TECHNICAL NOTE

Tree-Centered Spot Firing—A Technique for Prescribed Burning Beneath Standing Trees

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Prescribed burning beneath standing trees normally requires efforts to protect residual trees from excessive fire damage. Damage to both crowns and boles is strongly influenced by flame length, a fire characteristic functionally related to fireline intensity (Albini 1976). In a good prescribed burn, therefore, the prescription specifies desired or maximum flame lengths consistent with an acceptable level of tree damage, and firing techniques are selected and used so as to achieve those target flame lengths. Backing or strip-head fires, or combinations of the two, are the techniques generally employed in prescribed burning in stands (Martin and Dell 1978).

It is a common observation when prescribed burning in a stand, especially with strip-head firing, that some of the greatest flame lengths often occur where they are least wanted and most likely to cause damage—around the bases and boles of residual trees. There may be several reasons: (1) Fuel loading is frequently higher at tree bases. Natural accumulations of branch and leaf litter are greater directly beneath tree crowns, and in areas that are logged, skidding patterns often result in slash accumulations near tree bases; (2) under some conditions, fuels near tree bases may be drier, because of interception of precipitation by the crowns; (3) heat generated by a fire modifies normal air movement in a stand to favor the occurrence of eddies or "chimneys" of hot air, and associated higher fire intensities, immediately adjacent to trees, particularly on their downwind (uphill) side; and (4) radiation from backing or strip-head fires moving downslope can preheat the uphill side of a tree sufficiently to cause the bark to ignite when flames reach it.

This paper describes a new firing technique that reduces flame lengths in the immediate vicinity of trees, thereby decreasing the probability of aboveground damage. It can be used alone or in conjunction with backing or strip-head firing. It is basically a modification of spot firing (Martin and Dell 1978), but, we feel, a significant and potentially quite useful modification. We have dubbed the technique "tree-centered spot firing."

THE FIRING TECHNIQUE

In the course of conducting prescribed burns in a 60- to 70-year-old stand of California white fir (*Abies concolor* var. *lowiana* [Gord.] Lemm.) in northeastern California, we sought ways to reduce flaming adjacent to trees, because of the susceptibility of true firs to fire damage and subsequent decay. Some burn units within the stand had been commercially thinned, and others remained untreated, providing the opportunity to work with both slash and natural fuels.

We recognized that it is sometimes desirable to interrupt a strip-head firing pattern to permit fire to back through a concentration of fuels. Adapting that idea, we considered the fuels adjacent to crop trees to be the "concentrations" in which we wanted to lower flame lengths. Following a few false starts, we settled on the following scheme: We first determined a strip width that best met flame length objectives in normal strip-head firing. Then within a "swath" about 3 to 4 times the width of this strip, measured upwind (downhill) from the upwind edge of the fire, we "spot-fired" each crop tree with a drip torch (Figure 1). Noncrop trees—i.e., trees that did not need to be protected or saved—were not spot-fired. We did not connect the spot fires with strips of fire. A "spot" normally consisted of a continuous or intermittent circle of fire laid around the base of the tree.

In strip-head firing, flame lengths along a newly laid strip of fire are initially very short, increasing as the strip moves downwind (uphill), and reaching a maximum where the strip meets and interacts with the backing fire from the previous strip. Similarly, tree-centered spot firing tended to produce relatively small flames adjacent to crop trees, with flame lengths gradually increasing as the circles of fire moved away from the trees. Flame front interactions and maximum flame lengths tended to occur in the spaces between trees, where they were less likely to cause damage (Figure 1). For most crop trees in the swath, significant initial separation from other heat sources and consequently lessened preheating and predrying of surface fuels and bark probably accounted for most of the observed reduction in flaming around the bases of trees.

We found that tree-centered spot firing alone often provided sufficient burn coverage of a swath. At other times, fuelbed continuity or flammability were such that supplemental stripping following the spot firing was needed for adequate coverage. In such cases, strip firing could proceed much faster—often lighting the entire swath at once—than normal strip-head firing, because most of the more flammable fuels were already consumed and crop trees were buffered with "black lines." Sometimes fill-in strip firing could proceed concurrently with spot firing of the next swath.

As with strip-head firing, competent lighters could "read the fuels" and adjust the widths of swaths to maintain desired flame lengths. For example, swath width would be reduced in response to more flammable fuels, smaller or more closely-spaced crop trees, or excessive flame lengths in the previous swath—factors that also would suggest narrower strips in strip-head firing. The initial swath width of 3 to 4 times a strip width, referred to earlier, was simply used as a convenient first approximation. The intensity of one swath was allowed to peak and begin to diminish before lighting the next swath.

Following our initial development of tree-centered spot firing in California white fir, we used the technique in a diverse set of other stand and fuelbed conditions, including (1) shelterwoods of old-growth mixed California white fir and California red fir (*Abies magnifica* A. Murr.) with moderately heavy logging slash; (2) ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) and Jeffrey pine (*Pinus jeffreyi* Grev. & Balf.) of a wide range of sizes and spacings, interspersed in some areas with highly flammable needle-draped shrubs; and (3) ponderosa pine poles with old precommercial thinning slash. Slopes ranged up to about 40%. The following general observations apply to these trials:

- Our use of tree-centered spot firing did not eliminate high fire intensities adjacent to crop trees. As compared with normal strip-head firing under the same conditions,

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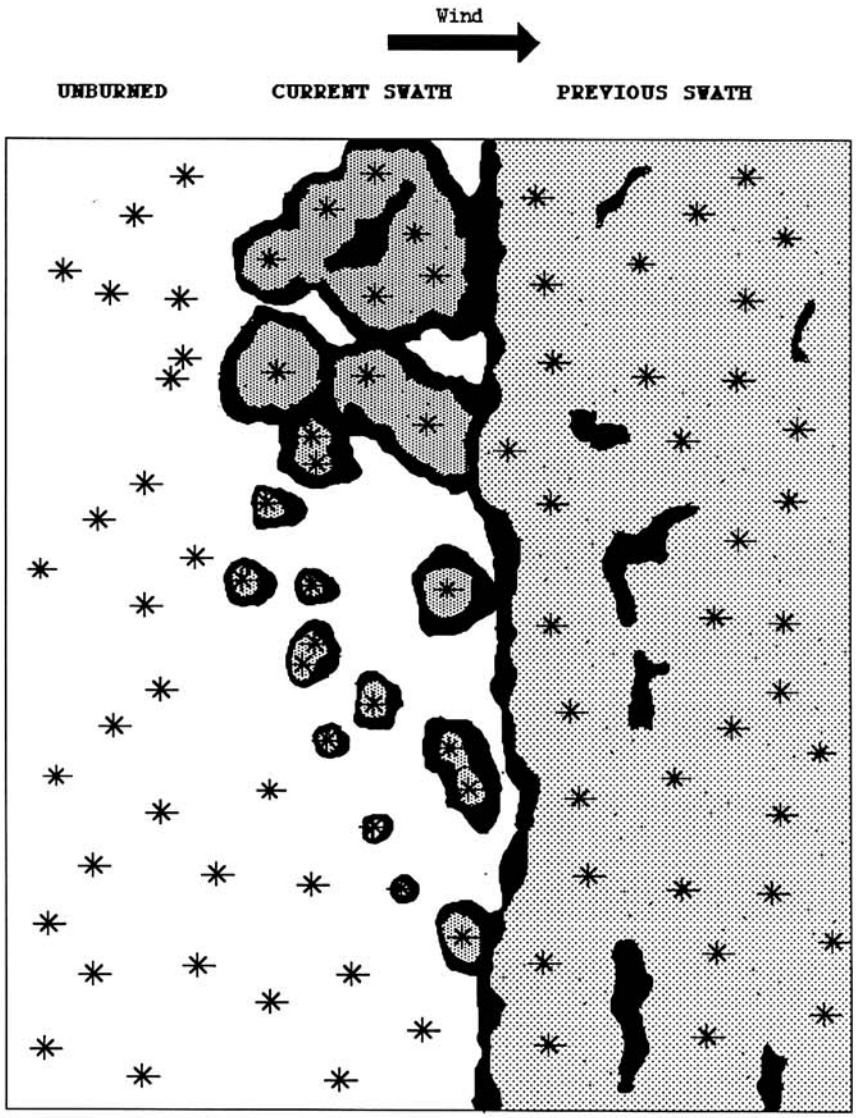

Fig. 1. Ignition pattern using tree-centered spot firing. Crop trees are indicated by asterisks, flaming zones by black, burned-out areas by the stippled pattern, and unburned areas by white. Firing within the current swath proceeds from left to right (facing the previous swath) and downwind to upwind. Burn patterns within this swath are compressed to show a range from mostly burned out to just ignited. Spot fires in the previous swath have coalesced into a single backing fire and some residual flaming in the larger openings between trees.

however, the technique rather consistently reduced flaming in the vicinity of crop trees.

- The reduction in flaming in comparison with strip-head firing—i.e., the advantage of spot firing—seemed more pronounced for trees having more flammable fuels near their bases.
- The technique often resulted in fewer "flare-ups" (flames moving up tree boles) on the downwind side of trees than either strip-head or backing fires. Although radiative heating of boles from nearby flames still took place, with spot firing most of it occurred *after*, rather than before, flames came in contact with the tree, thus reducing the probability of bark ignition.
- As compared with strip-head firing, tree-centered spot firing reduced the probability of torching (crown consumption) in small trees and in other trees with low crown bases.
- Spot firing in small poles was certainly more time-consuming than in larger trees. However, the time compared favorably with alternative firing methods—backing or narrow strip-head fires—in the same stand conditions. In closely spaced poles, there was an increased chance for heat to become too concentrated and cause excessive intensities (Sackett 1968). Therefore, lighters had to monitor fire behavior carefully, often reducing swath width locally or allowing fire to back through dense clumps of trees.
- We see no reason why tree-centered spot firing should not be applicable to additional forest types and stand/fuel conditions.

TIME AND COST COMPARISONS

How do time and fuel costs for lighting compare using tree-centered spot firing and alternative firing methods? In the areas where we tried the technique, we observed that fires could be safely advanced using tree-centered spot firing approximately as fast as with strip-head firing, while reducing flame lengths in the vicinity of crop trees. The number of lighters required, and associated worker costs, should be no more with spot firing than with strip-head firing. Drip torch fuel required for tree-centered spot firing is significantly less than for strip-head firing unless fill-in stripping is necessary, in which case fuel consumption should be similar.

Backing fires clearly progress much more slowly that either spot firing or strip-head firing. Unless coverage by lighters is marginal or intermittent, firing costs per acre burned are likely to be greater for backing fires than for the other firing methods.

Lining, clearing, and applying retardant around tree bases prior to burning sometimes have been used to protect trees from fire damage. Some of the benefits of these supplementary measures may be obtainable at lesser cost through tree-centered spot firing.

CONCLUSIONS AND RECOMMENDATIONS

Firing patterns strongly affect flame lengths and associated fire effects. By reducing flaming in the vicinity of trees, tree-centered spot firing should help to reduce above-ground damage to trees. Reduced bole damage is the most likely benefit. In some circumstances, this technique also might produce less crown scorch than strip-head firing, given the same flame lengths in the interaction zones of the two firing methods. With tree-centered spot firing, highest intensities (interaction zones) tend to occur in spaces between trees—areas that are more likely to lie beneath openings in the canopy. At low windspeeds, this may facilitate mixing and venting of more hot air through these openings, leaving less to scorch crowns. Any such benefit is less likely at higher windspeeds. To the extent that this technique reduces flare-ups and torching, associated crown damage is also reduced.

In contrast to above-ground effects, fire effects at or near the soil surface—e.g., damage to the root collar and shallow roots of trees, scarification or mortality of stored seeds, and changes in soil properties—are not related in a predictable way to firing patterns and flame lengths.

Our initial efforts with tree-centered spot firing have been best spent re-

fining it and qualitatively comparing it with other firing methods under a variety of stand and fuelbed conditions. To date we have not attempted to quantify fire characteristics or fire effects, or to employ a rigorous experimental design for comparing firing methods. Such rigor would have been prematurely time-consuming and site- and condition-specific, especially considering the inherently subjective nature of the application of firing techniques in prescribed burning. Our development and initial trials of the technique suggest sufficient promise and applicability to recommend that others try the technique for themselves.

Controlled experiments related to the efficacy and costs of tree-centered spot firing are now in order. The following is an example of a question that needs to be resolved by research. Duration of flame contact is an important determinant of cambium damage (Hare 1961). For a given amount of available fuel (the fuel that will burn under a specified set of conditions) for flaming combustion, it is reasonable to assume that a slower rate of consumption (lower intensity, shorter flame length) will be associated with a longer duration of flaming. This suggests that a firing technique that reduces flame lengths in the vicinity of trees would result in a greater duration of flaming, and therefore perhaps more, rather than less, damage to the area of bole contacted by flame (although the contacted area would certainly be smaller). Our observations failed to confirm this. Duration of flame contact with tree boles appeared to be no longer, and perhaps shorter, than with other firing methods. The explanation may be that available fuel for flaming combustion is reduced by tree-centered spot firing because of less preheating and predrying of fuels. A controlled study to compare this technique with alternative firing methods should include documentation of fire characteristics (including extent and duration of flame contact with tree boles), fuel consumption near trees, crown scorch, extent of cambium damage, and a time-temperature profile of selected points on the bark surface. □

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