PROGRESS IN REDUCING EMISSIONS FROM PRESCRIBED FOREST BURNING IN WESTERN WASHINGTON AND WESTERN OREGON

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Forest managers, before the visibility protection revisisions to the State Implementation Plan in either Washington or Oregon are adopted, have implemented practices that reduce emissions from prescribed fire by at least 30 percent, compared with the baseline period 1976-1979. The practices were developed through a cooperative effort of forest managers and air-rescurce managers. Emission reduction allows forest managers to retain a practice needed to regenerate forests and prevent wildfires while providing effective and necessary air quality. These reductions have become an important part of the strategy in Washington and Oregon to protect visibility in National Parks and Wilderness.

In this paper, I describe progress in reducing emissions in western Washington and western Oregon and include a projection for future improvement.

Quantitative goals for reducing emissions from prescribed fire are a new air-resource management tool. In the last decade, many states followed the lead of Washington and Oregon in developing cooperative smoke-management programs and scheduled prescribed fires to take advantage of meteorological conditions that would not have an impact on areas sensitive to smoke or that would dilute the smoke to acceptable concentrations. Now, Washington and Oregon States are the first to agree on targets for reducing emissions from prescribed fire: by 35 percent in Washington by 1990, and by 50 percent in Oregon by 2000 (relative to the 1976-1979 baseline.)

Before 1980, the assumption was that emissions could be reduced only by limiting the area treated by prescribed fire. That misconception put forest managers, convinced of the necessity of fire to maintain productivity in Northwest forests, in conflict with air-resource managers convinced of the necessity for source control measures to improve air quality. Realization that improved harvesting and burning techniques can achieve both objectives has promoted cooperative efforts to reduce emissions.

Cooperative Research Efforts Are More Efficient

Air-quality and smoke-management research has been a cooperative effort in the Northwest. The forest industry and public agencies find joint projects on research efficient for agreeing on key questions and sharing the answers. The USDA Forest Service Fire and Air Resource Management Research Work Unit in

Seattle, which I represent, has current studies in conjunction with the Environmental Protection Agency, Oregon Department of Environmental Quality, and Washington Department of Ecology; the USDA Forest Service, Pacific Northwest Region; several National Forests in Washington, Oregon, and California; the U.S. Department of the Interior, Bureau of Land Management; the U.S. Department of Energy, Bonneville Power Administration; the U.S. Department of Defense, Defense Nuclear Agency; the Oregon Department of Forestry; several private timber companies; four universities; and several consulting groups.

A New Emission-Inventory System Is Operational

A companion paper[1/] reports on a new emission-inventory system for prescribed burning that is already in use. The inventory system, first proposed by Sandberg and Peterson (1985), is based on combustion models. The system records individual burn parameters from several thousand burns per year, and uses the parameters to predict biomass consumption and combustion efficiency. Emission estimates are based on consumption algorithms and emission factors documented in the scientific literature (Ottmar 1987; Ward and Hardy 1984;

[1/] Peterson, Janice L. and Sandberg, D. V. "Analysis and reduction of errors of using inference modeling to predict prescribed burn emissions." Presented to: Annual meeting, Pacific Northwest International Section, Air Pollution Control Association. 1986 November 19-21, Eugene, OR.

Sandberg 1985). Duff consumption, which contributes about one-half the total emissions, is included for the first time. We no longer rely on foresters' subjective estimates of biomass consumption. The system can be easily modified as new research is completed to sharpen the algorithms. Sources of error and bias in the inventory system are perodically anlayzed to target future research.

Techniques that reduce emissions are explicitly recorded in the emission-inventory system, so that both the amount of improvement and the means of improvement are revealed. Factors such as residue utilization and fire meteorology have been surveyed periodically, and other factors such as ignition method and acres treated have been reported annually by the Washington Department of Natural Resources (Carnine 1984) and Oregon State Department of Forestry (1985). In 1987, the Smoke Management Reporting System in Oregon will collect all of the inputs to consumption algorithms from every burn permittee. Eventually, this system will inventory daily emissions, track progress toward emission-reduction goals, and project seasonal burn activity and emission yield to air-resource managers.

Annual reviews of progress in reducing emissions by the new inventory system will allow factual and productive discussion about the success of air-resource management strategies. The forest industry is now clearly a target for criticism or praise, depending on how well the goal is achieved.

Emission-Reduction Baseline

The average annual emission from 1976 through 1979 is the baseline value from which progress is measured toward emission-reduction goals. The period is a logical baseline because a regional assessment of preburn woody biomass was completed then (Howard 1981), so a more accurate emission inventory is possible for that period than for any other period. Also, emission-reduction techniques have been used increasingly since they were first used in 1980, so a baseline period of later years would ignore progress already made.

Total suspended particulate (TSP) emissions from slash burning during the baseline period averaged 77,000 tons per year in western Oregon and 40,000 tons per year in western Washington. Because of the biomass assessment (Howard 1981) and the availability of fire-weather records (Furman and Helfman 1973) for the period, the average biomass consumption can be established at 60 tons per acre in Oregon and 58 tons per acre in Washington. The estimates are subject to a residual error of ±5 percent, mainly because of uncertainty in the estimates of organic soil-layer thickness and the effectiveness of mass ignition in reducing emissions.

Emissions Were Reduced By 30 Percent By 1984 (Relative to the 1978-1979 Baseline)

In 1984, TSP emissions from slash burning are estimated to have been 56,000 tons in western Oregon and 28,000 tons in western Washington (Table 1).

Table 1.--Slash-burning emission inventory for western Washington and western Oregon for 1984 and the baseline period 1976-1979, with emission reduction during the period attributed to specific methods of emission reduction.

PARTICULATE (TSP) EMISSION	WASHINGTON	OREGON
	Tons/Year	
1976 through 1979 (baseline)	77300	39900
1984	55800	28100
REDUCTION	21500	11800
	Percent of baseline value	
TOTAL REDUCTION	-28	-30
REDUCTION ATTRIBUTED TO CHANGES IN:		
Acres burned	-4	+12
Shift from public to private burning	-7	-14
Mass ignition	-2	-5
Increased fuel moisture	-4	-4
Increased wood utilization	-16	-20

Biomass consumption averaged 44 and 37 tons per acre in the two states. The estimates are subject to residual error of ±28 percent, mainly because of the lack of a recent region-wide biomass assessment.

Increased utilization of logging residues appears to be the primary reason for reduced emissions in 1984. Forest utilization continues to improve, and less material is left to be consumed by prescribed fire. The increased effort to market residues (in part because of the increased value placed on air quality) reported by Berg (1985) improved forest utilization during the early 1980's, even while the timber industry suffered a severe recession.

Utilization is singly responsible for a 16-percent reduction in emissions in Oregon and 20 percent in Washington since the baseline period. Preliminary results from current research seem to confirm that 38 percent less large (greater than 3-inch diameter) woody residue was left after timber harvesting in 1984.[2/] Most of the increased utilization removes the largest residue pieces, so the remaining residue is smaller and more completely consumed by fire. Consumption of large woody residues is thought to have decreased by 25 percent, smaller (less than 3-inch diameter) residues by 32 percent, and duff (organic soil) layer by 27 percent (Figure 1).

[2/] Sandberg, D.V.; Ottmar, R.D.; and others. "Regional Reduction in Air Pollutant Emissions as a Result of Increased Forest Residue Recovery." Annual progress report on file at the USDA Forest Service Forestry Sciences Laboratory, Seattle; 1986. 17 p.

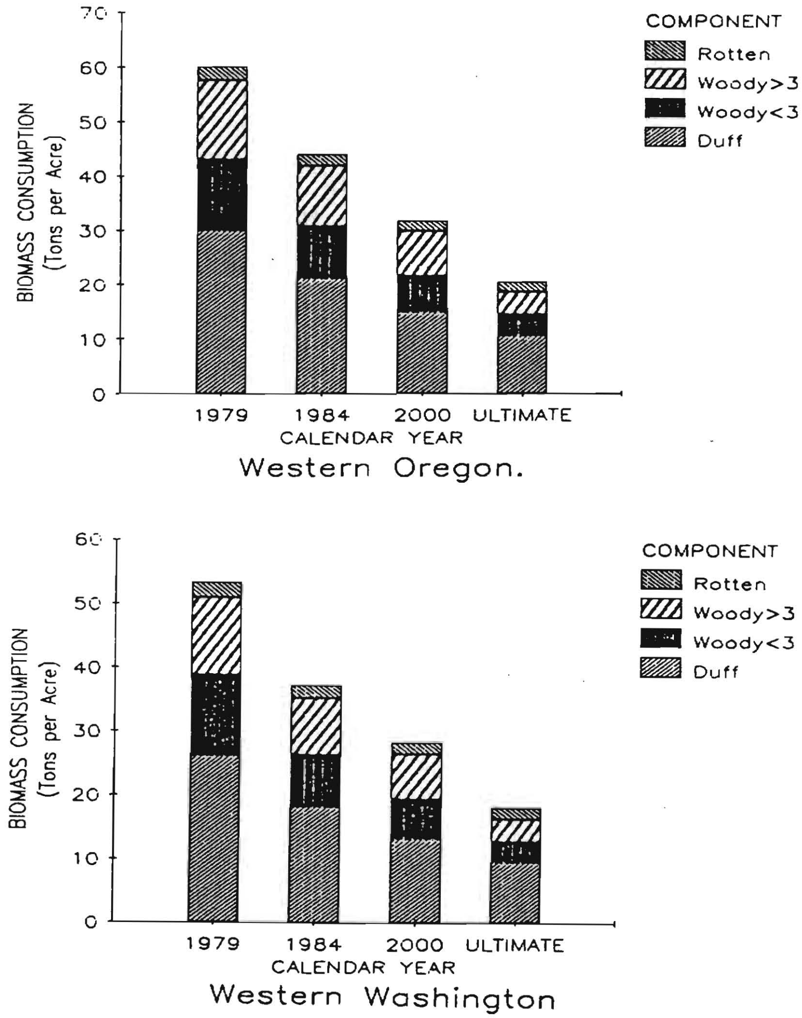


Figure 1.--Average biomass consumption by prescribed fire in 1979 and 1984 and projected biomass consumption for two possible levels of utilization in the year 2000. A. Western Oregon. B. Western Washington.

The area treated by prescribed fire has not been decreasing in the Northwest. In fact, total area burned in the two states in 1984 was higher than any year in history. Burned area decreased by 4 percent in western Oregon but increased by 12 percent in western Washington between the baseline period and 1984. The proportion of fire use on private lands has increased greatly (Figure 2) (Carnine 1984; Oregon State Department of Forestry 1985).

The shift in fire use to private lands had the net effect of reducing emissions by 7 percent in Oregon and 14 percent in Washington because less slash is typically left after harvest on private land. Howard (1981) measured an average 29 percent less large woody residue per acre on private land than on the National Forests.

Meteorological scheduling of burns to wetter seasons reduces emissions by limiting biomass consumption. A 1-percent increase in the moisture content of large residues decreases emissions an average of 3 percent (Sandberg 1984). The average fuel moisture in 1984 was slightly more than 1 percent higher than in the baseline period, which explains an emission reduction of 4 percent in both states. The higher average moisture was the result of an increase in broadcast burning in the spring (Figure 3).

Mass ignition of broadcast burn areas to improve combustion efficiency and limit biomass consumption decreased emissions by 2 percent in Oregon and 5 percent in Washington. The effectiveness of the technique has not been conclusively proved, so the modest assertions made were based on preliminary research results.

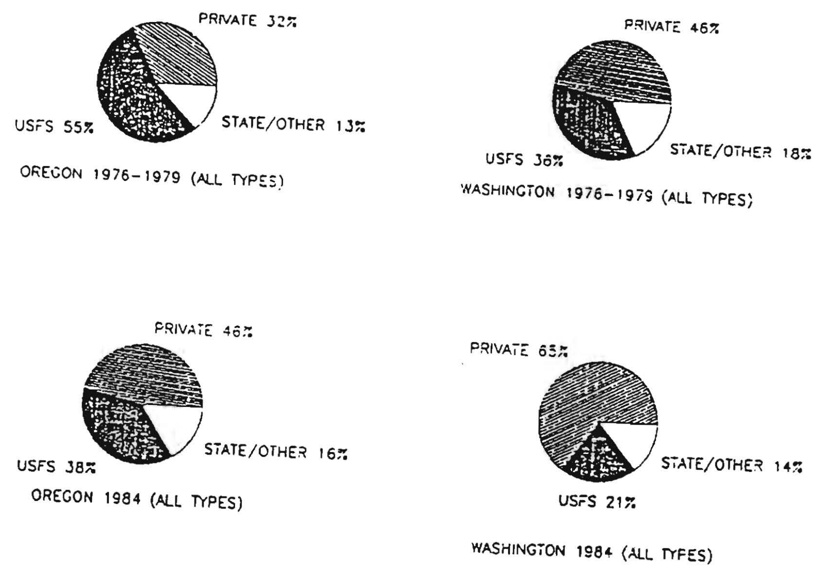
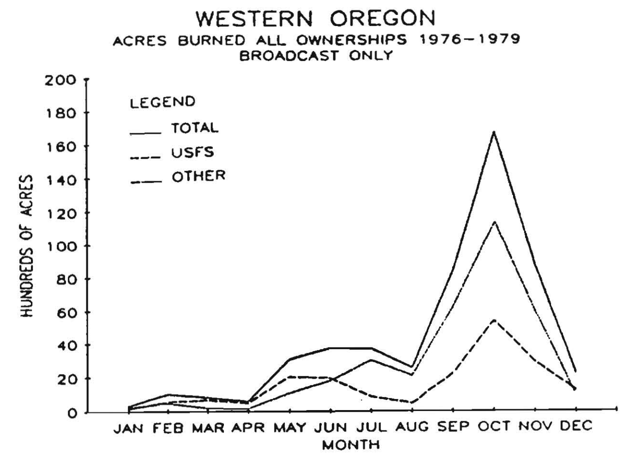


Figure 2.--The proportion of prescribed burning in western Washington and western Oregon was larger on private land during 1984 than during the baseline period 1976-1979.



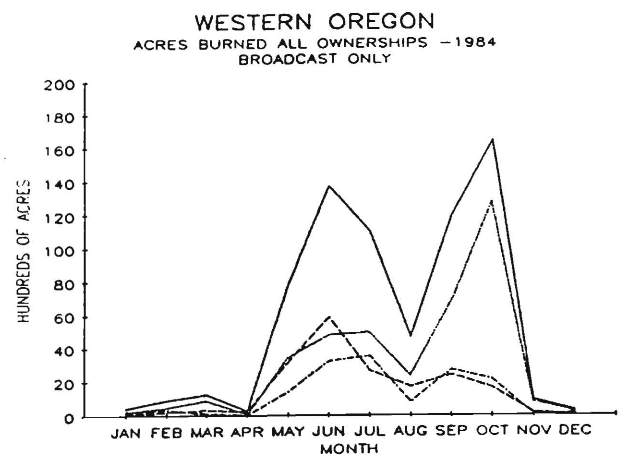


Figure 3.--Broadcast burning for all ownerships in western Oregon was done predominantly in the fall in 1976-1979, but spring burning became more important in 1984.

All residual errors in inventorying emissions and in measuring emission reduction are being cooperatively researched. A new biomass assessment (now 60 percent complete) will reduce the uncertainty by more than one-half. Measurement of other biotic factors, such as the distribution of duff depths and the presence of live vegetation on burn sites, will add small increments of accuracy. A new smoke-management reporting system used by all landowners in Oregon and by National Forests in Washington will improve the estimate of area burned and the use of mass ignition. Biomass-consumption models are being extended to several new forest types, and investigation continues into the effectiveness of mass ignition and other emission-reduction techniques (Ottmar 1987). Completion of these projects is assured before the 3-year review of the Washington and Oregon state implementation plans to prevent impairment of visibility.

Will The 50-Percent Emission-Reduction Goal Be Attained?

Now that emissions have been reduced by 30 percent, is an additional 29 percent from 1984 levels (for a total of 50 percent from the baseline) possible? Improvement depends on many factors that are difficult to predict, from resolution of the herbicide issues to energy demand and the strength of the dollar against Canadian and Asian currencies, but most observers are optimistic. Forest managers who proposed the goal to the Oregon Department of Environmental Quality believe it is attainable, provided some flexibility is retained in burn schedules and operations.

How Can the Additional Reduction Be Achieved?

Increased utilization: The forest industry in the Northwest is undergoing a transition to a second-growth timber cycle that should leave less defective large material. More efficient harvesting and milling allow removal of ever smaller pieces of wood. New markets are being developed internationally (Flora and Vlosky 1986), and domestic prices have stabilized (Warren 1986).

Utilization should continue to improve with improved economic conditions and increased attention to air quality values by forest managers. If we assume that the proportional decrease in large residues before 2000 is the same as it has been since the baseline period, consumption of biomass on the average burned acre will be reduced by about 25 percent from 1984 levels (22 percent in Washington and 27 percent in Oregon) (Figure 2).

Ultimately, utilization might increase even more. For example, if all woody material greater than 3 inches in diameter and 18 inches long were removed from a harvested area, biomass consumption would decrease to about 21 tons per acre (as shown by the last bar in Figure 1).

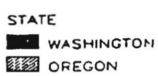
"Spring" burning: The full potential of burning under wetter, or "springlike," conditions has not been realized, despite a concentrated effort by forest managers to promote the practice. Each increase of 1-percent fuel moisture reduces emissions by 3 percent, and burning within 3 weeks of heavy

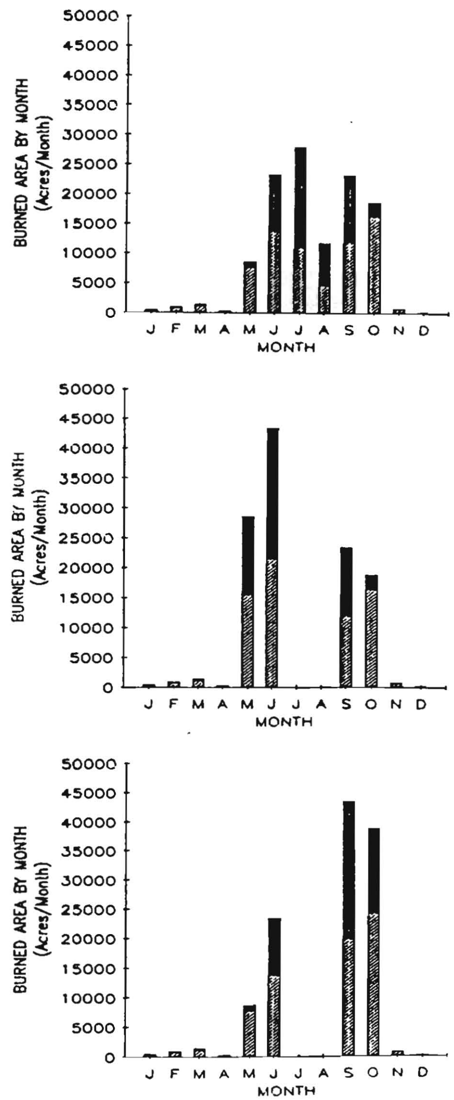
rainfall reduces emissions as much as 25 percent more (Sandberg 1984); yet the regional emission reduction from the practice has been only 4 percent. The reason for the modest results appears to be the shortage of allowable burn days in the year (forcing forest managers to burn during every available day in the year), and a reluctance to take air-quality risks in the spring (by allowing more burning on wet days with limited dispersion).

The effort to reduce emissions by encouraging spring burning will require a substantial change in smoke-management decisions. In Oregon, a general prohibition on summer (July and August) burning forces more burning in either spring or fall. If the burning is delayed until the dry fall months, the total annual emissions will increase by about 2 percent (Figure 4B). If emissions are to be decreased by 10 percent, all the summer burning and one-third of the burning now done in the fall will have to be done in the wetter spring months. That would require from two to six times more burning in the spring than was permitted in 1984 (Figure 4C).

What's likely to happen? My guess is that eventually up to twice as much spring burning as was done in 1984 will be permitted, resulting in an additional 5-percent reduction in annual emissions; for that to happen, smoke-management coordinators and air resource managers in the two states must agree on the strategy. Forest managers are generally eager to accommodate the change.

Figure 4.--Area burned per month in western Washington and western Oregon in 1984 under three sets of smoke-management rules, and the effect on total annual emissions. A. Actual practice in 1984, resulting in 83,431 tons of TSP. B. Simulates shift from burning in July and August to burning in September and October, resulting in a 2-percent increase in annual emissions. C. Simulated shift from July and August burning and one-third of fall burning to May and June, resulting in a 10-percent decrease in emissions.





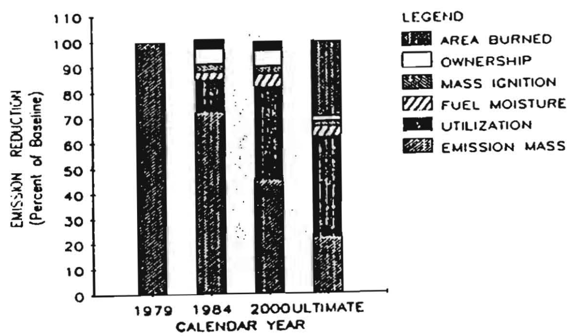
Together, the forecast improvement in residue utilization and spring burning would result in a 55-percent reduction in emissions by the year 2000 in western Oregon, measured from the baseline period 1976-1979, even without further reduction in the area burned or use of any other emission-reduction method (Figure 5A). If residue were completely used, I would expect the area treated by fire to also decrease by about 30 percent, resulting in a total emission reduction of 75 to 80 percent. The same expectations hold for western Washington, provided the area burned decreases by 11 percent to return to the baseline levels (Figure 5B).

An Optimistic Conclusion

I conclude that the emission-reduction goals for prescribed burning in western Washington and western Oregon will probably be met, even if the area burned remains the same. Increased utilization of forest residues has been and will continue to be the most important method for reducing emissions.

Spring burning is an important emission-reduction method but will be successful only if at least twice as much burning is permitted in the spring as is now permitted by the smoke management coordinators.

Air-resource management strategies are not entirely independent. Prevention-of-Significant-Deterioration (PSD) requirements, for example, that would limit daily emissions would no doubt frustrate efforts to reduce emissions and to schedule burning for days with good ventilation.



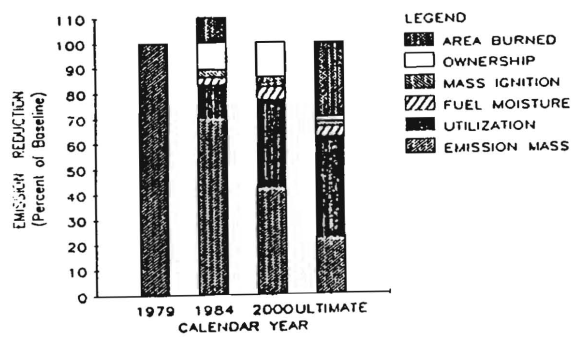


Figure 5.--Methods of achieving reduced emissions from prescribed fire from the baseline period 1976-1979 until 1984 and projected emission reduction for the year 2000 based on two levels of expected residue utilization. The bottom bar represents total annual emissions after methods are applied, and the upper bars represent the emission reduction attributed to each method. A. Western Oregon, showing a reduction of 28 percent in 1984 and a forecast reduction of 55 to 78 percent. B. Western Washington, showing a reduction of 30 percent in 1984 and a forecast reduction of 58 to 78 percent.

Literature Cited

Berg, S. Private forest industry efforts to reduce total emissions from wildfire and prescribed burning. IN: Proceedings, Pacific Northwest International Section, Air Pollution Control Association; 1984 November 12-14; Portland, OR. Portland, OR: Air Pollution Control Association; 1985. 8 p.

Carnine, George. Prescribed burning activities conducted under Washington smoke management plan. Annual report. State of Washington: Department of Natural Resources, Division of Fire Control; 1984. 70 p.

Flora, Donald F.; Vlosky, Richard P. Potential Pacific Rim demand for construction-grade softwood logs. Res. Pap. PNW-364. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station; 1986. 29 p.

Furman, R. William; Helfman, Robert S. A computer program for processing historic fire weather data for the National Fire-Danger Rating System. Res. Note RM-234. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1973. 12 p.

Howard, J.O. Logging residue in the Pacific Northwest: characteristics affecting utilization. Res. Pap. PNW-289. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1981. 41 p.

Oregon State Department of Forestry, Forest Protection Division. Oregon smoke management annual report 1984. Salem, OR: Oregon State Department of Forestry, Forest Protection Division; 1985. 19 p.

Ottmar, Roger D. Reducing smoke from prescribed fires: research solution to a management problem. IN: Proceedings, annual meeting of the Northwest Forest Fire Council; 1986 November 18-19; Olympia, WA. Portland, OR: Northwest Forest Fire Council; 1987.

Sandberg, David V. Research leads to less smoke from prescribed fire. IN: Proceedings, annual meeting of the Northwest Fire Council; 1983 November 21-22; Olympia, WA. Portland, OR: Northwest Fire Council; 1984: 107-121.

Sandberg, D. V. Scheduling prescribed fires for wetter periods reduces air pollutant emissions. A paper presented at the Society of American Foresters/American Meteorological Society, Detroit, MI; 8th National Conference on Fire and Forest Meteorology; 1985 April 29-May 2: 132-138.

Sandberg, D.V.; Peterson, Janice L. A source strength model for prescribed fires in coniferous logging slash. IN: Proceedings, annual meeting of the Air Pollution Control Association 84-20; 1984 November 12-14; Portland, OR: Air Pollution Control Association; 1985. 10 p.

Ward, Darold E.; Hardy, Colin C. Advances in the characterization and control of emissions from prescribed fires. IN: Proceedings, 77th annual meeting of the Air Pollution Control Association 84-36.3; 1984 June 24-29; San Francisco, CA. Pittsburgh, PA: Air Pollution Control Association; 1984. 32 p.

Warren, Debra D. Production, prices, employment, and trade in northwest forest industries, first quarter 1986. Resour. Bull. PNW-137. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station; 1986. 58 p.