Dynamically Incorporating Late-Successional Forest in Sustainable Landscapes

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Ecosystems and landscapes change over time as a function of vegetation characteristics and disturbance regimes, including fire. Interactions between disturbance events and forest development (succession) create patterns of vegetation across landscapes. These patterns result from, and change with respect to, species compositions and structures that arise from disturbance events interrupting successional pathways at different points during forest development. Vegetation patterns and disturbance regimes are modified by the effects of topography on the biotic and abiotic processes that drive forest development and disturbance regimes. The propagation and spread of disturbances are heavily influenced by the spatial arrangement of living and dead vegetation across the landscape.

Fire was, and will continue to be, a major disturbance agent in the Inland West. Fire history studies provide evidence that low intensity fires occurred frequently for at least several centuries prior to European-American settlement. This fire regime is characteristic of low and mid elevation sites, especially on south and west-facing aspects, and it perpetuated early-successional, fire-resistant species such as ponderosa pine (*Pinus ponderosa*) and western larch (*Larix occidentalis*). On mesic sites where fire return intervals were longer, forest development continued into mid- and later-successional conditions before being impacted by disturbance agents that included insects and pathogens as well as higher intensity fires. In much of the Inland West, steep precipitation gradients and rugged, mountainous terrain interacted with fire to create a patchy mosaic of forest stands having different species compositions and age structures. The heterogeneity of fuel loads and host species across the pre-settlement landscape provided a feedback mechanism that inhibited the spread of stand-replacing disturbance events across the landscape.

Not all areas within such a heterogenous landscape have an equal probability of attaining late-successional compositions and structures, nor of sustaining them over time. Prior to settlement, late-successional stands were embedded in a matrix of fire-resistant, early-successional forest. The occurrence of late-successional forest resulted from combinations of physiography and topography that lengthened fire return intervals, occasionally for periods of one to several centuries. In essence, these late-successional stands were fire "refugia." Fire refugia harbored plant and animal species that would have been missing if subjected to the characteristic disturbance regime of the surrounding forests.

Since European-American settlement, fire suppression and selective logging of large early-successional trees allowed late-successional tree species to establish and grow in forest understories throughout the Inland West. Individual stands are progressing farther along successional pathways before being interrupted by disturbances. In many areas, dense, multi-layered stands of late-successional true firs (*Abies* sp.) are replacing early-seral forests dominated by pine and larch. Landscape vegetation patterns that inhibited the spread of disturbances are being replaced by more homogeneous patterns in which disturbances such as insect outbreaks and stand-replacing fires can spread rapidly, sometimes with catastrophic effects.

The importance of late-successional forest compositions and structures to critical wildlife habitat is well documented. In a report published in 1993, the Forest Ecosystem Management Assessment Team (FEMAT) recommended setting aside large tracts of land in Washington, Oregon, and northern California to enhance and increase the abundance of old, late-successional forests throughout the Northwest. The practice of setting aside large tracts of land—a static model of custodial management (Botkin 1990)—is the current method for meeting the needs of species requiring late-successional forest habitat. This approach may work in some areas, but in many of the fire-dominated ecosystems and landscapes of the Inland West, large contiguous blocks of late-successional forest are not sustainable. As these forests age, they are at increasingly greater risk to insect and pathogen outbreaks and catastrophic fires that eliminate their function as late-successional habitat.

Fire Refugia in a Late-successional Reserve

In recent research in the Swauk Late-Successional Reserve (LSR) located in the Wenatchee National Forest (fig. 1), we correlated the probabilities of finding late-successional forest predating Euroamerican settlement with site physiography and topography. We found the highest probability for the occurrence of late-successional fire refugia on north-facing aspects at elevations above 1,225 m (4,000 ft) on one of the following topographic settings: at the confluence of two perennial streams, within a valley bottom, on a flat bench, or within a drainage headwall. Within the Swauk LSR, south-facing aspects historically had less than a 2 percent probability of having supported historic late-successional fire refugia.

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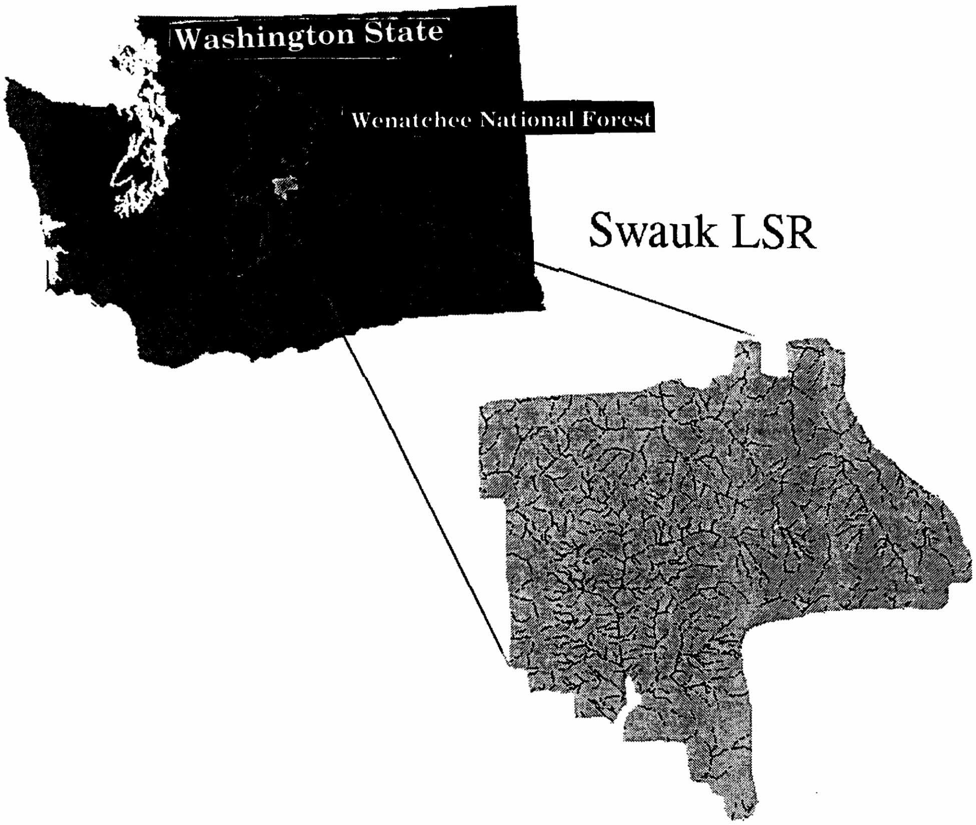

Figure 1—The Swauk Late-Successional Reserve on the Wenatchee National Forest in Washington State.

Predicting the Occurrence of Sustainable Refugia

Applying the results of our research to a digital elevation model of the Swauk LSR, we determined that almost two-thirds of the Reserve had less than a 2 percent probability of supporting late-successional forest (fig. 2). Probabilities of supporting late-successional forest reflect historic fire return intervals. High probability refugia sites had the longest intervals between fires (fig. 3). Immediately prior to Euroamerican settlement, about 12 percent of the Swauk LSR contained stands in mid- or late-successional condition; however, it appears from our research that up to 30 percent of the area within the Reserve has at least a moderate probability for supporting late-successional habitat. The reason that less than half of the potential refugial sites were occupied by late-successional forest stands in the mid to late 1800's was that fires occurred even within refugia, only not as frequently as in the surrounding matrix. Very few of the fire refugia we studied appeared to be persistent landscape patch types. Most existed for several centuries, but then burned—often catastrophically—leaving a legacy of very large snags and logs. Fire refugia within the Swauk LSR were relatively small and spatially unconnected. The largest one in our study was 40 ha. Small, fragmented refugia could not propagate large stand-replacing fires. Stand-replacing fires within refugia probably burned with less intensity and became low- to moderate-intensity fires upon entering the surrounding early-seral landscape.

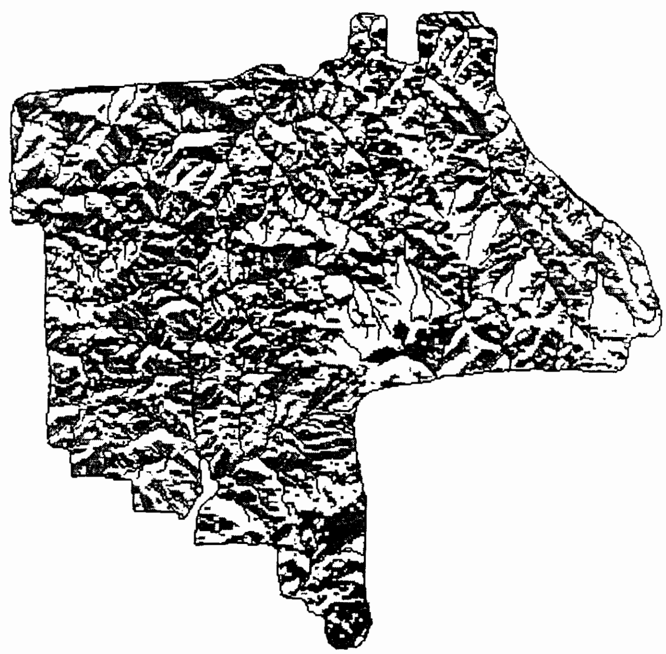

Figure 2—Nearly two-thirds of the Swauk Late-Successional Reserve (shaded areas) has less that a 2 percent probability of supporting late-successional fire refugia.

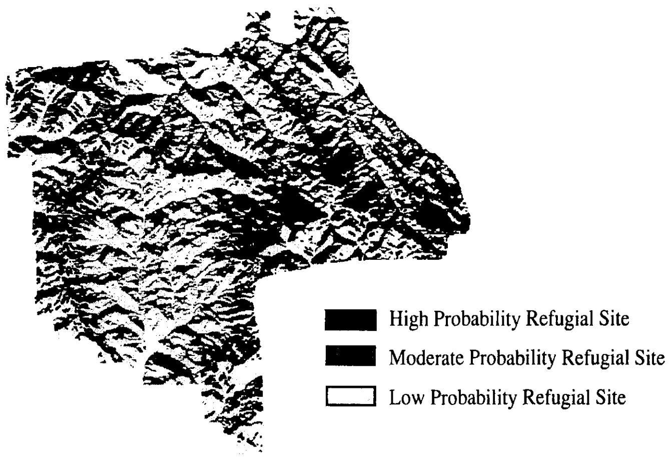

Figure 3—Locations within the Swauk Late-Successional Reserve that historically had high (black), moderate (dark gray), and low (light gray) probabilities of supporting late-successional forests.

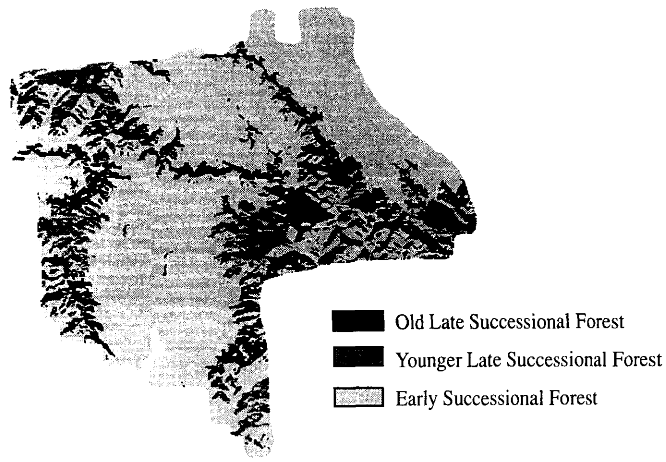

Figure 4—Distribution of successional stages under a low fire-risk alternative.

Management of Fire Refugia

We used information about historical fire refugia to develop management alternatives within the Swauk LSR that would provide late-successional habitat while minimizing risks of insect outbreaks, diseases, and catastrophic fires. These alternatives reflect a dynamic management model having the flexibility to incorporate varying amounts of late-successional forest with measurable levels of risk to future disturbances.

Old, late-successional forest patches are sited in areas that historically had the highest probability for supporting late-successional forest. These patches and the intervening matrix can be configured in numerous ways, each of which carries a greater or lesser risk of landscape-level disturbances. For example, a low fire-risk alternative would be to keep about one-half of the highest probability refugial sites in old, late-successional forest, with the remainder in younger stands dominated by late-successional species (fig. 4). As they age, younger stands would periodically replace older stands that had deteriorated from pathogen or insect activity. All late-successional patches in this alternative would be small and discontinuous. Areas having low or moderate probabilities for supporting refugia would be maintained in early-seral forests dominated by ponderosa pine and western larch. While this landscape configuration greatly reduces disturbance risks, it may not provide adequate late-successional habitat for some wildlife species.

Another alternative provides greater amounts of older and younger late-successional forest, and greater late-successional connectivity across the landscape (fig. 5). Under this moderate-risk configuration, old late-successional forest is still sited only on historical high-probability refugial sites.

Greater connectivity is achieved by silviculturally manipulating younger stands in the moderate-probability (moderate risk) areas to develop late-successional composition and structures. These stands would range in age from 50 to about 150 years. As stands approach the upper age limit, they would be evaluated for elevated populations of insects and pathogens. Those most at risk would be harvested, leaving some large trees, both living and dead, to provide late-successional structures within the regenerating stand. Late-successional connectivity would be maintained by younger stands having older forest compositions and structures; this connectivity would shift in both time and space.

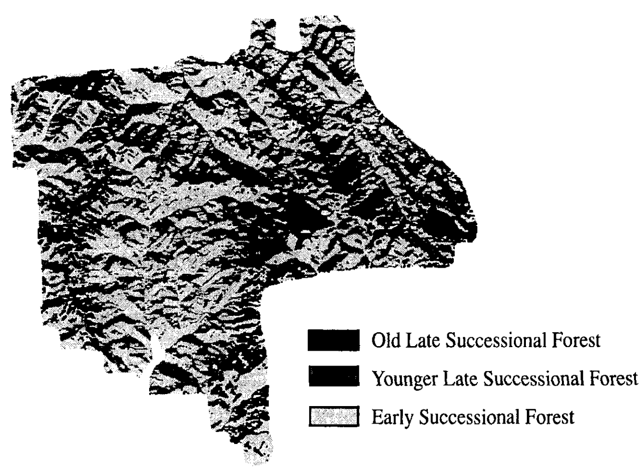

Figure 5—Distribution of successional stages under a moderate fire-risk alternative.

High-risk sites would be maintained in early-seral conditions (as in open park-like stands). In some cases later-successional understories within these early-seral stands might be allowed to develop for several decades before being removed. While this landscape configuration carries a greater risk of fire and other disturbances than the first alternative, it is still much more sustainable than present conditions in the Swauk LSR where aging late-successional forests occur extensively on high-risk sites (fig. 6).

A dynamic approach to incorporating late-successional forest habitat allows a pro-active management response to conditions such as droughts and global warming. Adjustments to the total amount of late-successional habitat and its connectivity across the landscape can be made where risk of habitat loss is greatest. A sustainable landscape is not static, but changes within a particular range of disturbance frequency, intensity, and extent. Managing landscapes using a static model of custodially managed reserves leaves landscapes in the Inland West at great risk to insects, diseases, and catastrophic fires. A dynamic model provides late-successional habitat that can be sustained over time and within changing conditions.

Conclusions

For a Late-Successional Reserve to sustainably provide critical habitat, old, late-successional forest must be sited where the probability of its destruction by fire, insects, or pathogens is low. Since areas of historic fire refugia fall within existing Reserves and outside Reserve boundaries, we suggest that late-successional habitat be sustainably incorporated into all areas, regardless of their emphasized use. Using younger stands having some old forest composition and structure can augment levels of late-successional forest and provide connectivity. Younger stands can be silviculturally manipulated to produce large trees and multiple canopy layers more rapidly than would occur without active management. These younger stands will necessarily shift in space and time, thus our model of managing for late-successional habitat is a dynamic one. Sites at high risk for fires should be managed primarily for early-successional species such as ponderosa pine and western larch. Disturbance risks change over time, and a dynamic model such as this one can be adjusted more rapidly to meet those changes.

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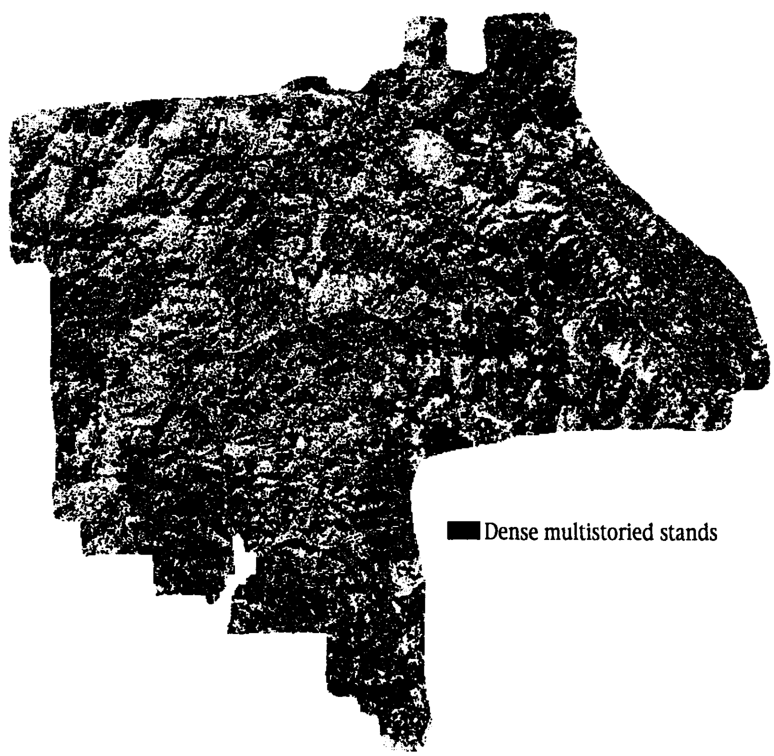

Figure 6—Dense multistoried stands in the Swauk Late-Successional Reserve occur extensively on high-risk sites.