

Fire Effects in Southwestern Chaparral and Pinyon-Juniper Vegetation

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Abstract—Periodic wildfires kept woodland communities relatively open, but fire suppression techniques encourage denser pinyon-juniper stands. In areas where prescribed fire has been used to open such stands and increase understory productivity, secondary successional patterns are similar. Herbaceous production often increases following burning but productivity declines as the woodland is reconstituted.

Fire in pinyon-juniper and southwestern chaparral communities is of interest for at least two reasons: the historical role of fire, especially with respect to maintaining grassland vegetation free from encroachment of trees and shrubs; and the use of prescribed fire as a management tool in these communities to increase herbaceous production for livestock, improve wildlife habitat, and decrease fuel accumulation for reduction of wildfires.

There is ample evidence that the density of trees within stands has increased as well as the total area occupied by woodlands (Pieper 1977, Pieper et al. 1987, Little 1977, Springfield 1976, West et al. 1975 and West 1984). The argument that frequent fires prevented expansion of pinyon-juniper woodland into grassland ranges is related to fire frequency and the efficiency of fire control programs which have reduced the areas burned annually by wildfire. The hypothesis is that periodic fires burned these grasslands at an interval frequent enough to kill any tree seedlings which had become established. When fire control procedures became effective these seedlings

were no longer killed by fire and they became established in the grassland which was eventually converted to a woodland or savanna. Coupled with this reduced fire impact was livestock grazing which may have reduced the fuels necessary to carry a fire. Evidence to test this hypothesis is difficult to obtain since stands which now burn are characterized by older and larger trees which are much more resistant to burning.

The role of fire in chaparral communities is obviously different from that of the pinyon-juniper communities. Many shrubs of the chaparral are crown sprouters and are fairly resistant to fire. In addition, chaparral islands in grassland may represent relicts of continuous stands rather than encroachments into grassland vegetation (Cable 1975).

The objective of this paper is to review the historical role of fire in these pinyon-juniper and chaparral communities, to review the ecological influence of fire and the possibility of using prescribed fire to meet certain management objectives. These topics are not mutually exclusive, but will involve some overlap.

Historical Role of Fire

Fire has been a frequent phenomenon in both pinyon-juniper and chaparral vegetation (Mueggler 1976). However, evidence concerning the frequency and extent of fires prior to the advent of European exploration

and settlement is scarce. Young and Evans (1981) studied fire scars on western juniper (*Juniperus occidentalis*) trees in low sagebrush communities in Lassen County California. These scars revealed large fires from 1640-1650, and 1830-1840 (fig. 1). However, scars on another tree indicated fires in 1770, 1780, 1790, 1830, and 1850. Use of these techniques to determine fire frequencies is imprecise (Young and Evans 1981). Perhaps fire histories from these western juniper stands can be extrapolated to similar situations for pinyon-juniper vegetation in the Southwest.

Wright et al. (1979) stated that fire frequencies of 10 to 30 years were one factor in restricting pinyon-juniper invasion into grassland. How-

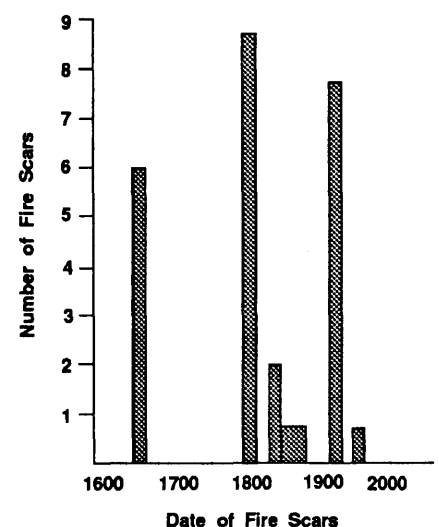


Figure 1.—Number of fire scars on singleseed juniper trees in Lassen County, California (Young and Evans 1981).

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ever, the only source for this fire interval in the Southwest was an earlier article by Leopold (1924) who also relied on fire scars to determine burning interval.

Information on fire history of chaparral vegetation is even more limited than that for the pinyon-juniper type. Cable (1975) stated that chaparral vegetation is not a fire climax although fire is a common occurrence. Some of his observations indicate that a few chaparral stands had not been burned for as long as 100 years. Another area had not been burned for at least 72 years (Pase 1972). Apparently many chaparral areas will not have sufficient fuel to carry a fire at intervals more frequent than 20 years. Chance occurrence of lightning storms and sufficient fuel to carry a fire are apparently two factors controlling fire frequency in chaparral communities.

Pinyon-juniper and chaparral both fit the fire climate defined by Fosburg and Furman (1973). These authors identified four distinct fire types in Arizona. The Central Basin included most of the chaparral type while the Central Basin and Grand Canyon-Mogollon Rim included most of the pinyon-juniper vegetation. Several fire types in New Mexico would include pinyon-juniper vegetation (e.g. Western Mountains, Sacramento Mountains, Northwest Plateau, San Juan Mountains, and Sangre De Cristo Mountains).

After burning occurs, it is difficult to prove the thesis that periodic burning prevented encroachment of pinyon-juniper and chaparral vegetation into grasslands. Several other factors may also be influential in this process. West and Van Pelt (1987) have traced some of these influences and resulting changes in Great Basin pinyon-juniper vegetation (fig. 2). These factors include depletion of understory vegetation through grazing, increase in annual herbaceous vegetation represented by species such as cheatgrass (*Bromus tectorum*), reduction of woody overstory

through post and fuelwood harvesting, etc. Many of these same factors probably influenced pinyon-juniper vegetation in the Southwest.

Fire also played a role in intercommunity cycles in presettlement time leading to alternations between savanna and dense woodland (fig. 3). This model indicates that present

vegetation may be only a phase in a cyclic process (West and Van Pelt 1987).

Ecological Responses to Fire

The effect of fire on trees in pinyon-juniper vegetation is influ-

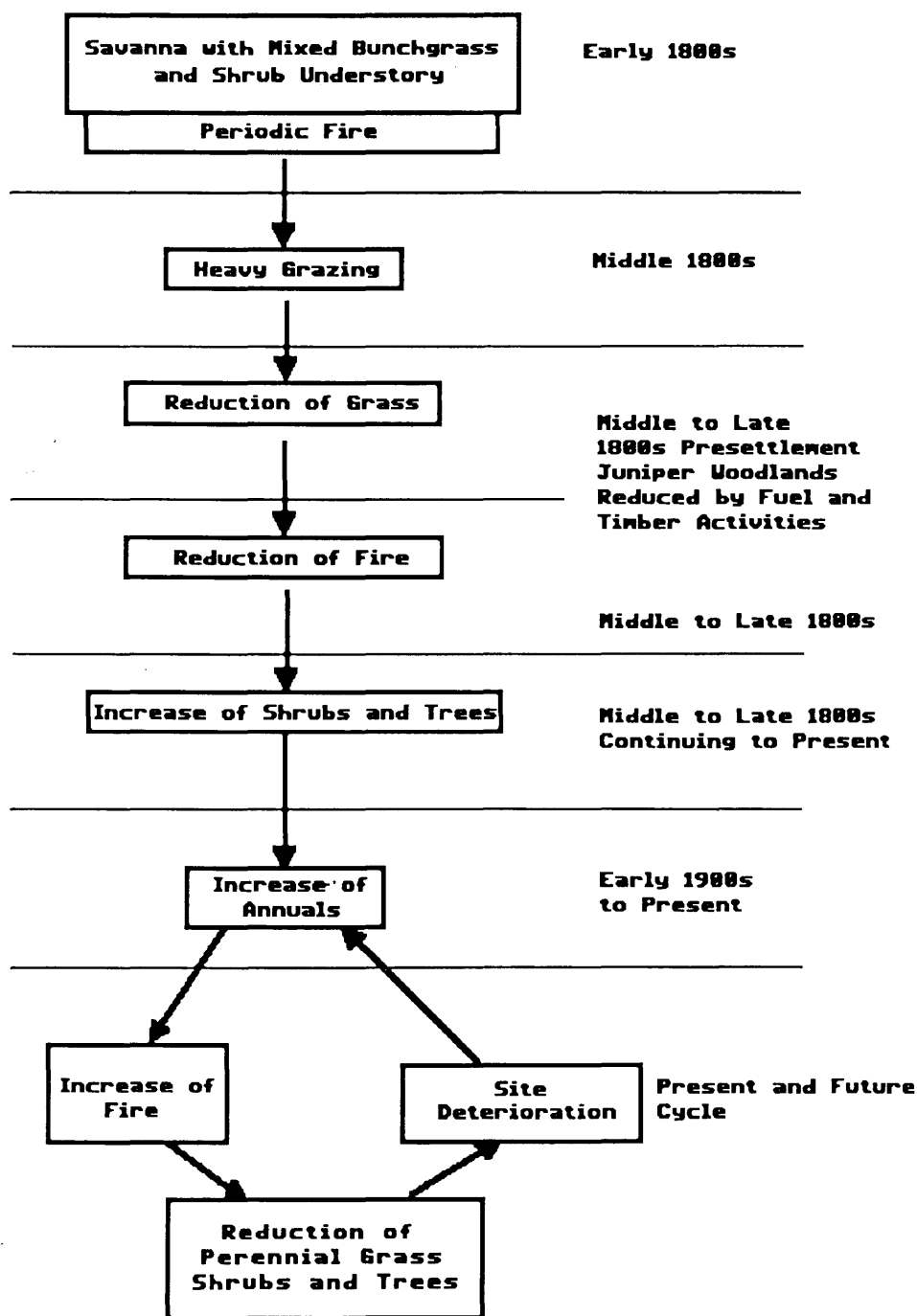


Figure 2.—Historical summary of events leading to current conditions in piñon-juniper woodlands in the Great Basin (from West and Van Pelt 1987).

enced by several factors including size of trees, amount of herbaceous fuel, wind speed, air temperature, stand density, vertical and horizontal fuel distribution and season (Bruner and Klebenow 1979, Wright et al.

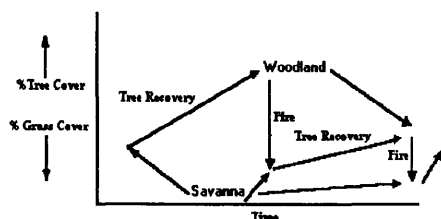


Figure 3.—Changes in pinyon-juniper vegetation and the role of fire in thickening toward woodland and thinning toward savanna (West and Van Pelt 1984).

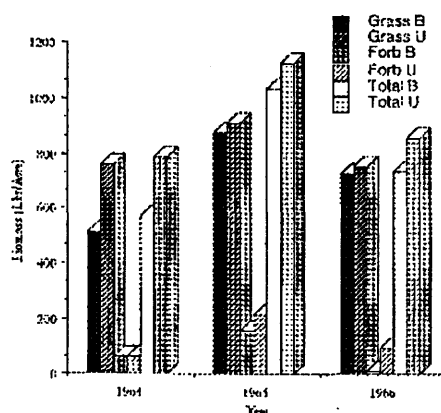


Figure 4.—Herbage production following burning in New Mexico (Dwyer and Pieper 1967).

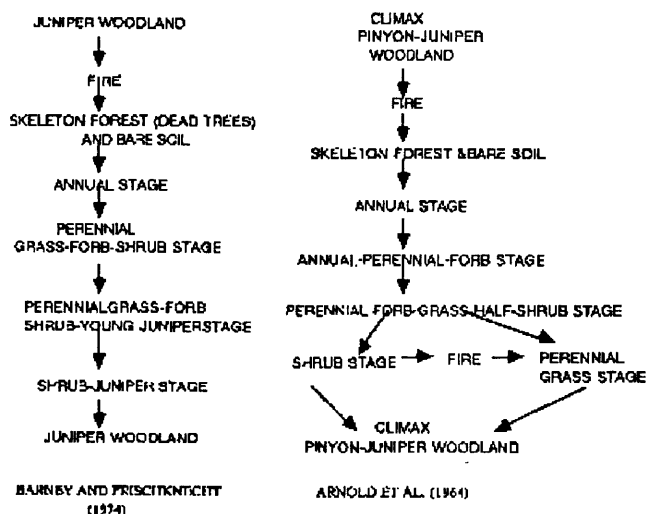


Figure 5.—Successional pattern following fire in piñon-juniper vegetation at three locations.

1979). Dwyer and Pieper (1967) reported that a rapidly moving wild-fire killed nearly 1/4 of singleseed juniper (*Juniperus monosperma*) trees and only 14% of Rocky Mountain pinyon (*Pinus edulis*) trees in southcentral New Mexico. However all trees under 4 ft. tall were killed by the fire. Jameson (1962) also reported that from 70 to 100% of singleseed juniper trees under 4 ft. tall were killed by spring fires in Northern Arizona. Mortality of trees 5 to 6 ft. tall was only 30 to 40%. Larger trees with accumulation of Russian thistle fuel under the canopy exhibited mortality of 60 to 90%. Canopy morphology also plays a role in susceptibility of trees to fire. Those trees with the canopy developed close to the ground are much more likely to have the crown catch on fire from fine fuels on the soil surface than those trees which have an elevated canopy. These morphological differences are often related to age of the tree, fire history and species. Pinyon would likely dominate stands under a history of repeated fires.

The effectiveness of wildfire in restricting spread of pinyon and juniper trees into grassland vegetation types depends on fire frequency and intensity of the fire. Information on

early growth rate of pinyon and juniper seedlings is lacking. The time required for these seedlings to reach 4 ft. in height appears to be critical. If severe fires occurred at intervals more often than the time required to reach a height of 4 ft., then fires could be effective in preventing encroachment of trees into grassland. Limited data on growth of both pinyon pine and juniper species suggest that many trees less than 4 ft. tall are over 10 years of age (Clendenen 1979 and Fowler et al. 1984). Chojnacky (1987) and Smith and Shuler (1987) presented graphs showing age:height relationships for pinyon and juniper trees, but few determinations were made for trees less than 6 ft. tall which were between 20 and 100 years old. Howell (1940) found that Rocky Mountain juniper (*Juniperus scopulorum*) seedlings were only 1 ft. tall after 8 years. Pinyon pine seedlings may be only 2 in. tall at two years of age and only 3-4 ft. tall at 25 years of age (Fowells 1965). These limited data suggest that fire frequencies were frequent enough to limit tree seedling establishment in grassland under some circumstances.

The initial effects of fire on herbaceous vegetation is a reduction in biomass for 1 or 2 years following the fire. Usually herbaceous vegetation recovers to preburn levels of biomass within a year or two following the fire (Dwyer and Pieper 1967, Jameson 1962) (fig. 4). Often there is an increase in abundance of annuals immediately following the fire.

Successional Patterns

Successional patterns following fire are remarkably similar for pinyon-juniper stands in Arizona, Colorado, and Utah (fig. 5). If the fire is severe enough to burn the tree overstory in addition to the herbaceous and shrubby understory, a skeleton of trees are left with considerable bare soil. The first vegetation becoming established following the

fire consists of annual herbs. In Nevada, annual herbs in early successional stages included coyote tobacco (*Nicotiana attenuata*), flaxweed tansy mustard (*Descurainia sophia*) and goosefoot (*Chenopodium album*). In Utah, cheatgrass brome (*Bromus tectorum*), Russian thistle (*Salsola pestifer*), sunflower (*Helianthus annuus*), pale alyssum (*Alyssum alyssoides*), flaxweed tansy mustard, and coyote tobacco were common components of the vegetation during early stages of succession. Successional patterns can be altered by fire intensity, season, post burn environment and past history of use.

The annual communities are gradually replaced by mixed annual and perennial species and eventually primarily by perennial species (fig. 5). The three models presented in figure 5 show a pronounced shrub stage before tree regeneration begins. However, in some cases this shrub stage may be reduced or absent (Schott and Pieper 1986, 1987).

The entire sequence from skeleton forest to climax pinyon-juniper woodland varies depending on climatic factors and soil characteristics. Erdman (1970) showed a time frame of 300 years to complete the sequence for his model in Colorado (fig. 5). Barney and Frischknecht (1974) found that the maximum number of pinyon and juniper trees in their study in Utah occurred 86 years following the fire (fig. 6). The density of trees declined slightly from 86 to 100 years.

Although these diagrams indicate that succession is relatively uniform from place to place, there are exceptions. Everett and Ward (1984) described multiple successional pathways and multiple entry points where fire could play a controlling role. These authors stated "Initial and relay floristics successional models are both operative in pinyon-juniper succession. Original preburn species rapidly reappear on the burns, perennial species outnumber annuals, and the species turnover

rate rapidly declines (initial floristics); but relay floristics (migration) determines the character of later stages, as we did not find singleleaf pinyon seedlings." In New Mexico grass forb and shrub stages were poorly represented on lithic hapustoll soils with extensive rock outcrops (Schott and Pieper 1986, 1987).

Successional patterns are somewhat truncated in chaparral communities compared to that in pinyon-juniper stands (Cable 1975). The forb stage in secondary succession reaches a peak during the second or third year following the fire. The grass stage reaches a peak from the fifth to seventh year following the fire. Most shrubs are sprouters and reestablish their canopies relatively rapidly after the fire (Pase and Lindenmuth 1971) (fig. 7). Hibbert et al. (1971) reported that more than 11 years was required for the shrub cover to reach preburn conditions. Pase and Lindenmuth reported that only desert ceanothus (*Ceanothus greggii*) and manzanita (*Arctostaphy-*

los pungens) did not sprout following a fire on the Sierra Ancha Experimental Forest in Central Arizona.

Use of Prescribed Burning

Prescribed burning is often used in pinyon-juniper vegetation to reduce overstory cover and increase understory production (Bunting 1987) or to reduce fuel levels for wildfire prevention (Kallander 1969). Prescribed burning has been used in several ways: (1) burning slash and debris left from other control methods, (2) burning individual trees, (3) burning grassland or sagebrush/grassland to kill invading trees, and (4) broadcast burning mature trees (Blackburn and Bruner 1975).

Recommendations for broadcast prescribed burning in pinyon-juniper vegetation varies with characteristics of the vegetation (Wright et al. 1979). For dense stands, Zwolinski and Ehrenreich (1967) recommended bulldozing a fire line around the area

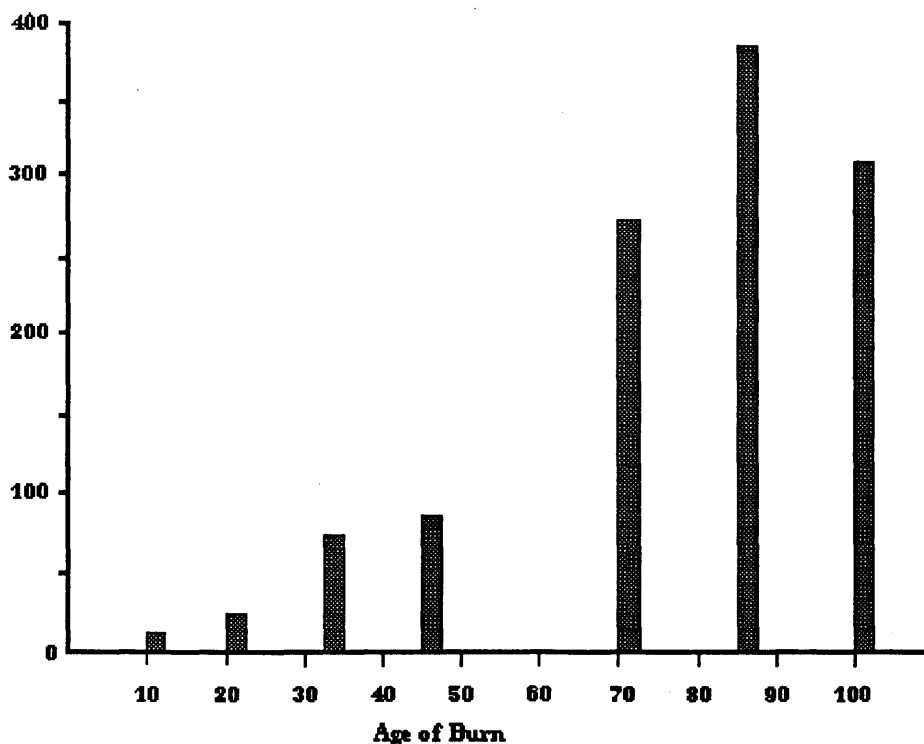


Figure 6.—Density of trees (Utah and singleleaf pinyon) following fires in Utah (modified from Barney and Frischknecht 1974).

to be burned and igniting the fuel during peak burning conditions in late June or early July in Arizona. Prescribed burning recommendations on the Hualapai Reservation in Arizona call for burning during the hottest and driest conditions possible during the year which is in late June before the summer rainy season (Despain 1987). Most burns have been conducted between June 20 and July 10. Other recommendations listed by Despain (1987) for this Reservation include the following:

- Fires should be ignited between noon and 3:00 p.m.
- Air temperatures must be in the high 80s or higher
- Wind velocity should be from 15-20 mph and steady
- Relative humidity should be less than 8%

Burning under these extreme conditions increases the possibility of the fire escaping the desired area to be burned. Maximum precautions are necessary and these will add to the

cost of the burn. Often closed stands of pinyon-juniper have little understory and are difficult to burn (Bruner and Klebenow 1979, Aro 1971, Blackburn and Tueller 1970, Wright et al. 1979). In these cases it may be necessary to use some other method to push the trees over where they are susceptible to burning.

Prescribed burning has been a part of the overall management plan for the Hualapai Indian Reservation in northwestern Arizona (Despain 1987, McNichols 1987). Approximately 22,000 acres have been burned with an additional 100,000 acres planned for burning (McNichols 1987).

Individual tree burning is desirable under some conditions where broadcast burning is not practicable (Jameson 1966, Springfield 1976, Wright et al. 1979). Propane or oil-burning torches can be used to ignite the trees (Jameson 1966). However, the method is not practical for large trees (10 ft. or taller) (Springfield 1976).

Baldwin (1968) has described procedures for prescribed burning of chaparral vegetation on the Tonto National Forest in Arizona. For best

results burning should be done when fire conditions are extreme and precaution is necessary to keep the fire under control. The fire is ignited on the ridge tops and progressively down the slopes until it is safe to start fires on the bottom of the slopes for the main fire to burn rapidly uphill. Follow-up management including seeding with grass species and herbicidal treatment 18 months following the burn to control sprouts and seedlings of the shrubby species is used on the Tonto National Forest. Pase and Lindenmuth (1971) described the use of mixtures of 2,4-D and 2,4,5-T as desiccants before burning chaparral vegetation. They recommended that the moisture content of desiccated leaves be less than 15% and nondesiccated leaves more than 85%. Cable (1975) listed the following conditions for favorable burning of chaparral vegetation:

- vegetation must be dormant or nearly dormant
- wind should not exceed 4 miles per hour
- relative humidity should be between about 14 and 35%
- fuel stick moisture should be between about 8 and 18%

Summary And Conclusions

Wildfires have played an important role in the development of pinyon-juniper and chaparral vegetation in the Southwest. Because of the relatively slow growth rate of both pinyon and juniper trees, fire frequencies were apparently frequent enough to restrict encroachment of tree seedlings into grasslands. However, the role of fire in these woodlands has changed with the advent of livestock grazing which reduced fuel loads and efficient fire control programs which reduced the extent and frequency of fires in these communi-

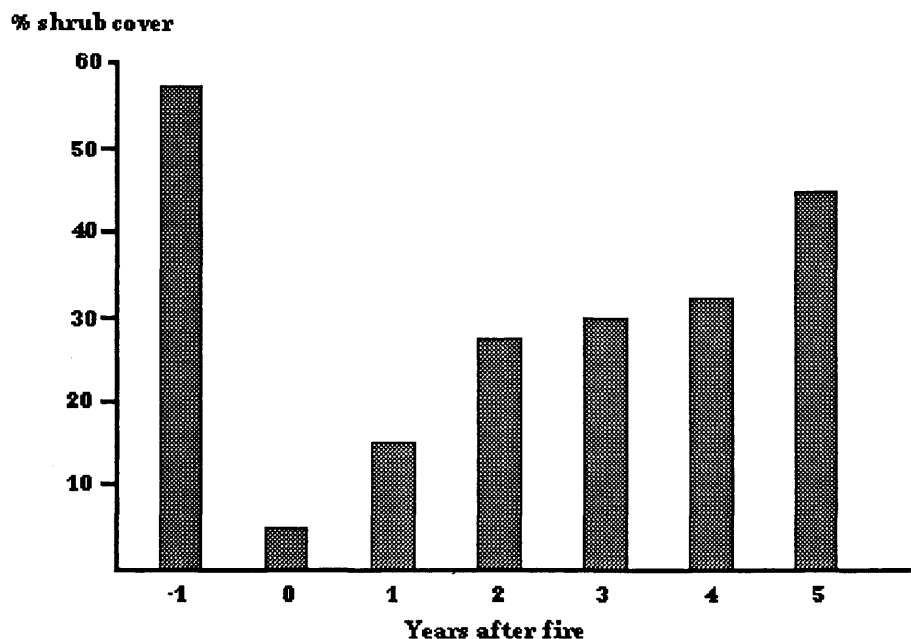


Figure 7.—Cover of shrubby species following fire in chaparral community in Arizona (Pase and Lindenmuth 1971).

ties. Now prescribed fires are being used as tools to reduce tree density and increase understory biomass for improved habitat for livestock and game. Prescribed burning techniques have been developed to meet management objectives for different areas.

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