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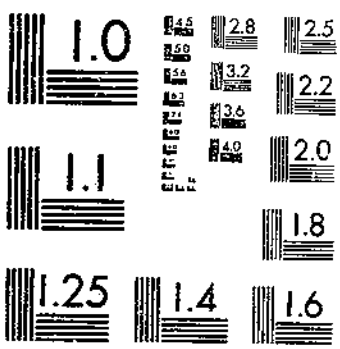

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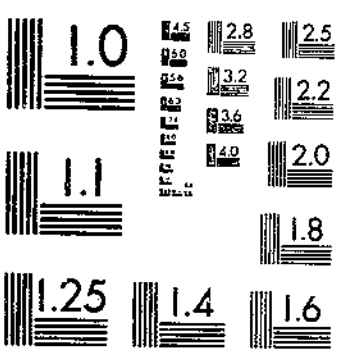

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Technical Bulletin No. 1075 · July 1953

UNITED STATES
DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

Ecological Effects of Planned Burning of Sagebrush-Grass Range on the Upper Snake River Plains[1]

By JAMES P. BLAISDELL,[2] *range conservationist, Intermountain Forest and Range Experiment Station, Forest Service*

CONTENTS

INTRODUCTION

Dense stands of big sagebrush[3] cause a serious grazing management problem on extensive areas of western range. Fully one-half of the 96 million acres of the sagebrush-grass type is believed to be covered by stands of big sagebrush frequently so dense that they are a barrier to livestock movements (fig. 1). Sheep can make their way through the sagebrush only with difficulty, considerable wool is pulled from the fleeces by the brush, and lambs are lost through straying. Even when livestock force their way into heavy sagebrush stands,

[1] Submitted for publication May 11, 1953.

[2] The author acknowledges his indebtedness to those who began and carried out the early work of this study, Joseph F. Pechanec, Chief, Division of Range Research, Forest Service; G. D. Pickford, Supervisor, Routt National Forest; and George Stewart, formerly in charge of Range Reseeding Research, Intermountain Forest and Range Experiment Station. He is also appreciative of the direction given in the collection of data in 1948 by Clark E. Holscher, now leader of the Blue Mountain Research Center, La Grande, Oreg., Pacific Northwest Forest and Range Experiment Station. Acknowledgment is also made to the Fremont County Woolgrowers' Association and the State of Idaho for their cooperation in the initial work of the Fremont County burning project, and to the Bureau of Animal Industry for its cooperation on sagebrush burning projects at the U. S. Sheep Experiment Station, Dubois, Idaho.

[3] Common and scientific names of species mentioned in this bulletin appear on p. 36.

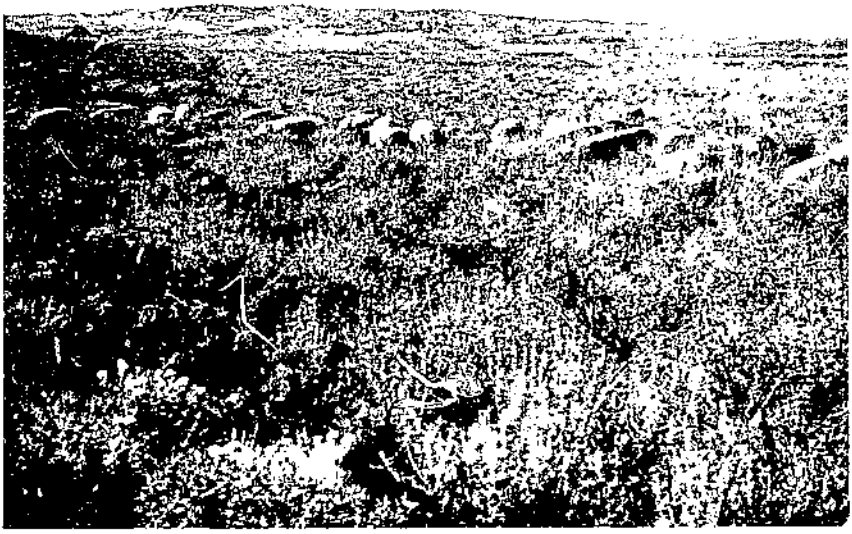

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FIGURE 1.—Sheep grazing in a dense stand of big sagebrush on the upper Snake River Plains.

they are often unable to reach more than half of the palatable grasses and forbs. Grazing capacity is further reduced by decreases in grass and forb yield resulting from sagebrush competition.

Where big sagebrush has gained control of any area, it forms a definite obstacle to range improvement. It is typically a long-lived shrub. Even-aged stands attain an age of 30 to 40 years, and individual plants may exceed 100 years. Because of its long life and ability to compete with perennial grasses and forbs for soil moisture, sagebrush in dense stands seriously retards range improvement that can be obtained by grazing management; only slight improvement may be realized in 10 to 15 years. Big sagebrush also hinders range reseeding by physically obstructing equipment and later competing with reseeded species for soil moisture.

Livestock operators have often used fire to rid their lands of sagebrush. When burning was followed by poor management, even heavier stands of sagebrush usually returned, and in many cases these were again removed by fire. Some perennial grasses and forbs were destroyed by fire and some were destroyed by overgrazing; consequently, this cycle often resulted in serious range depletion *(17)*.[1] Soil deterioration accompanied this destruction of perennial grasses and forbs.

Several studies, however, have indicated that planned burning is a valuable tool in range improvement. Through such burning of sagebrush-grass range in the Laramie River Valley of northwestern Colorado, Hanson *(7)* and Morris *(9)* obtained a 300-percent increase in grazing capacity. A previous publi-

[1] Italic numbers in parentheses refer to Literature Cited, p. 37.

cation *(15)*[5] concerning the Fremont and Clark County experimental areas showed that planned burning resulted in an increase of 60 percent in perennial grasses and forbs, or an increase of 69 percent in grazing capacity.

The purpose of this bulletin is to describe the long-term effects of planned burning and to supply ecological interpretations of these effects on the vegetation and soil. These effects were obtained from single planned burns. Repeated burning, especially at close intervals, would upset the ecological balance of the range, creating less desirable conditions. Caution must be used in applying this information to other conditions in other localities.

METHODS OF STUDY

Two large areas of sagebrush-grass range on the upper Snake River Plains were carefully burned in accordance with definite plans, one in 1933 and the other in 1936. Both areas were given complete protection for one year after burning and have since been conservatively grazed. Systematic observations on vegetation and soil were made prior to burning and at intervals afterwards until 1948.

Description of Experimental Areas

Fremont County

The Fremont County area is approximately 2 miles square and is located about 17 miles north of St. Anthony, Idaho, at an elevation of approximately 6,000 feet. The topography is similar to much of the Snake River Plains in that there is little surface drainage and slight relief except for lava outcrops. The soil is of basaltic origin and contains considerable sand. In depth, it varies from zero on the lava outcrops to more than 3 feet in swales, the average being about 18 inches.

Precipitation averages about 16 inches and is rather evenly distributed throughout the year. During the summer months, dry winds from the southwest occur almost daily, causing a high water loss from both soil and vegetation. Temperatures may reach a maximum of 100° F. in summer, and a minimum of −35° in winter. The frost-free period is approximately 95 days.

Prior to burning, this area supported a dense stand of big sagebrush 2 to 4 feet high. Beneath the sagebrush was an open yet fairly continuous stand of perennial grasses composed chiefly of thickspike wheatgrass, needle-and-thread, bluegrasses, and sedges.[6] Of the total vegetal cover, perennial grasses formed approximately 45 percent, perennial forbs 5 percent, sagebrush 35 percent, bitterbrush 10 percent, and miscellaneous shrubs and annuals 5 percent.

According to statements of longtime residents, the area was accidentally burned during the dry summer of 1910. Sagebrush was largely destroyed by the burn, and grasses grew abundantly. Unrestricted grazing followed burning, and after about 10 years sagebrush began to increase noticeably. By 1932 it was so dense that handling of sheep on the area was difficult. However, an understory of valuable grasses still remained.

[5] Farmers' Bulletin 1948 is primarily a report on the aspects of sagebrush burning having immediate application. It describes increases in grazing capacity as a result of planned burning and the disastrous effects of haphazard burning. It also discusses such essential considerations as where, when, and how to burn, management after burning, and costs.

[6] Sedges are included with the grasses throughout this bulletin.

In 1948 annual ring counts on sagebrush plants on parts of the experimental area that were not burned in 1933 showed the stand to be even-aged at approximately 35 years. This indicates that most of the sagebrush plants became established 2 or 3 years after the 1910 burn.

Clark County

The Clark County area occupies almost 1 square mile of the United States Sheep Experiment Station range about 11 miles northeast of Dubois, Idaho, at an elevation of approximately 6,000 feet. The soil contains less sand than that of the Fremont County area, and the annual precipitation averages only 11 inches. Otherwise topography, soil, and climate are similar.

In general, the vegetal cover prior to burning was similar to that of the Fremont County area except that bluebunch wheatgrass, plains reedgrass, spineless gray horsebrush, and downy rabbitbrush were present, but scarcely any bitterbrush. The vegetation was roughly 35 percent perennial grasses, 5 percent perennial forbs, 5 percent annual forbs, 40 percent sagebrush, and 15 percent rabbitbrush, horsebrush, and miscellaneous shrubs.

Burning and Subsequent Management

The Fremont County area was burned in September of 1933, and the Clark County area in August of 1936. At that time, seed of most perennial grasses and forbs had been disseminated and plants were dry or nearly dry. In order to allow an ample supply of flammable material to carry the fire, no grazing was permitted on either range during the growing season prior to burning. Carefully prepared firelines and trained crews were used in controlling the fires. Both burns left scattered unburned "islands" (fig. 2). Lava outcrops and other barriers prevented these islands from burning, and except for the outcrops, these unburned islands are typical of the burned areas. Many of the unburned islands were large. In planned burning operations, an attempt is usually made to burn out such areas, but they were left on the experimental burns to provide the needed untreated checks.

Complete protection from grazing for 1 full year following burning was given both areas. After that, conservative spring and fall grazing by sheep was practiced except on areas near established sheep camps and trails. Average rates of stocking were approximately 2.5 and 2 acres per sheep month on the Fremont and Clark County burns, respectively.

Inventories of Vegetation

Sampling Systems

Four hundred circular plots, each having an area of 100 square feet, were established at regular intervals on each area. Because a high percentage of the plots on lava outcrops remained unburned owing to the sparseness of their vegetation, it was thought that their inclusion in the analyses would present a biased picture of the range as a whole. They were therefore omitted. Also, certain parts of each burn were accidentally reburned prior to 1948, and they too were omitted. Only 250 of the original 400 plots on the Fremont County burn and 268 of those on the Clark County burn were available for final analysis.

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FIGURE 2.—A general view of the Fremont County area in 1935, 2 years after burning, showing lava outcrops and small unburned patches of sagebrush.

Prior to burning, 1 and 3 years after burning, and again in 1948, estimates were made of the quantity of each species on each of the circular plots. All herbage estimates were in units of weight *(13)* with the exception of those made in units of density *(26)* prior to and 1 year after burning on the Fremont County plots. In 1948, estimates were also made of the amount of each species available to livestock.

Immediately after the plots were burned, they were classified by intensity of burn as follows: (1) *Heavy burn*—Trunk or main stem of sagebrush consumed by fire; (2) *moderate burn*—larger branches of sagebrush remaining, but smaller branches and twigs consumed; (3) *light burn*—smaller branches and twigs unburned, only leaves consumed by fire; (4) *unburned*—no evidence of fire either in the understory or in sagebrush crowns.

Numerous general observations were made on both experimental areas. Extent of survival of big sagebrush and bitterbrush browse through sprouting was determined in 1934 on the Fremont County burn. Sagebrush plants were counted on all plots in 1937 and 1948 in Fremont County, and in 1939 and 1948 in Clark County. In 1948 the sagebrush was classified either as recent seedlings, large plants established since burning, or old unburned plants. Also in 1948, the distance of each burned plot from an unburned area was estimated in an effort to correlate sagebrush establishment with distance from seed source. In addition, bitterbrush plants were counted on the plots of both burns, and were classed as plants that had come up from seed since the burn, sprouts from burned bushes, or old unburned bushes.

Analysis of Data

Comparisons of 1948 data from unburned, lightly burned, moderately burned, and heavily burned areas were improved by making allowance for initial differences in vegetation. Burn intensity could not be predicted prior to burning and assigned to specific areas; therefore the resulting intensities may be partly due to variations in combinations and quantities of species. Because of this lack of experimental control, vegetation inventory data for 1948 were analyzed by covariance *(25)* to allow a statistical adjustment for the uncontrolled initial variations. The applicability of this method to similar data has been tested by Pechanec *(11)* who found that the use of covariance in adjusting for uncontrolled variables resulted in at least doubled precision.

Such analyses were made for only those species which prior to burning had an average cover of at least 0.1 square foot per plot on the Fremont County area or an average weight of at least 2 grams per plot on the Clark County area. Most species recorded in lesser amount prior to burning occurred on too few plots to provide adequate samples for statistical analysis. Data on herbage production for such species are presented for 1948.

Since there were wide fluctuations in herbage production from year to year even on unburned areas, as a result of variations in weather, vegetal trends resulting from burning are difficult to distinguish unless these natural fluctuations are eliminated. This has been accomplished by using unburned areas as a base and expressing production on burns as a percentage of that on the unburned. It must be kept in mind that these percentages are based on unadjusted values of density or weight and are presented only to show trends in relative production. Differences in 1948, at the end of the study, are better shown by comparing yields adjusted by covariance.

Measuring Soil Changes

Soil records were obtained from only the Fremont County burn. Samples were taken from 48 stations located at regular intervals over the area in 1932 before burning, in 1934 after burning, and again in 1948. These stations were classified by intensity of burn in the same way as the inventory plots. At each of the 48 stations, samples were taken of the top ½–inch soil layer and of the 2½–inch layer immediately beneath. Soil samples were analyzed for four properties using the following methods: (1) Schollenberger chromic-acid reduction for determination of organic matter; (2) standard Kjeldahl method for total nitrogen; (3) centrifuge method for moisture equivalent; and (4) Hellige disk-comparator method for pH. As with the data on vegetation, soil property differences in 1934 and 1948 were analyzed by covariance to allow for statistical adjustment of uncontrolled initial variations.

Estimates of intensity of wind erosion were made on the inventory plots in 1934, the year after burning. Degree of erosion for each plot was assigned to 1 of 6 classes ranging from none to very heavy.

EFFECTS OF BURNING ON VEGETATION

Responses of vegetation to burning are shown in two principal ways. First, production in pounds per acre in 1948, 15 and 12 years after burning in Fremont and Clark Counties, respectively, is given. These yields of herbage indicate what may be expected in the way of longterm effects of a single burn. Second, relative amounts of vegetation on burned as compared with unburned range are given for intervals during the study period, to indicate trends in production. Relative values are used here in order to minimize the effects of differences in methodology and fluctuations in herbage production caused by fluctuations in weather.

Fremont County

Grasses.—There were no significant differences between total grass production on the unburned, lightly burned, moderately burned, and heavily burned parts of the Fremont County area 15 years after burning. Each treatment produced about 300 pounds of grass per acre (table 1). Individual species, however, responded in various ways. Thickspike wheatgrass produced 50 pounds per acre more on heavily burned than on unburned range, and sedges 8 pounds more on the light burn. Prairie junegrass produced 11 pounds more on lightly burned and 21 pounds more on moderately burned than on unburned range. Bluegrasses, on the other hand, produced 14 pounds per acre less on heavily burned than on unburned range. These differences are all judged to be statistically significant.

Needle-and-thread and Columbia needlegrass were not significantly affected by any intensity of burn, although the former produced from 10 to 26 pounds more per acre on burned than on unburned range. Idaho fescue occurred on so few plots and in such small quantities in 1932 that covariance analysis and computation of adjusted values was not feasible. However, its strikingly lower production, as given by actual weights on all burn intensities in 1948, suggests that this species is severely injured by fire and is very slow to recover.

Trends in production of the various grasses after planned burning are indicated in table 2. Here production in each burn intensity is expressed as a percentage of density or weight of herbage on the unburned range in the

TABLE 1.—*Adjusted air-dry herbage production* [1] *of grasses in relation to treatment in Fremont County, together with variance ratios (F) and approximate least significant differences, 1948*

Species	Treatment				(F)	Least significant differences [2]	
	Unburned	Light burn	Moderate burn	Heavy burn		0.05	0.01
	Lbs./acre	*Lbs./acre*	*Lbs./acre*	*Lbs./acre*			
Thickspike wheatgrass	117.2	110.1	99.1	167.0	[4] 12.19	25	33
Sedges [3]	13.1	21.5	12.2	8.7	[4] 6.46	6	8
Idaho fescue	19.3	.2	3.8	1.6			
Prairie junegrass	32.8	43.6	53.4	36.8	[4] 6.92	10	12
Bluegrasses	21.9	23.1	16.4	7.9	[4] 10.08	6	8
Needle-and-thread	47.7	68.4	73.9	57.8	1.83		
Columbia needlegrass	37.1	28.1	48.8	35.7	1.50		
All grasses [5]	296.5	290.0	303.4	321.1	.73		

[1] Adjusted on the basis of 1932 densities through covariance analysis. Idaho fescue too limited in occurrence in 1932 to allow such analysis.

[2] Although number of plots in each treatment was not constant, for purposes of general evaluation least significant differences based on the average number of plots are shown.

[3] Several species grouped because of their infrequent occurrence.

[4] Highly significant.

[5] Includes minor grass species not listed, together with sedges.

same year. This method excludes effects of natural herbage fluctuations over the study period and permits a direct examination of trends due to burn intensity. Relative amounts of vegetation in 1932, the year before burning, and 1, 3, and 15 years after burning, are given in this way.

By the end of the first growing season after burning thickspike wheatgrass had increased markedly on burned areas, as compared with unburned, the degree of increase rising with intensity of burn. This relative increase continued, and by the end of the third growing season production on the burned range doubled or tripled that on the unburned range. However, after 15 years, relative production had declined on all burns, although, as shown by the adjusted yields in table 1, thickspike wheatgrass still produced significantly more herbage on the heavy burn than on unburned range. The trends of "All grasses" were similar to those of thickspike wheatgrass, which is not surprising since this species contributes between a third and a half of the total grass production.

As compared with the unburned area, sedges increased on the light burn from the beginning (table 2), until the significant difference shown in table 1 was reached in 1948. On the moderate and heavy burns, relative yield decreased the first year, and recovery was slowest on the heavy burn. Threadleaf sedge has previously been reported to be severely damaged by burning *(15)*. The present study, however, indicates that the effects of burning are not lasting, as actual yields of threadleaf sedge in 1948 were 2.5, 7.3, 4.8, and 2.2 pounds per acre on unburned, lightly, moderately, and heavily burned areas, respectively.

TABLE 2.—*Grass production* [1] *on burns of three intensities made in the fall of 1933 in Fremont County, expressed as a percent of the unburned each year of record*

Burn intensity and year	Thickspike wheatgrass	Sedges	Prairie junegrass	Bluegrasses	Needle-and-thread	Columbia needlegrass	All grasses [2]
Light:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1932 [3]	124	69	143	169	135	200	125
1934	185	76	320	900	107	132	145
1936	207	100	33	119	140	123	156
1948	98	155	137	113	173	81	108
Moderate:							
1932 [3]	113	86	110	189	169	275	133
1934	217	74	380	1,600	99	164	162
1936	338	84	52	78	118	213	226
1948	86	90	162	82	211	138	116
Heavy:							
1932 [3]	112	77	60	166	57	112	94
1934	239	43	340	900	18	87	125
1936	273	62	28	59	23	144	166
1948	145	62	108	39	92	96	106

[1] Estimated as density in 1932 and 1934, as weight in 1936 and 1948.
[2] Includes minor grass species not listed, together with sedges.
[3] Prior to burning; data are from plots later classified as light, moderate, and heavy burns, respectively.

Prairie junegrass and the bluegrasses increased enormously on all intensities of burn during the first season, as compared with the unburned. This, however, is at least partially a result of disproportionate decreases of these grasses on unburned range in the drought year 1934 *(14)*, which altered the basis for comparison. Since prairie junegrass and the bluegrasses showed very large relative decreases by the third season after burning, the early effect of burning was probably very injurious. Prairie junegrass had recovered by 1948, but the harmful effects of heavy burning on the bluegrasses were still evident 15 years after burning, as pointed out in the discussion of table 1.

Needle-and-thread and Columbia needlegrass showed relative decreases the first year after burning, more or less in accordance with intensity of burn. Needle-and-thread then increased consistently, but trends of Columbia needlegrass were variable.

Forbs.—Total forb production in 1948 was considerably higher on all burn intensities than on unburned areas (table 3). The differences on the light and moderate burns were highly significant; that on the heavy burn was just short of statistical significance. Of the species mainly responsible for the higher yield of forbs on burned areas, western yarrow, asters, fleabane, and goldenrods are rhizomatous perennials. Littleleaf pussytoes, a suffrutescent forb of low forage value, and sticky geranium, a perennial rated fair as forage, also contributed to the higher yield, especially on light and moderate burns. On the other hand, yield of knotweed, an undesirable annual, was greatest on the heavy burn.

Most of the individual species were present in such small quantities and on so few plots in 1932 that covariance analysis was not justified. Analyses made for littleleaf pussytoes, plumeweed, and eriogonum showed no significant

differences. However, the lower yield of plumeweed on the burned areas as compared to that on unburned does approach statistical significance. Responses of several species are apparently related to burn intensity, but much of the variation shown in table 3 may be due to scattered occurrence of the plants rather than degree of burn. Caution must be used in attaching importance to these unadjusted values.

TABLE 3.—*Adjusted air-dry herbage production*[1] *of forbs in relation to treatment in Fremont County, together with variance ratios (F) and approximate least significant differences, 1948*

Species	Treatment				(F)	Least significant differences [2]	
	Unburned	Light burn	Moderate burn	Heavy burn		0.05	0.01
	Lbs./acre	*Lbs./acre*	*Lbs./acre*	*Lbs./acre*			
Littleleaf pussytoes	15.8	22.0	25.3	18.0	1.17		
Plumeweed	6.4	3.1	1.5	1.9	2.16		
Eriogonum	21.0	17.0	24.0	15.1	1.41		
Western yarrow	16.8	23.5	30.1	17.1			
Asters	4.1	12.0	11.2	8.1			
Comandra	4.5	1.2	4.7	1.1			
Fleabane	8.4	8.4	18.9	17.3			
Sticky geranium	6.6	56.5	28.3	7.6			
Helianthella	6.5	5.5	18.2	3.5			
Knotweed	7.4	8.5	10.1	26.1			
Goldenrod	6.9	21.5	37.7	21.6			
All forbs [3]	126.6	190.7	236.8	170.0	[4] 7.84	47	62

[1] Adjusted on the basis of 1932 densities through covariance analysis. Species for which variance ratios are not shown were too limited in occurrence in 1932 to allow such analysis.

[2] Although number of plots in each treatment was not constant, for purposes of general evaluation least significant differences based on the average number of plots are shown.

[3] Includes minor species not listed.

[4] Highly significant.

The 1934 inventories showed a marked increase in production of "All forbs" on burned areas in relation to that on the unburned (table 4). This trend continued through the third year, especially on burns of light and moderate intensity. Although much of these early increases had disappeared by 1948, the adjusted yields on both light and moderate burns (table 3) were still significantly greater than those on the unburned. Trends of individual species were poorly defined, probably because of their small quantities and poor distribution over the study area. For this reason, trends of groups having similar growth form are shown.

Rhizomatous species on all burn intensities showed relative increases the first year after burning, but subsequent trends were variable. On the other hand, suffrutescent forbs (pussytoes and eriogonum) decreased markedly, roughly proportionate to burn intensity, and then increased. Annuals, chiefly gayophytum, knotweed, plumeweed, and goosefoot, made enormous relative increases in 1934, roughly in proportion to burn intensity. Some of this ap-

parent increase, however, is attributable to the very low production of annuals on the unburned plots in this drought year, which serves as a base for the percentages. Portions of these relative increases persisted through 1936, but had disappeared by 1948 on all but the heavy burn. The persistence of annuals on the heavy burn is shown by actual yield of knotweed in table 3, 26 pounds on the heavy burn as compared to 7 on the unburned. Other perennial forbs generally showed an initial but temporary increase after burning.

TABLE 4.—*Production*[1] *of forbs on burns of three intensities made in the fall of 1933 in Fremont County, expressed as a percent of the unburned each year of record*

Burn intensity and year	Rhizomatous forbs	Suffrutescent forbs [2]	Annuals	Others	All forbs
Light:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1932 [3]	340	96	47	314	97
1934	358	77	200	243	161
1936	278	163	174	219	229
1948	163	112	84	183	146
Moderate:					
1932 [3]	150	78	65	143	78
1934	258	38	1,000	293	131
1936	223	131	197	251	215
1948	252	128	86	171	174
Heavy:					
1932 [3]	80	53	90	100	69
1934	116	5	5,600	229	120
1936	109	62	446	199	147
1948	160	67	209	104	120

[1] Estimated as density in 1932 and 1934, as weight in 1936 and 1948.

[2] Perennial forbs with partially woody stem bases that do not die down to the ground each year.

[3] Prior to burning; data are from plots later classified as light, moderate, and heavy burns, respectively.

Although tables 2 and 4 indicate that some of the grass and forb species were not damaged by planned burning, it should be noted that inventories were made late in the growing season and therefore did not show conditions during the early part of the first growing season after burning. Actually, perennial vegetation that survived was clearly lowered in vigor, especially on the burns of heavier intensity. Leaves were shorter on all grasses and forbs, even on the rhizomatous species; clumps of bunchgrasses were badly broken up and were producing only a very few shoots.

The damage to grasses and forbs as a result of burning was further obscured by the severe drought of the 1934 season, which caused unburned perennial grasses and forbs on the upper Snake River Plains to decrease to 38 and 25 percent of their 1932 densities, respectively *(14)*. Therefore, it appears that many perennial grasses and forbs on areas burned in 1933 partially escaped the effects of this drought through reduction in shrub competition for soil moisture and were able to produce more than those on the unburned control areas during the first season.

Shrubs.—Shrubs were severely damaged by burning; the aerial part in nearly all cases was either killed by the heat of the fire or completely consumed. Fifteen years after burning on the Fremont County area, herbage yields of sagebrush and bitterbrush, as represented by leaves and current growth of twigs, were still significantly lower on burned than on unburned areas (table 5). Also yields on the moderate and heavy burns were significantly lower than those on the light burn. The shrubby vegetation in this locality is composed chiefly of sagebrush and bitterbrush; therefore the "All shrubs" herbage production closely paralleled that of these two species. Although individual statistical analyses were not made of the other shrub species, their 1948 yields are shown. Apparently creeping mahonia was favored by the heavy burn and rabbitbrush by both moderate and heavy burns.

Sagebrush was nearly always killed, but many other shrubs sprouted, especially on burns of lighter intensity. In 1934, the year after burning, 800 sagebrush plants were examined on burns of all three intensities, but not a single plant was sprouting. Examination of the same number of bitterbrush plants showed that 49 percent were sprouting on the light burn, 43 percent on the moderate burn, and 19 percent on the heavy burn. Numerous plants of downy rabbitbrush, snowberry, and creeping mahonia were also sprouting profusely.

Trends in production of sagebrush, bitterbrush, and "All shrubs" following planned burning are shown in table 6. Sagebrush was almost completely destroyed on the moderate and heavy burns, but a few plants survived on the light burn. However, many of these were apparently injured beyond recovery, because relative production on the light burn continued to decrease for the next 2 years despite invasion by seedlings. Bitterbrush, because of its ability to sprout, made some recovery by the end of the 1934 growing season, but was

TABLE 5.—*Adjusted air-dry herbage production*[1] *of shrubs in relation to treatment in Fremont County, together with variance ratios (F) and approximate least significant differences, 1948*

Species	Treatment				(F)	Least significant differences [2]	
	Unburned	Light burn	Moderate burn	Heavy burn		0.05	0.01
	Lbs./acre	*Lbs./acre*	*Lbs./acre*	*Lbs./acre*			
Sagebrush	522.7	241.3	132.1	54.7	[3] 56.96	77	102
Bitterbrush	311.2	215.7	147.6	156.8	[3] 13.71	58	76
Downy rabbitbrush	4.0	3.0	14.1	13.3			
Creeping mahonia	6.3	4.4	7.0	33.9			
Snowberry	6.7	2.6	6.6	3.0			
All shrubs [4]	850.4	523.1	317.9	267.7	[3] 51.36	102	134

[1] Adjusted on the basis of 1932 densities through covariance analysis. Species for which variance ratios are not shown were too limited in occurrence in 1932 to allow such analysis.

[2] Although number of plots in each treatment was not constant, for purposes of general evaluation least significant differences based on the average number of plots are shown.

[3] Highly significant.

[4] Includes minor species not listed.

TABLE 6.—*Herbage production*[1] *of shrubs on burns of three intensities made in the fall of 1933 in Fremont County, expressed as a percent of the unburned each year of record*

Burn intensity and year	Sagebrush	Bitterbrush	All shrubs [2]
Light:	*Percent*	*Percent*	*Percent*
1932 [3]	95	226	116
1934	19	63	31
1936	10	67	25
1948	45	86	63
Moderate:			
1932 [3]	117	214	131
1934	1	23	10
1936	1	46	13
1948	26	60	41
Heavy:			
1932 [3]	124	159	137
1934	0	10	10
1936	(4)	19	11
1948	12	54	36

[1] Estimated as density in 1932 and 1934, as weight in 1936 and 1948.
[2] Includes minor species not listed.
[3] Prior to burning; data are from plots later classified as light, moderate, and heavy burns, respectively.
[4] Less than 0.5.

still far below its original production. Sagebrush, bitterbrush, and "All shrubs" showed relative increases after 1936 on burns of all intensities, but the adjusted yields in table 5 indicate that in 1948 herbage production of shrubs was still significantly lower on burned than on unburned areas.

Sagebrush began to reinvade shortly after burning. Counts made 4 years after burning (1937) on the 100-square-foot plots showed an average of 0.43 plant per plot on the heavy burn, 0.64 on the moderate burn, and 2.52 on the light burn. By 1948, 15 years after burning, sagebrush had increased until there were more than half as many plants per plot on each intensity as on unburned areas (table 7). The aggressiveness of big sagebrush is well shown by the fact that most of the sagebrush reinvasion occurred after grasses and forbs had recovered from the burning injury (after 1937). Average air-dry herbage weight per sagebrush plant in 1948 was 44.4, 29.9, 18.4, and 8.2 grams on unburned, lightly, moderately, and heavily burned areas, respectively. Differences in plant size are partly due to relative ages, but grass and forb competition is undoubtedly an important factor.

There were approximately half as many bitterbrush plants on the burned areas as on unburned in 1948 (table 8). Plants on the burns were approximately the same size as those on unburned areas, averaging 43.2, 49.0, 38.9, and 46.8 grams on unburned, lightly, moderately, and heavily burned areas, respectively. The difference in size between sagebrush and bitterbrush plants on burned areas was chiefly due to sprouting of bitterbrush. Many bitterbrush plants sprouted soon after burning, made rapid growth, and gained a position of dominance within 9 years (fig. 3). Sagebrush, which must start from seed, was greatly handicapped by competition from herbaceous vegetation.

TABLE 7.—*Average number of sagebrush plants per 100-square-foot plot on the Fremont County area, 1948*

Treatment	Class of plants			Total	Percent of unburned
	Recent seedlings	Large plants established since 1933	Established prior to 1933		
Unburned	0.32	2.46	9.48	12.26	100
Light burn	.91	7.50	----------	8.41	69
Moderate burn	.93	6.56	----------	7.49	61
Heavy burn	1.18	5.75	----------	6.93	57

TABLE 8.—*Average number of bitterbrush plants per 100-square-foot plot on the Fremont County area, 1948*

Treatment	Class of plants			Total	Percent of unburned
	Established since 1933	Sprouts	Established prior to 1933		
Unburned	4.08	----------	3.42	7.50	100
Light burn	3.00	1.59	----------	4.59	61
Moderate burn	2.84	1.11	----------	3.95	53
Heavy burn	2.99	.50	----------	3.49	47

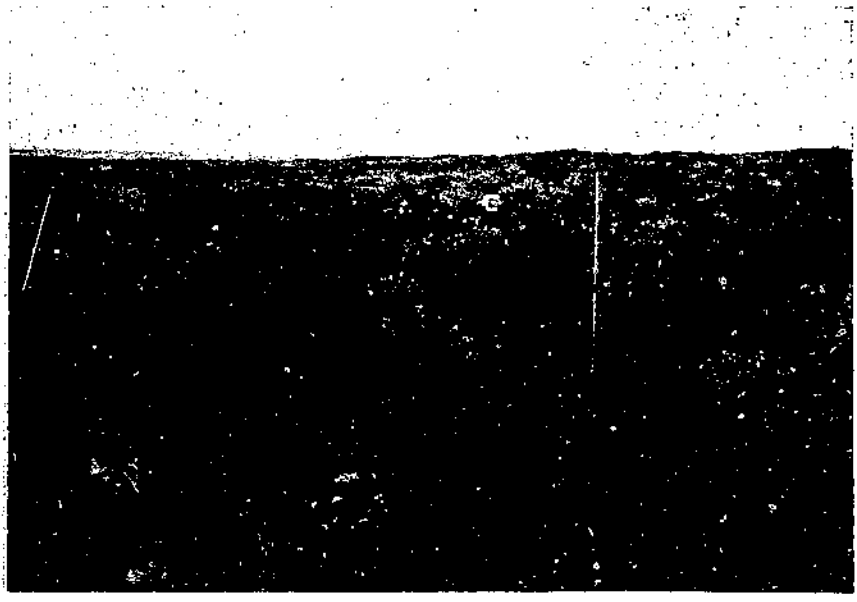

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FIGURE 3.—Bitterbrush was seriously damaged by burning, but plants that were able to sprout had made marked recovery 9 years after burning on the Fremont County area.

Clark County

Grasses.—In contrast with Fremont County, the Clark County burned areas after 12 years were producing significantly more grass than the unburned (table 9). Burn intensity had no effect on total grass production, however, as yields on all three intensities were practically identical. Only the rhizomatous grasses, thickspike wheatgrass and plains reedgrass, were producing significantly more herbage on burned than on unburned areas, and these species were chiefly responsible for the higher total grass yield on burns of all intensities. Although differences between burn intensities were not significant, higher yields of these two grasses were associated with the heavier burns.

Yields of bluebunch wheatgrass and Nevada bluegrass were considerably greater on the burned than on the unburned areas, but these differences were just short of statistical significance. Also, yield of Idaho fescue was markedly less on the heavy burn, but the difference was not statistically significant. Other grasses were not affected significantly by burning, but it is noteworthy that in practically every case there was a slightly higher production on burned areas.

Trends in production resulting from burning treatment are shown in table 10 as percentages of production on unburned range. With the exception of the jointly classified thickspike wheatgrass-plains reedgrass, the sedges, and

TABLE 9.—*Adjusted air-dry herbage production*[1] *of grasses in relation to treatment in Clark County, together with variance ratios (F) and approximate least significant differences, 1948*

Species	Treatment				(F)	Least significant differences[2]	
	Unburned	Light burn	Moderate burn	Heavy burn		0.05	0.01
	Lbs./acre	*Lbs./acre*	*Lbs./acre*	*Lbs./acre*			
Thickspike wheatgrass and plains reedgrass[3]	111.8	194.9	208.4	222.8	[4] 7.83	36	47
Bluebunch wheatgrass	16.5	32.3	29.5	23.1	2.42	------	------
Sedges	3.2	1.0	3.6	3.9	1.51	------	------
Idaho fescue	22.3	18.6	18.2	9.3	1.61	------	------
Prairie junegrass	9.4	14.2	13.3	10.7	1.35	------	------
Nevada bluegrass	17.8	38.4	25.7	31.6	2.34	------	------
Sandberg bluegrass	49.0	56.8	55.3	51.9	.32	------	------
Needle-and-thread	7.3	10.4	11.9	8.5	.52	------	------
All grasses[5]	240.8	367.2	364.7	369.0	[4] 6.83	45	60

[1] Adjusted on the basis of 1936 weight estimates through covariance analysis.

[2] Although number of plots in each treatment was not constant, for purposes of general evaluation least significant differences based on the average number of plots are shown.

[3] Grouped to allow rapid field identification.

[4] Highly significant.

[5] Includes minor grass species not listed, together with sedges.

Sandberg bluegrass on the light burn, relative production of all species decreased the year after burning. In almost every case, decreases varied roughly in proportion to burn intensity. Reductions in yields of most species were severe, especially on the moderate and heavy burns. Decreases were particularly evident in Idaho fescue and needle-and-thread, but thickspike wheatgrass-plains reedgrass was only slightly affected.

TABLE 10.—*Air-dry grass production on burns of three intensities made in 1936 in Clark County, expressed as a percent of the unburned each year of record*

Species	1936 [1]	1937	1939	1948
LIGHT BURN				
	Percent	*Percent*	*Percent*	*Percent*
Thickspike wheatgrass and reedgrass [2]	76	93	169	154
Bluebunch wheatgrass	116	106	266	231
Sedges	241	264	141	87
Idaho fescue	138	19	86	106
Prairie junegrass	167	89	113	172
Nevada bluegrass	89	76	251	220
Sandberg bluegrass	60	120	105	111
Needle-and-thread	591	106	286	455
All grasses [3]	102	100	170	156
MODERATE BURN				
Thickspike wheatgrass and reedgrass [2]	87	79	134	173
Bluebunch wheatgrass	168	84	308	237
Sedges	146	57	62	136
Idaho fescue	98	12	28	77
Prairie junegrass	183	59	71	164
Nevada bluegrass	89	24	130	146
Sandberg bluegrass	77	46	77	110
Needle-and-thread	179	9	40	326
All grasses [3]	107	68	130	155
HEAVY BURN				
Thickspike wheatgrass and reedgrass [2]	95	81	180	191
Bluebunch Wheatgrass	164	71	268	186
Sedges	88	47	71	121
Idaho fescue	133	8	7	53
Prairie junegrass	218	32	55	136
Nevada bluegrass	175	26	134	191
Sandberg bluegrass	92	36	52	105
Needle-and-thread	700	25	114	428
All grasses [3]	127	65	152	163

[1] Prior to burning; data are from plots later classified as light, moderate, and heavy burns, respectively.
[2] Grouped to allow rapid field identification.
[3] Includes minor grass species not listed, together with sedges.

Within 3 years thickspike wheatgrass-plains reedgrass and bluebunch wheatgrass recovered their initial relative losses and made substantial gains on burns of all 3 intensities. The rhizomatous thickspike wheatgrass and plains reedgrass maintained these gains during the next 9-year period and as shown by the adjusted yields in table 9 were still producing significantly more herbage on burned range. However, part of the early increase in bluebunch wheatgrass was lost by 1948, and differences in yield were not statistically significant. Idaho fescue, prairie junegrass, and needle-and-thread made partial recovery during the first 3 years, and bluegrasses completely recovered on all but the heavy burn. After 12 years, the failure of Idaho fescue on the heavy burn to regain its loss was the only one of these early decreases that was still noticeable; but as shown in table 9, even this difference was not significant. Because they were scattered and present only in small amounts, sedges were not adequately sampled and therefore display no definite trend.

Forbs.—After 12 years only the heavy burn in Clark County supported a significantly higher yield of forbs than the unburned area (table 11). As in Fremont County, most species were present in too small quantities and on too few plots to warrant individual statistical analyses. Yields of timber poisonvetch, plumeweed, and eriogonum were analyzed by covariance, but only in yields of plumeweed were there any significant differences. As in Fremont

TABLE 11.—*Adjusted air-dry herbage production[1] of forbs in relation to treatment in Clark County, together with variance ratios (F) and approximate least significant differences, 1948*

Species	Treatment				(F)	Least significant differences [2]	
	Unburned	Light burn	Moderate burn	Heavy burn		0.05	0.01
	Lbs./acre	*Lbs./acre*	*Lbs./acre*	*Lbs./acre*			
Poisonvetch	7.7	8.3	7.0	6.9	0.21		
Plumeweed	16.8	2.3	2.5	3.0	[3] 14.32	4	5
Eriogonum	19.4	33.8	18.3	21.8	2.20		
Yarrow	.8	1.2	2.2	2.2			
Pussytoes	10.8	14.4	11.5	10.6			
Arnica	13.2	15.4	13.7	7.4			
Milkvetch	2.0	1.5	1.0	1.4			
Astragalus	2.1	1.4	.7	1.0			
Thistle	.9	2.5	.5	2.8			
Hawksbeard	.3	1.4	.9	3.0			
Fleabane	8.0	26.5	18.5	22.8			
Lupines	2.3	3.6	5.4	54.4			
Penstemon	.5	.8	1.5	3.0			
Phlox	5.5	9.6	9.6	11.1			
Violet	1.9	1.3	.8	.9			
All forbs [4]	103.5	130.2	106.8	159.7	[5] 3.22	41	55

[1] Adjusted on the basis of 1936 weight estimates through covariance analysis. Species for which variance ratios are not shown occurred too infrequently in 1936 to allow such analysis.

[2] Although number of plots in each treatment was not constant, for purposes of general evaluation least significant differences based on the average number of plots are shown.

[3] Highly significant.

[4] Includes minor species not listed.

[5] Significant.

County, this species was producing much less on burned than on unburned areas.

Although actual air-dry herbage production of other forb species in 1948 is shown, differences between unadjusted values may be partly due to factors other than burning. However, it appears that fleabane and phlox (both rhizomatous species) on burns of all intensities and lupines on the heavy burn were producing more than on the unburned. The reason for this high lupine yield on only the heavy burn is not known, but it is obviously responsible for the significantly higher "All forbs" yield. Apparently the effect of burning on the other forbs was negligible after 12 years.

In contrast with Fremont County, inventories of Clark County plots the year after burning showed a decrease in "All forbs" on burned areas in relation to the unburned (table 12). By the third year considerable increases in relative yield were evident, but most of these early effects disappeared during the next 9 years. As in Fremont County, rhizomatous forbs generally increased the first year, but suffrutescent species—eriogonum and pussytoes—decreased markedly on all burns. Rhizomatous species continued to increase through the third year and then decreased. After the initial relative decreases, suffrutescent species increased throughout the study period and regained much of their original losses. With the exception of plumeweed, annuals were present only in very small amounts. Even plumeweed was virtually nonexistent on both burned and unburned areas in 1937 and 1939; therefore percentages for these years were of no value in depicting trends and have been omitted. Other perennial forbs increased the first year on burns of all intensities, but trends in following years were not well defined. Again, it should be noted that inventories were made late in the growing season and are not representative of conditions that existed during the early part of the first season after burning.

TABLE 12.—*Air-dry production of forbs on burns of three intensities made in 1936 in Clark County, expressed as a percent of the unburned each year of record*

Burn intensity and year	Rhizomatous forbs	Suffrutescent forbs	Annuals	Others	All forbs
Light:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1936 [1]	167	219	172	165	172
1937	108	42		208	128
1939	238	143		190	178
1948	192	198	21	342	147
Moderate:					
1936 [1]	103	231	101	113	116
1937	123	17		158	107
1939	262	75		177	178
1948	160	120	20	99	108
Heavy:					
1936 [1]	90	362	184	142	179
1937	159	22		263	160
1939	309	117		228	228
1948	158	156	20	351	182

[1] Prior to burning; data are from the plots later classified as light, moderate, and heavy burns, respectively.

Shrubs.—As in Fremont County, sagebrush on the Clark County plots was almost completely eradicated by burning, and even after 12 years its production on burned areas was only a fraction of that on the unburned (table 13). Production of rabbitbrush and horsebrush, however, was significantly higher on burned than on unburned areas in 1948, the tendency being for higher yields to be associated with burns of heavier intensity. Bitterbrush was represented by only a few scattered plants and did not warrant an individual analysis, but in 1948 it was producing less on burned areas. The "All shrubs" production, although modified to some extent by rabbitbrush and horsebrush, was much lower on burned than on unburned areas.

TABLE 13.—*Adjusted air-dry herbage production*[1] *of shrubs in relation to treatment in Clark County, together with variance ratios (F) and approximate least significant differences, 1948*

Species	Treatment				(F)	Least significant differences [2]	
	Unburned	Light burn	Moderate burn	Heavy burn		0.05	0.01
	Lbs./acre	*Lbs./acre*	*Lbs./acre*	*Lbs./acre*			
Bitterbrush	5.1	0	0.7	2.8			
Sagebrush	519.6	48.7	42.8	73.5	[3] 79.41	47	62
Rabbitbrush	27.9	64.2	77.2	89.3	[3] 7.56	21	28
Horsebrush	23.5	59.2	89.8	88.0	[3] 9.08	21	28
All shrubs [4]	547.0	175.5	218.8	255.1	[3] 32.11	54	71

[1] Adjusted on the basis of 1936 weight estimates through covariance analysis. Species for which variance ratios are not shown occurred too infrequently in 1936 to allow such analysis.
[2] Although number of plots in each treatment was not constant, for purposes of general evaluation least significant differences based on the average number of plots are shown.
[3] Highly significant.
[4] Includes minor species not listed.

The difference in response to burning between sagebrush and species that are able to sprout is clearly shown in table 14, which indicates trend by expressing herbage production on burns as a percentage of production on unburned areas in the same year. Sagebrush was practically eliminated by burning, and its re-establishment from seed was very slow, whereas rabbitbrush and horsebrush sprouted profusely. These sprouts quickly regained or surpassed the original size of the plant, and in addition produced seed for the establishment of new plants; consequently yield of rabbitbrush and horsebrush was increased by the third year after burning despite the initial decrease.

Sagebrush counts in 1948 in Clark County showed only about one-fifth as many plants on burned as on unburned areas (table 15), considerably less than the proportion on the Fremont County burn. As in Fremont County, plants on the burned areas were smaller than those on the unburned, the weight of the herbage averaging about 12 and 23 grams per plant, respectively.

In 1948 burned plots on both experimental areas were classified according to distance from nearest seed source in an effort to determine the effect on sagebrush re-establishment. Analysis of these data shows that there is a negative correlation between the number of sagebrush plants and distance from

TABLE 14.—*Air-dry herbage production of shrubs on burns of three intensities made in 1936 in Clark County, expressed as a percent of the unburned each year of record*

Burn intensity and year	Sagebrush	Rabbitbrush	Horsebrush	All shrubs [1]
Light:	*Percent*	*Percent*	*Percent*	*Percent*
1936 [2]	116	289	250	132
1937	2	118	52	7
1939	3	362	300	16
1948	10	692	812	33
Moderate:				
1936 [2]	80	233	320	100
1937	0	135	119	7
1939	(3)	464	768	24
1948	8	745	1,336	40
Heavy:				
1936 [2]	101	241	269	117
1937	(3)	150	116	8
1939	(3)	532	730	25
1948	14	871	1,238	47

[1] Includes minor species not listed.
[2] Prior to burning; data are from plots later classified as light, moderate, and heavy burns respectively.
[3] Less than 0.5.

TABLE 15.—*Average number of sagebrush plants per 100-square-foot plot on the Clark County area, 1948*

Treatment	Class of plants			Total	Percent of unburned
	Recent seedlings	Large plants established since 1936	Established prior to 1936		
Unburned	2.20	4.44	16.96	23.60	100
Light burn	.57	6.32	----------	6.89	29
Moderate burn	.40	2.79	----------	3.19	14
Heavy burn	.49	4.44	----------	4.93	21

seed source, with a small but highly significant correlation coefficient ($r = -0.138$). In other words, burned plots adjacent to unburned areas were supporting more sagebrush plants than plots at greater distances from a source of sagebrush seed.

TOTAL PRODUCTION AND GRAZING CAPACITY

In order to appraise the overall effects of sagebrush burning, the data were averaged by weighting each burn intensity according to its relative size. Total herbage production on the two experimental areas 15 and 12 years after burning was considerably higher on the unburned than on the burned range (table

16). Although grass and forb production on burned range was greater than on unburned, this difference was more than offset by the lower production of shrubs. An examination of tables 5 and 13 clearly shows that sagebrush is responsible for the higher herbage yields on the unburned areas.

Apparently sagebrush-grass-forb mixtures produce a much higher herbage yield than grasses and forbs grown alone. Since previous studies *(1)* have shown that sagebrush-grass mixtures also produce a higher yield than sagebrush grown alone, it appears that sagebrush and herbs are each able to use some moisture which is not available to the other. Removal of sagebrush, then, may result in only partial replacement by herbaceous vegetation.

In order to compare grazing capacities of burned and unburned ranges, it is necessary to consider both availability and palatability of the herbage. Estimates of herbage availability made concurrently with the 1948 inventories show that vegetation is considerably more accessible to livestock on the burned areas. This is especially true of herbaceous species. In 1948 total production

TABLE 16.—*Air-dry herbage, forage production, and estimated grazing capacity on burned and unburned areas of Fremont and Clark Counties, 1948* [1]

County and plant class	Total herbage		Available herbage [2]		Forage [3]	
	Unburned area	Burned area [4]	Unburned area	Burned area [4]	Unburned area	Burned area [4]
Fremont County:	*Lbs./acre*	*Lbs./acre*	*Lbs./acre*	*Lbs./acre*	*Lbs./acre*	*Lbs./acre*
All grasses	296.5	306.6	171.8	260.3	95.1	144.6
All forbs	126.6	200.6	79.8	172.1	18.6	50.1
All shrubs	850.4	350.6	416.7	218.3	50.8	30.5
Total	1,273.5	857.8	668.3	650.7	164.5	225.2
Clark County:						
All grasses	240.8	367.9	158.9	327.2	89.3	161.6
All forbs	103.5	144.6	74.5	130.8	17.0	48.3
All shrubs	547.0	235.5	289.8	168.7	1.7	3.4
Total	891.3	748.0	523.2	626.7	108.0	213.3

[1] Adjusted by covariance.
[2] Readily accessible to livestock, that is, not protected by stiff branches and twigs of shrubs.
[3] Herbage that is both available and palatable. Fremont County unburned areas had a grazing capacity of 27 sheep days per acre; burned, 38; Clark County unburned areas, 18; burned, 36.
[4] Average of light, moderate, and heavy burns, weighted by the relative size of each.

of grasses and forbs on the Fremont County burn was 20 percent higher than on the unburned, but available herbage was 72 percent higher than on the unburned. Similarly on the Clark County burn total grass and forb herbage production was 49 percent higher than on the unburned, but available herbage was 96 percent higher. On the other hand, both total and available herbage of shrubs, consisting mainly of sagebrush, was much higher on unburned than on burned range.

When allowance is made for palatibility of individual species, the effect of burning on grazing capacity is more apparent. Twenty-six to twenty-nine percent of the herbage production on the burned range was both available and palatable, as compared with only 12 to 13 percent on the unburned. Of the shrubs, only bitterbrush on the Fremont County area made a substantial contribution to total forage; its reduction on the burned range partly offset the increases in grass and forb forage. Forbs provided more forage on burned than on the unburned range, partly because they were more abundant on burned range and partly because of higher yields of such relatively palatable forbs as asters, sticky geranium, goldenrods, and lupines. Grasses also provided more forage on burned than on unburned range. The proportion of grass forage to available herbage on the burned range in Clark County was somewhat less than in Fremont County, because of the increase on all burn intensities of the coarse, rhizomatous thickspike wheatgrass and plains reedgrass there.

Forage production 15 years after the Fremont County burn was 225 pounds per acre on burned as compared with 165 pounds on unburned range, and in Clark County 12 years after the burn, 213 as compared with 108 pounds. Thus burning was responsible for increases in grazing capacity of 11 sheep days per acre in Fremont County, and 18 sheep days per acre in Clark County, increases of 40 and 100 percent.

In a typical sheep grazing operation, however, differences in value between burned and unburned areas are even greater. Difficulty in handling sheep, together with loss of wool and lambs, makes the actual grazing value of ranges covered with dense stands of sagebrush even less than forage production figures indicate.

EFFECTS OF BURNING ON SOILS

Soil Properties

Organic matter, total nitrogen, and moisture equivalent as measured 1 year after burning were significantly reduced in the top half inch of soil on the heavily burned areas of Fremont County (table 17), but these properties were unaffected on burns of light and moderate intensity. Hydrogen ion concentration was not changed on burns of any intensity. Soil properties at the 2½–inch depth showed the same trends as at the top half inch, but these were not statistically significant. Organic matter consisted of material incorporated in the soil mass, distinct from surface litter and debris, and its reduction on the heavily burned area was probably responsible for the corresponding reduction in nitrogen and moisture equivalent. The reduction in organic matter and nitrogen was temporary, however, as analyses made 14 years later showed no differences between unburned and heavily burned areas. It should be noted that data for 1934 and 1948 are not directly comparable because there were slight differences in analytical procedure.

These slight and temporary effects of planned sagebrush burning on soil properties are much as would be expected. Because of the absence of litter, sagebrush fires usually go over an area very rapidly, heating only the surface of the soil. In swales where heavy brush occurs together with an accumulation of some litter, fire may become very hot and linger for a short time, but even here the soil is heated only to a shallow depth. In such cases some organic matter in the surface soil is destroyed, but with the rapid return of a grass and forb cover, such losses are soon replaced.

TABLE 17.—*Soil properties in 1934 and 1948 on the Fremont County area adjusted on the basis of the 1932 values through covariance analysis*

Year and treatment	½-inch soil layer				2½-inch soil layer			
	Organic matter	Nitrogen	Moisture equivalent	pH	Organic matter	Nitrogen	Moisture equivalent	pH
1934	*Percent*	*Percent*	*Percent*		*Percent*	*Percent*	*Percent*	
Unburned	5.2	0.23	17.6	6.9	3.1	0.16	16.1	7.0
Light burn	5.2	.24	18.7	6.9	3.5	.17	17.1	7.0
Moderate burn	5.1	.24	17.8	6.9	3.4	.18	16.1	6.9
Heavy burn	[1] 3.8	[1] .17	[1] 16.0	6.9	2.9	.15	15.1	6.9
1948								
Unburned	3.7	.19	----------	----	2.6	.14	----------	----
Heavy burn	3.8	.20	----------	----	2.7	.16	----------	----

[1] Highly significant difference between heavy burn and other three treatments.

EROSION

The surface soil of the Fremont County area contains approximately 60 percent sand and is classed as a sandy loam. Slight relief and lack of surface drainage prevented water erosion, but some accelerated wind erosion occurred largely in late summer and fall of 1933. Degree of wind erosion on the circular plots in 1934 was assigned to 1 of 6 classes ranging from no erosion (0) to very heavy erosion (5). On this basis, average erosion on the unburned plots was 0.0; on the lightly burned, 1.2; on the moderately burned, 1.9; and on the heavily burned, 3.3. It is evident that amount of wind erosion increased with burn intensity. The accelerated erosion, however, was effectively arrested by 1935 (fig. 4). The surface soil in Clark County was not nearly so sandy, and, because erosion was so slight, specific classifications were not made.

Since the experimental burning in both Fremont and Clark Counties was done late in the summer, the ground was not exposed long before the advent of fall rains that helped prevent blowing. Snow covered the area during the winter, and soon after it melted in the spring perennial grasses and forbs began rapid growth and arrested most of the erosion. Burning too early in the season, stirring up the surface by trailing or grazing during the fall and spring after burning, or absence of a perennial grass and forb cover would probably have caused serious erosion.

DISCUSSION

RESPONSE OF VEGETATION TO BURNING

Damage to vegetation through burning is caused by both heat of the fire and removal of all or some of the aerial part of the plants (fig. 5). During burning of California chaparral, Sampson *(21)* has recorded temperatures of nearly 1,000° F. in the litter on the soil surface. Although of short duration and lower than those in chaparral, moderately high temperatures are probably produced by burning dense stands of big sagebrush. Such heat undoubtedly

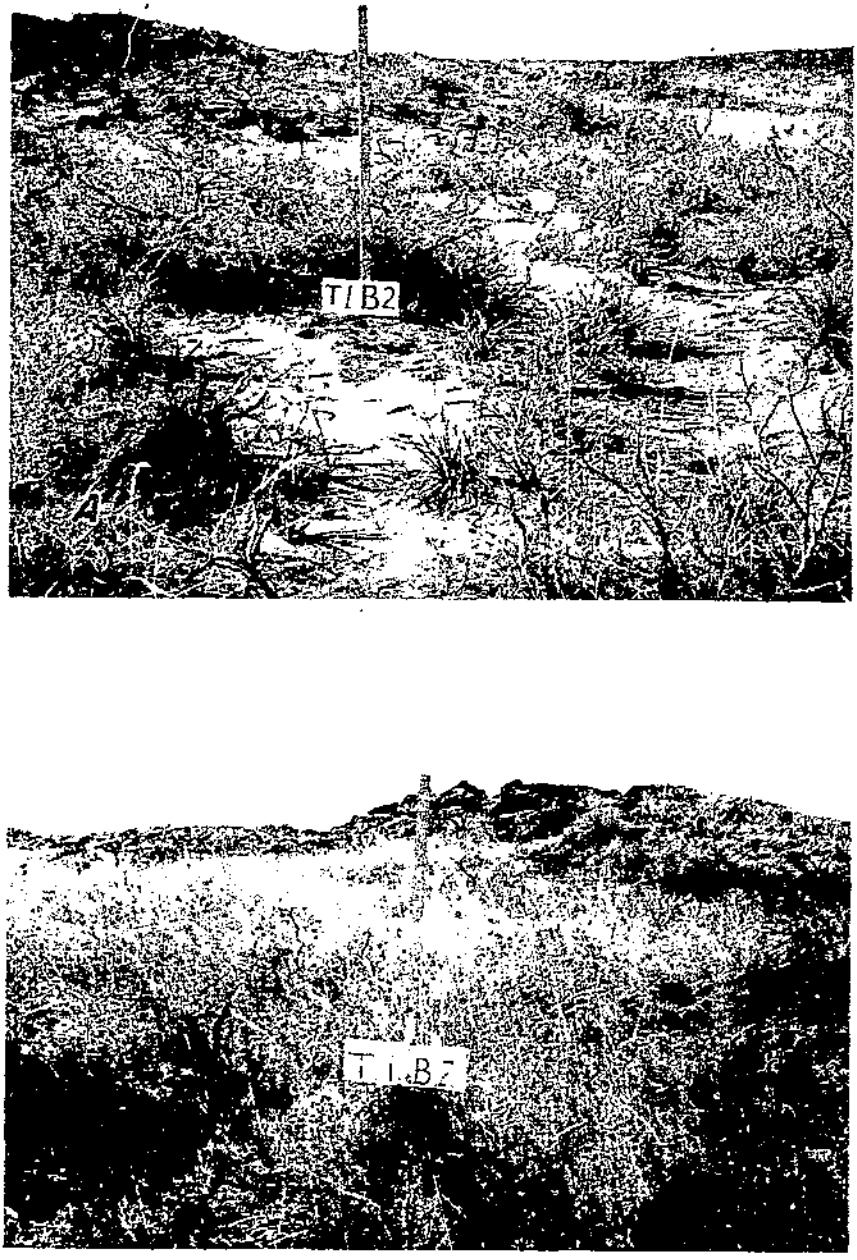

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FIGURE 4.—*A*, Plot on the Fremont County burn in 1934 showing deposition of sand from wind erosion after the burn. *B*, The same plot 2 years later when the soil surface had become completely stabilized by vegetation.

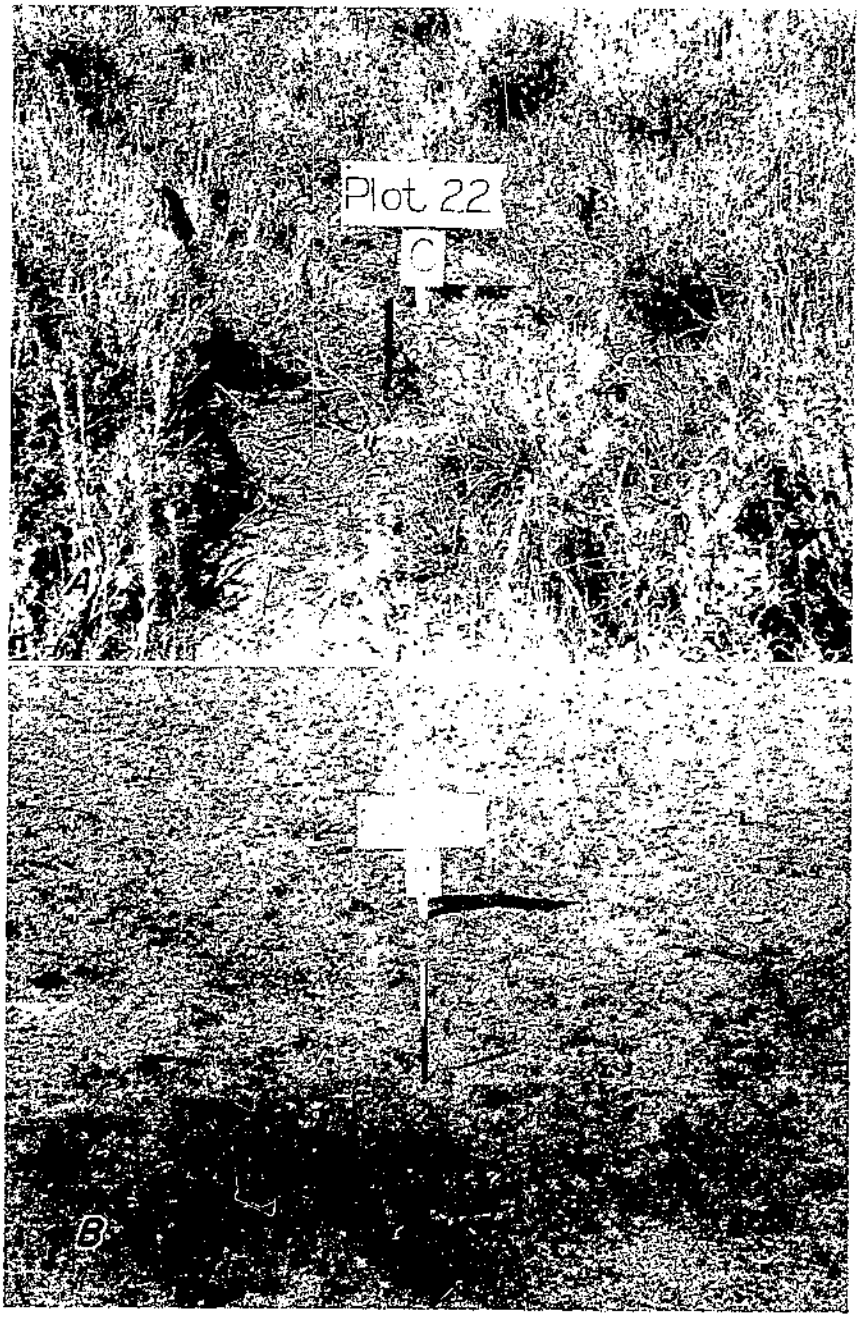

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FIGURE 5.—*A*, Plot on the Clark County area prior to burning, and *B*, the same plot immediately after burning at heavy intensity. (The plot numbering system was changed after the first photo was taken.)

kills some plants outright and at least injures root crowns and roots lying near the ground surface. Although top removal is perhaps less injurious, numerous clipping studies indicate that all species suffer to some degree, especially during certain seasons of the year *(2, 8, 22, 27)*. Extent of injury from these two sources cannot be readily separated. Further damage may be caused by exposure of the unprotected crowns during the winter and following spring.

There are, however, certain favorable effects of planned burning, at least to plants that are not completely killed. Since sagebrush is virtually eliminated by fire, the more fire-resistant species are always assured of a substantial decrease in competition. Also, many of the more resistant plants are apparently stimulated by release of additional nutrients in the ashes. Several studies cited by Shantz *(24)* and Sampson *(21)* indicate that burning releases soluble mineral nutrients for use by the plants, but that such benefits may be relatively short-lived as a result of removal of these minerals by leaching or erosion.

The response to burning, then, will depend on the relative effects of the actual damage to the plant and the benefit it receives through improved growing conditions. Species that make rapid recovery from fire injury are able to use the additional moisture and nutrients, and increase at the expense of species that make slower recovery. Thus, increase of any species is related to abundance and character of associated species and to the effect of fire on them. Statistical studies by Pechanec *(11)* have effectively demonstrated this.

Throughout the study numerous general observations were also made of burned areas other than those discussed here, in order to supplement the formal data collected only in certain years. In the following discussion an attempt is made to provide a more complete description of what happens to vegetation after burning by including changes observed in this way.

During the early part of the first growing season after burning, it is evident that actual damage to vegetation far outweighs the benefits. Perennial grasses and forbs are clearly lowered in vigor; old clumps are badly broken up and remaining plants are small and scattered. Although rhizomatous species are apparently damaged less than others, even these have poor vigor. Shrubs are represented by only a few sprouts. Much bare ground is exposed, but an abundant growth of annuals may fill many of the openings. As the season progresses, new shoots of rhizomatous grasses and forbs appear and tuft-forming species begin to stool out. Although greater vigor is apparent in most plants, scarcely any flower stalks are produced. Perennial grasses and forbs on burns remain green about 2 weeks longer than on unburned areas.

Despite the injurious effects of burning, rhizomatous species are often able to produce an increased amount of herbage by the end of the first year, but production of most other species is still below the original level. The appearance of a typical year-old burn is shown in figure 6, *A*.

During the second year, perennial grasses and forbs continue to increase and vigor is high. Sprouting shrubs are larger, but are still an inconspicuous part of the vegetation. The most noticeable feature of the burn during the second year is the abundant flower stalk production of almost all grasses and forbs (fig. 6, *B*). The reason for this phenomenon is not known, but it may be related to a temporary increase in mineral nutrients and increased soil moisture. At any rate, this profuse flowering of grasses and forbs is typical of 2-year-old burns on sagebrush-grass ranges and supplies a source of seed for revegetation of areas that may not be supporting a full plant cover.

F–359775, 375494

FIGURE 6.—*A*, Plot shown in figure 5 one year after burning. Note the small, scattered plants. *B*, Two years after burning. The abundant grass flower stalk production is typical of 2-year-old burns.

Total herbage production of grasses and forbs generally reaches its maximum about the third year after burning, largely as a result of increases in the fire-resistant rhizomatous species. Although this increased production may persist indefinitely, more often it declines in subsequent years. This general decline in grass and forb production is accompanied by an increase in shrubs and many nonrhizomatous herbaceous perennials.

Of the individual grass species occurring on the upper Snake River Plains, thickspike wheatgrass, plains reedgrass, and bluebunch wheatgrass are apparently least damaged by burning, for within 3 years these had recovered and were producing considerably more herbage on burned than on unburned areas. Other grasses are slower to recover but after 12 and 15 years only bluegrasses and Idaho fescue showed any substantial reductions on burned as compared to unburned areas, and the latter only on the Clark County area. Apparently losses suffered by most individual grasses are recovered in less than 15 years.

Gains made by some species are more permanent, but only in the case of thickspike wheatgrass-plains reedgrass on the Clark County burn was the increase large enough to be of practical importance in increasing total grass production. The rapid increase of these two species after they overcome the initial setback from burning and the temporary decrease of most of the other grasses suggests that repeated burning of such range might produce a fire subclimax dominated by coarse rhizomatous grasses. The fact that certain decreases in bluegrass and fescue were still evident after 12 and 15 years (especially on heavy burns) suggests that burning sagebrush-grass ranges that have an herbaceous understory dominated by such finer bunchgrasses might result in a permanent reduction in total grass yield or a shift to a higher proportion of coarse rhizomatous grasses.

Many forbs, especially the rhizomatous ones, make rapid recovery from burning and produce an increased amount of herbage within 3 years. Others, particularly the suffrutescent species, are slower to recover, but none of the perennial forbs are permanently damaged, and many apparently benefit from burning, as shown by significant increases in "All forbs" herbage production.

Shrubs are apparently more damaged by burning than either grasses or forbs. Not only is all of the current herbage destroyed by fire, but the aboveground, woody parts are either killed or completely consumed, resulting in destruction of stored reserves. This may also be the reason that suffrutescent forbs are more severely damaged than other forbs having no aboveground, perennial parts. However, rabbitbrush and horsebrush sprout profusely following burning and are only temporarily injured. They quickly regain or surpass their original size (fig. 7, *A*), and in addition their rapid recovery allows early production of seed and subsequent establishment of new plants. Bitterbrush plants that sprout grow rapidly, and some exceed their original size. However, part of the recovery of this species comes from new plants established from seed, especially on burns of heavy intensity where most of the old plants are killed.

Big sagebrush, which is completely killed and must re-establish itself entirely from seed, is much slower to recover. On the upper Snake River Plains no appreciable big sagebrush sprouting has been observed, and the absence of sagebrush is often an indicator of past burns. Since other shrubs associated with sagebrush on these ranges are able to sprout, at least to some degree, it is significant that sagebrush by seedlings alone has been able to maintain a prominent position in the vegetation.

F 434041, 434640

FIGURE 7.— *A*, Six years after burning. Horsebrush plants, which are barely discernible in figure 6, have become prominent. Sagebrush seedlings are also apparent; note the one to the left of the peg. *B*, Twelve years after burning. The only marked change is an increase in size of horsebrush and sagebrush plants.

The overall ultimate effect of planned burning on shrubs, then, is to increase species that sprout profusely, slightly decrease or have little effect on species that are only partially able to sprout, and greatly decrease species that are unable to sprout. Repeated burning would probably produce objectionable stands of such species as horsebrush and rabbitbrush where these species are present in the original stand (fig. 8), and might eradicate bitterbrush and other shrubs which only partially sprout. As a matter of fact, even one burning of sagebrush-grass ranges having a high percentage of rabbitbrush and horsebrush may be unwise.

F-461070

FIGURE 8.—A part of the Clark County burn in 1950 supporting a fairly thick stand of horsebrush and rabbitbrush. Prior to burning these species were only minor components of the vegetation.

It is apparent that response to burning within each class—grasses, forbs, or shrubs—is highly variable. If initial effects that are generally injurious to all species are ignored, the following classification based on sprouting ability of shrubs and growth form of herbs is fairly reliable for describing response of perennial species:

Severely damaged.—Shrubs that are unable to sprout; suffrutescent forbs; some of the fine bunchgrasses—particularly Idaho fescue.

Only slightly affected.—Coarse bunchgrasses; some of the fine bunchgrasses; forbs that are neither suffrutescent nor rhizomatous; shrubs with weak sprouting habit.

Considerably benefited.—Shrubs with strong sprouting habit; rhizomatous grasses; rhizomatous forbs.

It must be remembered that the results reported herein were obtained on areas of the upper Snake River Plains which prior to burning were covered with dense stands of sagebrush but had a fairly continuous understory of perennial grasses and forbs. Cheatgrass, an annual associated with frequent fires and abundant on much of the Snake River Plains, was virtually non-existent on these areas. In addition, both ranges were burned only once and were protected from grazing for one full year after burning, and then were grazed conservatively.

Observations of haphazard burning in this area *(15)* indicate that had grazing been allowed the year after burning when the plants were low in vigor, or had too heavy grazing been practiced later, the results would have been entirely different. Also, it cannot be overemphasized that the effects described here were obtained from single planned burns. Repeated burning, especially at close intervals, would completely upset the ecological balance, causing a shift to a more fire-resistant type of vegetation and accompanying soil deterioration. It is therefore obvious that caution must be used in attempting to apply this information to other conditions in other localities.

Sagebrush Re-establishment

Normally, sagebrush re-establishment after planned burning is a gradual process. Numerous seedlings may become established during the first 2 years before a vigorous stand of perennial grasses and forbs develops, but after this period sagebrush seedlings invade slowly because of the severe competition for soil moisture.

Since observations made in 1948 showed a negative correlation between sagebrush numbers and distance from seed source, size of the area and thoroughness of the burn may influence the rate of sagebrush re-establishment. The light burns in Fremont and Clark Counties produced more sagebrush plants than the heavier burns. Apparently, this was not a result of the heat of the fire, but of the location of the various burn intensities. Usually a belt of lightly burned range adjoined the unburned, and therefore lightly burned areas were usually closer to source of sagebrush seed than those more heavily burned. If all of a large area is burned, the seed supply will be remote and the rate of invasion may be slow.

Observations on the upper Snake River Plains have shown that heavy sagebrush seedling stands sometimes become established a year after burning, regardless of quantity of grass before burning or management after burning. For example, areas burned in 1937 and 1942 were invariably covered with a thick stand of sagebrush seedlings the following year. Factors causing such sagebrush re-establishment are not known, but some peculiarity of the season involved is apparently responsible. Since the ranges were burned before seed maturity, the seed that germinated must either have been lying dormant in the soil or have been carried in from the surrounding areas. If the soil usually held dormant seed and this seed was responsible, it seems reasonable that burning would regularly result in heavy sagebrush seedling establishment during the improved moisture conditions the year after burning. Since this is not often the case, there must be some other explanation.

One explanation is that sagebrush seed may have blown into the burns from the surrounding areas in the unusual years. Although sagebrush seed is fairly heavy and has no plume, it is possible that an extremely high wind just at the time of dissemination of an unusually good seed crop might result in

distribution over a burn. There is also evidence that seed can be carried considerable distances across the snow during winter blizzards, which might explain widespread distribution during the period after an incomplete seed dissemination.

Another explanation that has been suggested is that heavy stands of sagebrush seedlings result when especially dry weather conditions follow years of heavy seed production. Seed may lie on the ground or in the litter throughout the following spring and summer to germinate the second year if conditions are favorable. Such delayed germination is rather infrequent because in most years conditions are favorable for germination the spring following seed maturity. None of these explanations, however, seems fully satisfactory.

Because benefits derived from burning are relatively short-lived when such sagebrush re-establishment occurs, this problem should receive further study. Until it is solved, rapid return to a dense stand of sagebrush can occasionally be expected despite all known precautions.

Effects of Burn Intensity

Burns of heavy intensity are more injurious to nearly all species than moderate and light burns. Even after the 12– and 15–year periods, herbage production of more than 6 grasses and sedges, 4 forbs, and 2 shrubs was considerably lower on heavy than on lighter burns. These species, whose yields usually were less with heavier burn intensity, are: Prairie junegrass, bluegrasses, sedges, needle-and-thread, Idaho fescue, bluebunch wheatgrass, eriogonum, arnica, geranium, pussytoes, sagebrush, and bitterbrush. On the other hand, thickspike wheatgrass, plains reedgrass, knotweed, lupines, rabbitbrush, and horsebrush were producing more herbage on the heavier burns. Evidently burn intensity has considerable effect on the character of vegetal trends.

From an examination of these lists, it appears that the best results are to be obtained through a burn of light intensity. Of the species favored by the heavier burns, only lupines can be classed as highly desirable forage plants for sheep on these spring-fall ranges. Horsebrush, creeping mahonia, rabbitbrush, and knotweed are of low forage value. Thickspike wheatgrass and plains reedgrass, because of their coarseness, are the least palatable of the grasses on these areas. Conversely, most of the species which receive the greatest damage from the heavier burns are desirable forage plants. Sagebrush, of course, is an exception, but is effectively controlled by light burning.

Soils also fare better on the lighter burns. Organic matter, nitrogen, and moisture-holding capacity were all temporarily reduced on heavy burns, but they were unchanged on light and moderate burns. Also, there was considerably more wind erosion on heavy than on light and moderate burns.

Although a burn of light intensity appears most desirable, it cannot be obtained over an area extensive enough to make such a burning operation practical. Most of the sagebrush-grass type of the upper Snake River Plains is broken by numerous lava outcrops that bear only a thin stand of vegetation, i. e., a light stand of fuel. If an attempt is made to burn ranges late in the fall when humidity and fuel moisture are high, or early in the summer while grasses and forbs are partially green, a light-intensity burn may be realized on a small part of the area, but the major part will remain unburned. Such a small degree of success would not justify costs of fireline construction and other protective measures. Also, benefits of a light burn obtained while grasses and forbs are partially green are offset by injury to the plants through

herbage destruction before maturity *(2, 8, 15, 27)*. From the standpoint of handling range sheep, light burns are initially less satisfactory than moderate and heavy burns because of the standing sagebrush skeletons that snag considerable wool.

For these reasons, burning in late summer or early fall soon after most perennial grasses and forbs have matured their seed and are dry or nearly dry will give the best results. At that time fire will sweep over most areas having only a scattered covering of fuel. Since it is not possible to control the heat of the fire, the advantages of a light-intensity burn have to be sacrificed for a satisfactory burn.

The Goal of Planned Burning

Data from these two planned burns 12 and 15 years after burning emphasize that many of the striking changes of the first few years are temporary and that a planned burning program must consider long-time vegetal trends. The goal of sagebrush burning should not be inconsistent with the climax cover that can be attained in a particular area. It is true that forage production on a burned area a few years old might surpass that on a similar area in climax condition because of replacement of sagebrush by perennial grasses and forbs. However, ranges that are naturally sagebrush-grass climax cannot be entirely freed of sagebrush for an indefinite period. Repeated burning, especially at close intervals, to keep an area in such a subclimax stage would probably result in eventual impoverishment of the soil and loss of desirable vegetation.

Weaver and Clements *(28)* have pictured the climax vegetation of the Snake River Plains as a grassland similar to the Palouse Prairie of Washington. However, reports of early explorers *(5, 6, 10, 23)* indicate that sagebrush was a dominant of the Snake River Plains and that grasses and forbs were a minor component of the original vegetation. More recently a geologist *(20)* and several ecologists *(3, 4, 12, 16, 18, 19)* have presented what is believed to be a more accurate conception of the original sagebrush-grass range on the Snake River Plains. Although there may have been considerable local variation from heavy stands of sagebrush to almost pure grassland, the major part of the present sagebrush-grass type was probably an open stand of sagebrush with some other shrubs, beneath which thrived a vigorous stand of perennial grasses and forbs.

The present vegetation of the Fremont and Clark County burns substantiates the latter conception (fig. 9). After 12 to 15 years, there were somewhat more grasses and forbs on burned than on unburned areas, and there were fewer and smaller sagebrush plants. Sagebrush was virtually eliminated as a result of burning, and vigorous stands of perennial grasses and forbs covered the burns within a few years. The fact that sagebrush was able to reinvade such areas under conservative grazing indicates that it is an integral part of the climax vegetation. It is expected that increases in size of plants already present and, to a lesser extent, the establishment of new plants will cause increased sagebrush production, especially on the more recent Clark County burn. The striking contrast between burned and unburned areas after 12 and 15 years, however, suggests that the vegetation of the burns will be stabilized before sagebrush becomes as dense as it was in 1948 on the unburned areas. On the upper Snake River Plains, then, an open stand of sagebrush with a scattering of other shrubs and an understory of perennial grasses and forbs should be the goal of range improvement through planned burning.

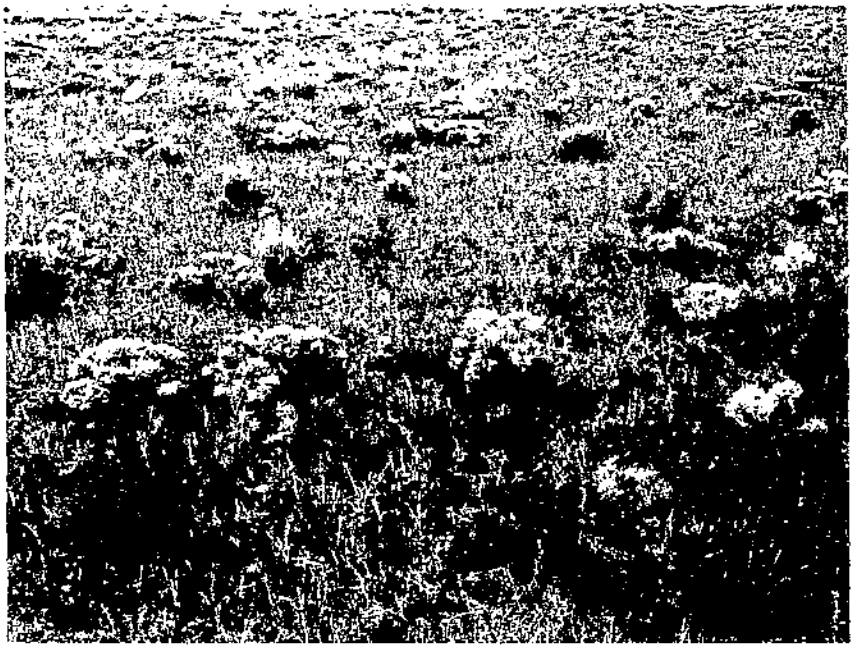

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FIGURE 9.—*A*, A general view of the Clark County burn in 1950. The shrubs are horsebrush, rabbitbrush, and sagebrush; the grasses mainly thickspike wheatgrass and plains reedgrass. *B*, A view of the Fremont County burn in 1948, showing a slightly better-than-average site. Shrubs are bitterbrush and sagebrush. Compare with the dense stand of sagebrush in figure 1.

SUMMARY AND CONCLUSIONS

Dense stands of big sagebrush cause a serious grazing management problem on extensive areas of western range. Fire has been widely used in sagebrush eradication, but unrestricted burning followed by overgrazing has often resulted in serious range depletion. Several studies have indicated that planned burning can be a valuable tool in improvement of sagebrush-grass ranges. This bulletin describes changes in vegetation and soil on two planned burns on the upper Snake River Plains over 15— and 12—year periods.

Before burning, each of these areas supported a dense stand of sagebrush with a fairly uniform understory of perennial grasses and forbs. The Fremont County burn was made in September 1933, and the Clark County burn in August 1936. Complete protection from grazing was given both areas for 1 year, after which conservative spring and fall grazing by sheep was practiced.

Vegetation in Fremont County was sampled by herbage estimates on 250 plots of 100 square feet and in Clark County on 268 plots prior to burning, 1 and 3 years later, and again in 1948. Soil samples were taken from 48 stations on the Fremont County area prior to burning, 1 year after burning, and 15 years after burning, and were analyzed for nitrogen, organic matter, moisture equivalent, and pH. Both vegetation and soil data were analyzed by covariance to allow for statistical adjustment of uncontrolled initial variations.

All grasses were injured by burning, but thickspike wheatgrass, plains reedgrass, and bluebunch wheatgrass recovered rapidly and made substantial increases within 3 years as compared to the same species on unburned control areas. Other grasses were slower to recover, but by 1948 nearly all were producing as much as or more herbage on burned areas than on the unburned. Some of the finer bunchgrasses were apparently damaged, especially by heavy burns. Although burning caused increased yields of several grasses, only in the case of thickspike wheatgrass and plains reedgrass on the Clark County burn were the increases large enough to be of practical importance as late as 1948.

As with grasses, forbs were injured to some degree by burning, but most of the rhizomatous species recovered rapidly and within 3 years were producing more herbage on burned than on unburned range. Yield of suffrutescent species was greatly reduced initially, but none of the perennial forbs were permanently damaged, and many apparently benefited from the reduced competition as shown by significantly higher "All forbs" herbage production on the burns in 1948.

Shrubs were apparently more damaged by burning than grasses or forbs, but rabbitbrush and horsebrush sprouted profusely and quickly regained or surpassed their original size. Substantial numbers of bitterbrush plants also sprouted, and these were quickly able to gain a position of dominance. Sagebrush, which must start entirely from seed, was greatly handicapped.

In 1948 total herbage was considerably higher on the unburned areas, because of their much greater amount of sagebrush, than on the burns. Available herbage, however, that which is readily accessible to livestock and not sheltered beneath shrubs, was nearly as great or greater on the burned areas. The amount of forage, which is affected by both availability and palatability of the herbage, was markedly greater on the burned than on the unburned ranges. The estimated grazing capacity of the burned range was 40 percent greater than that of the unburned in Fremont County and 100 percent greater in Clark County.

Organic matter, nitrogen, and moisture equivalent were significantly reduced in the top half inch of soil on the heavily burned areas of Fremont County, but these reductions were only temporary. Accelerated wind erosion was marked on the heavily burned areas but was effectively arrested within 2 years.

From the results of this study, the following conclusions are drawn with respect to planned burning of sagebrush-grass range:

1. Such burning is ultimately beneficial to shrubs with a strong sprouting habit and to rhizomatous grasses and forbs, but nonsprouting shrubs, suffrutescent forbs, and some of the finer bunchgrasses are severely injured. Other species are only slightly affected.

2. Because of this variation in response, composition of the stand should be carefully considered when planning a sagebrush burning operation. A large number of undesirable sprouting shrubs or of desirable fine bunchgrasses or suffrutescent forbs may preclude improvement through burning.

3. Although total yield of grasses and forbs is greatly increased within 2 or 3 years after burning in comparison with production on unburned range, much of this early increase may be short-lived.

4. Increased availability of herbage and ease in handling livestock are often the main benefits from planned burning.

5. Some soil properties are slightly altered by burns of heavy intensity, but such changes are only temporary.

6. The best results are apparently produced by light burns, but the advantages of a low-intensity fire must be sacrificed in order to secure a satisfactory coverage.

7. Normally sagebrush re-establishment following planned burning is a gradual process, but sometimes sagebrush seedlings become established the following year on burned areas regardless of the amount of grass present before burning or management after burning.

8. The goal of sagebrush burning should be consistent with the climax cover that can be attained. The objective of range improvement on the upper Snake River Plains through planned burning should not be complete eradication of sagebrush but the attainment of an open stand with a scattering of other shrubs and an understory of perennial grasses and forbs.

COMMON AND SCIENTIFIC NAMES OF SPECIES MENTIONED

Grasses and Grasslike Plants

Bluegrasses ..... *Poa* spp.
Bluegrass, Nevada ..... *P. nevadensis* Vasey
Bluegrass, Sandberg ..... *P. secunda* Presl
Cheatgrass (cheatgrass brome) ..... *Bromus tectorum* L.
Fescue, Idaho ..... *Festuca idahoensis* Elmer.
Junegrass, prairie ..... *Koeleria cristata* (L.) Pers.
Needle-and-thread ..... *Stipa comata* Trin. & Rupr.
Needlegrass, Columbia ..... *S. columbiana* Macoun
Reedgrass, plains ..... *Calamagrostis montanensis* Scribn.
Sedges ..... *Carex* spp.
Sedge, threadleaf ..... *C. filifolia* Nutt.
Wheatgrass, bluebunch ..... *Agropyron spicatum* (Pursh) Scribn. & Smith
Wheatgrass, thickspike ..... *A. dasystachyum* (Hook.) Scribn.

FORBS

Arnica, orange ..... *Arnica fulgens* Pursh
Asters ..... *Aster* spp.
Astragalus, saline ..... *Astragalus salinus* Howell
Comandra, common ..... *Comandra umbellata* (L.) Nutt.
Eriogonum, Wyeth ("buckwheat") ..... *Eriogonum heracleoides* Nutt.
Fleabane, purple-daisy ..... *Erigeron corymbosus* Nutt.
Gayophytum (bigflower groundsmoke) .. *Gayophytum diffusum* Torr. & Gray
Geranium, sticky ..... *Geranium viscosissimum* Fisch. & Mey.
Goldenrods ..... *Solidago* spp.
Goosefoots ..... *Chenopodium* spp.
Hawksbeard, tapertip ..... *Crepis acuminata* Nutt.
Helianthella, oneflower ..... *Helianthella uniflora* (Nutt.) Torr. & Gray
Knotweed, Douglas ..... *Polygonum douglasii* Greene
Lupine, tailcup ..... *Lupinus caudatus* Kell.
Lupine, velvet ..... *L. leucophyllus* Dougl.
Milkvetch ..... *Astragalus diversifolius* A. Gray
Penstemon, royal ..... *Penstemon speciosus* Dougl.
Phlox, longleaf ..... *Phlox longifolia* Nutt.
Plumeweed, bushy ..... *Cordylanthus ramosus* Nutt.
Poisonvetch, timber ..... *Astragalus convallarius* Greene
Pussytoes, littleleaf ..... *Antennaria microphylla* Rydb.
Pussytoes, low ..... *A. dimorpha* (Nutt.) Torr. & Gray
Thistle, wavyleaf ..... *Cirsium undulatum* (Nutt.) Spreng.
Violet, tongueleaf .... *Viola nuttallii* Pursh var. *linguaefolia* (Nutt.) Jepson
Yarrow, western ..... *Achillea lanulosa* Nutt.

SHRUBS

Bitterbrush ..... *Purshia tridentata* (Pursh) DC.
Horsebrush, spineless gray . *Tetradymia canescens* var. *inermis* (Nutt.) A. Gray
Mahonia, creeping ("Oregon grape") ..... *Mahonia repens* (Lindl.) G. Don
Rabbitbrush, downy ..... *Chrysothamnus puberulus* (D. C. Eat.) Greene
Sagebrush, big ..... *Artemisia tridentata* Nutt.
Snowberry, mountain ..... *Symphoricarpos oreophilus* Gray

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