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HISTORICAL FIRE FREQUENCY ON CONTRASTING SLOPE FACETS ALONG THE MCKENZIE RIVER, WESTERN OREGON CASCADES

Peter J. Weisberg[1]

ABSTRACT.—Fire has been a critical influence on forest dynamics over much of western North America, and knowledge of historical fire regimes provides a valuable reference point for guiding ecosystem management. Spatial and temporal variations in historical (1550–1997) fire frequency were quantified for a 145-km^2 area straddling the McKenzie River in the central western Cascades of Oregon. Fire-scar and tree-origin years estimated from cut stumps in 63 clearcut sites were used to approximately date fires. The estimated natural fire rotation was 162 years for the presettlement period (1550–1849). Natural fire rotation varied considerably over the period of record, ranging from 40 years for the Euro-American settlement period (1850–1924) to 504 years for the recent (1925–1997) fire-suppression period. Such temporal variation in fire regime may be attributed to a combination of climatic and anthropogenic influences. The study area also experienced 2 periods of widespread fire recorded at a majority of sample sites: one in the mid-1500s and the other from 1850 to 1925. Historical fire frequency has also varied spatially over at least 2 distinct scales. At the slope-facet scale, fire frequency was greatest on the generally south-facing slope to the north of the McKenzie River. At the finer scale of individual 4-ha sites, local topographic influences varied according to a site's broad geographical context north or south of the river. Results suggest that meaningful fire-regime characterization may require information derived from multiple spatial scales.

Key words: fire history, topographic effects, scale, riparian areas, fire and climate, natural fire rotation, Douglas-fir forests.

In the western United States, natural disturbance processes such as wildfire have been critical influences on forest succession and structure, from stand to landscape scales (Agee 1993). Retrospective studies of historical disturbances provide important reference points for understanding the range of structural conditions available for species habitat, nutrient cycling, and other ecological processes. Thus, reconstructions of historical fire regimes are useful for guiding ecosystem management over various forest types (Swetnam et al. 1999), including the Pacific Northwest (PNW) Douglas-fir forests (Cissel et al. 1999). Historical fire regimes have been mapped at a national level in an effort to identify areas where current conditions indicate the greatest need for forest restoration management, based on the degree to which fire suppression has altered fuel loads and fire regimes (Schmidt et al. 2002).

Most tree-ring-based fire-history studies in the westside PNW have been conducted for montane or subalpine forests (e.g., Hemstrom and Franklin 1982, Agee et al. 1990, Morrison and Swanson 1990, Agee 1991, Impara 1997, Weisberg 1998, Agee and Krusemark 2001). There has been a paucity of dendroecological studies at lower elevations and along the major rivers. Furthermore, the evidence of fire history is rapidly disappearing from such areas, many of which were among the earliest to be clearcut harvested. Sites that are currently on their second or third harvest rotations are not likely to include old trees with fire-scar evidence.

Fire history west of the Oregon Cascades has varied with elevation along an east-west gradient from the broad Willamette Valley to the Cascade Crest. Fires in the valley bottoms were historically frequent and associated with Native American land uses and cultural practices (Johannessen et al. 1971, Boyd 1986). The foothill and valley margin environments represent a transition zone between valley bottoms and montane forests, both climatically and in terms of human land use, pre- and post-settlement. Certain portions of the Willamette Valley foothills, including the Coburg Hills adjacent to the study area, experienced partial stand-replacing fires with mean return intervals of approximately 60 years (P.J. Weisberg unpublished data). In the more montane western

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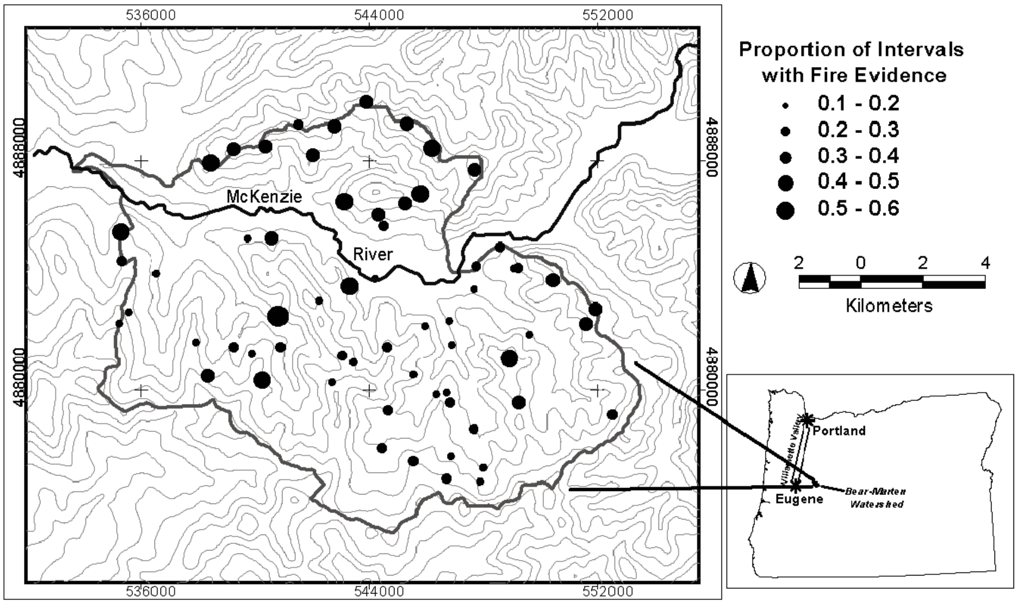


Fig. 1. Map of the study area, showing location of the McKenzie River, 100-m altitudinal contour intervals, and graticule in UTM units (zone 10). Sampled sites are shown with dot sizes proportional to fire frequency (i.e., proportion of 25-year intervals with fire evidence) over the 1550–1997 period.

Cascades, mean fire-return intervals for forests dominated by Douglas-fir and western hemlock averaged approximately 100 years (range 67–409 years), including fires of varying severity (Weisberg 1998). The area investigated in this study lies between the foothills of the Willamette Valley to the west and the more montane Cascades to the east.

Historical fire frequency in the Oregon Cascades and Coast Range has varied spatially with topography (Impara 1997, Weisberg 1998) and temporally in a pattern consistent with both climatic and anthropogenic influences (Berkley 2000, Weisberg and Swanson 2003). Heyerdahl et al. (2001) demonstrated for the Blue Mountains of eastern Washington and Oregon that spatial variation in historical fire regimes may best be understood when considered at multiple scales. Top-down controls (e.g., regional climate) on fire regime may be most apparent at coarse spatial scales, while bottom-up controls (e.g., local topography) may be most apparent at fine spatial scales.

This study describes a multiscale analysis of spatial and temporal variation in the fire history of a watershed along the margins of the McKenzie River, one of the major east–west-trending tributaries of the Willamette River. The goals are therefore to (1) describe how fire frequency has varied over the period of record (1550–1997) in ways that might be consistent with temporal changes in both climate and patterns of human ignition and suppression and (2) describe how past fire patterns of the study area have varied spatially in response to geographic and topographic features representing local (site-specific) and landscape (slope-facet) scales. A key question is addressed: at what scale does variation in topography and landforms influence fire frequency? The answer has important implications for how we generalize fire regime from a limited number of case studies to large, contiguous landscapes or regions.

METHODS

Study Area

The "Bear-Marten" study area includes the Bear Creek, Rough Creek, Marten Creek, Deer Creek, and Ennis Creek subdrainages and is located approximately 30 km east of

Eugene in the central western Oregon Cascades (Fig. 1). This 14,504-ha area is split by the McKenzie River and encompasses an altitudinal range from 228 to 1272 m. Mean annual precipitation is 106 cm, and mean annual temperature is 7.1 °C (Berkley 2000). Despite abundant annual precipitation, periods of extended drought commonly occur during the summer months. The combination of summer drought, east-wind events, and lightning storms leads to a favorable fire climate for the region in some years.

The study area lies within the western hemlock (*Tsuga heterophylla*) forest series, and Douglas-fir is the dominant tree species (Franklin and Dyrness 1988). Western hemlock, western redcedar (*Thuja plicata*), and incense-cedar (*Calocedrus decurrens*) are occasionally found. Bigleaf maple (*Acer macrophyllum*) and red alder (*Alnus rubra*) are common early-seral hardwoods. Some of the driest, low-elevation sites are occupied by plant communities in the Douglas-fir forest series where Douglas-fir is considered to be the dominant climax species. Other tree species present at the driest sites include incense-cedar, sugar pine (*Pinus lambertiana*), Pacific madrone (*Arbutus menziesii*), and giant chinquapin (*Castanopsis chrysophylla*).

Human activities may have played an important role in the fire history of the study area. Prior to Euro-American settlement, the Molala lived in this area, wintering along lower-elevation rivers and streams and moving upland during the summer to hunt, fish, and gather vegetable foods (Minor and Pecor 1977). The Kalapuya peoples, associated primarily with the Willamette Valley, may also have utilized the uplands of the Cascades for summer food-gathering (Minor and Pecor 1977). Native populations were decimated by a series of epidemics from 1782 (smallpox) to 1833 (malaria) resulting from contacts with early fur traders in neighboring areas (Mackey 1974). From the 1850s to 1893, when the Cascade Forest Reserve was set aside, the lower elevations of the study area were heavily utilized by successions of ranchers, farmers, homesteaders, and travelers, while upper elevations were utilized by local herders and miners (Burke 1979). The McKenzie Valley became a primary travel corridor through the Cascades. All of these activities have been (and still are) associated with a high incidence of anthropogenic fire. Today, various land ownerships are represented, including the Bureau of Land Management (BLM), the USDA Forest Service, and several private timber companies. Fire suppression has been effective in the study area since the early 1900s, due in part to a dense road network and historical fire lookout operations.

Field Methods

Fire-scar and tree-origin dates of primarily Douglas-fir trees were obtained from field counts on cut stumps in 63 clear-cuts (Fig. 1). Fire history is most efficiently sampled in clear-cuts in the central western Cascades because the dominant tree species, Douglas-fir, often survives fire with small scars, frequently associated with bark furrows, that heal completely within 5–20 years. Fire scars in standing Douglas-fir forests are difficult to locate and, once located, are difficult to date using tree-coring procedures. In clear-cuts, numerous trees can be efficiently examined for evidence of past fires.

In an effort to sample extensively over the entire study area, one randomly selected clear-cut was sampled in every township and range section where at least one recent (i.e., less than approximately 15 years old) clear-cut was available. Data were collected in 1995 and 1997. The township and range sections formed a contiguous grid of approximately 2.79-km^2 (1-mi^2) cells, although areas varied. Some portions of the study area were undersampled, including the higher elevations along the southern boundary and much of the area adjacent to the McKenzie River (Fig. 1). As a result of timber harvesting earlier in the century, these locations did not provide recent clear-cuts in nonharvested forest to sample. A total of 63 sites and 1561 trees were sampled, for an overall mean sampling density of 0.43 sites and 10.69 trees · km^{-2}.

All Douglas-fir tree stumps with fire-history evidence were sampled within two 0.1-ha plots located 200 m apart and along a 2-m-wide belt transect between the 2 plots. In addition, stumps with especially valuable fire-history evidence were searched for and sampled opportunistically. Areas searched in the different sites were variable but roughly comparable (2–5 ha), and it is likely that all fire-scar years present were sampled at each site.

Fire scars and tree origins were dated in the field by counting tree rings under appropriate magnification (using a 3X, 10X, or 16X hand lens) after preparing the stump surface with hand tools (scrapers and wire brushes). Stump surfaces were still rough after preparation, and it is likely that there were counting errors. For fire-scarred Douglas-fir trees in this region, field-counted scar years are likely to be within 10 years of their true values 75% of the time and within 20 years 87% of the time (Weisberg and Swanson 2001). To allow more accurate estimates for 12 of the 34 fire years (35%), cross sections were removed from 19 trees at 5 sites. These cross sections were sanded with progressively finer grades of sandpaper until cellular structure was clearly visible and then counted using appropriate magnification. There are likely counting errors for fire years determined from the prepared cross sections, since fire years were not cross-dated (Stokes and Smiley 1968). However, Weisberg and Swanson (2001) observed that for Douglas-fir trees in this region, the error associated with careful (but non-cross-dated) laboratory counts on well-prepared cross sections was small (mean error 1.5 years). Nonetheless, the imprecision of fire-year estimates from the field counts used in this study was likely significant. Therefore, the data were aggregated to an appropriate temporal resolution (25-year intervals) before analysis for spatial and temporal variability, as described below.

Fire episodes, which might represent single fires or multiple fires occurring closely in time and space, were dated using fire scars. Tree-origin years were used as corroborating evidence or to decide if a particular fire had also occurred where neighboring sites had scar evidence. The origin year was estimated by counting the number of tree rings from the pith to the most recent growth ring and subtracting this number from the harvest year. The average width of the first 3 rings was used to estimate tree age at stump height, according to empirical relationships developed for nearby Douglas-fir forests and given in Morrison and Swanson (1990). The origin-year estimate was then corrected by adding the estimated age of the tree at stump height.

Environmental Variables

The following environmental variables were obtained for each site and considered in all statistical analyses: elevation, aspect, slope steepness, and location north or south of the McKenzie River. Approximate site locations were digitized into the ARC/INFO geographical information systems (GIS) software, and elevation was obtained at 30-m resolution from a digital elevation model (DEM). Slope aspect was measured in the field. Subsequently, a cosine transformation was applied to convert slope aspect into a continuous variable representing the moisture gradient from drier southwest aspects (–1) to more moist northeast aspects (+1; Beers et al. 1966). Slope steepness (degrees) was estimated from the DEM.

Data Analysis

Since the non-cross-dated fire dates were likely imprecise, fire occurrence data were aggregated to an appropriate level of resolution prior to comparing fire history among time periods and according to spatially heterogeneous environmental variables. Following the analysis of Weisberg and Swanson (2001) for this same study area and other non-cross-dated fire-history studies in the region, 25-year intervals were used. To describe how fire regime has varied over the period of record (1550–1997), it was first necessary to estimate the area burned in each 25-year interval. This was estimated using a ratio method introduced by Morrison and Swanson (1990) and employed in several other studies (Taylor and Skinner 2003, Weisberg and Swanson 2003):

$$A_i = A(n_i / n - k_i)$$

where A_i is the estimated area burned in time period i ($1 \le i \le 24$), A is the study area size, n_i is the number of sites with a record of fire in time period i, n is the total number of sites in the study area, and k_i is the number of sites where the maximum tree age is less than $i \cdot 25$ years (i.e., sites where trees were not old enough to have recorded a fire in that time interval, had one occurred). The natural fire rotation (NFR), or the number of years required to burn an area equal in size to the study area (Heinselman 1973), was calculated using the estimated burned areas. This approach to estimating NFR assumes a completely randomized sampling scheme; thus, the NFR estimates may be biased due to lack of recent clear-cuts for sampling at the higher elevations and immediately adjacent to the McKenzie River. However, clear-cuts were generally abundant and evenly distributed throughout the

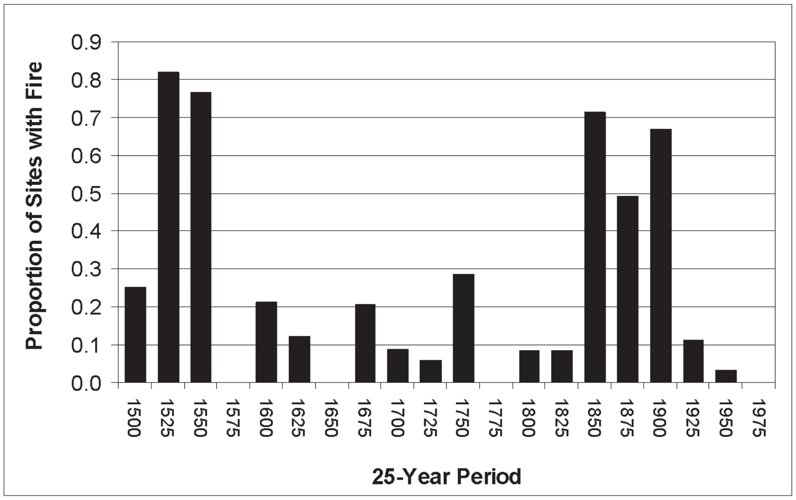


Fig. 2. The proportion of sites recording fire for each 25-year time period from 1500 to 1997, only considering sites with trees old enough to have recorded fire over that time period. Years labeled on the x-axis refer to the earlier endpoint of each 25-year interval.

remainder of the study area, and our NFR estimates are likely to be broadly representative.

The NFR was calculated for the entire period of record, as well as for the presettlement (1550–1849), settlement (1850–1924), and fire-suppression (1925–1997) periods. Temporal variation in fire history was then assessed in 2 ways: (1) using the NFR calculations for the 3 time periods reflecting different potential human influences and (2) directly plotting the proportion of sites burned against 25-year periods of time to identify periods of widespread versus infrequent fire. Although a longer period of record (1500–1997) was used for the graphical approach, the period of record used for the NFR calculation extended back only to 1550 because of a relatively small number of sample sites with trees predating that year.

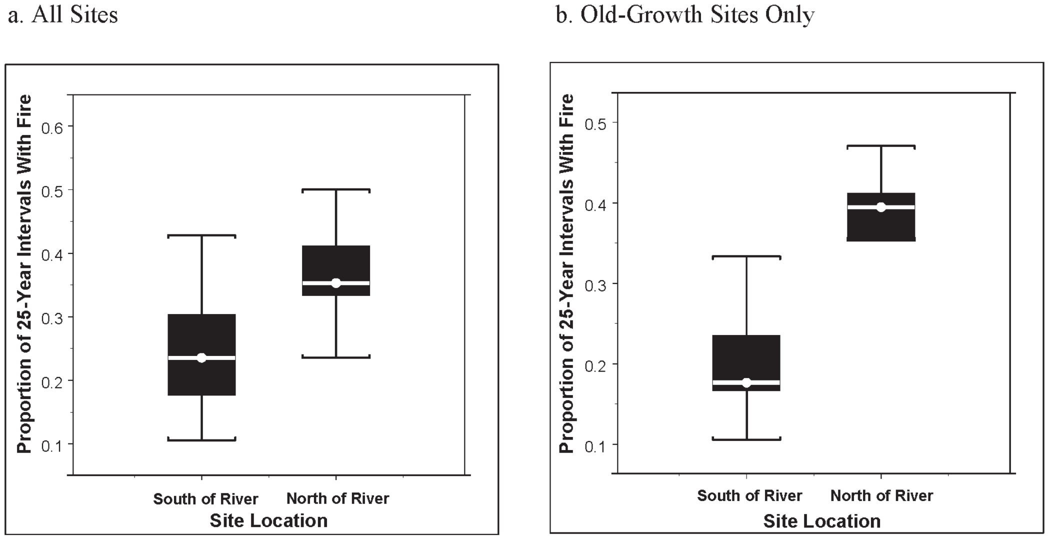
For quantifying spatial patterns of historical fire frequency, the response variable calculated for each site was the proportion of 25-year intervals within the period of record for which fire evidence was recorded. The period of record is the time frame extending from the time of harvest back to the origin year of the oldest tree sampled at each site. The proportion of 25-year intervals (i.e., fire frequency) was normalized using an arcsine square-root transformation, as is commonly applied to proportional data prior to statistical analysis (Zar 1999, p. 278). All analyses were conducted using S-PLUS software (Version 6.2.1, Insightful, Inc., 2003).

Following Heyerdahl et al. (2001), spatial variation in fire frequency was analyzed at 2 spatial scales. By splitting the study area at the McKenzie River, 2 distinct slope facets, or areas of relatively homogeneous slope and aspect, were delineated (Fig. 1; Daly et al. 1994). Fire frequency was compared north and south of the river using a Welch's modified 2-sample *t* test, accounting for unequal variances. Given that there were differences observed at the slope-facet level, correlations between historical fire frequency and local topographic variables (elevation, local aspect, and slope steepness) were evaluated separately for north- and south-facing slope facets using Spearman's rank correlation coefficients.

RESULTS

Temporal Changes in Fire Regime

Fire frequency has been quite variable over the period of tree-ring record, even when the record was aggregated to 25-year intervals. The study area has undergone 2 periods of widespread fire recorded at a majority of sites: one in the mid-1500s and the other from roughly 1850 to 1925 (Fig. 2). An estimated 82% of sampled sites burned at least once from 1525 to 1550, and 77% burned at least once during the time



a. All Sites

b. Old-Growth Sites Only

Fig. 3. Box plots showing distributions of fire frequency (i.e., proportion of 25-year intervals recording fire) for sites north and south of the McKenzie River. Solid boxes show the interquartile range (IQR) of data values, horizontal white lines show median values, and whiskers (vertical lines) show the range of values within 1.5 IQR of the box: 3a, all 63 sites; 3b, all 35 old-growth sites, with oldest trees dating prior to 1800.

period immediately following, 1550–1575. Most of the sampled stands date to these earlier periods, making it difficult to reconstruct earlier fire history using tree-ring-based methods.

Fire was recorded relatively infrequently from ca. 1575 to 1850, although >20% of sites burned during the 1600–1625, 1675–1700, and 1750–1775 periods (Fig. 2). Starting ca. 1850, another period of widespread fire began, which lasted approximately 75 years. Since ca. 1925, the Bear-Marten study area has experienced a very low proportion of sites burned. The 1975–1997 period was one of only 4 (approximately) 25-year time periods since 1525 during which no fires were recorded.

Given the estimates of area burned that were calculated using the ratio method (Eq. 1), natural fire rotation was calculated for various time periods. The NFR was 116 years over the period of record (1500–1997), implying that an area the size of the study area has burned every 116 years on average, although some portions may have burned multiple times and others not at all. However, as Fig. 2 shows, fire frequency has varied widely over time. The estimated NFR was 162 years for the presettlement period (1500–1849), 40 years for the period of Euro-American settlement (1850– 1924), and 504 years for the recent fire-suppression period (1925–1997). These NFR values are likely overestimates (i.e., fire frequency is underestimated) since multiple fires (i.e., "reburns") may have occurred within the broad time span of each 25-year interval used in this study.

Spatial Variability in Fire Frequency

Fire frequency over the entire period of record differed significantly depending upon whether a site was located north or south of the McKenzie River ($t = -4.95$, df = 36, $P < 0.001$; Fig. 1). Mean fire frequency, reported as the proportion of 25-year intervals recording fire, was 0.25 south of the river (95% CI 0.22–0.28) compared to 0.37 north of the river (95% CI 0.33–0.42). The differences between north and south portions of the study area were slightly greater when only sites with old-growth Douglas-fir trees (i.e., trees with origin years prior to 1800) were considered (Fig. 3). For the 36 sites that met this criterion, mean fire frequency was 0.20 south of the river (95% CI 0.18–0.22) compared to 0.38 north of the river (95% CI 0.29–0.46). Old-growth sites therefore had lower fire frequency south of the river than sites without old-growth because the period of record for old-growth sites was more likely to include time periods without fire. The relatively limited fires of the 1600s and 1700s (Fig. 2) burned a greater proportion of the area north of the river.

Fire frequency was only weakly correlated with local topography and with different slope facets reflecting the location of sites north or south of the McKenzie River. North of the river, fires were more frequent on drier (i.e., more southwesterly) slope aspects ($r = -0.81$ with northeastness, $P < 0.01$). None of the other variables were significantly associated with fire frequency for sites north of the river. For sites located south of the river, the only significant correlation between fire frequency and topography was a weakly positive association with slope steepness ($r = 0.31$, $P < 0.05$).

DISCUSSION

Anthropogenic and Climatic Influences on Fire Regime

The 2 periods of widespread fire observed in this study (mid-1500s and 1850–1925; Fig. 2) correspond to roughly synchronous patterns of fire occurrence throughout the Oregon Cascades and Coast Range (Weisberg and Swanson 2003). This pattern is best explained by a combination of climatic and anthropogenic influences (reviewed in Weisberg and Swanson 2003). Both periods have been associated with relatively warm temperatures (e.g., Graumlich and Brubaker 1986). Archival sources indicate that 1868 and 1902 were major regional fire years (Morris 1934); these correspond to 2 of the nineteenth-century spikes in Fig. 2.

The fire regime of the study area may have been especially sensitive to patterns of human settlement and use since the area is bisected by the McKenzie River, a primary travel corridor through the Cascades. The latter widespread-fire period is associated with Euro-American settlement, which began in the McKenzie Valley by the mid-1840s, following a period when native Molalla populations had been decimated (Burke 1979). Homesteading and logging practices associated with Euro-American settlement would be expected to increase fire frequency, and fire events of the historical record have indeed been strongly associated with Euro-American travel corridors (Burke 1979) and may have been linked to the travel corridors of native peoples in earlier times.

It is impossible to separate climatic from human influences on fire regime using only the results of this study. However, patterns of infrequent small fires in the mid- to late 1900s are associated with a period of relatively warm climate and are almost certainly the result of effective fire suppression by Euro-Americans.

Scale-Dependency of Topographic Influences on Fire Regime

Fire frequency is expected to vary according to elevation and slope aspect, which in turn influence fuel loading, moisture, and continuity (Agee 1993). However, topographic and landform influences may be less important for fires of greater intensity and severity, where the influence of weather may outweigh that of fuels (Turner and Romme 1994, Bessie and Johnson 1995). Additionally, while many fire-history studies explicitly address the potential influences of topographic variables on fire regime parameters, topographic variables are usually of a local scale, and few studies consider multiple scales of investigation, as does Heyerdahl et al. (2001). The relevant spatial scales at which topography influences fire frequency are therefore poorly known. This study considered spatial variation in fire frequency at the scale of both slope facet (i.e., north and south of the McKenzie River) and local topography (i.e., individual 2–5-ha sites).

At the slope-facet scale, fire frequency was greater on the generally south-facing slopes to the north of the river. This distinction makes sense in terms of known environmental effects on fuel conditions and fire behavior. More mesic slope aspects should have moister fuels and hence a shorter fire season, resulting in lower fire frequency. Perhaps fire responds to spatial variation in fuel moistures over broad slope-facet scales such as this. Lower fire frequency for more mesic aspects, or for forest community types associated with more mesic aspects, has been reported for other study areas in western North America, including the nearby Blue River watershed (Weisberg 1998), the northern Washington Cascades (Agee et al. 1990), the southern Oregon Cascades (VanNorman 1998), and southern British Columbia (Heyerdahl et al. 2007). However, no relationship between fire frequency and slope aspect was found for study areas of lower overall topographic relief in the Oregon Coast Range (Impara 1997) and the northern Oregon Cascades (Garza 1995).

It is also possible that the south-facing slope facet has experienced more frequent fires because it is open to the dominant lightning-storm track patterns (i.e., trending from the southwest) or because its east-bounding ridge is the first major topographic barrier that would obstruct east-wind-driven fire events channeled through the McKenzie Valley from the east. East of the study area, the McKenzie Valley is fairly broad. Near the eastern boundary, where a major tributary (Quartz Creek) flows into the McKenzie River, the river valley becomes more confined and meanders sharply to the south. Desiccating downslope east-wind events, occurring mainly in the late summer and early autumn after periods of drought, have been linked to high-severity, widespread fires in the region (Teensma 1987, Agee 1993).

Local topography also significantly influenced fire frequency at the scale of individual sites. However, these differences varied depending on whether the site was located north or south of the river. North of the river, fire frequency was greater on drier aspects. Drier aspects north of the river often hosted vegetation in the Douglas-fir forest series, which have been observed to burn more frequently than more mesic sites in the western hemlock series (Means 1982). Slope-aspect effects were unimportant south of the river, perhaps because fewer sites hosted Douglas-fir-series vegetation.

Regardless of location, steeper slopes have greater preheating of fuels during surface-fire spread, hence faster rates of spread and greater fireline intensities (Rothermel 1983). Thus, it might be expected that this effect would lead to steeper slopes experiencing greater fire severity than, but similar fire frequency as, sites of gentler slope (Heyerdahl et al. 2001). However, the only significant influence of local topography on fire frequency for sites south of the river was actually a weakly positive association of fire frequency with slope steepness.

There was no relationship between fire frequency and elevation (perhaps because the altitudinal range of the study area was limited) without areas of persistent winter snowpack or thin-barked, hence fire-susceptible, *Abies* forest. Decreasing fire frequency with increasing elevation has been observed for many areas in western Oregon and western Washington, including Crater Lake National Park (McNeil and Zobel 1980), the Little River watershed in the southern Oregon Cascades (VanNorman 1998), the northern Oregon Cascades (Garza 1995), Desolation Peak in the Washington Cascades (Agee et al. 1990), and the neighboring Blue River watershed in the central western Oregon Cascades (Morrison and Swanson 1990, Weisberg 1998). However, the reverse trend of greater fire frequency at higher elevations has also been observed for the Oregon Cascades (Teensma 1987, Agee and Krusemark 2001).

These results emphasize the multiscale nature of interactions between fire and landscape. There is no single correct scale for understanding the relationships between fire and topography because the nature and direction of topographic influences on fire regime vary depending upon the spatial scale considered. Just as specifying the spatial resolution of investigation is critical for quantifying fire-regime descriptors, such as mean fire-return interval (Arno and Peterson 1983), it is also essential to explicitly consider the scale-dependent nature of topographic influences on fire regime. There is a need for multiscale studies of landscape factors that influence fire regime. These studies should consider not only the relative importance of local versus regional influences (e.g., Heyerdahl et al. 2001) but also topographic effects along a broad continuum of scales. This study suggests that, in the case of the Bear-Marten study area, topographic variation in fire regime may be more strongly manifested at coarser scales represented by slope facets rather than at site-specific scales of one to a few hectares.

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LITERATURE CITED

AGEE, J.K. 1991. Fire history along an elevational gradient in the Siskiyou Mountains, Oregon. Northwest Science 65:188–199.

______. 1993. Fire ecology of Pacific Northwest forests. Island Press, Washington, DC.

AGEE, J.K., M. FINNEY, AND R. DE GOUVENAIN. 1990. Forest fire history of Desolation Peak, Washington. Canadian Journal of Forest Research 20:350–356.

AGEE, J.K., AND F. KRUSEMARK. 2001. Forest fire regime of the Bull Run Watershed, Oregon. Northwest Science 75:292–306.

ARNO, S.F., AND T.D. PETERSEN. 1983. Variation in estimates of fire intervals: a closer look at fire history on the Bitterroot National Forest. Research Paper INT-301, USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

BEERS, T.W., P.E. DRESS, AND L.C. WENSEL. 1966. Aspect transformation in site productivity research. Journal of Forestry 64:691–692.

BERKLEY, E.L. 2000. Temporal and spatial variability of fire occurrence in western Oregon, A.D. 1200 to present. Master's thesis, University of Oregon, Eugene. 110 pp.

BESSIE, W.C., AND E.A. JOHNSON. 1995. The relative importance of fuels and weather on fire behavior in subalpine forests. Ecology 76:747–762.

BOYD, R. 1986. Strategies of Indian burning in the Willamette Valley. Canadian Journal of Anthropology 5:65–86.

BURKE, C.J. 1979. Historic fires in the central western Cascades, Oregon. Master's thesis, Oregon State University, Corvallis.

CISSEL, J.H., F.J. SWANSON, AND P.J. WEISBERG. 1999. Landscape management using historical fire regimes: Blue River, Oregon. Ecological Applications 9:1217–1231.

DALY, C., N.P. NEILSON, AND D.L. PHILLIPS. 1994. A statistical-topographic model for mapping climatological precipitation over mountainous terrain. Journal of Applied Meteorology 33:140–158.

FRANKLIN, J.F., AND C.T. DYRNESS. 1988. Natural vegetation of Oregon and Washington. Oregon State University Press, Corvallis.

GARZA, E.S. 1995. Fire history and fire regimes of East Humbug and Scorpion creeks and their relation to the range of *Pinus lambertiana* Dougl. Master's thesis, Oregon State University, Corvallis.

GRAUMLICH, L.J., AND L.B. BRUBAKER. 1986. Reconstruction of annual temperature (1590–1979) for Longmire, Washington, derived from tree rings. Quaternary Research 25:223–234.

HEINSELMAN, M.L. 1973. Fire in the virgin forests of the Boundary Waters Canoe Area, Minnesota. Quaternary Research 3:329–382.

HEMSTROM, M.A., AND J.F. FRANKLIN. 1982. Fire and other disturbances of the forests in Mount Rainier National Park. Quaternary Research 18:32–51.

HEYERDAHL, E.K., L.B. BRUBAKER, AND J.K. AGEE. 2001. Spatial controls of historical fire regimes: a multiscale example from the interior West, USA. Ecology 82:660–678.

HEYERDAHL, E.K., K. LERTZMAN, AND S. KARPUK. 2007. Local-scale controls of a low-severity fire regime (1750–1950), southern British Columbia, Canada. Ecoscience 14:40–47.

IMPARA, P.C. 1997. Spatial and temporal patterns of fire in the forests of the central Oregon Coast Range. Doctoral dissertation, Oregon State University, Corvallis.

JOHANNESSEN, C.J., W.A. DAVENPORT, A. MILLET, AND S. MCWILLIAMS. 1971. The vegetation of the Willamette Valley. Annals of the Association of American Geographers 61:286–302.

MACKEY, H. 1974. The Kalapuyans: a sourcebook on the Indians of the Willamette Valley. Mission Mill Museum Association, Inc., Salem, OR.

MCNEIL, R.C., AND D.B. ZOBEL. 1980. Vegetation and fire history of a ponderosa pine–white fir forest in Crater Lake National Park. Northwest Science 54:30–46.

MEANS, J.E. 1982. Developmental history of dry coniferous forests in the central western Cascade Range of Oregon. Pages 142–158 *in* J.E. Means, editor, Forest succession and stand development research in the Northwest: Proceedings of a symposium, Oregon State University, Corvallis.

MINOR, R., AND A.F. PECOR. 1977. Cultural resource overview of the Willamette National Forest. University of Oregon Anthropological Papers No. 12, Eugene.

MORRIS, W.G. 1934. Forest fires in western Oregon and western Washington. Oregon Historical Quarterly 35:313–339.

MORRISON, P.H., AND F.J. SWANSON. 1990. Fire history and pattern in a Cascade Range landscape. General Technical Report PNW-GTR-254, USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

ROTHERMEL, R.C. 1983. How to predict the spread and intensity of forest and range fires. General Technical Report INT-143, USDA Forest Service.

SCHMIDT, K.M., J.P. MENAKIS, C.C. HARDY, W.J. HANN, AND D.L. BUNNELL. 2002. Development of coarse-scale spatial data for wildland fire and fuel management. General Technical Report RMRS-GTR-87, USDA Forest Service, Rocky Mountain Research Station, Missoula, MT.

STOKES, M.A., AND T.L. SMILEY. 1968. An introduction to tree-ring dating. University of Chicago Press, Chicago, IL.

SWETNAM, T.W., C.D. ALLEN, AND J.L. BETANCOURT. 1999. Applied historical ecology: using the past to manage for the future. Ecological Applications 9:1189–1206.

TAYLOR, A.H., AND C.N. SKINNER. 2003. Spatial patterns and controls on historical fire regimes and forest structure in the Klamath Mountains. Ecological Applications 13:704–719.

TEENSMA, P.D.A. 1987. Fire history and fire regimes of the central western Cascades of Oregon. Doctoral dissertation, University of Oregon, Eugene.

TURNER, M.G., AND W.H. ROMME. 1994. Landscape dynamics in crown fire ecosystems. Landscape Ecology 9:59–77.

VANNORMAN, K. 1998. Historical fire regime in the Little River watershed, southwestern Oregon. Master's thesis, Oregon State University, Corvallis.

WEISBERG, P.J. 1998. Fire history, fire regimes, and development of forest structure in the central western Oregon Cascades. Doctoral dissertation, Oregon State University, Corvallis.

WEISBERG, P.J., AND F.J. SWANSON. 2001. Fire dating from tree rings in western Cascades Douglas-fir forests: an error analysis. Northwest Science 75:145–156.

_____. 2003. Regional synchroneity in fire regimes of western Oregon and Washington, USA. Forest Ecology and Management 172:17–28.

ZAR, J.H. 1999. Biostatistical analysis. 4th edition. Prentice Hall, Inc., Upper Saddle River, NJ.

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