Prescribed Fire in Arizona Ponderosa Pine Forests: A 24-Year Case Study[1]

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Abstract.—A prescribed fire was set to consume three-fourths of the forest floor depth in a ponderosa pine forest. Evaluations of the effects of this prescribed fire were made 1 month, and 1, 2, 11, and 24 years after the fire. The objective of the fire was accomplished. Other effects of the fire included thinning of the forest overstory from below, increased ponderosa pine seedling establishment, increased production of herbaceous plants, and a temporary reduction of fire hazard. The future of prescribed burning in Arizona's ponderosa pine forests seems favorable.

A prescribed fire was set to burn approximately three-fourths of the forest floor depth in a ponderosa pine forest near Flagstaff, Arizona, in October 1964. The forest floor, by definition, is the accumulation of dead organic plant material on mineral soil. This objective of the prescribed fire generally was achieved (Davis et al. 1968). Other effects of the fire included the thinning of the forest overstory from below, an increase in the germination and initial survival of ponderosa pine seedlings, and a small increase in the production of herbaceous plants. A temporary reduction of fire hazard also was attained.

The study described in this paper was conducted to analyze the effects of this fire through time after the burning, on those characteristics originally modified by the burn. In essence, this paper presents a case study of the effects of prescribed fire in a ponderosa pine forest, as evaluations of these effects were made 1 month, and 1, 2, 11, and 24 years after the fire. A partial insight into the future of prescribed burning in these forests also has been obtained from this study.

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Methods

Two one-fourth-acre areas, designated Area A and Area B, with similar characteristics were selected for burning (table 1). On each area, 16 sample points were spaced systematically, 25 by 25 feet. Measurements taken at each of the sample points included:

Forest floor depth.—Total depth measured before and 2, 11, and 24 years after the prescribed fire.

Needle deposition.—Needle drop caught by a 12- by 12-inch hardware cloth square in burned and unburned conditions before and 1 month, and 1 and 2 years after burning. These measurements were discontinued 2 years after burning.

Fire effects on trees.—Crown damage of trees tallied by point sampling with a 25-factor angle gage was classified as (1) severe—more than two-thirds damaged, (2) moderate—one-third to two-thirds damaged, (3) light—less than one-third damaged, and (4) none—no apparent crown damage. Mortality in each crown damage class was recorded 2 years after the fire.

Forest density.—Square feet of basal area per acre estimated by point sampling with a 25-factor angle gage. Diameter breast high (dbh), crown position, and length of live crown were recorded for all trees tallied. Measurements were taken before and 2, 11, and 24 years after burning.

Table 1.—Characteristics of areas selected for prescribed fire (Davis et al. 1968)

Characteristics	Area A	Area B
Forest floor		
Depth (inches)	1.7	3.0
Weight (tons per acre)	10.2	17.6
Forest overstory	Ponderosa pine poles, 5 to 11 inches dbh, with scattered sawtimber and a few Gambel oak	
Basal area (ft² per acre)	170	305
Herbaceous plants	Dominately perennial grasses, including muttongrass and bottlebrush squirreltail	
Soils	Volcanic	Volcanic
Topography	Level terrain	30% to 35% slope to the southeast

Seedling germination and survival.—Mil-acres stocked, 16 on and 16 adjacent to each burned area. Observations were made 1, 11, and 24 years after burning.

Herbage production.—Weight of grasses, forbs, and browse species estimated on 9.6-square-foot plots before and 1, 11, and 24 years after burning.

To achieve the objective of consuming three-fourths of the forest floor depth, a moderately intense surface fire, with flame heights generally 1 to 2 feet, was prescribed. The conditions selected for the prescribed fire and those observed on the two study areas are presented in table 2.

Although the areas burned were relatively small, it was concluded that the same burning procedure apparently would have been successful on larger areas (Davis et al. 1968). The fuels ignited easily and carried the fire well. Estimated fireline intensities were 48 BTUs per second per foot on Area A, and 90 BTUs per second per foot on Area B. In retrospect, these estimated fireline intensities probably were high. Flame heights of about 2 feet generally are associated with fireline intensities of 30 to 35 BTUs per second per foot (Martin et al. 1979). The fire on Area B was more intense than on Area A because of the slope, and higher wind speed and air temperature at the time of burning. The ignition lines on Area B were spaced more closely than on Area A to hold the flame heights to the prescribed limits.

Results and Discussion

Forest Floor

The prescribed fire consumed 71% of the forest floor depth on Area A, and 73% of the depth on Area B (Davis et al. 1968). On the combined areas burned, the L layer, consisting of unaltered organic material, was consumed completely at 69% of the sample plots. The F layer, consisting of partly decomposed organic material, and the H layer, consisting of well-decomposed organic material, were consumed completely at 13% of the sample plots. It was concluded, therefore, that the objective of setting a prescribed fire to consume three-fourths of the forest floor depth was satisfied.

Eleven years after the prescribed fire, the depth of the forest floor on Area A was 0.8 inch, or 47% of the pre-fire depth of 1.7 inches (Ffolliott et al. 1976, 1977). On Area B, the forest floor depth was 1.2 inches, which was 40% of the original depth. In the 11 years since the fire, the additional needle fall that had accumulated on the two burned areas was 15 to 20% of the pre-fire forest floor depth.

Twenty-four years after burning, the forest floor depth on Area A was 1.1 inches, or nearly two-thirds of the pre-fire depth. The depth of the forest floor on Area B was 2.2 inches, or 73% of the original depth. Needle fall and subsequent forest floor development on the two areas in the 24 years since the prescribed fire represented 35% to 45% of the pre-fire forest floor depth.

The forest floor on the two burned areas has been returning to pre-fire conditions, at least in terms of depth. Furthermore, in the 24 years since the prescribed fire, the depth of the forest floor on the two areas has been approaching that generally found in cutover ponderosa pine forests in north-central Arizona (Ffolliott et al. 1968) and in the Southwest (Sackett 1979). The density of the forest floor on the burned areas remains less than that in unburned ponderosa pine forests, however.

An unknown quantity of fire-killed twigs, branches, and small trees have fallen to the ground on both burned areas in the 24 years since the fire.

Needle Deposition

Immediately following the prescribed fire, about the same amount of needles fell on both the burned areas and adjacent unburned areas (Davis et al. 1968). The period of this accumulation represented the normal needle-drop period for Arizona's ponderosa pine forests. During the remainder of the first year after burning, however, the needle deposition on the two burned areas was greater than on the unburned areas (table 3).

Needle deposition decreased on the burned areas 2 years after burning, apparently in response to the decreased volume of tree crowns. Needle fall on the adjacent unburned areas, when "prorated" to account

Table 2.—Conditions selected for prescribed fire and observed conditions when fires were set (Davis et al. 1968).

Burning conditions	Prescribed fire	Area A	Area B
Fuel moisture			
L and F layers	6-12%	8.6%	8.0%
H layer	15% or more	17.6	26.0
Fuel temperature			
Upper 1 inch	80° F., average	86° F., sun 75° F., shade	85° F., sun 75° F., shade
Air Temperature	75° F. or higher	75° F.	80° F.
Wind velocity in flame zone	2-5 mph	1-4 mph	3-5 mph
Weather	Clear	Clear	Clear
Ignition pattern	Strips into the wind or downslope, spaced 10-20 feet to maintain prescribed flame height		

for differences in time, showed little change in comparison to the previous depositions.

As previously mentioned, the measurements of needle deposition were discontinued 2 years after the prescribed fire.

Tree Mortality

Trees killed by the fire, or damaged and subsequently died, generally were the suppressed and intermediate saplings (less than 5 inches dbh) (Davis et al. 1968). Mortality was less in poles (5 to 11 inches dbh) and sawtimber (greater than 12 inches dbh). No trees less than 4.5 feet in height survived on either of the burned areas. Seventy-six percent of the severely damaged trees died within 2 years of the fire, a similar result to that reported in a fire near the Fort Valley Experimental Forest (Herman 1950). Most of the moderately and lightly damaged trees survived.

Forest Density

A general effect of the prescribed fire was a thinning from below (Davis et al. 1968). On Area A, 47% of the pre-fire basal area was lost in 2 years, a reduction to 90 square feet per acre. Twenty-three percent of the original basal area was lost on Area B, a reduction to 235 square feet per acre. Again, on both areas, most of the basal area reduction was in suppressed and intermediate saplings. Area A lost more of its pre-fire basal area because a greater proportion of the trees were saplings, which were more susceptible to damage by the fire than the generally larger trees (in the pole and sawtimber size classes) on Area B.

Eleven years after burning, the basal area on Area A had increased to 120 square feet per acre, indicating an average growth rate of 3% annually (Ffolliott et al. 1976, Ffolliott et al. 1977). However, on Area B, the basal area was 210 square feet per acre, a forest density level that was less than that measured 2 years after the prescribed fire. Apparently, enough trees initially damaged by the fire had died in the intervening time period to offset the growth of the residual trees.

There has been little change in the basal areas on the burned areas in recent years. Twenty-four years after the fire, the basal area on Area A was 127 square feet per acre, an increase of only 6% in the last 13 years. On Area B, the basal area was 213 square feet per acre, which represented an increase of less than 1 percent. It appeared that, on both areas, growth has been offset largely by mortality in recent years. Both of the burned areas still contain too many trees for maximum wood production (Schubert 1974), so the growth rates remain low, relatively.

Seedling Germination and Survival

More ponderosa pine seedlings germinated and survived initially on the burned areas than on adjacent unburned areas (Davis et al. 1968). One year after the fire, newly started seedlings occupied 85% of the mil-acre plots on Area A and 95% on Area B, compared with 20% and 12%, respectively, of the same number of unburned plots. Most of these new seedlings were short-lived, however.

Seedlings established since the fire stocked only 25% of the mil-acre plots on both of the burned areas 11 years after the fire (Ffolliott et al. 1976, Ffolliott et al. 1977). None of the unburned plots supported seedlings at this time.

Twenty-four years after the prescribed fire, established seedlings still occupied 25% of the mil-acre plots on Area A. However, no plots on Area B supported seedlings, and no seedlings stocked the unburned plots adjacent to either burned area. The failure of seedlings to survive on the burned areas has been attributed largely to the returning of the forest floor to pre-fire conditions.

Herbage Production

Annual herbage production on Area A increased from 3 pounds per acre before the fire to 40 pounds per acre 1 year after the burn (Davis et al. 1968). Most of this increase was attributed to the presence of mullein, a relatively unpalatable forb. Herbage production on Area B had remained at the pre-fire level of 5 pounds per acre. It was concluded that grazing values, which were negligible before the prescribed fire, were not changed by burning.

Eleven years after the fire, annual

Table 3.—Needle deposition on the burned areas and adjacent unburned areas (Davis et al. 1968).

	Area A		Area B	
Post-fire period	Burned	Unburned	Burned	Unburned
	tons per acre			
First 34 days	0.72	0.73	0.80	0.76
Remainder of first year	1.75	.96	2.72	.78
Second year	.76	1.76	1.58	2.19
Total	3.23	3.45	5.10	3.73
Difference	-.22		+1.37	

herbage production on Area A also was approximately 40 pounds per acre, although the species composition had changed (Ffolliott et al. 1976, Ffolliott et al. 1977). Mullein had been replaced by a mixture of bottlebrush squirreltail, mutton bluegrass, showy goldeneye, red-and-yellow-pea, and buckbrush. On Area B, the herbage production had increased to 17 pounds per acre, and the species composition generally was similar to that on Area A. Still, the grazing values were considered negligible on the burned areas.

Annual herbage production had decreased on both burned areas 24 years after burning. On Area A, the herbage production was 13 pounds per acre, while that on Area B was 11 pounds per acre. These decreases in herbage production appeared to be related, in part, to the general return of the forest floor to pre-fire conditions. Earlier work in Arizona's ponderosa pine forests had shown that herbage production decreased as the total depth of a forest floor increased (Clary et al. 1968), as reported here.

Fire Hazard

The fire hazard on the burned areas was reduced by the consumption of nearly three-fourths of the forest floor. However, this reduction was only temporary, as the L layer of the forest floor was built up to pre-fire levels in 2 years (Davis et al. 1968). In addition, an unknown quantity of fire-killed limbs and small trees fell to the ground in the years immediately after the fire (Ffolliott et al. 1976, Ffolliott et al. 1977). If the areas in question had been burned again at regular intervals, the fire hazard might have remained low.

Management Implications

The future of prescribed fire in Arizona's ponderosa pine forests seems favorable. As survivors of periodic wildfire (Dieterich 1980), these forests should benefit from carefully prescribed burning programs. Prescribed fire already is used to dispose of debris from logging operations and to thin dense forest stands, with roughly 35,000 to 40,000 acres of debris burned annually by the USDA Forest Service. The use of fire to reduce unwanted herbaceous vegetation and small trees requires more skill in selecting the conditions for burning, and probably not more than 6,000 to 8,000 acres of National Forest land are treated in this way in Arizona each year.

Through the removal of dead organic material on mineral soil, other potential benefits of prescribed fire can include increased seedling establishment and reduced fire hazard. Herbage production also can be increased, although the burning should be prescribed on more productive sites or in lower density forest stands than reported upon herein. Importantly, many of these benefits only will be temporary, unless prescribed fire is scheduled at regular intervals.

Obstacles in the way of prescribed fire programs are a lack of people experienced in prescribed burning, a difficulty in protecting forests from "runaway" fires in areas where fuels (including logging debris and herbaceous plants) have been allowed to accumulate, and insufficient funding for the program. Fortunately, these are not insurmountable obstacles, and progress is being made toward the use of prescribed fire as an effective tool in forest management.

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