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Abstract

This case study approaches uneven-age management as a tool that will assist silviculturists and land managers in implementing operational regimes that incorporate ecologically-based principles into scientifically and economically sound land stewardship practices. Uneven-age management practices offer the opportunity to mimic, and where possible, restore natural disturbance regimes in geographically specific, forested landscapes. The historic, fire-generated disturbance pattern has resulted in a predominately Douglas-fir forest type in the Puget Trough. The landscape and stand-level characteristics of that historical fire regime are first documented. Conventional forest practices typically result in a change in the frequency and scale from the patterns created by historical disturbances. Most silvicultural activities; timber harvest, regeneration and thinning, can be tailored to resemble specific natural disturbances inherent to forests. The spatial and temporal aspects of the fire disturbance regime in the southern Puget Trough are two quantifiable aspects that are examined for application in silvicultural regimes.

A silvicultural regime designed to blend high quality timber production with late successional structural characteristics is analyzed for its ability to mimic the spatial and temporal aspects of the historic disturbance regime, within the economic and operational constraints of a non-industrial private forest. Two new silvicultural tools, variable retention harvesting and multi-density thinning, are considered for their applicability in regimes mimicking fire disturbance impacts on forest function.

Introduction

The Cowlitz Ridge Tree Farm (CRTF) is a Non-Industrial Private Forest (NIPF), located in southwestern Washington state. NIPF's are defined as private forest ownerships of less than 1000 acres with no primary manufacturing facility. In Washington state NIPF's represent about 25% (approximately 3 million acres) of the available forest land base. A recent Department of Natural Resources report states that 100 acres a day of NIPF land are being converted to non-forest uses. Foremost among the challenges facing NIPFs, is the development of economically and ecologically sound land stewardship practices. The CRTF is attempting to blend these two objectives with a stand level, uneven-aged management silvicultural system.

The silvicultural regime of the CRTF does not fit the classic definition of uneven-age management; individual tree selection followed by natural regeneration. However, if the premise of mimicking the natural disturbance process is accepted as the foundation of the definition of uneven-age management and we extend management scale from the tree to the stand or landscape level, the CRTF silvicultural regime fits well into an expanded and inclusive definition of uneven-age management. Given the recent popularity of uneven-age management, particularly by groups proposing standards for green certification, an expanded, inclusive definition of uneven-age management, based on the premise of mimicking natural disturbance regimes, seems appropriate.

Study Site

Geographically, the forest is located in the southern section of the Puget Trough on a ridge (elevation 33 m.) south of the Cowlitz River, five and a half kilometers east of the town of Toledo. The Puget Trough Province (Franklin and Dyrness 1973) extends the length of Washington from the Canadian border to Oregon, where the Willamette Valley is its southern boundary. The southern half of the province is primarily the Cowlitz River valley and the upper basin of the Chehalis River. The Puget Trough Province is the result of several glacial epochs, the most recent being the Vashon glaciation. The terminal moraine of the Vashon glacier is approximately 16 to 24 kilometers south of Olympia. For about 50 kilometers south of the terminal (approximately to Toledo) the area is predominately covered by outwash sands and gravels resulting from the melting Vashon glacier (Franklin and Dyrness 1973). Soils on the CRTF Toledo tract are predominately Lacamas gravelly loam of alluvial origin. The 50 year site index ranges from 100 to 120, resulting in a high 3 to low 2 site (King 1966). The vegetation composition is best represented by the *Tsuga heterophylla* zone, in particular the *Pseudotsuga menziesii/Holodiscus discolor* association (Franklin and Dyrness 1973). Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) represents approximately 90% of the tree species in stands that are naturally regenerated. Annual rainfall averages between 100 and 125 centimeters (Stinson, personal communication 1996), most of which falls in the period from late October to June.

Fire History

Pollen analysis of sediment cores from Mineral lake (approximately 25 kilometers north of the CRTF) indicate that fire has been a predominate factor in the vegetative composition of the Puget Trough for at least 10,000 years (Tsukada and Sugita 1982) Similar analysis also shows that Douglas-fir has been a dominant forest species in this area for about the last 5,000 years (Tsukada 1982).

While charred stumps are scattered through out the CRTF acreage, none of them are solid enough to provide reliable fire scar records. Examination of recently cut stumps from the oldest (1902) cohort showed no signs of scarring due to fire damage.

A detailed historical account of fires between the early 1800's and 1902 has been given by William Morris in the Oregon Historical Quarterly (Morris 1936). Morris reports that a recently completed survey of land in western Oregon and western Washington, done by the Pacific Northwest Forest Experiment Station, determined the acreage of even-aged stands of timber for each 10 year age class up to 100 years. The acreage found covered by timber 40, 50, 60, and 70 years of age, indicates that forest fires have burned increasingly more land since white settlement began. In a decade approximating 1845-1855, about seven times as much land was de-forested as in any of the three previous decades. The ten years represented by this period are the years in which European settlers first began to settle western Oregon and Washington in significant numbers. This is also the time in which hearsay assigns great fires in the coast country. The cutting done in the early days for logging and agricultural clearing could not account for large acreage’s of timber 80-90 years old (in 1934), implying that most of this acreage represents land regenerating from forest fires.

Morris provides a map of major fires in 1869 and 1902, the two years of the greatest recorded fire occurrence. The map shows an 1869 fire in south central Lewis County which is within 24-30 kilometers of the CRTF. Though no mapping is done in that area for the 1902 fire, there are several printed reports of severe fire in that vicinity. Fires are recorded in Castle Rock, Chehalis, Olympia and Elma. Reference is also made to poor navigation capabilities along the Cowlitz River south of Chehalis. If a rough triangle is drawn with Castle Rock, Olympia and Elma as corner points, the CRTF is within the triangle boundary. Weather played and important role in both these fire years. Strong winds and extremely dry conditions are reported in 1868 and 1902. The Chehalis River (approximately 15 kilometers northwest of the CRTF) was reported by the *Olympia Transcript* in 1902, to be "lower than ever before known to white settlers and the Willamette River is 20 centimeters lower this season than ever before known" (Morris 1934). While weather conditions were optimal for fire, the source of ignition is thought to be human.

Peter Morrison and Frederick Swanson compiled information from a study of a fire regime similar to that of southwest Washington, a moderate severity regime in the central-western region of the Oregon Cascades (Morrison and Swanson 1990). Their study shows many parallels with the information gathered in the southwest Washington historical data and from the CRTF, the strongest being the common dominant vegetation type *Pseudotsuga menziesii/Holodiscus discolor* Fire history from years 1150 to 1985 was reconstructed by analyzing forest stands in two 1940-hectare areas. The steeper, more dissected, lower elevation (820m) Cook-Quentin study area experienced more frequent fires (natural fire rotation = 95 years), that were commonly low to moderate in severity. The fires created a complex mosaic of stands with variable date and severity of last burn. Fire-created forest patches in the Cook-Quentin study area originating in 1800-1900 are generally less than 10 hectares. Since 1900, very little of the study areas burned, probably due to active human fire suppression. Forest fire initiation and spread in this fire regime are promoted by several climatic factors. Summer thunderstorms occur on the average of only few days of a year, but caused over 60% of the fire ignitions recorded in recent years (Morrison and Swanson 1990). A seasonal water deficit occurs during the summer throughout the Pacific Northwest coast because of low precipitation, high temperature, and high potential evapotranspiration. Periodic, summer east winds bring dry air from the high desert east of the Cascade Range, and relative humidity can drop to 10% or less. Topographic and convective winds during warm, dry periods are locally important in the spread of fire. These winds are the source of the foehn or east wind so often associated with fire conditions. The fire regime of the Cook-Quentin study area was characterized by fairly frequent, medium to low severity fires that have occasionally crowned out and created patches of even-aged stands very similar to what is observed on the Cowlitz Ridge Tree Farm. The narrow age spread of Douglas-fir trees in stand replacement patches could be caused by rapid regeneration made possible by abundant surrounding seed source and the more mesic site conditions. Moderate-severity fire regimes occur in areas with typically long summer dry periods and fires will last weeks to months. Periods of intense fire behavior are mixed with periods of moderate and low intensity fire behavior with fluctuations in weather responsible for the variable fire effects. Climatic and cultural changes over the years have affected the distribution forest types, fire ignition and behavior patterns and subsequent ecological effects. Consequently, it is difficult to chose a period in history to define as “natural” and attempt to mimic that period’s particular disturbance attributes.

Fire is a classic disturbance agent. Pickett and White (1985) define disturbance as follows; disturbance is any relatively discrete event in time that disrupts ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment. Fire is a relatively discrete event in time, although it may vary from seconds in light fuels to weeks or months in a severe stand replacing fire. Fire changes ecosystem, community, and population structure, either by selectively favoring certain species or creating conditions for a new species to invade. These effects are generally site specific. Given a particular forest type, the ecological effects of fire can be better understood by knowledge of the species present and their relative competitive abilities, as well as of their reaction to the complex processes of fire (Kauffman 1990). All forest organisms of the Pacific Northwest are intimately suited for survival in their environment, and this includes specific adaptations to ensure survival following fire. Growth characteristics typified by those resistant to fire include thick bark, deep rooting habits, and self thinning crowns. Douglas-fir exemplifies all these characteristics. Douglas-fir is also well suited to regeneration in moderate to severe disturbance events. Its light and wind dispersed seeds are well adapted to regenerating in the spatial scale of disturbances caused by moderate to high severity fire regimes. On the west side of the Cascades it a shade intolerant species and it thrives in the openings created by fire. Conversely, Douglas-fir seldom regenerates under the forest canopy in the Puget Trough. When it is able to regenerate in the understory, resulting growth rates are closely linked to the density of the overstory. Wampler (1993) determined that Douglas-fir seedlings regenerating under a mature overstory obtained optimum growth rates at overstory densities of less than 45 trees per hectare.

Fire also plays an important role in the coarse woody debris cycle in forested landscapes. The functional role of coarse woody debris includes nutrient and carbon storage, sites for plant establishment, the maintenance of soil stability, and the presence of wildlife habitat. In many ecosystems, fire is an important disturbance which influences both input and disappearance of coarse woody debris. In regimes characterized by stand-replacement fires, huge inputs of coarse woody debris occur following fire. In regimes characterized by frequent surface fires, the input may be relatively continuous, with small quantities added with each fire. Consumption by fire may be the primary means of disappearance of coarse woody debris in regimes with frequent fire return intervals, whereas, decay or decomposition is more important in forests with long fire return intervals (Kauffman 1990).

Closely related to the role of coarse woody debris is the composition and function of the soil. Soil health on managed forests depends to a great extent on the management regime and the associated harvest rotation interval. It is also dependent on nutrient inputs from the atmosphere, mainly from nitrogen fixation. Combustion of coarse woody debris, forest floor litter and soil organic matter may have both short and long-term consequences. Changes in the soil environment include decreased acidity, changes in nutrient capabilities, altered temperature and moisture regimes (Borchers and Perry, 1990). Fire can have an impact on some plant diseases. In the case of the fungus *Rhizina undulata* it tends to increase after hot burns in many instances (Agee 1993). In southwestern Washington, the most serious disease is probably the root disease, *Phellinus weirii.* Given the infrequency of fire and the climate of western Washington it is doubtful that fire has effect on *Phellinus weirii* While many questions remain, what current research has shown is that the soil ecosystem is exceedingly complex and full of interactions. Since most trees are symbiotic, it is clear that long term productivity of the forest is dependent on a healthy soil community. A landscape under a stable natural disturbance regime should develop toward a dynamically stable mosaic of patches of different ages, each resulting from a single disturbance at some time in the past. Imposing an excessively high disturbance frequency over a long period of time may result in a decline in the organic matter content of the soil accompanied by a loss of the nutrients formerly contained in the organic matter.

Stand History and Characteristics

Dry Douglas-fir forests may be found in the west-central Cascades, in the San Juan Islands and further south in the Puget Trough, and along the mid-elevation eastern Cascades. Fire frequency is generally in the range of 70-100 years. In these forests, where summer moisture is quite limiting, adequate growing space for regeneration is often linked to forest disturbance which creates sites for tree establishment as a result of overstory mortality (Agee 1993). Natural regeneration of Douglas-fir on the CRTF rarely occurs under the forest canopy. This observation holds even in stands 65 years old, stocked at 195 trees per hectare, a relative density between 30 and 35, which have been thinned from below twice in the last 20 years.

Four tracts combine for a total area of 398 hectares. The oldest stands on the Cowlitz Ridge Tree Farm are just over 100 years old (CRTF was high graded in the early 1930's) and the youngest naturally regenerated stands are about 65 years of age. These stands are even aged, and range from 15-110 acres in size. On the Toledo tract (101 ha.) there are four distinct Douglas-fir cohorts with regeneration dates of approximately 1950, 1935, 1925 and 1902. Western red cedar (*Thuja plicata*)*,* red alder(*Alnus rubra*)*,* and big leaf maple (*Acer macrophyllum*) have a minor presence in the forest overstory. Understory species include ocean spray (*Holodiscus discolor*), vine maple (*Acer circinatum*)*,* Pacific yew (*Taxus brevifolia*)*,* red huckleberry (*Vacinium parvifolium*)*,* and Oregon grape (*Berberis nervosa*).. Given the historical data and the variable range of regeneration for a cohort under this disturbance regime, it is possible that the naturally regenerated stands on the CRTF originated after the 1902 fire. Considering the historical, scientific and ancillary information , the Cowlitz Ridge Tree Farm fire regime is determined to be a moderate severity regime with a fire return interval in the 50 to 100 year range (Agee, personal communication 1997).

Management Objectives and Silvicultural Regime

The Cowlitz Ridge Tree Farm is located within the Interstate 5 corridor, the core of the rural urban interface, surrounded by numerous smaller landowners, none of whom have re-introduced the natural fire disturbance regime as a management objective. This fact combined with the relatively small acreage of the CRTF and the intensity of the natural fire regime, excludes the possibility of management at CRTF re-introducing fire to their forested landscape.

To fulfill the CRTF objective of maintaining a healthy forest with these constraints, the prospect of mimicking the fire disturbance regime with silvicultural operations is the most realistic. With the ecological impacts of fire in mind, the silvicultural regime of the CRTF is analyzed for its ability to mimic the natural disturbance regime of fire. A sustainable harvest philosophy provides the basis for the CRTF silvicultural operations. The CRTF defines sustainable harvest as harvesting no more that the sum of the mean annual growth per acre per year across the farm. This is further defined in that the growth and harvest must balance within a ten year period. Any volume not harvested within a period will be rolled over into the following measurement period. Analysis of a cumulative five year inventory record is used to determine the annual growth rates. This analysis is ongoing and the growth rate will be refined as the measurements continue. In the last 25 years of CRTF management, approximately 60% of the annual growth has been harvested. Supporting the sustainable harvest philosophy is the management's viewpoint that the biological productivity of the soil is the CRTF's greatest financial asset. With this in mind, care of the soil is the fundamental objective in all silvicultural operations.

The management objectives of the Cowlitz Ridge Tree Farm are:

1. to earn a living
2. to live in balance with nature
3. to keep the land forested for future generations
4. to educate the public and other Non-Industrial Private Forests

The underlying philosophy behind the silvicultural regime is straight forward: to keep the best trees growing as fast as possible for as long as possible. If this can be accomplished, a high quality wood product will be developed, which the CRTF management feels is the best approach to long term economic stability. The silvicultural regime applies only to the most productive lands on the CRTF. Forested wetlands make up approximately 20% of the ownership. These lands are managed primarily for their ecological and habitat values. Another 10% of the ownership is in non-productive land; *phellinus weirii* pockets, mountain beaver colonies, roads, seeps, rock outcroppings, utility and county right of ways.

The silvicultural regime on the Cowlitz Ridge Tree Farm is as follows:

1) an eighty year harvest rotation, which when combined with thinning regimes has many ecological benefits which include: larger trees; higher values of per unit of volume; improved habitat for some wildlife; increased carbon storage associated with larger growing stock; more naturally occurring snags and down material; sharply reduced land area in the regeneration and early developmental stages; and perhaps improved long-term site productivity (Curtis and Carey 1996);
2) a combination of small clear-cut and variable retention rotation harvest methods. Small (0.5-8 ha.) clear-cuts are necessary to create the growing space needed by Douglas-fir for successful regeneration and growth on north western Cascade Douglas-fir sites. Harvest operations remove the merchantable boles of the trees only. Burning of the harvest units will occur only on landings where logging slash prevents successful regeneration operations. Emphasis of the harvest operation will be on care of soil (harvest activities are delayed under adverse weather conditions). The variable retention harvest system is based on the concept of retaining structural elements of the harvested stand for at least the next rotation in order to achieve specific management goals. Variable retention harvesting has three objectives:
    a. "life boating" species and processes immediately after logging and before forest cover is re-established;
    b. "enriching" re-established forest stands with structural features that would otherwise be absent; and
    c. "enhancing connectivity" in the managed landscape (Franklin et al. 1997);
3) a five year intensive regeneration phase that begins with planting in harvested areas at 1330 trees per hectare ensuring a high level of stocking from the initial (most cost effective) planting. Red alder, western red cedar, and western white pine (P*inus monticola* (Douglas)) will also be planted in place of, or along with Douglas-fir in site specific areas, particularly in those infected with *Phellinus weirii.* Herbicides will be manually applied during this period on high productivity sites and sites that have developed mature shrub and herbaceous layers due to multiple understory thinnings;
4) a pre-commercial thinning regime to provide the optimum growing space, prevent mortality from competition and to provide an opportunity to select the best tree stock for future management options.
5) a pruning regime in selected stands to improve wood quality and create habitat features necessary for some bird species;

6) commercial thinning from the understory at ten year intervals to continue to provide optimum growing space, increase wood quality and provide income prior to rotation harvest.
7) annual gap planting with western red cedar to provide species diversity, increase vertical composition and provide a future niche market;
8) maintenance of legacy snags and down woody debris and creation of these structures as feasible, to improve late successional structural characteristics and increase forest biodiversity and function.

Discussion

Forestry practices to maintain biodiversity (i.e. uneven-age management) should mimic natural disturbance patterns which differ across forest types (Bunnell 1995). Most silvicultural activities such as timber harvest, regeneration and thinning can be tailored to resemble specific natural disturbances inherent to forests. The main impact of human activity is to change the frequency and scale with which the different types of disturbances occur (Oliver and Larson 1996). Knowledge of the temporal and spatial aspects of the historic disturbance regime of fire allows silviculturalists to mimic these quantifiable aspects with silvicultural regimes. The greatest impact of the CRTF silvicultural regime will be seen with the length of the harvest rotation. An eighty year rotation closely mimics the approximated fire return interval of 50-100 years on this site. The harvest unit size will also play an important role. The interplay of disturbances of different sizes is probably more important than the existence of a single intermediate disturbance type in determining species diversity and other community properties (Runkle 1985). Low to moderate fire regimes in dry Douglas-fir sites that have been studied, all indicate mean patch sizes between 0.3 hectares to 10.0 hectares (Bunnell 1995; Morrison and Swanson 1990; Agee and Dunwiddie 1984; Means 1982). Estimates of disturbance rates in forest range from 0.5 and 2% per year (Runkle 1985; Bunnell 1995). A mean patch size between .3 and 10 hectares with a harvest rotation interval of 80 years results in a disturbance rate between 03 and 1.2 %. Also of importance is the selection (i.e. understory thinning) harvest program which occurs up until the final harvest. According to Means (1982) who studied stand development of dry coniferous forests in the central western Cascades of Oregon, shelterwood or selection harvests will most closely mimic the effects of a low severity natural disturbance regime. Pruning and commercial thinning will mimic the role of the lower severity fires impact on stand structure. Annual gap planting with western red cedar and the maintenance of legacy snags and down logs, along with the creation of coarse woody debris as feasible will both add to the species diversity and function of this forest ecosystem.

While it is probable that a silvicultural regime of uneven-age management at the stand level will mimic the spatial and temporal aspects of the historic disturbance regime of fire, there are some unknown variables. For instance, how will soil productivity over several rotations without the nutrient cycling impacts of burning be affected? Will the regime create enough coarse woody debris (in particular, snags) to successfully function like a "natural system". How will a patch size mean of approximately 4 hectares effect species dependent upon interior habitat characteristics? How do patch structural characteristics interplay with adjacent patches in terms of landscape level habitat characteristics? To be sure that we effectively note the directions of these processes, a long term monitoring program coupled with on going learning processes must be enacted. Several criteria are necessary for a long term monitoring program to be successful. An adaptive management framework with clearly stated objectives and a sufficient feedback loop must be implemented (McLain and Lee 1996).

Landscape level uneven-age management objectives must be flexible enough to allow discretion at the operational level to adapt to site specific circumstances. Uneven-age management will never be an exact science. Its best implementation will be at the operational level as an art form, practiced by individuals with site specific knowledge and experience. If applied in this manner, uneven-age management will be a useful tool in maintaining and creating forests that provide the range of values expected by society today and in the future.

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