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INTRODUCTION

Land managers need site-specific information on the mid- to long-term effects of fire management alternatives. Specifically, managers need to project and compare effects of alternatives including combinations of harvest and prescribed fire, fire suppression, wildfire, and salvage logging, on fuel dynamics and potential fire intensity over subsequent decades.

For example, consider a prescribed burn proposed for treating an overstocked stand. The fire would result in an immediate reduction of surface fuels and potential fire intensity. In the short run, however, fuels could be expected to increase as fire-killed trees began to fall. Over time, fuels may accumulate more slowly than in an adjacent untreated stand, since the residual stand may be more open and vigorous. Then consider a wildfire at some future time in the two adjacent stands. Since the fuels would be different, fire intensity would be different. Since the stands would differ in composition and structure, they would be impacted differently. This kind of information may be helpful to a manager deciding whether or not, or under what conditions, to conduct the prescribed burn. It is difficult, however, to generalize about these relationships. The results will depend entirely on the site condition, the particular stand, and the specific treatment.

Fire behavior, fire effects, fuel dynamics, and stand dynamics all interact. Projections of fuels and potential fire intensity are complicated by the interactions of the processes involved. In fire behavior, the key process is combustion, which causes fire effects like tree mortality and fuel consumption. With respect to fire effects, key processes include tree mortality, which influences stand dynamics and fuel consumption, which influences fuel dynamics. In fuel dynamics, key processes are fuel accumulation and decomposition. These processes influence fire behavior and fire effects. Finally, in stand dynamics, key processes are tree regeneration, growth, and mortality. Stand dynamics influence fire behavior (since fire behaves differently in stands of different structures), fire effects (since fire causes different tree mortality in different stands), and fuel dynamics (since different stands will have different rates of litterfall, mortality, and snagfall).

Human intervention influences each of these processes. We influence fire behavior and effects through prescribed fire. We influence fuel dynamics through fuel treatment and fire suppression. We influence stand dynamics through timber harvest. We can not intervene in any of these processes in isolation from the rest.

PREVIOUS WORK

Modeling tools are currently available to look at most of these processes separately.

For simulating fire behavior, a number of tools are available including the computer program BEHAVE (Andrews 1986). Inputs include fuel quantity and characteristics, fuel moisture content, and windspeed. Outputs include flame length and fire intensity.

Fire effects can be predicted using the program FOFEM—a First Order Fire Effects Model (Reinhardt et al. 1997). Inputs to this program include flame length, fuel quantity, and fuel moisture. Outputs include fuel consumption, smoke production, and tree mortality.

A model for projecting stand dynamics is the Forest Vegetation Simulator (FVS), or Prognosis Model

Table 1. Predicted fuel consumption, smoke production, and tree mortality following a prescribed underburn and a wildfire, for a single ponderosa pine-Douglas-fir stand in the Bitterroot National Forest, MT.

Fuel consumption (tons per acre)	Prescribed underburn	Wildfire
Duff	2.0	5.1
Small Woody (0–3″ dia)[a]	3.5	3.5
Large Woody (3+″ dia)	3.7	4.1
Canopy fuels	1.0	5.4
PM 10 emissions (pounds per acre)	271	450
Tree Mortality (percent) all species, by diameter		
0–4″	91	96
4.1–8″	63	96
8.1–12″	40	79
12.1–16″	27	88
16.1″+	23	80

[a] 1 inch = 2.54 centimeters.

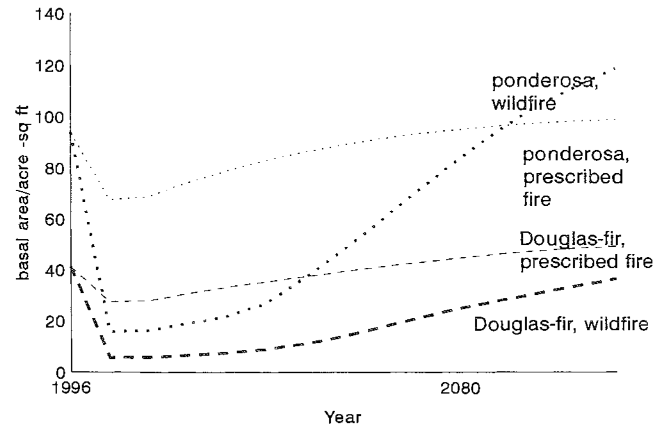

Fig. 1. Basal area (square feet per acre) of ponderosa pine and Douglas-fir. Simulated treatments were a prescribed underburn versus a wildfire in 1997.

(Wykoff et al. 1982). This tree stand model (which is independent of individual tree distances) predicts stand development over a several hundred year time frame. Originally developed for the Interior West, variants are currently available that cover the U.S. The model allows the user to simulate management actions such as harvests, thinnings, and plantings. It also has a number of extensions to model effects of insects and diseases. FVS provides a useful link between modeling subcomponents because it predicts long-term effects.

Modeling fuel dynamics provides the link that can pull 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. 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 available is a long-term model of fuel accumulation and decomposition. Inputs to such a model must include contributions from litterfall, activity fuel, and natural mortality, as well as decomposition rates. Outputs would be projected fuel loadings over time.

METHODS

Recently, Intermountain Research Station scientists, in cooperation with ESSA Technologies, Vancouver, B.C., have worked on linking FVS with fire behavior and fire effects models, including development of a fuel dynamics model (Beukema et al. 1996). The linked model uses the forest vegetation simulator to grow stands over time. It allows the user to simulate harvest, planting, salvage logging, prescribed fire and wildfire, as well as fuel treatments such as piling and jackpot burning. At annual time steps it adjusts fuel loads for contributions from litterfall, snagfall and activity fuel, and losses due to decomposition and fuel consumption.

As an example of the type of information this linked model can provide, we made a number of runs comparing alternatives for a single stand on the Bitterroot National Forest in western Montana. The stand is a dense (168 square feet of basal area per acre (39 square meters per hectare)), multi-storied stand of mostly ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*). The habitat type is *Pseudotsuga menziesii-Vaccinium globulare* (Pfister et al. 1977). The stand is typical of many that present problems to managers. It is in the wildland urban interface; it is overstocked, with a potential for forest health problems; and its multi-storied structure provides ladder fuels that increase potential for crowning, torching, and extreme fire behavior.

RESULTS AND DISCUSSION

In the first analysis, we compared the predicted results of a wildfire and a prescribed fire. The simulated flame lengths, based on current fuels and assumed windspeeds and moisture contents typical of wildfire and prescribed fire situations, were 2 feet (0.6 meter) for the prescribed fire and 4 feet (1.2 meters).

Table 1 shows the effects of the two treatments. The wildfire was predicted to consume more duff than the prescribed fire because of drier conditions, and to consume some canopy fuels that were predicted unburned by the prescribed fire. As a result, the wildfire was predicted to produce almost twice as much smoke as the prescribed fire. Predicted tree mortality was also greater in the wildfire, especially in the larger diameter trees that were expected to survive the prescribed fire.

Predictions of the immediate effects of the two fire treatments are more useful when coupled with the Forest Vegetation Simulator to show the long-term predicted consequences of the fire-caused tree mortality on stand development. Figure 1 shows the projected basal area per acre of the major tree species over a 120-year time period following the two treatments. Differences between the two fire treatments persist over this entire time period.

In a separate analysis, we projected potential fire intensity over 120 years following three different treatments: a prescribed underburn, a thinning from below to an 8″ diameter, and a no action alternative. Figure 2 shows the potential flame length under wildfire conditions as fuels and stand structure change over the

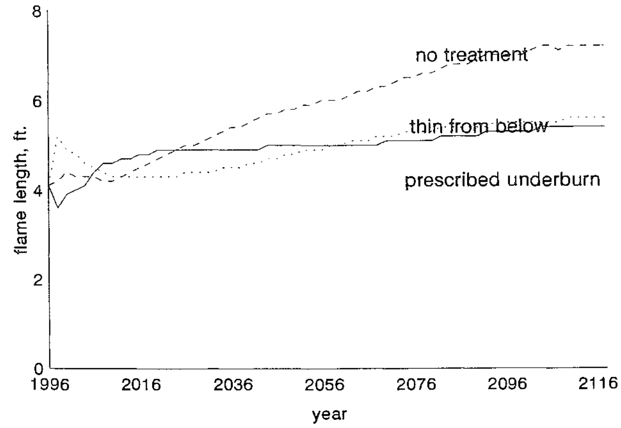

Fig. 2. Potential flame length (feet) assuming wildfire conditions in the 120 years following a prescribed underburn, a thinning from below to an 8″ diameter, and no action.

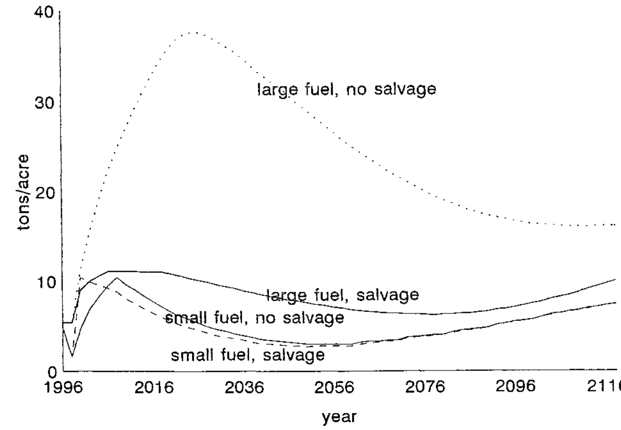

Fig. 3. Predicted fuel loads of small (0–3″ diameter) and large (3+″ diameter) woody fuels. Simulations show a 1997 wildfire followed by salvage harvest versus a 1997 wildfire without subsequent salvage.

simulation period. A sharp decline in potential flame length is predicted following the prescribed underburn because surface fuels have been reduced. This is followed by a fairly rapid increase in potential flame length as fire-killed trees start to come down and contribute to increased fuel loads. Predictions for the thinning treatment show an opposite effect: there is a short spike in potential flame length due to activity fuels created by the thinning. This is followed by a relatively quick reduction as these fuels settle and decompose. In the long run, the model predicts that these two treatments will have fairly similar trends in potential flame length because the stands created by the two treatments are actually quite similar. The model predicts that the no action alternative will initially result in potential flame length between the other two treatments, but over time the fire intensity will increase beyond those of the other two treatments because the stand has greater density, litterfall, branchfall, and mortality.

Finally, in another analysis with the same stand, we compared a wildfire followed by salvage logging to a wildfire without salvage logging. We looked at predicted fuel loads and flame length over 120 years. Figure 3 shows the projected loadings of small (0–3″ diameter) and large (3+″ diameter) woody fuels. The salvage simulation predicts more small fuels in the short-term because of activity fuels created by the salvage operation. In the long-term, the unsalvaged stand has much greater loadings of large fuels. Figure 4 shows results in terms of potential fire intensity: again, in the short-term, predicted potential flame lengths are greater in the salvaged stand. From 8 to 40 years following treatment this situation is expected to be reversed, and in the long run potential flame lengths are similar between the two simulations.

CONCLUSIONS

These results are not meant to provide general conclusions about the differential effects of wildfire and prescribed fire, or prescribed fire and thinning, or salvage and no salvage. The results are dependent on the initial fuels, the initial stand, site characteristics, and the particular treatments simulated. The utility of this kind of analysis is not to provide general results but rather to provide a tool that allows comparison of specific alternatives on a specific site.

Linking existing modeling tools provides a method that expands our ability to provide long-term, site-specific evaluations of management actions on fuels and potential fire intensity.

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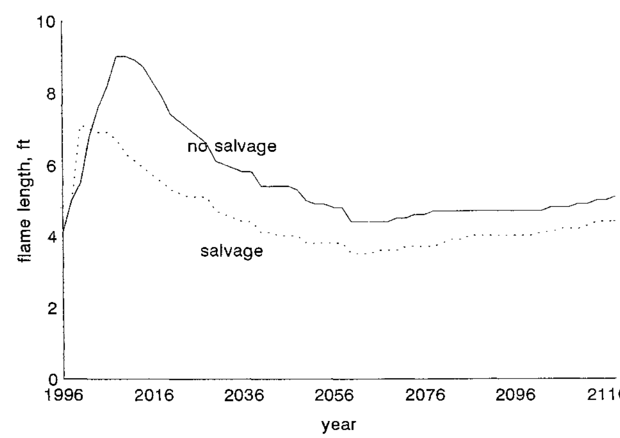

Fig. 4. Potential flame length (feet) over time. Simulations compare a 1997 wildfire followed by salvage harvest versus a 1997 wildfire without subsequent salvage.

LITERATURE CITED

Andrews, P.L. 1986. BEHAVE: fire behavior prediction and fuel modeling system—BURN subsystem, Part 1. General Technical Report INT-194, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Beukema, S.J., J.A. Greenough, W.A. Kurz, and D.C.E. Robinson. 1996. FVS-Fire Model: model description. Working document prepared by ESSA Technologies Ltd., Vancouver, B.C. for U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Pfister, R.D., B.L. Kovalchik, S.F. Arno, and R.C. Presby. 1977. Forest habitat types of Montana. General Technical Report INT-34, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Puckett, J.V., C.M. Johnston, F.A. Albini, J.K. Brown, D.L. Bunnell, W.C. Fischer, and J.A.K. Snell. 1979. User's guide to debris prediction and hazard appraisal. U.S. Department of Agriculture, Forest Service, Northern Region, Missoula, MT.

Reinhardt, E.D., R.E. Keane, and J.K. Brown. 1997. First Order Fire Effects Model: FOFEM 4.0, User's Guide. General Technical Report INT-344, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Wykoff, W.R., N.L. Crookston, and A.R. Stage. 1982. User's guide to the stand prognosis model. General Technical Report INT-133, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.