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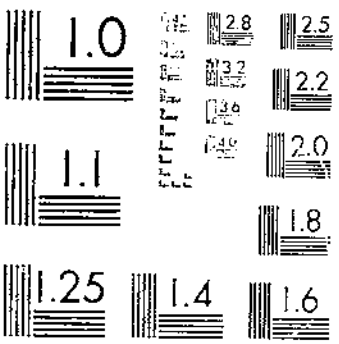

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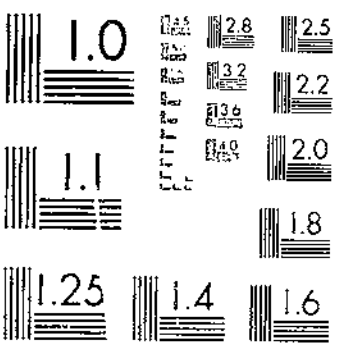

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THE INFLUENCE OF CLIMATE AND GRAZING ON SPRING-FALL SHEEP RANGE IN SOUTHERN IDAHO[1]

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CONTENTS

SIGNIFICANCE OF SPRING-FALL RANGE STUDIES

Ranges that are suitable for spring and fall grazing constitute a vital link in the year-round feed supply for range sheep production throughout a large portion of the western United States. As the name implies, these lands are utilized for two important grazing periods each year—the first, for several weeks or months in the spring during and following lambing, before the high summer range is ready, when succulent feed is essential to give lambs a proper start in growth and development; the second, for a like period in the fall, when ewes should be attaining proper condition for breeding, and before snows force the flocks to sheltered winter ranges or feed lots.

The foothill lands of southern Idaho have been found to be especially well adapted for meeting these spring and fall range requirements. In the spring the fresh green bunchgrasses and weeds that grow in

[1] Received for publication May 28, 1937.

[2] This study was made possible through a cooperative agreement whereby the Bureau of Animal Industry supplied livestock, grazing areas, and accommodations for the Forest Service technicians at the United States Sheep Experiment Station, near Dubois, Idaho, for the 9 years of the study. Very considerable assistance was contributed by W. A. Denecke, former superintendent of the Sheep Experiment Station, in helping to plan the study and in taking and compiling records on numbers of livestock grazed, weights, losses, and yields during the major part of the test period. During the remainder of the time that the tests ran, able assistance in recording, compiling, and analyzing similar records was rendered by his successor, J. M. Cooper. C. L. Forsling was director of the Intermountain station during the period of this study. Weather data were obtained, in cooperation with the Weather Bureau.

mixture with sagebrush on these lands are highly nutritious and palatable, and what is not then consumed cures well during the dry summers and remains available for grazing in the fall. The one crop of forage usually produced on these lands is, therefore, suitable for the two grazing seasons (pl. 1, *A*). In addition, these lands are centrally located between the mountain summer range and valley winter range and feed lots, and are characterized by a rolling topography that simplifies herding and enables close supervision of the flocks during the critical periods of lambing and breeding.

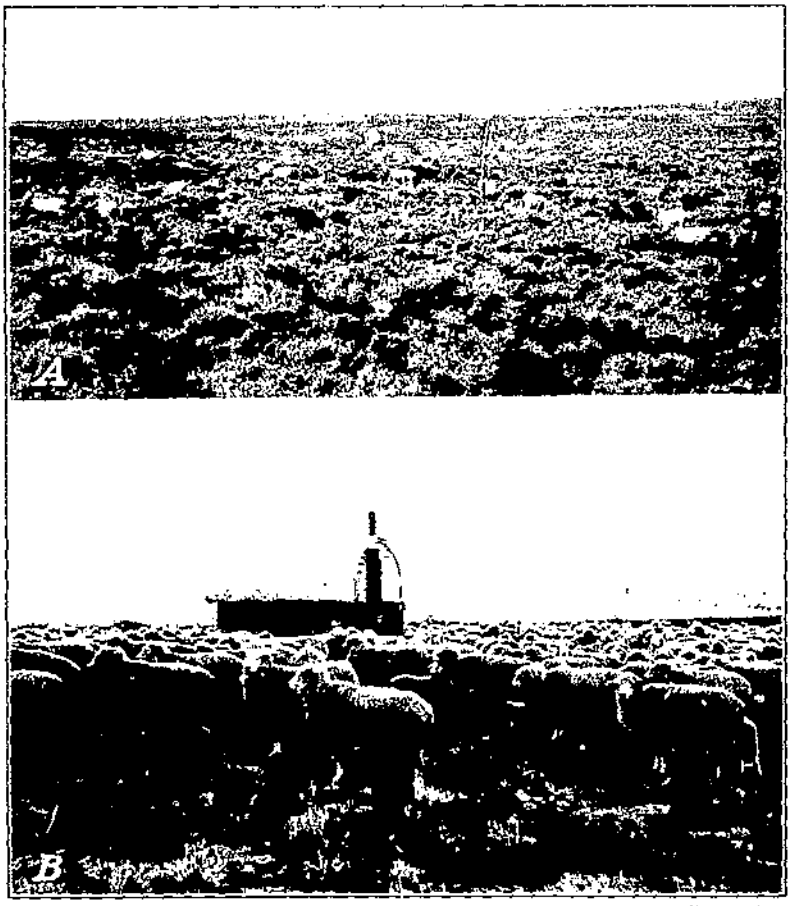
From the early days of settlement, graziers have planned their yearly calendar of operations in accordance with the availability of forage; today about 2,000,000 of the 6,000,000 sheep that graze annually within the Intermountain region are herded over the foothill lands of southern Idaho during the spring and fall seasons. The general practice today, as in earlier days, is to turn sheep on the range as soon as forage becomes available in the spring, hold the flocks there until summer range is ready, and return them in the fall to utilize remaining forage.

In recent years increased competition for range and the recurrence of drought have resulted in an intensified use of foothill lands to the detriment of the range resource. In an effort to shorten the winter feeding period and to exclude competing herds from the range, it has become a common practice, for example, for operators to commence grazing their sheep as soon as plant growth starts in the spring and to utilize nearly all of the forage during the spring period, leaving little or none for fall. Severe overgrazing has resulted, and as a consequence extensive areas of spring-fall range lands are in a seriously depleted condition and the possibilities for profitable range sheep production are greatly diminished.

Clearly, if the spring-fall range lands of southern Idaho are to continue to be profitable for range sheep production, the extent to which these lands can be grazed without detrimental effects must be ascertained and improved systems of management based on the known limitations and potentialities of the forage resource put into effect. As a first step in this direction, this report presents the results of studies extending over the 9-year period 1924–32 on the influence of climate and grazing on the sagebrush-wheatgrass range type at the United States Sheep Experiment Station. The major phases of these studies include: (1) The influence of climate, more especially temperature and precipitation, on the periods of range use, annual forage production, and the productivity of range sheep; (2) the effects of different intensities of spring grazing on forage production and the natural revegetation of the bunchgrass and other types of forage in the sagebrush-wheatgrass range type; and (3) the development of principles of management, based on results of these studies, which it would be desirable to apply to spring-fall range for the most effective conservation and use of the forage for range sheep production.

STUDY AREA

The United States Sheep Experiment Station, located near the northeastern extremity of the Snake River plains of southern Idaho (fig. 1) at an elevation ranging from 5,500 to 6,000 feet, covers 28,160 acres, of which 16,640 acres was under fence during the study. In



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EWES AND LAMBS ON SPRING-FALL RANGE.

1, The grasses and weeds that grow in mixture with sagebrush and other shrubs are relished by sheep in the spring and fall and constitute an important link in the year-round feed supply for range-sheep production in southern Idaho. *B*, Sheep on the conservatively grazed experiment-station range are maintained in thrifty condition and produce consistently high lamb crops and yields of wool.

comparatively recent geologic times a lava flow covered the entire station range and surrounding territory, creating a flat to gently rolling surface on which a sandy loam soil a few inches to several feet in depth has developed. The area is readily accessible to livestock, but because of the absence of surface water except where an intermittent stream crosses the northwest corner of the property, it is necessary to haul water to the sheep from a deep well at headquarters.

Temperatures are generally favorable for plant growth from early April until late October. Precipitation rarely exceeds 15 inches annually. Somewhat less than half of the precipitation occurs as snow

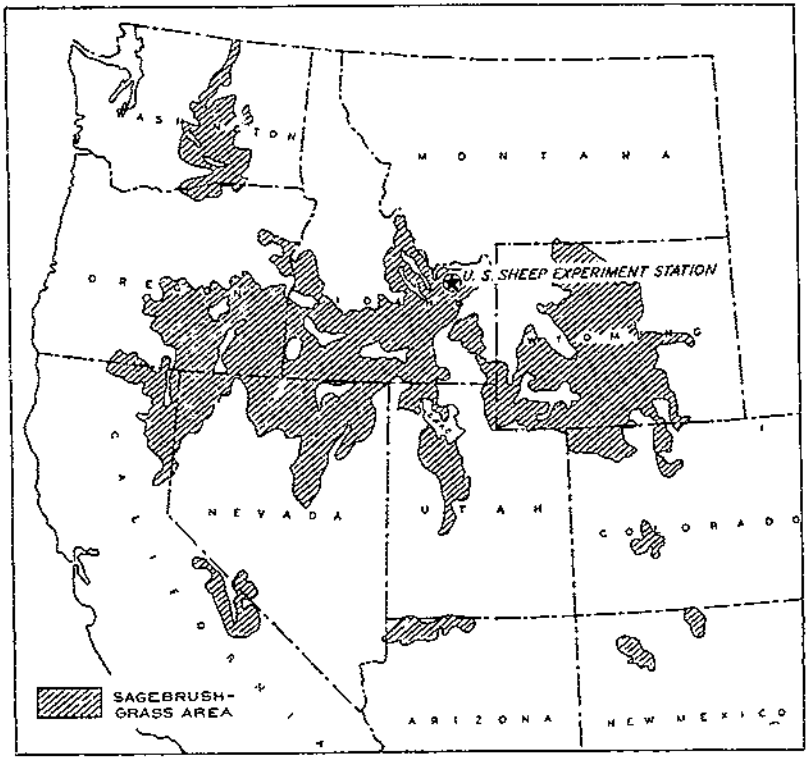

FIGURE 1.—Location of the United States Sheep Experiment Station near Dubois on the Snake River plains of southern Idaho and the range of the sagebrush grass cover type in the 11 Western States.

during the late fall and winter; rains are most common in spring and summer. During late spring, and especially through the summer months, rainless periods are common, during which the soil becomes thoroughly dried for weeks at a time.

In response to the climate and soil, the vegetation on the station range is an unbroken gray-brush formation covering about 25 percent of the ground surface, in which big sagebrush (*Artemisia tridentata*), or a closely related threetip sagebrush (*A. tripartita*), and bluebunch wheatgrass (*Agropyron spicatum*) are dominant. Shrubs constitute more than half of the plant cover, but grasses and weeds make up 86 percent (58 and 28 percent, respectively) of the palatable part of the vegetation, of which slightly more than 61 percent is contributed by

three species—bluebunch wheatgrass, bluegrass (*Poa secunda*), and balsamroot (*Balsamorhiza sagittata*), as shown in table 1.

TABLE 1.—*Total plant cover and prevalence of palatable forage, on 100 sample plots of spring and fall range at the U. S. Sheep Experiment Station, by species*

Species	Total plant cover		Estimated relative palatability of species	Palatable forage	
	Density	Composition		In total cover	Composition
Shrubs:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Sagebrush (*Artemisia tripartita*)	10.861	39.41	5	1.97	6.3
Yellowbrush (*Chrysothamnus puberulus*)	1.510	5.50	20	1.10	3.5
Bitterbrush (*Purshia tridentata*)	1.127	4.09	25	1.02	3.3
Horsebrush (*Tetradymia canescens*)	.998	3.62	5	.18	.6
Others	.163	.59	33	.20	.6
Total	14.665	53.21		4.47	14.3
Grasses:					
Bluebunch wheatgrass (*Agropyron spicatum*)	4.228	15.34	75	11.50	36.8
Bluegrass (*Poa secunda*)	1.608	3.66	90	3.28	10.5
Junegrass (*Koeleria cristata*)	.509	1.85	70	1.29	4.1
Big-spiked wheatgrass (*Agropyron dasystachyum*)	.434	1.57	50	.78	2.5
Needlegrass (*Stipa comata*)	.299	1.08	70	.76	2.4
Ricegrass (*Oryzopsis hymenoides*)	.121	.44	65	.29	.9
Others	.191	.69	20	.14	.5
Total	6.790	24.63		18.04	57.7
Weeds:					
Balsamroot (*Balsamorhiza sagittata*)	2.999	10.88	40	4.30	13.9
Lupine (*Lupinus caudatus*)	.798	2.90	40	1.16	3.7
Indian-tobacco (*Eriogonum* spp.)	.353	1.28	20	.26	.8
Pussytoes (*Antennaria microphylla*)	.315	1.14	15	.17	.5
Hawksbeard (*Crepis acuminata*)	.215	.78	90	.70	2.2
Phlox (*Phlox multiflora*)	.212	.77	85	.65	2.1
Aster (*Aster* spp.)	.198	.72	25	.18	.6
Loco (*Astragalus* spp.)	.181	.66	60	.40	1.3
Snakeweed (*Gutierrezia sarothrae*)	.147	.53	10	.05	.2
Stickweed (*Lappula occidentalis*)	.116	.42	5	.02	.1
Others	.572	2.08	40	.82	2.6
Total	6.106	22.16		8.77	28.0
Total, all species	27.561	100.00		31.28	100.00

The range forage makes its maximum growth in the spring after temperatures rise to a level favorable for plant growth and when moisture from the accumulated winter snows is available. Ordinarily the grasses and weeds start growth early in April and complete growth before July 1, after which they remain dormant during the dry summer. In some years sufficient precipitation occurs in the fall to induce regrowth of grasses, but even in favorable years the volume of forage produced as regrowth is negligible. The grasses that complete their growth in the spring cure well during the summer, however, and when moistened by the fall rains they are readily grazed by sheep.

The experiment station maintains about 2,500 sheep, including Rambouillet, Corriedale, and Columbia breeds. These are selected and bred to develop qualities of thriftiness by which they will make the most profitable use of the native forage under the prevailing circumstances of climate, topography, and essential methods of handling (*1*)[3] (pl. 1, *B*). The aim of management on the station range as a whole has been to provide, through a conservative rate of stocking, ample forage for the sheep in the spring and fall seasons.

[3] Italic numbers in parentheses refer to Literature Cited, p. 42.

METHODS OF STUDY

Five 80-acre paddocks were made available by the Sheep Experiment Station for purposes of this study. These were located within a short distance of the station headquarters and were fairly similar with respect to plant cover, topography, and soil to the herded portion of the station range already described. Because of differences in the amount of palatable forage, however, the grazing value of the paddocks differed somewhat at the beginning of the study. As shown later in tables 9, 12, 15, 18, and 21, the estimated average total forage production per paddock during the first 2 years of the test period ranged from 81.25 to 65.25 sheep-days per acre, or a difference of about 18 percent between the best and poorest areas, which was considered of minor importance in this study. On these paddocks intensive use of the forage was instituted during the years 1924 to 1932, inclusive, approximating the systems of use commonly applied in private operations on comparable range lands in the vicinity of the station. A different system was applied to each paddock. These may be explained briefly as follows:

A. Heavy continuous spring and late fall grazing (paddock 2). In this paddock an average of about 68 percent of the forage was removed during approximately a 2-month period in the spring after grasses reached 2 inches in height; 25 percent was taken in the fall, making a total of 93 percent for the year. This system is representative of practices on extensive range areas where one or several bands of sheep graze more or less continuously throughout the spring period and utilize nearly all of the forage at that time, only to return and regraze the area in the fall.

B. Heavy early spring and late fall grazing (paddock 3). On this area an average of about 36 percent of the forage was taken during approximately a 4-week period in the spring commencing after grasses reached 2-inch height growth, and about 46 percent was removed in the fall. This system is typical of use on areas where sheep are turned out to graze about the same time each spring, but, because of available range elsewhere, the lack of water, or other reasons, the use is limited to an early, short period in the spring, followed by more complete utilization in the fall.

C. Heavy late spring and late fall grazing (paddock 8). This pasture was grazed each year so as to utilize about 53 percent of the forage in the spring within the average of approximately a 3-week period after grasses reached a 6-inch height growth, and 37 percent in the fall. This arrangement corresponds to situations where sheep reach the range and consume about half of the current growth after the forage has attained advanced stages of development and where the same range is subjected to close fall grazing.

D. Moderate late spring and heavy fall grazing (paddock 7). Grazing on this area removed, during approximately 3 weeks in the spring, an average of 19 percent of the forage after grasses reached 6-inch height growth, while in the fall 66 percent was removed. This system differs from that followed on paddock 8, in that spring grazing was confined to a shorter period and was less heavy. It is characteristic of the manner in which some ranges are grazed rather lightly in the spring, after which they are heavily utilized in the fall.

E. Heavy fall grazing only (paddock 1). As check on the other systems, this paddock was grazed only late in the fall, forage consumption averaging approximately 83 percent.

The paddocks were grazed in the spring by ewes and young lambs, while in the fall only mature ewes were admitted, except for a few rams during part of the time for breeding. The numbers usually grazed in each area from day to day varied from 30 to 40 head, although for a few days at a time it was found necessary to decrease the numbers to 10 or less when sheep were not available, or to increase the numbers to 100 or more in order to "mop up" remaining "feed." The sheep were of the same classes that were grazed on the main portion of the station range; the paddocks, however, were grazed without herding, while on the station range the bands were under the care of shepherds. Since the number of sheep-days of feed per acre obtained under pasture grazing may not be comparable to the number obtained under herded conditions, the days of feed per acre from the paddocks have not been taken as an indication of carrying capacity for herded range, but have been used simply as an index of range productivity.

Detailed records were kept of the number of stock admitted to each paddock, as well as to the herded range, and of the number of days they were grazed in the spring and fall. At the close of the fall season the grass consumption was estimated, clumps taken to within 1 inch of the ground being considered 100-percent grazed. The extent to which grasses were cropped at the end of the season was taken as a convenient and fairly reliable index of the total quantity of forage consumed. For each year, the sum of this amount added to the remaining grass—expressed in sheep-days of feed—was taken as the total quantity of forage produced.[4] It was realized from the outset that a direct and accurate measure of utilization of all classes of forage was desirable for this study, since observations indicate that sheep consume considerable quantities of weed feed during the spring when grasses are available and increasing amounts of sagebrush foliage in the fall as the grass feed becomes exhausted. Grasses not only constitute the major portion of the forage crop on this range but are the only plants of which the utilization can be readily measured.

The response of the range cover to the influence of climate and grazing was determined from plant-development records, plant inventories, and measured quadrats. The plant-development records included observations of the time when the grasses, as the principal forage plants, started growth each year and reached 2-, 4-, and 6-inch height growth, seed formation, and the start of curing. An inventory of the vegetation in the paddocks was made by range reconnaissance[5] in 1924 and again in 1930 to determine the trends in the density and composition of the vegetation. The behavior of the grasses was observed more critically in the years 1923, 1926, 1927, 1929, 1930, 1931, and 1932 on a meter-square quadrat in each of the five paddocks

[4] The 9-year average estimated total forage production was derived similarly, using the 9-year averages of yearly total use of range and percent forage used as a base. The percent of forage used in the spring and fall each year was derived from the ratios of the sheep-days per acre use of the range in the spring and fall, respectively, to the estimated total forage production for that year. Similarly, the 9-year average percents of forage used in the spring and fall were derived from the ratios of the 9-year average sheep-days per acre use of range in the spring and fall, respectively, to the calculated 9-year average estimated total forage production.

[5] Made in accordance with Instructions for Grazing Surveys on National Forests, mimeographed report of the Forest Service, last revised in 1935.

and on two quadrats in each of two small fenced areas from which grazing was excluded.

In connection with the concurrent breeding studies being conducted by the Bureau of Animal Industry, individual records of weights, losses, and production were maintained for all animals. Although no special group of animals was used in the grazing tests, records were made available for determining the influence of range conditions from year to year on body weights of mature ewes in the spring and fall, weights of fleeces at shearing, number of lambs born, and weight of lambs at birth and weaning.

Since January 1, 1924, records of maximum and minimum temperatures and precipitation have been made daily in the vicinity of the sheep station headquarters. Precipitation records were also available at Idaho Falls for the 27-year period 1906–32, and at Boise for the 60-year period 1873–1932. Although these latter stations are situated at distances of about 50 miles south and about 200 miles southwest, respectively, of the station range, the records are fairly comparable and are indicative of the climate which prevailed over the Snake River plains prior to and during the period of study.

CLIMATIC INFLUENCES

Climate, with its baffling uncertainties, is generally recognized as one of the most important single influences affecting range sheep production on the spring-fall range lands. It influences the period of growth as well as the quantity of forage produced. These in turn affect the period of use of the range and the number of sheep-days of feed produced each year. Heretofore, on spring-fall range, these influences have for the most part been determined only in general terms. In the present study, definite measurements were made of the extent to which periods of range use, annual forage production, and the thriftiness of range sheep are affected by precipitation and temperature.

CLIMATE DURING THE PERIOD OF STUDY

TEMPERATURES

Temperatures, as summarized in table 2, indicate a 7-month growing season extending in most years from April through October, with the lowest mean monthly temperature in January and the highest in July. Mean monthly temperature dropped below 40° F. in October 1928, although in all other years the mean for this month exceeded 40°. It continued especially low in the early spring of 1929, the mean for April having been only 31.55° as compared to 49.87° in 1930 and the average of 42.38° for the 9-year period. Low daily temperatures were recorded even into early summer, and again in early fall. Frost occurred in all months of each year except July and August. Because of this wide range of daily temperatures, the time at which mean temperatures rose to 40° in the spring or fell below this level in the autumn, delimiting the favorable growing season, varied widely from year to year. In general, however, it may be said that daily mean temperatures remained above 40° from April 10 to October 20, constituting an average period generally favorable for plant growth of 193 days. This may be accepted as the average growing period for this locality; but it must be kept in mind at the same time that tem-

peratures within this period are subject to occasional wide fluctuations which may also have an important bearing on the growth, development, and use of the range forage.

TABLE 2.—*Mean monthly temperatures at the United States Sheep Experiment Station, 1924–32*

Year	January	February	March	April	May	June	July	August	September	October	November	December
	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
1924	19.47	26.60	28.72	42.43	61.05	67.00	68.37	67.14	45.11	43.61	30.13	14.79
1925	21.48	29.05	32.48	43.58	55.19	66.55	67.73	63.20	55.35	44.48	31.93	20.71
1926	19.47	26.68	35.58	40.18	52.81	62.16	65.52	62.65	47.18	45.79	34.00	21.66
1927	20.51	23.89	30.81	41.23	47.87	61.08	69.10	64.93	55.47	47.00	36.45	17.70
1928	23.08	24.74	35.35	39.78	57.02	56.30	69.41	64.68	56.60	37.32	31.72	18.60
1929	11.90	14.90	26.50	31.55	46.79	55.88	66.98	66.71	40.18	42.74	24.10	25.53
1930	11.10	28.67	31.98	49.87	52.08	59.90	72.24	67.85	57.20	42.01	28.65	16.95
1931	20.32	24.14	27.20	43.30	56.00	64.78	78.30	68.80	62.80	46.70	28.80	20.03
1932	11.80	18.70	24.00	46.20	52.00	59.00	66.60	66.35	59.20	41.73	33.40	13.40
Average	17.39	24.59	30.29	42.38	53.52	60.30	69.36	65.82	54.23	43.50	31.13	19.48

PRECIPITATION

Precipitation averaged 10.18 inches for the seasonal year (Oct. 1 to Sept. 30) during the period 1924–32 (table 3). On the average, 4.38 inches fell as snow and rain during the 6-month period, October 1 to March 31, and 5.80 inches principally as rain during the spring and summer months. The average fall, however, varied widely from year to year, from month to month in the same year, and between the same months in different years.

TABLE 3.—*Monthly, seasonal, and annual precipitation recorded at the United States Sheep Experiment Station, October 1923 to September 1932, inclusive* [1]

Month	1923–24	1924–25	1925–26	1926–27	1927–28	1928–29	1929–30	1930–31	1931–32	9-year average
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
October [2]	2.40	1.38	1.18	0.12	1.30	0.53	0.71	2.33	0.14	1.12
November [2]	.37	.41	.45	1.31	.69	.93	.17	1.25	.69	.69
December [2]	.76	1.12	1.15	.98	.05	.72	.45	.17	2.46	.87
January	1.25	.64	.51	.39	.21	.45	.32	.63	.78	.57
February	1.99	1.16	.48	.65	.30	.96	.83	.41	.49	.70
March	.14	1.40	.08	.37	.10	.87	.10	.56	.23	.43
April	.01	1.70	.50	.41	.21	1.87	.93	.01	.87	.73
May	.22	1.26	.46	2.59	1.10	.53	1.44	1.06	.74	1.04
June	.57	1.96	.13	.92	1.55	1.34	1.90	.30	2.01	1.09
July	.35	.89	.16	.38	.70	.94	.21	.67	2.52	.70
August	0	2.67	.74	.78	.35	.65	2.59	.68	1.26	1.08
September	1.70	2.07	.16	1.55	.55	.97	2.01	.82	.6	1.10
12-month total	8.78	16.66	6.00	10.39	7.01	10.76	10.79	8.92	12.27	10.18
Winter period (Oct. 1 to Mar. 31)	5.92	6.11	3.85	3.76	2.55	4.46	2.58	5.35	4.70	4.38
Spring period (Apr. 1 to June 30)	.83	4.92	1.09	3.92	2.86	3.74	3.37	1.40	3.65	2.86
Summer period (July 1 to Sept. 30)	2.03	5.63	1.06	2.71	1.60	2.56	4.84	2.17	3.83	2.94

[1] Because it conforms more nearly to the end of the period when temperatures are favorable to plant growth, the record has been compiled for the 12-month period ending Sept. 30 rather than the regular calendar year.

[2] The values for October, November, and December of the calendar year 1923, herein listed as the first 3 months of the seasonal year 1923–24, were derived from records at 8 stations within the Snake River plains section having essentially the same character and amount of precipitation as at the Sheep Experiment Station.

According to the records at the experiment station, 1925 and 1932 were the only 2 years in which precipitation was distinctly above average, while 1924, 1926, 1928, and 1931 were considerably below average. That precipitation may have been generally more deficient than is indicated by this short record is suggested by the longer record of precipitation at Idaho Falls. For example, as is shown in table 4, the average annual precipitation at Idaho Falls during the period 1924–32 was 9.75 inches, as compared to 10.18 inches for the same period at the experiment station.[6] The 27-year record at Idaho Falls, however, shows that 11.62 inches is more nearly normal annual precipitation for that locality, suggesting that the 9-year period 1924–32 was about 16 percent below average. According to this relationship and in view of the similarity of the climate at these two stations, more nearly normal precipitation at the experiment station should be about 12.15 inches, instead of the 10.18 inches recorded. On this basis, it is not unreasonable to assume that 1925 was the only distinctly wet year at the experiment station during the period of study, all other years, except 1932, having been considerably below normal.

TABLE 4.—*Annual precipitation at Idaho Falls (Oct. 1 to Sept. 30), 1906–32*

Year	Precipitation	Year	Precipitation	Year	Precipitation	Average	Precipitation
	Inches		*Inches*		*Inches*		*Inches*
1906	14.48	1915	15.65	1924	6.16	27-year average (1906–32)	11.62
1907	17.91	1916	16.99	1925	12.50		
1908	13.94	1917	11.17	1926	7.58	9-year average (1921–32)	9.75
1909	14.42	1918	10.67	1927	10.48		
1910	7.71	1919	8.11	1928	8.77	10-year average (1906–15)	14.62
1911	15.25	1920	9.41	1929	12.19		
1912	16.89	1921	11.25	1930	8.85	17-year average (1916–32)	9.86
1913	15.33	1922	9.95	1931	8.21		
1914	14.61	1923	8.30	1932	13.02		

Further analysis of the records at Idaho Falls, as presented in figure 2, shows that precipitation was distinctly below normal, not only during the 9-year period in which the studies were conducted at the experiment station but for a period beginning as early as 1916. For example, although the mean annual precipitation for the 10-year period 1906–15 was about 26 percent more than the long-time average, with only 1 year of drought, the 17-year period 1916–32 was in all but 3 years considerably below average. The mean for the latter period was about 15 percent less than the long-time average.

Further evidence of the severity of the drought in recent years and the probability of recurring periods of dry years can be deduced from precipitation records at Boise for the 60-year period 1873–1932 (fig. 3), during which an alternate series of wet and dry years very much resembled the shorter cycle shown in figure 2, except that the drought that began in 1916 at Idaho Falls did not start at Boise until 1918. The record at Boise also shows that comparable cycles occurred prior to 1905, but they were irregular in duration and not nearly so long as the most recent drought. It appears obvious that periods of

[6] The slightly higher precipitation on the sheep station range undoubtedly is accounted for by its closer proximity to the Continental Divide.

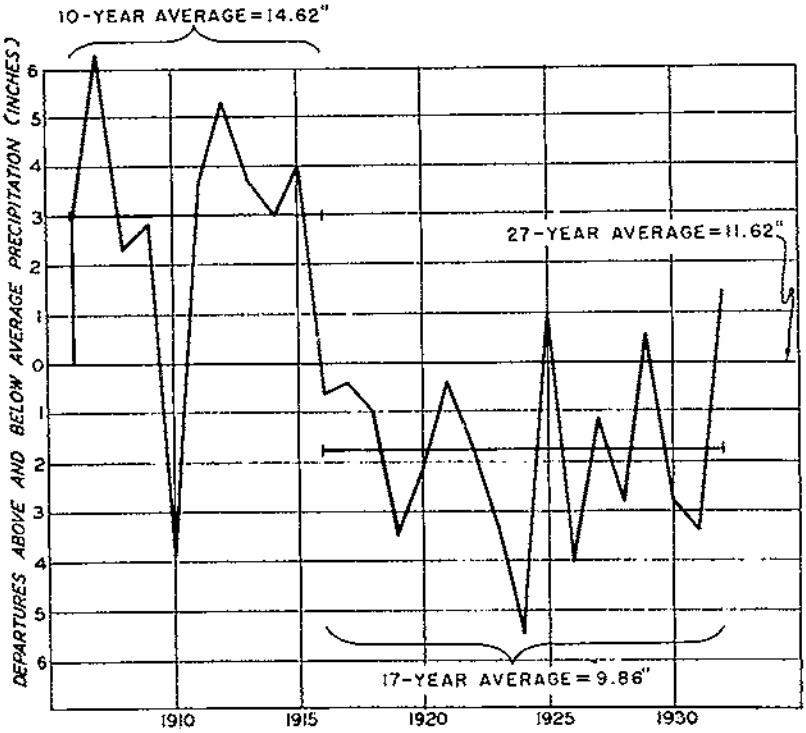

FIGURE 2.—The departures from normal precipitation at Idaho Falls, 1906–32, showing a concentration of surplus moisture during the period 1906–15 and an accumulation of moisture deficiency during the period 1916–32.

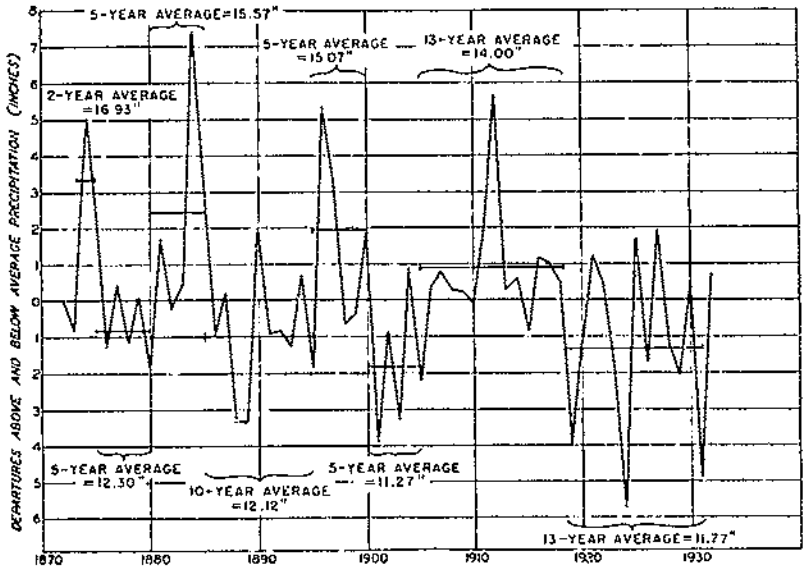

FIGURE 3.—Departures from the normal precipitation at Boise, Idaho, during the 60-year period 1873–1932, showing the irregularly cyclic trends of wet and dry years.

drought may be expected every few years in this locality and that some of the periods during which moisture is deficient may on the average be extended over as many as 17 years.

INFLUENCE OF CLIMATE ON GRAZING PERIODS

The start of plant growth in the spring and the rate at which the forage develops are of great importance to the users of spring-fall range, since they determine the availability of succulent forage at that time of year and fix the date when spring grazing can begin. Moreover, the length of time during which the forage remains green in the spring largely controls the duration of the spring grazing period. Similarly, the length of the fall grazing period hinges largely on the amount of feed that is left after the spring period, the amount of regrowth which occurs in the fall, and the occurrence of deep snows.

Detailed observations of the growth stages of bluebunch wheatgrass, as summarized in table 5, reveal that this plant started growth on the station range as early as March 20 and as late as April 24. Two-inch height growth on the average was attained on April 22, but once as late as May 1. Four- and six-inch stages of growth were reached in 1 year as early as April 21 and 26, respectively, and in another year as late as May 16 and June 1. Seed was formed before June 10 in 5 different years, and curing started at different dates between June 11 and August 5. All these growth periods varied widely from year to year in their dates of occurrence.

TABLE 5.—*A chronological record of the stages of growth of bluebunch wheatgrass (Agropyron spicatum), 1923–32*

Year	Grass started growth	Grass 2 inches high	Grass 4 inches high	Grass 6 inches high	Seed formed	Curing started
1923	Apr. 9	Apr. 28	May 16	June 1	June 7	June 28
1924	Apr. 7	Apr. 23	May 7	.....	June 1	June 11
1925	Apr. 2	Apr. 14	Apr. 30	May 6	May 26	July 10
1926	Apr. 1	Apr. 16	Apr. 21	Apr. 26	May 12	June 14
1927	Apr. 24	May 1	May 17	May 25	June 15	June 19
1928	Mar. 20	Apr. 27	May 6	May 10	May 27	July 25
1929	Apr. 14	Apr. 30	May 10	May 18	June 24	July 21
1930	Apr. 1	Apr. 15	Apr. 22	May 5	June 26	June 25
1931	do	Apr. 18	Apr. 30	May 10	.....	June 15
1932	Apr. 10	Apr. 15	May 2	May 16	July 10	Aug. 5
Average	Apr. 6	Apr. 22	May 4	May 13	June 8	July 2
Range of dates	*Days* 36	*Days* 18	*Days* 27	*Days* 37	*Days* 60	*Days* 56

The dates on which plant growth started were especially variable, the range in the 2 years 1927 and 1928 being 36 days. On the other hand, the earliest and latest dates on which 2-inch height was reached never exceeded a range of 18 days. Since soil moisture ordinarily is plentiful for a period of at least 2 weeks following the melting of snow, the primary reason for the great difference in range between the start and completion of the first stage of growth appears to be due to temperature. That there is a close relationship between the early development of this grass and the rise of temperatures is indicated in figure 4. Here it can be seen that the average and range of dates on which the start of growth and 2-inch development occurred nearly

coincide with the average and the lowest and highest mean monthly temperatures.

Later stages of development, including 4- and 6-inch stages of height growth, seed formation, and curing, also varied widely because, in addition to the varying temperatures to which the plants were subjected, moisture became increasingly uncertain as the seasons progressed. The combined effect of temperature and precipitation on plant development is illustrated in the growth record of the bluebunch wheatgrass under the different conditions prevailing in the 2 years 1930 and 1931 (fig. 5).

In these 2 years, growth started at the beginning of April. Slightly higher temperatures prevailed during that month in 1930 than in 1931.

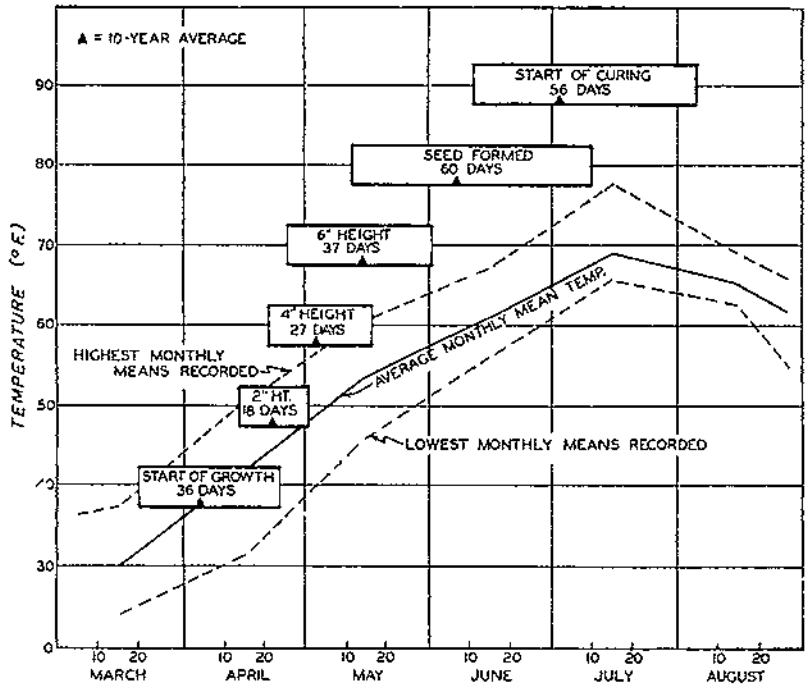

FIGURE 4.—Average and range in dates on which bluebunch wheatgrass reached important stages of development in relation to average and lowest and highest mean monthly temperatures recorded, 1924–32.

Moreover, rains occurred in each 10-day interval in 1930, whereas only one light shower occurred toward the end of the month in 1931. As a result, early forage growth was the more rapid in 1930.

A substantial rain early in May 1930 contributed materially toward the maintenance of adequate moisture for that month, but a lowering of temperatures occasioned by the storm tended to curb forage development. Although temperatures were higher in 1931, a continued lack of moisture held plant growth in check until near the end of the month. As a consequence, the net growth of forage in both years up to June 1 was about the same, with the important exception that in 1930 the grasses quickly attained a height growth sufficient for grazing, whereas feed was short during most of May 1931.

Late in May 1931 a heavy shower occurred which completely altered plant growth in June of that year as compared to the same month in 1930, when only light showers were recorded. In 1931 height growth was extended from 15 cm on June 1 to 35 cm by June 30, while in 1930 lesser showers and somewhat cooler temperatures permitted total height growth to reach only 23 cm, or about 35 percent less than in 1931.

A continued rise in temperatures and a lack of precipitation in late June of both years halted further spring growth and started curing of the forage.

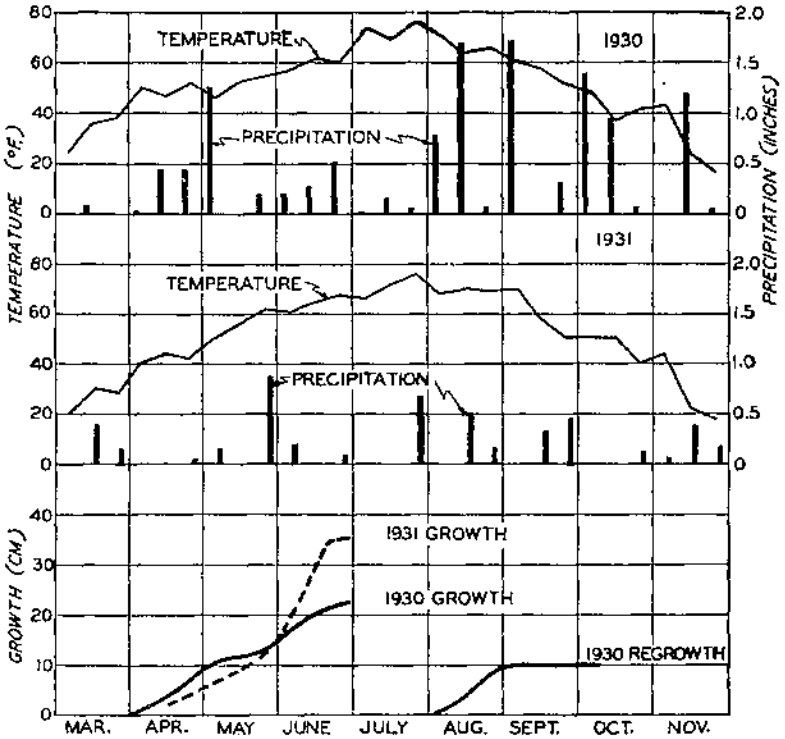

FIGURE 5.—The cumulative growth of bluebunch wheatgrass (*Agropyron spicatum*) and 10-day summations of temperature and precipitation, 1930 and 1931.

Significantly different range conditions prevailed during the fall of these 2 years—again largely due to differences in precipitation. In 1930 precipitation was very heavy; in 1931 storms were light and scattered. As a result, there was a considerable amount of regrowth in August and September of 1930 but practically none in 1931. This regrowth in 1930 more than offset the short spring growth and in general created excellent early fall grazing conditions. The advantage created by 1930 fall weather did not hold, however. In November a snowstorm so deeply covered the range that the sheep had to be moved to feed lots a month earlier than usual. On the other hand, heavy snows did not come until late December 1931, so that it was possible in that year to utilize practically all of the avail-

able feed on the ground before moving to the winter range and feed lots.

The records of these 2 years show very clearly the combined action of climatic forces in determining the grazing periods from year to year, whereby the start and early development of range forage is largely controlled by temperature; precipitation becomes a major influence during late spring, summer, and fall, and temperature and precipitation combined determine whether the close of the fall grazing period shall be early or late.

From a practical management standpoint, the relatively short range in the dates on which grasses reach 2-inch height growth (18 days) clearly suggests that the average date for this stage of growth (Apr. 22, 1923–32) should be used as the date for starting spring grazing, and as a basis for planning the year-long calendar of operation. There are several advantages in the use of this base. Since this date is likely to be at all times within about 8 days of accuracy, 8 to 10 days of supplemental feed is needed in reserve as insurance against a shortage of range forage in occasional years of delayed growth, as compared to the 18- to 20-day feed supply that would be needed if start of growth were the basis. Further, 2-inch height growth of grasses provides forage sufficient to insure the maintenance of ewes in good condition and normal gains in lamb weight and development. Lastly, when the forage is grazed by the proper numbers, a large part of it will reach advanced stages of development before being cropped, permitting the production of seed and the restoration of vigor by plants on at least a part of the range each year.

The close of the fall grazing season would naturally be planned for the average date on which deep snow may be expected. But snow occurrence is so variable that at least a 30-day reserve supply of hay and supplements, or their equivalent in winter range, should be maintained in addition to the normal requirements for the winter period.

The utilization of the experiment-station range in the spring and fall is planned in accordance with the availability of the forage and the exigencies of climate insofar as this is practical. Beginning in 1930, the sheep were turned out on the range each year when the grasses had reached 2-inch growth. Sheep were removed from the range about December 1, although in some years it has been possible to use the range up to January 1, and in others, such as 1930 and 1932, snow closed the grazing season about the middle of November.

INFLUENCE OF CLIMATE ON FORAGE PRODUCTION

The most obvious influence of climate—more especially precipitation—on the spring-fall range is in the volume of forage produced from year to year and therefore in the numbers of stock that can be grazed on a given unit over a period of years. The influence of climate on forage production has been observed on ranges in the Southwest (*4*, *6*) and in Utah (*2*, *7*) but not on the sagebrush-wheatgrass range type of southern Idaho. In the present study, the influence of precipitation on forage production on spring-fall range is indicated by the manner in which the average volume of feed on two of the 80-acre experimental paddocks fluctuated from year to year during the period 1924–32. One of the paddocks used in this phase of the study (paddock 1) was

grazed only late in the fall; the other (paddock 7) was grazed moderately for an approximate average period of 3 weeks in the spring after grasses reached 6-inch height growth and again in the fall. Because the major use of these areas was obtained in the fall after plant growth was completed, it is considered that grazing has been a relatively minor factor in forage production as compared to the effect of climate.

Total forage production on the average amounted to 5,651 sheep-days of feed per 80-acre paddock annually, but the volume from year to year varied irregularly above and below this average, responding rather closely to fluctuations in the occurrence of precipitation during the current spring and preceding winter period (Oct. 1 to June 30), as shown in figure 6. For example, forage production was 41, 23, and 7 percent above average in 1925, 1932, and 1929, respectively. During these years precipitation was also above the study-

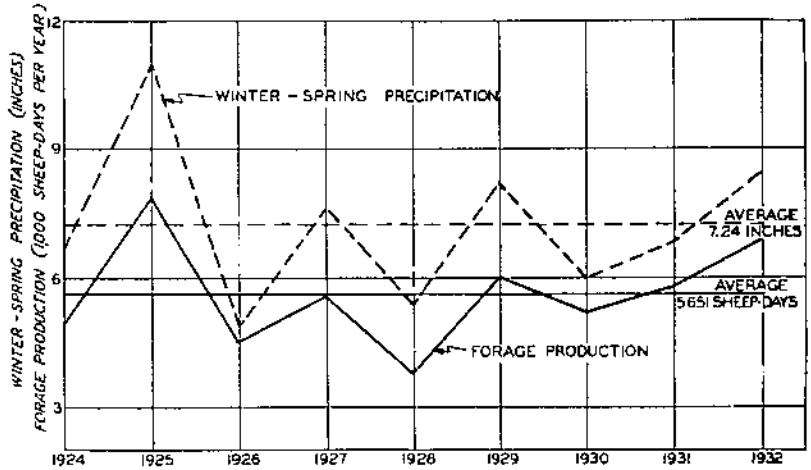

FIGURE 6.—Forage production and winter-spring precipitation on two experimental paddocks, 1924-32.

period average in the winter and spring seasons. In 1928, 1926, 1924, and 1930 forage production was 33, 20, 10, and 8 percent, respectively, below average, and in each of these years precipitation was also definitely subnormal. In 2 of the years, 1927 and 1931, both forage production and precipitation were about average. A statistical analysis of the relationship between forage production and precipitation during the spring and preceding winter, yielded a correlation coefficient of 0.944, which is considered highly significant for the number of cases involved.

The fluctuations in forage production on these areas were undoubtedly due in large measure to differences in the growth of grasses, not only because these plants constituted a major portion of the available forage, but also because they are especially sensitive to changes in moisture conditions. This sensitivity is seen in the measured expansion and contraction of the basal area of clumps of the grasses on four meter-square fenced quadrats, as illustrated in figure 7. The average basal area of grasses on these quadrats in 1923 was 668.5 cm^2. This was increased to 959.8 cm^2 by 1926, through

the expansion of individual clumps by tillering. Although 1926 was a dry year, the high density recorded on the quadrats in that year undoubtedly is a reflection of the exceptionally good growing conditions of 1925. Conversely, it appears that moisture in 1926 was insufficient to maintain the expanded root systems and as a consequence the grass clumps split into small plants, resulting in an average stand on the four plots of only 736.5 cm² in 1927. The year of 1928 was again deficient in precipitation, and the average basal area of the grasses decreased further to 484 cm² in 1929, and to a low of 476.2 cm² in 1930. There was an indication of respreading of the grass clumps in 1931 and 1932 in which years the average spread increased to 515 and 542.5 cm². In spite of this, however, average basal area of the grasses in 1932 was about 19 percent less than in 1923—not a sur-

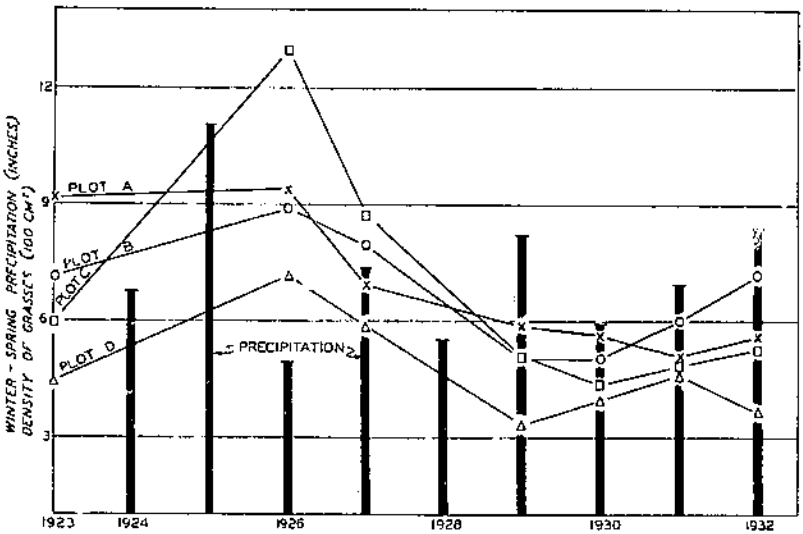

FIGURE 7.—Annual changes in basal area of grasses on four ungrazed quadrats at United States Sheep Experiment Station, and the corresponding record of winter-spring precipitation, 1924–32.

prising result when it is considered that precipitation during the period as a whole was at least 16 percent below normal for this locality.

The variability in forage production recorded on this range is in general agreement with results obtained by Nelson (6) in studies of the black grama grass in the Southwest. As in the Southwest, the great variability of forage production from year to year caused by differences in climate clearly indicates the futility of stocking the range on the basis of good or even average years, as is common practice on western rang areaes.

INFLUENCE OF CLIMATE ON RANGE SHEEP

Animal husbandmen generally have recognized that the quantity and quality of feed available to livestock has a material bearing on their thriftiness and productivity. The extent to which climate influences the productivity of range sheep through its effect on forage growth, has not, however, been so well understood, especially on the spring-fall range. Many other factors are involved on this type of

range than the closely related elements of climate and plant growth. These factors include effects as difficult to measure as cumulative improvement by breeding, changes in methods of handling, quality and quantity of winter feed, and forage production on the summer range. Moreover, sheep are on the spring-fall range for only 2 to 3 months in the spring and in the fall. The highly variable conditions to which sheep are subjected during the entire year are indicated in the qualitative summary given in table 6.

TABLE 6.—*A qualitative summary of seasonal conditions affecting experiment-station sheep, largely as a result of climatic factors, 1924–32*

Year	Fall range [1]	Winter range [1]	Feed lot	Feed-lot conditions [1 2]	Spring range [1]	Summer range [1]
			Days			
1923–24	E	E	70	F	P	F
1924–25	P	P	107	G	E	E
1925–26	E	E	47	F	VP	P
1926–27	VG	E	75	G	G	G
1927–28	G	G	64	G	G	G
1928–29	G	G	56	G	P	[3] G
1929–30	G	F	64	F	G	G
1930–31	E	P	141	VG	P	P
1931–32	P	P	109	VG	E	E

[1] VP=very poor, P=poor, F=fair, G=good, VG=very good, E=excellent.
[2] Including quality of hay.
[3] Summer range conditions were average in 1929, but lambs were not able to recover from the set-back caused by a very unfavorable spring season.

Although these variables made it impossible to isolate and evaluate the specific influence of climate on all aspects of range sheep production on the spring-fall range, it has been possible to determine this influence on two important aspects, namely, the fall weights of sheep and the number of lambs born.

BODY WEIGHTS OF MATURE EWES

The average weights of 3-year-old Rambouillet and Corriedale ewes for the period 1925–33 are given in table 7. These weights were taken in June after shearing; in October at culling; in late November, when rams were turned in; and in early January, when the rams were removed. November and January weights were not started until the year 1927–28, and no weights were taken in January 1932 because of heavy snows and a hard trail that would have resulted in weights not representative of the actual condition of the sheep.

TABLE 7.—*Seasonal weights of 3-year-old Rambouillet and Corriedale sheep at the United States Sheep Experiment Station during the period 1925–33*

Year	Rambouillets				Corriedales			
	June	October	November	January	June	October	November	January
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1925–26	101.36	122.96	.....	.....	98.71	122.20	.....	.....
1926–27	103.53	127.76	.....	.....	97.69	123.00	.....	.....
1927–28	104.33	135.04	128.92	117.74	96.85	127.54	122.30	113.48
1928–29	115.35	126.17	115.97	112.97	111.75	124.55	115.85	112.14
1929–30	107.73	130.38	121.83	121.00	104.81	130.42	132.50	124.71
1930–31	123.87	133.24	125.40	130.11	117.11	130.82	128.95	120.63
1931–32	126.98	136.58	126.88	.....	124.06	132.99	127.87	.....
1932–33	121.05	138.04	134.91	135.05	121.00	139.49	133.70	135.82
Weighted average	111.22	130.21	125.59	123.47	107.78	128.30	127.42	123.99

As might be expected, both Rambouillet and Corriedale sheep weigh least in June, after shearing and at a time when ewes are nursing lambs. Weights are highest in October, after the lambs are weaned and after the ewes have spent the summer on good mountain range feed. A gradual decrease in weight occurs in November and January, principally because of a change to dry forage and increased difficulty of reaching the feed through deepening snow. In the last years of the study, there was a decided trend toward increased weights and fluctuations in weights from year to year above and below the average for the period.

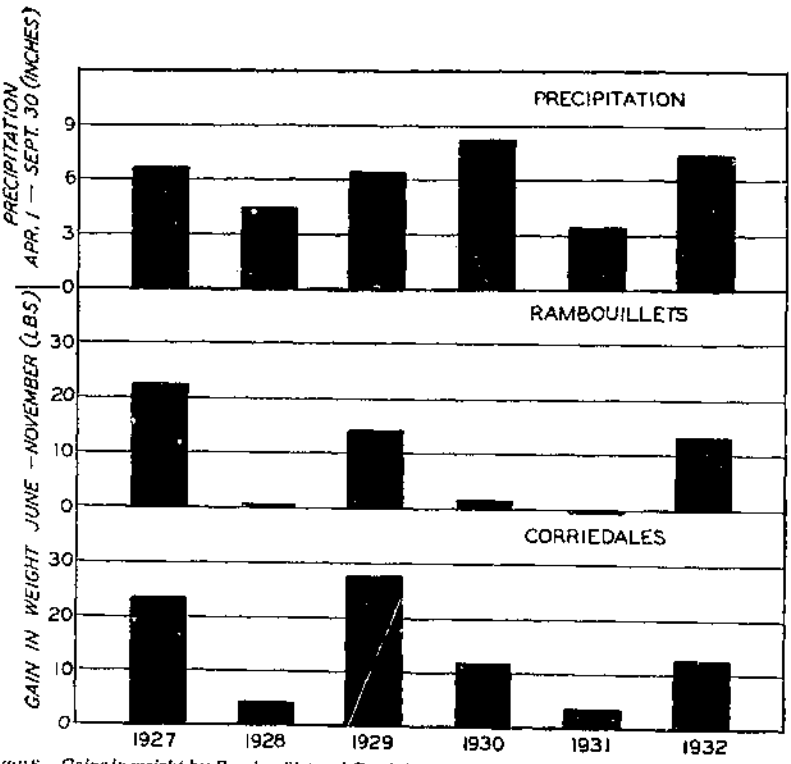

FIGURE 8.—Gains in weight by Rambouillet and Corriedale ewes between June 1 and November 30, 1927–32, with average seasonal (Apr. 1 to Sept. 30) precipitation for the same period.

November weights are considered a reliable index of forage conditions on spring-fall range. While it is true that they reflect the influence of summer grazing, summer range conditions approximate so closely those of spring range (table 6) that, for the purpose of establishing the relationship between sheep condition and variations in weather as here shown, the summer range period need not be segregated.

The relation between annual fluctuations in weights of mature sheep and general range conditions are illustrated in figure 8, wherein departures from average gains in weight between early June and late November during the years 1927 to 1932 are compared with average seasonal precipitation. The difference between June and November weights are used because this most accurately reflects the sum of forage quality and quantity during the spring, summer, and fall graz-

ing periods. Seasonal precipitation, April 1 to September 30, likewise is an approximation of the general moisture conditions which prevailed on the spring-fall range and had a direct bearing on forage production.

The heaviest gains of Rambouillet and Corriedale ewes reflect the favorable moisture conditions in 1927, 1929, and 1932. Similarly, the inadequate moisture for good forage production in 1928 and 1931 is reflected in very slight gains for those years, with an actual loss in the Rambouillet breed in 1931. The comparatively low gains in 1930, despite abundant moisture and favorable range conditions up to November, are explained by the heavy snow in November of that year, which necessitated a premature and hard trail to the feed lots. Weights obtained thereafter evidently reflect the effects of trailing rather than moisture conditions. A somewhat similar condition developed in 1932, but only the Corriedales were affected, and only slightly.

These data show that, over and above any improvement in adaptability for making and maintaining good weights that is attained through breeding, annual variations in weight may be expected to result from fluctuations in weather and forage production. Because of the relationship between sheep weights and forage, the best insurance against severe losses in body weight during drought years is to stock the range on a sufficiently conservative basis so that, even in the poorest years, ample forage will be available for the sheep.

LAMB PRODUCTION

The pounds of lamb produced per ewe is one of the most important aspects of range sheep production, and the number of lambs born and born alive per ewe bred is obviously of primary consideration. The extent to which the numbers of lambs born and born alive per ewe are affected by range conditions is indicated in a summary of this phase of lamb production for the period 1925–32 (table 8).

TABLE 8.—*Summary of Rambouillet and Corriedale lamb production at the United States Sheep Experiment Station, 1925–32*

RAMBOUILLETS

Year	Ewes at breeding	Ewes with lamb		Lambs dropped by ewes bred		Lambs dropped alive by ewes bred	
	Number	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
1925	317	255	80.44	264	83.28	259	81.70
1926	335	277	82.69	312	93.13	290	86.57
1927	350	285	81.43	300	85.71	247	70.57
1928	325	279	85.85	297	91.38	277	85.23
1929	660	481	72.88	518	78.18	436	66.06
1930	427	391	91.57	437	102.34	410	96.02
1931	297	260	87.54	326	109.76	295	99.33
1932	296	268	90.54	295	99.66	275	92.91
Total	3,007	2,496	83.01	2,747	91.35	2,489	82.77

CORRIEDALES

1925	343	295	86.30	327	95.34	323	94.17
1926	308	281	91.23	340	110.39	324	105.19
1927	329	290	88.07	326	99.09	296	89.97
1928	331	307	92.75	342	103.32	321	96.98
1929	599	546	91.15	585	97.66	515	85.98
1930	415	395	95.18	439	105.78	419	100.90
1931	317	298	94.01	358	112.93	326	102.84
1932	309	288	93.20	315	101.94	290	93.85
Total	2,951	2,707	91.73	3,032	102.74	2,814	95.36

For Rambouillets, the average of 16.99 percent of ewes not with lamb included all drys and all ewes dead or missing from breeding to lambing. Percent of ewes with lamb varied by 18.69 from 1929 to 1930. The number of Rambouillet lambs dropped per 100 ewes bred varied by 31.58, and those dropped alive by 33.27, between 1929 and 1931.

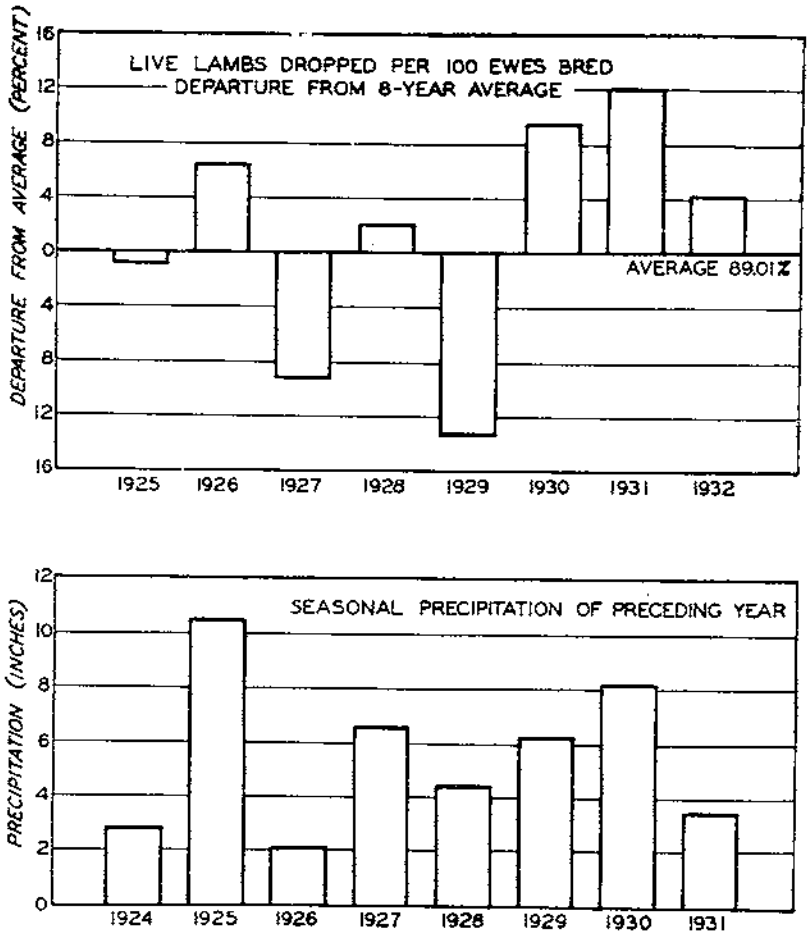

FIGURE 9.—The average number of lambs born alive per 100 ewes bred (Rambouillets and Corriedales) in relation to the seasonal precipitation (Apr. 1 to Sept. 30) of the preceding year, 1925–32.

The Corriedale group were in general more productive, and the range of variations from year to year was much smaller. Difference in percent of ewes with lamb was 8.88; of lambs dropped, 17.59; and of lambs dropped alive, 19.21. The high years for the first two items were 1930 and 1931, and the high year for lambs dropped alive was 1926. The low year for lambs dropped alive by both breeds was 1929.

When the number of lambs born and the number born alive per 100 ewes bred are compared with April to September precipitation

records (fig. 9), it is noted that the lamb crop fluctuated from year to to year closely in accordance with variations in moisture conditions which prevailed during the preceding year; that is, the number of lambs born alive was below average in 1925, 1927, and 1929, whereas precipitation during each of the preceding years—1924, 1926, and 1928—was also below normal. On the other hand, the number of live lambs born in 1926, 1928, 1930, and 1931 was above average, and these values corresponded to favorable moisture conditions during each previous fall. Similarly, lamb production was relatively lower in 1932 than in 1931 as precipitation was lower in 1931 than in 1930. Thus it appears that ewes in a thrifty condition in the fall, as the result of abundant forage, tend to produce more live lambs in the following spring than do ewes in a year following a poor fall.

No consistent relationship appears between climate and later stages of lamb development, such as pounds of gain per lamb from birth to weaning, the numbers weaned per 100 ewes bred, or the weaned weight of lambs and pounds of lamb produced per ewe. Climate and the quantity and quality of forage on the spring-fall range undoubtedly have some effect on these phases of lamb production but it is obscured by other factors such as death due to predators, disease, and straying; slow development due to inferior breeding, mothering, and methods of handling; and conditions on the summer range where the lambs matured (*1*).

Other important aspects of range-sheep production, including yields of wool and death losses, varied from year to year during the period of study partly in response to climate and forage production, but the presence of other factors precluded isolation and evaluation of the specific influence of climatic factors.

GRAZING INFLUENCES

The important bearing that climate has on the growth and development of forage from year to year on spring-fall range must be understood and be given careful consideration in establishing periods of use and a basic rate of stocking, but that alone is not enough. The influence of "good years" and "bad years" is a serious matter; but the stark necessity of anticipating such climatic variations is not convincingly apparent until studies have been carried further and have revealed the effect of time and intensity of grazing upon the range in years of drought and years of plenty. Such studies of grazing influences make it clear that overgrazing may result in range depletion of a far more lasting and serious character than any temporary declines in productivity normally induced by drought alone (pl. 2). The degree to which the sagebrush-bunchgrass type of spring-fall range land can be damaged by overgrazing in a relatively short period of years is shown in the results presented in the following pages. These results were obtained from the four 80-acre paddocks, designated 2, 3, 8, and 7, already described. Each paddock was utilized to different degrees and for different periods in the spring, followed in each case by the removal of nearly all of the remaining forage in the fall. At the same time, paddock 1, grazed only in the fall, was held as a check area, to show the maximum improvement that might have been expected under prevailing climatic conditions during the period of the study.

RANGE DEPLETION RESULTING FROM HEAVY CONTINUOUS SPRING AND LATE FALL GRAZING

The degree to which sagebrush-bunchgrass spring-fall range in Idaho can be depleted by heavy continuous spring and late fall grazing is illustrated by results obtained during the period 1924–32 on paddock 2. Here approximately 68 percent of all available forage was utilized in the spring, starting when grasses reached 2-inch height growth and ending at the close of the spring grazing season, and 25 percent was consumed in the fall, leaving on the average only 7 percent of the forage unutilized (table 9).

TABLE 9.—*Actual use, under heavy continuous spring and late fall grazing, of paddock 2, 1924–32*

Year	Spring grazing			Fall grazing			Yearly total		Estimated total forage production [1]
	Period of use	Use of range	Forage used	Period of use	Use of range	Forage used	Use of range	Forage used	
		Sheep-days per acre	*Percent*		*Sheep-days per acre*	*Percent*	*Sheep-days per acre*	*Percent*	*Sheep-days per acre*
1924	Apr. 20–May 31	25.54	50	Oct. 5–Nov. 13	21.28	42	46.82	92	50.89
1925	Apr. 14–June 15	62.32	72	Oct. 16–Nov. 10	24.65	28	86.97	100	86.97
1926	Apr. 17–May 27	37.80	95	Nov. 10–Nov. 20	1.18	3	38.98	98	39.78
1927	Apr. 30–June 11	24.42	66	Oct. 20–Nov. 7	12.48	34	36.90	100	36.90
1928	Apr. 25–June 8	24.92	70	Oct. 26–Dec. 1	6.63	21	31.55	100	31.55
1929	May 7–June 12	18.73	74	Oct. 31–Nov. 9	4.85	19	23.58	93	25.35
1930	Apr. 19–June 16	8.67	54	Nov. 5–Nov. 18	6.46	40	15.13	94	16.10
1931	Apr. 29–June 12	10.57	67	Nov. 2–Nov. 10	4.70	30	15.27	97	15.74
1932	May 1–Aug. 6	17.92	55	Nov. 1–Nov. 6	3.39	10	21.31	65	32.78
Average	Apr. 25–June 15	25.65	[2] 68	Oct. 28–Nov. 15	9.51	[2] 25	35.16	93	[2] 37.81

[1] Estimated total forage production (sheep-days per acre), average 1924–25, 68.93; 1931–32, 24.26. Loss in forage value between 1924–25 and 1931–32, 65 percent.
[2] Computed average. See footnote 4, p. 6.

The respective averages for 1924–25 and 1931–32 and the difference in percent between them, shown at the bottom of table 9, are highly significant. Since 1924 was a very poor growth year, while 1925 was very good, the average number of sheep-days of feed per acre produced in these 2 years is considered to be a reliable index of the productivity of the pasture at the start of the grazing tests. Similarly, 1931 and 1932 were relatively poor and good years, respectively; hence the average of these 2 years is considered a fair index of the productivity of the area at the end of the test period.

Under this system and intensity of grazing, the number of sheep-days of feed fluctuated about in accordance with growing conditions on the range during the first 2 years of the study. After the exceptionally good growth year of 1925, however, and in spite of fairly favorable growing conditions in 1927 and 1929, the productivity of the pasture declined consistently to the low level of less than 16 sheep-days of feed per acre in 1931 (fig. 10). As the result of better-than-average growing conditions in 1932, a little more than twice as much forage was produced in that year, but the average of feed produced in these last 2 years was 65 percent less than the average of the first 2 years of the study.

Coincidental with the decline in the sheep-days of feed produced, significant changes occurred in the vegetative cover (pl. 3). Ac-

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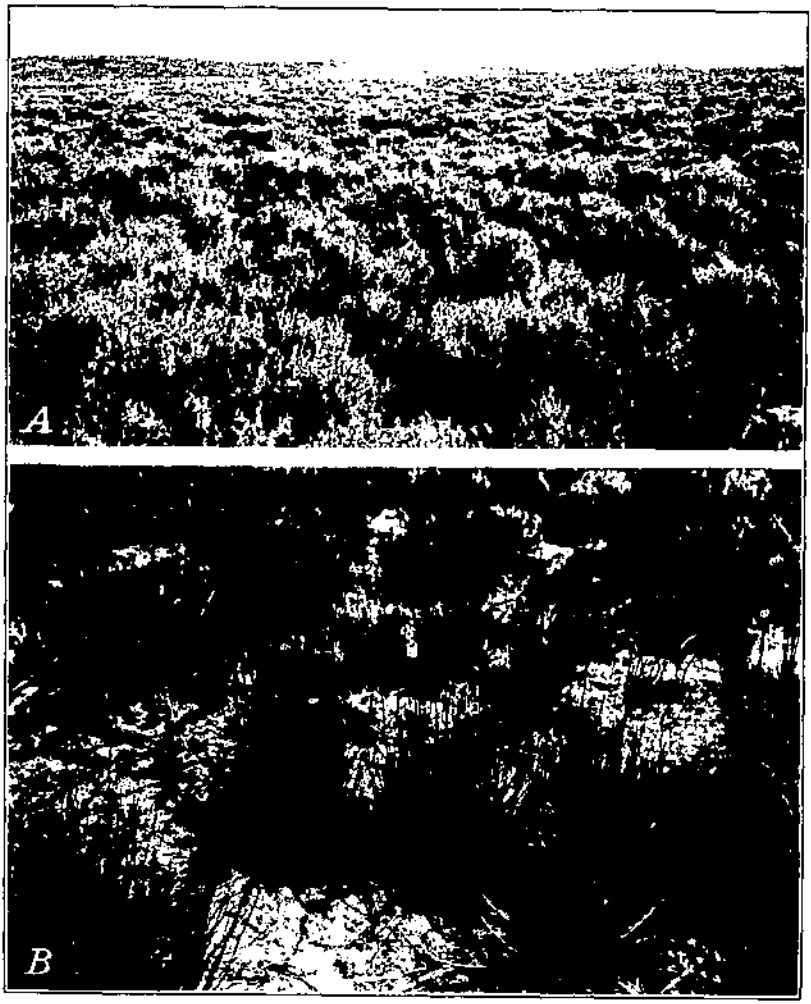
CONSERVATIVELY GRAZED VS. OVERGRAZED SPRING-FALL RANGE.

Grasses and weeds grow luxuriantly on spring-fall range as conservatively grazed as paddock 1, to the left of the fence on paddock 2, to the right, which has been overgrazed, sagebrush and other less palatable plants have crowded out the bunchgrass and weed forage. More detailed views of the vegetation on such conservatively grazed and overgrazed range lands are shown in plate 3.



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OVERGRAZING DESTROYS; CONSERVATIVE GRAZING BUILDS UP.

Density of the relatively unpalatable sagebrush is increased by too heavy use of bunchgrasses and weeds (*A*) and range lands thereupon become worthless for ranch-sheep production. Ranges in this condition are very low in carrying capacity, lambs are lost from straying, and much wool is pulled from the sides and bellies of the sheep, considerably lowering wool yields. On the other hand, where the valuable bunchgrasses are protected by conservative grazing (*B*), they will not only build up good weights in the ewes and insure good lamb crops, but in addition they will be able to compete successfully with the less desirable sagebrush and keep it down. Note the sagebrush plant killed out, in the right foreground.

cording to ocular estimates of the vegetation over the area as a whole, the density of the highly palatable grasses and weeds decreased 67 and 81 percent, respectively, between 1924 and 1930 (table 10).

The losses in these two classes of forage were confined principally to the wheatgrasses, needlegrasses, and bluegrasses, and to such choice weed plants as the crepis and balsamroot, which were either killed or reduced in size. On the other hand, the density of the relatively unpalatable shrubs, principally sagebrush, increased by nearly three-fourths in the same 6 years, partly through the establishment of

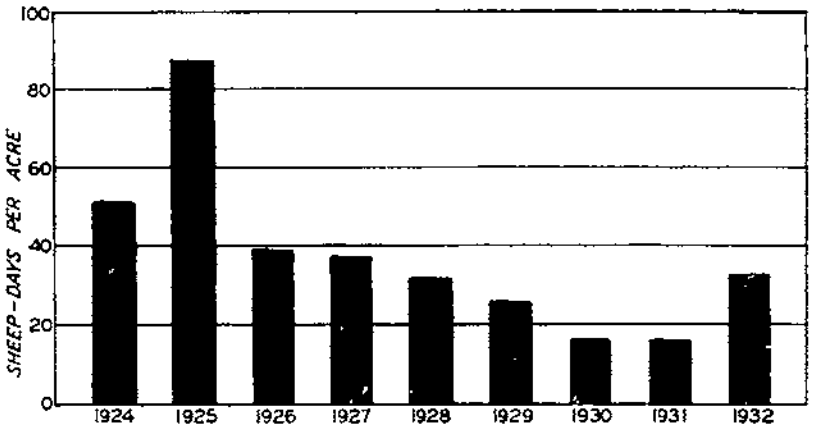

FIGURE 10.—Trend in estimated total annual forage production under heavy continuous spring grazing and late fall use, 1924–32.

TABLE 10.—*Effect of heavy continuous spring and late fall grazing on paddock 2, as shown by the relative composition and ground cover of the vegetation in 1924 and 1930*

Class of forage	Composition of cover		Area of paddock covered by vegetation					
			Total cover			Palatable cover		
	1924	1930	1924	1930	Change	1924	1930	Change
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Browse	40.64	81.26	11.62	20.12	+73	1.24	1.47	+19
Grass	39.19	13.85	11.34	3.43	−70	7.94	2.62	−67
Weeds	20.86	4.89	6.06	1.20	−80	2.93	.55	−81
Total	100.00	100.00	29.02	24.75	−15	12.11	4.64	−62

new plants and partly by vigorous expansion of the crowns of old ones (fig. 11). Although the increase in the growth of sagebrush and other shrubs tended to compensate for the losses of grasses and weeds in the stand, the total density of the cover in 1930 was about 15 percent less than in 1924.

Further indication of the manner in which such heavy grazing reduced the forage value of this range was gained from a comparison for the years 1923–32 of the basal area of perennial grasses on a meter-square quadrat laid out on a portion of this paddock that was fairly representative of the area as a whole. As may be seen from table 11,

the decrease in basal area for the entire period was 92 percent. The weakening effects of this character of grazing is illustrated also by the declining vigor of the herbaceous vegetation, to the degree that during the last 4 years of the grazing period the development of the herbaceous vegetation to 2-inch height growth lagged from 2 to 14 days behind the time when similar plants on less heavily grazed range reached this stage. Random measurements of height growth and flower-stalk counts confirmed these evidences. Balsamroot plants on this area produced annually only one or two flower stalks from 4 to 5 inches in length per plant, whereas 12 to 15 flower stalks 12 to 20 inches in length were produced on balsamroot plants nearby under moderate grazing.

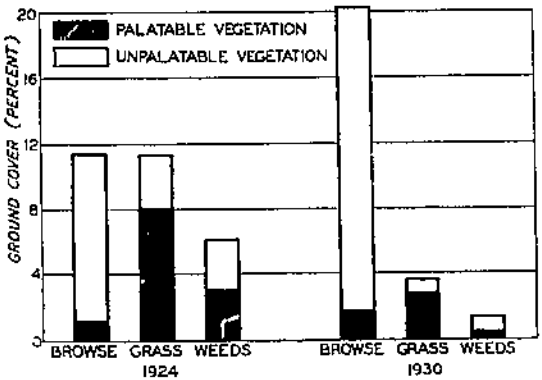

FIGURE 11.—Effect of heavy continuous spring and late fall use on the palatability of range cover between 1924 and 1930.

TABLE 11.—*The shrinkage in basal area of perennial grasses on a representative meter quadrat in paddock 2 and the lag in readiness for grazing (2-inch height growth) as compared to protected range*

Years	Basal area	Lag in readiness	Years	Basal area	Lag in readiness	Years	Basal area	Lag in readiness
	Cm²	*Days*		*Cm²*	*Days*		*Cm²*	*Days*
1923	386	0	1929	193	2	1932	31	14
1926	727	0	1930	163	7			
1927	321	0	1931	127	11	Shrinkage	355	

Furthermore, observations made within a rod-square portion of this range, which was protected from grazing in 1930 and 1931, revealed that the balsamroot and other weakened palatable plants failed to show any appreciable return in vigor by the end of the spring growing season in 1931, in spite of the fact that growing conditions were nearly normal in these years. Thus it appears that when sagebrush-bunchgrass range of this character is seriously depleted it will require several years to restore the normal vigor of the remaining desirable forage plants and, undoubtedly, many more years of protection, or a combination of protection and very conservative grazing, before new plants will take the place of those killed.

The decline in the productivity of this range area is comparable to the depleted condition of extensive areas of spring-fall range lands in southeastern Idaho on which grazing is uncontrolled. One band of sheep follows another on the range in the spring, utilizing a large percentage of the forage as rapidly as it is produced. In many instances, the same ranges are again grazed very heavily in the fall. Such utilization has no place in good range management.

DEPLETION FROM HEAVY EARLY SPRING AND LATE FALL GRAZING

Several years of early spring grazing, repeated at approximately the same period of plant growth each year and followed by fall grazing, may also be detrimental to sagebrush-bunchgrass range. This is evident in the results of grazing tests in paddock 3 during the years 1924–32. A summary of these tests in table 12 shows that 36 percent

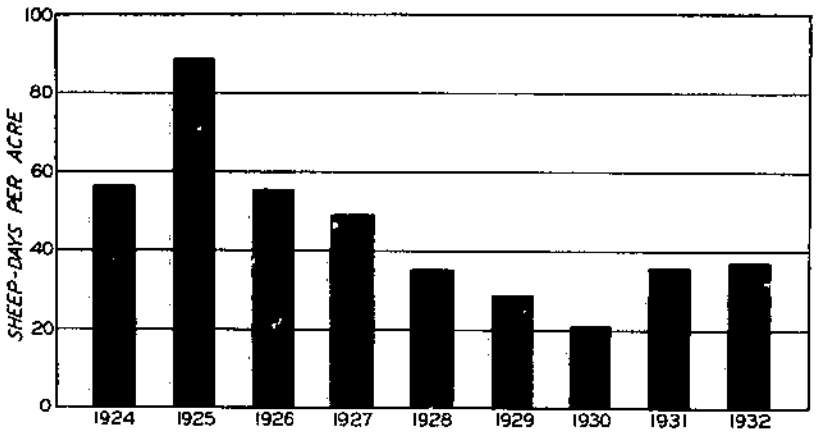

FIGURE 12.—Trend in estimated total annual forage production under heavy early spring and heavy fall use of the range, 1924–32.

of the forage was utilized on the average in a 4-week period each spring, starting after grasses reached 2-inch height growth. A somewhat larger percent (46) was removed in the fall, representing a total annual utilization of 82 percent.

TABLE 12.—*Actual use, under heavy early spring and late fall grazing, of paddock 3, 1924–32*

Year	Spring grazing			Fall grazing			Yearly total		Estimated total forage production [1]
	Period of use	Use of range	Forage used	Period of use	Use of range	Forage used	Use of range	Forage used	
		Sheep-days per acre	*Percent*		*Sheep-days per acre*	*Percent*	*Sheep-days per acre*	*Percent*	*Sheep-days per acre*
1924	Apr. 23–May 29	19.26	34	Oct. 5–Nov. 13	28.14	50	47.40	84	56.43
1925	Apr. 13–May 10	27.44	31	Oct. 16–Nov. 24	54.26	61	81.70	92	88.80
1926	Apr. 17–May 10	20.97	54	Oct. 15–Nov. 20	17.15	31	47.12	85	55.44
1927	Apr. 29–May 31	14.70	30	Oct. 20–Nov. 20	29.74	60	44.44	90	49.38
1928	Apr. 26–May 19	18.28	52	Oct. 26–Dec. 1	15.25	43	33.53	95	35.29
1929	May 6–May 20	8.81	30	Nov. 12–Nov. 27	19.32	67	28.13	97	29.00
1930	Apr. 19–June 4	9.57	45	Nov. 5–Nov. 16	6.46	31	16.03	76	21.09
1931	Apr. 30–May 21	12.17	34	Nov. 2–Nov. 25	13.80	38	25.97	72	36.07
1932	May 4–June 1	9.30	25	Nov. 1–Nov. 12	7.88	21	17.18	46	37.35
Average	Apr. 25–May 23	16.61	[2] 36	Oct. 25–Nov. 23	21.33	[2] 46	37.94	82	[2] 46.27

[1] Estimated total forage production (sheep-days per acre), average 1924–25, 72.62; 1931–32, 36.71. Loss in forage value between 1924–25 and 1931–32, 49 percent.
[2] Computed averages. See footnote 4, p. 6.

This area produced an estimated average of 73 sheep-days of feed per acre in the first 2 years of the experiment. But here, as in other paddocks heavily grazed in the spring, early forage production declined consistently to a low level by the end of the period (fig. 12). The average of the 2 years 1931 and 1932 was only 37 sheep-days, or nearly 50 percent less than the average of the first 2 years. Although this was an improvement over the preceding 2 years, attributable to the more favorable growing conditions in 1932, it did not affect materially the definite downward trend for the period as a whole.

As under heavy continuous spring grazing in paddock 2, this considerable decline in available forage resulted in a very significant change in the composition and hence in the palatability of the vegetation, as shown in table 13 and figure 13. In 1924 grass and browse covered nearly equal portions of the paddock, but by 1930 the density of shrubs increased more than 50 percent and covered about three and one-half times the grass area. Most of this increase was due to the expansion of the size of sagebrush and other relatively unpalatable shrubs. The reduction in density of the grasses by more than 50 percent and that of the weeds by 18 percent were largely due to the destruction of the most desirable forage plants, such as wheatgrass, bluegrass, crepis, and balsamroot. Moreover, as is evident in table 14, the basal area of perennial grasses on a meter-square quadrat decreased between 1926 and 1932 by 77 percent.

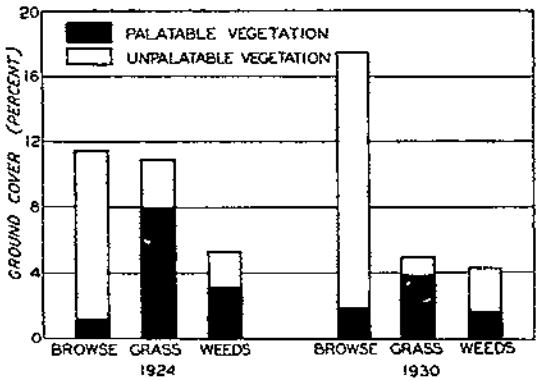

FIGURE 13.—Effect of heavy early spring and late fall grazing on palatability of range cover between 1924 and 1930.

In addition to these gross changes in the plant cover, table 14 reveals a measurable decrease in the vigor of the herbaceous plants during the last 4 years of the study period. Two-inch-height growth was not attained on this area until 6 to 10 days after the same stage of development was reached on more conservatively grazed adjacent range. Moreover, flower stalks on the balsamroot plants were neither so numerous nor so long-stemmed as those on protected range.

TABLE 13.—*Effect of heavy early spring and late fall grazing on paddock 3, as shown by the relative composition and ground cover of the vegetation in 1924 and 1930*

Class of forage	Composition of cover		Area of paddock covered by vegetation					
			Total cover			Palatable cover		
	1924	1930	1924	1930	Change	1924	1930	Change
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Browse	41.38	65.05	11.45	17.57	+53	1.18	1.62	+54
Grass	39.29	18.77	10.89	5.08	−53	7.94	3.84	−52
Weeds	19.33	16.18	5.35	4.38	−18	3.14	1.61	−49
Total	100.00	100.00	27.69	27.03	−2	12.26	7.27	−41

TABLE 14.—*Shrinkage in basal area of perennial grasses on a representative meter quadrat in paddock 8 and their lag in readiness for grazing (2-inch-height growth) as compared to protected range*

Year	Basal area	Lag in readiness	Year	Basal area	Lag in readiness	Year	Basal area	Lag in readiness	Year	Basal area	Lag in readiness
	Cm²	*Days*		*Cm²*	*Days*		*Cm²*	*Days*		*Cm²*	*Days*
1923	474	0	1927	466	0	1930	273	4	1932	139	8
1926	601	0	1929	193	6	1931	245	10	Shrinkage	335	.....

The productivity of this area was not impaired to the same degree as that of paddock 2, on which 68 percent of the forage was removed in the spring; but it is clear that the removal of even 36 percent of the forage in the early spring, when this is repeated at approximately the same growth period each year and is followed by the utilization of 46 percent of the remaining feed in the fall, or a total of 82 percent, will result in such serious damage to the range as to preclude consideration of this form of use as a practical system of management on sagebrush-bunchgrass lands.

DEPLETION FROM HEAVY LATE SPRING AND LATE FALL GRAZING

Persistent heavy spring use of these ranges, even when deferred until 6-inch-height growth of grasses is attained and continued for an average of only 23 days, may result in very unsatisfactory conditions if the range is heavily used in the fall. This is evident in table 15, showing the results obtained on paddock 8. On the average, 53 percent of the forage was consumed in the spring after the principal grasses reached a 6-inch-height growth. Fall use made up an average total annual utilization of 90 percent of the forage.

Feed produced on this area averaged 66 sheep-days for the first 2 years of the 9-year period of study. This is less than on paddock 3 and the better paddocks (7 and 1), the difference being due to lower density of palatable vegetation on this paddock—particularly to the unusually small percentage of weed feed. In other respects, however, this paddock was fairly characteristic of the station range.

TABLE 15.—*Actual use, under heavy late spring and late fall grazing, of paddock 8, 1924–32*

Year	Spring grazing			Fall grazing			Yearly total		Estimated total forage production[1]
	Period of use	Use of range	Forage used	Period of use	Use of range	Forage used	Use of range	Forage used	
		Sheep-days per acre	*Percent*		*Sheep-days per acre*	*Percent*	*Sheep-days per acre*	*Percent*	*Sheep-days per acre*
1924	May 2–May 29	18.47	38	Oct. 5–Nov. 13	28.20	59	46.67	97	48.11
1925	May 5–June 30	54.27	65	Oct. 16–Nov. 19	24.59	30	78.86	95	83.01
1926	May 7–May 26	40.85	74	Oct. 15–Oct. 28	10.56	26	41.21	100	41.21
1927	May 23–June 15	34.40	66	Nov. 14–Nov. 26	15.12	29	49.52	95	52.13
1928	May 8–May	22.20	62	Oct. 26–Nov. 24	11.96	33	34.25	95	36.05
1929	May 19–June 12	18.04	71	Oct. 31–Nov. 13	6.06	24	24.10	95	25.37
1930	May 14–May 28	9.91	50	Nov. 5–Nov. 16	8.11	40	18.02	90	20.02
1931	May 13–June 2	7.65	31	Nov. 2–Nov. 25	16.38	66	24.03	97	24.77
1932		0	0	Nov. 1–Nov. 21	17.00	50	17.00	50	34.00
Average	May 11–June 6[2]	21.74	[3]53	Oct. 27–Nov. 17	15.33	[3]37	37.07	90	[3]41.10

[1] Estimated total forage production (sheep-days per acre), average 1924–25, 65.56; 1931–32, 29.39. Loss in forage value between 1924–25 and 1931–32, 55 percent.

[2] 8-year average.

[3] Computed averages. See footnote 4, p. 6.

During the first 5 years of the study, forage production varied from year to year in response to general growing conditions (fig. 14). The estimated feed in sheep-days was high in 1925, when moisture was above average, and in 1927 when it was average, and low during the dry years of 1924, 1926, and 1928. Following the poor year of 1928,

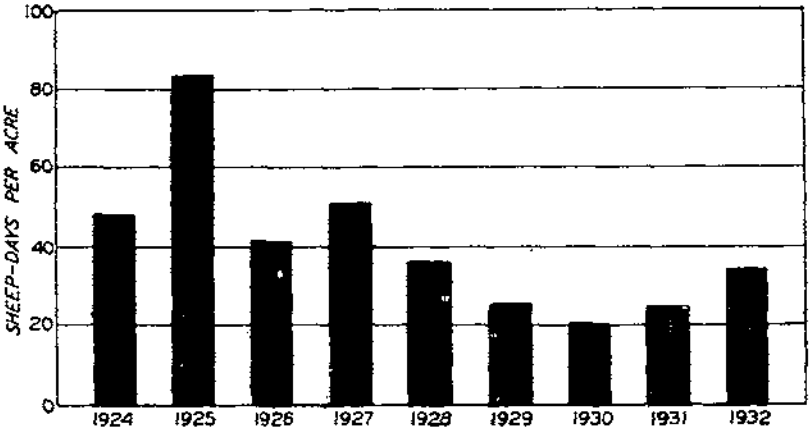

FIGURE 14.—Trend in total annual forage production under heavy late spring and late fall use of range, 1924–32.

however, the herbaceous vegetation failed to respond to the rather favorable conditions in 1929, and by 1930 the number of sheep-days of feed dropped to the low level of 20. The upward trend in forage production during 1931 and 1932 only feebly compensated for the sharp decline of the 2 preceding years. Feed produced in the last 2 years of the experimental period averaged 55 percent less than that produced in the first 2 years.

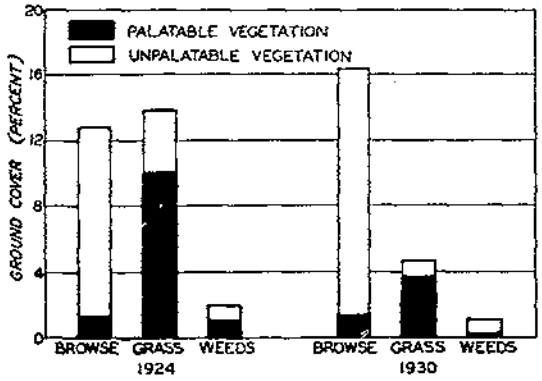

FIGURE 15.—Effect of heavy late spring and late fall grazing on the palatability of range cover between 1924 and 1930.

Although the delayed use of this area in the spring appeared to maintain the grazing value of the herbaceous vegetation for a period of 4 years, as compared to a period of only 2 years on paddock 2, which was grazed earlier and for a longer period in the spring, the removal of more than half of the available forage in the spring and up to a total of 90 percent of the forage in the fall, together with the effect of grazing at a fixed period each spring, resulted in serious damage to the range cover. Although by 1930 the shrubs on this range increased 27 percent in density (table 16), there was no increase in their palatability.

Meanwhile, palatable grasses decreased 65 percent and palatable weeds 64 percent (fig. 15). On a meter-square quadrat within the area, the decline in basal area of the grasses was also pronounced, amounting to a net loss of 86 percent. The progress of this decline is shown in table 17.

TABLE 16.—*Effect of heavy late spring and late fall grazing on paddock 8, as shown by the relative composition and ground cover of the vegetation in 1924 and 1930*

Class of forage	Composition of cover		Area of paddock covered by vegetation					
			Total cover			Palatable cover		
	1924	1930	1924	1930	Change	1924	1930	Change
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Browse	45.00	75.00	12.84	16.30	+27	1.20	1.20	0
Grass	48.31	20.78	13.78	4.52	−67	9.91	3.47	−65
Weeds	6.69	4.22	1.90	.92	−52	.99	.36	−64
Total	100.00	100.00	28.52	21.74	−24	12.10	5.03	−58

TABLE 17.—*The shrinkage in basal area of perennial grasses on a representative meter quadrat in paddock 8 and their lag in readiness for grazing (6-inch-height growth) as compared to protected range*

Years	Basal area	Lag in readiness	Years	Basal area	Lag in readiness	Years	Basal area	Lag in readiness	Years	Basal area	Lag in readiness
	Cm²	*Days*		*Cm²*	*Days*		*Cm²*	*Days*		*Cm²*	*Days*
1923	616	0	1928		3	1930	155	8	1932	55	4
1926	677	0	1929		1	1931	203	3			
1927	290	0							Shrinkage	631	

Other observable effects of this system of grazing showed that the vigorous expansion of sagebrush and other relatively unpalatable plants was accompanied by a sharp decline in the vigor of the surviving palatable grasses and weeds. In 1928 the grasses did not reach 6-inch-height growth until 3 days later than on more conservatively grazed and protected range; and in 1929 and 1930 this stage of development was delayed 1 and 8 days, respectively. During these 3 years weed-flower production was noticeably less than on the station range as a whole. In 1931 and 1932, although general growing conditions were somewhat more favorable than in 1929 and 1930, there was still a lag of 3 to 4 days in 6-inch-height growth of grasses, and weed-flower production continued to be negligible.

Although there was no apparent change in the grazing value of the vegetation on this area during the first 4 years of study, other than changes normally to be expected from weather fluctuations, the extent to which the palatable forage was reduced in density or otherwise replaced by less palatable shrubs during the last 5 years of the study clearly indicates that serious depletion occurred and that this system of grazing and intensity of use has no practical value in range-sheep production.

DEPLETION FROM MODERATE LATE SPRING AND HEAVY FALL GRAZING

Of the four pastures in which grazing values decreased, the least change occurred in paddock 7, where approximately 19 percent of the forage was utilized in an average period of 20 days in the spring after the herbaceous vegetation reached 6-inch height growth, and heavy fall grazing brought the total use up to 85 percent. As may be seen from the record of depletion summarized in table 18, an average of 82 sheep-days of feed per acre was produced on this area in 1924 and 1925, or from 9 to 16 days more than on any of the other paddocks thus far considered. This is due to the relatively greater percentage of palatable forage in the vegetative cover; but in other respects the range was similar, including species present and climate and soil factors.

TABLE 18.—*Actual use, under moderate late spring and heavy fall grazing, of paddock 7, 1924–32*

Year	Spring grazing			Fall grazing			Yearly total		Estimated total forage production[1]
	Period of use	Use of range	Forage used	Period of use	Use of range	Forage used	Use of range	Forage used	
		Sheep-days per acre	*Percent*		*Sheep-days per acre*	*Percent*	*Sheep-days per acre*	*Percent*	*Sheep-days per acre*
1924	May 1–May 6	11.35	19	Oct. 5–Nov. 20	40.18	69	51.53	88	58.56
1925	May 6–May 15	14.77	14	Oct. 10–Dec. 12	75.65	72	90.42	86	105.14
1926	May 8–May 24	19.70	33	Oct. 15–Nov. 20	33.33	57	53.03	90	58.92
1927	May 23–June 10	2.58	4	Oct. 25–Dec. 2	67.57	96	70.15	100	70.15
1928	May 5–June 2	12.06	21	Oct. 26–Dec. 2	37.65	71	49.71	93	50.72
1929	May 7–May 30	6.79	10	Nov. 2–Nov. 26	61.02	87	67.81	97	69.91
1930	May 2–May 22	15.16	25	Aug. 21–Nov. 16	23.62	40	38.78	65	59.66
1931	May 8–June 4	15.52	28	Nov. 2–Nov. 25	22.14	41	37.66	69	54.58
1932	May 7–June 9	14.13	18	Aug. 16–Nov. 27	39.36	52	53.49	70	76.41
Average.	May 7–May 27	12.45	[2] 19	Oct. 7–Nov. 27	44.50	[2] 66	56.95	85	[2] 67.00

[1] Estimated total forage production (sheep-days per acre), average 1924–25, 81.85; 1931–32, 65.50. Loss in forage value between 1924–25 and 1931–32, 20 percent.
[2] *Computed averages. See* footnote 4, p. 6.

During the 9-year period there was no definite downward trend in grazing value. The number of sheep-days of feed fluctuated from year to year rather closely in accordance with growing conditions on the range, large quantities of feed having been produced in the wet or generally favorable years of 1925, 1927, 1929, and 1932, as compared to a lesser volume in the dry or otherwise unfavorable years of 1924, 1926, 1928, 1930, and 1931 (fig. 16). Moreover, there was no observable decline in the vigor of the range plants, and the time growth started and the height of grass and weed growth were comparable with these developments on conservatively grazed and ungrazed range. As compared to the average of the first 2 years of the experimental period, however, the number of sheep-days feed produced in the last 2 years was 20 percent less.

Concurrently with these fluctuations and the final net loss in grazing value, significant changes occurred in the vegetative cover of this range, as summarized in table 19. For example, the relatively unpalatable shrubs increased 50 percent in density from 1924 to 1930, while the density of weeds and grasses decreased 8 and 15 percent, respectively.

TABLE 19.—*Effect of moderate late spring and heavy fall grazing on paddock 7, as shown by the relative composition and ground cover of the vegetation in 1924 and 1930*

Class of forage:	Composition of cover		Area of paddock covered by vegetation					
			Total cover			Palatable cover		
	1924	1930	1924	1930	Change	1924	1930	Change
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Browse	30.32	52.87	11.00	16.50	+50	1.46	2.02	+38
Grass	43.40	32.92	12.14	10.25	−15	8.99	7.75	−14
Weeds	17.28	14.21	4.83	4.43	−8	1.81	2.00	+10
Total	100.00	100.00	27.97	31.21	+12	12.26	11.77	−4

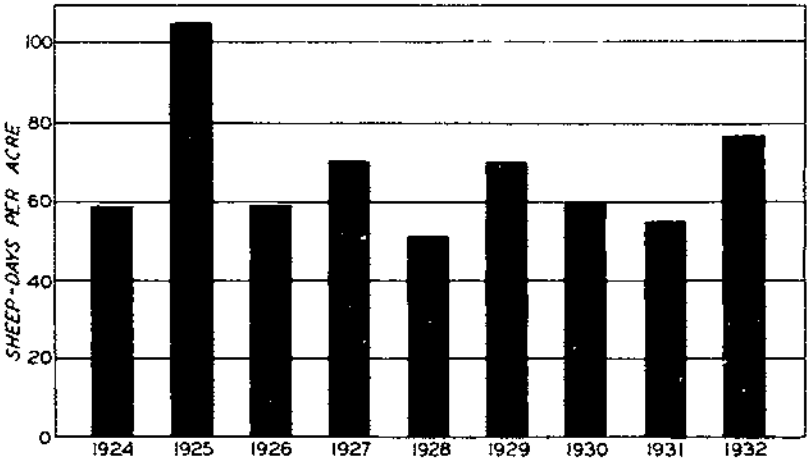

FIGURE 16.—Trend in total annual forage production under moderate spring and heavy fall use of range, 1924–32.

TABLE 20.—*Shrinkage in basal area of perennial grasses on a representative grazed meter quadrat in paddock 7, compared with that on 4 ungrazed quadrats located on comparable range*

Year	Basal area		Year	Basal area		Year	Basal area	
	Grazed quadrat	Ungrazed quadrats		Grazed quadrat	Ungrazed quadrats		Grazed quadrat	Ungrazed quadrats
	Cm²	*Cm²*		*Cm²*	*Cm²*		*Cm²*	*Cm²*
1923	357	688	1929	288	484	1932	226	542
1926	572	860	1930	401	470			
1927	476	736	1931	395	515	Shrinkage	161	126

Unquestionably, both drought and grazing contributed to the depletion of this area. Apparently climate was much less influential in this connection than grazing, however, since the basal area of grasses on four meter quadrats on protected range, as shown in table 20, decreased only 19 percent between the years 1923 and 1932, but on a quadrat within the grazed range the reduction was 42 percent.

These data show also that the decline in the number of estimated sheep-days of feed on this area was not nearly so great as on comparable areas on which a third or more of the forage was removed in the spring followed in each case by heavy utilization of the remaining feed in the fall. Moreover, since the decline in the productivity of paddocks 2, 3, 8, and 7 was in each case approximately in direct proportion to the intensity with which each was utilized in the spring, these studies suggest that the extent to which sagebrush-bunchgrass range will be depleted hinges largely upon the intensity of spring use. This is in agreement with studies conducted by Sampson and Malmsten (*9*) who observed on the Wasatch Plateau of Utah a reduction in the vigor of range plants that were cropped frequently in the spring. These workers recommended the use of a deferred and rotation system of grazing as described by Jardine and Anderson (*3*) which would permit the forage plants on at least part of the range to reach maturity before being grazed, and to permit regrowth of plants that were grazed

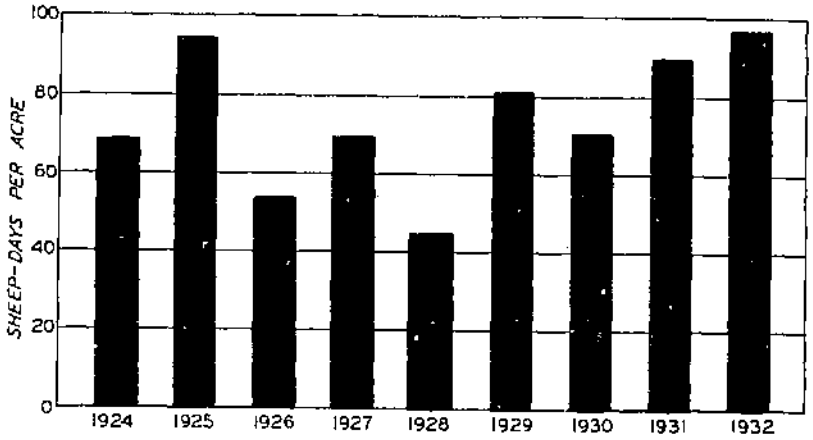

FIGURE 17.—Trend of improvement in range under late fall grazing only, 1924–32.

early in the season. Measurements of carbohydrate metabolism of grasses made later by Sampson and McCarty (*8*) and by McCarty (*5*) showed conclusively that excessive cropping—particularly during the period of maximum aerial growth—by interfering with the storage of food, seriously impairs the vigor of range plants. Thus, while some spring grazing is not inimical to the requirements of range grasses, it is clear that consistently excessive spring grazing over a period of years must be avoided.

RANGE IMPROVEMENT FROM LATE FALL GRAZING ONLY

Further evidence to substantiate the vulnerability of the sagebrush-wheatgrass range to spring grazing is revealed by observations on the check paddock 1, which was grazed heavily in the fall and subjected to the same climatic influences as the other paddocks during the 9-year period, but was not utilized in the spring (fig. 17). On this area the average estimated sheep-days of feed produced in 1931 and 1932, despite generally unfavorable climatic conditions for the period

as a whole, was 15 percent greater than the average produced in 1924 and 1925. Moreover, between 1924 and 1930 there was a substantial increase in the density of palatable grasses and weeds, while shrubs, chiefly sagebrush, decreased in density (fig. 18). Since fall grazing had no serious effect upon this range, it must be concluded that spring is the critical grazing season on areas characterized by sagebrush-bunchgrass vegetation.

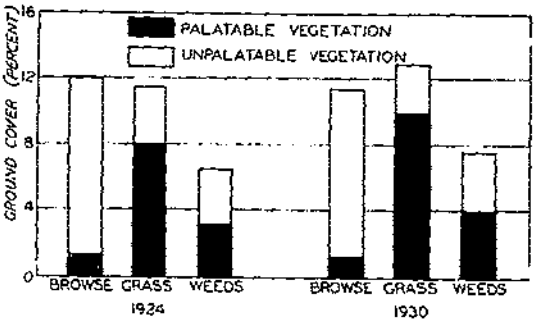

FIGURE 18.—Improvement in palatability of range cover through eliminating spring use of forage.

Improvement of depleted sagebrush-bunchgrass lands can thus be obtained without sacrificing current forage production by deferring the use of the range until fall. The year-by-year progress of such improvement is shown in table 21. An average of 83 percent of all available forage was removed by grazing each fall between the approximate average dates of September 5 and November 30. In the first 6 years from 93 to 100 percent of the forage was consumed, but during the last 3 years the early occurrence of snow and a change in breeding operations necessitated the removal of the animals before much more than half of the available forage was consumed.

TABLE 21.—*Actual use, under heavy fall grazing only, of paddock 1, 1924–32*

Year	Fall grazing			Estimated total forage production[1]	Year	Fall grazing			Estimated total forage production[1]
	Period of use	Use of range	Forage used			Period of use	Use of range	Forage used	
		Sheep-days per acre	*Percent*	*Sheep-days per acre*			*Sheep-days per acre*	*Percent*	*Sheep-days per acre*
1924	Oct. 5–Nov. 16	64.71	95	68.12	1930	Aug. 29–Nov. 16	35.17	59	70.34
1925	Aug. 6–Dec. 14	88.47	91	91.12	1931	Aug. 24–Nov. 28	54.82	61	89.87
1926	Sept. 15–Nov. 22	52.46	98	53.53	1932	Aug. 19–Nov. 26	56.09	58	96.71
1927	Oct. 20–Nov. 29	69.15	100	69.15					
1928	Sept. 14–Dec. 2	42.25	95	44.47	Average.	Sept. 5–Nov. 30	58.84	83	[2]72.10
1929	Aug. 12–Dec. 30	75.40	93	81.08					

[1] Estimated total forage production (sheep-days per acre), average 1924–25, 81.12; 1931–32, 93.29. Gain in forage value between 1924–25 and 1931–32, 15 percent.
[2] Computed average. See footnote 4, p. 6.

As a result of this system of use there were many indications that the area increased in grazing value. First is the increase in feed from an average of 81 sheep-days in 1924 and 1925 to 93 in the last 2 years. Second, inventories taken in 1924 and 1930, as summarized in table 22, revealed that the shrubs had declined 5 percent in the stand and that grasses and weeds, respectively, had each increased 15 and 16 percent. These changes included increases in the density of such palatable grasses as the bluebunch wheatgrass, bluegrass, and needlegrass (pl. 3, *B*), and of such valuable weeds as crepis, balsamroot, and Indian-tobacco.

TABLE 22.—*Effect of no spring grazing and heavy fall use only on paddock 1, as shown by the relative composition and ground cover of the vegetation in 1924 and 1930*

Class of forage	Composition of cover		Area of paddock covered by vegetation					
			Total cover			Palatable cover		
	1924	1930	1924	1930	Change	1924	1930	Change
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Browse	40 66	35 55	12 01	11 41	−5	1 31	1 09	−16
Grass	38 17	40 79	11 42	13 09	+15	7 88	9 55	+21
Weeds	21 17	23 66	6 54	7 60	+16	3 18	3 94	+24
Total	100 00	100 00	30 00	32 10	+7	12 10	14 58	+20

Except for annual variations occasioned by fluctuations in weather, there was no observable change in the vigor of the herbaceous vegetation, as judged by time when plants started growth. As summarized in table 23, measurements of the basal area of grasses on a meter quadrat within the grazed range showed that these plants declined only about 6 percent in basal area between 1923 and 1932, whereas on the four quadrats on protected range, earlier mentioned, the decline in the basal area of grasses during the same period was 19 percent. That grasses protected from grazing should decline in density during drought years such as were experienced during the study period as a whole, is comprehensible; but why the grasses on the grazed range should during the same period decline less, as indicated by the quadrats, or even show moderate gains, as indicated by the survey (table 22), is not so easily understood. An explanation of this apparent paradox may be that the loss of sagebrush on the grazed area lessened the competition for available soil moisture.

TABLE 23.—*Shrinkage in basal area of perennial grasses on a representative fall-grazed meter quadrat in paddock 1, compared with that on 4 ungrazed quadrats located on comparable range*

Year	Changes in basal area from 1923			Year	Changes in basal area from 1923		
	Grazed quadrat		Ungrazed quadrats		Grazed quadrat		Ungrazed quadrats
	Cm²	*Percent*	*Percent*		*Cm²*	*Percent*	*Percent*
1923	852			1931	555	−37	−23
1926	826	−6	+44	1932	830	−6	−19
1927	510	−42	+10				
1929	513	−58	−28	Shrinkage	52	6	19
1930	377	−57	−20				

In view of the fact that bunchgrasses and perennial weeds tended to crowd out inferior shrubs when the herbaceous plants were permitted to reach maturity before being grazed, it would appear that fall grazing offers a practical method of improving sagebrush-wheatgrass range lands that have been seriously depleted of the better forage plants by overgrazing, fire, or other causes. It is recognized that deferred grazing is not a practical system for all spring-fall range lands because it affords no use of the forage in the spring. However, by setting aside sufficient acreage to carry sheep during the spring

period, deferred use of the remainder will, over a period of years, permit maximum improvement of the vegetation without any material loss of total forage produced.

THE SIGNIFICANCE OF RANGE DEPLETION THROUGH OVERGRAZING

In view of the results on these five experimental areas, it is obvious that any method of utilization which in a period of 9 years will result in a reduction of 20 to 65 percent in the grazing value of the spring-fall range lands has no place in a practical plan of management for range sheep production. In the first place, a certain number of sheep cannot be maintained satisfactorily over a period of years on a unit of range while the relatively palatable herbaceous forage plants are being replaced in a wholesale manner by comparatively unpalatable shrubs and other plants. Range depletion of this character must be met by drastic reductions in the numbers of sheep that are grazed on each unit of range or by a corresponding increase in the range acreage that is made available to the same numbers of sheep, by feeding hay and grain to supplement the losses of forage, or by a combination of these measures, all of which are either impracticable or ruinous financially. In the second place, the delayed growth of forage in the spring on depleted ranges as a result of decreased plant vigor constitutes a further loss in range forage at a time when green feed is essential for ewes with young lambs. This loss can be met only by further grazing limitations and increased costs of operation. Even more discouraging is the fact that the possibilities of improvement by natural revegetation are greatly diminished because of the weakened fruiting habits or destruction of desirable range plants and because of the increased vigor and site dominance of less desirable species.

Unfortunately, extensive areas of spring-fall range lands have been grazed year after year in a manner comparable to the way in which the four experimental paddocks were utilized on the sheep station range during the 9-year period, 1924–32, and are in an even more seriously depleted condition. A survey made by the Intermountain Forest and Range Experiment Station in 1932 revealed, for example, that on 342 heavily grazed and burned areas between Weiser and Dubois in southern Idaho, the estimated grazing value of the vegetation was 80.2 percent less than the average value of the plant cover found on 164 areas of comparable range lands which had been protected or used only moderately for a long period of years. The density of the perennial grasses on the heavily grazed areas was found to be 83.5 percent less than on lightly used range. These valuable forage plants were displaced on some areas by increased numbers of sagebrush plants and on others by annuals of inferior grazing value.

On many areas the relatively unpalatable sagebrush has become so dense that lambs are lost and much wool is pulled from the sides and bellies of the ewes while grazing, thus further reducing the value of the depleted range for grazing. On other areas where the sagebrush has been killed by repeated fires the quality of the annual vegetation now present is so inferior that many operators are forced to supplement the range forage with hay and grain in order to fatten the lambs for market and to maintain the breeding stock in thrifty condition. Rehabilitation of areas such as these constitutes one of the most important problems needing solution in the West.

RANGE MAINTENANCE BY CONSERVATIVE SPRING AND FALL GRAZING

Although more or less serious damage occurred to the range cover in four of the five experimental paddocks under systems of grazing which removed part of the forage in the spring and practically all of the available remaining herbaceous vegetation in the fall each year, observations on the herded portion of the Station range show that, under a conservative system of grazing, the sagebrush-bunchgrass type of cover can be utilized both in the spring and fall without serious effects. It is not primarily a question of early or late use of spring range or of whether grazing should continue for 2 weeks or 2 months, since range sheep production requires that forage be available during the entire spring season; but it is rather a question of so alternating use of different portions of each range area as to preclude utilization of the same forage plants during the same growth stage each year, and also of limiting the intensity of grazing to guard against overgrazing and the vicissitudes of climate.

In this connection, it has been generally recognized that good range management requires the adjustment of numbers and periods of use so that the equivalent of approximately 20 to 25 percent of the forage is left unutilized at the end of the grazing season, as a means of maintaining the vigor of the plant cover. In addition to this safeguard, however, it is apparent that further adjustment—either in numbers grazed or periods of use—is necessary in order to allow for differences in forage production as a result of climatic fluctuations.

In limiting the use of the spring-fall range to insure maintenance or increase of palatable and nourishing forage, the criterion must be neither the forage production of "good years" nor of average years. While stocking the range on the basis of average years may be satisfactory on the prairies as suggested by Sarvis (*10*), this practice cannot be considered satisfactory in the intermountain region, with its great annual and periodical fluctuations in precipitation. In this region, the general result has been that in dry years more livestock were on the range than it could support on a sustained-yield basis, and before the numbers of animals could be reduced or the good years returned, the range suffered a far greater decline in productivity than several seasons of average or better conditions could restore. The serious depletion of much of the spring-fall range today is mute evidence of such consequences and clearly suggests the need for improved management practices which will make adequate provision for the influence of fluctuations in precipitation and other weather factors.

An example of the necessity for such provision is afforded by the record of average annual production of paddocks 1 and 7. Had the rate of stocking been set to consume on the average not more than 80 percent of the total available forage in average years (fig. 19), a shortage of forage involving serious damage to the range would have resulted in 2 of the 9 years of this study period, and in 3 other years less than 20 percent would have remained as reserve. A 20-percent surplus would have been left in 1925, 1929, 1931, and 1932 only.

It is obvious that a safety allowance for drought in addition to a conservative degree of forage utilization in average growth years must be applied in arriving at a long-time rate of stocking. Considering that

forage production on the experimental paddocks varied as much as from 33 percent below to 41 percent above normal, it is clear that in average years a drought allowance of 10 to 20 percent should be added to the utilization allowance of 20 or 25 percent to arrive at a safe rate of stocking if all overgrazing and supplemental feeding is to be avoided (fig. 19).

On the herded portion of the sagebrush-wheatgrass range at the United States Sheep Experiment Station, the general practice has been to utilize only 60 to 65 percent of the grasses in average years. This basis of utilization has provided for ample forage even in the poorest growth years and hence has precluded the necessity for supplying expensive supplemental feed. During the average and better years it has permitted the range plants to recover from the debilitating effects of intervening drought years.

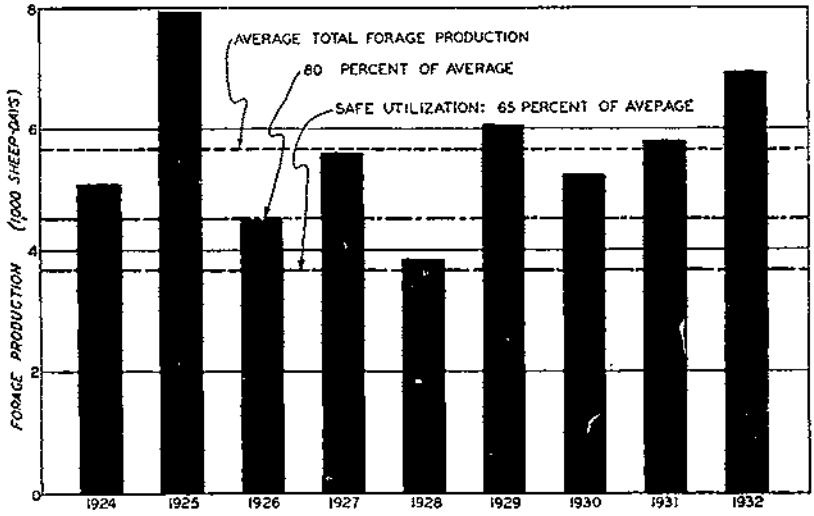

FIGURE 19.—Average total forage production of paddocks 1 and 7. Forage production in 1923-32 varied so greatly that stocking of the range based on the use of 80 percent of average forage production on these paddocks would have utilized every scrap of forage in 2 of the years and brought about a serious shortage of feed. A further allowance for climatic vicissitudes, corresponding to the use of 65 percent of production, would have left no feed shortage in 1928 and a comfortable margin in other years for building up a greater total production for the future.

As is shown in table 24, this range unit of 12,377 acres was stocked on the average basis of about 20 sheep-days per acre, or 1½ acres per head per month for two periods of approximately 2½ months each in the spring and fall, resulting in the utilization on an average of 65 percent of the bunchgrass forage annually.

Under this system of grazing and rate of stocking, adequate forage was available for the sheep in all years in the spring as well as in the fall. For example, observations made late in the fall each year revealed that never was more than 85 percent of the bunchgrasses utilized even in the poor years of 1924, 1926, and 1928 when growth was short. In years of comparatively luxuriant growth, such as 1925 and 1932, these grasses were grazed only 50 percent or less. This unit was grazed on a rotation plan, whereby in the spring of one year the sheep were routed over the area in one direction and the next year

in a different direction, beginning each spring about the time the grasses approached 2-inch height growth and ending at the close of the growing season on about June 25. In this manner the portion of the range grazed early in one year was not grazed until late in the spring of the next year, when vegetation had reached full development. A similar rotation system of herding was followed in the fall in most years, beginning about September 15 and ending about December 1. During the period as a whole, spring and fall grazing were about equally heavy.

TABLE 24.—*Actual use, under conservative spring and fall use, of 12,377 acres of the United States Sheep Experiment Station range stocked at the rate of 20 sheep-days per acre, or approximately 1½ acres per head per month for 5 months, 1924–32*

Year	Spring grazing			Fall grazing			Yearly total		Estimated total forage production [1]
	Period of use	Use of range	Forage used	Period of use	Use of range	Forage used	Use of range	Forage used	
		Sheep-days per acre	*Per cent*		*Sheep-days per acre*	*Per cent*	*Sheep-days per acre*	*Per cent*	*Sheep-days per acre*
1924	Mar. 28–June 26	11.57	54	Sept. 15–Nov. 4	6.79	31	18.36	85	21.60
1925	Apr. 6–June 29	13.34	34	Sept. 23–Dec. 31	6.28	16	19.62	50	39.24
1926	Apr. 12–June 28	11.77	34	Sept. 16–Dec. 19	17.40	51	29.17	85	34.32
1927	Apr. 12–July 10	11.55	43	Sept. 9–Dec. 9	8.71	32	20.26	75	27.01
1928	Apr. 17–June 21	10.88	39	Sept. 15–Dec. 4	12.27	44	23.15	83	27.89
1929	Apr. 18–June 24	11.02	39	Sept. 20–Nov. 29	6.75	24	17.77	63	28.21
1930	Apr. 14–June 18	6.19	21	Sept. 12–Nov. 10	10.51	35	16.70	56	29.82
1931	Apr. 16–June 19	6.13	18	Aug. 25–Nov. 16	12.14	37	18.57	55	33.76
1932	Apr. 23–June 27	4.59	14	Sept. 18–Dec. 12	7.81	23	12.40	37	33.51
Average	Apr. 13–June 26	9.67	[2] 32	Sept. 14–Dec. 2	9.88	[2] 33	19.55	65	[2] 30.08

[1] Estimated total forage production (sheep-days per acre), average 1924–25, 30.42; 1931–32, 33.64. Gain in forage value between 1924–25 and 1931–32, 11 percent.
[2] Computed averages. See footnote 4, p. 6.

Systematic measurements of the vegetation were not made over the herded portion of the station range, although general observations, as well as the grazing record, indicate that the range cover has been maintained from year to year in a high stage of productivity. For example, when the number of sheep-days use per acre for each year is weighted by the degree to which the bunchgrasses were utilized, the estimated feed per acre of this class of forage increased from an average of 30 sheep-days for the 2-year period, 1924–25, to an average of 34 during the last 2 years of the 9-year period, or an increase for the period of about 11 percent. This increase in productivity is considered especially significant in view of the generally unfavorable climatic conditions which prevailed during the study period.

On ranges in reasonably good condition, characterized by a plant cover of 25 percent density, comprising 45 percent of bunchgrass and palatable weeds and 55 percent of less palatable shrubs, this system and degree of spring and fall utilization is well adapted to the requirements of range sheep production. It provides feed at an early date in the spring and an adequate supply of cured forage in the fall, and eliminates grazing on the identical range unit at the same time each year. Moreover, stocking to allow a surplus of feed on the ground in normal years assures a full-length grazing season in dry years. In

wet years many plants have a chance to reach maturity before being grazed and thereby to recover from previous severe drought.

The rate of stocking applied in this rotation plan on this particular range may not apply to other ranges because of differences in the kind and amount of forage that may be available. Regardless, however, of the productivity of the range, it is highly essential that the influence of climate be recognized and that the basic rate of stocking include a margin of safety against the vicissitudes of drought. Successful management of the spring-fall type of range therefore necessitates a careful evaluation of the influence of climate on forage production as well as a recognition that the ability of forage plants to withstand grazing is limited.

SUMMARY AND CONCLUSIONS

The influence of climate and grazing on (1) the periods of range use, (2) forage production, and (3) the condition and yields of range sheep was investigated at the United States Sheep Experiment Station near Dubois, Idaho, during the period 1924–32. The studies yielded the following results:

Spring-fall range lands in southern Idaho are subject to wide fluctuations of climate from year to year.

Monthly mean temperatures ranged from 17.69° F. in January to 69.36° in July, while daily extremes as low as —26° occurred in January and as high as 102° in July. On the average, temperatures remained above 40° from April 10 to October 20, or a period of 193 days.

Precipitation averaged 10.18 inches annually, 4.38 inches of which occurred as snow and rain during the 6-month period, October 1 to March 31. It is subject to wide fluctuations from year to year and from month to month. Rainfall is particularly uncertain during the spring and summer months, rainless periods often permitting the soil to become thoroughly dry for weeks at a time after June. The maximum annual precipitation was 16.66 inches and the minimum 6.00 inches. During the 9-year period 2 years were above average, 3 were about average, and 4 distinctly below average.

When compared with records at Idaho Falls, 50 miles distant, it is evident that precipitation during the 9-year period of study was about 16 percent below normal and that the period of study was part of the longest of several dry cycles on record for that section.

The annual fluctuations in weather resulted in important changes in the amount of forage produced, thus directly affecting the periods of use, the grazing capacity of the range, and to some extent the condition and productivity of sheep.

The start of forage growth in the spring varied from as early as March 20 to as late as April 24, or a range of 36 days, largely as the result of fluctuations in the time at which temperatures rose to levels favorable for plant growth.

Two-inch height growth was reached on the approximate average date of April 22 and was subject to a range of only 18 days between the earliest and latest dates, also largely due to fluctuations in temperature.

Four- and six-inch stages of height growth, seed formation, and curing varied in occurrence with respect to the earliest and latest date during the study period by 27, 37, 60, and 56 days, respectively,

partly due to temperature but more especially to differences in precipitation.

The volume of forage produced varied from 41 percent above to 33 percent below the 9-year average, largely as the result of precipitation during the winter and spring season.

The basal area of perennial grasses on protected quadrats declined 19 percent during the period 1923–32, owing to the breaking up of large clumps following drought.

Livestock condition and yields appeared to fluctuate in accordance with general range conditions, but other elements including improvement by selection and breeding, the maintenance of the sheep in generally high condition at all times, and the condition to which the sheep were subjected on the summer and winter range and winter feed lots, tended to obscure the specific influence of climate during the spring and fall seasons. The most striking relationships indicated that body weights of sheep were partially affected by both spring and fall range conditions, and the number of lambs born alive was influenced by climatic conditions of the preceding year.

Over and above the influence of climate, the intensity and periods of grazing had a profound effect upon the grazing value of the spring-fall range.

Serious range depletion occurred on four 80-acre range areas where for 9 years from 19 to 68 percent of the available forage was utilized in the spring followed by the removal of from 25 to 66 percent of the forage in the fall, or a total for the year of 82 to 93 percent. The degree of depletion on the four ranges was approximately directly proportional to the intensity of spring use. Measurable effects of overgrazing included the reduction of from 20 to 65 percent in grazing value, an increase of 27 to 73 percent in the density of relatively unpalatable sagebrush and other shrubs, a decrease of 14 to 81 percent in the density of highly palatable weeds and bunchgrasses, and a delay of as many as 14 days in the occurrence of 2-inch height growth of grasses and diminished weed-flower production due to decreased vigor.

On another 80-acre range area on which, on the average, 83 percent of all available forage was utilized in the fall and none in the spring, the range definitely improved. This improvement was characterized by an increase of 15 percent in grazing value, a 15- and 16-percent increase in the density of grass and weed forage, respectively, and a 5-percent decrease in the density of sagebrush and other shrubs.

The herded portion of the station range was maintained in a productive condition when grazed according to a rotation system whereby in average years approximately 30 to 35 percent of the available bunchgrasses were utilized in the spring, starting when the grasses approached 2-inch height growth; and about 33 percent in the fall, or up to 65 percent for the year as a whole. For the 9-year period this range was used at the rate of about 1½ acres per sheep per month, for approximately 2½ months in the spring and in the fall.

From these results the following conclusions are drawn with respect to proper periods of range use, the rate of stocking, and systems of grazing for range sheep management on spring-fall ranges in southern Idaho characterized by sagebrush-bunchgrass vegetation.

1. The yearly calendar of operations should be planned so as to begin spring grazing after grasses reach 2-inch height growth. There is a minimum of variation in this stage of development, thus insuring available forage in most years and necessitating the maintenance of not more than a 10-day supply of reserve feed for the exceptional year when forage development is late. This also precludes misuse of the range, since, from this time on, forage growth will ordinarily progress in advance of the sheep, insuring that adequate feed will be available during the entire spring season if the range is not overstocked. Near Dubois, Idaho, 2-inch height growth is reached on the approximate average date of April 22. Spring grazing should end when bunchgrasses begin to cure, which occurs about July 2 near Dubois.

2. Fall grazing should begin when summer range is utilized, but preferably after rains start regrowth of grasses or soften the cured bunchgrasses. Since fall grazing must end with the coming of deep snow and this occurrence is extremely variable, a 30-day reserve supply of feed or its equivalent of protected winter range over and above normal winter requirements should be maintained as insurance against years of early snows.

3. For ranges having a total plant cover of about 25 percent, comprising approximately 45 percent of bunchgrasses and palatable weeds and 55 percent of sagebrush and other less palatable shrubs, stocking should be at the rate of two-thirds of a sheep per acre per month for approximately 2½ months in the spring and in the fall. A lower rate of stocking is recommended where relatively less bunchgrass and weed forage is available, and a higher rate on areas supporting a more dense stand of palatable vegetation.

4. Rotation spring grazing is essential for maintaining sagebrush-bunchgrass range under the conditions of climate which prevail in this section. This system can be applied by dividing the range into two or more convenient units and routing the sheep from one to the other as the season advances, beginning this process with a different unit each succeeding year. The periods of use and rate of stocking should be adjusted so that approximately one-third of the available bunchgrasses over the range as a whole are utilized during the spring season after grasses reach 2-inch height growth, and not to exceed two-thirds of the total in the fall of average growth years. This system of management will insure adequate forage in the poorest growth year and in good years will permit range plants which may have been heavily grazed in previous years of drought to recover vigor. Moreover, because ample forage is available under this system, the sheep can be expected to be maintained in a thrifty and productive condition.

5. Deferring all grazing until fall for a period of several years on successive portions of the range is recommended for obtaining maximum improvement of depleted range.

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