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Vegetative Patterns, Disturbances, and Forest Health in Eastern Oregon and Washington

Abstract

Vegetation patterns in eastern Oregon and Washington are largely a result of environmental conditions, species distributions, plant ecology, and disturbances operating at multiple scales and in different environments. In turn, vegetative patterns strongly influence the amount, severity, and distribution of disturbances generated by various agents. This paper focuses on the latter—the relations between vegetation pattern, disturbance, and forest health and productivity. At all scales, vulnerability to disturbance appears to increase when vegetation condition and pattern differs from the historical or expected range for a given environment. Generally, forests that are older, composed of larger trees, denser, more homogeneous, or more contiguous than would be expected under natural or historical disturbance regimes are more vulnerable to mortality from insects and disease. Factors related to vulnerability include site potential, host abundance, canopy structure, host size, patch vigor, patch density, patch connectivity, topography, and logging disturbance. Mortality from insects and disease contributes to diverse habitat, but current levels of tree mortality from insects and disease are often outside the historical or expected range given site environment. High levels of mortality may continue because many forests have become more homogeneous, contiguous, and dominated by shade-tolerant species owing to fire suppression and management. Uncharacteristically severe fires will likely increase in the next 100 years even with restoration management because of changed vegetation patterns and other factors. Information at stand or site scales is relatively abundant in the scientific and management literature. Much broad-scale information is based on models and expert opinion. Research at broad scales is scanty and difficult.

Background

The study of plant communities and landscape patterns has long been a staple of the ecological literature (e.g. Clements 1916, Braun-Blanquet 1932, Daubenmire 1968, Pielou 1979). Many sources provide useful conceptual summaries of landscape vegetation patterns and processes (e.g. Picket and White 1985, Forman and Godron 1986, Turner 1987, Allen and Hoekstra 1992, Schimel et al. 1997) and the patterns generated by the interplay of vegetation and environment (e.g. Gleason 1939, Major 1951, Whittaker 1960, Daubenmire 1974, Rowe 1980, Swanson et al. 1988). The most comprehensive reviews of broad and mid-scale vegetation patterns, the processes that generate them, and their links to forest health in Eastern Oregon and Washington come from a series of assessments, generally done to assist in the preparation of environmental impact statements, by federal agencies (Caraher et al. 1992, Everett et al. 1994, Quigley et al. 1996, Quigley and Arbelbide 1997, Quigley et al. 1997, Hessburg et al. 1999a).

There is an abundant literature on vegetation patterns, forest health and productivity, and the effects of fire, insects, and disease at fine scales (stand to subwatershed). While research at this scale is interesting and useful, the practitioner must be careful when extrapolating results to other areas or broader scales. Research at fine scales is often, of necessity, case study. Stratification and replication across a range of settings above the stand scale is generally time consuming, difficult and expensive. While this caveat should flavor any interpretation or extrapolation of finer-scale research, the practitioner may have no alternative.

Issues of ecological interpretation and scale are, of themselves, the subjects of a considerable literature. While an in-depth discussion of these issues is not the focus in this paper, the reader would be well advised to consider scale carefully for many reasons. Among the most important for this discussion are 1) different ecological characteristics are evident at different scales; 2) processes that are evident at a particular scale may be viewed as higher-scale constraints at a finer scale; and 3) processes that occur at finer scales may be too rapid or poorly resolved to be visible at a bigger scale (e.g. Allen and Hoekstra 1992, Levin 1992, Allen et al. 1994, Klijn and UdoDeHaes 1994).

This paper attempts to summarize knowledge on the multi-scale forest health and productivity relations between vegetation patterns and fire, insect, disease, and ungulate grazing disturbances in eastern Oregon and Washington. It poses two questions: How do vegetation patterns influence future forest health and productivity at several scales? How do fire, insect, disease, and ungulate grazing disturbances influence vegetative patterns at several scales? Answers to these questions are inextricably tangled. Vegetation patterns are largely a result of environmental conditions and disturbances operating at multiple scales, which generate a variety of patch conditions (Forman and Godron 1986). In turn, vegetative patterns strongly influence the amount, severity, and distribution of disturbances generated by various agents (Hayes and Daterman 2001, Ottmar and Sandberg 2001, Parks and Flanagan 2001, Thies 2001, Kie and Lehmkuhl 2001, and Torgersen 2001). Here the emphasis is on the relation between disturbances and vegetation rather than the relation between environment and vegetation, though vegetation, disturbance and environment are strongly intertwined. Any research into the effects of disturbance on vegetation pattern or vegetation on disturbance pattern must account for underlying environmental drivers.

Some of the following discussion refers to the historical, typical, or natural range of conditions. The context for this discussion comes from the need for a baseline against which to compare change (Hann et al. 1997, Landres et al. 1999). Hann et al. (1997) defined "historical range" as a several-century period preceding Euro-American settlement. Hann et al. (1997) and Hemstrom et al. (2000) also used this definition. Hann et al. (1997) and Hemstrom et al. (2000) defined the "normal" or "typical" portion of the historical range as the central 50% of the modeled historical range. Their definition, used in this paper, presents difficulties regarding the roles of climate change, exotic plant species invasion, and other factors (see especially Tausch et al. 1993), but an alternative description of expected or typical range of vegetation and disturbance conditions for the Inland Northwest has not been published.

How Does Current Vegetative Pattern Influence Future Forest Health and Productivity?

Vegetative patterns influence future forest health and productivity largely by affecting 1) local vegetative competition, 2) tree and stand growth rates and competition stress, 3) susceptibility to insect, pathogen, and fire disturbances, and 4) local to broad-scale disturbance patterns and regimes.

Vegetative patterns influence future forest health and productivity through several disturbance mechanisms, including susceptibility to insects and diseases; probability, severity, intensity, and spatial pattern of fire; and (much less understood) producing habitat conditions that encourage ungulate grazing that may influence vegetation conditions. Vegetative patterns also influence future forest health and productivity by affecting disturbances from other agents, including wind throw, snow breakage, snow avalanches, and others. Complex mechanisms intertwine environmental conditions, disturbances, vegetation patterns, and forest health and productivity at many scales (e.g. Turner 1989, Allen and Hoekstra 1992, Wickman 1992, Everett et al. 1994, Harvey 1994, Hessburg et al. 1994, Johnson 1994, Hemstrom et al. 2000).

Site/Stand Scale

The influences of stand-scale vegetative patterns on forest health and productivity (i.e. tree and stand growth and vigor) are well documented in the literature. Stand-scale vegetative patterns reflect the complex interaction of environment, disturbance history, and vegetative development. Discussions of the relations between vegetation, disturbance, and environment abound in the literature (e.g. Daubenmire 1968, White 1979, Forman and Godron 1986, Allen and Hoekstra 1992). Silviculture and forestry manuals and texts provide in-depth discussions in both general concepts (e.g. Smith 1962, Hall 1989, Oliver and Larson 1996) and details for specific species (e.g. Cochran 1985; Baumgartner et al. 1985; Baumgartner and Lotan 1988; Burns and Honkala 1990; Cochran and Barrett 1993; Cochran 1998; Cochran and Barrett 1998; Cochran and Dahms 1998; Cochran and Barrett 1999a, 1999b; Cochran and Seidel 1999). At least cursory information on site or stand-scale relations between local environmental settings, vegetative pattern, and future forest health and productivity exists across most forested lands in eastern Oregon and Washington (e.g. Franklin and Dyrness 1973, Hall 1973, Hopkins 1979a, Hopkins 1979b, Williams and Lillybridge 1983, Volland 1985, Johnson and Simon 1987, Johnson and Clausnitzer 1992, Clausnitzer 1993, McNab and Avers 1994, Lillybridge et al. 1995, Williams et al. 1995).

Fine-scale change from historical to current conditions across eastern Oregon and Washington varies considerably by terrestrial forest community type, environment, and management regime (Table 1; Hann et al. 1997, Hemstrom et al. 2000). The most pervasive changes at the stand scale are a general reduction in the time required for canopy closure (due to artificial regeneration), a decrease in large-tree abundance, and a decrease in large-snag and down-wood structure. Reduced time to canopy closure also reduces the abundance and longevity of shrub-herb successional stages. The result has often been higher levels of wood fiber production; increased insect, disease, and fire risk in the absence of continued silvicultural manipulation; and decreased shrub-herb, large snag, and down wood habitat features.

Stand-scale structure and composition also vary by environmental setting (Hann et al. 1997). Under historical disturbance regimes, dry ridges and southerly exposures often supported late-seral single-layer forests (Figure 1). Tree density generally increased on moist lower slopes, then decreased on well-drained valley floors. Traditional commodity-oriented management regimes often resulted in substantial reductions in late-seral forests, large snags, and large down wood (Figure 2). Fire suppression allowed succession of much of the remaining late-seral forest to multi-storied condition. Early seral stands were planted, usually with one or two tree species, resulting in rapid canopy closure and a shortened shrub-herb-grass condition. Traditional reserve-oriented management changes fire regimes through growth suppression, resulting in seedling recruitment, canopy fill-in, and increasing standing and down woody debris (Figure 3).

TABLE 1. Multi-scale changes in structure and pattern characteristics of major forested terrestrial communities in eastern Oregon and Washington from historical to current disturbance regimes (summarized from Hann et al. 1997 and Hemstrom et al. 2000).

Terrestrial Forest Community	Stand-Scale	Subbasin and Larger Landscape Scales
Early seral, lower montane	Higher tree density	Increased area, more contiguous
Early seral, montane	More rapid canopy closure, lower snag and down wood density in managed areas	Decreased area, less contiguous
Early seral, subalpine	More rapid canopy closure, lower snag and down wood density in managed areas	Slightly increased area
Mid-seral, lower montane	More rapid canopy closure in managed areas	Substantially increased area, decreased fragmentation
Mid-seral, montane	More rapid canopy closure, lower snag and down wood density in managed areas	Substantially increased area, decreased fragmentation
Mid-seral, subalpine	More rapid canopy closure, lower snag and down wood density in managed areas	Slight decline in area
Late-seral, multi-layer, lower montane	Lower large snag and down wood density in managed areas. More dense small snags and down wood.	Increased area, more contiguous
Late-seral-single-layer, lower montane	Higher tree density, higher density of small snags and down wood	Substantially decreased area, highly fragmented
Late-seral, multi-layer, montane	Lower large snag and down wood density in managed areas. More dense small snags and down wood.	Decreased area, increased fragmentation
Late-seral-single-layer, montane	Higher tree density, higher density of small snags and down wood	Substantially decreased area, highly fragmented
Late-seral, subalpine	Similar to historical	Similar to historical

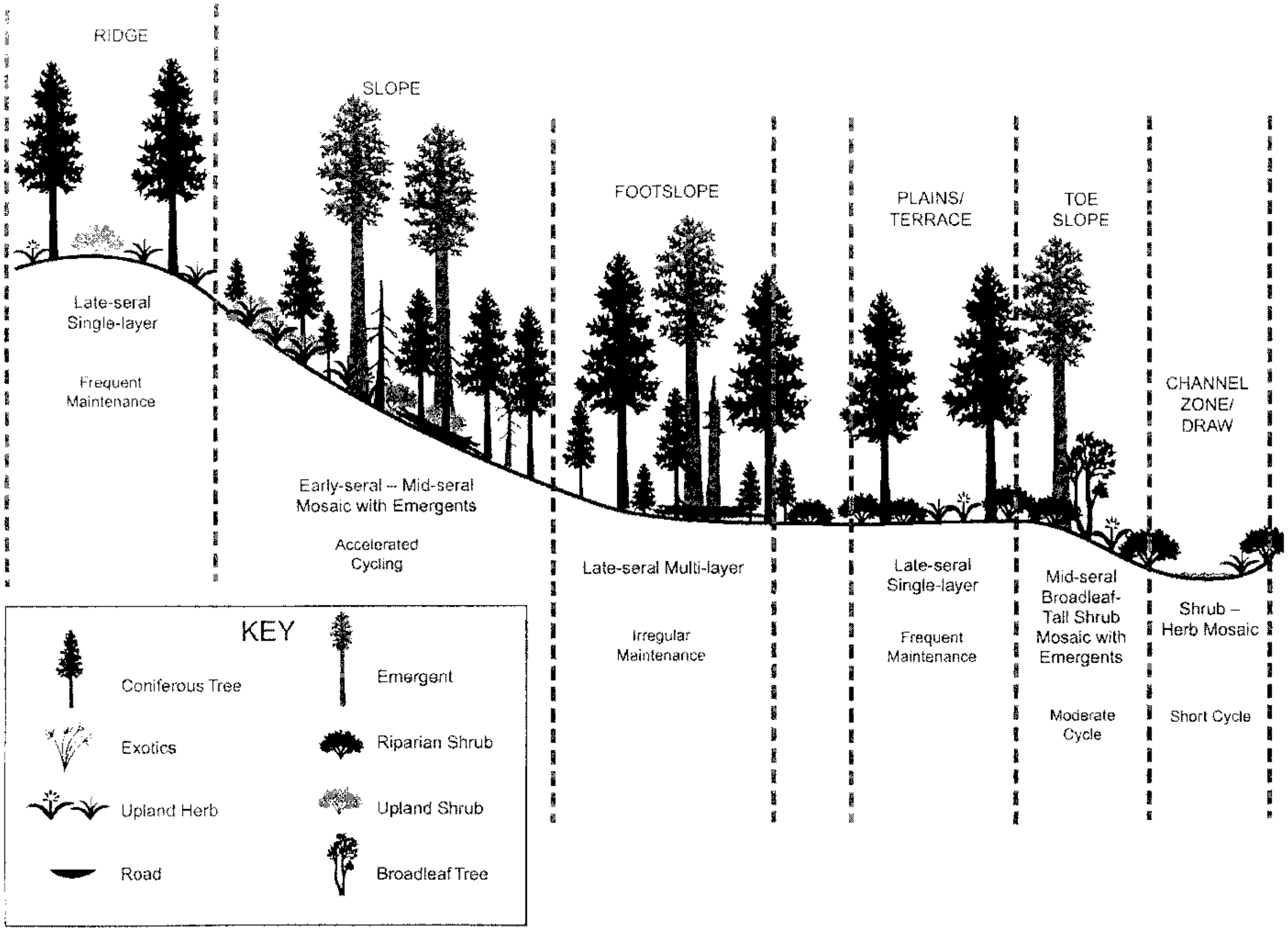

Figure 1. Landforms, forest landscape patterns and vegetation structure under historical disturbance regimes in the interior Columbia basin (from Hann et al. 1997).

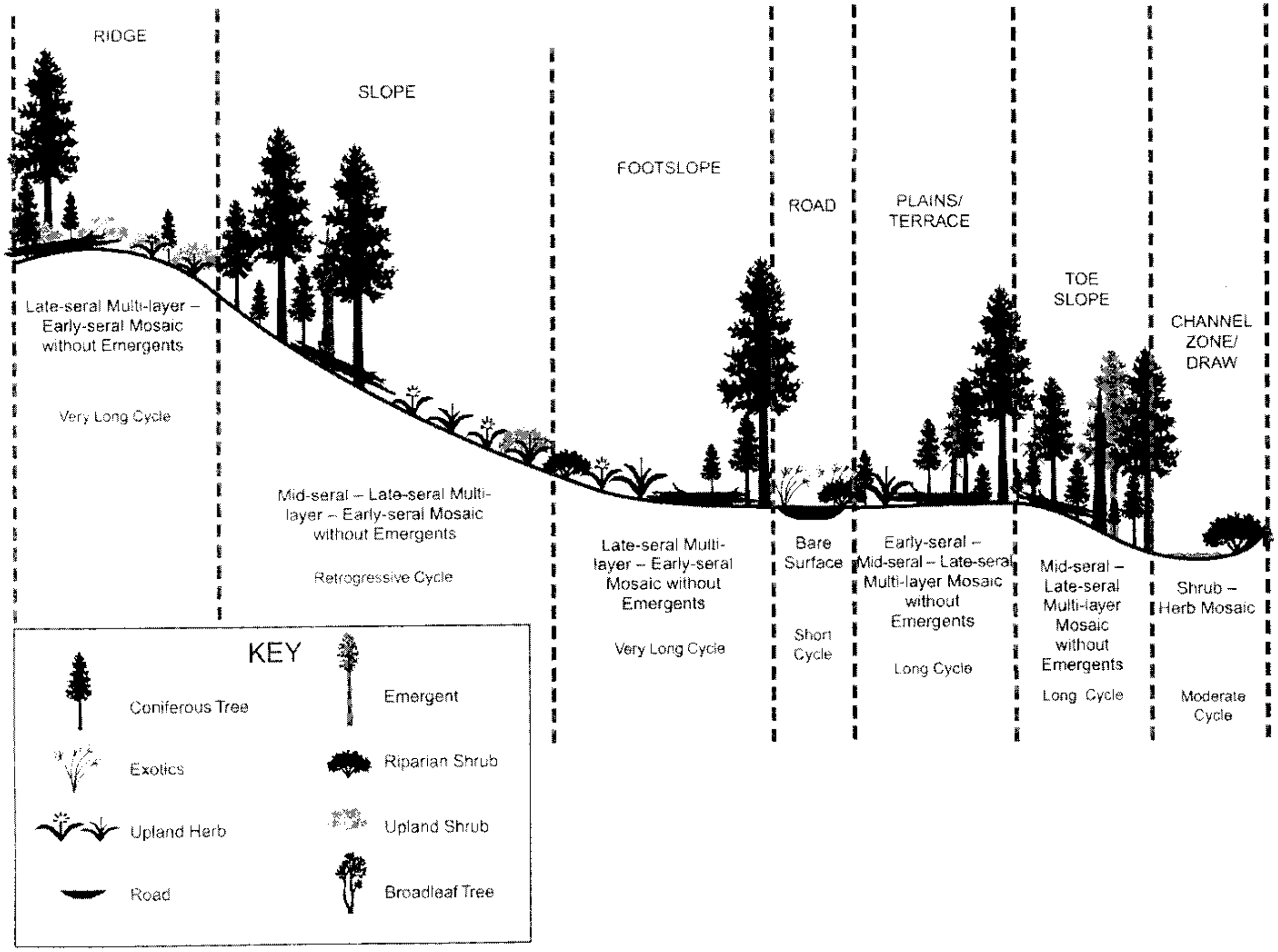

Figure 2. Landforms, forest landscape patterns and vegetation structure under traditional commodity-oriented disturbance regimes in the interior Columbia basin (from Hann et al. 1997).

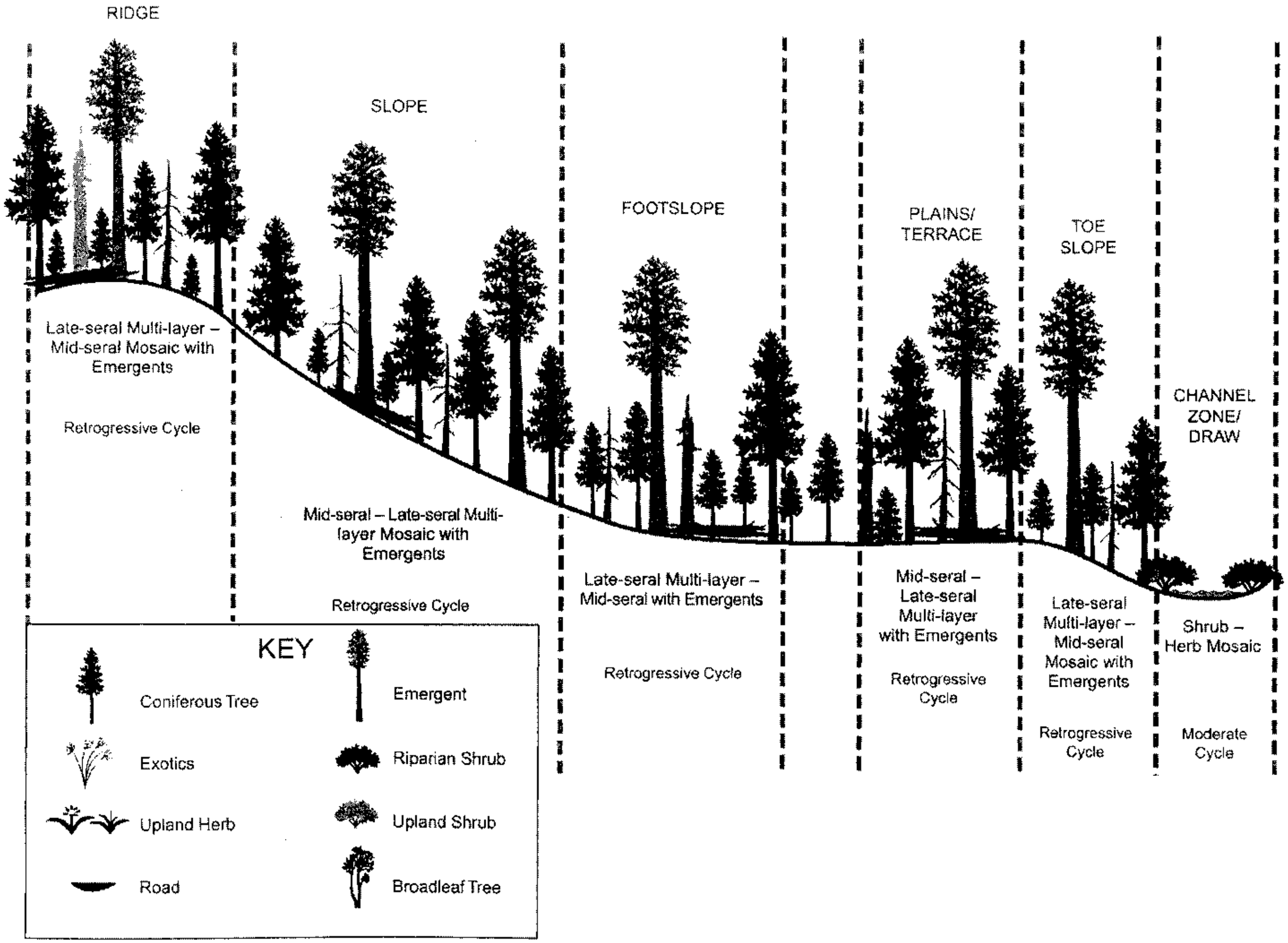

Figure 3. Landforms, forest landscape patterns and vegetation structure under traditional reserve-oriented disturbance regimes in the interior Columbia basin (from Hann et al. 1997).

Insects and Disease

The susceptibility of forests in eastern Oregon and Washington to mortality from insects and disease is often a function of stand density, tree species composition, and tree size class distribution. These relations are relatively well known for the most common forest types in the region (Hayes and Daterman 2001, Parks and Flanagan 2001, Thies 2001, Torgersen 2001).

Generally speaking, as forest stands in eastern Oregon and Washington become older, composed of larger trees, denser, more homogeneous, and more contiguous across landscapes, they become more susceptible to insect and disease mortality (Everett et al. 1994, Hessburg et al. 1994, Hann et al. 1997). Susceptibility is increased by prolonged drought stress, competition stress, and physical damage from fire and mechanical sources (Everett et al. 1994, Hessburg et al. 1994, Hann et al. 1997, Hessburg et al. 1999b).

Stand pattern also influences mistletoe levels (e.g. Dixon et al. 1979, Filip et al. 1989, Hawksworth and Johnson 1989, Parks and Flanagan 2001). In this case, small trees regenerating under a canopy or within a short distance of large, infected trees are more susceptible to infection. Homogeneous stand structures, especially consisting of appropriately spaced, large, infected trees with an abundant understory of small trees, as typically exists in shelterwood harvests, can be particularly vulnerable.

Fire

Fire effects depend to some degree on the composition, structure, homogeneity, and contiguity of forests at the stand level (Kessell and Fischer 1981, Agee 1993, Ottmar and Sandberg 2001), as well as the local topographic (Agee 1993, Camp et al. 1997) and fire weather conditions (Agee 1993). The natural or background fire regimes for forests in the region run the gamut from very infrequent, stand-replacing events to frequent, low-intensity burns (Agee 1993, Hann et al. 1997, Hessburg et al. 1999a, Ottmar and Sandberg 2001). Forests in cold, moist environments (e.g. spruce-fir, mountain hemlock, Pacific silver fir) tend to experience infrequent, stand-replacement fires. Montane forests in cool to warm moist environments (e.g. grand fir-white fir, moist Douglas-fir) tend to experience stand-replacement fires more frequently. Fires typically generate vegetation mosaics. Relatively frequent underburns were characteristic of fire regimes in drier lower-montane forests (e.g. drier grand fir-white fir, dry Douglas-fir, ponderosa pine environments). Many of these natural or background fire regimes have been altered by fire suppression (Agee 1993, Everett et al. 1994, Hann et al. 1997). Fire suppression has produced increased fuel loads, increased ladder fuels that allow crown fire, and increased tree densities in many forest types (Agee 1993). As a result, fires in many forest types are less frequent and more intense than was historically the case (Hann et al. 1997).

Fire, insects, and disease often work synergistically (Geiszler et al. 1980, Agee 1993, Hann et al. 1997, Hessburg et al. 1999a). Mortality from insects and disease across several stands or larger landscapes can increase fuel loads and the size and intensity of subsequent fire.

Fire can produce relatively long-lasting effects on soils and site productivity by altering soil nutrients, soil organic matter, water infiltration rates, and mycorhizal communities (Agee 1993). Hydrophobic soils resulting from intense fire may be more susceptible to erosion, with resulting long-term effects on site productivity. Fire suppression and increased fuel loads have likely produced increased fire intensities on some sites and consequently have long-term effects.

Other Stand-Scale Disturbances

Vegetation patterns can influence future health and productivity of forests at the stand scale by altering the patterns of abiotic disturbances (Pickett and White 1985, Oliver and Larson 1996). Dense stands of tall, thin trees are more susceptible to wind and snow breakage (Oliver and Larson 1996), especially following thinning disturbances. Stand edges, particularly edges introduced into previously closed forests, are susceptible to increased wind throw and other disturbances (Franklin and Forman 1987, Oliver and Larson 1996).

Subwatershed Scale

Forest health and productivity at the subwatershed and broader scales in eastern Oregon and Washington appear to be strongly influenced by vegetation patterns, though the relation is less documented at broader scales.

Hessburg et al. (1999a) conducted a comprehensive examination of landscape vegetation patterns and the vulnerability of vegetation to fire, insect, and pathogen disturbances across a stratified random sample of 337 subwatersheds in the interior Columbia River basin. They suggest that subwatersheds seem to be the most appropriate spatial scale for analysis of change in vulnerability to pathogen and insect disturbances. Subwatersheds often exhibit high levels of vulnerability that can be masked or appear insignificant at broader scales. Subwatersheds often exhibit high variability in vegetative communities, biophysical conditions, climate, and disturbance regimes that are strongly related to insect, fire, and pathogen disturbances. They suggest that the vulnerability of forests to insect and pathogen disturbances increases as vegetation conditions and patterns differ from those that could be considered normal or expected, as judged by a range of historical conditions, for different biophysical environments.

Hessburg et al. (1999a) summarized subwatershed and watershed changes in landscape patterns. They found that overall forest cover increased and the current structure of forests was simpler compared to historical conditions. The increase in forest cover and connectivity was largely due to afforestation of areas previously kept open by wildfire. Simplification of forest structure was, they hypothesized, due to a combination of factors, including wildfire suppression, timber harvest, fire exclusion, and domestic livestock grazing. The area of early-seral forest structures declined in many of the areas they examined. Mid-seral forests increased in many areas, probably due to both timber harvest and increased levels of stand-replacement wildfire. Area in old forests decreased, as did large, remnant trees. They concluded that the most important change in forest structure in many areas was the decline in area containing medium-sized and large trees.

Hann et al. (1997) assessed landscape conditions, including the relations between fire, insects, diseases, and vegetation patterns, across the interior Columbia River basin by aggregating information on 1-km pixels to subwatersheds and larger drainages. Hemstrom et al. (2000) predicted current and future levels of "uncharacteristic" (that is outside the middle portion of historical ranges) fire, insect, and disease risk, and ungulate grazing effects for the same area. Both assessments indicate high levels of geographic variation in the vegetation patterns and predicted fire, insect, and disease effects at subbasin and larger scales. While their data are very coarse at the scale of individual subwatersheds, they suggest that uncharacteristic insect- and disease-induced tree mortality is associated with vegetation patterns that differ from normal or historical conditions. They found vegetation patterns, structure, composition, and disturbance regimes to be highly related to current landscape health and likely future landscape health trends. Landscape health is difficult to assess across areas smaller than subwatersheds because a healthy condition includes expected variability at finer scales (Hemstrom et al. 2000).

Fire

The pattern of stands across subwatersheds affects the spread, intensity, and mosaic pattern of fire (Morrison and Swanson 1990, Agee 1993, Ottmar and Sandberg 2001). Fuel contiguity changes the stand-to-stand spread of fire and fire intensity, though in extreme events firebrands can produce spotting for long distances (Agee 1993, Ottmar and Sandberg 2001). Fire patterns and intensities at the subwatershed scale can have important and long-term consequences for forest health and productivity. Nominal or natural fire regimes can maintain typical forest composition, structure, pattern, growth, and productivity (Hann et al. 1997; Hessburg et al. 1999b, 1999c; Landres et al. 1999) and are often considered part of healthy forest condition (Everett et al. 1994, Hann et al. 1997, Quigley et al. 1997). Altered fire regimes can change soil water infiltration, soil nutrient levels, soil organic matter, mycorhizal communities, and ground water nutrient levels (Agee 1993), with consequent effects on forest health and productivity.

Insects and Disease

Subwatershed-scale and larger vegetation patterns alter the susceptibility of forests to insect and disease mortality (Everett et al. 1994; Hessburg et al. 1994; Hann et al. 1997; Hessburg et al. 1999a, 1999b; Hemstrom et al. 2000). Landscape health, at the subwatershed and broader scales, generally includes, by definition, some normal, nominal or historical range of insect and disease mortality (Hann et al. 1997, Hemstrom et al. 2000).

Insect and disease activity is often essential in producing habitat for terrestrial fauna (Bull et al. 1997) by generating standing and down dead trees.

Stand structure, composition, and pattern at subwatershed and broader scales can dramatically influence probabilities of tree mortality from insects and disease (Everett et al. 1994, Hessburg et al. 1994, Hann et al. 1997, Hessburg et al. 1999a, Hemstrom et al. 2000). Hessburg et al. (1999b) examined the link between vegetation patterns and vulnerability of forests to insect and pathogen disturbance on a stratified random sample of 337 subwatersheds across the interior Columbia River basin. They used patch composition, patch structure, logging disturbance, and physical environment attributes to compare the historical and current vulnerability of subwatersheds. These were combined into sets of vulnerability factors that were unique for the each of the 21 different pathogen and insect disturbances they modeled. Vulnerability factors included site quality (differences in ecological site potential), host abundance, canopy structure, host size, patch vigor, patch (stand) density, connectivity of host patches, topographic setting, and logging disturbance.

Watershed Scale

Most existing information about the effects of forest vegetation patterns on forest health and productivity in eastern Oregon and Washington focuses on either relatively fine scales (stands and groups of stands) or has been generalized to larger landscapes (Everett et al. 1994, Hann et al. 1997, Hemstrom et al. 2000). Hessburg et al. (1999a) examined subwatershed relations and summarized them to ecological reporting units (subbasin and larger scale entities). The literature on the effects of vegetation patterns on forest health and productivity at the intermediate watershed scale is scanty. It appears that either researchers have found stand (site), subwatershed, subbasin, and basin scales sufficient to portray effects, or that watershed scale effects are not well documented. It is likely that watershed-scale effects are similar to subwatershed-scale effects. Interestingly, Hessburg et al. (1999a), who examined vegetation and disturbance patterns at subwatershed and aggregated them to larger land units found that the high level of variability that occurs in individual subwatersheds is masked, at least to some degree, by their inclusion in larger land units.

Subbasin Scale and Up

Hann et al. (1997) and Hemstrom et al. (2000) described general changes in forest composition, structure, and pattern across the interior Columbia basin (Table 1). Lower montane forest areas (often dominated by ponderosa pine) have expanded into previously non-forest and woodland areas, resulting in an increase in early seral forest amount and contiguity. Traditional commodity management has often resulted in abundant, small mid-seral patches. Combined with succession in recently afforested woodland, these two trends have increased the area of mid-seral lower montane forests. Single-layer, late-seral forests declined substantially, a result of the combined effects of timber harvest and fire suppression. While fire suppression, and the consequent conversion of single-layer to multi-layer structure, generated more late-seral, multi-layer forests, timber harvest, and to a lesser degree wildfire, eliminated large areas of late-seral forests. The result has been a substantial decline in amount of late-seral forests at mid and low elevations. Late-seral, single-layer forests have become uncommon and isolated. Late-seral, multi-layer forests have declined in area but, allowing for high levels of finer-scale fragmentation, have likely become more contiguous than they were in the past.

Insects and Disease

Hessburg et al. (1999a) sampled vegetation patterns and associated insect and pathogen disturbances at subwatershed scales and summarized results to ecological reporting units (ERUs). ERUs are large land units used to generalize broad-scale and mid-scale assessments in the interior Columbia River basin (Quigley and Arbelbide 1997) and are generally the size of subbasins or larger. They found that shade-tolerant tree species dominate the forests of the basin more today than they did in the past. Consequently, because these species are often susceptible to insect and disease disturbance and because forests are more dense and contiguous, they expect that insect and disease disturbances will have expanded roles in forests of eastern Oregon and Washington. Direct effects (tree mortality) and indirect effects (higher fuel loads and changed fire regimes) are to be expected. These findings correspond to other forest health assessments in the region (e.g. Everett et al. 1994).

Hann et al. (1997) and Hemstrom et al. (2000) estimated historical, current, and potential future vegetation patterns and insect and disease disturbances at broad scales across the interior Columbia River basin. Although the composition and structure of forest vegetation in the basin are highly variable, their work indicates that forests at present tend to be more homogeneous, contiguous, and dominated by shade-tolerant species than those of historical times. They estimate that insect- and disease-induced tree mortality potentials have departed from typical historical ranges in many forests as a consequence of the combined effects of timber harvest, fire suppression, and (possibly) climate change. Hemstrom et al. (2000) project continued increases in uncharacteristic insect- and disease-induced tree mortality over many forested areas in eastern Oregon and Washington.

Fire

Vegetative patterns have a profound influence on fire regimes at the subbasin and larger scales in eastern Oregon and Washington. Hann et al. (1997) estimated historical and current vegetation patterns and fire regimes for the interior Columbia River basin. Their estimates of historical fire regimes come from transition and pathway models of vegetation succession and disturbance under modeled historical vegetation conditions given biophysical environment strata. Current fire regimes were estimated from 1-km pixel vegetation maps, biophysical environment strata, and transition and pathway models. They found that fire suppression, timber management, livestock grazing, successional momentum, and other factors have produced substantial changes in vegetation patterns from historical to current times. Dry and moist forest environments have likely been most altered, especially those environments that typically supported single-story old-forest structures in the past. In these areas, fire suppression and timber management have produced increased understory tree densities, shifts to more shade-tolerant (and less fire resistant) tree species composition, and decreased landscape patch heterogeneity. Fire regimes have often become less frequent and more severe. Cold forests have been slower to change, given the slower rates of succession and tree regeneration characteristic of those environments. Nevertheless, even cold forests have experienced changes in fire regimes due to increased landscape homogeneity and higher fuel loads.

Hemstrom et al. (2000) projected future vegetation patterns and fire conditions, building on the work of Hann et al. (1997). They projected "uncharacteristic" wildfire effects probabilities across the interior Columbia River basin. Uncharacteristic fires produce higher severities and intensities, burn larger areas, and are often much more difficult to control compared to more normal wildfires. Their estimates indicate that most forested lands in the basin do not currently experience high risks of uncharacteristic fires, but that uncharacteristic fires will likely increase in the next 100 years, even under moderately aggressive restoration management. Increases in uncharacteristic wildfire effects are the result of changed vegetation patterns resulting from fire suppression, timber harvest, and increased insect- and disease-induced tree mortality. Lands managed with passive approaches, rather than more aggressive restoration, and continued fire suppression are most at risk.

How do Insects, Disease, Fire and Ungulates Influence Vegetative Pattern?

Site/Stand Scale

Insects and Disease

Site or stand-level disturbances produce a variety of effects ranging from individual tree mortality to canopy gaps or forest openings (Pickett and White 1985, Chen et al. 1992, Oliver and Larson 1996). Canopy gaps may allow the persistence of relatively more shade-intolerant tree species in otherwise closed forests. Individual tree mortality in closed dense canopies may allow regeneration of only the most shade-tolerant species. Openings and stand edges produce warmer, drier (and sometimes frostier) environments often suited to more shade-intolerant species.

Effects can vary depending on the disturbing agent, environment, disturbance intensity and other factors (Pickett and White 1985; Oliver and Larson 1996; Hessburg et al. 1999a, 1999b, 1999c). Insect and disease disturbances can produce many different effects:

1. Low levels of chronic mortality of selected tree species resulting in gap regeneration by shade-tolerant tree species (Hayes and

Daterman 2001, Parks and Flanagan 2001, Thies 2001, Torgersen 2001).

2. Small group or patch mortality of trees of a particular species, species group, and size class resulting in the regeneration of shade-intolerant tree species in an otherwise closed forest (Hayes and Daterman 2001, Parks and Flanagan 2001, Thies 2001, Torgersen 2001).
3. Mortality of large patches or entire stands that are dominated by a particular tree species and size class resulting in stand replacement and regeneration of shade-intolerant trees (Hayes and Daterman 2001, Thies 2001, Torgersen 2001).
4. Mortality of most or all the trees of a particular size and species within a stand, resulting in establishment of a new tree cohort (Hayes and Daterman 2001, Torgersen 2001).

Fire

Fire affects vegetative pattern at the stand scale in a variety of ways, ranging from mortality of a few trees in a stand to patches to entire stands (Agee 1993). Typical fire regimes and effects vary by forest type and environment. For simplicity, the following discussion uses three broad forest environments described by Hann et al. (1997). Dry forests occur in warmer and drier environments, generally dominated by ponderosa pine, dry Douglas-fir and dry grand fir communities. Moist forests occur at middle elevations with higher precipitation levels and are generally dominated by grand fir, white fir, Douglas-fir, western larch, ponderosa pine, western redcedar, western hemlock and other species. Cold forests, at higher elevations, are generally dominated by subalpine fir, Englemann spruce, western larch, white fir, lodgepole pine and, at the highest elevations, whitebark pine and subalpine larch.

Light-intensity underburns are characteristic of many dry forests in eastern Oregon and Washington (Agee 1993, Everett et al. 1994, Hann et al. 1997). They typically consume some to most of the litter, duff, and fine fuels. They generally kill some or most small trees, especially thin-barked species like grand fir, white fir, subalpine fir, and Englemann spruce. Frequent, light underburns were key to maintaining the open stands of large old trees that were historically abundant in drier, low-elevation forests in western Oregon and Washington (Agee 1993, Everett et al. 1994, Hann et al. 1997, Camp et al. 1997). Fire suppression has resulted in increased fuel loads, increased tree densities, and more abundance of shade-tolerant species in many of these forests. These, in turn, have resulted in increased fire intensities when fires do occur and in increased tree stress and insect and disease disturbance.

Moist forests in eastern Oregon and Washington typically experienced less-frequent and more-intense fire (Agee 1993, Everett et al. 1994, Hann et al. 1997). In some places, relatively frequent fire maintained open stands of large, shade-intolerant trees. More often, relatively less-frequent but more-intense fire generated patch mosaics of stand ages, compositions, and structures. Fire suppression, with increased fuel loads and increased fuel continuity, has reduced fire frequency and increased severity, patch size, and contiguity compared to natural or native fire regimes (Hann et al. 1997).

Cold forests generally burn infrequently in stand-replacing events (Agee 1993, Everett et al. 1994, Hann et al. 1997). Englemann spruce and subalpine fir forests, in particular, may experience stand-replacement fire only every few centuries. Lodgepole pine-dominated stands often undergo episodic combinations of mountain pine beetle attack and fire that replace stands across large landscapes (Baumgartner et al. 1985, Agee 1993, Hann et al. 1997).

Ungulate Grazing

The literature on the effects of ungulate grazing on forest vegetation pattern in eastern Oregon and Washington is scanty. Studies in other areas suggest that ungulates can play a substantial role in tree species composition and density in forested environments (Turner and Bratton 1987, Harmon and Franklin 1989). Case studies of livestock and big game exclosures in eastern Oregon and Washington document substantial alteration of vegetation composition and structure, including tree species (Riggs et al. 2000), indicating that ungulates probably have significant stand-level effects.

Subwatershed Scale

Effects of fire, insects, disease, and ungulate grazing on vegetation pattern at the subwatershed scale in eastern Oregon and Washington have been less documented than stand-scale effects. Hessburg et al. (1999a) described the linkages between vegetation patterns and vulnerability to insect and pathogen disturbances across a stratified, randomly selected set of 337 subwatersheds in the interior Columbia River basin. In a related effort, Hessburg et al. (1999b) documented changes to forest spatial patterns in a set of 48 randomly selected subwatersheds on the eastern flank of the Washington Cascades. Hann et al. (1997) and Hemstrom et al. (2000) modeled the historical, current, and projected future vegetation conditions by subwatershed across the interior Columbia River basin, but emphasize that their data are coarse at the subwatershed scale. Camp et al. (1997) described the effects of landscape, vegetation, and fire patterns in creating old-growth refugia in an area on the east flank of the Washington Cascades. Agee (1993 and 1994) discusses the interactions of fire and vegetative patterns in eastern Oregon and Washington at several scales.

Fire

In general, fire produces a very large range of vegetative pattern effects in east-side forests. Hessburg (1999a and 1999b) found high levels of variability in fire effects depending on biophysical environment and vegetation conditions. Light-intensity underburns can move through forested areas and, while changing fuel loads and small tree densities, have very little detectable short-term effect on vegetation patterns at the subwatershed and broader scales (Agee 1993). Repeated underburning, as was typical of many dry forests under natural conditions, plays a substantial role in maintaining open forest structure and decreasing the incidence of stand-replacement fire (Agee 1993, Hann et al. 1997). More-intense fires can produce local crown consumption and patchy underburning (Agee 1993, Hann et al. 1997). These effects can be visible at subwatershed scales because they may produce patchy and heterogeneous forest structure and composition. Stand-replacement fires are more typical of fire regimes in relatively moist forest environments (Agee 1993, Hann et al. 1997). Such fires can range in size from a few acres to thousands of acres or more (Agee 1993). Effects are often obvious, dramatic, and long lasting at the subwatershed scale. They may produce large areas of younger forest and isolated patches of remnant old forest (Camp et al. 1997).

Insects and Disease

Hessburg et al. (1999b) found that insect and pathogen activity can generate ecologically significant change from historical to current times in vegetation patch type area, patch density, mean patch size, and landscape patch patterns at the subwatershed scale. They found that a combination of timber harvest, fire suppression, wildfire, and insect and pathogen disturbances had produced, in at least some of their sampled subwatersheds: 1) more fragmentation of both old forest and early-seral forest, 2) dramatic reductions in amounts of old forests, 3) smaller and less-connected old-forest patches, 4) more early- and mid-seral forest, 5) more total patch-type diversity, and 6) more homogeneity and dominance of a few patch types. They did not specifically separate the effects of fire, insects, and diseases on vegetation patterns, and most of their landscape results include the effects of timber harvest. Hessburg et al. (1999a) found similar trends across a much larger sample of 337 subwatersheds in the interior Columbia River basin.

Ungulate Grazing

The effects of ungulate grazing on subwatershed-scale and larger forest vegetation patterns in eastern Oregon and Washington have not been well documented. Hann et al. (1997) and Hemstrom et al. (2000) included ungulate grazing disturbances in their models of disturbance and succession in potentially forested environments. They discussed the effects of grazing on rangelands at broad scales, but did not describe effects in forested environments.

Watershed Scale

The effects of fire, insect, and disease disturbances on forest vegetation patterns in eastern Oregon and Washington have generally not been separated from effects at subwatershed or subbasin and broader scales. Hessburg et al. (1999a) summarized subwatershed effects to broader ecological reporting units. They noted that averaging subwatershed-scale results to larger land units often masked high variability at the subwatershed scale. Hann et al. (1997) and Hemstrom et al. (2000) also summarized subwatershed effects to subbasins or other broad-scale lands units and did not focus on watershed-scale patterns.

Subbasin Scale and Up

The effects of fire, insect, and disease disturbances on forest vegetation become harder to untangle at broader scales. While broad-scale studies of disturbance effects are reported in the literature (e.g. Heinselman 1973, Hemstrom and Franklin 1982, Swetnam and Lynch 1993), they often do not discuss underlying synergistic relations among disturbances. For example, broad-scale fire disturbances may be associated with broad-scale climate and landform patterns and broad-scale insect and disease disturbances (Hemstrom and Franklin 1982; Agee 1993, 1994; Hann et al. 1997). Many fire history studies document fire patterns and, sometimes, associated climatic conditions, but have no information on insect and disease disturbances that may have been precursors or, at least, associated with the same general climate conditions. Insect and disease disturbances are more difficult to detect in dendrochronological studies and may be very difficult to distinguish from fire events.

Fire

Fire can produce large-scale changes in vegetation patterns (e.g. Heinselman 1973; Hemstrom and Franklin 1982; Romme 1982; Knight 1987; Swanson et al. 1990; Agee 1993, 1994; Camp et al. 1997; Hann et al. 1997). Heinselman (1973) describes large landscape-scale patterns generated by wildfire in the virgin forests of the Boundary Waters Canoe Area in Minnesota. Hemstrom and Franklin (1982) document the role of fire and other disturbances in generating forest pattern at Mt. Rainier National Park, Washington. Romme (1982) discusses the role of fire in maintaining large landscapes dominated by lodgepole pine in Yellowstone National Park; a role confirmed by the large wildfires in the Park in 1988 (Romme and Despain 1989). In this case, hundreds of thousands of acres were burned, as had occurred in the past, resulting in large landscape patches. Camp et al. (1997) found that the interactions of fire with physiography and topography play large roles in determining the spatial distribution and location of late-successional forests on the eastern slope of the Cascades in Washington. Hann et al. (1997) describe the changes in forest vegetation pattern across the interior Columbia River basin resulting from fire suppression over the past 50 to 100 years. In this case, fire suppression generated several related effects, dependent on environmental setting. Low-elevation, dry-site forests became more homogeneous and contiguous, extending into lands once kept open by frequent fire. Mid-elevation moist forests became more homogeneous in composition and structure, somewhat more patchy and fragmented, fuel-rich, and susceptible to stand-replacement fire, insect, and disease disturbances. Cold, high-elevation forest effects differed depending on forest type. Lodgepole pine forests became dense, fuel-rich and susceptible to extensive fire, insect, and disease disturbance. More moist spruce-fir forests changed less quickly, but were slowly becoming more dense, fuel-rich, and susceptible to disturbance. Their projections of historical, current, and future vegetation patterns provide some indication of amounts and trends in "transitory rangelands" (that is, early-seral stages that provide palatable forage in forest environments). Grasslands and shrublands in potentially forested environments have declined due to fire suppression, a trend that seems likely to continue. Their models also indicate that forests and woodlands have encroached upon grasslands and shrublands maintained by frequent fire in historical times. This trend, too, is projected to continue into the future. It is possible that increasingly dense forests and an increase in forested lands, resulting from fire suppression, could reduce grasslands and shrublands in currently forested and non-forested environments at the broad scale.

Fire episodes extending across large landscapes in the Interior Northwest may be associated with the juxtaposition of prolonged climatic dry periods or with other unusual events such as dry summers, lightning storms, and abundant contiguous fuels over large areas (Knight 1987, Romme and Despain 1989, Swetnam and Betancourt 1990, Agee 1993). Bessie and Johnson (1995) found that severe weather conditions may completely over-ride fuel effects in some forest types. Swetnam and Betancourt (1990) examine the relation between fire episodes and the Southern Oscillation (El Niño) effect in the Southwestern United States.

Insects and Disease

Insects and diseases can produce broad-scale disturbances to forest vegetation (Hayes and Daterman 2001, Torgersen 2001). Effects can range from general defoliation, and sometimes mortality, of a variety of tree to the decline or loss of one species. Broad-scale insect and disease disturbances have occurred in eastern Oregon and Washington. Large disturbances have been produced by several insect species, especially mountain pine beetle, western pine beetle, Douglas-fir beetle, Douglas-fir tussock moth, fir engraver, spruce beetle, and western spruce budworm (Hessburg et al. 1999a, Hayes and Daterman 2001, Torgersen 2001). These may produce episodic disturbances across thousands of acres or more in a relatively short time. Other pathogen disturbances may change species composition or produce more localized mortality that could affect broader-scale vegetation patterns (Hessburg et al. 1999a, Hayes and Daterman 2001, Parks and Flanagan 2001, Thies 2001, Torgersen 2001). This category includes several different root rots, mistletoes, root diseases, butt rot, and blister rust. The substantial decline in western white pine and whitebark pine across most or all of eastern Oregon and Washington (Hessburg et al. 1999a, Hann et al. 1997) from an introduced blister rust (*Cronartium ribicola* Fisch.) is an obvious example.

The few attempts to study broad-scale insect and disease disturbances using dendrochronolocical methods have raised interesting possibilities. For example, Swetnam and Lynch (1993) examined tree rings in spruce-fir forests in the Rocky Mountains and found evidence of recurrent spruce beetle disturbances across large landscapes over the past several centuries.

Ungulate Grazing

The potential effects of ungulate grazing in forested landscapes across subbasin and larger scales in eastern Oregon and Washington have not been well described (see discussion above for the subwatershed scale). Broad-scale effects of ungulate grazing in other areas have received some attention. Hann et al. (1997) and Hemstrom et al. (2000) described grazing effects across the interior Columbia River basin, especially in rangeland settings. They discuss grazing effects that appear at broad scales as including alteration of the cover and structure of native plant communities, decline in vigor of some native plant communities, impacts to microbial crusts that may increase erosion rates and alter plant communities, the introduction of exotic plant species, and alteration of fire regimes due to changed fuel conditions. The introduction of exotic plant species, consequent changes in fuel conditions, and altered fire regimes have produced vegetation communities that are highly departed from historical conditions in many rangeland settings across the basin. This set of conditions can be very difficult to change once in place owing to feedback loops involving increased levels of fine fuels and increased fire frequency and severity (Tausch et al. 1993, Billings 1994). The ecological effects and costs of livestock grazing across large landscapes is a topic of considerable debate (e.g. Fleischner 1994).

Synergistic Effects

Combinations of fire, insect, disease, and ungulate grazing disturbances with human activities can generate large changes in broad-scale vegetation patterns in eastern Oregon and Washington (Hessburg et al. 1994). Hann et al. (1997) used 1-km pixel data, summarized to subwatersheds and larger landscapes, to assess the historical and current conditions of the interior Columbia River basin. While their data are coarse at the subwatershed scale, their assessment indicates that old forests (especially single-story forests) have declined substantially in dry and moist environments at the subwatershed scale across the entire basin from the combined effects of fire suppression, wildfire, insect, and disease disturbance, and timber harvest. Mid-seral forests, on the other hand, have increased due to the same combination of disturbances. Early-seral forests have declined in some forest environments, but not in others. Pinyon-juniper woodlands have increased substantially in extent, often invading shrub-steppe. While these changes may often be due to changes in disturbance regimes (e.g. Gedney et al. 1999), other factors, such as climate change and introduction of exotic plants, may play strong roles (e.g. Jakubos and Romme 1993, Tausch et al. 1993)

Hemstrom et al. (2000) made projections of changes in forest vegetation patterns due to fire, insect, and disease disturbances under current management strategies and more aggressive restoration approaches. Their hypothesis is that past fire suppression, timber management, livestock grazing, other human uses, and (possibly) climate change have generated successional, disturbance and change momentum across very large areas of the interior Columbia River basin. They suggest that successional momentum will continue to produce higher levels of insect, disease, and fire disturbance in many forested environments, even under moderately aggressive restoration approaches.

Summary

Considerable information exists on the relations between insects, disease, fire, and forest vegetation patterns at stand scales in eastern Oregon and Washington. Information at subwatershed scales comes from fewer sources, many of which are essentially case studies of relatively small areas. Hessburg et al. (1999a) provide the only known subwatershed and broader-scale effort to systematically sample and describe fire, insect, and pathogen disturbances and their effects on vegetation patterns. Useful information on subwatershed and broader-scale relations comes from assessment work by Everett et al. (1994), the Blue Mountains forest health assessment (Caraher et al. 1992), Hann et al. (1997), and Hemstrom et al. (2000). These are useful and interesting examinations and projections of disturbance and vegetation patterns. However, they are largely based on models and expert opinion. While Hann et al. (1997) and Hemstrom et al. (2000) relied on a mid-scale subsample (Hessburg et al. 1999a) to validate some information and provide data for developing some relations, much of their effort relies on formal gatherings of expert opinion. Expert opinion is a valuable information source, but would be more robust if supported by independent analyses. Additional research, using stratified random sampling at multiple scales, would be very useful to help test hypotheses generated by expert opinion.

The relations between ungulate grazing and vegetation patterns in forested environments above the stand scale are very poorly documented. Considerable work exists at finer scales and in rangeland settings. It could be argued that ungulate grazing does not have an appreciable effect at mid and broad scales. Without reliable data, it's difficult to say whether that is true or not. Certainly some fine-scale work indicates the possibility of substantial ungulate grazing influences on vegetation composition and structure, perhaps sufficient to alter larger landscape vegetation patterns in forested environments.

Decision Support Tools

Several tools are available to assist the assessment, modeling, and extrapolation of vegetation patterns and associated disturbances. The most refined tools project vegetation composition and structure at the stand or site scales. Past efforts to build tools for projecting vegetation patterns or disturbances have been cumbersome to use, difficult to calibrate, or focused on particular disturbance agents. Few integrated, widely useful, and easy-to-use tools for projecting spatial vegetation and disturbance patterns across watersheds and larger areas exist.

The following summaries do not represent a complete review of all available tools. They are a starting point from which exploration of other possibilities might begin. Most or all of these are being used by vegetation managers or researchers working in eastern Oregon and Washington.

The Vegetation Development Dynamics Tool (VDDT) (ESSA Technologies Ltd., http://www.ssa.com/forestry/VDDT/index.htm) provides a modeling framework for examining the role of various disturbances on the composition and structure of vegetation patches (Beukema and Kurz 1995). It uses transition probabilities within vegetation strata to model the effects of disturbance and succession over time. Vegetation cover and structure combinations are projected by cell or pixel for variable numbers of cells and over user-specified time intervals. VDDT does not explicitly consider spatial contagion across cells.

The Tool for Exploratory Landscape Scenario Analyses (TELSA) is

> "a spatially explicit model of forest succession, natural disturbances, and forest management activities. It represents forest succession and the impacts of management and natural disturbances as changes in species composition and structural stages of stands. Diagrams developed with the Vegetation Dynamics Development Tool (VDDT) define the transition times between various succession classes (combinations of species composition and stand development stage) and the probabilities and impacts of disturbance by insects, fire or other agents. These diagrams also define the impacts of forest management actions on stand structure and composition. The area disturbed annually, and the size and types of disturbances respond to landscape changes from succession or management. Forest management, including salvage logging, is also defined by specifying which actions to schedule based on the condition of stands and of the landscape. TELSA includes an automated approach to designing management units based on user-specified criteria. It can therefore be used to assess alternative size ranges for management units and mixtures of management systems.

(TELSA, the tool for exploratory landscape scenario analyses, ESSA Technologies, Ltd., Vancouver, BC, http://www.essa.com/forestry/telsa/index.htm). TELSA incorporates spatial contagion and works at user-defined scales.

The Forest Vegetation Simulator (FVS) is the USDA Forest Service's nationally supported framework for growth and yield modeling at the stand scale (Crookston and Stage 1999). FVS simulates the growth and mortality of forests at the stand scale. It includes numerous disturbance and management activities in simulations. The Growth and Yield Unit of the Forest Management Service Center in Fort Collins, Colorado, developed, maintains, and supports FVS (USDA Forest Service, http://www.fs.fed.us/fmsc/fvs/). They provide FVS information, software, and related programs and training. "Suppose" (Crookston 1997) is the graphical user interface for FVS. Suppose runs under Windows 95/98/NT and Version 4 of AIX (IBM's version of Unix). Software is available on the Internet (USDA Forest Service, http://www.fs.fed.us/fmsc/fvs/suppose.htm).

The Stand Visualization System (SVS; R.J. McGaughey, USDA Forest Service, Pacific Northwest Research Station, at University of Washington, Seattle, http://faculty.washington.edu/mcgoy/) generates graphic images depicting stand conditions represented by a list of individual stand components, e.g., trees, shrubs, and down material generated by FVS. The images produced by SVS, while abstract, may provide a readily understood representation of stand conditions and help communicate silvicultural treatments and forest management alternatives to a variety of audiences.

The ecosystem management decision support (EMDS) system (Reynolds 1999a) and Netweaver for EDMS (Reynolds 1999b) allow the development of knowledge bases, formalizing knowledge gained and integration with geographic information systems. Methods in these systems are useful in a variety of situations, including vegetation condition, forest type suitability, et al. This tool can be calibrated for various scales and kinds of information.

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