Forest fuel treatments in western North America: Merging silviculture and fire management

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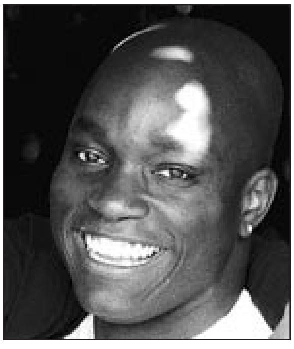
ABSTRACT:
For many years silviculture and fire management have mostly been separate forestry disciplines with disparate objectives and activities. However, in order to accomplish complex and multiple management objectives related to forest structure, fuels, and fire disturbance, these two disciplines must be effectively integrated in science and practice. We have linked scientific and management tools to develop an analytical approach that allows resource managers to quantify and evaluate the effectiveness of alternative fuel treatments in dry interior forests of western North America. The principal tool is the Fire and Fuels Extension of the Forest Vegetation Simulator (FFE-FVS) for characterizing fuel succession and fire behaviour, and for quantifying and visualizing stand structure. FFE-FVS provides a user-friendly framework that facilitates rapid evaluation of thinning and surface fuel treatments intended to reduce crown fire potential and fireline intensity. This approach quantifies fire hazard at small and large spatial scales, assists with treatment priorities and schedules, and generates stand and landscape visualizations that facilitate decisions about appropriate fuel treatments.

Key words: fire behaviour, fire hazard, fuel treatments, silviculture

RÉSUMÉ
Depuis plusieurs années, la sylviculture et le contrôle des feux de forêt ont été en majeure partie deux disciplines indépendantes avec des objectifs et des activités indépendantes. Cependant, dans le but de réaliser les objectifs d'aménagement complexes et multiples rattachés à la structure forestière, aux combustibles et aux perturbations provoquées par le feu, ces deux disciplines doivent être effectivement intégrées au niveau des sciences et de la pratique. Nous avons relié les outils scientifiques et d'aménagement pour élaborer une approche analytique qui permet aux gestionnaires des ressources de quantifier et d'évaluer l'efficacité des traitements alternatifs des combustibles des forêts sèches de l'ouest de l'Amérique du Nord. Le principal outil est le Fire and Fuel Extension du Forest Vegetation Simulator (FFE-FVS) qui caractérise la succession des combustibles et le comportement du feu et qui permet de quantifier et de visualiser la structure du peuplement. Le FFE-FVS constitue un cadre de travail facile d'utilisation et simplifie l'évaluation des traitements d'éclaircie et des combustibles en surface visant à réduire le potentiel de feu de cime et l'importance des lignes coupe-feu. Cette approche quantifie le danger de feu en fonction de grandes ou de petites échelles spatiales, contribue au traitement des priorités et des calendriers et génère des représentations du peuplement et du paysage qui facilitent les décisions en matière de traitements appropriés des combustibles.

Mots clés : comportement du feu, traitements des risques d'incendie des combustibles, sylviculture



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Integrating Silviculture and Fire Management

Silviculture, the practice of manipulating forest structure, establishment, composition, and growth, consists of a diversity of applications intended to regulate and enhance forests to accomplish forest management objectives (Smith *et al.* 1996). There are two categories of treatments: regeneration cuttings (e.g., clearcutting) and intermediate cuttings (e.g., thinnings). Regeneration cuttings remove mature trees and prepare the site for regeneration, whereas intermediate cuttings are implemented to control forest structure, establishment, composition, density, and growth. Intermediate cuttings are of interest to fire and forest managers whose management objectives are to reduce fire hazard in dry interior forests.

Resource managers are beginning to recognize the significance of integrating silviculture and fire management techniques in order to accomplish complex and multiple management objectives related to forest structure, fuels, and fire hazard.

Silvicultural thinnings and surface fuel treatments influence stand structure, species composition, available fuel, fuel arrangement, fuel moisture, and surface winds (Graham *et al.*

1999). Crown and ladder fuels can be modified with operations such as thinning from below, which targets crown classes, stand basal area, or canopy bulk density.

Forest Structure Changes

Fire exclusion has altered the distribution of fire regimes in the interior west of North America. Ponderosa pine (*Pinus ponderosa*)/Douglas-fir (*Pseudotsuga menziesii*) fire regimes (low severity, high frequency) provide the most empirical fire data and have undergone significant structural and compositional changes (Agee 1993). Vertical distribution and horizontal continuity in arid and semiarid low and mid elevation forests in western North America differ from historical stand structures. The solution to forest fuel accumulations and the incidence of large wildfires seems simple—implement treatments to modify fuel quantity and spatial arrangement—but this objective is complex in practical terms.

The relationship between stand structure and wildfire behaviour has been relatively well documented (e.g., Weaver 1943, Cooper 1960, Dodge 1972, Van Wagner 1977, Rothermel 1991, McLean 1993). Several stand attributes are linked to crown fire initiation and crown fire, specifically canopy bulk density, canopy base height, surface fuels, and canopy closure (Van Wagner 1977, Rothermel 1991, Scott and Reinhardt 2001, Peterson *et al.* 2005). Silvicultural treatments and surface fuel treatments that target these stand characteristics could reduce wildfire behaviour, but there is no consensus about which fuel treatments are appropriate. Fire and forest managers need a tool to evaluate the efficacy of fuel treatments in modifying potential fire hazard and predict ecological effects of treatments at different spatial and temporal scales.

The *Guide to Fuel Treatment in Dry Forests of the western United States* (Johnson *et al.* 2005) was recently developed by scientists at the Pacific Wildland Fire Sciences Laboratory, Pacific Northwest Research Station, in cooperation with other scientists and resource managers. The guidebook links information and data from silviculture and fire science to (1) assist decision-making about fuel treatments in dry-forest stands, and (2) provide quantitative guidelines for fuel treatment that allow consideration of desired future conditions for multiple resources (e.g., wildlife, water, timber production). Scenarios displayed in the *Guide* represent a range of dry-forest types, specifically those forests dominated by ponderosa pine, mixed conifer (often including Douglas-fir as a codominant), and pinyon-juniper (*Pinus* spp. and *Juniperus* spp.).

Despite the huge literature available for silviculture and fire science as individual disciplines, quantitative guidelines for integrating those disciplines to assist decisions about fuel treatments have never been developed. The *Guide* is a proof of concept for how to do this integration based on established scientific principles; it (1) analyzes a fuel and vegetation treatments for 26 representative dry-forest stands, (2) provides quantitative guidelines for treatments based on scientific principles of reducing fire hazard, and (3) displays treatment effects on stand structure, surface fuel loading, and potential fire behaviour.

A scientific proof of concept will evolve into a successful management application only if potential users have a significant role in product development. In this case, forest stand scenarios and alternative fuel treatments were determined only after we received extensive feedback from federal fire managers and silviculturists following demonstrations and presentations. All empirical data on stand structure were received directly from timber managers on U.S. national forests. This breadth of input and data allowed us to develop fuel treatment scenarios that are truly representative and likely to be encountered in operational management and planning (without being comprehensive). Although quantitative guidelines are needed at all spatial scales, we feel it is imperative that competence be developed first for small scales, ranging from approximately 1 to 500 hectares. At this scale, planning assessments required by the U.S. National Environmental Policy Act (NEPA) can be confidently documented with scientific information on the effects of modifying forest structure and surface fuels. Scaling up to larger treatment areas will require considerably more effort.

Table 1. Summary of outputs of FFE-FVS simulations for each forest stand scenario, where all combinations of thinning and surface fuel treatments are considered

Type of output	Method of reporting
Initial stand conditions	Verbal description, visualization
Stand conditions following thinning	Visualizations
Fuels, fire behaviour, fire effects immediately following treatment	Fuel loadings by size class, flame length, type of fire (crown vs. surface), tree mortality
Fuels, fire behaviour, fire effects for 50 years following treatment	Fuel loadings by size class, flame length, type of fire (crown vs. surface), snags; reported at 10-year increments
Forest stand structure for 50 years following treatment	Stand density, diameter, basal area, crown closure, etc.; reported at 10-year increments
Summary of stylized fuel models for 50 years following treatment	Fuel model number(s); reported at 10-year increments
Fire weather	Temperature, relative humidity, wind speed, fuel moistures
Summary narrative	Verbal description of important outputs, such as effects of different levels of thinning, transitions between surface and crown fire, etc.

Approach

Resource managers in western North America currently use a range of thinning and burning treatments to meet silvicultural objectives. We selected six silvicultural options (thinning to 120 trees per hectare (tph), 240 tph, 480 tph, and 720 tph; no thinning; and prescribed fire only) in combination with three surface fuel treatments (pile and burn, prescribed fire, no treatment) (Fig. 1). All thinning prescriptions were thin from below with a 45-cm upper dbh limit. Output from model

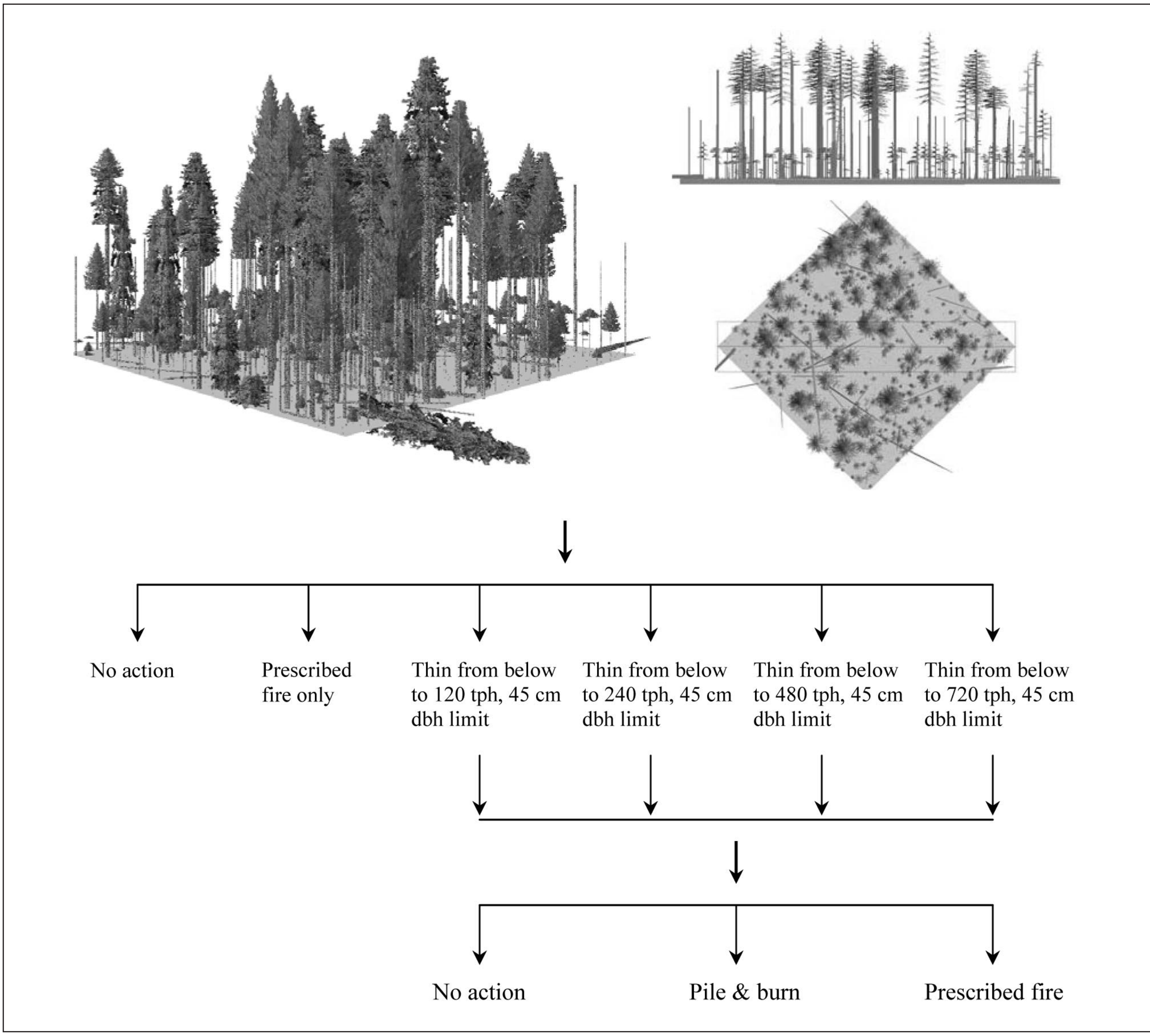

Fig. 1. Conceptual diagram of the process used to simulate the effects of fuel treatments for a forest stand in FFE-FVS.

projections was summarized for each stand with visualizations and tabular data. In addition, changes in forest structure and fuels were calculated for 50 years post-treatment at 10-year increments, so that long-term stand conditions could be assessed.

Forest stand attribute data from national forests were converted into Forest Vegetation Simulator (FVS)-ready files. Model default values were used as initial surface fuel loading and live and duff fuel moisture. The 75th percentile (moderate) and 98th percentile (severe) historical fire weather data (1-hr (0–0.6 cm), 10-hr (0.6–2.5 cm), 100-hr (2.5–7.6 cm), and > 1000-hr (> 7.6 cm) fuel moisture percentages (Reinhardt and Crookston 2003) and temperature) from each geographic area were obtained from Remote Automated Weather Stations located in the vicinity of each national forest. A Fire and Fuels Extension of the Forest Vegetation Simulator (FFE-FVS) portfolio (Reinhardt and Crookston 2003) was developed for each national forest using the FVS-ready files, historical fire weather data, and default surface fuel loadings. Each portfolio was projected 50 years to observe the potential fire behaviour under moderate and severe weather scenarios. Twenty-six candidate stands were selected from among the different national forests. Each stand was visualized in Stand Visualization Software and converted to EnVision images to observe the horizontal and vertical distribution of stand structure before and after treatments.

Discussion

Resource managers need clear, straightforward guidance to expedite decision making. To that end, the results of simulations can be organized effectively in a few pages per scenario (Table 1). A review of the 25 scenarios for dry forest stands indicates that thinning to 120–24 tph is necessary to reduce the long-term potential of crown fire in most stands (Johnson *et al.* 2005). Thinning to higher densities does not reduce fuels sufficiently to eliminate crown fire. The heavier thinnings reduce ladder fuels and crown bulk density (initial stand density is often > 2500 tph), thereby discouraging propagation of surface fire to a crown fire. In addition, some type of surface fuel treatment is usually needed to reduce fine fuels, and to keep flame length well below canopy base height. This combination of heavy thinning plus surface fuel treatment is usually needed in stands from which fire has been excluded for many decades; either thinning or surface fuel treatment alone are insufficient.

Seedling regeneration eventually provides new ladder fuels that facilitate potential crown fire 20 to 40 years following treatment. Maintenance thinning and possibly additional surface fuel treatment would then be needed to provide continued fire resilience in the stand. The objective of minimizing crown fire will often need to be balanced against ecological, social, and economic objectives for desired stand conditions.

A disadvantage of FFE-FVS is related to fire behaviour calculation. Fire behaviour outputs generated by FFE-FVS depend on stylized fuel models (Anderson 1982) rather than actual fuels. When silvicultural treatments are implemented in the model, the actual activity fuels or slash created from the treatment is not used to calculate potential fire behaviour. Instead the model uses the loadings and other stand characteristics to select one or more models from 14 stylized fuel models to calculate fire behaviour (Reinhardt and Crookston 2003).

However, FFE-FVS is currently the best available tool for predicting the effects of fuel treatment on fire hazard in dry forests of western North America. The process described here represents a proof of concept that can be illustrated with representative examples. Those examples can be used directly, or users can extend them to specific management situations. Ideally, an increasing number of users will run FFE-FVS themselves—using our approach as a point of departure—to develop their own management scenarios and alternative treatments.

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