Integrating Stand Density Management With Fuel Reduction[1]

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Abstract

The widespread effort to reduce fuel hazards in western forested ecosystems places significant emphasis on surface and small ladder fuels. Changes in canopy density, for purposes of either reducing potential crown fire impacts or insect/pathogen-related mortality, are less frequently considered. Providing a sound basis for treating more than surface and small ladder fuels is possible and can be smoothly integrated with most fuel reduction proposed actions. This paper illustrates a strategy that has potential to accomplish this goal.

Introduction

In January of 2004, the Record of Decision (ROD) for the Sierra Nevada Forest Plan Amendment Supplemental Environmental Impact Statement (SEIS) (USDA Forest Service 2004) was signed. This was the second ROD associated with approximately 25 years of analysis and evolving management objectives. The first (USDA Forest Service 2001), signed in 2001, was determined to be difficult to implement, pointing to possible failure in meeting the core goals. In 1993, the focus was largely limited to issues surrounding the protection of California spotted owl habitat. Then, in 1998, concerns were expanded. In the Sierra Nevada Forest Plan Amendment Final Environmental Impact Statement, one of the identified problem areas was fire and fuels management.

The 2004 ROD, while continuing to emphasize wildlife habitat conservation, added needed flexibility to address the increasingly hazardous fuel environment. Treatments modeled in the SEIS rely heavily on surface and ladder fuel reductions, accomplished by both mechanical and prescribed fire. Canopy fuel reduction is limited by SEIS Standards and Guidelines that set standards for residual canopy cover.

The major Standards and Guidelines that guide project design are essentially characterized by a canopy cover lower limit. Depending on land allocation, the limit is generally set at 50%, although 40% is acceptable in limited situations. For perspective, in Sierra Nevada forests, typically-applied thinning from below would likely yield canopy closures closer to 40% than to 50%.

Management direction focuses treatments toward Wildland Urban Interface (WUI) areas as well as the adjacent landscapes. Despite existing and threatened lawsuits, general support for reducing hazardous fuel remains high. There remains,

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however, controversy regarding treatment extent and intensity. In an effort to avoid potential controversy and get fuel reduction projects accomplished, canopy fuel reduction may be overlooked or minimized to ineffective levels. When this occurs, canopy fuel and stand density are often left at undesirably high levels. Project planners can benefit from a strategy that provides for compliance with the ROD as well as a clear linkage to the developing science basis for canopy fuel and stand density reduction.

Strategy

This paper describes an effective, ROD compliant strategy for increasing tree vigor while ensuring fuel hazards are reduced. The following sections describe an approach that relies on a combination of treatment unit design, density management, and tree selection principles.

The basis for fuel reduction treatments is well established (Graham et al. 2004). Reductions in surface fuel are almost always an essential step in a successful project. Significant reductions in fire intensity are provided by effective surface fuel treatments. Reducing ladder and canopy fuel, without surface fuel reductions, may actually increase wildfire hazard. The following discussion will focus on the related and complementary management of the larger tree portion of the fuel ladder and the canopy fuels.

Treatment Unit Design

The core principle related to treatment unit design is that a strategic pattern of effective fuel reduction will provide for landscape-scale benefits. To be regarded as strategic, treatment units need to be spatially located in a partially overlapping pattern, with a general alignment across the predicted fire spread direction. To be effective, significant reductions in rate of spread must occur within the treated areas, resulting in an increase in flanking fire behavior around the treatment units, while fire moves slowly within it. The basis for this strategy has been developed by Finney (2001).

Assuming an effective strategic placement, significant fuel reduction inside the treatment unit is essential. While multiple Standards and Guidelines limit forest structure change, the SEIS assumes effective treatment of surface and a portion of the ladder fuels. In practice, excepting the steepest slopes and complicated property boundaries, reducing surface and small ladder fuels is generally feasible, given adequate budgets.

The geographic area for assessing ROD compliance is the treatment unit. Its size can vary and was expected to vary from less than 150 to several hundred acres. In the modeling associated with the SEIS, canopy cover standards typically limited treatment intensity. However, specific values are not expected to be met on every acre, but, rather, over the treatment unit. When attempting to meet both fuel and stand density reduction objectives, project implementation can be adjusted to meet forest structure objectives at the individual tree or group level. I refer to this as the tree neighborhood level. The tree neighborhood is the geographic area where inter-tree competition is assessed. It can be thought of as a single tree and all the neighboring trees that influence its growth (vigor) environment.

An increasing body of evidence is accumulating to validate that effective fuel treatments play a critical role in reducing the adverse effects of wildfire (Landram and Hermit, 1996). In the specific case of the 2003 Cone fire, the incidence of fire-caused tree mortality rapidly declined as fire moved into treated areas (Skinner et al. 2002, Ritchie in press, Nakamura 2002).

Figure 1 illustrates a stylized approach to treatment unit design that can meet unit average canopy cover standards and guidelines. In this example, fires approaching from the southwest or north are received by effective fuel treatments, incorporating surface, ladder, and canopy fuel reductions. Fire behavior can be expected to change in response to these reduced fuel levels. Active or passive crown fire would be expected to shift to surface fire as it enters the treatment unit. Surface and small ladder fuel reductions in the core would decrease the likelihood of torching throughout most of the remainder of the treatment unit, despite higher canopy cover levels, especially if the spatial connectivity of high density forest is low. Higher residual canopy cover, on other portions of the unit, can be designed to obtain the desired treatment unit average.

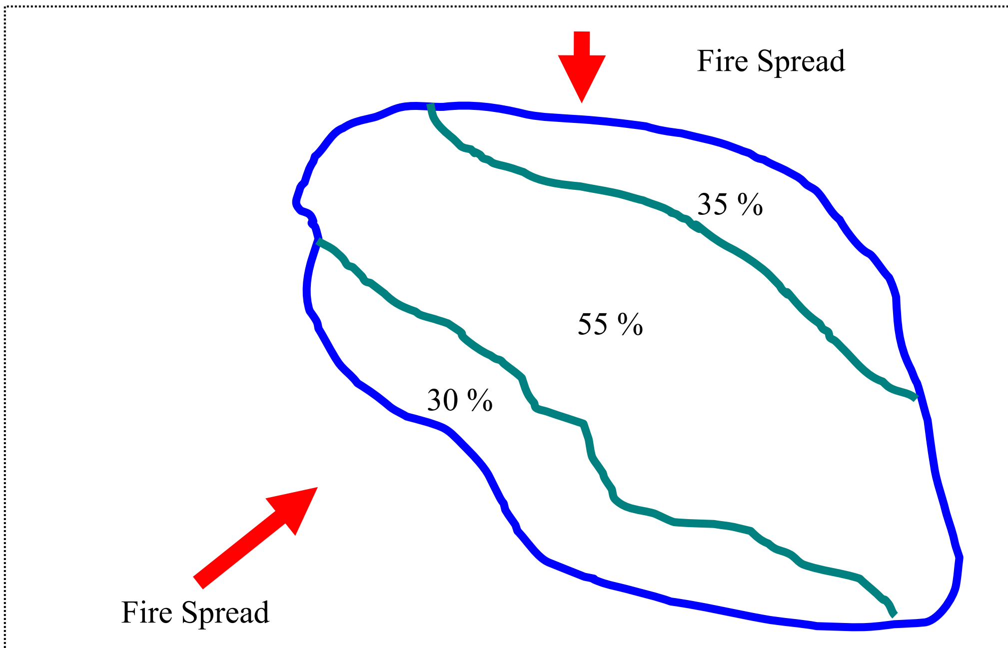

Figure 1—Strategy for canopy cover design that provides for increased probability for changing crown fire to surface fire upon entry into the treatment unit.

Figure 2 illustrates a variation of the above strategy, attempting to exploit the typical vertical and horizontal pattern variation of mixed conifer forests. Actual zones may be more highly varied than illustrated in this simplified graphic. This approach continues to provide for a reduced fuel profile along at-risk unit boundaries, as well as providing for tree size and arrangement patterns within. Important wildlife habitat features can be cultured at the tree neighborhood scale without placing extensive areas of high-density forest at risk of loss from wildfire.

Density Management

After treatment unit design, identifying a residual density that reduces crown fire spread hazard and unacceptable insect/pathogen-related mortality will ensure that the

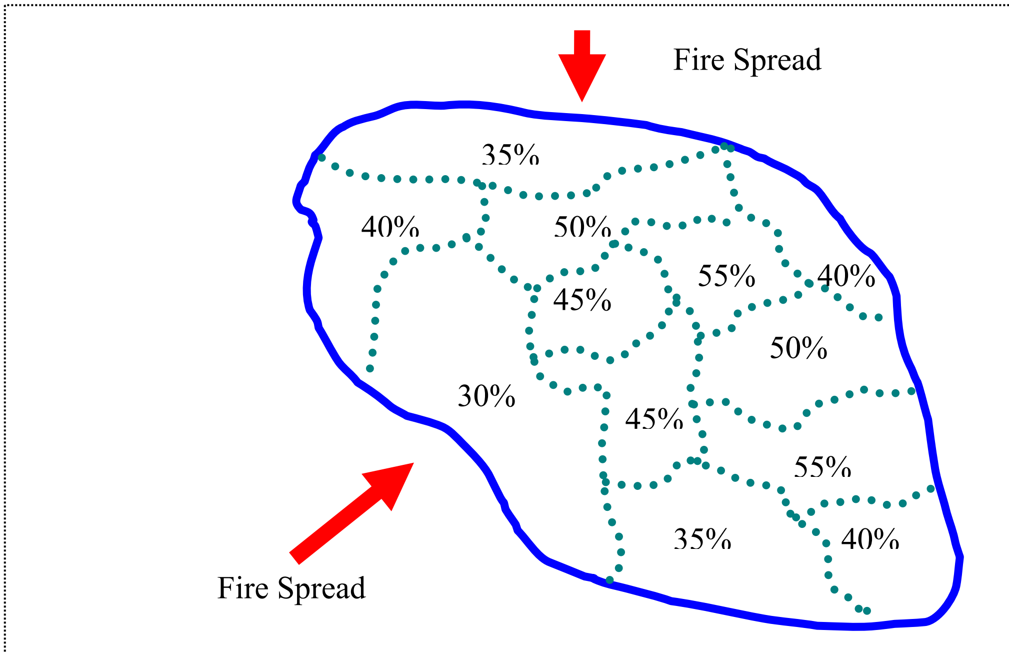

Figure 2—Strategy revision that provides for increased probability for changing crown fire to surface fire upon entry into treatment unit. In this case, variations are more complex, favoring habitat features as they exist and/or providing for even greater reductions in canopy fuel levels in places that will increase treatment efficacy.

post-treatment conditions meet the composite goals of the ROD. Given the desire to restore higher levels of large diameter trees, steps to reduce the potential for loss seem essential. Stand density index (SDI) estimates can be used to indirectly assess individual tree vigor at the per acre scale. The use of crowning and/or torching indices can add fuel hazard additional perspective to stocking levels.

While maximum SDI levels have been estimated for many Sierra Nevada species, specific data identifying critical, or threshold, values are not common. An SDI management range has been suggested by multiple researchers. This range is meant to characterize densities between the onset of competition and the lower limit of the zone of imminent mortality. Dean and Baldwin (1996) describe a management range between 20-30 and 50-55 percent of maximum. Similarly, Long and Shaw (2005) describe the range as 35 to 55-60 percent. Mortality projections, made by the Western Sierra Nevada variant of the Forest Vegetation Simulator (FVS WESSIN), initiate density-related mortality at 55% of maximum and peak mortality levels at 85%.

Ponderosa pine stand density appears to be regulated by *Dendroctonus* bark beetles more than by competition-induced mortality (Oliver 1995). Bark beetles define ponderosa pine's maximum SDI at 365, with a threshold for the zone of imminent mortality at 230 (Oliver and Uzoh 1997). For ponderosa pine stands, reducing existing densities to levels that remain below or near 230 appear to provide for the highest assurance that desired trees persist over time.

Limited data for natural white fir and red fir stands indicate a maximum density of 800 and 1,000, respectively (Oliver and Uzoh 1997). In contrast to ponderosa pine, mortality appears to be driven by intertree competition. Oliver and Uzoh (1997) suggest that, currently, the quantity of this data may not be sufficient to justify the replacement of other recommendations.

In conjunction with an effort to improve the characterization of mortality risk, Forest Inventory and Analysis (FIA) data from California plots has been summarized for the period from 1980 to 2000[3]. In contrast to earlier efforts, individual plots were assessed, instead of cluster plot averages. Plots were stratified, based on species dominance (≥80% by basal area), and maximum SDI levels were identified for several species. *Table 1* lists maximum SDI and the associated lower limit of self-thinning values. Many of the maximums derived from the FIA data are higher than those previously identified (and used in FVS WESSIN). This was expected, as the recent calculations are based on individual points and not from cluster plot averages. Also, while the sheer quantity of plots used in the FIA analysis easily outnumbers those available to Oliver and Uzoh, the nature of the stands is fundamentally different. High levels of variation exist within the FIA plot data; in particular, significant differences in age and development history make this collection distinct. Oliver and Uzoh used data from even-aged planted and natural stands. For even-aged ponderosa pine stands, an SDI value of 230 should be regarded as a threshold, beyond which mortality levels can be expected to increase. For other species, the general principles underlying the lower and upper limits of maximum stocking levels should be used as a guide. Maintaining stocking near the lower limit of self-thinning should provide for minimum mortality losses. The calculated FIA maximums should be regarded as preliminary and, most likely, more suitable at the tree neighborhood scale.

The use of density measures, that are characterized at the acre level, need to be further supported by tree-level assessments, as described in the following section. The vigor status of individual trees is a function of its position within its local neighborhood, and that is where the appropriate focus for final decisions should be.

Tree Selection

The final component of the strategy is the identification of individual trees that are intended to satisfy the goals of treatment at the tree neighborhood scale. The flexibility provided for canopy cover variability allows silviculturists to design treatments that are responsive at this scale. Recognizing that the applicable canopy cover standard and guideline is assessed at the treatment unit scale, portions of higher canopy cover need to be recognized and included in the overall strategy. Specific sites, where, historically, higher canopy cover was more likely to have persisted, may be a suitable approach. This may lead to the designation of portions of north- and/or east-facing slopes, as well as selected lower slopes on all aspects. Combined with site-specific identification of key habitat features, this approach may provide for environmental conditions that provide for even higher levels of suitable habitat than would be achieved with a more generalized approach.

This last aspect provides for the tree-specific decisions that can maintain or improve the vigor of individual trees. The use of risk-rating systems, crown classes,

[3] Unpublished data on file, F. Michael Landram, Regional Silviculturist, Pacific Southwest Region, Vallejo, California.

Table 1—*Maximum SDI values as indicated by Oliver and Uzoh, FVS WESSIN, and FIA data, with associated lower limit of self-thinning values.*

Species	Maximum SDI			Lower Limit of Self-Thnning		
	Oliver & Uzoh	FVS (WESSIN)	FIA	Oliver & Uzoh	FVS (55%)	FIA (55%)
Abies concolor	800	759	900		417	495
Pseudotsuba menziesii		547	800		301	440
Pinus ponderosa	365	571	650	230	314	358
Pinus jeffreyi		571	600		314	330
Abies magnifica	1,000	800	1,050		440	578
Calocedrus decurrens		706	700		388	385
Quercus chrysolepsis			750			413
Quercus kelloggii		382	550		210	303
Pinus contorta			850			468
Pinus lambertiana		647	400		356	220

and individual tree characteristics can be combined to provide an increased level of confidence when identifying which trees to favor.

Risk-rating systems, developed by Dunning, Keen, Salman and Bongberg, and Ferrell, can be used to guide how choices are made between individual trees (Dunning 1928, Miller and Keen 1960, Keen 1943, Salman and Bongberg 1942, and Ferrell 1989).

In 1928, Duncan Dunning published the first classification system for ponderosa pine in the Sierra Nevada. Subsequently, Keen expanded the classification from seven to sixteen classes (*fig. 3*), refining Dunning's effort to distinguish important distinctions by age, crown size, and dominance (Keen 1943). *Figure 4* illustrates the work of Salman and Bongberg, who, in 1942, published a four class risk-rating system. These efforts attempted to interpret tree vigor in an effort to predict susceptibility to pine beetle-caused mortality. Each of the illustrations included in *figs. 3, 4, 5* were designed to enable field interpretation of crown characteristics regarded as key indicators of tree persistence.

While the use of these systems cannot provide absolute certainty, the underlying principles contribute to the set of factors that can be used when making informed selection decisions. Significant discussion regarding these and other systems is well documented (Miller and Keen 1960) and the reader is referred to this publication for additional information. Despite the absence of a perfect classification system, a focus on the crown characteristics will reveal important information about the vigor status of the individual tree. Combining several of the crown characteristics will likely increase the probability of selecting trees most likely to thrive.

A risk-rating system for red fir and white fir growing in northern California adds additional information related to tree selection (Ferrell 1989). Three factors, all crown-related, can be used to predict mortality *(fig. 5).* The most useful characteristics were live crown percent, crown density, and ragged percent. This modern-day use of crown conditions seems to reinforce earlier efforts to recognize tree vigor by visual characteristics.

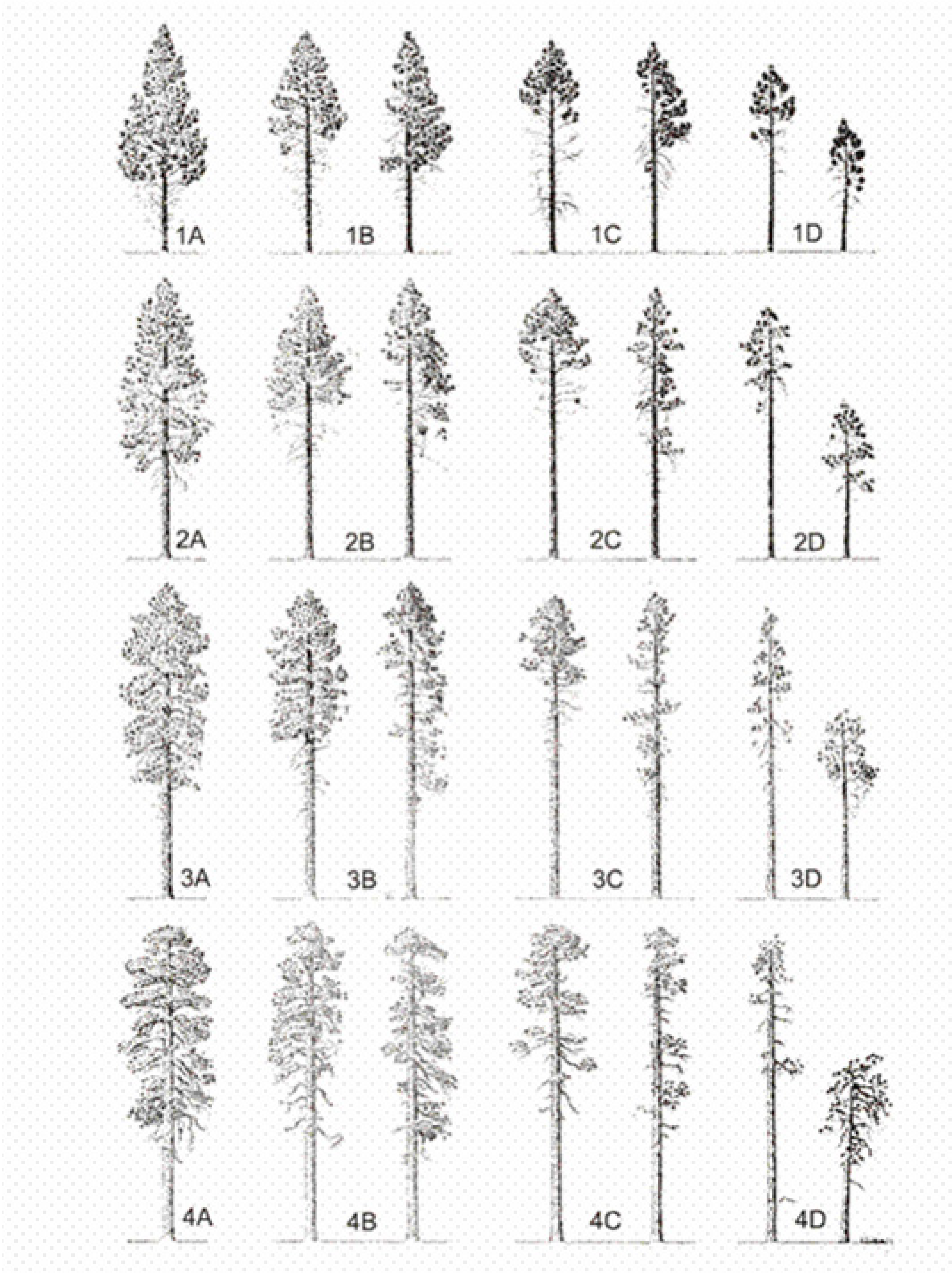

Figure 3—A ponderosa pine tree classification based on age (increasing from 1 to 4) and vigor (decreasing from A to D), from Miller and Keen 1960, page 178.

Figure 4— Degree of risk in ponderosa pine tree, from Miller and Keen 1960, page 183.

Crown classification adds additional tree-specific information to assist with the identification of trees capable of sustained and vigorous growth. The linkage between health and crown class is regarded as very high, when assessing trees within a cohort (Smith 1962). The Forest Inventory and Analysis (FIA), National Core Field Guide defines crown classes as displayed in *fig. 6.* This, and similar illustrations, attempt to differentiate tree crowns based on the relative share of sunlight and growing space afforded to individual trees. Favoring crown classes that have already exhibited an ability to acquire a larger share of the light resource, especially when combining

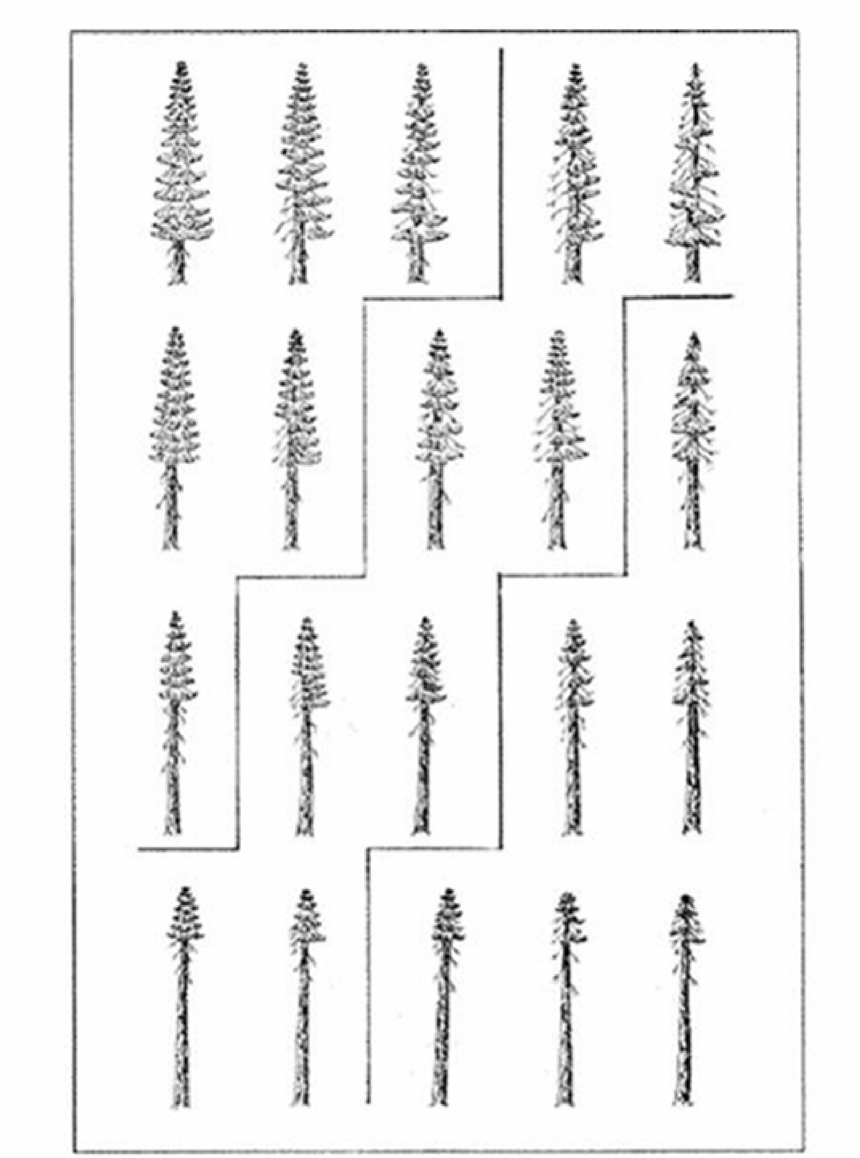

Figure 5—Risk classes for rapid visual prediction of 10-year mortality in California red fir and white fir: (left to right) low, medium, and high risk (Ferrell 1989, page 9).

indicators described above, will likely provide for higher levels of resilience and sustained vigor. Altering inter-crown spacing will allow for increased persistence of the lower crown, maintaining or increasing crown ratios and photosynthetic area.

The use of traditional external indicators of tree vigor can also be relied on to assess the status of individual trees. Crown indicators include shape, patchiness, and ratio. Stem indicators include bark fissure depth and color. Needle characteristics, such as length, color, and retention can be used as well.

Utilizing the combined strength of risk-rating systems, crown classification, and tree characteristics can increase the likelihood of selecting trees most capable of sustaining vigorous growth rates and to benefit from any associated fuel reduction treatments.

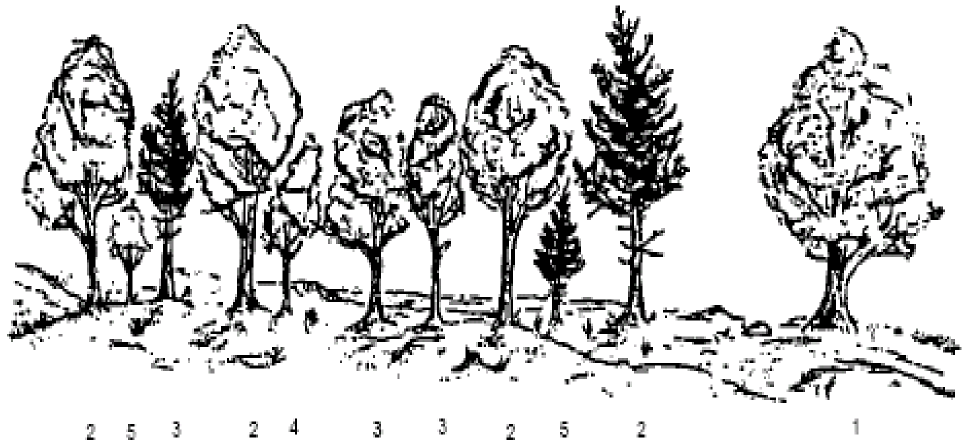

Figure 6—Examples of FIA crown class code definitions. (1 = open grown, 2 = dominant, 3 = co-dominant, 4 = intermediate, and 5 = overtopped. Taken from the FIA Field Guide for Phase 2 Measurements (2004), page 76.

Summary

The 2004 ROD provided additional flexibility needed to be more successful in meeting management goals. Fuel reduction projects that focus on surface and small ladder fuel attract relatively few appeals and are making progress, especially adjacent to forested residential areas. In some cases, larger fuel ladder and/or canopy fuel reduction projects, implemented via timber sale contracts, may be at risk of appeal or lawsuit. It may be possible to increase the level of advocacy among those who threaten appeals or lawsuits by more clearly describing the basis for management action. The threat of harm by wildfire appears to have motivated many to advocate actions that reduce hazards. Perhaps the adverse effects of stand density hazards need to be more clearly described. The loss of forest structure and composition, especially if the larger diameter trees are reduced, appears to be in clear opposition to the desired conditions of current Forest Plans. Managers may benefit from the described strategy as they strive for successful implementation of projects.

As canopy cover is assessed at the treatment unit scale, which can be several hundred acres in size, variation would be both inevitable and desirable. Using this allowance can provide for low-density environments to favor key trees, or groups of trees, as well as provide a fuel environment that will not support crown fire. Likewise, higher-density tree environments can be spatially intermixed to provide for higher-density habitat needs in places that minimize the risk of wildfire loss. Although Standards and Guidelines are commonly expressed as per acre criteria, treatment unit objectives are met by the summation of multiple tree neighborhood decisions.

Using the flexibility that exists, projects that reduce density and, simultaneously, reduce canopy fuel are possible. Unit design strategies can be implemented to assure that adverse landscape-level fire effects are reduced. At the treatment unit scale, strategic variations in density are likely to provide for beneficial changes in fire behavior, with reductions in acres affected by crown fire. An informed choice of residual stand density will increase the likelihood that excessive insect, pathogen, and/or intertree competition-related mortality will not cause adverse effects to wildlife habitat and that individual trees will be more resilient in the face of wildfire, drought, and other environmental stress agents. At the tree neighborhood scale, the use of tree selection criteria, as described above, will likely ensure that the remaining trees persist, providing for higher levels of large-diameter trees as well as intact forest habitat.

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