In Proc. Symposium on the Loblolly Pine Ecosystem (East Region), Dec. 8-10, 1982, Raleigh, NC. N.C. State Univ. & USDA, Southeast. For. Exp. Stn. pp. 154-162. 1983.

PRESCRIBED BURNING: Uses and effects

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Abstract--Fire has been used to improve range and wildlife conditions in coastal loblolly types for many years. More recently, prescribed burning has been recognized as an indispensable multipurpose silvicultural tool for fuel hazard reduction, control of pests and competing vegetation, site preparation and improvement of habitat for domestic and wild animals. Concerns have been expressed about possible adverse effects of prescribed burning on air, soil and water quality. Experiments to date show no effects of consequence on these environmental parameters from prescribed burning. If there is concern about potential "off site" effects, use of appropriate scheduling prescriptions and scaling factors will reduce risks of adverse effects to rather modest levels.

Deliberate burning of pine forests in the Atlantic Coastal Plain has been a recurrent ecological factor for many years. Indians fired the woods because game species were attracted to new growth on fresh burns. Early settlers and their descendants set fires to improve hunting and to reduce dense undergrowth that harbored snakes, ticks and, perhaps, hostile savages. Mainly however, burning was used to maintain open-range forest grazing until the end of World War II when introduction of registered cattle and improved pastures brought passage of fence laws in the southern seaboard states.

Use of fire in southern pine management was not recognized by professional foresters--mainly U.S. Forest Service men--in the '30s and early '40s because they were regenerating battered remnants of old growth forests acquired as National Forests. The appeals of men like H.H. Chapman, who saw its useful role in maintenance of pine types, generally were ignored. However, as a result of Forest Service research in the late '40s, public and private forest managers gradually became convinced that controlled burning could be a valuable tool in multi-use management of coastal pine forests, even though arson-caused wildfire remained a major forestry problem. As Joe Riebold, a former Supervisor of the South Carolina National Forests, used to say, "On the Francis Marion we have three causes of fire--men, women, and children." Nevertheless, it became increasingly apparent that prescribed burning could be used as a multipurpose method to prevent hazardous accumulations of fuel, to reduce competing vegetation, to manipulate forage for wild and domestic animals, and to lessen impacts of disease and insect pests.

In using fire for these purposes, it is necessary to assess its "on site" effects on flora, fauna and soil; its "off site" effects on air and water quality; and the management options for achieving desired purposes with minimal risk of adverse effects. The remainder of this paper will address these topics.

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FIRE EFFECTS

Causal conditions

The magnitude of fire effects is determined mainly by fire intensity and frequency, with high intensities and frequencies obviously producing effects of gretest magnitudes.

Fire intensity is a result of prevailing combinations of fuel types, amounts, and flammability. The latter is strongly affected by moisture content and oxygen supply as determined by antecedent and prevailing weather conditions. Although fire intensities often are described as low, medium and high, measurements of flame length, flame depth and rate of spread provide better bases for quantitative description of fire characteristics as related to fire effects (Byram 1959, Rothermel and Deeming 1980).

Main points to remember in using fire for management purposes are that desired effects can be produced by burning when conditions will produce appropriate intensities and by prescribing appropriate frequencies of burns.

Fauna

Most macrofauna avoid immediate effects of fire by fleeing from the burned area. Animals that live in the soil usually are not affected because temperatures are not raised very much at depths below one or two centimeters. Species that live in litter layers are killed, but these populations rebuild rapidly after fires (Metz and Farrier, 1973).

The most important effects of fire on animals are the long-term ones caused by changes in the composition and structure of ground and understory vegetation. Thus, managers can favor various species of wild and domestic animals by controlling fire intensity and frequency to produce suitable habitats for selected animals.

Flora

Susceptibility of overstory and understory vegetation to prescribed fires in coastal loblolly types is discussed comprehensively by Langdon (1981). As he mentions, thickness and insulation efficiency of bark as determined by species and tree size are important variables correlated with topkill. Seasonal weather conditions, e.g., winter vs summer, that affect differentials between ambient air and lethal tissue temperatures are also major determinants not only of amount of topkill, but more importantly, numbers of rootstocks killed by burning. Season of burning when coupled with fire frequency can have large influence on composition and density of vegetation by disrupting metabolic and reproductive processes.

While there are many reports of effects of prescribed fires on vegetation in the Atlantic Coastal Plain, the long-term studies at the Santee Experimental forest in Berkeley County, South Carolina provide the most comprehensive chronological account of changes in vegetation caused by varying fire regimes.

The burning treatments of the Santee study included annual and periodic winter and summer fires, biennial summer burning and controls (no fire). These prescriptions were applied as low intensity backing, flank, or head fires, depending on burning conditions. These treatments have been continued for more than 30 years.

Major results of this study as related to vegetation (Langdon 1981) are:

... Stems larger than 10 cm in diameter usually are not severely damaged by low intensity fires.

... Numbers of stems in 5-10 cm sizes are dramatically reduced by all fire treatments (Table 1).

... Numbers of small stems (0-2.5 cm) of trees and shrubs increase after periodic burns as a result of basal sprouting (Table 2).

... Frequent summer fires--especially annual burns--cause large reductions in numbers of small stems by killing rootstocks of tree sprouts and shrubs (Table 2).

... Frequent summer fires cause striking increase in cover of grasses and herbs.

... All types of prescribed fires increase palatability and availability of forage for browsing and grazing animals.

TABLE 1 --Effects of Fire Treatments on Numbers of Large Understory Trees (5-10 cm dia.)

Fire Treatment					
Control	Periodic Winter	Periodic Summer	Annual Winter	Biennial Summer	Annual Summer
--------------No. Stems ha^{-1}--------------					
1077	133	164	217	32	37

TABLE 2 -- Effects of Fire Treatments on Numbers of Small Understory Trees (0-2.5 cm dia.) and Shrubs

Vegetation Types	Fire Treatment					
	Control	Periodic Winter	Periodic Summer	Annual Winter	Biennial Summer	Annual Summer
	----------- No. Stems $ha^{-1} \times 10^{-3}$ -----------					
Small Tree Stems (0-2.5 cm. dia.)	10.9	13.7	18.1	47.7	19.4	0.7
Shrubs	100.6	122.3	141.1	54.3	41.8	7.9
Total	111.5	136.0	159.2	102.0	61.2	8.6

Soil

Effects of fire on physical properties of soil were reviewed by Ralston and Hatchell (1971). Although wildfires can sometimes result in soil erosion and increased runoff, low intensity prescribed burns usually have little effect on soil physical properties or hydrologic regimes. This is because less than one-third of the forest floor is consumed in such burns, leaving a substantial protective cover for the mineral soil. Moreover, prescribed fires do not cause appreciable soil heating except at the surface of the mineral soil (0-1 cm).

McKee (1982) studied effects of long-term prescribed burning on soil and forest floor chemical properties at several Coastal Plain pine sites. In addition to the 30-year burn plots on the Santee, samples were taken from control plots and plots burned each winter for 65 years in the Middle Coastal Plain of Louisiana; those of a biennial winter fire study (5 fires) in the Upper Coastal Plain of Alabama; and from a site on the Osceola National Forest in the flat woods of the North-central Florida Coastal Plain. Soils ranged from sandy aquods (organic hardpans), sandy paleudults (red-yellow podzolics), and loamy paleaquults (gleys) to silty hapludalfs (high base saturation clay subsoils).

Estimates of macro-nutrients in mineral soil profiles of these studies appear in Table 3.

TABLE 3 -- Estimated total nutrients in mineral profiles sampled for four burning studies (McKee, 1982)

Site location and burn treatment	N[1]	P	K	Ca	Mg
	kg/ha				
Alabama (0-40 cm)					
Control	1,800	32	44	770	55
Biennial Winter	2,100	38	47	1,050	75
Florida (0-40 cm)					
Control	2,200	25	25	130	40
Periodic winter	2,400	28	29	140	55
Annual winter	2,800	30	29	160	55
Louisiana (0-50 cm)					
Control	4,500	6	98	3,250	670
Annual winter	3,800	7	81	3,050	615
South Carolina (0-50 cm)					
Control	3,520	4	125	700	360
Periodic winter	2,960	6	135	650	325
Annual winter	3,700	6	126	630	295
Biennial summer	3,240	5	115	570	315
Annual summer	3,680	5	115	710	320

1 Total N; other elements expressed as exchangeable ions.

When interpreting these data, it should be noted that although there are conspicuous differences in amounts of some elements between sites, there are no significant effects of treatments at any site for the total profile depth sampled. If only surface soils (0-9 cm) are considered, at some sites there are small increases in pH as a result of calcium and magnesium releases from burned litter and greater availability of phosphorus from ash depositions. Nitrogen budgets do not appear to be significantly affected by prescribed burning, for even though fires release nitrogen gases (mainly N_2) from forest floor materials, post-burn nitrogen fixation by wild legumes and soil bacteria is stimulated and seems to restore the nitrogen balance quite rapidly. With respect to calcium cycling and long-term effects on soil acidification, McKee (1982) speculates that prescribed fires reduce rates of soil acidification by releasing calcium and other basic cations that are immobilized in litter layers. This observation should be of particular interest to those concerned about effects of "acid rain" on forest soils of the Northeast, Lake States, and eastern Canada. In these environments a major portion of recyclable calcium and magnesium is tied up in thick forest floor deposits. Release of these basic elements by prescribed burning could have a large effect on neutralizing the acidic components in regional precipitation, as well as releasing nutrients to increase tree growth.

Water

There have been rather vocal expressions of concern that prescribed burning may produce adverse effects on quality of stream flow from forested watersheds as a result of nutrient enrichment. Because of these concerns, a study of effects of prescribed fire on chemical composition of runoff from a loblolly pine stand on the Santee Experimental Forest was begun in 1976. Volume and chemical contents of precipitation inputs and streamflow outputs from two gaged watersheds have been measured on a weekly basis since that time. After a calibration period, one watershed comprised of 20 management compartments (each about 7 ha) has had periodic winter burns on a 5- year cycle, i.e., 20 percent of the watershed was burned each winter. In addition, one or more compartments scheduled for harvest and regeneration were burned in summer.

Applications of these treatments for three years has produced no measureable effects on chemical composition of stream flow (Figure 1, Richter et al., 1982). Reasons for this outcome are:

... The release of soluble elements from prescribed fires is small, because only a small fraction (25% to 35%) of the forest floor, having low mineral content, is consumed by the fires.

... Filtration and absorption by residual litter layers and underlying mineral soil removes ash solutes and particulates before they reach the stream channel.

... Buffer strips (15m) bordering streams provided additional protection against washout of sediments and solutes.

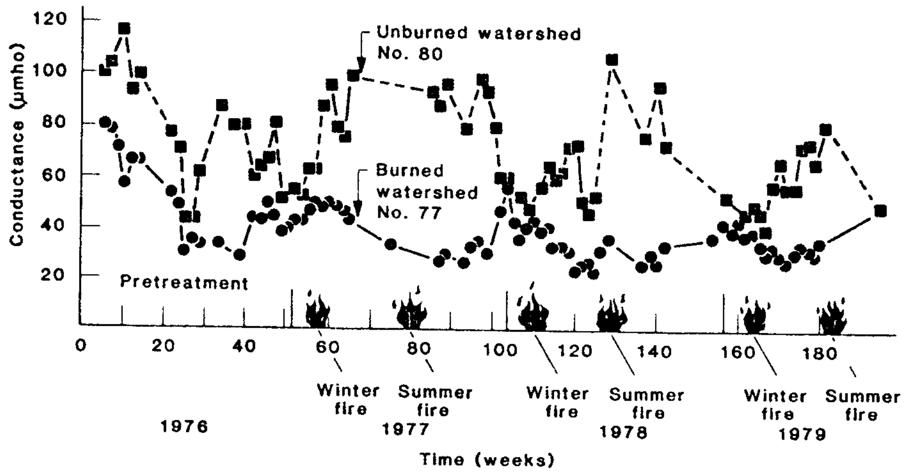

Fig. 1. Weekly specific conductance of streamflows from burned and unburned watersheds at the Santee Experimental Forest in South Carolina. Higher conductance values for the unburned watershed result from ground water inputs from shallow calcareous substrata.

Air

Magnitude of fire effects on air quality deserves attention because certain atmospheric emissions from wild and prescribed fires have been subjects of much speculation about their ecological and social consequences. Although most of the products of combustion of forest fuels are CO_2 and H_2O (90%), other products have properties that cause them to be classed as air pollutants. Absolute and relative contributions of wild and prescribed fires in the U.S. to certain types of air pollutants are shown in Table 4 (EPA Staff, 1978).

TABLE 4

Air Pollutant Type	Air Emissions (metric tons /yr. x 10^{-6})	
	Forest Fires (wild & prescribed)	All Sources
Particulates	0.5[1]	12.4
Sulfur oxides	0.0[2]	27.4
Nitrogen oxides	0.1	23.1
Volatile organics	0.7	28.3
Carbon monoxide	4.3	102.7

[1]About 0.22 x 10^6 mt attributed to prescribed burning in the South.

[2]Zero indicates < 50,000 mt yr^{-1}. 16,300 mt yr^{-1} attributed to prescribed burning in the South.

Although it is evident that forest fires are not major persistent sources of undersirable atmospheric pollutants, when large fires occur, local emissions of steam and smoke are highly visible and may cause serious temporary disruption of air and highway traffic. While little can be done to mitigate such effects of wildfires, a number of smoke management guidelines have been developed to aid managers using prescribed burning in avoiding undesirable visual effects.

MANAGEMENT CONTROLS

Fire effects for a wide spectrum of management uses can be controlled by prescriptions that apply proper scheduling and scaling factors for each fire.

Scheduling has to do with prescribing burning methods appropriate to status of fuel and seasonal weather conditions to produce fire intensities and smoke management requirements that meet given operational purposes. Thus, appropriate scheduling can control the intensity of fire effects on physical, chemical, an biotic components of ecosystems, and as a result, can provide forest managers substantial means to meet their management objectives.

Scaling factors are useful for assessing regional significance of fire effects and for controlling magnitudes of local effects of prescribed burning.

The following statistics (1968-76) indicate the scale of annual fire effects in the southern region:

... Forest land area - 207 million acres

... Average annual wildfire area - 1.23 million acres

... Average annual prescribed fire area - 2.72 million acres

This mean that 0.6% of the forest area is affected by wildfires annually, and that prescribed burns are set on 1.3% of the woodlands of the region. Thus, the regional scale of total fire effects is about that of a 50-year burning cycle. This means that fire on forest lands is not likely to be a factor of major consequence in determining regional air and water quality.

The concept of scaling factors is useful at the local level for keeping adverse external (off site) environmental effects of management practices within acceptable limits. While it has been shown that the overall regional effects of fire are not likely to have major effects on environmetal quality, effects on local water and airsheds could be significant. For example, burning a 30,000 acre management unit on a 5-year cycle would require treatment of 6,000 acres each year. In the Lower Coastal Plain where watersheds of perennial streams may comprise 1,000 to 2,000 acres, subdivision of the management area into 5 annual burning compartments might cause undesirable local effects. Experience to date in loblolly types (Richter et al., 1982) suggest that burning schedules for such management units be applied to 15-30 compartments, depending on watershed size, to minimize fire effects on quality of groundwater and stream flow.

SUMMARY AND CONCLUSIONS

Intentional burning of Coastal Plain loblolly pine forests for a variety of reasons has been practiced by aboriginal peoples and European colonists for many years. In the past three decades it has become evident that prescribed burning provides managers of pine forests a method for accomplishing a number of regulatory puposes simultaneously at least cost. Reduction in wildfire and pest hazards, control of unwanted vegetation and manipulation of composition and density of understory vegetation as foods for wild and domestic animals are all possible and predictable consequences of suitable burning prescriptions. By paying some attention to scaling fire prescriptions to sizes of local watersheds, prescribed burning purposes can be achieved with insginificant effects on soil, air, and water quality. It is highly unlikely that alternative methods for producing these management results can be effected at lower environmental and economic costs.

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