EVALUATING PRESCRIBED UNDERSTORY FIRE AS A SITE PREPARATION ALTERNATIVE IN SHELTERWOODS: A MODEL FOR ESTIMATING LEAVE TREE MORTALITY

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PURPOSE

The purpose of this project is to determine the extent to which commercial tree species, both tolerants and intolerants, of the cedar-grand fir/pachistima habitat types can tolerate site preparation by prescribed fire. A set of parameters for estimating risk of mortality to residual overstory trees, by species, will be defined and a predictive equation developed.

JUSTIFICATION AND BACKGROUND

Prescribed burning is currently in use as a site preparation tool by forest managers in both private industry and on federal and state forest lands that have been clearcut. It is, comparatively speaking, less damaging to site quality (soils and watershed) and considerably cheaper than mechanical methods (Cleary et al., 1978). Slash/fuel load reduction, duff layer reduction, seed bed preparation, and reduction of competing vegetation are effectively and economically accomplished by controlled burning (Cleary et al., 1978).

On ground steeper than 35 percent slope that has been logged using cable-type logging systems, fire is often the one and only option that forest managers have available for site preparation. In the West, particularly in Rocky Mountain and Cascade ranges, steep ground and cable logging are the rule, not the exception. Mechanical site preparation is not possible on this type of ground. Crawler-type machines have a working limit of approximately 35 percent slope (Studier & Binkley, 1974). If they could operate on slopes exceeding 35 percent, soil erosion and compaction, and subsequent site and water quality damage would result. In addition, these machines are expensive in terms of initial capital outlay, maintenance, labor/operator costs, and fuel costs. Properly managed, fire exhibits none of these deficiencies, so it is employed extensively in site preparation of clearcuts in the West.

Commercial timber stands are often regenerated naturally through the employment of shelterwood cuts and other partial cutting systems. They have silvicultural advantages, the discussion of which is not within the scope of this study. Also they are aesthetically pleasing when compared to clearcuts, and it may be argued that, in certain circumstances, shelterwoods are a more economical means to regenerate a stand than planting.

With shelterwood systems, slash disposal becomes an even more serious problem, regardless of whether the ground is steep or gently sloping. Fire could be the most appropriate site preparation method available in shelterwood cuts if the residual overstory trees could survive the intensity and duration of burn required to accomplish site preparation objectives.

In the moister habitat types of the Rocky Mountain forests of northern Idaho, it is common to find several species of coniferous trees in a given stand (Daubenmire, 1968). Those habitat types provide the best sites for production of commercial timber in the Rocky Mountains. Most important among these commercial species are ponderosa pine, western larch, Douglas-fir, grand fir, lodgepole pine, western white pine, Engelmann spruce, western redcedar, and western hemlock. The first three are relatively fire tolerant, but the actual threshold of that tolerance, in the instance of prescribed understory fires, is yet to be established conclusively (Norum, 1977). For the remaining species listed, even less information regarding fire tolerance is available.

Currently, attempts at classifying these species place them in the low to medium range of tolerance to _wildfire_ (Wellner, 1970). However, such information is of little value in the case of prescribed fire following logging. A means for predicting the mortality given various stand, site, tree, environment, and fire parameters would provide a powerful management tool. An intelligent assessment of the risks and costs of using fire versus alternative site preparation techniques would be facilitated by such a tool.

Identification of trees most likely to die following fire has been of major concern to timber managers since the 1920s (Bevins, 1980). Past research has related percentage of tree mortality following fire to one or more indicators such as fire intensity, crown scorch, bole scorch, percent needle consumption, beetle activity, cambium damage, season of fire occurrence, and bud kill and twig kill. The objective of these efforts has often been to identify and attempt to salvage this imminent mortality, recover value from dead and dying trees, while protecting survivors from attack by pests. Ponderosa pine (_Pinus ponderosa_) was a subject of much earlier research in this regard, particularly in the southwest. Increased susceptibility of fire damaged trees to bark beetle (_Dendroctonus_, spp.) attack was addressed by Miller and Patterson (1927), Salman (1934), Connaughton (1936), Herman (1954), and Wagener (1955). In 1950, Herman related post-fire tree mortality to fire intensity and tree size. Lynch (1959) found stem diameter and percent live crown scorch were the best indicators of ponderosa pine mortality in northeastern Washington. Studies of a similar nature have also been performed with slash pine (_Pinus elliottii_), longleaf pine (_Pinus palustris_), and shortleaf pine (_Pinus echinata_) in the Southeast

(McCulley, 1950, Ferguson, 1955, Storey and Merkel, 1960, Mann and Gunter 1960, and Martin, 1965) along with red pine (*Pinus resinosa*) and eastern white pine (*Pinus strobus*) in the North and Midwest (Van Wagner, 1963, Sucoff and Allison, 1968, and Methven, 1971). Again, tree mortality as a stand average was related to diameter, crown damage, cambium damage, season of burn, and attack by insects. Wagner (1961) published a set of *Guidelines for Estimating the Survival of Fire Damaged Trees in California* which discusses crown scorch tolerances, bark char/cambium kill relationships, post-fire seed production and insect activity for Jeffrey pine (*Pinus jeffreyi*) ponderosa pine, sugar pine (*Pinus lambertiana*), white fir (*Abies* concolor), Douglas-fir (*Pseudotsuga menziesii*, var. pseudotsuga), red fir (*Abies magnifila*), incense cedar (*Calocedrus decurrens*), and giant sequoia (*Sequoiadendron giganteum*). In tabular form he presented a list of minimums for the survival indicators: cambium injury, percent live crown, and percent green foliage.

In March of 1980, Bevins published a set of criteria for estimating survival and salvage potential of fire-scorched Douglas-fir. A useful set of criteria was presented in graphical format, but as with most of the previously mentioned studies, this work addressed an after-the-fact situation where wildfire had damaged timber and salvage operations must be undertaken. Bevins did, however, use the RISK model (Hamilton, 1974), an adaptation of which will be used for this study. For interior Douglas-fir, Bevins reports that stem dbh combined with crown scorch height are the independent variables that most closely predict death or survival.

Norum (1977), working in the intermountain region of the Northern Rockies in western larch (*Larix occidentalis*)/Douglas-fir forests, indicates that minimal crown scorch appears to be the most important single element for these species' survival. Fuel moisture guidelines, weather parameters, and fuel loadings are described by Norum, along with burning patterns and associated hazards and a procedure for a pre-fire estimation of duff reduction. Norum's work attempts to produce an effective tool for the manager who must determine whether and how to accomplish an effective understory burn for site preparation in the intermountain forests. Its limitations are that it is quite generalized in its application. The guidelines being, presumably, applicable to all situations where Douglas-fir and western larch exceed five feet dbh. Albini's (1975) crown scorch model used in conjunction with Norum's guidelines is probably adequate for planning and conducting burns under standing larch and Douglas-fir; but, for these and other associated species grand fir/cedar pachistima habitat types where the silvicultural system employed is the shelterwood, a more precise individual tree and species oriented tool is needed, providing this tool will be an objective of this project.

It is essential to the success of an understory burning operation that the fire boss and his crew understand what type of burning pattern to employ and the significant hazards to overstory trees associated with that pattern. Minimizing crown scorch while simultaneously accomplishing site preparation objectives, particularly duff reduction, are the critical elements.

Norum's (1977) guidelines, with some degree of modification, should also pertain where crown scorch is to be controlled while burning beneath a mixed conifer overstory. However, for those species other than Douglas-fir and western larch, the additional element of cambium kill due to excessive heat at the tree base becomes immensely more important. The reason for this is that these more shade-tolerant species have a lower bark thickness to dbh ratio and are subject to a greater degree of heat conduction to the cambial tissue. Norum (1977) states that most thin barked trees will be killed by prescribed fires for site preparation of logged areas. It is the intent of this study to determine whether and to what extent this is true for the thinner barked species and, also, to determine more precisely the limitations to understory burning for Douglas-fir and western larch, especially where the residual overstory is more dense, as is the case for shelterwood harvest/regeneration systems. This additional crown density probably inhibits dispersion of heated air through and out of the stand, thereby increasing temperatures in the air surrounding the tree foliage and increasing the duration of exposure to these temperatures.

Hypothesis: For any individual tree of the aforementioned coniferous tree species there exists a threshold of tolerance to understory fire. That threshold is dependent upon certain tree and fire parameters that can be identified and, once identified, can be used in a model to predict mortality prior to burning. By first determining mean values for the tree and fire variables within a given stand, the model can then be applied to project an estimated percentage of mortality sustainable for that stand when site preparation is to be accomplished by prescribed burning.

OBJECTIVES

1. Develop a model to predict fire associated mortality to individual trees in north Idaho coniferous tree species of the grand fir/cedar pachistima habitat types following the use of prescribed understory fire for site preparation after logging.

2. Document the amount of duff reduction obtained by these experimental burns. This will serve as an indicator of the level of site preparation accomplished.

3. The model should relate tree survival following prescribed burning to a grove of easily assessed and quantifiable indicators. Equations predicting survival for each species following prescribed understory fire should result.

METHODS

Field Methods

The Research Stands

Two six-acre stands will be selected, one on steep ground (average slope exceeding 35%) and the other on gently sloping ground (10-30% slope). Both will be marked and harvested to provide shelterwoods of approximately 40 trees per acre composed of interior Douglas-fir, western larch, ponderosa pine, western white pine (*Pinus monticola*), grand fir (*Abies grandis*), and western redcedar (*Thuja plicata*). Selection of leave-trees will involve a departure from accepted principles of sound silviculture in that species and diameter distribution within species will be the primary criteria for selection. A range of diameters and heights will be chosen for each species. Tree vigor will also, however, be an important factor in selection. A live skyline system will be used to log the steeper ground of the first stand and a crawler tractor and rubber-tired skidder will harvest the second stand. Following the timber harvest and removal of logs to the mill, each stand will be divided into 3 segments or blocks to represent 3 burn intensities with two replications of each intensity (Fig. 1).

Fuel Inventory

For each stand, 18 fuel transects will be constructed (Fig. 1) using Brown's (1974) Planar Intersect Method for inventorying dead and down woody fuels. Each block will contain six transects. Also, 180 duff stakes, 60 per block, will be placed in each stand to measure duff reduction. These stakes will consist of an 8-inch gutter nail with a sliding round metal plate at the top. As the duff burns off, the plate will slide down the nail and the duff removed can be determined by measuring the length of exposed nail. This will be done the following spring (1982). These stakes will be placed in four lines across each block, with 15 stakes per line located at three-meter intervals.

Tree Inventory

Approximately 240 trees will comprise the residual overstory for each of the two stands. Each of the aforementioned species will be represented to the extent that its natural distribution and the physical condition of its members within the stand allows. This will result in an average of 80 trees or sample units per block in each of the stands. Each tree will be numbered using fireproof metal tags.

A 100 percent cruise will be conducted to include the following units of data.

Pre-burn Data

1. Tree number;
2. species;
3. tree height;
4. height to live crown;
5. height to dead crown (if significant);
6. crown ratio;
7. diameter at breast height;
8. bark thickness at one foot, at breast height;
9. vigor classification (Ferr~~ous~~ell, 1980);
10. fuel depth (average) for two meter radius around tree base;
11. number of fuel particles > three-inch diameter within two meters;
12. slope;
13. aspect.

Post-burn Data

14. Bark scorch height;
15. crown scorch height;
16. percent crown scorch;
17. bud kill.

In late June of the succeeding year, following budburst, each tree will be classified alive or dead based on visual observation. A subsample of 40 percent of the individuals of each species will be exposed to a tissue dye of 1 percent solution of orthotolidine followed by a 3 percent solution of hydrogen peroxide as described by Hare (1965). Living cambium turns blue upon exposure to this solution. Dead tissue remains uncolored. Cambial cores from four sides (one upslope, one downslope, two cross-slope samples) for each tree will be exposed to this solution. Trees will be considered dead if three or more cores so indicate. The visual inspection will be correlated with the tissue dye results.

Experimental Prescribed Burns

Prescribed understory burning, using strip head fires, will take place in the fall of 1981 when duff moisture, ~~as well as~~ 0-1" FUEL MOISTURE, AND atmosphere/weather conditions are correct. By monitoring these factors and timing the burns correctly, three different burns at three intensities (low, medium, hot) will be accomplished for each of the two shelterwoods. The critical factor in regulating these intensities will be duff moisture content. For the low intensity, this value should approximate 30-33 percent, with moderate at 25 percent and hot at 20 percent. Zero to one-inch fuels will also be important in carrying the fire, and their moisture contents will also be watched.

Prior to burning, measurements of fuel loads, duff depth, duff and fuel moisture contents, slope, aspect, wind speed, relative humidity, shade factor, and herbaceous material (if present in significant quantities) and its moisture content will have been taken (Fischer 1978). Tree data, as listed previously, will also have been recorded. Advance estimates of fire behavior will be made using Albini's (1975) nomograms. These will be used for planning purposes and for comparison with actual fire behavior.

Subsequent to the first wetting fall rains that follow the burns, measurements of duff reduction, fuel load reduction, and percent mineral soil exposed will be taken. Determinations of survival/mortality will be made following budburst, but it is important to note at this point that some fire-associated mortality could occur at some time later than the end of this one-year interval. This is likely to be quite low, but it does merit some mention because in shelterwood systems, the leave trees must be expected to survive and provide shelter until the next rotation is established and the overstory removal operation has been completed. Five to ten years is the common time period for this, but the maximum may be 20 percent of the length of the rotation (Smith, 1962).

Analytical Methods

In previous studies trees have been placed in size (dbh, height) or fire damage classes (Bevins, 1980) based on the assumption that mean survival probability for the class could be used to represent survival probability for individual trees within that class. This is misleading, since individual tree survival is a dichotomous event. The tree either lives or it dies. Based upon a set of predictor variables, a regression equation will predict the dichotomous outcome (0 = alive, 1 = dead) for each tree one year following understory fire. This should be preferable to assigning trees to groups, then computing group survival probability.

A dichotomous event regression program entitled RISK (Hamilton, 1974) will be used to derive tree survival predictions within the probability interval (0, 1).

The program will fit the data to a logistic function as follows:

$$P = (1 + e^{(a + b^{1} x)})^{-1}$$

P = event outcome probability in the interval (0, 1)
e = base of the natural logarithm
a = regression constant
b^1 = transpose of the vector of regression coefficients
x = vector of independent variable

Potential survival indicators from the fire, site, weather, and these data at the time of the burn will be tested alone and in combination to select a model that best fits the data. Incorporated into Hamilton's RISK routine is a goodness of fit test using the chi-square statistic. Deviation of model predictions (0, 1) will be evaluated by the chi-square.

RISK also computes students t statistics for the regression coefficients in the model for determination of whether they differ significantly from zero. An analysis of variance, F ratio, to test the significance in the amount of variation in the data explained in the model is also provided.

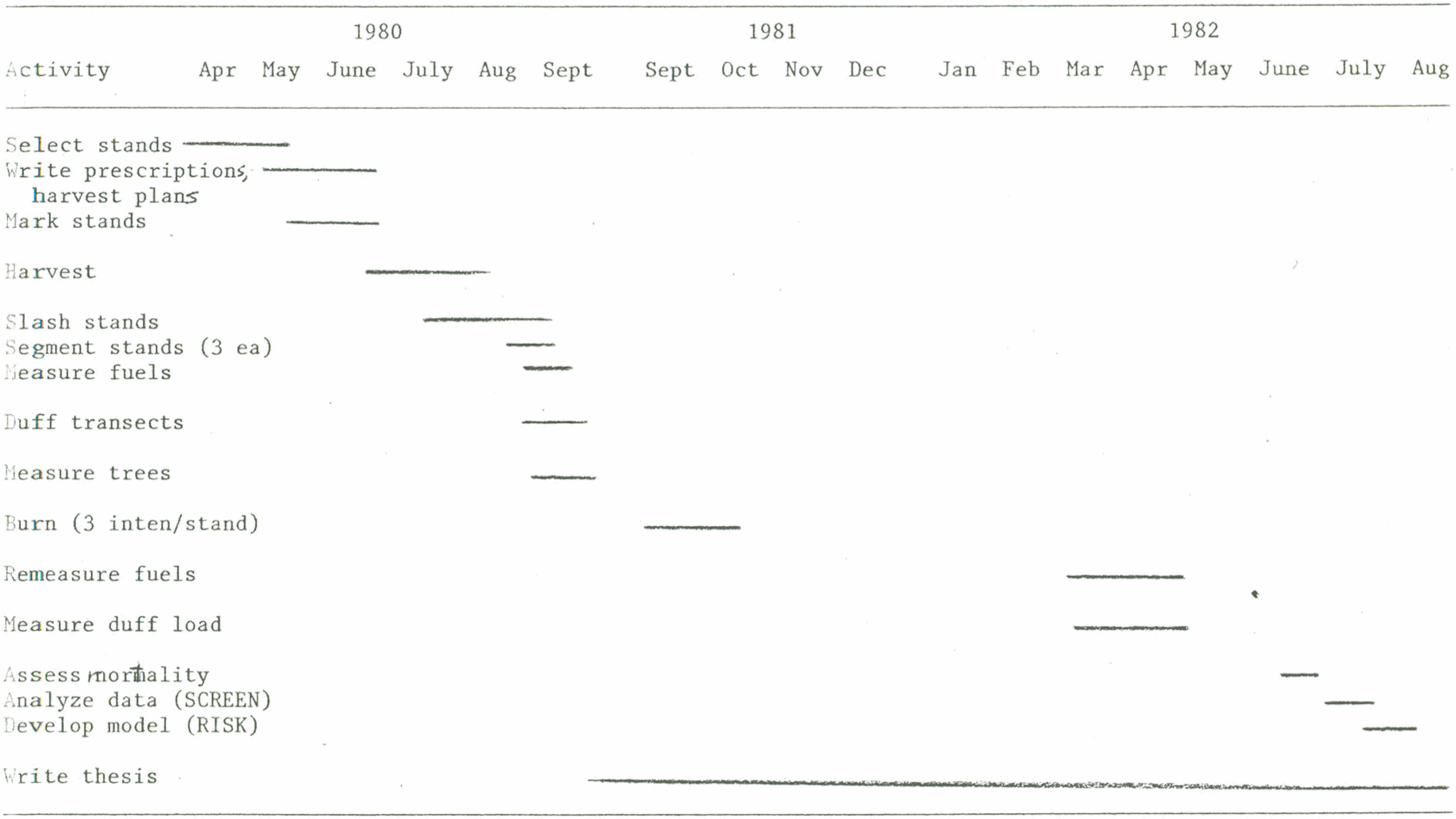
Another program entitled SCREEN (Hamilton and Wendt, 1975) will select the predictor variables for the dichotomous dependent variables. Potential predictors of mortality from the data set and their relationship to the dichotomous dependent variable will be screened using this algorithm. SCREEN will be run for each of the species present to identify factors that best predict mortality. SCREEN also reports changes in mortality rate over the range of the predictors. The user specifies the level (or levels) of significance acceptable for the independent variables. Glesser and Gollen (1972) also discussed the algorithm and an example of its use. Sterling and others (1969) present the underlying theory.

As stated, SCREEN and RISK will be the basis for screening the data collected in the field on fuels, fire, tree, weather, and for assembling from the data the mortality model. RISK will test that model's accuracy in fulfilling its stated purpose. This portion of the project will begin in the latter part of June 1981 and the model and associated thesis will be targeted for completion on or about August 15, 1982.

FUTURE POSSIBILITIES

The percentage survival for leave trees 1 year after burning and 5 years after is expected to be similar, but some variation can be expected. Subsequent research to confirm this will be needed. UI Experimental Forest Manager, H. Osborne, perceives the possibility of this becoming an ongoing project to follow the development of the new stand, the response from competing vegetation that might be associated with fire and the adequacy of fire-related seed bed preparation as relates to particular tree species, and insect activity (postfire).

TIME SCHEDULE



STAND 1

cool (flames 2-4 feet)

moderate (flames 4-6 feet)

hot (flames 6-10 feet)

SLOPE

STAND 2

moderate

cool

hot

Figure 1.

BUDGET

Transportation	$1200.00
Irregular Help	1384.50
Expendable Supplies	175.00
Total	$2759.50

"In kind" support is to be provided by H. L. Osborne, Manager, U of I Experimental Forest.

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DOWNED FUEL INVENTORY

ͅREST		SUBCOMPARTMENT		ASPECT	
OCK		STAND		COVER TYPE	
OMPARTMENT		ELEVATION		HABITAT TYPE	

SIZE CLASS (In.) :	0 - 1	1 - 3	3+
LENGTH OF SAMPLING PLANE (Ft.) :			

		NO. OF INTERSECTS			DUFF DEPTH		3+ DIAMETER						FUEL DEPTH		
Plot No.	Slope	0 - .25"	.25 - 1"	1 - 3"	First	Second	Sound	Sound	Sound	Rotten	Rotten	Rotten	First	Second	Third

If heavy slash, code 1 :

GROUND FUEL COMPOSITION	
Species	*Percent*
1.	
2.	
3.	

Location of Complete Research:

Author & Title: Spicer, James L.

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