Vegetation Changes Following Fire in the Pinyon-Juniper Type of West-Central Utah

MILO A. BARNEY AND NEIL C. FRISCHKNECHT

Highlight: *The stages of succession following fire began with weedy annuals that reached a peak within 3 to 4 years. Juniper woodlands were well developed 85 to 90 years following fire. Intermediate stages of succession varied, but followed a general pattern of perennial grasses, perennial grasses-shrubs, and perennial grasses-shrubs-trees. The percentage of dead sagebrush was positively correlated with density of junipers. Thirty-three years was the average minimum age at which Utah juniper produced seed.*

Juniper and pinyon trees in the Intermountain region have expanded their range greatly since settlement, primarily in the last 100 years. Existing speculation suggests that a major cause of this expansion, either directly or indirectly, was the reduction in fires following settlement. Some authors consider the juniper-pinyon expansion to be several times that of the original cover (Cottam and Stewart, 1940; Woodbury, 1947). In 1951 it was estimated that this type covered about 30% of the State of Utah (Reuss and Blanch, 1951). The expansion has been primarily into the sagebrush-grass community on the lower edges of original pinyon-juniper. If unchecked, trees become dominant and eventually crowd out most herbaceous and shrub species that provide forage for livestock and big game.

The purpose of this study was to examine the vegetation on burns of various ages and determine the successional patterns following fire. The study was conducted primarily on the lower slopes and foothills of the Sheeprock Mountains in Utah and surrounding areas in the vicinity of the Benmore Experimental Range; however, one area was located in the Valley Mountains west of Fayette, Utah. Fire scars of various ages are generally evident in these areas. Tree species in the areas studied were Utah juniper (*Juniperus osteosperma*) and singleleaf pinyon (*Pinus monophylla*).

Location and Description of Study Area

The Sheeprock Mountain Range is approximately 20 miles long and 6 to 10 miles wide and most of it lies within the Vernon division of the Wasatch National Forest. The Sheeprocks, which merge with the West Tintic Mountains to the east, rise to a maximum elevation of 9,000 ft; but the pinyon-juniper type occurs mainly between 5,800 and 7,800 ft elevation. The Sheeprocks are separated from the Onaqui Range to the north by Lookout Pass and from the Simpson Range to the west by Erickson Pass. The Sevier Desert lies to the south and Rush Valley to the north.

The Sheeprock Mountains are composed chiefly of consolidated sedimentary rocks of Precambian and Paleozoic age. Several areas of both intrusive and extrusive rocks are also present. Unconsolidated sediments cover much of the foothill region as pediment gravels, lake deposits, and alluvium (Cohenour, 1957). The average annual precipitation is 12.8 inches for a 60-year period (1911-1971) as recorded at the Benmore Weather Station (elevation 5,975 ft) on the north side of the Sheeprocks.

No quantitative data are available on past or present grazing of the areas studied. However, it is generally agreed that rangelands in Utah were grazed heavily by domestic livestock during the late 1800's and for at least the first 30 to 40 years of the present century. Livestock numbers in Utah reached their peak around the turn of the century (Pickford, 1932). Glynn Bennion (1924), grandson of the earliest settler in the Benmore area, wrote that in 1870 upwards of 25,000 head of cattle and horses were summered and wintered in Rush and Skull Valleys. He further indicated that by 1924, less than one-tenth that number could be summered in the same areas.

Methods

Data were collected from 28 different burns in 17 localities of west-central Utah. Aerial photographs, where available, were used to delineate areas that had burned. Information on the age of the most recent burns was obtained from the Forest Service, Bureau of Land Management, and private individuals. Ages of older burns were estimated from ring counts of old trees that did not burn and from ring counts of the invading trees. Further, at each burn, ring counts were made on stem cross sections of trees that appeared to be the youngest producing seeds.

Depending upon size, burns were sampled on two to eight transects of from five to 10 plots each. At each plot location a series of nested circular plots having a common center were used for taking data on trees, shrubs, and herbaceous species. Sizes of plots used for sampling vegetation were: trees 0.01-acre (radius 11.77 ft); shrubs 100 ft^2 (radius 5.64 ft); and herbaceous plants 10 ft^2. Tree data included density (numbers), height, crown diameter, and stem diameter at 1 ft above ground level. Shrub data included density by species, estimated yields of shrub herbage in grams per plot, and counts of dead sagebrush plants.

Frequency of herbaceous species was determined from plot data. Cover for both shrub and herbaceous species was determined by a line-point adapted from Levy and Madden (1933). Our method employs a 12-ft aluminum rod marked in 1-ft segments and having pins projecting down at each foot marker. The rod is placed along the transect line, first on one side of the plot center and then on the opposite side, so as to give 25 points per plot. Nomenclature follows Welsh et al.

The authors are range research technician and range scientist, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, Utah, stationed in Provo, Utah, in cooperation with Brigham Young University. Milo A. Barney is at present land specialist, Division of State Lands, State Capitol, Salt Lake City, Utah.

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Table 1. Crown cover (%) and basal area (ft^2/acre) of *Juniperus osteosperma* and *Pinus monophylla* by age of burn (years).

Approximate age of burn	Crown cover	Basal area
3	–	–
6	–	–
11	t[1]	t[1]
22	0.5	0.6
36	1.2	1.9
46	1.3	1.6
71	16.0	21.5
86	17.2	33.4
100+	31.8	142.6
	0.9[2]	2.9[2]

[1] Trace.
[2] *Pinus monophylla.*

Table 2. Density (trees/acre) of *Juniperus osteosperma* and *Pinus monophylla* by height class (ft) and age of burn (years).

Approximate age of burn	Height class 0-1	1-4	4-9	9+	Total
3	–	–	–	–	–
6	–	–	–	–	–
11	0.1	0.0	0.0	0.0	0.1
22	4.1	18.3	6.1	0.0	28.5
36	9.6	43.2	30.4	1.6	84.8
46	12.3	42.2	42.2	0.0	96.7
71	20.0	65.0	140.0	55.0	280.0
86	54.3	61.4	187.1	92.9	395.7
100+	73.3	36.2	101.2	110.2	320.9
	4.7[1]	0.0[1]	6.9[1]	2.3[1]	13.9[1]

[1] *Pinus monophylla.*

(1965), except as updated by him (personal communication, 1972).

A soil pit was opened at each location and the profile described. Soil texture was determined by the Bouyoucos (1936) technique. The pH was determined from a saturated soil paste. An extract was obtained from the paste and the soluble salt content determined by use of a solu-bridge (U.S. Department of Agriculture, 1954).

Data from the 28 burns were grouped for analysis into nine age classes, based on age of burn. These age classes and number of burns studied (shown in parentheses) are as follows: 3(2); 6(1); 11(3); 22(3); 36(6); 46(1); 71(2); 86(5); and 100+(5). The actual age is known for the burns in the first three classes; age was approximated for the remaining burns. Ages shown for classes 11, 22, 36, and 86 represent a midpoint year for those burns in each class. Study areas in the 100+-year-old class were adjacent to known burns; also, they appeared to have burned at some time, but an accurate age was not determined for these burns.

Results and Discussion

Trees

Both the tree crown cover and basal area increased with age of burn and reached maximum values in the oldest stands (Table 1). (Pinyon pine occurred in minor amounts only in one of the oldest stands and will not be considered further in this paper.) Overall tree density (numbers) followed a slightly different pattern, reaching maximum value on the 86-year-old burns and decreasing slightly in the oldest stands (Table 2). Decreases, however, occurred only in the intermediate height classes; trees over 9 ft high and those less than 1 ft were most numerous on the oldest burns. Most of those stands in the 100+-year-old class were growing on shallow rocky soils, and perhaps the decrease in density of the intermediate height classes was due to failure of the young trees to develop on these sites because of a closed community.

Juniper crown cover increased slowly during the first 46 years following fire and then accelerated (Table 1). Basal area followed a similar pattern but showed greater proportional increase in the oldest stands. It appears that trees begin to dominate these sites 46 to 71 years after burning (Tables 1, 2, and Fig. 1). During this period the first generation trees have been producing seeds for possibly 15 years or more, and the second generation trees are beginning to exert an influence on the understory vegetation. The increase in juniper crown cover occurs along with a decline in cover of both sagebrush (*Artemisia* spp.) and perennial grasses (Fig. 1).

No trees were found in sample plots on either the 3- or 6-year-old burns; one small tree was observed outside the plots in the 6-year-old burn, apparently originating from a residual seed. However, on sample plots of all older burns, young juniper trees were evident. Ages of trees on the 11-year-old burns indicated that most were established within 1 or 2 years following the fire; others were established within 4 or 5 years following the fire. The Utah juniper established immediately following fire was found both adjacent to and under the crowns of trees killed by fire. This indicates that these junipers started from residual seeds. Pinyon pine occurred only in one of the oldest stands.

Analysis of tree stands on burns of various ages indicates that on 22-year-old burns approximately two-thirds of the

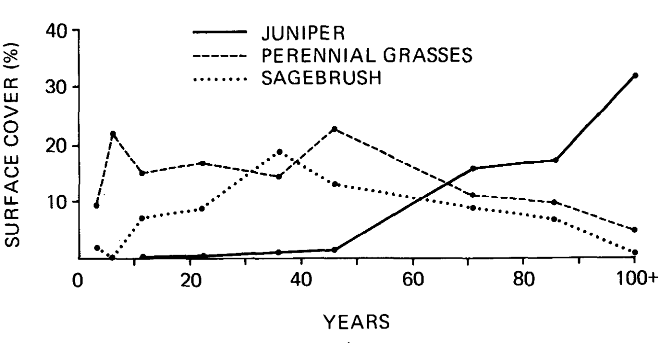

Fig. 1. *Surface cover of juniper, perennial grasses, and sagebrush by age of burn.*

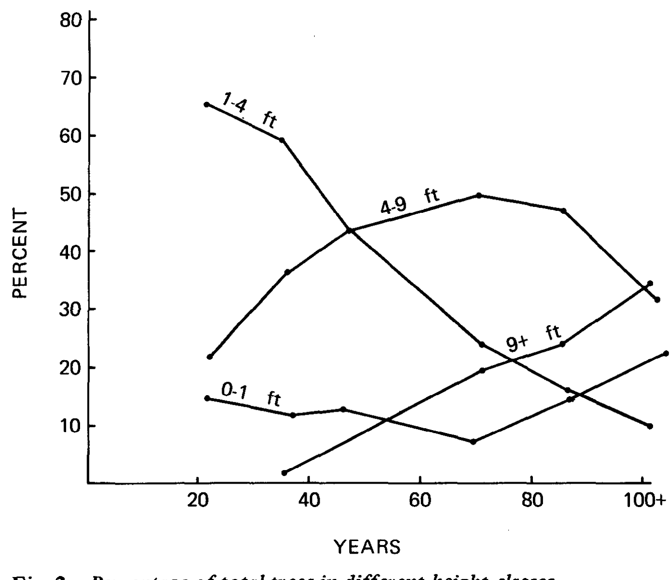

Fig. 2. *Percentage of total trees in different height classes.*

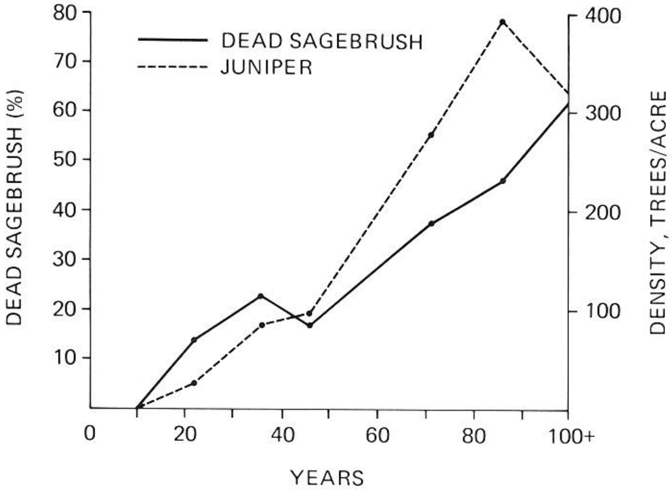

Fig. 3. *Density of juniper (trees/acre), and percent of sagebrush plants that are dead, by age of burn.*

Fig. 4. *An 86-year-old stand at Redskin Knoll showing sparse understory vegetation and decadent nature of sagebrush plants.*

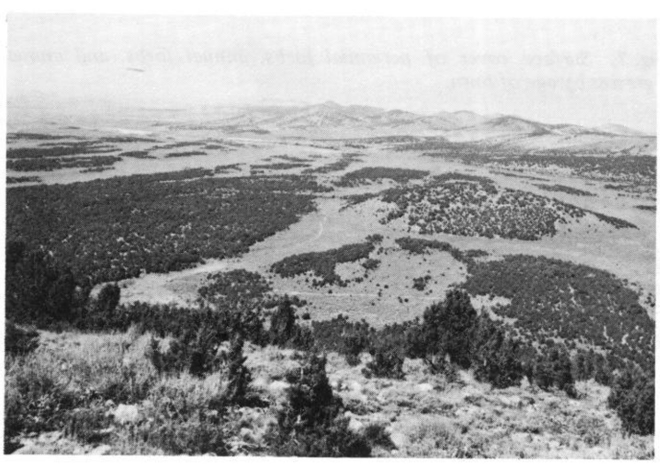

Fig. 5. *A view of the Redskin Knoll area showing burn patterns in the juniper stands.*

trees were in the 1- to 4-ft height class, 20% in the 4- to 9-ft height class, and 14% in the 0- to 1-ft height class (Fig. 2). A few trees exceeded 9 ft in height as burns approached 40 years of age and, of course, trees of this size became more numerous as age of burn increased. Tree stands on burns approximately 70 years old showed the highest percentage (50%) of trees in the 4-to-9 ft height class. The percentage of trees less than 1 ft high was most consistent of any height class over the age-range of burns—mostly between 10 and 15% of the stand.

Shrubs

Sagebrush occurred on all burn areas studied, although it was not found on the sample plots of the 6-year-old burn (Table 3). This shows that it can reinvade rather quickly following fire if a seed source is available. This ability is significant because sagebrush does not resprout following burning as several of the other shrubby species do. The pattern of invasion observed on the 11-year-old burns is probably typical. A few small plants became established from residual seed the first or second year following the fire. As these plants matured and produced seed, a second age class of sagebrush plants developed and filled in the interspaces. General observations suggest that in many cases sagebrush acts as a nurse plant for the establishment of juniper seedlings; most juniper seedlings occurred either under the crown of sagebrush plants or closely adjacent to them.

The percentage of dead sagebrush plants increased from none in the first three age classes of burns, to 16.2% in the 46-year-old burn, and 66.6% in stands that were over 100 years old (Fig. 3). As junipers began to exert an influence in the sagebrush community, sagebrush began declining and reached a point of either partial or total elimination (Figs. 4 and 5). Although mortality of sagebrush plants could be due to factors other than competition from junipers, the latter gradually dominate a site to the exclusion of sagebrush.

Two other shrub species occurring consistently on the burns studied were little rabbitbrush (*Chrysothamnus viscidiflorus*) and snakeweed (*Gutierrezia sarothrae*). These species were observed on eight of the nine age classes of burns. Little rabbitbrush was not found on the 6-year-old burn and snakeweed was not found on the 71-year-old burns. Both resprout following fire and the new plants tend to invade open areas rather rapidly. Peak frequencies were found on 22-year-old burns for snakeweed and 36-year-old burns for little rabbitbrush (52% and 42%, respectively); both declined thereafter to less than 10% on 100+-year-old burns (Fig. 6).

Black sagebrush (*Artemisia nova*), bitterbrush (*Purshia tridentata*), and snowberry (*Symphoricarpos vaccinioides*) were important on certain areas. Black sagebrush occurred mainly on areas having shallow soils within the older burns. Bitterbrush occurred on only three of the nine burn classes; it resprouted following fire, but did not invade so quickly as little rabbitbrush or snakeweed. Although snowberry occurred on five of the nine classes of burns, it was an important constituent on only three of the five on north or northwest-facing slopes.

Herbs

Total perennial grass cover varied among burns; but in general, it increased rapidly during the first 5 to 6 years after fire, maintained a somewhat uniform value for the next 40 years, and then declined (Fig. 1). The lowest point of grass cover was reached in the oldest stands. The point at which juniper cover began to increase rapidly corresponded to that point of decrease in perennial grass cover. On all, except the 3- and 36-year-old burns, bearded bluebunch wheatgrass (*Agropyron spicatum*) was the most important native perennial species in terms of cover. Within the 3- and 36-year-old burns were draw bottoms containing heavy soils where bluestem wheatgrass (*A. smithii*) was most prominent. Sandberg bluegrass (*Poa secunda*), Indian ricegrass (*Oryzopsis hymenoides*), and bottlebrush squirreltail (*Sitanion hystrix*) were the next most important native perennial species. Of the three, *P. secunda* was the most abundant species. Fairway wheatgrass (*A. cristatum*) and intermediate wheatgrass (*A. intermedium*) occurred on a few recent burns where they had been aerially broadcast following fire.

Perennial forbs did not constitute a large amount of the cover on any of the burns sampled (Fig. 7), although the frequency of perennial forbs was high on all burns.

The cover value of cheatgrass brome (*Bromus tectorum*), which was the only annual grass on the sampled burns, varied from 12.6% in the 3-year-old burns to 0.9% in the oldest stands. *B. tectorum* declined in cover the first 22 years after fire, then leveled off and stayed about the same for the remainder of the invasion sequence (Fig. 7).

Annual forbs followed a pattern similar to *B. tectorum*. They were most abundant during the first 3 or 4 years following fire, constituting 21.0% of the cover on the 3-year-old burns. On the 6-year-old burn, annual forb cover was less than 5.0%. Cover of annual forbs remained low on all older burns studied. The lowest point was reached in the 100+-year-old burns (Fig. 7). The most abundant annual forbs during the first stages of succession were pale alyssum (*Alyssum alyssoides*), flixweed tansy-mustard (*Descurainia sophia*), sunflower (*Helianthus annuus*), coyote tobacco (*Nicotiana attenuata*), and Russianthistle (*Salsola pestifer*). In each of the six burn classes, *A. alyssoides* and *D. sophia* were present but were much more abundant on the recent burns.

The percentage of bare ground, which varied with the age of the burn, was highest in the most recent burns and in the oldest stands due to lack of herbaceous vegetation. Litter cover was lowest in the 3-year-old burns and reached its peak in the 86-year-old burns; then it dropped in the oldest stands (Fig. 8) where most of the litter occurred under the crowns of trees.

Soils

Soils on juniper sites varied from deep alluvial to shallow residual. Residual soils, generally found on ridgetops and upper slopes, were frequently interrupted by rock outcrops of limestone or quartzite. Depth to the C horizon, or bedrock, was often 1 ft or less. Generally, the older juniper stands were found on these shallow residual soils.

Alluvial soils occurred mostly on the fans and in the draw bottoms. These soils were usually deeper than the residual soils but generally had less horizon development. North-facing slopes had deeper soils and better root penetration than south-facing slopes. Although texture varied from sandy loam to clay, gravelly loams and gravelly clay loams were most common. The pH down to the C horizon varied from 6.9 to 8.4, but most soils were within a pH range of 7.4 to 8.0. Soluble salts were well within the range for productive soils—the highest value being 160 ppm.

Factors Affecting Vegetation Change

The rate at which juniper invades a burned area varies

Table 3. Density (plants/plot), cover (%), and yield (g/plot) of *Artemisia tridentata* by age of burn (years).

Approximate age of burn	Density	Cover	Foliage yield
3	0.7	2.1	29.0
6	–	–	–
11	7.3	7.8	141.4
22	6.8	8.8	350.6
36	10.4	19.0	441.3
46	10.5	13.7	352.0
71	6.8	9.4	148.3
86	7.3	7.3	144.1
100+	1.5	1.2	19.5

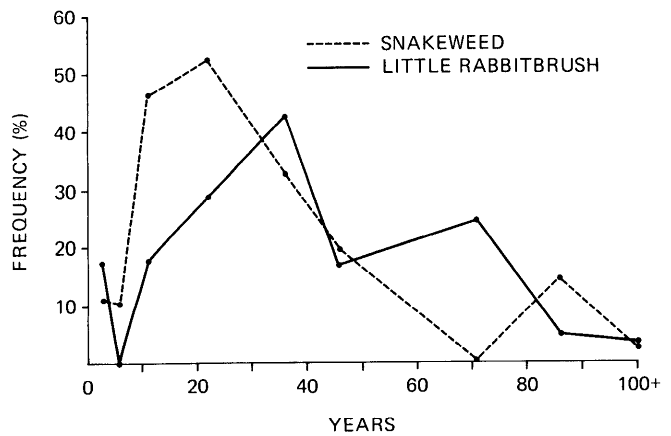

Fig. 6. *Percent frequency of snakeweed and little rabbitbrush by age of burn.*

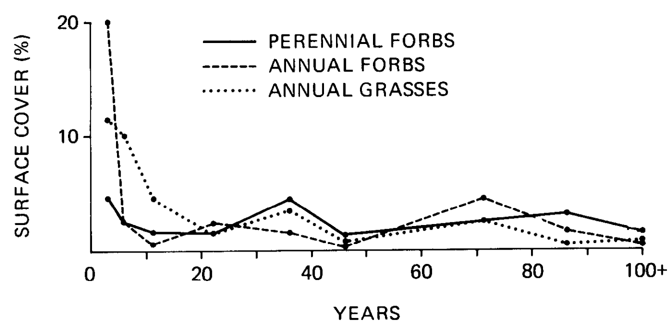

Fig. 7. *Surface cover of perennial forbs, annual forbs, and annual grasses by age of burn.*

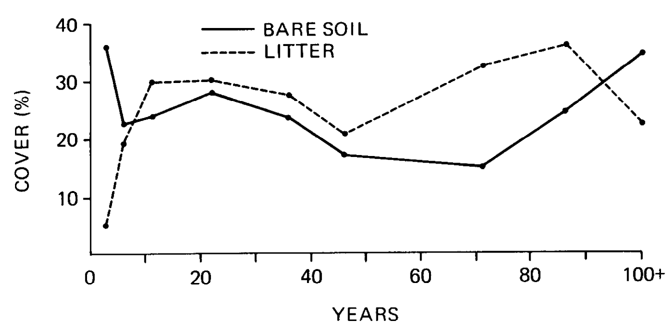

Fig. 8. *Ground-cover characteristics by age of burn.*

considerably, depending upon several factors working independently or together. The stage of stand maturity at the time of fire is an important factor. The rate of juniper invasion will be slower in a young stand having no seed-producing trees than in a mature stand which has been producing seed for a number of years. In the burns studied, many of the first trees to become established appeared to be from residual seed. These initial trees, in approximately 33 years, would then be a potential new source of seed, inasmuch as it was determined that the youngest seed-producing trees were approximately 33 years old.

Factors such as seed source, seed dissemination, size of burn, and grazing also influence the rate of succession. Succession could be a slow process if the invasion occurred only from the burn edge; this is especially true on large burns, but rate of succession would depend on the kinds and numbers of seed-dispersing agents. Of these agents, water and animals are probably the most important. Birds and many large and small herbivores and even some carnivores consume the so-called "berries." Rodents carry and store juniper seeds. Some seedlings on the burns studied appeared to be from rodent caches; several seedlings were growing at a single spot. Jackrabbits were probably the most important means of dispersal observed in this study. Juniper seeds were observed in jackrabbit pellets over a half mile from the nearest juniper tree; as many as 12 seeds were found in a single pellet.

Large herbivores have great influence on the rate of succession. Heavy grazing following fire will reduce the vigor and cover of perennial grasses and increase the rate at which shrubby species, particularly sagebrush, invade the site (Fig. 9). Trampling by animals also may aid in planting juniper seeds

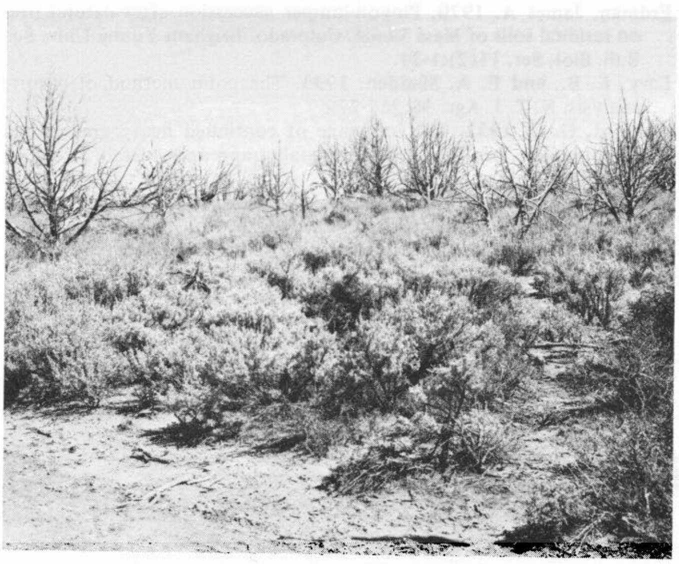

Fig. 9. *A sagebrush community that developed in 11 years on the Erickson Pass burn.*

Fig. 10. *A sagebrush-grass community on the Watts Pass burn. Note young trees invading the site (46-year-old burn).*

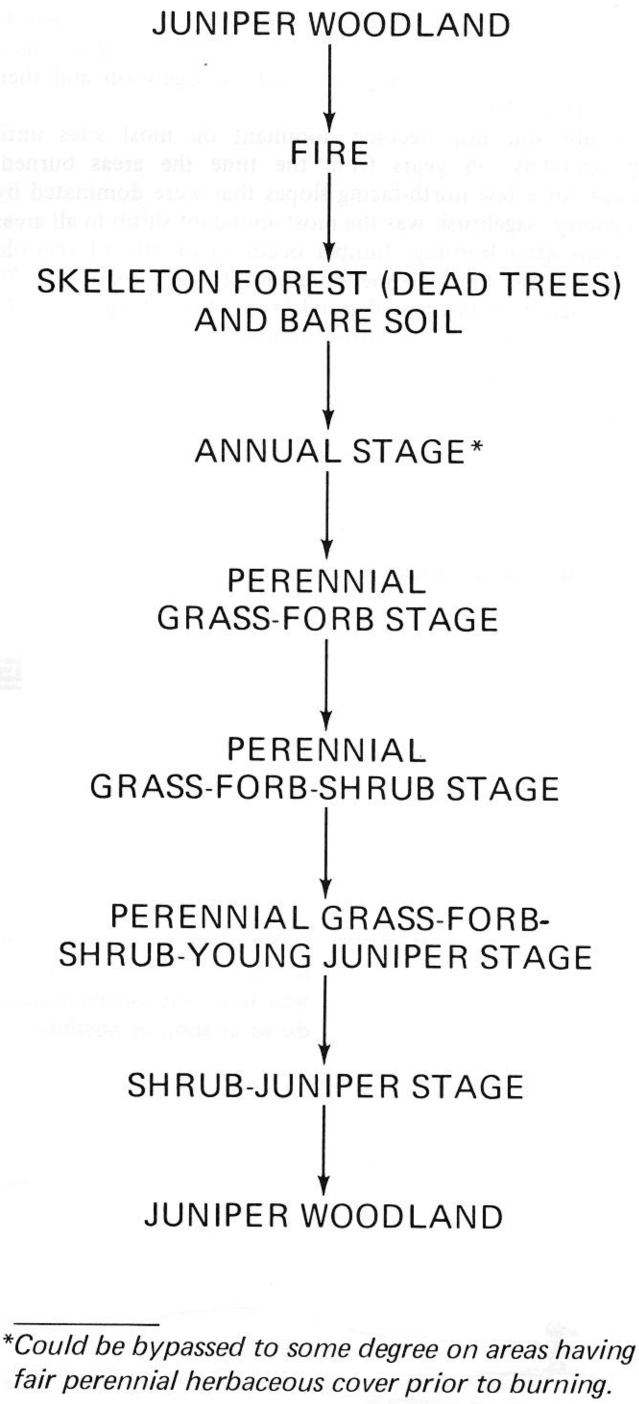

Fig. 11. *Vegetation changes following fire in the juniper woodlands of west-central Utah.*

distributed by other means.

Summary and Conclusions

In summarizing the pattern of succession following fire on areas studied, the initial stage was annual, reaching maximum development in the first 3 to 4 years. In such successions, the annual stage is generally replaced by a perennial-grass-forb stage by the fifth or sixth year if there is a fair remnant of native grasses prior to the burn. Under natural conditions, these would consist primarily of bottlebrush squirreltail, bearded bluebunch wheatgrass, Indian ricegrass, and Sandberg bluegrass. A shrub stage may follow the annual stage if shrubs are dominant to the exclusion of perennial grasses prior to the fire. Figure 9 shows a sagebrush community that developed in 11 years on the Erickson Pass burn. If a perennial grass stand develops first, it is usually followed by sagebrush and then juniper (Fig. 10).

Shrubs did not become dominant on most sites until approximately 35 years from the time the areas burned. Except for a few north-facing slopes that were dominated by snowberry, sagebrush was the most abundant shrub in all areas 35 years after burning. Juniper occurred on the 11-year-old burns but did not become dominant for approximately 70 years; there was an upward trend in numbers of trees after 46 years. On the 86-year-old burns, juniper completely dominated the site. Other plant species were sharply reduced in vigor and density. These successional stages are summarized in Figure 11. They are not greatly different from the ones outlined by Arnold et al. (1964) in Arizona and Erdman (1970) in Colorado.

The burns sampled do not give sufficient information to determine the place of pinyon in the successional sequence.

Two little-understood basic factors in tree invasion are the frequency of good seed crops and the combination of climatic factors that influence high germination. The variety and complexity of factors influencing succession demonstrate the need for multifacet research to answer the many questions involved and provide a sound basis for managing the vast acreage occupied by this type.

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