Linking Vegetation Patterns to Potential Smoke Production and Fire Hazard[1]

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During the past 80 years, various disturbances (such as wildfire and wind events) and management actions (including fire exclusion, logging, and domestic livestock grazing) have significantly modified the composition and structure of forests and ranges across the western United States. The resulting fuel loadings directly influence potential smoke production from wildland and prescribed fires and affect the vulnerability of landscapes to extreme fire behavior and crown fires. Assessments of potential smoke production and tradeoffs in air quality and fire hazard relative to managed fire and wildfire during large landscape assessments are essential to inform stakeholders involved in landscape-level decision making.

Little information is available on how shifts in forest and range composition and structure over time have changed fuel accumulation on landscapes or affected the associated fire vulnerability and smoke production. The analysis of current and recent (historical) aerial photographs for the *Eastside Forest Health Assessment* (Huff and others 1995) represented an initial attempt to compare potential fire behavior and smoke production in historical and current time periods, based on the comparison of vegetative conditions in 49 watersheds in eastern Oregon and Washington. However, this methodology was designed for forested landscapes and had limited application to other types of landscapes in the West.

We developed a more general method to compare fuel loading, modeled fuel consumption, smoke production, fire behavior, and susceptibility to crown fire in recent historical versus current time periods, on the basis of attributes of vegetation at a variety of spatial scales. Vegetation cover, structure, and management disturbance features were delineated from recent historical and current aerial photography. These features were matched to one of 192 fuel characteristic classes and assigned fuel loadings (Ottmar and others 2001, Schaaf 1996). The fuel loadings were then coupled with typical wildfire and prescribed fire fuel moisture scenarios and entered into fuel consumption models Consume 2.1 (Ottmar and others 2001) and FOFEM 4.0 (Reinhardt and others 1997) to predict fuel consumption and smoke emissions. Finally, the surface fire behavior and crown fire susceptibility of each vegetation patch was modeled using various fire models, such as NFDRS (Deeming and others 1977), other published hazard models (Fahnestock 1970, Rothermel 1972), fuel characteristics, and weather scenarios typical of wildfire and crown fire situations. The changes in area and connectivity of fuel loading, smoke production, and fire hazard could then be quantitatively assessed over time (McGarigal and Marks 1995).

This method was used for the mid-scale assessment of the Interior Columbia River Basin Ecosystem Management Project. The study compared fuel loadings, modeled fuel

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consumption, smoke production, fire behavior, and crown fire potential in historical and current time periods, based on vegetative attributes of 337 subwatersheds (average size: 9,500 ha [23,475 acres]) distributed in 43 sampled subbasins (average size: 404,000 ha [998,324 acres] average size) selected by random draw from all public and private ownerships within the interior Columbia River drainage and portions of the Klamath and Great Basins. Vegetation cover, structure, and management disturbance features were delineated from historical (1930s to 1960s) and current (1985 through 1993) aerial photography of the sampled subwatersheds. Results of the statistical change analysis were reported at four scales, including the entire Interior Columbia River Basin, the 13 province-scale ecological reporting units (ERUs), subbasins, and selected subwatersheds.

The Interior Columbia River Basin as a whole showed a small but significant increase in fuel loading, wildfire fuel consumption, smoke production of particulate matter less than 10 microns in diameter (PM_{10}), fire line intensity, rate of spread, flame length, and crown fire potential during the past 80 years. Fuel loading increased over the sample period in 8 of the 13 ERUs. In general, an increase in fuel loading was positively correlated with forest vegetation composition shifts from open patches of mid-seral species such as ponderosa pine and western larch to dense patches of mixed coniferous forests. Increased fuel loading was responsible for increases in smoke production, fire behavior parameters, and vulnerability to crown fires. Decreased fuel loading was positively correlated with the occurrence of recent wildfires or harvest activities that had been followed by fuels treatment. Decreases in fuel loading were generally responsible for declines in wildfire smoke, fire behavior parameters, and vulnerability to crown fires. Under current conditions, potential PM_{10} smoke production from a wildfire was two to four times the amount from a prescribed fire.

At the smaller scale, individual subwatersheds generally displayed much greater changes over time than were apparent at the much larger ERU scale. Change at the subwatershed scale was typically related to disturbances such as wildfires or management actions. For example, the Upper Coeur d'Alene #0501 Subwatershed displayed a large increase in fuel loading over time, with a correspondingly large increase in modeled smoke production, fire behavior, and crown fire vulnerability. Major wildfires in 1910 burned a majority of this subwatershed, and as a result, stands of grand fir and Douglas-fir were initiated during the 1920s and 1930s. Under a fire exclusion policy, forests matured into predominantly understory reinitiation structures, resulting in the noted fuel loading increases *(figs. 1–4)*.

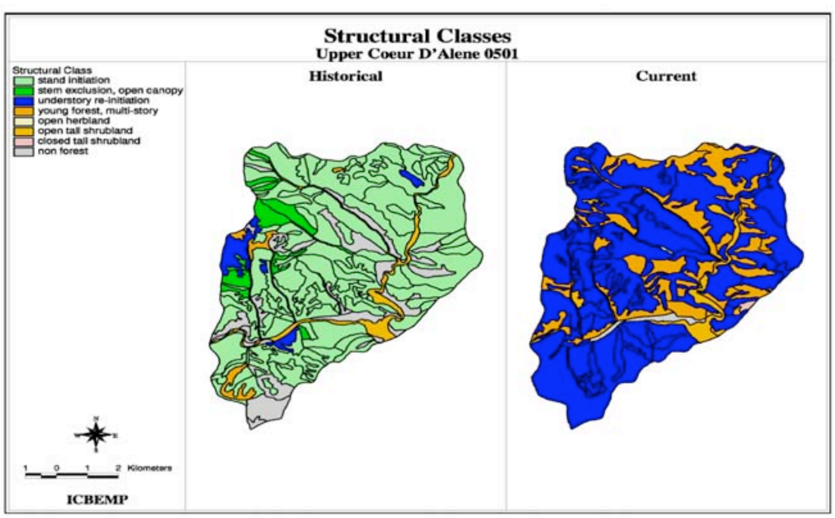

Figure 1— Historical and current structural classes for the Upper Coeur D'Alene #0501 Subwatershed in the mid-scale assessment of the Interior Columbia River Basin.

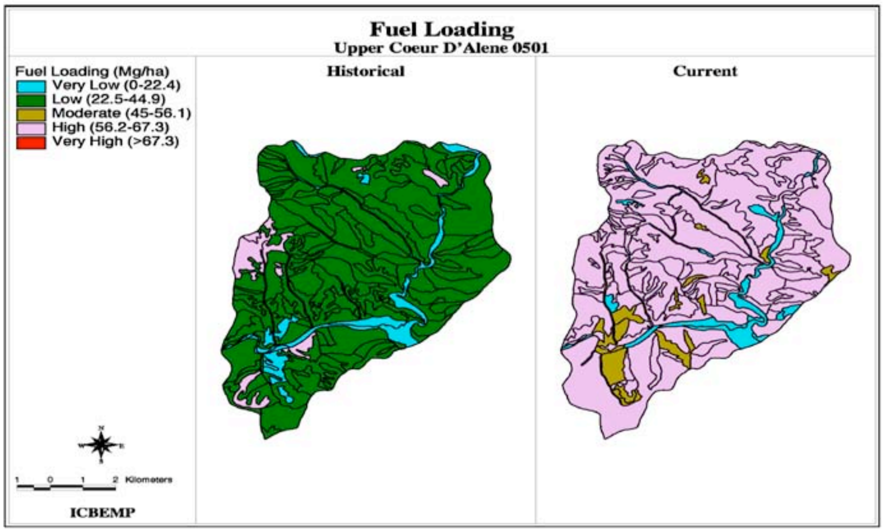

Figure 2— Historical and current fuel loading classes for the Upper Coeur D'Alene #0501Subwatershed in the mid-scale assessment of the Interior Columbia River Basin.

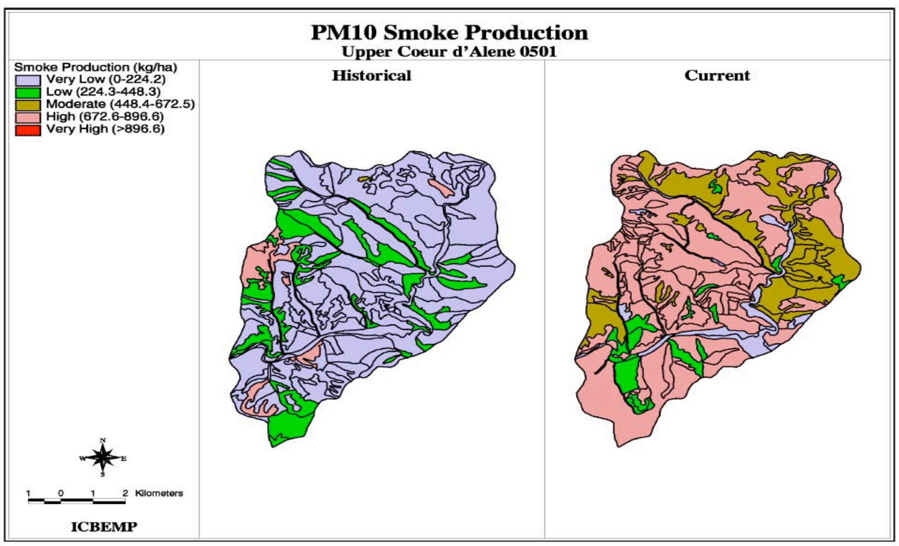

Figure 3— Historical and current potential PM_{10} smoke production classes for the Upper Coeur D'Alene #0501 Subwatershed in the mid-scale assessment of the Interior Columbia River Basin.

Our general landscape pattern analysis also indicated that changes in fuels, smoke, and potential fire behavior had occurred between the two time periods we examined. Overall, there was an increase in the size and continuity of areas with higher fuel loading, fire line intensity, crown fire susceptibility, rate of spread, and flame length, indicating a higher potential on current landscapes for large, continuous wildfires that produce substantial amounts of smoke.

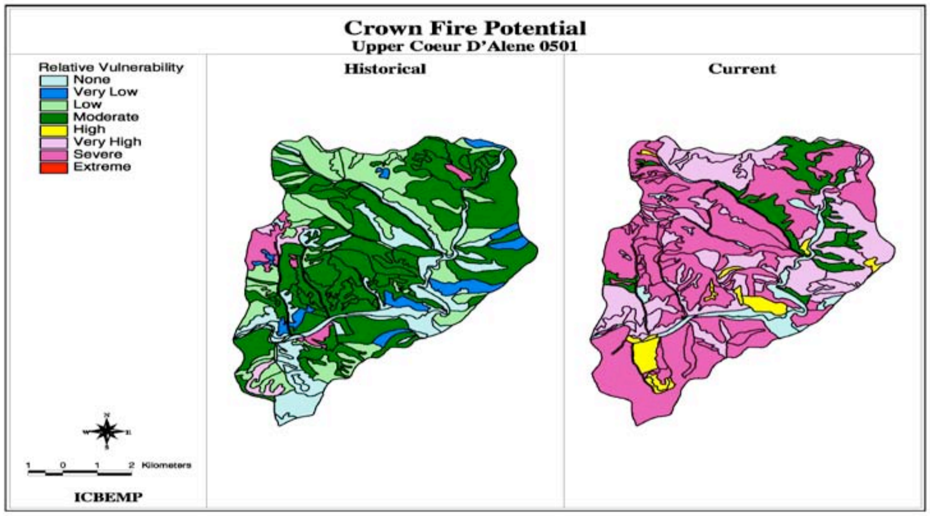

Figure 4— Historical and current crown fire potential classes for the Upper Coeur D'Alene #0501 Subwatershed in the mid-scale assessment of the Interior Columbia River Basin.

Since the early 1900s, human activities such as logging and fire exclusion policies, along with natural disturbances, have significantly changed the spatial distribution and composition of forests and rangelands of the western United States. Understanding changes in vegetation patterns and how these changes will affect the likelihood and outcomes of further natural disturbances and human activities will inform managers and policy makers addressing fire-related problems and decisions.

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