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EFFECTS OF DIFFERENT SYSTEMS OF GRAZING BY CATTLE UPON A WESTERN WHEAT-GRASS TYPE OF RANGE

NEAR FORT COLLINS, COLORADO

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FORT COLLINS, COLORADO

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EFFECTS OF DIFFERENT SYSTEMS OF GRAZING BY CATTLE UPON A WESTERN WHEAT-GRASS TYPE OF RANGE

NEAR FORT COLLINS, COLORADO[1]

By Herbert C. Hanson[2], L. Dudley Love[3] and M. S. Morris[4]

Scientific range management is dependent upon the application of knowledge from various fields to the production of livestock. As complete information as possible is needed about the composition of the vegetation, the life histories and habits of the most important species constituting the vegetation, the relations of the most important species to environmental influences including grazing, the needs and habits of livestock, water resources, relation of topographic and climatic conditions to livestock, and the economic conditions affecting the production and sale of livestock. These seven fields may be considered basic factors in range management. So many factors, varying in time as well as in space, make the proper management of range lands a very complicated task. Thoro knowledge of most of these factors in each range or locality can only be secured by detailed studies extending over a period of many years. The purpose of this bulletin is to analyze, in relation to range management, the most important of these basic factors on a range near Fort Collins, Colorado.

The range was located at an elevation of 5,100 feet, about 4 miles west of Fort Collins (Figs. 15-22). It included most of the first foothill as well as the plain at the base. Only the plains portion is treated in this bulletin because this part furnished most of the grazing and was fairly homogeneous in vegetation and topography. Up to 1905 this area was open range (6). It was then fenced and used until July 1, 1920, as a horse pasture for breeding work. During the rest of 1920 it was not grazed. In the spring of 1921 it was divided into two pastures. The plains portion of each of these was about one-fourth of a mile wide and about three-fourths of a mile long. Beginning in 1921, one of these pastures was grazed continuously by cattle, the other was grazed by the deferred and rotation method.

[1]This bulletin reports the botanical phases of a joint project of the Departments of Animal Husbandry and of Botany. The livestock was handled by the former department.

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The vegetation, chiefly western wheat grass, in these pastures was typical of much of the plains adjacent to and between the lower foothills in Northern Colorado. Intensive studies have been conducted in these pastures from July, 1926, to September, 1930.

METHODS

HANDLING STOCK.—The deferred and rotation pasture was divided into two parts so that the plains portion (103 acres) was in one part and the foothills portion (126 acres) in the other. The cattle (Hereford cows and their calves) were kept off the pasture during the spring period, from about March 15 to about May 1, while the soil was moist and the chief grasses were growing rapidly. From about May 1 to about August 15, the cattle were allowed to graze only one of the two parts, but after about August 10 they were given free access to both parts. This procedure was continued for 2 successive years. During the next 2 years the part that had been grazed between May 1 and August 15 was not opened until after the latter date. Both parts, then, were protected every year from early grazing, and a 4-year rotation cycle was followed for later deferred grazing on each part.

The pasture (total area including foothills, 157 acres) that was grazed continuously was open to stock the year round. Usually grazing did not begin in the spring until about April 15. There was little evidence of grazing for several weeks, but there were numerous signs of trampling and sliding. During winter and early spring the cattle limited their activity chiefly to the feeding yard and water trough.

Usually there were 28 head of cattle in the deferred and rotation pasture and 19 head in the continuously grazed pasture. This makes an average of about 8 acres per head in each pasture.

During the winter the cattle were fed hay and a small amount of cottonseed cake. A shed afforded protection during storms (Fig. 17.) Water was supplied by means of a spring, which fed continuously into a tank. Additional water was available in a small lake in the continuously grazed pasture. The calves were usually born early in the spring and were removed from the pastures in the autumn. The cows were frequently weighed.

VEGETATION STUDIES.—An isolation transect (1) was located in each pasture (Figs. 15 and 16). These were so arranged that in each a square, 20 by 20 feet in area, was opened to grazing every year and another square was closed to grazing. Records of the vegetation in these squares were secured by means of square-meter quadrats and occasional larger quadrats.

The vegetation of the pastures as a whole was analyzed by means of list quadrats arranged systematically over the entire area.

Weekly notes were taken thruout most of the year on the condition of the vegetation. Detailed growth and other phenological records were secured of important species.

ENVIRONMENTAL FACTORS.—Continuous records were secured of soil temperature and of the temperature and humidity of the air. Soil-moisture data were collected thruout the growing season. The evaporating power of the air was measured during the frostless season by means of atmometers. Mechanical and chemical analyses and profile studies were made of the soil. Precipitation records were also secured.

ENVIRONMENTAL FACTORS

PRECIPITATION.—The mean annual precipitation at Fort Collins during a period of 41 years was 15.06 inches (8). It varied from 7.11 to 27.57 inches. Most of the precipitation came during the spring and summer months, as is shown in the following monthly means:

	Inches		Inches
January	0.35	July	1.81
February	0.60	August	1.24
March	1.06	September	1.30
April	2.16	October	1.19
May	2.81	November	0.46
June	1.57	December	0.51

The average number of days during the year with 0.01 inch or more of precipitation was 80. The average annual amount of snowfall was 42.8 inches.

The precipitation record (7) is given by weeks in Table 1 and in Figure 1 for the period that the range was intensively studied.

The data in Table 1 may be summarized by comparison with the monthly means. The spring of 1926 was moister, but the summer was drier than usual. In 1927 only one-third of the usual precipitation fell during May. The precipitation in the other months of the growing season was very satisfactory. In 1928, April was unusually dry, July and August were also dry, but the rest of the months were above normal. May was characterized by heavy precipitation. In 1929, March and April were above average, May and June were slightly below, July and August were about 50 percent below average. During the week ending August 5, a large amount (1.40 in.) of rain fell, ending a drought period of about 8 weeks. In 1930, March and April were very dry; May was above normal, especially the week ending May 20, when about 3 inches fell; June was slightly above normal, due to heavy precipitation during the week ending June 10; the long drought extending from June 10 thruout July was broken by precipitation of 2.51 inches during the week ending August 12, followed by 1.90 inches the following week.

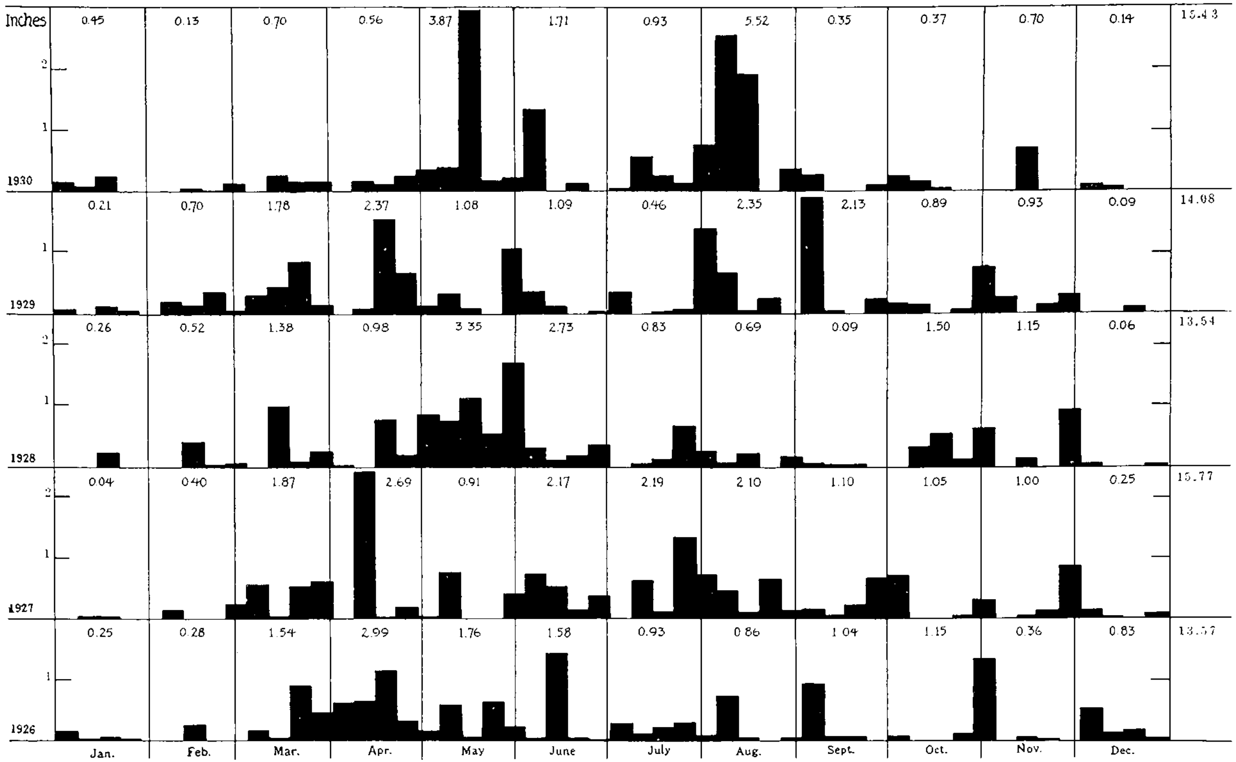

Fig. 1. Histogram showing precipitation for each of 5 years at Fort Collins. Each vertical column represents the total precipitation during a week. The figures give the total for each month and for each year.

Table 1.—Precipitation in Inches at Fort Collins for Weekly Periods from 1926-1930.

Week Ending		1926	1927	1928	1929	1930
January	7	.16	..	..	.06	.14
"	14	.01	.02	..	..	.07
"	21	.05	.02	.26	.13	.24
"	28	.03	..	..	.02	..
Totals*		.25	.04	.26	.21	.45
Febru'y	4	..	..	..	..	..
"	11	..	.15	..	.20	..
"	18	.28	..	.41	.13	.06
"	25	..	..	.04	.37	.07
Totals		.28	.40	.52	.70	.13
March	4	..	.29	.07	.03	.13
"	11	.19	.58	..	.30	..
"	18	.05	.03	1.00	.44	.27
"	25	.96	.57	.10	.87	.14
April	1	.48	.65	.28	.14	.16
Totals		1.54	1.87	1.38	1.78	.70
April	8	.65	..	.01	..	..
"	15	.68	2.47	..	.08	.18
"	22	1.18	.01	.77	1.59	.11
"	29	.34	.21	.20	.69	.27
Totals		2.99	2.69	.98	2.37	.56
May	6	.18	.01	.88	.12	.37
"	13	.61	.79	.75	.35	.38
"	20	.07	..	1.14	.10	2.96
"	27	.67	..	.54	..	.16
Totals		1.76	.91	3.35	1.08	3.87
June	3	.23	.43	1.71	1.08	.23
"	10	.05	.79	.34	.39	1.36
"	17	1.47	.48	.13	.11	..
"	24	.05	.18	.20	..	.12
July	1	.01	.40	.39	.03	..
Totals		1.58	2.17	2.73	1.09	1.71

Week Ending		1926	1927	1928	1929	1930
July	8	.30	..	..	.37	.04
"	15	.12	.67	.06	..	.56
"	22	.21	.12	.12	.02	.22
"	29	.30	1.34	.65	.07	.11
Totals		.93	2.19	.83	.46	.93
August	5	.09	.74	.24	1.40	.77
"	12	.75	.49	.07	.69	2.51
"	19	.02	.11	.21	.02	1.90
"	26	..	.69	..	.24	..
Sept.	2	.01	.13	.17	..	.34
Totals		.86	2.10	.69	2.35	5.52
Sept.	9	.95	.15	.06	1.90	.27
"	16	.04	.03	.01	.01	..
"	23	.04	.23	.02	..	..
"	30	..	.69	..	.22	.08
Totals		1.04	1.10	.09	2.13	.35
October	7	.06	.72	..	.16	.22
"	14	..	..	.32	.14	.13
"	21	..	..	.53	..	.02
"	28	.10	.01	.12	.05	..
Totals		1.15	1.05	1.50	.89	.37
Nov.	4	1.32	.32	.61	.77	..
"	11	..	..	..	.26	..
"	18	.02	.01	.15	..	.70
"	25	.01	.12	..	.14	..
Totals		.36	1.00	1.15	.93	.70
Dec.	2	..	.87	.92	.30	..
"	9	.53	.15	.05	..	.09
"	16	.12	.01	..	..	.05
"	23	.17	..	..	.09	..
"	31	.01	.09	.01	..	..
Totals		.83	.25	.06	.09	.14
Annual		13.57	15.77	13.54	14.08	15.43

Since the period for most active plant growth is during April, May and June, it appears that well-distributed and ample precipitation during this period is more important than at any other time. According to this criterion, then, 1926 appears most favorable of these 4 years for plant growth, and 1929 and 1930 as the least favorable. These records are important in the interpretation of measurements and observations of plants later.

EVAPORATING POWER OF THE AIR.—Livingston standardized cylindrical atmometers were used to measure the evaporating power of the air. Measurements taken during four growing seasons are given in Table 2 and expressed graphically in Figure 2.

*Totals give amounts of precipitation for the calendar month.

Table 2.—Average Daily Evaporation in c.c. from Livingston Standardized Cylindrical Atmometers During Four Seasons. Each Reading Is the Average of the Losses from Two Instruments.

1927		1928		1929		1930	
Period	c.c.	Period	c.c.	Period	c.c.	Period	c.c.
				May 8-13	21		
				" 14-21	31		
May 23-30	36	May 23-28	18	" 22-28	30		
" 31-June 6	6	" 29-June 4	8	" 29-June 4	20	May 26-June 2	15
June 7-13	17	June 5-11	11	June 5-11	19	June 3- 9	27
" 14-20	15	" 12-18	13	" 12-18	30	" 10-17	42
" 21-27	26	" 19-25	19	" 19-25	35	" 18-24	46
" 28-July 4		" 26-July 2	15	" 26-July 2	42	" 25-July 1	53
July 4-11		July 3- 9	28	July 3- 9	35	July 2- 8	61
" 12-18	27	" 10-16	25	" 10-16	38	" 9-15	43
" 19-25	23	" 17-23	15	" 17-23	33	" 16-21	13
" 25-Aug. 1	16	" 24-30	15	" 24-30	47	" 21-27	37
Aug. 2- 8	9	" 31-Aug. 6	21	" 31-Aug. 9	17	" 28-Aug. 5	29
" 9-15	16	Aug. 7-13	32	Aug. 10-16	34	Aug. 6-12	19
" 15-22	22	" 14-20	30	" 17-23	30	" 13-19	18
" 23-29	16	" 21-28	37	" 24-30	23	" 20-27	30
" 30-Sept. 5	29	" 29-Sept. 4	28	" 31-Sept. 6	10	" 28-Sept. 3	24
Sept. 6-12	27	Sept. 5-11	34	Sept. 7-13	19	Sept. 4-10	23
" 13-18	33			" 14-20	26		

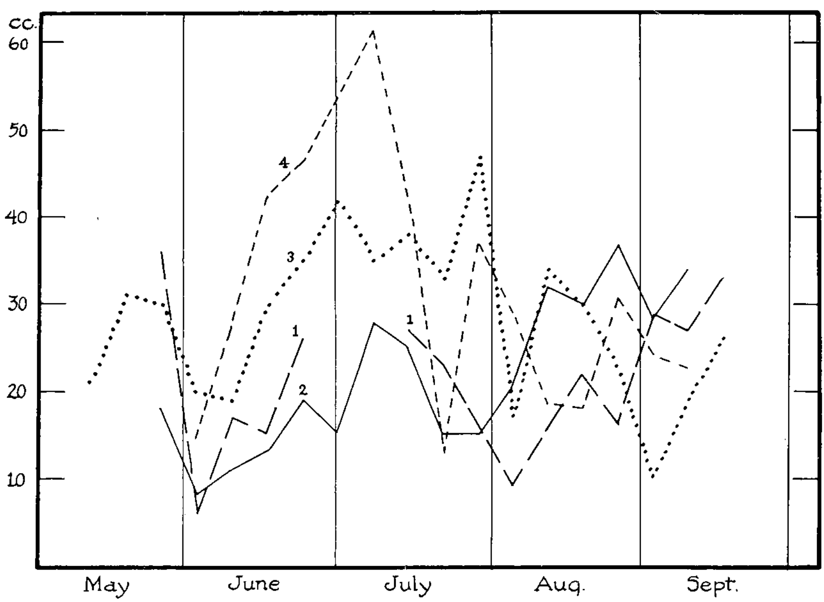

Fig. 2. Graph showing daily evaporation in c.c. for weekly periods from Livingston standardized cylindrical atmometers. Curve composed of long dashes (1) represents 1927 record; continuous line (2), 1928; dotted line (3), 1929; short dashes (4), 1930.

The average daily evaporation for the season is usually about 20 cubic centimeters per day, and the extreme range for weekly periods is from 6 in June, 1927, to 61 in July, 1930. The years 1930 and 1929 were marked by the greatest losses, especially during June and July. The years 1928 and 1927 had much lower losses during these 2 months and were therefore more favorable for the growth of the range plants. A fairly close and uniform relationship is noted to precipitation. Usually when the amount of precipitation is high, the evaporation is low, as in the first part of August, 1929, when 2 inches of rain fell and the evaporation was only 17 cubic centimeters per day. When the amount of precipitation was small, then the evaporation was great, as in the latter part of June and the first part of July, 1930, when the precipitation amounted to only 0.16 inch in a period of 4 weeks and the amount lost by evaporation averaged about 50 cubic centimeters per day.

These records show further that the evaporating power of the air varies considerably from season to season and from week to week during the same season. In 1927 and also in 1928 there were usually greater losses in late summer than in midsummer, but in 1930 and in 1929 the losses were much greater in midsummer than in late summer. In 1930 the evaporating power of the air was unusually high from June 10 to about July 15.

Records of evaporation from a free-water surface are available from Fort Collins (8), 4 miles east of the pasture. The average annual evaporation for a period of 40 years was 43.49 inches. The monthly distribution in inches was as follows:

	Av. Loss, Inches		Av. Loss, Inches
January	1.41	July	5.79
February	1.56	August	5.36
March	2.62	September	4.41
April	4.27	October	3.28
May	4.98	November	1.61
June	5.60	December	1.30

The greatest loss by evaporation during the year occurs during July, the next greatest in June and the next in August. The evaporation records for 1929 and 1930, secured from the atmometers in the pastures, resemble the course of evaporation indicated by the 40-year record more than do the records for 1927 and 1928.

HUMIDITY.—Continuous records of humidity were secured for 4 years by means of a Friez hygrothermograph enclosed in a suitable shelter set on the ground. The average winter humidity was about 72 percent and during July and August about 60 percent. During the winter the weekly average of the maximum humidity for each day usually ranged from about 85 to 98 percent. Rarely did the average of a week fall below 80 percent. During the rest of the year averages between 70 and 80, altho never occurring frequently, were more numerous than during the winter months. The weekly average of the minimum humidity usually ranged during the winter from about 40 to 60 percent and during the rest of the year, from about 25 to 40 percent. The lowest daily minima, 5 to 12 percent, occurred rather frequently during the period from March 1 to about November 15.

The fairly low humidity or great saturation deficit prevailing during the growing season was an important factor in the evaporation of water from the soil and in the transpiration of plants. These in turn affected the composition of the vegetation, the seasonal behavior of species and the anatomy of the plants. All of these vegetational effects are closely related to range management.

AIR TEMPERATURE.—Thermographic records of air temperatures were secured in the pasture from April, 1927, to December, 1930. The air temperatures were taken at a height of about 6 inches by means of a Friez hygrothermograph, properly housed. The daily maxima as well as the daily minima were averaged for weekly periods. These data are given in full in Table 3 and expressed graphically in Figures 3 and 4.

The data given in Table 3 and in Figures 3 and 4 may be summarized in a few lines. From the latter part of November to February, inclusive, the average weekly maximum temperatures usually ranged between 25 and 55° F.; from March to the third week in June the temperature rose. From the last week in June to about the first week in September the range in weekly maximum averages was usually between about 80 and 90° F., and from the second week in September thru most of November the temperature fell. This general course was also taken by the average minimum temperatures. The range of average minimum temperatures during the winter was usually between about 0 and 25° F.; during the summer between 45 and 58° F. The graphs show that there was considerable variation in different years. Outstanding are the low temperatures during January, 1930, the cool April and June in 1928, cool May in 1929, warm April, June and July in 1930, warm May in 1927, and a great drop in early September, 1929. During this entire period there were only 8 weeks when the weekly maximum average was 90° F. or above. In Figure 5 is reproduced a hygrothermograph record for the week, June 25 to July 2, 1930. The daily fluctuations and the relationship of temperature and humidity are clearly shown.

According to Weather Bureau data the mean annual temperature at Fort Collins is 46.5° F. The mean maxima during July and August are 82.9 and 83.1° F. respectively. The mean minimum during January is 11.9° F. The season free from killing frosts averages

Table 3.—Average Weekly Maximum and Minimum Air Temperatures in Degrees Fahrenheit.

Week Ending		1927 Max.	1927 Min.	1928 Max.	1928 Min.	1929 Max.	1929 Min.	1930 Max.	1930 Min.
January	7	..	..	32	14	35	11	38	10
	14	..	..	59	35	55	27	14	– 5
	21	..	..	35	16	41	17	6	-17
	28	..	..	48	18	27	2	28	- 4
February	4	..	..	52	23	42	14	38	- 9
	11	..	..	55	24	21	- 7	52	25
	18	..	..	38	11	31	3	52	25
	25	..	..	39	9	33	3	52	21
March	4	..	..	44	20	34	15	39	10
	11	..	..	63	26	59	31	52	24
	18	..	..	43	23	41	22	51	22
	25	..	..	65	29	49	24	49	23
April	1	..	..	56	20	54	25	47	21
	8	68	32	50	25	61	28	74	35
	15	46	28	53	21	65	33	70	41
	22	52	22	58	26	58	37	66	35
	29	74	38	64	32	57	31	60	33
May	6	75	39	66	34	58	34	69	38
	13	74	39	69	42	62	37	56	35
	20	81	42	69	42	70	37	58	33
	27	77	42	74	47	77	44	70	38
June	3	68	42	69	47	72	41	66	42
	10	75	49	65	43	75	49	72	43
	17	68	46	69	43	78	47	86	47
	24	86	53	73	41	79	44	88	51
July	1	86	56	94	50	90	52	86	50
	8	87	52	87	47	84	50	95	56
	15	83	54	87	53	89	53	86	57
	22	89	57	85	56	90	57	86	58
	29	84	56	87	55	90	58	84	54
August	5	77	54	84	52	86	60	90	59
	12	82	54	86	49	81	55	82	59
	19	81	52	91	49	89	58	76	53
	26	84	53	86	45	88	56	86	54
September	2	87	52	83	49	88	57	76	51
	9	87	54	88	48	54	37	80	49
	16	87	54	79	43	73	40	78	46
	23	77	44	75	42	82	45	80	47
	30	60	41	76	38	59	39	72	39
October	7	59	30	77	38	69	42	64	41
	14	67	27	63	38	67	36	69	41
	21	75	35	57	32	69	35	54	25
	28	73	38	60	26	60	24	62	30
November	4	60	36	35	18	35	12	65	27
	11	62	28	53	25	42	20	65	29
	18	50	19	50	23	52	21	50	24
	25	52	24	51	17	38	6	35	19
December	2	49	18	35	12	39	11	52	19
	9	31	6	33	3	49	22	52	18
	16	30	8	32	7	53	26	44	20
	23	33	6	41	13	27	1	37	9
	31	35	7	54	31	49	20	45	9

Fig. 3. Weekly averages of maximum air temperatures. Long dashes (1), 1927; continuous line (2), 1928; dotted line (3), 1929; short dashes (4), 1930.

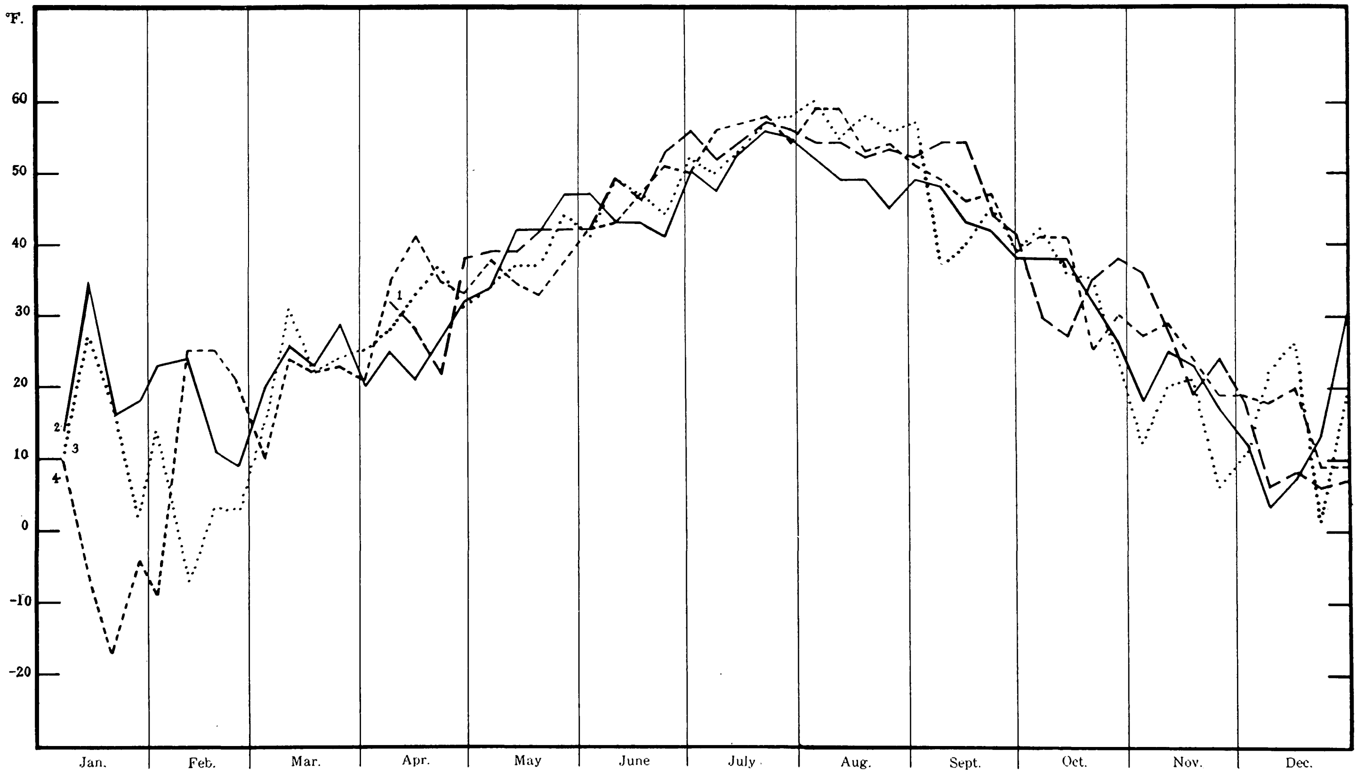

Fig. 4. Weekly averages of minimum air temperatures. Long dashes (1), 1927; continuous line (2), 1928; dotted line (3), 1929; short dashes (4), 1930.

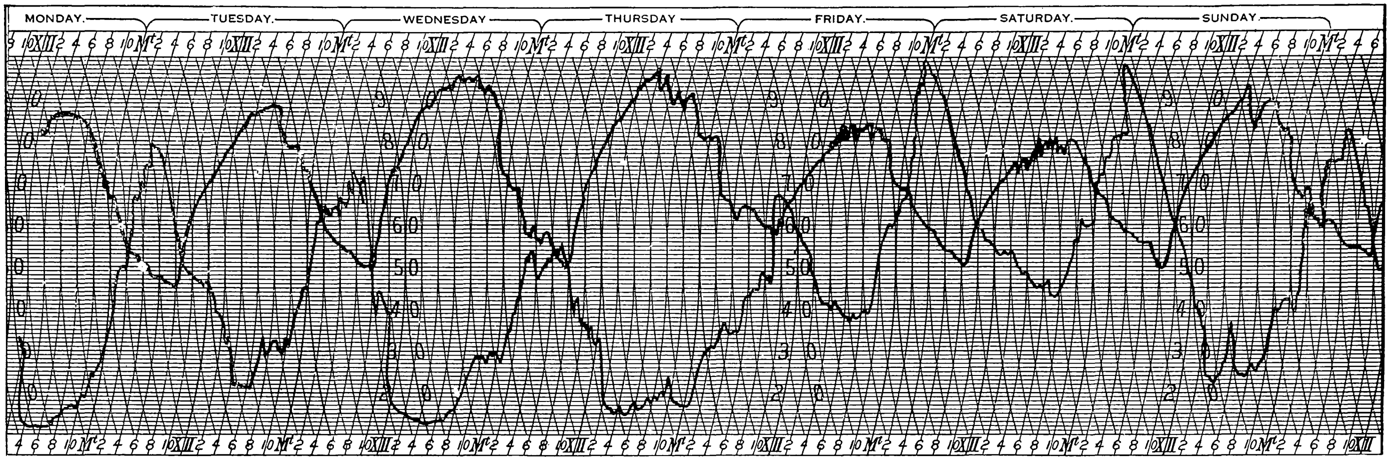

Fig. 5. Hygrothermograph record for the week June 25 to July 2, 1930, in degrees Fahrenheit.

138 days, extending from May 8 to September 27. The latest spring frost has come as late as June 3 and the earliest in the fall on September 7.

SOIL TEMPERATURE.—By means of a Friez soil thermograph located in the pasture, continuous records were secured of temperature at a depth of 4 inches. Data secured from these records are given in Table 4 and expressed graphically in Figure 6.

Table 4.—Average Weekly Soil Temperatures at a Depth of 4 Inches.

Week Ending	1927	1928	1929	1930	Week Ending	1927	1928	1929	1930
Jan. 7	..	29	30	29	July 8	79	75	72	79
14	..	32	30	27	15	77	76	77	..
21	..	33	30	25	22	77	73	77	78
28	..	30	27	25	29	75	73	81	77
Feb. 4	..	31	27	27	Aug. 5	69	68	79	79
11	..	33	26	32	12	70	73	73	80
18	..	33	27	33	19	71	73	76	72
25	..	33	28	36	26	69	72	75	74
Mar. 4	..	33	28	33	Sept. 2	72	68	75	70
11	..	35	33	34	9	71	70	55	68
18	..	37	35	41	16	73	65	59	67
25	..	42	36	39	23	65	64	64	66
Apr. 1	..	43	39	38	30	52	61	..	60
8	52	45	45	48	Oct. 7	51	54	..	56
15	45	45	45	55	14	51	48	54	55
22	46	50	48	54	21	56	46	54	47
29	55	52	48	56	28	54	48	47	46
May 6	59	57	52	57	Nov. 4	47	42	39	44
13	57	57	54	50	11	43	41	36	42
20	63	58	61	52	18	41	42	..	41
27	66	66	66	59	25	39	37	30	34
June 3	64	67	63	59	Dec. 2	38	37	..	32
10	68	63	66	66	9	32	36	33	..
17	63	63	68	70	16	31	35	33	30
24	70	66	70	72	23	29	33	33	27
July 1	73	70	73	81	31	29	33	30	25

During the winter the average weekly temperatures ranged from 25 to about 35° F. During July and August they were from 68 to about 80° F. The general course of the soil temperature at this depth is very similar to the courses of maximum and minimum temperatures. From about December 1 to about March 6 the graph recording the soil temperature thruout the week failed to show diurnal variations, but during the rest of the year they were pronounced. The thermograph record for 1 week, July 21-28, 1930, reproduced in Figure 7, shows the daily variations. During most of the period from about February 4 to about the middle of May, 1929, the soil ranged from about 3 to 6° F. cooler than during the same period in other years. During July, 1930, and August, 1929, the soil was warmer than in the other years. Usually the average

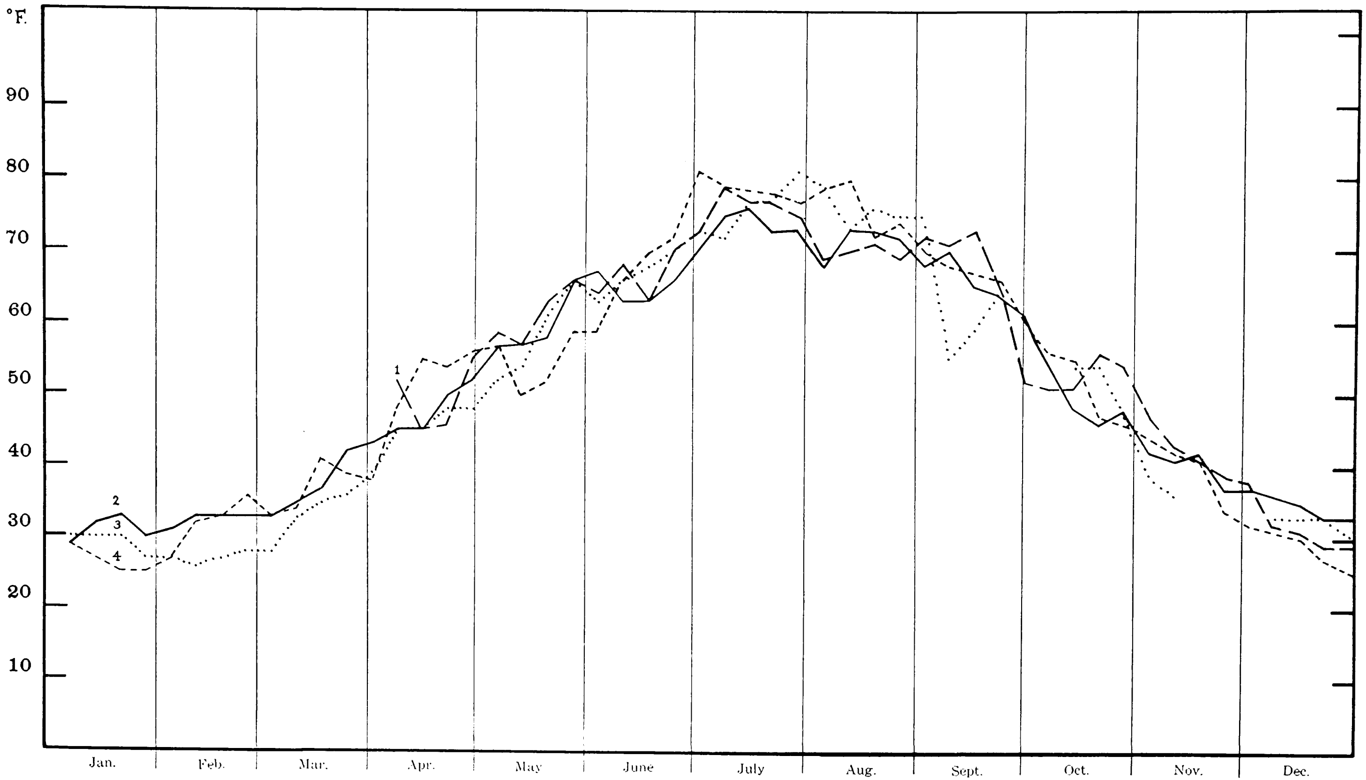

Fig. 6. Weekly averages of temperature at a depth of 4 inches in the soil. Long dashes (1), 1927; continuous line (2), 1928; dotted line (3), 1929; short dashes (4), 1930.

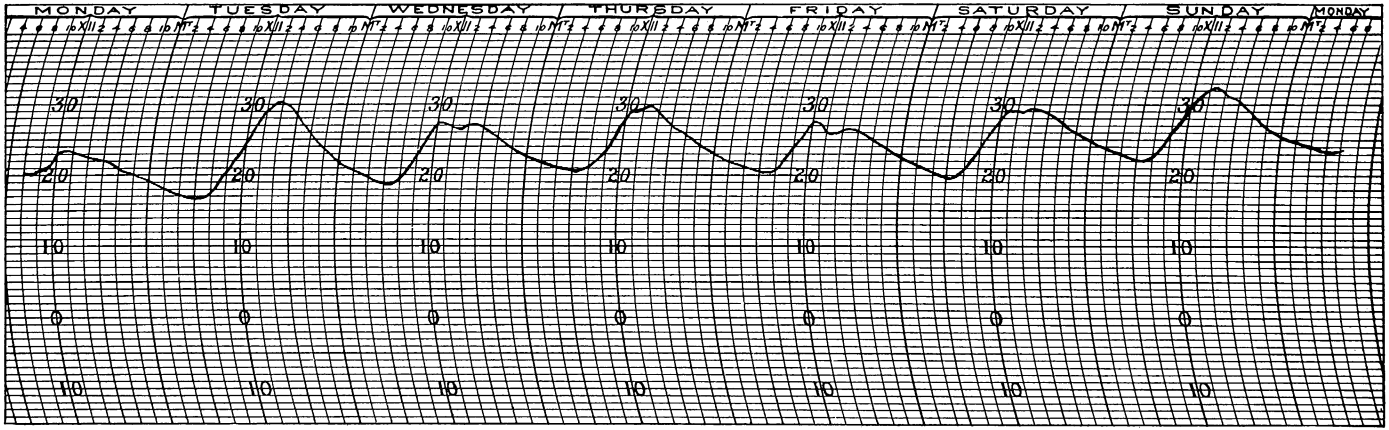

Fig. 7. Soil thermograph record for the week July 21 to 28, 1930, in degrees Centigrade.

temperatures for any given week in the different years do not vary more than 4 to 8° F. from one another.

A long record of temperatures at various depths has been secured at the Colorado Experiment Station (8). The averages for each depth are given in Table 5.

Table 5.—Monthly Average Soil Temperatures in Degrees Fahrenheit, at Various Depths, over a Period of 39 Years, at Colorado Experiment Station. (Taken from Trimble.)

Depth in Inches	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
3........	27.7	29.6	36.5	46.6	56.5	66.7	71.4	69.3	61.1	48.3	36.7	29.7
6........	29.3	30.6	37.1	47.4	56.6	67.0	71.9	70.4	62.8	50.8	39.0	30.2
12........	32.8	31.1	36.6	45.5	55.8	65.5	70.9	70.1	63.7	52.3	40.7	33.2
24........	32.9	32.7	36.8	45.3	53.3	62.5	68.5	68.8	64.0	54.4	43.7	36.5
36........	35.4	32.6	37.1	43.6	51.1	59.1	65.2	66.6	63.4	55.5	46.0	38.9
72........	42.5	40.5	40.8	44.2	48.8	54.2	59.2	61.8	62.0	58.0	52.1	46.5

The month when the surface foot of soil is warmest, according to Table 5, is July, followed by August and then by June. Below 1 foot the soil is warmest in August, followed by July or September and then by September or July. At 3 and at 6 inches the soil is coldest in January, but below these depths it is coldest in February. In January the average temperature varies with depth from 27.7° F. at 3 inches to 35.4 at 3 feet and 42.5 at 6 feet. In July the temperature at 3 inches averages 71.4° F., at 3 feet, 65.2, and at 6 feet 59.2.

SOIL PROFILE, PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE SOIL[1].—Rock particles of various sizes were scattered over the surface and in the soil. Usually the textural grade of the soil was a clay, but in a few places marked by growth of three-awn grass, it was gravelly. Since the fine-textured condition was more general, the profile description is based upon it. This soil is classified as an alluvial soil but the material from which it has been formed was modified by colluvial material.

The A horizon in most places extended down to about 15 inches. It was grayish-brown in color and contained from 55 to 60 percent clay and 20 to 23 percent silt (Table 6). The surface inch was very finely granular or powdery in dry weather, but in wet weather it was very sticky. Large chunks mixed with grass stalks would form on the hoofs of the cattle when it was in that condition. The soil gradually became lighter in color as the depth increased to the B_2 horizon. The B_2 horizon was very light gray, due largely to an accumulation of lime carbonate. Below the surface inch or so the soil in drying, due to vertical and horizontal cleavages, formed very hard,

[1]The authors are greatly indebted to Professor R. D. Hockensmith, Associate Agronomist at the Colorado Experiment Station, for determination of the horizons in the soil profile and for the data on the mechanical and chemical analyses of the soil.

small lumps or clods, varying in size and shape. It was very difficult to separate roots from these adobe-like masses. Roots were most abundant in the A_1 horizon, between 1 and 8 inches, and slightly less abundant in the A_2 horizon, between 8 and 15 inches.

The B horizon extended from about 15 inches to about 42 inches. The color gradually became lighter gray as the depth increased, so that at about 23 inches, or near the bottom of the B_1 horizon, it was a fairly light gray. The B_1 horizon was composed of about 52 percent clay and 28 percent silt (Table 6). Granules and masses of calcium carbonate were infrequent at 15 inches, but they increased rapidly with depth so that from about 25 to 42 inches, the B_2 horizon, so much had accumulated that a very compact hardpan layer had formed. Roots decreased in number very rapidly in the B_1 horizon and below 26 inches they were scarce. During most of the year the soil was very dry below 18 to 20 inches, but the spring rains usually caused the soil to become moist for several weeks, down to about 26 inches.

The C horizon, consisting of reddish-colored gravel and sand, began at about 42 inches. Accumulations of calcium carbonate were not present in this layer.

In Table 6 are given mechanical analyses of soils from various depths in places where profile studies were made, based upon the portion that passed thru a 2-m.m. sieve.

Table 6.—Mechanical Analyses of the Range Pasture Soils from Various Depths.

Depth. Inches	Total Sand (2.0-0.05 m.m.)	Fine Gravel (2.0-1.0 m.m.)	Coarse Sand (1.0-0.5 m.m.)	Medium Sand (0.5-0.25 m.m.)	Fine Sand (0.25-0.1 m.m.)	Very Fine Sand (0.1-.05 m.m.)	Silt (.05-.005 m.m.)	Clay (0.005-000 m.m.)	Colloidal Clay (0.002-000 m.m.)
	ALL IN PERCENTAGES								
Surface 6	18.78	1.23	.98	2.36	6.86	7.26	20.70	60.52	51.37
6-12	21.18	1.79	1.45	2.32	6.37	9.14	23.50	55.32	43.96
12-24	20.22	1.99	1.61	1.99	5.58	9.02	28.17	51.61	35.40

The total proportion of clay and silt combined is close to 80 percent for each horizon of soil. This very fine texture is important in relation to the plant cover, which consists chiefly of western wheat grass.

In Table 7 is given a partial chemical analysis of soils from different horizons in the range pasture. Since buffalo grass replaces wheat grass when the latter is too closely or improperly grazed, it was thought advisable to compare the amount of certain chemical constituents beneath each type of cover. The roots of buffalo grass are concentrated near the surface to a much greater extent than those of wheat grass. The latter penetrate more deeply. Wheat grass has a long growing season, buffalo grass a short one. The former develops an open sod with much bare soil between the stalks; the latter forms a dense mat with very little bare soil exposed. The shoots of wheat grass grow 8 to 12 inches or more tall, those of buffalo grass only 2 to 4 inches.

Table 7.—Partial Chemical Analysis of Soils from Range Pasture, May, 1930.

Vegetation	Description of Sample	Total Nitrogen (Percentage) N	Total Phosphorus (Percentage) P_2O_5	Total Lime (Percentage)
Western Wheat Grass	A_1—Surface, 8 inches	0.2440	0.1688	11.70
		0.2434	0.1713	11.50
	A_2—Subsurface, 8-15 inches	0.1834	0.1809	31.55
		0.1813	.....	30.85
	B_1—Subsoil, 15-26 inches	0.1277	0.1606	38.10
		0.1286	0.1563	38.00
	B_2—Subsoil, 26-42 inches, hardpan	0.0960	.....	55.70
		0.0920	.....	55.15
	C—Gravel, 46-50 inches	.....	0.0915	13.20
		.....	0.0883	13.80
Buffalo Grass	A_1—Surface, 1-8 inches	0.2349	0.1756	9.60
		0.2361	0.1839	9.50
	A_2—Subsurface, 8-15 inches	0.1790	0.1731	26.55
		0.1800	0.1738	26.15
	B_1—Subsoil, 15-24 inches	0.1420	0.1719	35.70
		0.1408	0.1851	35.70
	B_2—Subsoil, 24 inches, hardpan	0.0823	0.1355	47.65
		0.0788	0.1334	47.20

The nitrogen contents were high and the lime contents were extremely high. About February 10, 1931, another analysis for nitrogen gave the following average readings: Under wheat grass 0-1 inch, 0.2709 percent; 1-8 inches, 0.1926; 8-15 inches, 0.1564; under buffalo grass, 0-1 inch, 0.3750 percent; 1-8 inches, 0.1706; 8-15 inches, 0.1398 percent. There was slightly more nitrogen in the A_1 and A_2 horizons (to 15 inches) in the wheat-grass type than in the buffalo-grass type. At all depths there was slightly more phosphorus in the buffalo-grass type than in the wheat-grass type, altho the difference was probably within experimental sampling error.

SOIL MOISTURE.—Data on soil moisture were gathered at weekly or fortnightly intervals during four growing seasons, from 1927 to 1930. Since there were so many rocks in the soil, a soil-tube could not be used, so a small trench had to be dug with a spade. Samples were secured in clay soil in the continuously grazed pasture at three depths, 0 to 6 inches, 6 to 12, and 12 to 24 inches. The soils were dried out in an oven at 100 to 110° C. and percentages of water calculated in the usual way. The data for the four seasons are presented in Table 8 and in Figures 8, 9 and 10. Each reading is the average of two samples.

Table 8.—Percentages of Total Soil Moisture at Three Depths During Four Growing Seasons, 1927-1930, in Range Pasture. Hygroscopic Coefficients: 0-6 Inches, 14.34 Percent; 6-12 Inches, 13.28 Percent; 12-24 Inches, 11.16 Percent. Heavy Type Indicates that the Water Content Is Below the Hygroscopic Coefficient for that Layer of Soil.

Week Ending	0-6 In.				6-12 In.				12-24 In.			
	1927	1928	1929	1930	1927	1928	1929	1930	1927	1928	1929	1930
Mar. 25	..	27	30	27	..	23	25	22	..	16	17	16
Apr. 1	..	26	26	..	..	23	21	..	..	19	16	..
8	24	..	21	22	22	..	22	17	20	..	16	14
15	23	24	22	..	23	22	21	..	24	19	17	..
22	25	27	29	21	22	23	25	20	21	18	20	14
29	19	..	26	..	20	..	23	..	20	..	21	..
May 6	..	26	22	16	..	25	22	17	..	23	20	13
13	21	28	22	20	21	25	20	17	20	23	19	14
20	19	..	18	28	19	..	21	24	19	..	19	23
27	15	26	17	21	16	21	17	21	19	20	18	20
June 3	25	..	19	20	15	..	17	20	14	..	16	20
10	24	26	20	19	16	24	17	19	18	23	17	18
17	18	21	17	**13**	**13**	21	17	16	17	22	16	18
24	**14**	..	**14**	**13**	16	..	14	15	18	..	14	15
July 1	**14**	18	**11**	**12**	17	20	15	14	15	20	13	14
8	**12**	**12**	**12**	**12**	**13**	16	14	**13**	13	16	13	13
15	**13**	**13**	**11**	**12**	**13**	15	14	**13**	13	15	13	13
22	**13**	..	**11**	..	**13**	..	**13**	..	12	..	12	..
29	19	19	..	**12**	14	15	..	**12**	14	15	..	12
Aug. 5	21	..	28	**12**	**13**	..	15	**11**	**11**	..	13	**11**
12	15	**13**	..	27	**11**	15	..	**13**	12	14	..	**11**
19	**14**	..	15	23	**13**	..	20	20	**11**	..	14	12
26	**14**	**11**	..	..	**13**	15	..	..	**11**	14	..	..
Sept. 2	..	..	15	18	..	..	16	20	..	..	14	17
9	**12**	..	..	18	**12**	..	..	19	**10**	..	..	17
16	..	..	25	..	..	..	22	..	..	..	15	..
23	..	..	..	..	..	..	..	..	..	..	..	..
30	16	..	21	..	**12**	..	18	..	**11**	..	14	..
Oct. 7	21	..	..	..	15	..	..	..	**11**	..	..	..
21	17	..	..	..	**13**	..	..	..	12	..	..	..
Nov. 11	19	..	..	..	**13**	..	..	..	**11**	..	..	..
25	16	..	..	..	**12**	..	..	..	**11**	..	..	..
Dec. 9	23	..	..	..	**13**	..	..	..	12	..	..	..

Examination of Table 8 and the graphs shows that in these 4 years soil moisture was ample in the upper 2 feet during the latter part of March and during April, May and the first half of June. During the latter part of June and in July, August and September, the water-content in the first foot frequently fell below the hygroscopic coefficient. This occurred particularly in July. The water-content did not fall below the hygroscopic coefficient as early in the 6-12-inch layer as in the 0-6-inch layer. In the second foot the hygroscopic coefficient was not reached until in August and in some years the soil moisture was not exhausted to that point during the entire season. By late summer or fall the moisture in this layer was fairly well exhausted and it was not replenished until early the following spring. During March, April and into May the water penetrated

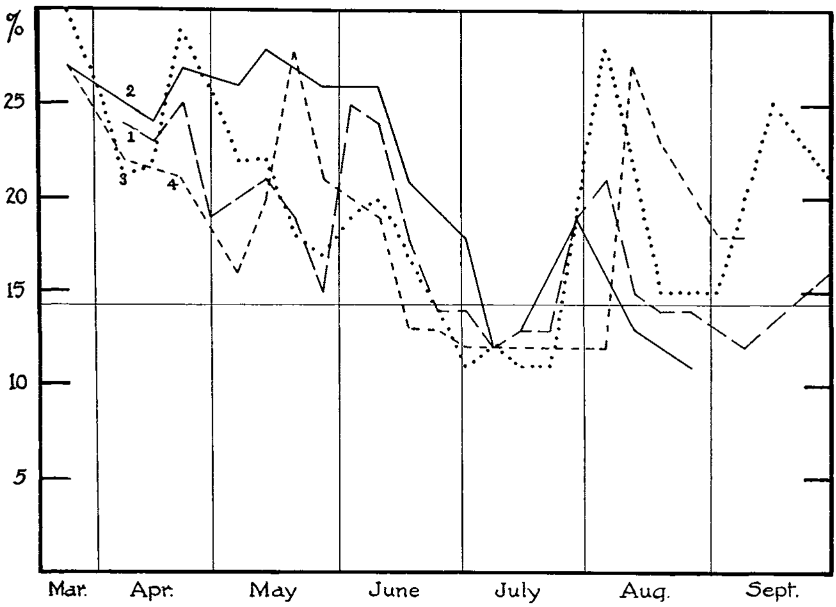

Fig. 8. Total soil moisture and the hygroscopic coefficient at 0 to 6 inches in the continuously grazed pasture, clay soil. Long dashes (1), 1927; continuous line (2), 1928; dotted line (3), 1929; short dashes (4), 1930.

more and more into this layer, increasing the total supply from about 16 percent to 20-23 percent. The rate at which the water-content increased and the maximum amount which it reached in different years depended upon the degree of depletion during the preceding season and upon the time and amount of precipitation in the spring.

The data demonstrate that the soil was drier for longer periods in 1927 and 1930 than in 1928 and 1929. The 1928 season was especially favorable because of the high water-contents from March 25 to July 8, the period of most active growth for the more important species, especially western wheat grass. The other seasons, especially those of 1930 and 1927, were much less favorable. During the summer and fall of 1927 the soil in the 6-12 and the 12-24-inch layers was especially dry.

During 1928 soil-moisture determinations were made in the deferred and rotation pasture as well as in the one continuously grazed. In nearly every case the water-content was slightly higher in the former pasture.

WILD ANIMALS.—Rodents appeared to be very scarce. A few jack rabbits and mice were seen occasionally. Grasshoppers, however, were very abundant in some years (as in 1926) and caused

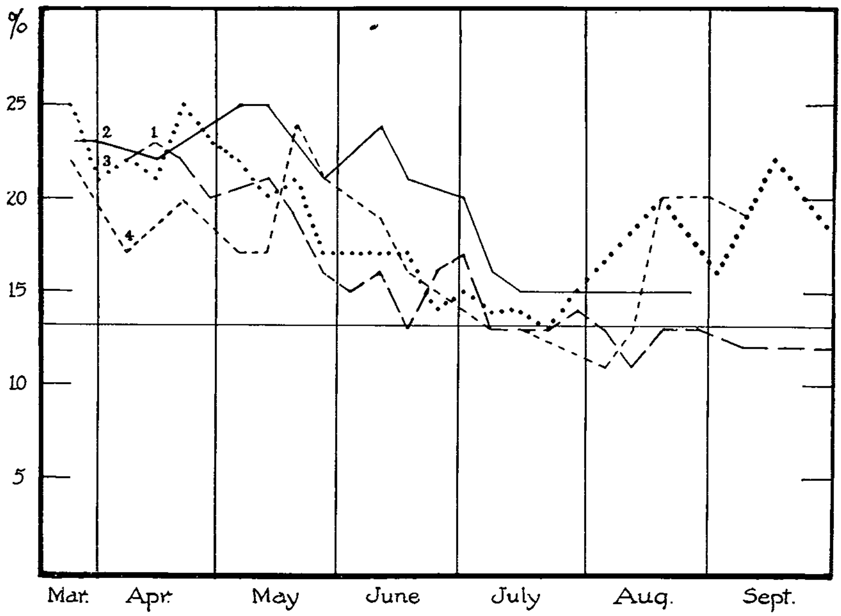

Fig. 9. Total soil moisture and the hygroscopic coefficient at 6 to 12 inches. Designations as in Figure 6.

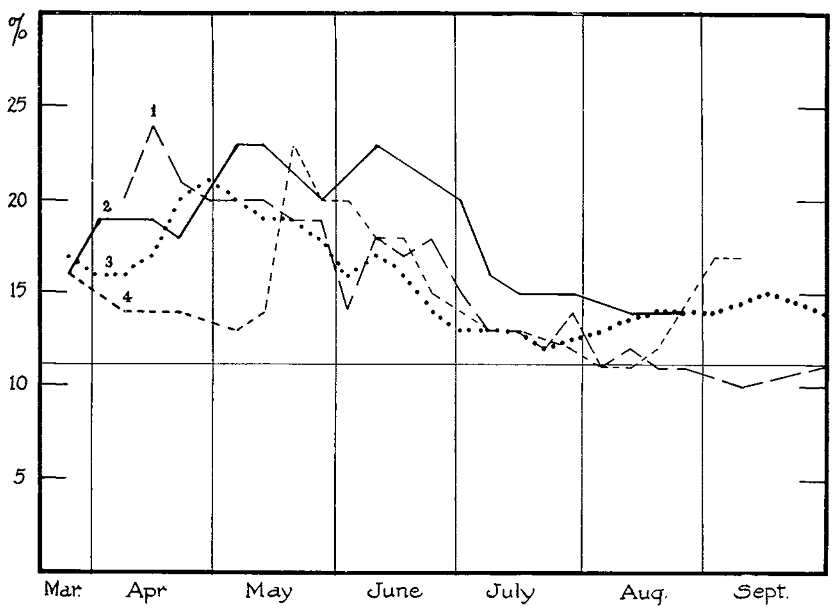

Fig. 10. Total soil moisture and the hygroscopic coefficient at 12 to 24 inches. Designations as in Figure 6.

considerable damage. *Bulbilis* appeared to be the first choice but *Gaura, Aster, Agropyron* and *Bouteloua* were also eaten and damaged by having the stems and leaves cut off.

SUMMARY OF ENVIRONMENTAL FACTORS.—In 1927 the precipitation was very low during May, but it was very favorable during the rest of the growing season; evaporation was intense in May, but fairly low the rest of the summer; the maximum air temperature was considerably higher during May, but lower in August than in the other 3 years; air and soil temperatures rose very rapidly during the latter part of April; soil temperature was lower in August and higher in September than in the other years; and the soil moisture was less for longer periods in 1927 and 1930 than in 1928 and 1929.

In 1928 the first part of April was unusually dry, July and August were also dry, but the period from the middle of April thru June, especially May, was marked by unusually favorable precipitation; evaporation was less intense during June and July but more intense in August than in any of the other years; air and soil temperatures were high during January, February and March, but unusually low in June; and soil moisture was especially favorable from March 25 to July 8, the period of most active growth for the more important range plants.

In 1929 the precipitation during March and April was fairly satisfactory, but during May, June and July it was deficient; the evaporation intensity was great from early in May to August; temperatures were fairly low from February to the latter part of May except during the middle of April; they were high in August and there was a pronounced drop during the second week in September; soil moisture was usually favorable except from June 24 to July 22, when it fell below the hygroscopic coefficient in the 0-6-inch layer.

In 1930 precipitation was unusually low during the first 4 months, unusually high in May and August and low in June and July. Except for 1 rainy week in May when about 3 inches fell, there was a shortage of precipitation from January until August. Evaporation was unusually intense during most of June and July. Temperatures were unusually low in January and for a week or two in the middle of May. They were high during the latter part of April and from the latter part of June to the first part of August. Soil moisture was lower in the 6-24-inch portion of the soil during April and the first half of May than in the other years and it was below the hygroscopic coefficient in the 0-6-inch layer for a longer continuous period (June 17 to August 12 inclusive) than in any other year. The soil was much drier in the growing season of 1930 than in 1928 or 1929.

During these 4 years the best season for the growth of the range plants appears to have been 1928 and the poorest season, 1930.

SEASONAL DEVELOPMENT IN RELATION TO ENVIRONMENTAL FACTORS

PHENOLOGY.—It is necessary to understand interrelations between the vegetation and the chief factors of the soil and climate before the effects of different systems of grazing may be evaluated. Changes in the vegetation that may appear to be due to grazing may have been caused by changes in climatic or soil factors. Even when these latter factors have been measured, it may be difficult to evaluate the grazing effects, partly because of the residual effects of factors, as depletion of soil moisture, or excessively close grazing, during preceding seasons.

SEASONAL DEVELOPMENT.—Growth of the range plants usually began about the middle of March when grasses and forbs began to show green at the base of the previous year's stalks or new shoots

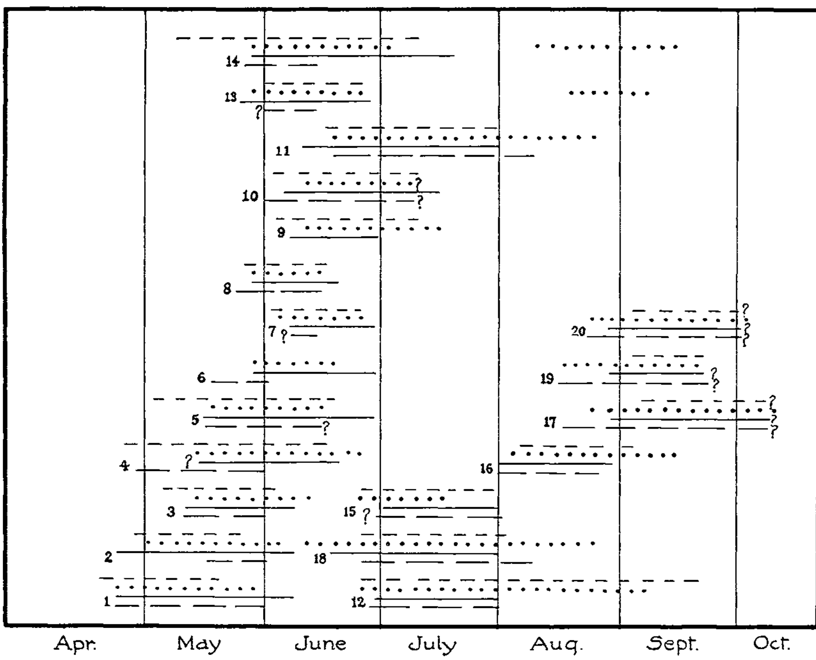

Fig. 11. Blooming periods of 20 important forbs in each of 4 years. Long dashes (lowest line for each species), 1927; continuous line, 1928; dotted line, 1929; short dashes (uppermost line for each species), 1930.

1. *Mertensia ciliata*
2. *Musineon divaricatum*
3. *Senecio perplexus*
4. *Astragalus missouriensis*
5. *Astragalus hypoglottis*
6. *Astragalus drummondii*
7. *Astragalus bisulcatus*
8. *Allium reticulatum*
9. *Gaura coccinea*
10. *Malvastrum coccineum*
11. *Stanleya pinnata*
12. *Psoralea tenuiflora*
13. *Sophora sericea*
14. *Linum Lewisii*
15. *Helianthus pumilus*
16. *Liatris punctata*
17. *Aster hebecladus*
18. *Argemone intermedia*
19. *Gutierrezia longifolia*
20. *Senecio spartioides*

appeared (Figs. 11 and 18). Some of the first ones to show green were *Agropyron Smithii, Stipa comata, S. viridula, Astragalus bisulcatus, Lesquerella, Linum Lewisii, Aragallus albiflorus, Cogswellia orientalis* and *Townsendia exscapa.* By the first week in April the range had a pale-green or yellowish-green color, due to the mixture of the new growth with the old growth of chiefly western wheat grass and other grasses.

Plant growth during April varied considerably in different years but usually the rate of growth was slow (See Figs. 12-14) because of low temperatures (mean soil temperature at 3 to 4 inches was about 46° F., and average minimum temperatures were frequently below 32° F.). Species that began to bloom during April were *Townsendia exscapa, Cogswellia orientalis, Thlaspi coloradense, Musineon divaricatum, Mertensia ciliata,* and *Viola nuttallii.* Toward the end of April, due to rising temperatures, the grasses began to grow in height more rapidly, changing the aspect of the vegetation to a greener shade. The yellow caused by old stalks still persisted.

During May development was very rapid. The grasses were growing at their maximum rate and numerous forbs came into bloom (See Figs. 11-14). The dominant color of the vegetation became bluish green, due to the abundance of western wheat grass. Yellowish-green patches or mats of the short grasses, the clumps of forbs, usually darker green in color, and the scattered blue, yellow and white flowers gave considerable variety to the bluish-green background. Species whose flowers added conspicuously to the aspect during this period were *Musineon* and *Mertensia* in the first part, *Senecio perplexus, Astragalus hypoglottis, A. drummondii, Linum Lewisii* and *Aragallus albiflorus* in the latter part (Fig. 20). The last species to begin growth were *Sophora, Psoralea, Helianthus pumilus* and *Malvastrum.*

The vegetation reached its maximum of development during June (See Figs. 11 and 21). Western wheat grass and the porcupine grasses completed their growth and there were more species in bloom than at any other period. Some of the forb species, especially *Psoralea,* had overtopped western wheat grass, so there was an upper yellowish-green layer composed of scattered forbs and a bluish-green understory or background of western wheat grass. The bluish-green background was spotted with yellowish-green mats of short grasses and the whole aspect was dotted with a variety of flowers that changed from day to day. In the morning the light-blue flowers of flax were especially conspicuous. The variegated colors of the flowers of *Astragalus bisulcatus* and the creamy white flowers of *Sophora,* the yellow flowers of *Stanleya,* the large white flowers of *Argemone*, and others less conspicuous, intermingled in profusion in June.

Moisture conditions have great influence in determining the length as well as the stage of development of this climax period. The development was poorer in 1930 than in 1929, but excellent in 1928. In 1930 *Astragalus drummondii* failed to bloom but in 1928 the blooming period lasted a month. *A. bisulcatus* had very few flowers in 1930, but very many in 1928.

During July, grasses, as western wheat grass, bloomed and the herbage began to dry. Species with conspicuous flowers were *Psoralea*, *Argemone*, *Stanleya*, *Helianthus pumilus*, *Carduus* and *Gaura*. The yellowish flower stalks of *Agropyron* and *Stipa* became prominent. Many species, as *Astragalus* spp., *Aragallus* spp., *Allium*, *Linum*, *Stipa* spp., *Schedonnardus*, *Sitanion* shed or began to shed their fruit at this time.

By August the vegetation had usually become fairly dry and yellowish to yellowish green in color (Fig. 22). Many of the early species, as *Cogswellia*, had disappeared. Favorable rains, as in 1929 and 1930, would revive the vegetation for a while, causing a second period of blooming in some species (*Bulbilis*, *Bouteloua*, *Linum*, etc.). Leaves of many species, especially grasses, as *Bulbilis*, became dry. Grasshoppers sometimes became abundant and caused much damage. Most plants had completed blooming and were either shedding or had completed shedding fruit. The few late summer species that bloomed at this time were *Liatris*, *Aster hebecladus*, *Gutierrezia*, *Senecio spartioides*, *Grindelia* and *Artemisia* spp.

In September the ripening and drying of the vegetation continued (Fig. 16). *Aster*, *Senecio* and *Gutierrezia* usually continued to bloom into October. *Psoralea* plants were soon broken off at the ground level and were blown into heaps along fences. Some of the grasses became yellowish in appearance. Shedding of fruit continued in many species. *Sophora*, *Stipa* spp., *Linum*, *Aristida*, *Malvastrum* and several other species usually remained conspicuously green thruout September.

By the latter part of October the late summer species had all completed blooming. *Agropyron* and *Stipa* spp. were usually fairly green, especially the latter, but the other grasses, especially *Bulbilis* and *Bouteloua*, were dry. The range had a dull yellow appearance. Several species, as *Senecio spartioides*, *Sideranthus*, *Liatris*, *Aster*, *Gutierrezia* and *Carduus* were shedding seed at this time.

In Figure 11 are shown the blooming periods of 20 important forbs during 4 seasons.

Most of these 20 species were in bloom in the latter part of May or in June. There was considerable uniformity in the beginning of the blooming period but less in the closing for the same species in different years. For most species the blooming period closed several days to a week or more earlier in 1929 and in 1930 than it did in 1928. This was apparently due to the more favorable soil moisture conditions in 1928 during May and June than in the other 2 years (See Table 8 and Figs. 8, 9 and 10).

GROWTH RATE OF GRASSES.—The chief species of grasses fall into two groups according to measurements of growth rates. The tall grasses, *Agropyron Smithii* and *Stipa viridula* are early growers; the short grasses, *Bouteloua gracilis, Bulbilis dactyloides, Schedonnardus paniculatus* and *Aristida longiseta,* are later growers. The growth curves of these six species are illustrated in Figure 12. Growth began in the latter part of March in all species except *Bulbilis,* which did not begin until a week later. *Stipa* grew most rapidly, *Agropyron* next, and *Bouteloua, Aristida* and *Schedonnardus* grew even more slowly. During April and May, growth was very rapid in both *Stipa* and *Agropyron* except during the middle of May when the growth rate of the latter was retarded because temperatures were unseasonably low. (See Tables 3 and 4, and Figures 3,

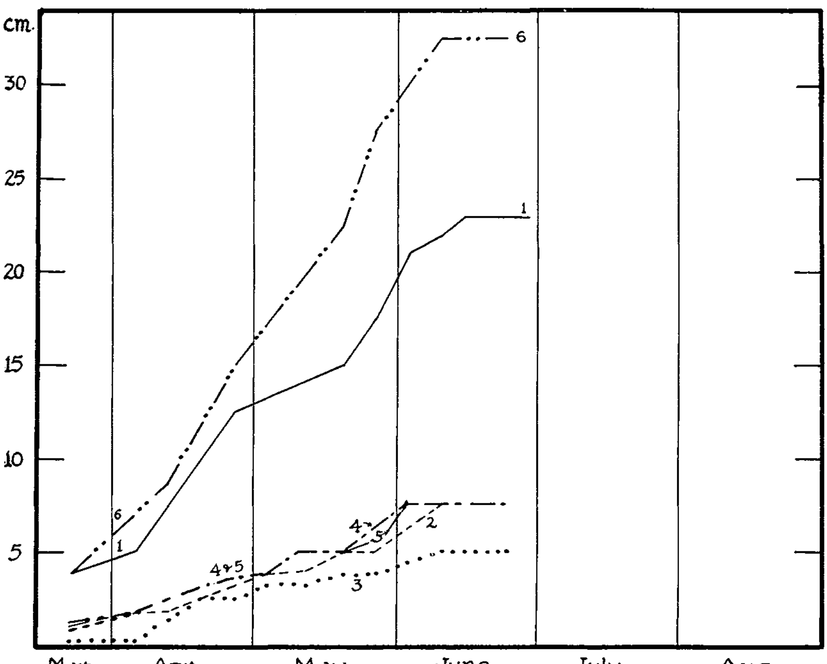

Fig. 12. Curves representing average maximum heights of six grasses at frequent intervals in 1930.

1. *Agropyron Smithii*
2. *Bouteloua gracilis*
3. *Bulbilis dactyloides*
4. *Aristida longiseta*
5. *Schedonnardus paniculatus*
6. *Stipa viridula*

4 and 6.) It is significant that the growth rate of *Stipa* was scarcely retarded. Growth in height in all species was completed about the same time, about the middle of June. The total heights reached were 34 centimeters for *Stipa*, 23 for *Agropyron*, about 7.5 for *Bouteloua*, *Schedonnardus* and *Aristida*, and about 5 for *Bulbilis*.

Growth measurements for 3 years of *Agropyron* and of *Stipa* are given in Table 9. *Agropyron* was measured under three conditions: Under total protection within an isolation transect, under deferred and rotation grazing, and under continuous grazing. Ten clumps of *Stipa* and 10 of *Agropyron* under each condition were carefully measured on each date by the same person. The growth curves of *Agropyron* for 3 years are shown in Figure 13, those for *Stipa* in Figure 14.

Table 9.—Average Heights in Centimeters of Agropyron Smithii and Stipa viridula on the Dates Indicated, During 1928, 1929 and 1930.

Week Ending	AGROPYRON SMITHII									STIPA VIRIDULA		
	Isolation Transect			Deferred Rotation Pasture			Continuous Pasture			Deferred Rotation Pasture		
	1928	1929	1930	1928	1929	1930	1928	1929	1930	1928	1929	1930
March 18......	5	..	4	..	..	4	..	..	3	3	..	4
25......	5	2	4	3	2	4	3	2	3	4	3	4
April 1......	5	3	5	4	3	4	3	2	4	7	4	5
8......	..	5	..	..	4	..	..	4	..	..	7	..
15......	6	5	8	5	6	7	4	5	6	9	9	12
22......	6	5	10	6	7	9	5	6	8	11	12	16
29......	..	6	..	..	8	..	..	6	..	..	13	..
May 6......	8	6	12	9	9	12	7	7	10	14	15	20
13......	11	9	14	12	11	13	10	8	11	22	17	22
20......	..	12	16	..	14	15	..	9	13	..	22	24
27......	18	15	18	16	17	17	13	11	15	32	27	27
June 3......	..	16	21	..	19	20	..	12	17	..	30	31
10......	21	20	22	18	20	22	16	14	18	40	33	34
17......	23	22	23	19	21	23	18	15	18	42	33	34
24......	..	23	23	..	22	23	..	15	18	..	..	34
July 1......	25	23	..	21	22	..	18	15	..	43	..	..
8......	26	..	..	22	..	..	19	..	..	43	..	..
15......	26	..	..	22	..	..	19	..	..	43	..	..

The best growth during these 3 years in both *Agropyron* and *Stipa* was in 1928. The growing season was longer and the total heights were greater. Soil moisture conditions due to well-distributed precipitation were more favorable during May and June of this year than they were during the same period in 1929 or in 1930. Growth was more rapid during most of April in 1930 in both species than it was in either 1928 or 1929. This was due to the higher average soil and air temperatures that prevailed during much of April in 1930. The growth of *Agropyron* was retarded during the latter

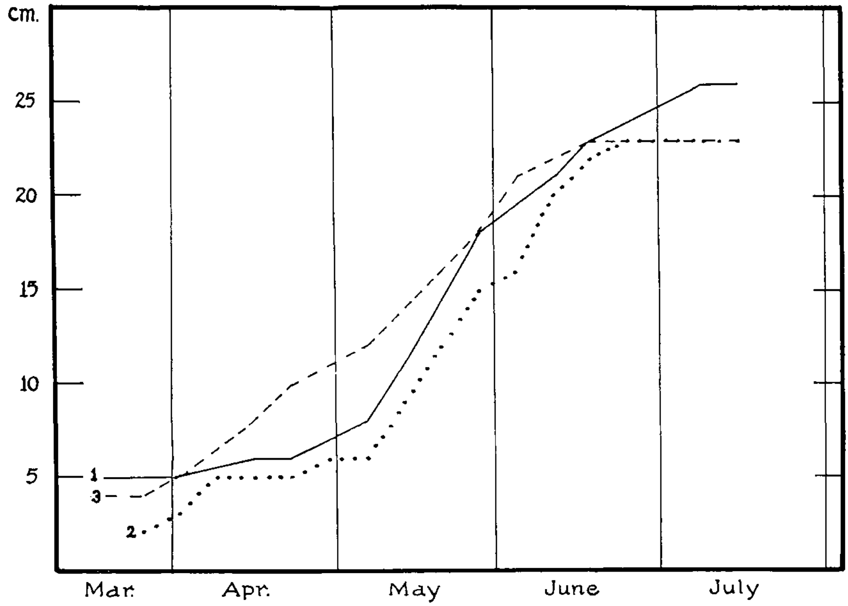

Fig. 13. Growth rate of *Agropyron Smithii* in 3 different years. Each point on the curves represents the average maximum height of 10 clumps in an isolation transect. Continuous line, 1928; dotted line, 1929; short dashes, 1930.

part of April and the first week in May in 1929 due to low temperatures. From about February 4 to about the middle of May, 1929, the soil temperature at 4 inches was from 3 to 6° F. cooler than during the same period in the other years. This may account for the retardation of the growth rate during this period (see Figure 13). Comparison of Figures 13 and 14 indicates that the growth rate of *Stipa* was retarded somewhat less by the low temperatures that prevailed during this period than was that of *Agropyron*. The decrease in the growth rate for the week ending June 3, 1930, was evidently due to lower temperatures and was more pronounced in *Agropyron* than in *Stipa*.

The chief factors that influenced the height growth of these two grasses appear to be temperature and soil moisture. Temperature determined in large measure the time when growth began in the spring and influenced the rate of growth, particularly during the early part of the season, the latter part of March, April and the first part of May. The growth rate did not appear to reach the maximum in *Stipa* until the air temperatures ranged from a weekly minimum of 41 or 42° F. to a maximum of 69 or 70° F.

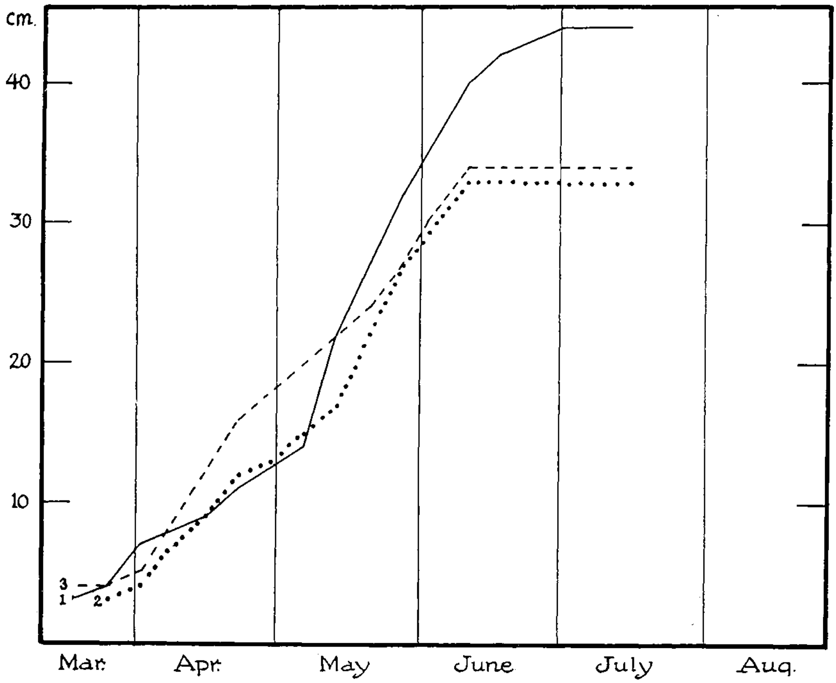

Fig. 14. Growth rate of *Stipa viridula* in 3 different years. Each point on the curves represents the average maximum height of 10 clumps in an isolation transect. Continuous line, 1928; dotted line, 1929; short dashes, 1930.

Soil moisture is important in limiting the total height growth and perhaps in determining the close of the growing season for height. It is significant that about the middle of June the soil moisture in the first 6 inches usually fell below the hygroscopic coefficient. In 1928, however, it did not fall below this point until July 8 (See Table 8 and Figures 8, 9 and 10).

EFFECTS OF DIFFERENT SYSTEMS OF GRAZING UPON THE VEGETATION

Different systems of grazing may affect the vegetation in various ways. The composition of the vegetation, i. e., the kinds of species present, may become different as two pastures that originally had the same kind of vegetation are grazed by different methods. The composition may remain the same, but the density or abundance may become modified. The frequency, i. e., the distribution of species over the area, may become different. One, or more likely, all of these floristic effects may be produced. The vegetative

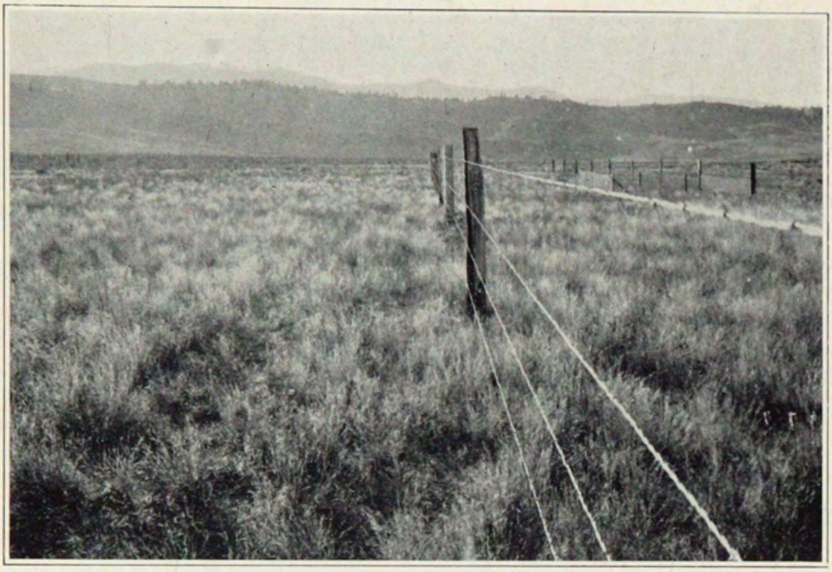

Fig. 15. Appearance of the range in late summer of 1921 along the fence exclosing the isolation transect from the continuously grazed pasture. Compare with Figs. 16, 20 and 21 for appearance in 1927 and in 1930. *Aristida longiseta* is the chief species.

growth as well as the reproduction of any one species may be different under various systems of grazing. Two species may respond in opposite ways. Buffalo grass may be favored under continuous grazing, and handicapped under deferred and rotation grazing due to the competition of western wheat grass.

The same species may be affected in different, and even in opposite directions, under the same kind of grazing due to differences in soil or climatic conditions, or because of differences in the kinds or abundance of other species that constitute the type. The reason that buffalo grass may decrease under deferred and rotation grazing is because conditions of soil and climate are such that western wheat grass may grow vigorously under this system and tend to suppress the buffalo grass. If the soil conditions were different so that the growth of western wheat grass would not be favored, then buffalo grass might increase faster under deferred and rotation grazing instead of losing out. The competition afforded by associate species is another factor to consider.

The effects of different systems of grazing, then, must be considered from the viewpoints, or analyzed thru the factors, of the composition of the vegetation and the influences of soil and climatic

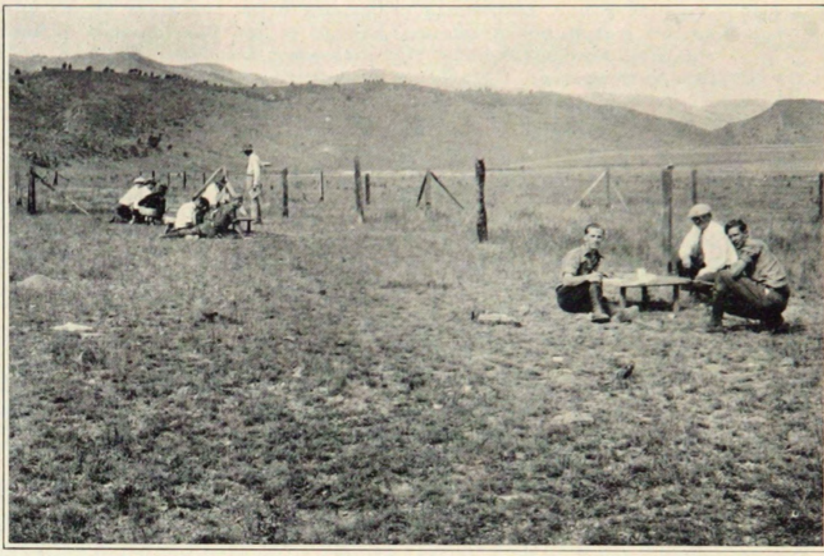

Fig. 16. View of portion of continuously grazed pasture and isolation transect on Sept. 24, 1927. The students are working within the 20 by 20 feet squares opened to grazing in successive years. Dark clumps of grass in foreground are *Aristida longiseta*.

conditions. Only in this way will the effects become intelligible and consistent with results of investigations in different areas. It is important, therefore, to consider first the composition, frequency and abundance of the vegetation in the range pastures.

COMPOSITION OF THE VEGETATION, FREQUENCY AND ABUNDANCE OF SPECIES.—Unfortunately, exact data on the vegetation are not available for the pastures at the beginning of the experiment. Exact data were secured during the summer of 1929, after the pastures had been grazed under different systems for slightly over 8 years. The method employed to locate the quadrats was to lay out three lines equidistant from each other and parallel with the width of the pasture. One of these lines was near the middle of the area under study, the other two toward the ends. On each of these lines 10 points for quadrat studies were located at intervals of 125 feet (38 meters) in the deferred and rotation pasture and at intervals of 80 feet (24 meters) in the continuous pasture. These data have been published in detail, but from a different point of view by Hanson and Love (4). Since the conclusion in that paper indicated that the 2-square-meter quadrat was a proper size to use, the data given in Table 10 are for this size only.

Table 10.—Frequency and Abundance of Species in 30 Quadrats in the Deferred and Rotation Pasture and 30 in the Continuously Grazed Pasture, June 11-28, 1929. The Following Abbreviations Are Used: VS, Very Scarce; S, Scarce; I, Infrequent; F, Frequent; Ab, Abundant.

SPECIES	Deferred and Rotation Pasture		Continuous Pasture	
	Frequency Percentage	Abundance Number	Frequency Percentage	Abundance Number
Desirable species:				
Agropyron Smithii Rydb.	100	27,460	100	17,921
Schedonnardus paniculatus (Nutt.) Trel.	90	I	60	S
Senecio perplexus A. Nels.	70	591	40	85
Eurotia lanata (Pursh) Moq.	70	69	0	0
Astragalus drummondii Dougl.	60	113	30	61
Bouteloua gracilis (H. B. K.) Lag.	47	I	73	F
Aristida longiseta Steud.	37	S	64	S
Helianthus pumilus Nutt.	30	51	40	91
Stipa viridula Trin.	20	110	0	0
Vicia linearis (Nutt.) Greene	3	23	3	7
Carex stenophylla Wahl.	0	0	3	241
Trifolium repens L.	0	0	3	1
Poa sp.	0	0	3	VS
Undesirable species:				
Gutierrezia longifolia Greene	77	75	73	48
Iva axillaris Pursh	67	716	43	606
Psoralea tenuiflora Pursh	63	165	100	544
Linum Lewisii Pursh	47	103	33	107
Artemisia gnaphalodes Nutt.	43	278	53	260
Bahia oppositifolia Nutt.	40	138	37	275
Bulbilis dactyloides (Nutt.) Raf.	37	I	23	S
Helianthus annuus L.	33	31	10	3
Opuntia humifusa Raf.	23	S	13	3
Quincula lobata (Torr.) Raf.	20	22	7	3
Muhlenbergia gracillima Torr.	17	S	3	VS
Yucca glauca Nutt.	17	9	20	8
Artemisia frigida Willd.	17	12	47	57
Aster hebecladus DC.	13	282	37	193
Artemisia dracunculoides Pursh	13	17	27	9
Argemone intermedia Sweet	10	9	17	9
Sitanion brevifolium J. G. Smith	10	22	27	34
Hordeum nodosum L.	7	2	10	20
Cryptantha crassisepala (T. and G.) Greene	7	10	0	0
Grindelia squarrosa (Pursh.) Dunal	3	1	13	4
Nothocalais cuspidata (Pursh) Greene	0	0	10	9
Bromus tectorum L.	0	0	17	35
Asclepias pumila (Gray) Vail	0	0	3	30
Euphorbia marginata Pursh	0	0	3	1
Astragalus bisulcatus (Hook.) Gray	0	0	3	12
Sporobolus cryptandrus (Torr.) Gray	0	0	3	VS
Stanleya pinnata (Pursh) Brit.	7	9	0	0
Carduus undulatus Nutt.	0	0	3	2
Immaterial species:				
Sophora sericea Nutt.	100	466	43	173
Gaura coccinea Nutt.	97	342	93	194
Musineon divaricatum (Pursh) C. and R.	97	1,010	97	771
Malvastrum coccineum (Pursh) Gray	83	537	83	339
Draba nemorosa L.	80	956	63	958
Sophia pinnata (Walt.) Brit.	70	131	83	211
Allium reticulatum Fraser	67	67	30	16

SPECIES	Deferred and Rotation Pasture		Continuous Pasture	
	Frequency Percentage	Abundance Number	Frequency Percentage	Abundance Number
Viola nuttallii Pursh	63	67	30	18
Polygonum douglasii Greene	60	73	13	12
Lepidium apetalum Willd	50	194	53	78
Lappula occidentalis (Wats.) Greene	50	126	23	58
Astragalus hypoglottis L.	43	246	47	303
Lithospermum angustifolium Michx	40	34	7	2
Astragalus shortianus Nutt	37	15	17	13
Lactuca pulchella DC	33	20	27	12
Evolvulus pilosus Nutt	33	110	50	194
Allionia linearis Pursh	27	17	33	24
Petalostemon oligophyllus (Torr.) Rydb	27	59	20	20
Lesquerella montana (Gray) Wats	20	16	10	11
Plantago purshii R. and S.	17	108	23	38
Taraxacum officinale Weber	17	14	7	3
Eriogonum effusum Nutt	17	18	27	15
Androsace occidentalis Pursh	13	22	7	10
Liatris punctata Hook	13	22	43	89
Astragalus flexuosus (Dougl.) Hook	13	64	33	104
Astragalus missouriensis Nutt	13	23	60	67
Sideranthus spinulosus (Pursh) Sweet	13	12	13	6
Euphorbia robusta (Engelm.) Small	13	25	17	14
Festuca octoflora Walt	10	232	20	141
Leucocrinum montanum Nutt	10	4	13	4
Pentstemon secundiflorus Benth	7	4	0	0
Hedeoma hispida Pursh	7	2	3	1
Astragalus tridactylicus Gray	3	6	3	1
Specularia leptocarpa (Nutt.) Gray	3	1	0	0
Aragallus albiflorus A. Nels	3	1	0	0
Cogswellia orientalis Jones	3	1	7	10
Pentstemon angustifolius Pursh	3	1	17	17
Tragopogon pratensis L.	3	1	10	3
Collemia micrantha Kell	3	1	0	0
Malacothrix sonchoides (Nutt.) T. and G.	3	3	0	0
Lygodesmia juncea Don	0	0	30	58
Myosurus minimus L.	3	11	0	0
Chenopodium album L.	3	2	0	0
Paronychia jamesii T. and G.	3	2	3	1
Comandra pallida A. DC	3	4	3	9
Thelesperma gracile (Torr.) Gray	0	0	3	2

In Table 10 the species were grouped on the basis of grazing value for cattle into three classes—desirable, undesirable and immaterial. The desirable species are those that furnish considerable forage or that are highly palatable but because of their scarcity may furnish little feed. The undesirable species are those that are poisonous, mechanically injurious, or that are not grazed and in addition make heavy demands upon essential factors as soil moisture. Often they are strong and aggressive competitors. The immaterial species are those that are grazed but slightly, and often perhaps accidentally with other plants, or those that are not grazed and, moreover, appear not to make heavy demands upon the habitat, nor do they appear to be aggressive competitors. This grouping is merely for convenience in analyzing the data. Some of the immaterial species should perhaps have been placed in the undesirable group. Two groups may have been better than three because if a species does not furnish desirable forage it is not particularly desirable.

Sixty-four species found in the deferred and rotation pasture were also found in the continuous pasture. Eleven species occurred in the former that did not occur in the latter, and 12 occurred in the latter that did not occur in the former. So the total number of species listed in the 30 quadrats (60 square meters) in the deferred and rotation pasture was 75, and in the same number of quadrats in the continuous pasture, 76. The total number of species found in the quadrats in both pastures was 87. There were 25 other species found in one or the other pasture, but not found in any of the quadrats, making a grand total of 112 species for the area.

In order to secure quantitative expressions of the floristic importance, frequency and abundance, data were secured and are given in Table 10. The frequency is given in percentage, i. e., the percentage figure for each species represents the percentage of 30 quadrats in which the species was found, as 90 for *Schedonnardus* means that it occurred in 27 of the 30 quadrats. For every species where it was possible, the stalks growing in the quadrat were counted. In the case of a few bunch-grasses and mat-formers as *Schedonnardus* and *Bulbilis* only an estimate of the abundance of the species on the area could be given.

This analysis yielded many facts regarding the structure of the vegetation and revealed a number of important differences between the two pastures.

There was only one species, *Agropyron Smithii,* that was very high in both frequency and abundance. In both pastures it was found in every quadrat, making the frequency 100 percent. The total number of stalks in the quadrats in the deferred and rotation pasture was 27,460 or an average of 912 ± 75.23 per quadrat (2 square meters); and in the continuous pasture, 17,921 stalks, or an average of 597 ± 50.48 per quadrat (2 square meters). The difference between these average figures well exceeds 3.3 times the mean probable error of the two averages. No other species compared to this in abundance so western wheat grass must be considered the chief or dominant species on this area. The great frequency and abundance are related to the soil and climatic conditions, particularly, it appears, to low soil moisture, beginning in the latter part of June, and the high clay content of the soil. On gravelly areas in the vicinity there is less western wheat grass and in somewhat lower, more clayey areas that have been protected from grazing, almost

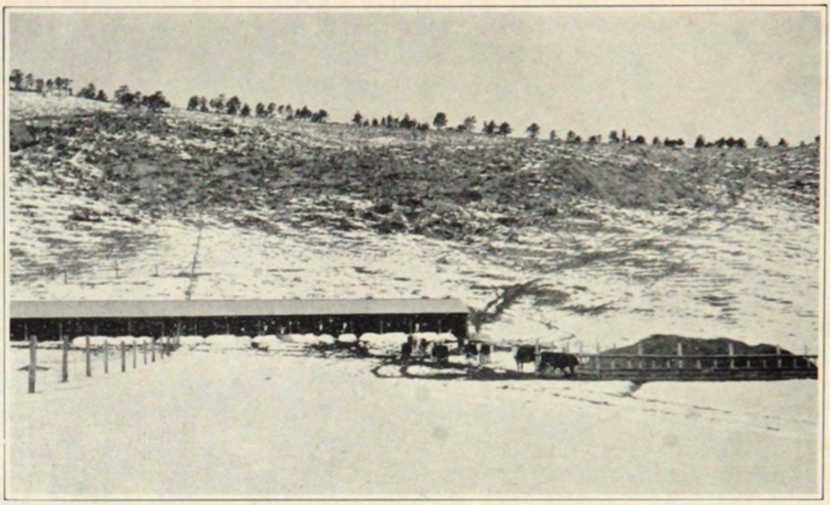

Fig. 17. On March 20, 1928, after a fairly heavy snowfall which melted quickly. During the winter and at this time the cattle limit their activity largely to the shed, feeding pens and water trough.

pure stands of this grass are found (Figs. 39 to 41). The percentages of probable errors (8.2 and 8.4 percent) of the average number per quadrat are nearly equal. This indicates that the frequency, i. e., the distribution of stalks over the area, but not the abundance, of western wheat grass was very similar in the two pastures.

Western wheat grass must be considered as the most important species constituting the vegetation. Range utilization must be based chiefly upon this species not only because of its abundance and high frequency, but also because of the large amount of highly nutritious forage that it yields. It cures on the ground and is readily eaten by cattle thruout the year. Because of its rhizome habit it is resistant to close cropping and trampling. Chemical analyses (5) show that the crude protein content is high, ranging from 8 to over 18 percent, even higher than for blue grama and buffalo grass. Chemical analyses made by Hopper and Nesbitt (5) of western North Dakota plants showed the following percentages of mineral constituents: Nitrogen 1.436, phosphoric acid (P_2O_5) 0.482, potash (K_2O) 2.704, soda (Na_2O) 0.584, lime (CaO) 0.320, magnesia (MgO) 0.229, sulfur trioxide (SO_3) 0.269.

The question as to the effects of the different systems of grazing upon the vegetation in these pastures resolves itself, then, largely into one concerning the effects upon western wheat grass.

In regard to frequency of western wheat grass there appears to be no effect of the different systems of grazing in these two pastures, but in a nearby pasture which had been heavily overgrazed for some time by cattle and horses, its frequency was reduced to 4 percent.

The conclusion appears valid, then, that the continuous system of grazing has either not been continued for a sufficient number of years on this pasture to have produced detrimental effects, or that the number of stock grazed in the continuous pasture is not excessive. In regard to abundance, however, there was a great difference. *The number of stalks in the quadrats in the deferred and rotation pasture was 53 percent greater than in those in the continuous pasture. This was the chief difference, expressed quantitatively, that was found between these two pastures.* Just how much this difference of 53 percent in 1929 was due to the difference in the grazing method cannot be definitely determined because similar data are not available for the beginning of the grazing trial in 1920. Photographs and other data indicate that there was less western wheat grass, especially in the continuous pasture, in 1920 than there was in 1929 (Figs. 15 and 16). Soil variations may, however, account for the difference in 1920 and part of the difference of 53 percent in 1929. If the continuous pasture had a greater area of gravelly soil than the other pasture, then less western wheat grass would be expected. Examination of the data for other species may clarify the problem.

Bouteloua gracilis grows well on clay soils and it is less abundant or lacking on sandy soils in Eastern Colorado. On a nearby overgrazed pasture, where the soil was similar, this grass had a frequency of 100 percent and it was very abundant, forming a sod over most of the area. Observation indicates that over-grazed western wheat grass is replaced by blue grama grass. In the deferred and rotation pasture it had a frequency of 47 percent, in the continuous one, 73 percent. It was also more abundant in the latter pasture. Since this grass, as well as western wheat grass, grows better in clayey than in gravelly soils, the differences in frequency and abundance would indicate that the soil variations are not the cause of the vegetational differences, but that the system of grazing is the cause.

There are several other species that yield similar evidence. *Eurotia lanata*, or winter fat, one of the most palatable plants in this region, grazed closely by the cattle, had a frequency of 70 percent in the deferred and rotation pasture, but 0 in the continuous pasture. *Senecio perplexus*, also very palatable and much grazed by cattle in May and June, had a frequency in the former pasture of 70 percent and 40 in the continuous one. There were 591 stalks recorded in the former, only 85 in the latter. *Stipa viridula*, also relished by the livestock, had a frequency of 20 percent in the deferred and rotation pasture, but 0 in the continuous one. *Schedonnardus pani-*

Fig. 18. In March the ground is wet, due to melting of snow, as seen in Fig. 17. This view, showing cow tracks, was taken in the continuously grazed pasture on March 17, 1927. The dried vegetation is chiefly *Agropyron Smithii* and *Schedonnardus*.

culatus, which was grazed considerably and usually closely, had a frequency of 90 percent in the former, 60 percent in the latter. All of these species indicate that the system of continuous grazing reduced the distribution and abundance of the most desirable grazing plants as compared with the deferred and rotation method.

Aristida longiseta had a frequency of 37 percent in the deferred and rotation pasture but 64 percent in the continuous pasture. It has been classified with the desirable species because it was grazed at times to a considerable degree. On account of the objectionable awns and because it occupied space that may have been better occupied by *Agropyron Smithii,* it should, perhaps, have been listed instead with the undesirable species. If it had been so listed, its frequency would have been due to the differences in the grazing systems. If it does properly belong with the desirable species, then it may indicate that the deferred and rotation pasture had less gravelly area than the other pasture, or that the continuous-grazing method had as yet not affected this species particularly. Photographs and other data indicate that this species was more abundant in the continuous pasture especially, in 1921 than it was in 1929.

The data on some of the undesirable species lead to conclusions similar to those derived from the data on some of the desirable species. The most significant species appears to be *Psoralea tenuiflora,* which is never grazed, and may grow to a height of 2.5 feet with a top spread of about 2 feet in diameter. In the deferred and rotation pasture its frequency was 63 percent and its abundance 165 stalks. In the continuous pasture the frequency was 100 percent and the abundance, 544. The average number of stalks per quadrat (2 square meters) was 18 ± 2.254 in the continuous pasture and 5.0 ± 0.9594 in the deferred and rotation pasture. The differences between these average figures well exceeds 3.3 times the mean probable error of the two averages. The percentage of error in the former case is about 12 percent, in the latter about 5 percent. These percentage figures appear to indicate that *Psoralea* individuals were more thinly and uniformly distributed in the deferred and rotation pasture than in the other. This may indicate further that conditions, especially competition during ecesis with other species as western wheat grass, were less favorable for *Psoralea* in the deferred and rotation pasture than in the continuous one. These figures, concerning a clearly objectionable species, indicate that the difference in grazing methods has probably caused differences in both frequency and abundance. The data regarding other species lead to less definite conclusions.

The data on abundance was summarized by securing the total number of stalks of desirable species, of undesirable species, and of immaterial species. A number of species as *Stipa, Bouteloua, Schedonnardus, Aristida* and *Bulbilis* whose stalks could not be counted, had to be omitted. If these could have been included it appears that they would have about offset each other. These figures on abundance are as follows:

	Deferred and Rotation Pasture	Continuous Pasture	Ratio
Stalks of desirable species	28,415	18,407	1.54
Stalks of undesirable species	1,874	2,271	0.82
Stalks of immaterial species	5,099	4,001	1.27

The number of stalks of desirable species and of immaterial species was greater in the deferred and rotation pasture than in the continuous pasture; but the number of stalks of undesirable species was lower. This strengthens the conclusion stated above that differences in the vegetation in 1929 were due, at least in part, to differences in the grazing systems. Increases in frequency and abundance of *Psoralea tenuiflora* and *Bouteloua gracilis* and decreases in frequency and abundance of *Agropyron Smithii,* taken together, appear

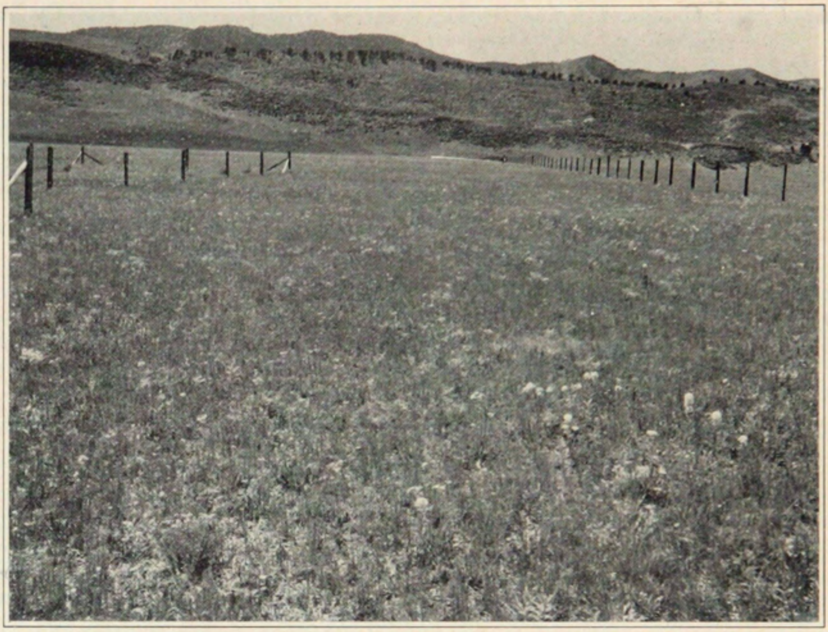

Fig. 19. Appearance of the range in deferred and rotation pasture on May 28, 1930. Compare with Fig. 20. Flowers of *Senecio perplexus* are numerous. *Agropyron Smithii*, the most abundant species, is growing very rapidly at this time.

to indicate range deterioration due to faulty management practices in this type of vegetation.

GROWTH OF SPECIES UNDER DIFFERENT SYSTEMS OF GRAZING.—Measurements during 3 years (1927, 1929, 1930) of the growth rate of *Agropyron Smithii* based on 10 clumps (2 to 10 stalks per clump) in the deferred and rotation pasture and of 10 clumps in the continuous pasture, are given in Table 9. In each year the total height attained as well as the length of the growing season, were greater in the deferred and rotation pasture than in the other. The total heights were 2 to 5 centimeters greater, the growing season 1 to 2 weeks longer.

In 1926, measurements of the maximum heights of *Agropyron Smithii* and of *Stipa viridula* were secured after the close of the growing season of these grasses in both pastures. These measurements are summarized in Table 11. The stalks were cut at the surface of the ground, taken indoors, and the maximum heights of each of 100 shoots measured. Grazing was deferred in 1926 on the portion of the deferred and rotation pasture from which the shoots were taken. No plants that had been grazed were measured.

Table 11.—Maximum Heights (Averages of 100 Measurements) of Agropyron Smithii and Stipa viridula in Each of the Pastures, August 9, 1926.

Species	Pasture	Height, Inches
Agropyron Smithii	Deferred and Rotation	23.0 ± .2263
	Continuous	18.7 ± .2063
Stipa viridula	Deferred and Rotation	32.1 ± .3834
	Continuous	24.1 ± .3737

The data in Table 11 show that the average height of *Agropyron Smithii* shoots was 23 percent greater and that of *Stipa viridula* 33 percent greater in the deferred and rotation pasture than in the continuous pasture. In both cases the differences between the average figures, as given in Table 11, exceeds 3.3 times the mean probable error of the two averages. On August 1, 1927, similar measurements were made. In the deferred and rotation pasture (grazing not deferred this year) the average height of 100 stalks of *Agropyron* was 20.5 inches, in the continuous pasture 18.9 inches. The corresponding measurements for *Stipa* were 21.7 and 18.7 inches. Soil-moisture determinations in the 1928 season showed that the water content was slightly higher in the former pasture, so the moisture supply may have been the determining factor, altho differences in the vigor of the plants may also have been important.

The oven-dry weight of 500 seeds of *Stipa viridula* collected on July 9, 1926, was secured for both pastures. The weight of 500 seeds from the deferred and rotation pasture was 2.483 grams, 28.3 percent heavier than those from the continuous pasture, which weighed 1.935 grams. A germination test in the Colorado Seed Laboratory on February 18, 1927, showed 32 percent for seeds collected on July 9, 1926, in the deferred and rotation pasture and 12 percent for those from the continuous pasture.

ISOLATION TRANSECT STUDIES.—An isolation transect (1) was located in each pasture (Figs. 15 and 16). Successive areas, 20 by 20 feet square, along one side of each transect, were opened to grazing each year, beginning in 1922. On the opposite side similar areas were closed to grazing each year. A carefully placed quadrat was located in each square and studied, usually at 2-year intervals (1926, 1928 and 1930) by a combination of the pantograph-chart and count-list methods (3). A few additional quadrats were located in other parts of the pastures and studied by the same method. A few clipped quadrats were also used.

The data gathered, usually from 3 analyses of each quadrat, are summarized as follows:

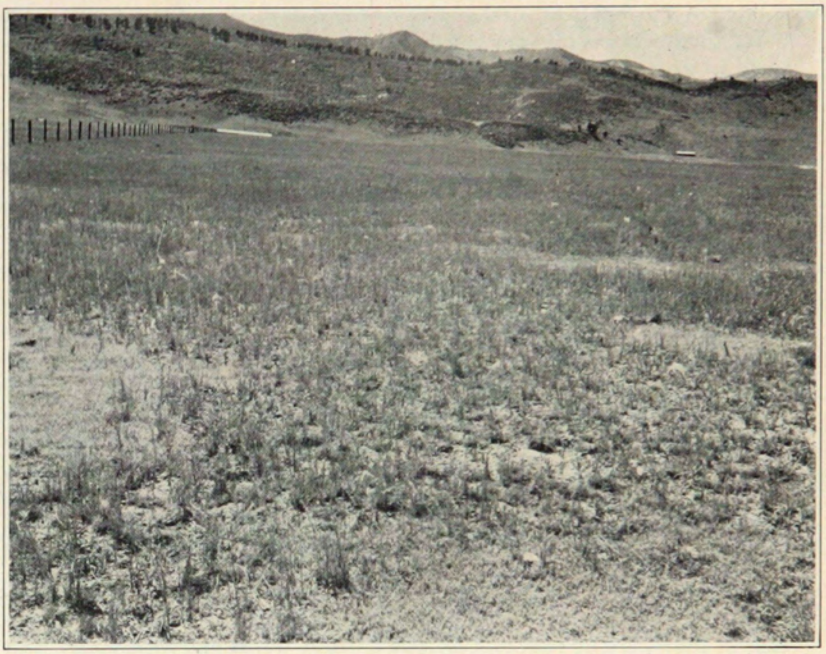

Fig. 20. Appearance of range in continuously grazed pasture on May 28. 1930. Compare with Fig. 19. *Senecio perplexus* and *Agropyron Smithii* are much less abundant, mats of *Bulbilis* are much more abundant.

CONTINUOUS PASTURE

QUADRAT 7. CLOSED TO GRAZING IN 1922.

Competition between *Agropyron* and *Aristida* on a gravelly area not grazed.

PRINCIPAL SPECIES.—*Agropyron.*—Considerable reduction since 1926, from 747 stalks in 1928 to 579 in 1930. There were 73 flower stalks in 1926 and none in 1928 and 1930.

Aristida.—485 sq. cm. in 1921, 637 in 1926, 421 in 1928 and 467 in 1930.

Aster.—19 stalks in 1921, 21 in 1926, 27 in 1928 and 31 in 1930.

Astragalus hypoglottis increased from 15 in 1928 to 84 in 1930.

LESS IMPORTANT SPECIES.—*Psoralea* increased from 2 stalks in 1926 to 8 in 1930.

Linum Lewisii increased somewhat.

Schedonnardus decreased from 21 sq. cm. in 1921 and 22 in 1926 to 12 in 1928 and 0 in 1930.

Sophora.—10 stalks in 1926, 1 in 1928, 0 in 1930.

Little or no change in *Artemisia gnaphalodes, Senecio perplexus, Astragalus missouriensis, Yucca.*

INFREQUENT TO SCARCE.—*Tragopogon, Gaura, Camelina, Viola, Musineon, Euphorbia glyptosperma, Liatris, Allionia, Lesquerella, Petalostemon.*

ABSENT.—*Bulbilis, Iva, Helianthus pumilus, Astragalus drummondii, Stipa viridula, Malvastrum.*

CONCLUSIONS.—Since this quadrat had not been grazed since 1921, the decrease in *Agropyron* since 1926 was probably due to unfavorable moisture conditions accompanied by increased abundance of *Aster, Astragalus hypoglottis, Psoralea* and *Linum.*

QUADRAT 8. OPENED TO GRAZING IN 1922.

Competition between *Agropyron* and *Aristida* on a gravelly area under continuous grazing.

PRINCIPAL SPECIES.—*Agropyron.*—Appears to have increased somewhat since 1921. In 1921 there appear to have been 182 stalks and in 1930, 261 stalks. In 1926 there were 12 flower stalks; in 1928, 1; in 1930, 7.

Aristida.—2,739 sq. cm. in 1921, 2,073 in 1926, 1,902 in 1928, 1,420 in 1930.

Aster.—1 stalk in 1926, 17 in 1928 and 30 in 1930.

Psoralea.—1 in 1926, 4 in 1928 and 9 in 1930.

LESS IMPORTANT SPECIES.—*Helianthus pumilus, Sophora,* reduced in abundance.

Schedonnardus.—121 sq. cm. in 1926, 22 in 1928, 197 in 1930.

Bromus tectorum, Musineon, remained about the same.

INFREQUENT TO SCARCE.—*Senecio perplexus, Malvastrum, Evolvulus, Linum, Gaura, Lactuca, Gutierrezia, Sitanion, Astragalus tridactylicus, Petalostemon, Opuntia humifusa, Lithospermum, Liatris, Euphorbia glyptosperma, Salsola, Allionia.*

ABSENT.—*Bulbilis, Iva, Artemisia gnaphalodes, Astragalus drummondii, Stipa.*

CONCLUSIONS.—The apparent increase in *Agropyron* and the considerable reduction in *Aristida* is unexpected on this quadrat which has been under continuous grazing since 1922. These results are opposite to those in quadrat 7, which was closed in 1922. The decrease in *Aristida* was caused partly by trampling of the cattle. *Agropyron* suffered less from this. The decrease in *Aristida* and the lack of intense competition from other species may have been factors in the increase of *Agropyron.*

QUADRAT 6. CLOSED TO GRAZING IN 1924.

Competition under protection from grazing of *Agropyron, Bulbilis, Aristida* and *Psoralea* especially.

PRINCIPAL SPECIES.—*Agropyron.*—Abundance about the same in 1926 and in 1928, decreased about 15 percent from 1928 to 1930. In 1926 there were 41 flower stalks, none in 1928 and in 1930.

Bulbilis.—1,450 sq. cm. in 1926, 1,656 in 1928, 1,680 in 1930.

Aristida.—618 sq. cm. in 1926, 477 in 1928, 338 in 1930.

Psoralea.—None in 1926, 7 stalks in 1928, 15 in 1930.

LESS IMPORTANT SPECIES.—*Schedonnardus.*—144 sq. cm. in 1926, 34 in 1928, 0 in 1930.

Artemisia gnaphalodes.—0 in 1926, 1 stalk in 1928, 37 in 1930.

Liatris punctata.—2 stalks in 1926, 8 in 1928, 19 in 1930.

Linum Lewisii.—4 stalks in 1926, 5 in 1928, 9 stalks and 18 seedlings in 1930.

INFREQUENT TO SCARCE.—*Astragalus hypoglottis, A. missouriensis, Draba nemorosa, Musineon, Senecio perplexus, Sophora, Lesquerella, Gaura, Stipa viridula, Tragopogon, Helianthus pumilus, Evolvulus, Euphorbia glyptosperma, Sophia, Petalostemon, Allionia.*

ABSENT.—*Aster, Iva, Astragalus drummondii, Malvastrum.*

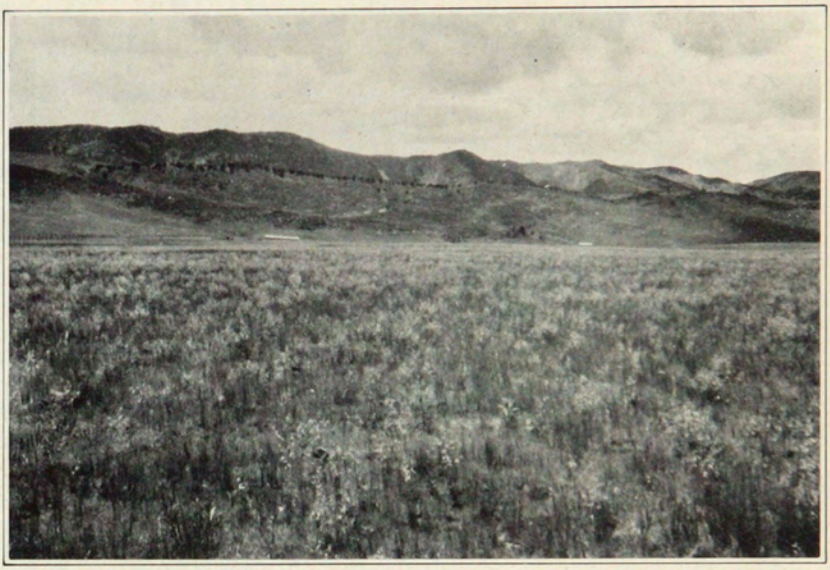

Fig. 21. Appearance of range on June 19, 1928, in continuously grazed pasture. *Psoralea tenuiflora* is the most conspicuous because it is just beginning to overtop *Agropyron Smithii.*

CONCLUSIONS.—The small decrease in *Agropyron* may have been due to unfavorable moisture conditions rather than to increased competition resulting from increases in abundance of *Psoralea, Bulbilis, Artemisia gnaphalodes, Liatris* and *Linum*. The decrease in area occupied by *Aristida* is striking.

QUADRAT 5. OPENED TO GRAZING IN 1924.

Competition under continuous grazing between *Agropyron, Aristida* and *Aster* chiefly.

PRINCIPAL SPECIES.—*Agropyron.*—Remained about the same since 1926. In 1926 there were 9 flower stalks, in 1928 and 1930 no flower stalks.

Aristida.—1,162 sq. cm. in 1926, 1,247 in 1928, 1,510 in 1930.

Aster.—26 stalks in 1926, 40 in 1928, 43 in 1930.

LESS IMPORTANT SPECIES.—*Psoralea.*—1 stalk in 1926, 7 in 1928 and 7 in 1930.

Artemisia gnaphalodes.—Decreased considerably; 17 stalks in 1928, 8 in 1930.

Gaura, Musineon, Evolvulus, Liatris.—Remained about the same.

INFREQUENT TO SCARCE.—*Astragalus missouriensis, Comandra, Euphorbia robusta, Linum, Petalostemon, Lithospermum, Lesquerella, Helianthus pumilus, Euphorbia glyptosperma, Erysimum, Schedonnardus.*

ABSENT.—*Bulbilis, Iva, Sophora, Astragalus drummondii, Stipa, Senecio perplexus, Malvastrum.*

CONCLUSIONS.—Under increased competition from *Aristida, Aster* and *Psoralea,* under continuous grazing and with low soil moisture in several seasons, the abundance of *Agropyron* remained about the same, or at the most decreased only slightly.

QUADRAT 4. CLOSED TO GRAZING IN 1925.

Competition of *Agropyron*, under protection from grazing, with *Aristida*, *Schedonnardus*, *Psoralea*, *Iva* and other forbs.

PRINCIPAL SPECIES.—*Agropyron*.—About the same in 1926 and in 1928; 346 stalks in 1928, 321 in 1930; 5 flower stalks in 1926, 0 in 1928 and 1930.

Aristida.—455 sq. cm. in 1926, 512 in 1928, 325 in 1930.

Artemisia gnaphalodes.—1 stalk in 1926, 6 in 1928, 31 in 1930.

LESS IMPORTANT SPECIES.—*Schedonnardus*.—246 sq. cm. in 1926, 190 in 1928, 67 in 1930.

Psoralea.—5 stalks in 1926, 2 in 1928, 4 in 1930.

Iva.—19 stalks in 1926, 21 in 1928, 18 in 1930.

Liatris.—Increased; 27 stalks in 1928, 34 in 1930.

Musineon.—Appears to have increased; 30 stalks in 1930.

Gaura.—Increased; 1 in 1926, 14 in 1928, 18 in 1930.

Astragalus hypoglottis.—Increased; 2 in 1926, 5 in 1928, 16 in 1930.

Lygodesmia.—Decreased; 20 in 1926, 17 in 1928, 15 in 1930.

Evolvulus.—Remained about the same (29 stalks in 1930).

Vicia.—Increased; 1 stalk in 1928, 24 in 1930.

INFREQUENT TO SCARCE.—*Senecio perplexus*, *Malvastrum*, *Euphorbia* spp. *Bahia*, *Astragalus missouriensis*, *Lavauxia*, *Petalostemon*, *Stipa*, *Sophia*, *Asclepias*, *Linum*, *Aster*, *Gutierrezia*, *Lesquerella*.

ABSENT.—*Bulbilis*, *Helianthus pumilus*, *Astragalus drummondii*.

CONCLUSIONS.—There were more species of forbs that increased in abundance than decreased, so the small decrease in *Agropyron* was accompanied by a net increase in forbs and a decrease in *Schedonnardus* and in *Aristida* since 1928.

QUADRAT 3. OPENED TO GRAZING IN 1925.

Competition under continuous grazing of *Agropyron*, *Bulbilis* and *Aristida*.

PRINCIPAL SPECIES.—*Agropyron*.—Appears to have increased slightly since 1926. There was a total of 684 stalks in 1930. In 1926 there were 14 flower stalks, 2 in 1928, 0 in 1930.

Bulbilis.—314 sq. cm. in 1926, 431 in 1928, 640 in 1930.

Aristida.—592 sq. cm. in 1926, 874 in 1928, 895 in 1930.

LESS IMPORTANT SPECIES.—*Astragalus hypoglottis*.—9 stalks in 1926, 20 in 1928, 38 in 1930.

Lesquerella.—Increased; 9 in 1928, 53 in 1930.

Schedonnardus.—2 sq. cm. in 1926, 8 in 1928, 24 in 1930.

INFREQUENT TO SCARCE.—*Artemisia gnaphalodes*, *Sophora*, *Lygodesmia*, *Musineon*, *Gaura*, *Viola*, *Bahia*, *Draba*, *Gutierrezia*, *Pentstemon*, *Linum*, *Psoralea*, *Yucca*, *Evolvulus*, *Euphorbia glyptosperma*.

ABSENT.—*Aster*, *Iva*, *Helianthus pumilus*, *Astragalus drummondii*, *Stipa viridula*, *Senecio perplexus*, *Malvastrum*.

CONCLUSIONS.—*Agropyron*.—Increased slightly in abundance under continuous grazing since the spring of 1925. Its chief competitors, *Bulbilis*, *Aristida*, *Astragalus hypoglottis* and *Lesquerella*, also increased. These increases may have been made possible because the other forbs were infrequent to scarce or absent in each year, and *Bulbilis* was not abundant. In 1930 the stand still appeared rather open, much more so than the corresponding quadrat closed in 1925.

QUADRAT 1. CLOSED TO GRAZING IN 1927.

Competition under protection from grazing of *Agropyron, Bulbilis, Aristida, Aster* and *Astragalus hypoglottis.*

PRINCIPAL SPECIES.—*Agropyron.*—Decreased somewhat; 479 stalks in 1928, 371 in 1930. In 1926 there were 14 flower stalks, 0 in 1928 and 1930.

Bulbilis.—891 sq. cm. in 1926, 1,429 in 1928, 3,691 in 1930.

Aristida.—234 sq. cm. in 1926, 196 in 1928, 187 in 1930.

Aster.—21 stalks in 1926, 25 in 1928, 33 in 1930.

Astragalus hypoglottis.—9 stalks in 1926, 31 in 1928, 105 in 1930.

LESS IMPORTANT SPECIES.—*Schedonnardus.*—136 sq. cm. in 1926, 82 in 1928, 15 in 1930.

Helianthus pumilus.—Remained about the same, 8 stalks in 1930.

Musineon.—39 in 1930.

INFREQUENT TO SCARCE.—*Lygodesmia, Iva, Artemisia gnaphalodes, Senecio perplexus, Gaura, Gutierrezia, Petalostemon, Linum, Liatris, Lesquerella, Psoralea, Evolvulus, Euphorbia robusta, Lavauxia, Sophia, Argemone, Allionia, Chenopodium, Salsola, Lithospermum, Sophora.*

ABSENT.—*Astragalus drummondii, Stipa viridula, Malvastrum.*

CONCLUSIONS.—*Agropyron* decreased but little even when *Bulbilis, Aster* and *Astragalus hypoglottis* increased. Other forbs, however, were not very abundant.

QUADRAT 2. OPENED TO GRAZING IN 1927.

Competition of *Agropyron* with *Aristida* and forbs under continuous grazing.

PRINCIPAL SPECIES.—*Agropyron.*—Decreased somewhat in abundance; 5 flower stalks in 1926, 3 in 1928, 0 in 1930; total stalks in 1930 was 671.

Aristida.—83 sq. cm. in 1926, 153 in 1928, 181 in 1930.

Astragalus hypoglottis.—21 stalks in 1926, 22 in 1928, 60 in 1930.

LESS IMPORTANT SPECIES.—*Artemisia gnaphalodes.*—3 stalks in 1926, 16 in 1928, 25 in 1930.

Aster.—4 stalks in 1926, 2 in 1928, 12 in 1930.

Psoralea.—2 stalks each year.

Schedonnardus.—46 sq. cm. in 1926, 35 in 1928, 36 in 1930.

INFREQUENT TO SCARCE.—*Gutierrezia, Lesquerella, Liatris, Musineon, Yucca, Pentstemon, Erysimum, Evolvulus, Linum, Petalostemon, Allionia, Euphorbia* spp. *Lactuca.*

ABSENT.—*Bulbilis, Iva, Helianthus pumilus, Sophora, Astragalus drummondii, Stipa, Senecio perplexus, Malvastrum.*

CONCLUSIONS.—The rather small decrease in *Agropyron* was accompanied by increases in *Aristida, Astragalus hypoglottis, Artemisia gnaphalodes* and *Aster.* The quadrat appeared fairly open in 1928 and in 1930. The greater apparent density in 1927 and 1926 was due more to dead stalks of previous years than to living stalks.

QUADRAT 11. CLOSED TO GRAZING IN 1928.

Effect of a change from continuous grazing to total protection upon a stand composed chiefly of *Agropyron, Bulbilis, Aristida, Schedonnardus.*

PRINCIPAL SPECIES.—*Agropyron.*—Appears to have decreased somewhat from 1927 to 1928; decreased from 947 stalks in 1928 to 552 in 1930. No flower stalks in any of the 3 years.

Bulbilis.—700 sq. cm. in 1927, 643 in 1928, 1,075 in 1930.

Aristida.—269 sq. cm. in 1927, 242 in 1928, 256 in 1930.

Schedonnardus.—113 sq. cm. in 1927, 118 in 1928, 56 in 1930.

LESS IMPORTANT SPECIES.—*Musineon.*—Increased, 14 in 1930.

Liatris.—Increased, 11 stalks in 1928, 18 in 1930.

Bahia.—12 stalks in 1927, 15 in 1928, 16 in 1930.

Gaura.—7 stalks in 1927, 9 in 1928, 10 in 1930.

INFREQUENT TO SCARCE.—*Psoralea, Senecio perplexus, Lavauxia, Lygodesmia, Petalostemon, Gutierrezia, Linum, Astragalus missouriensis, Quincula, Lithospermum, Allionia, Evolvulus, Chenopodium, Euphorbia glyptosperma, Malvastrum, Artemisia gnaphalodes.*

ABSENT.—*Aster, Iva, Helianthus pumilus, Sophora, Astragalus drummondii, Stipa.*

CONCLUSIONS.—The response to total protection from grazing was increased height growth of *Agropyron* which tended to mask the apparent decrease in abundance which continued into 1930. *Bulbilis* and some of the forbs increased somewhat. Unfavorable moisture conditions may have been partly responsible for the decreased abundance of *Agropyron* in 1930. Perhaps the effect of protection is greater the first year or two after the change than it is later.

QUADRAT 12. OPENED TO GRAZING IN 1928.

Effect of a change from total protection from grazing to continuous grazing upon a stand composed chiefly of *Agropyron, Bulbilis, Aristida, Psoralea, Aster* and *Artemisia gnaphalodes.*

PRINCIPAL SPECIES.—*Agropyron.*—Decreased from 1927 to 1928; increased from 406 stalks in 1928 to 465 in 1930; 1 flower stalk in 1927, 2 in 1928, 0 in 1930.

Bulbilis.—1,364 sq. cm. in 1927, 466 in 1928, 1,319 in 1930.

Aristida.—960 sq. cm. in 1927, 608 in 1928, 700 in 1930.

Psoralea.—5 stalks in 1927, 9 in 1928, 8 in 1930.

Aster.—4 stalks in 1927, 18 in 1928, 22 in 1930.

Artemisia gnaphalodes.—8 stalks in 1927, 12 in 1928, 13 in 1930.

LESS IMPORTANT SPECIES.—*Gutierrezia.*—0 in 1927, 2 stalks in 1928, 6 in 1930.

Schedonnardus.—About 0.5 sq. cm. in 1927, 5 in 1928, 17 in 1930.

INFREQUENT TO SCARCE.—*Musineon, Linum, Evolvulus, Viola, Gaura, Lesquerella, Yucca, Tragopogon, Lithospermum, Astragalus hypoglottis, Euphorbia glyptosperma, Petalostemon.*

ABSENT.—*Iva, Helianthus pumilus, Sophora, Astragalus drummondii, Stipa viridula, Senecio perplexus, Malvastrum.*

CONCLUSIONS.—The changes in *Agropyron* and *Bulbilis* from 1927 to 1928 were reductions in abundance; from 1928 to 1930, increases. *Aristida* decreased but several forbs, usually not grazed, increased. In 1930 the quadrat appeared much more weedy than in 1927. The change in the appearance of the *Aristida* plants was very striking. In 1927 they were up to 10 inches

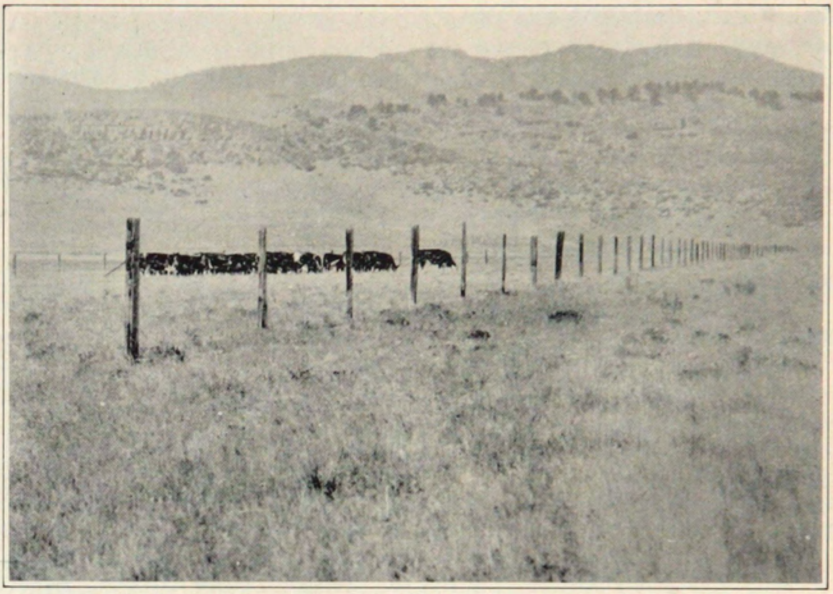

Fig. 22. Cattle grazing in a compact herd as they go to water, resulting in paths or streaks of grazed grass. August, 1930.

tall with abundant fruit. In 1930 they were much shorter with little fruit. In this quadrat it appears that continuous grazing has more detrimental effects upon *Aristida* than upon *Agropyron*.

QUADRAT 15. CLOSED TO GRAZING IN 1929.

Effect of a change from continuous grazing to total protection upon a stand composed chiefly of *Agropyron*, *Stipa*, *Iva* and other forbs.

PRINCIPAL SPECIES.—*Agropyron*.—550 stalks in 1928, 398 in 1930; 1 flower stalk the first year, 0 the second.

Stipa viridula.—Appears to have increased somewhat from 1928 to 1930; 186 stalks in 1930.

Iva.—31 stalks in 1928, 67 in 1930.

Aristida.—194 sq. cm. in 1928, 190 in 1930.

Senecio perplexus.—146 stalks in 1930.

LESS IMPORTANT SPECIES.—*Helianthus pumilus*.—10 stalks in 1928, 16 in 1930.

Artemisia gnaphalodes.—11 stalks in 1928, 17 in 1930.

Psoralea.—5 stalks each year.

Schedonnardus.—56 sq. cm. in 1928, 29 in 1930.

Astragalus hypoglottis.—9 stalks in 1928, 23 in 1930.

Liatris.—18 stalks in 1928, 22 in 1930.

Gaura.—16 stalks in 1928, 11 in 1930.

Musineon.—13 stalks in 1930.

Petalostemon oligophyllus.—13 stalks in 1928, 18 in 1930.

Linum.—10 stalks in 1928, 6 in 1930.

INFREQUENT TO SCARCE.—*Astragalus missouriensis, Evolvulus, Astragalus drummondii, Eriogonum effusum, Paronychia, Sophora, Gutierrezia, Lithospermum, Lygodesmia, Malvastrum.*

ABSENT.—*Bulbilis, Aster.*

CONCLUSIONS.—When this quadrat, which contained a large variety of species, had been closed to grazing for 2 seasons, *Agropyron* decreased considerably and the forbs and *Stipa* increased somewhat.

QUADRAT 16. OPENED TO GRAZING IN 1929.

Effect of a change from total protection to continuous grazing upon a stand composed chiefly of *Agropyron, Bulbilis, Aristida* and forbs.

PRINCIPAL SPECIES.—*Agropyron.*—288 stalks in 1928, 332 in 1930; no flower stalks either year.

Bulbilis.—600 sq. cm. in 1928, 2,316 in 1930.

Aristida.—332 sq. cm. in 1928, 347 in 1930.

LESS IMPORTANT SPECIES.—*Artemisia gnaphalodes.*—9 stalks in 1928, 21 in 1930.

Astragalus hypoglottis.—2 stalks in 1928, 19 in 1930.

Helianthus pumilus.—20 stalks in 1928, 8 in 1930.

INFREQUENT TO SCARCE.—*Schedonnardus, Psoralea, Senecio perplexus, Linum, Musineon, Gutierrezia, Liatris, Evolvulus, Aster, Lesquerella, Petalostemon* spp., *Euphorbia robusta, Tragopogon, Sophia, Draba, Dysodia, Lithospermum, Sophora, Yucca.*

ABSENT.—*Iva, Astragalus drummondii, Stipa, Malvastrum.*

CONCLUSIONS.—The abundance of *Agropyron* increased about 15 percent from 1928 to 1930 with continuous grazing starting in 1929. *Bulbilis* increased greatly, *Aristida* remained about the same. The quadrat appeared much more open in 1930 than it did in 1928, due chiefly to removal of the growth of preceding years.

QUADRAT 41. CLOSED TO GRAZING IN 1930.

Effect of a change from continuous grazing to total protection upon a stand composed chiefly of *Agropyron, Bulbilis, Aristida, Psoralea* and other forbs.

PRINCIPAL SPECIES.—*Agropyron.*—408 stalks in 1929, 483 in 1930.

Bulbilis.—1,143 sq. cm. in 1929, 972 in 1930.

Aristida.—340 sq. cm. in 1929, 515 in 1930.

Psoralea.—10 stalks in 1929, 9 in 1930.

Artemisia gnaphalodes.—22 stalks in 1929, 37 in 1930.

Malvastrum.—30 stalks in 1929, 37 in 1930.

LESS IMPORTANT SPECIES.—*Schedonnardus.*—35 sq. cm. in 1929, 192 in 1930.

Iva.—14 stalks in 1929, 15 in 1930.

Astragalus missouriensis.—12 stalks in 1929, 17 in 1930.

Musineon.—19 stalks in 1929, 33 in 1930.

INFREQUENT TO SCARCE.—*Liatris, Gutierrezia, Helianthus pumilus, Astragalus drummondii, A. hypoglottis, Linum, Gaura, Lesquerella, Eriogonum, Sophia, Pentstemon, Senecio perplexus, Lygodesmia, Allionia.*

ABSENT.—*Aster, Sophora, Stipa.*

CONCLUSIONS.—There were increases in abundance of *Agropyron, Aristida, Schedonnardus* and a few forbs, decreases in *Bulbilis* and a few forbs.

These changes cannot be ascribed to the effects caused by differences in the grazing system because the time was too short. These changes may have been due entirely to other environmental influences, as moisture and competition between species.

QUADRAT 40. OPENED TO GRAZING IN 1930.

Effect of a change from total protection to continuous grazing upon a stand composed chiefly of *Agropyron* and *Aristida*.

PRINCIPAL SPECIES.—*Agropyron*.—352 stalks in 1929, 522 in 1930.

Aristida.—801 sq. cm. in 1929, 845 in 1930.

LESS IMPORTANT SPECIES.—*Bulbilis*.—100 sq. cm. in 1929, 247 in 1930.

Senecio perplexus.—17 stalks in 1929, 11 in 1930.

Liatris.—17 stalks in 1929, 7 in 1930.

Psoralea.—6 stalks in 1929, 2 in 1930.

Helianthus pumilus.—5 stalks in 1929, 8 in 1930.

Astragalus hypoglottis.—3 stalks in 1929, 25 in 1930.

INFREQUENT TO SCARCE.—*Draba, Yucca, Gaura, Lesquerella, Gutierrezia, Evolvulus, Petalostemon, Linum, Viola, Sophora, Musineon, Astragalus missouriensis, Sophia, Euphorbia glyptosperma.*

ABSENT.—*Aster, Iva, Artemisia gnaphalodes, Stipa, Malvastrum.*

CONCLUSIONS.—*Agropyron, Aristida, Bulbilis* and a number of forbs increased in abundance from 1929 to 1930. The increases were greater than in the corresponding quadrat that was closed to grazing at the same time (spring of 1930). Part of the increase in abundance appears to be due to the change in grazing.

QUADRAT 140. GRAZED CONTINUOUSLY SINCE 1921.

Effect of continuous grazing upon a stand consisting chiefly of *Agropyron, Bulbilis, Aster* and *Schedonnardus*.

PRINCIPAL SPECIES.—*Agropyron*.—About the same from 1926 to 1928, but decreased from 463 stalks in 1928 to 172 in 1930.

Bulbilis.—2,080 sq. cm. in 1926, 2,360 in 1928, 2,375 in 1930.

Aster.—27 stalks in 1926, 29 in 1928, 59 in 1930.

Schedonnardus.—473 sq. cm. in 1926, 209 in 1928, 201 in 1930.

LESS IMPORTANT SPECIES.—*Astragalus hypoglottis*.—27 stalks in 1926, 15 in 1928, 35 in 1930.

Helianthus pumilus.—2 in 1926, 0 in 1928 and 1930.

INFREQUENT TO SCARCE.—*Musineon, Senecio perplexus, Gutierrezia, Linum, Gaura, Artemisia gnaphalodes, Erysimum, Lesquerella, Sophora, Eriogonum, Psoralea, Evolvulus, Bahia, Lithospermum, Euphorbia robusta.*

ABSENT.—*Iva, Astragalus drummondii, Stipa, Malvastrum.*

CONCLUSIONS.—The decrease of over 50 percent in the abundance of *Agropyron* from 1928 to 1930 was accompanied by a considerable increase in *Aster* and decreases in *Schedonnardus, Astragalus hypoglottis* and *Helianthus pumilus*. *Bulbilis* increased slightly from 1926 to 1930.

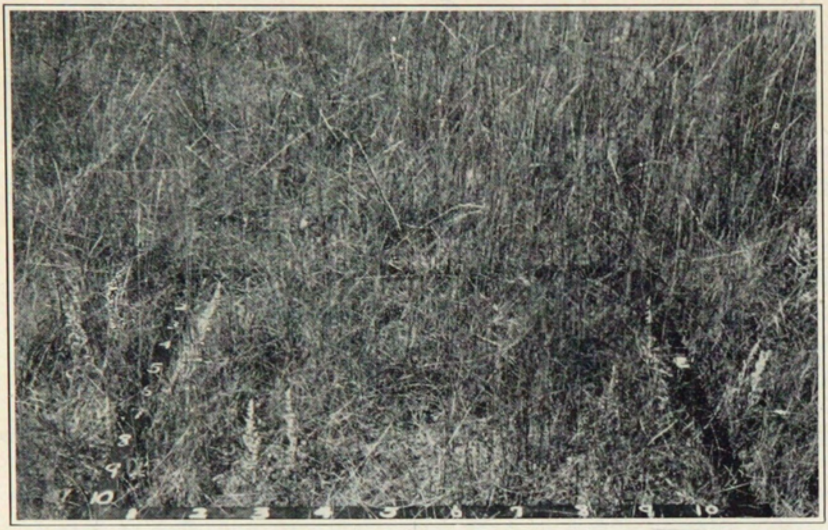

Fig. 23. Quadrat 160, grazed since 1921, isolation transect, deferred and rotation pasture. Aug. 23, 1926. Figs. 24 and 25.

DEFERRED AND ROTATION PASTURE

QUADRAT 160. UNDER DEFERRED AND ROTATION GRAZING SINCE 1921. (FIGS. 23, 24 AND 25.)

Effect of deferred and rotation grazing upon a stand consisting chiefly of *Agropyron, Bulbilis* and *Schedonnardus.*

PRINCIPAL SPECIES.—*Agropyron.*—About the same from 1926 to 1928, but decreased from about 700 stalks in 1928 to 339 in 1930.

Bulbilis.—1,436 sq. cm. in 1926, 1,570 in 1928, 1,885 in 1930.

Schedonnardus.—1,148 sq. cm. in 1926, 435 sq. cm. and 93 seedlings in 1928, 615 sq. cm. in 1930.

LESS IMPORTANT SPECIES.—*Sophora.*—18 stalks in 1926, 10 in 1928, 17 in 1930.

Artemisia gnaphalodes.—12 stalks in 1926, 4 in 1928, 11 in 1930.

Senecio perplexus.—22 stalks in 1930.

INFREQUENT TO SCARCE.—*Psoralea, Aster, Astragalus drummondii, A. hypoglottis, Linum, Lepidium, Gaura, Draba.*

ABSENT.—*Aristida, Iva, Helianthus pumilus, Stipa, Malvastrum.*

CONCLUSIONS.—*Agropyron* held its own during 1927 and 1928 when grazing was not deferred, but during 1929 and 1930 when grazing was deferred, the abundance decreased about 50 percent. *Bulbilis* increased from 1926 to 1930, *Schedonnardus* decreased from 1926 to 1928 and increased from 1928 to 1930. Establishment conditions for seedlings of the latter species were favorable in this quadrat in 1928. The results of this quadrat are similar to those in quadrat 140 which was grazed continuously after 1921. The changes that occurred from 1926 to 1930 appear to be due more to environmental factors than to differences in the grazing system.

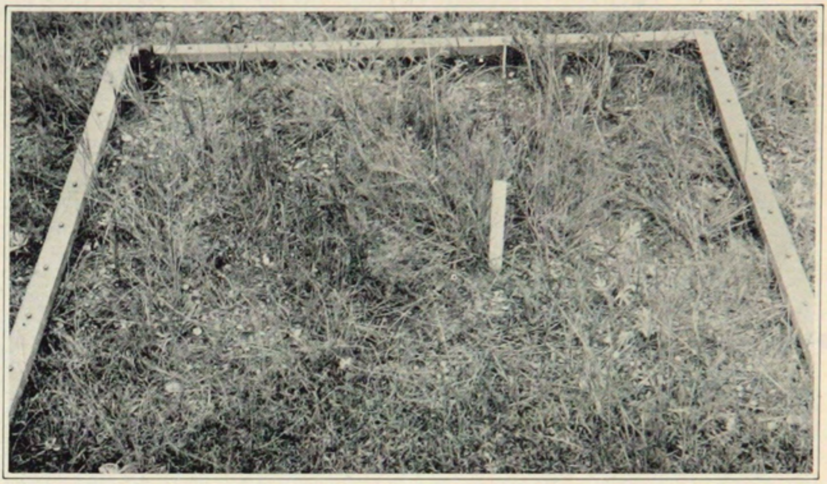

Fig. 24. Quadrat 160. August 4, 1928.

QUADRAT 27. CLOSED TO GRAZING IN 1922

Growth of *Agropyron* when not grazed nor subjected to severe competition.

PRINCIPAL SPECIES.—*Agropyron*.—Abundance does not appear to have changed very much since 1921; in 1926 there were 123 flower stalks, in 1928 none, and in 1930 there were 2.

LESS IMPORTANT SPECIES.—*Schedonnardus*.—61 sq. cm. in 1921, 108 in 1926, 80 in 1928, 94 in 1930.

Iva and *Malvastrum*.—Decreased considerably since 1926.

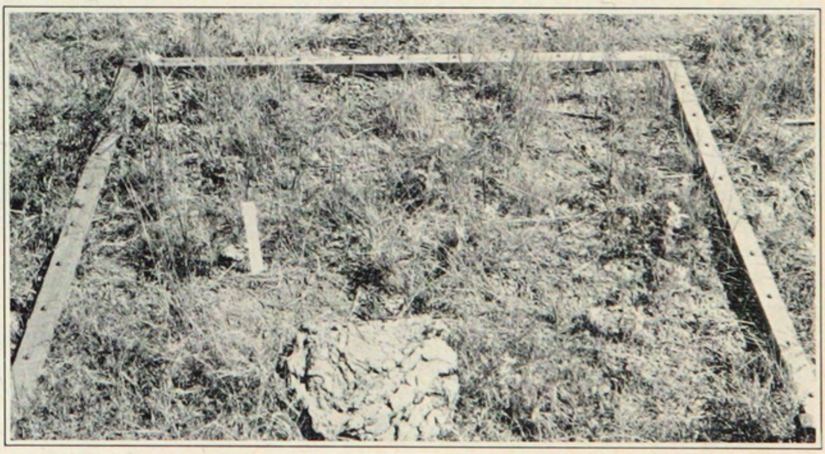

Fig. 25. Quadrat 160. July 15, 1930. *Agropyron* decreased greatly from 1927 to 1930. *Bulbilis*, in front part of quadrat, increased from 1,436 sq. cm. in 1926 to 1,885 in 1930.

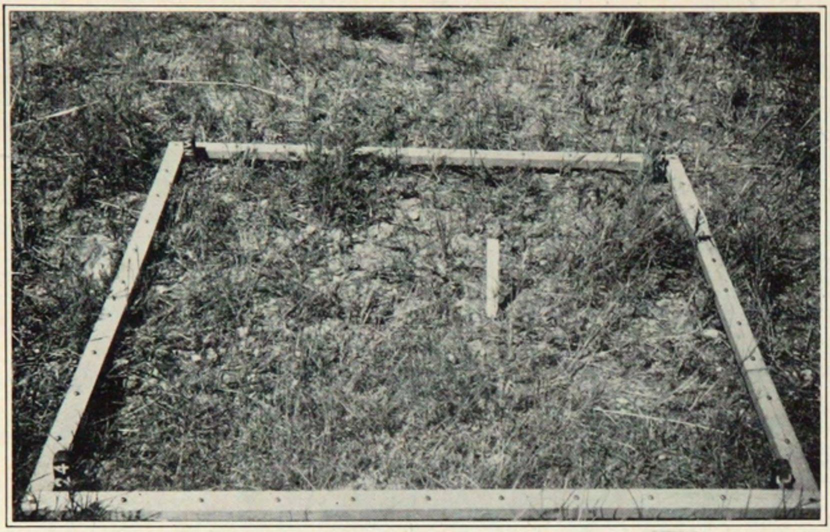

Fig. 26. Quadrat 24, opened to grazing in 1924, isolation transect, deferred and rotation pasture. August 5, 1927. See Figs. 27 and 28.

Artemisia gnaphalodes.—0 in 1926, 4 in 1928, 22 in 1930.

Sophora, Astragalus drummondii, Senecio perplexus, Musineon remained about the same.

INFREQUENT TO SCARCE.—*Gaura, Gutierrezia, Linum, Astralagus missouriensis, Viola, Bahia, Draba.*

ABSENT.—*Bulbilis, Aristida, Psoralea, Aster, Helianthus pumilus, Stipa viridula.*

CONCLUSIONS.—It appears that due to the lack of aggressive competitors (as *Bulbilis, Aster* and *Stipa*) *Agropyron* has been able to hold its own in spite of variations in soil moisture.

QUADRAT 26. OPENED TO GRAZING IN 1922.

Competition between *Bulbilis* and *Agropyron.*

PRINCIPAL SPECIES.—*Agropyron.*—Abundance decreased by at least 50 percent since 1921. In 1926 there were 47 flower stalks, in 1928, 2, and in 1930, only 1.

Bulbilis.—2,097 sq. cm. in 1926, 3,017 in 1928, 2,804 in 1930.

Schedonnardus.—418 sq. cm. in 1921, 358 in 1926, 155 in 1928, 284 in 1930.

Iva.—Remained about the same (62 stalks in 1930) since 1926.

LESS IMPORTANT SPECIES.—*Gaura* and *Musineon.*—Remained about the same.

INFREQUENT TO SCARCE.—*Sophora, Astralagus drummondii, Senecio perplexus, Malvastrum, Mertensia, Pentstemon, Linum, Allionia, Lesquerella.*

ABSENT.—*Aristida, Psoralea, Aster, Artemisia gnaphalodes, Stipa viridula.*

CONCLUSIONS.—The large decrease in *Agropyron* may be due to a combination of factors; unfavorable moisture conditions, competition with *Bulbilis* and undeferred grazing during 1923, 1924, 1927 and 1928.

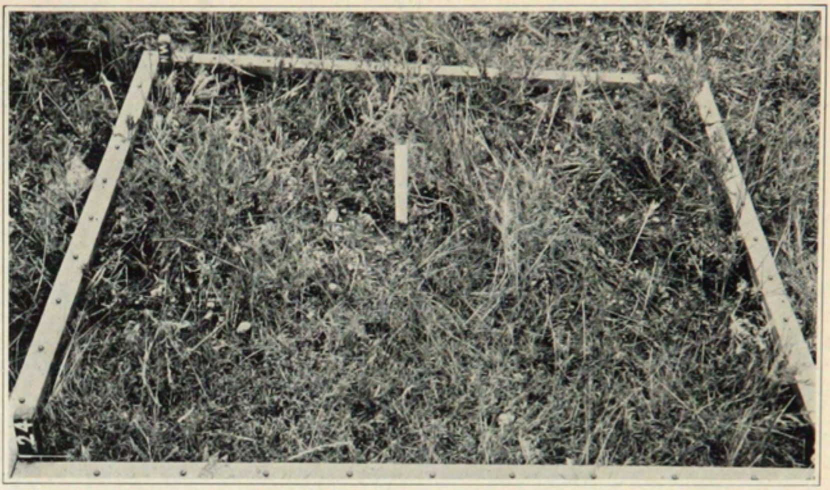

Fig. 27. Quadrat 24. July 24, 1928.

QUADRAT 24. OPENED TO GRAZING IN 1924 (FIGS. 26, 27 AND 28).

Will *Bulbilis* and *Agropyron* increase under deferred and rotation grazing?

PRINCIPAL SPECIES.—*Agropyron*.—Appears to have decreased greatly from 1926 to 1927 and gradually since then. In 1926 there were 34 flower stalks averaging 20 inches tall; in 1927, 1928 and 1930 there were no flower stalks.

Bulbilis.—2,452 sq. cm. in 1926, 2,097 in 1927, 2,812 in 1928, 3,514 in 1930.

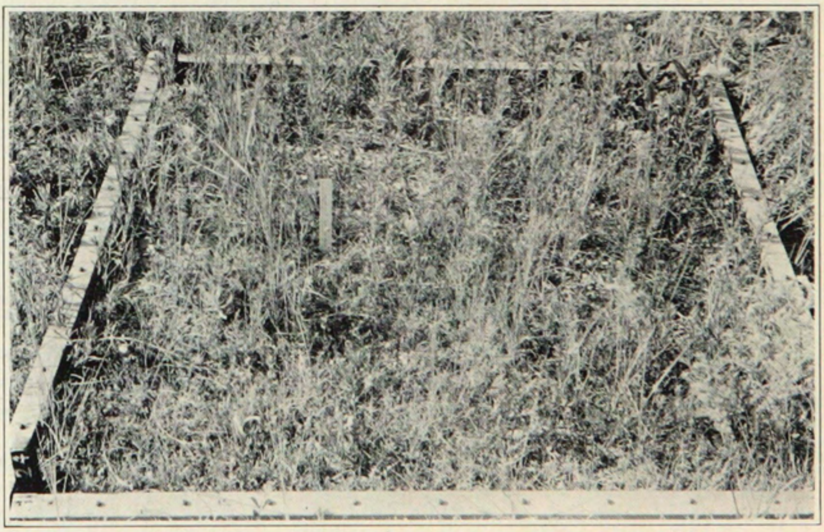

Fig. 28. Quadrat 24. June 14, 1930. *Agropyron* and *Bulbilis* (in foreground) increased. A number of forbs, especially *Aster*, also increased.

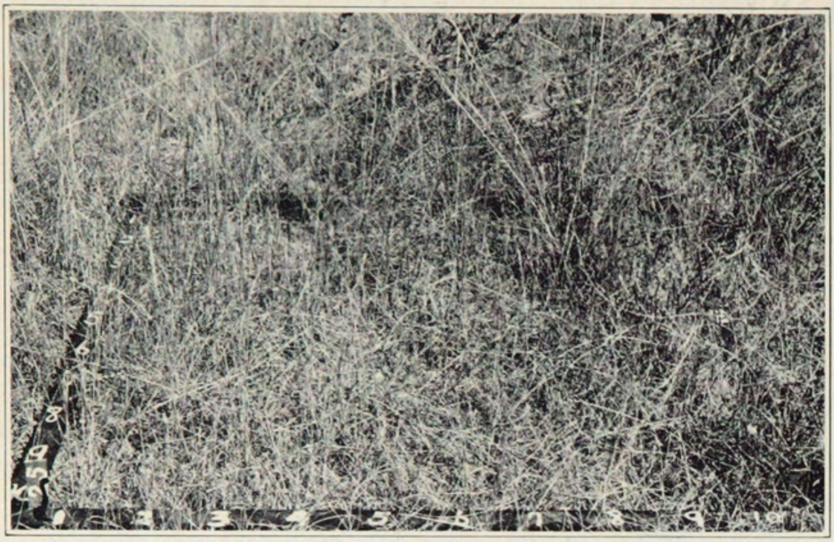

Fig. 29. Quadrat 25, closed to grazing in 1924, isolation transect, deferred and rotation pasture. August 28, 1926. See Figs. 30 and 31.

Aster.—140 stalks in 1926, 93 in 1927, 95 in 1928, 209 in 1930.

LESS IMPORTANT SPECIES.—*Schedonnardus.*—164 sq. cm. in 1926, 31 in 1927, 56 in 1928, 42 in 1930.

Artemisia gnaphalodes, Gaura, Malvastrum coccineum, Psoralea, Astragalus drummondii.—Increased slightly.

Helianthus pumilus, Sophora, Musineon, Senecio perplexus.—Remained about the same.

INFREQUENT TO SCARCE.—*Astralagus drummondii, Lesquerella, Viola, Allionia, Yucca, Eriogonum, Carex, Evolvulus, Helianthus annuus, Linum, Salsola, Festuca octoflora.*

ABSENT.—*Bulbilis, Aristida, Psoralea, Iva, Stipa viridula.*

CONCLUSIONS.—*Agropyron.*—The decrease in 1927 may have been due to less favorable soil moisture and to grazing which was not deferred in 1927, but was in 1926. Under deferred grazing in 1929 and 1930 unfavorable soil moisture may have prevented its increasing.

Bulbilis.—The considerable increase since 1926 was due perhaps to soil moisture conditions favoring the spread of this grass, but not the spread of *Agropyron.* Grazing before Aug. 15 in 1927 and 1928 would tend to handicap *Agropyron* but not *Bulbilis.*

Schedonnardus.—Decrease due perhaps to unfavorable conditions for seed production and establishment of seedlings.

This quadrat was in the area opened to grazing in 1924, and grazing was deferred in the years 1925, 1926, 1929 and 1930. *Bulbilis* and *Aster* both increased more in this quadrat than in the quadrat closed to grazing in 1924, but *Agropyron* decreased more in the latter where there was considerable competition with *Stipa.*

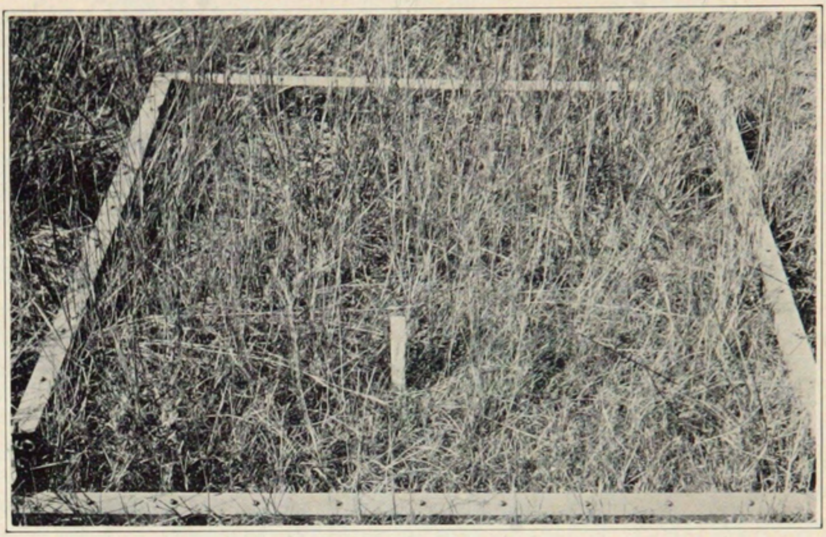

Fig. 30. Quadrat 25, July 23, 1928.

QUADRAT 25. CLOSED TO GRAZING IN 1924 (FIGS. 29, 30 AND 31).

Will *Bulbilis* lose out in competition with *Agropyron* and *Stipa?*

PRINCIPAL SPECIES.—*Agropyron.*—Decreased greatly from 1928 to 1930; slight

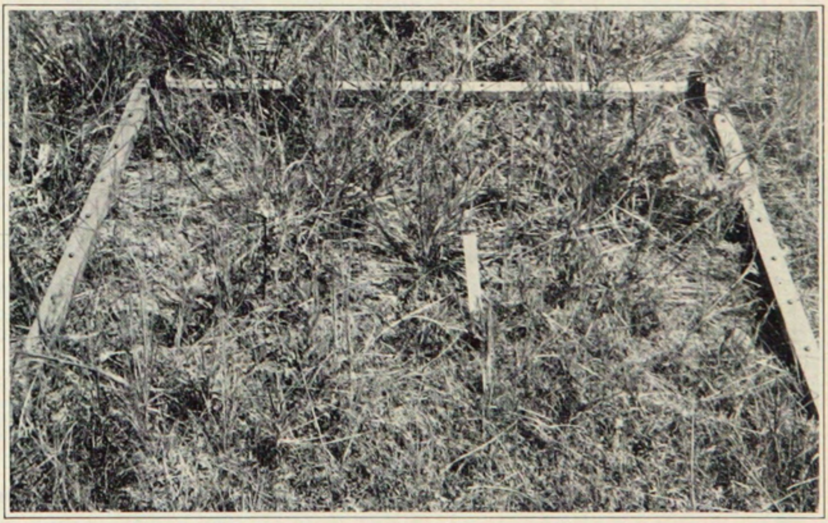

Fig. 31. Quadrat 25, June 21, 1930. *Agropyron* decreased. *Stipa viridula,* dark tufts in back part of quadrat, increased from 1928 to 1930. *Bulbilis,* in foreground, increased slightly. *Aster* increased from 9 stalks in 1926 to 27 in 1928, to 47 in 1930.

decrease from 1926 to 1928. Flower stalks: 64 in 1926, 10 in 1927, 3 in 1928, 0 in 1930.

Bulbilis.—2,345 sq. cm. in 1926, 2,247 in 1927, 2,265 in 1928, 2,615 in 1930.

Stipa viridula.—Decreased from 1926 to 1928; doubled from 1928 to 1930 (127 to 275 sq. cm.). Flower stalks: 36 in 1926, 6 in 1927, 11 in 1928, 4 in 1930.

Aster.—9 in 1926, 11 in 1927, 27 in 1928, 47 in 1930.

LESS IMPORTANT SPECIES.—*Schedonnardus.*—Great decrease from 1926 to 1927, 0 to scarce since.

FREQUENT.—*Senecio perplexus, Musineon.*

INFREQUENT TO SCARCE.—*Sophora, Malvastrum, Astragalus drummondii, A. hypoglottis, Gaura, Allionia, Stanleya, Sophia, Lesquerella, Lactuca, Evolvulus.*

ABSENT.—*Aristida, Psoralea, Iva, Helianthus pumilus, Artemisia gnaphalodes.*

CONCLUSIONS.—*Bulbilis.*—Increased slightly since 1928 due perhaps to favorable precipitation in summers of 1929 and 1930 for spread of this species but unfavorable for competitors.

Agropyron.—Decreased greatly (about 50 percent) since 1928, due perhaps to deficient soil moisture.

Stipa viridula.—Decreased a little from 1926 to 1928, increased slightly from 1928 to 1930. This increase may be due to decrease in competition from *Agropyron.*

Schedonnardus.—Decrease due perhaps to unfavorable conditions for seed production and establishment of seedlings.

In this quadrat, which was not grazed during the period 1924-1930, it appears that environmental conditions, in 1929 and 1930 especially, were favorable for the maintenance or increase in abundance of *Aster, Bulbilis* and *Stipa,* but unfavorable for *Agropyron.*

QUADRAT 23. CLOSED TO GRAZING IN 1925.

Growth under protection from grazing of *Agropyron,* not in competition with *Bulbilis, Aristida, Stipa* or *Aster.*

PRINCIPAL SPECIES.—*Agropyron.*—Abundance about the same in 1926 and in 1928, but decreased from 637 stalks in 1928 to 563 in 1930; 132 flower stalks in 1926, 3 in 1928, 0 in 1930.

Astragalus drummondii.—Increased from 0 in 1926 to 25 stalks in 1930.

Artemisia gnaphalodes.—Increased from 4 stalks in 1926 to 21 in 1930.

Helianthus pumilus.—16 stalks in 1926, 42 in 1928, 8 in 1930.

Schedonnardus.—Decreased from 491 sq. cm. in 1926 to 2 in 1928, to 6 in 1930.

LESS IMPORTANT SPECIES.—*Iva* and *Sophora* decreased in abundance.

Senecio perplexus.—Remained about the same.

INFREQUENT TO SCARCE.—*Sophia, Lygodesmia, Musineon, Linum, Euphorbia glyptosperma, Gaura, Lithospermum, Artemisia dracunculoides, Malvastrum.*

ABSENT.—*Bulbilis, Aristida, Psoralea, Aster, Stipa.*

CONCLUSIONS.—Decrease from 1928 to 1930 in *Agropyron* under total protection from grazing may be due to unfavorable moisture conditions. The increase in competition due to the greater abundance of *Astragalus drummondii* and *Artemisia gnaphalodes* was hardly counteracted by the decrease in numbers of *Helianthus, Schedonnardus, Iva* and *Sophora.*

QUADRAT 22. OPENED TO GRAZING IN 1925

Growth of *Agropyron* not in competition with *Bulbilis, Aristida* or *Aster,* under deferred and rotation grazing.

PRINCIPAL SPECIES.—*Agropyron.*—Decreased slightly since 1926. In 1926 there were 36 flower stalks, 1 in 1928 and 6 in 1930.

Schedonnardus.—433 sq. cm. in 1926, 274 in 1928, and 826 in 1930.

LESS IMPORTANT SPECIES.—*Iva.*—Decreased; 20 stalks in 1928 and 11 in 1930.

Sophora.—12 stalks in 1926, 6 in 1928 and 6 in 1930.

Gaura.—9 stalks in 1926, 30 in 1928 and 23 in 1930.

Musineon (31 stalks in 1930), *Senecio perplexus* (26 stalks in 1930), *Malvastrum, Artemisia gnaphalodes.*—Remained about the same.

INFREQUENT TO SCARCE.—*Astragalus drummondii, Gutierrezia, Eriogonum effusum, Yucca, Artemisia gnaphalodes, Liatris, Stipa viridula, Festuca octoflora, Euphorbia glyptosperma, Lactuca.*

ABSENT.—*Bulbilis, Aristida, Psoralea, Aster, Helianthus pumilus.*

CONCLUSIONS.—In spite of the lack of deferred grazing in 1927 and 1928 and unfavorable growing conditions in 1929 and in 1930, *Agropyron* did not decrease greatly between 1926 and 1930. The absence of strong competitors as *Bulbilis* and *Aster* may have had much influence.

QUADRAT 21. CLOSED TO GRAZING IN 1927.

Effect of a change from deferred and rotation grazing to protection upon a stand consisting chiefly of *Agropyron, Schedonnardus, Aster* and other forbs.

PRINCIPAL SPECIES.—*Agropyron.*—Little change from 1926 to 1928, large decrease from 1928 to 1930; 98 flower stalks in 1926, 5 in 1928, 0 in 1930. Total number of stalks in 1930 was 480.

Schedonnardus.—1,101 sq. cm. in 1926, 110 in 1928, 22 in 1930.

Aster.—26 stalks in 1926, 69 in 1928, 90 in 1930.

LESS IMPORTANT SPECIES.—*Sophora.*—16 stalks in 1926, 17 in 1928, 7 in 1930.

Artemisia gnaphalodes.—Increased; 2 stalks in 1928, 31 in 1930.

Senecio perplexus.—30 stalks in 1930.

Iva.—Decreased considerably; 4 stalks in 1930.

INFREQUENT TO SCARCE.—*Lithospermum, Musineon, Gaura, Viola, Astragalus drummondii, Lygodesmia, Gutierrezia, Helianthus pumilus, Euphorbia robusta, Draba, Polygonum douglasii, Anogra albicaulis.*

ABSENT.—*Bulbilis, Aristida, Psoralea, Stipa, Malvastrum.*

CONCLUSIONS.—*Agropyron, Schedonnardus, Sophora* and *Iva* decreased considerably, but *Aster* increased greatly, under total protection from grazing.

QUADRAT 20. OPENED TO GRAZING IN 1927 (FIGS. 32, 33 AND 34).

Effect of a change from total protection to deferred and rotation grazing upon a stand consisting chiefly of *Agropyron, Schedonnardus, Helianthus pumilus* and forbs.

PRINCIPAL SPECIES.—*Agropyron.*—Appears to have increased; 140 flower stalks in 1926, 0 in 1928, 7 in 1930. Total stalks in 1930, 489.

Schedonnardus.—84 sq. cm. in 1926, 229 in 1928, 912 in 1930.

Helianthus pumilus.—Decreased greatly from 1926 to 1928; 5 stalks in 1928, 6 in 1930.

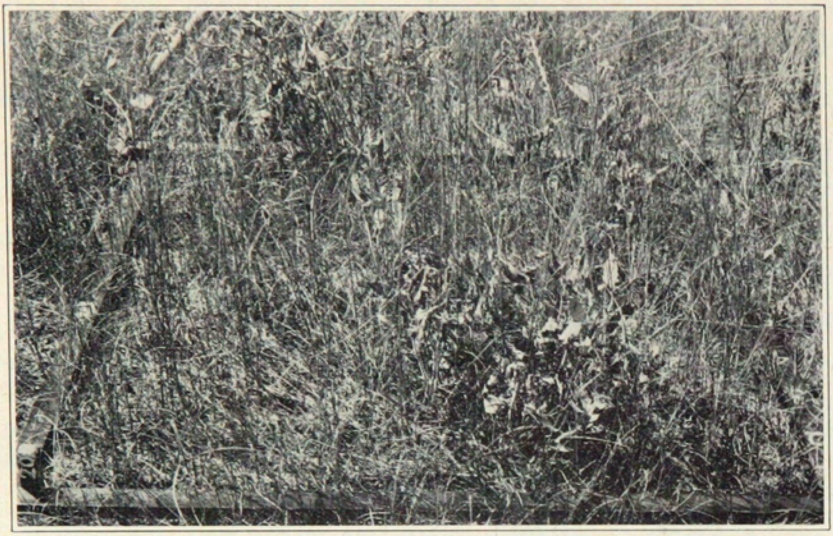

Fig. 32. Quadrat 20, opened to grazing in 1927, isolation transect, deferred and rotation pasture. August 27, 1926. See Figs. 33 and 34.

LESS IMPORTANT SPECIES.—*Aster.*—1 stalk in 1926 and in 1928, 35 in 1930.

Aristida.—0 in 1926, 29 sq. cm. in 1928, 25 in 1930.

Senecio perplexus.—21 stalks in 1930.

Musineon.—25 stalks in 1930.

INFREQUENT TO SCARCE.—*Yucca, Bahia, Allionia, Malvastrum, Sophora, Artemisia gnaphalodes, Pentstemon, Astragalus hypoglottis, A. drummondii, Lesquerella, Taraxacum, Euphorbia glyptosperma.*

ABSENT.—*Bulbilis, Psoralea, Iva, Stipa.*

CONCLUSIONS.—In contrast to Quadrat 21 which was closed to grazing in 1927 and in which *Agropyron* decreased considerably, there was not much change in abundance of *Agropyron* in this quadrat. *Helianthus* (relished by the cattle) decreased, while *Aster* (usually not grazed), *Schedonnardus* (grazed) and *Aristida* (grazed) increased.

QUADRAT 31. CLOSED TO GRAZING IN 1928.

Effect of a change from deferred and rotation grazing to protection upon a stand consisting chiefly of *Agropyron, Bulbilis, Schedonnardus* and forbs.

PRINCIPAL SPECIES.—*Agropyron.*—Does not appear to have changed much since 1927; 4 flower stalks in 1927, 5 in 1928, 0 in 1930. Total stalks in 1930, 718.

Bulbilis.—900 sq. cm. in 1927, 617 in 1928, 1,332 in 1930.

Schedonnardus.—93 sq. cm. in 1927, 130 in 1928, 97 in 1930.

Artemisia gnaphalodes.—Increased; 39 stalks in 1928, 73 in 1930.

LESS IMPORTANT SPECIES.—*Sophora.*—20 stalks in 1927, 21 in 1928, 15 in 1930.

Senecio perplexus.—16 stalks in 1930.

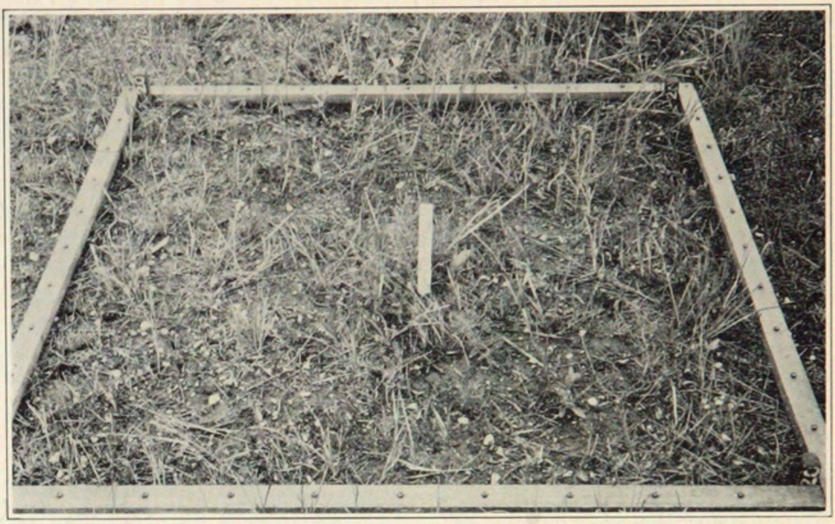

Fig. 33. Quadrat 20, July 24, 1928.

INFREQUENT TO SCARCE.—*Gutierrezia, Astragalus drummondii, A. hypoglottis, Psoralea, Yucca, Lygodesmia, Sophia, Musineon, Euphorbia glyptosperma.*

ABSENT.—*Aristida, Aster, Iva, Helianthus pumilus, Stipa, Malvastrum.*

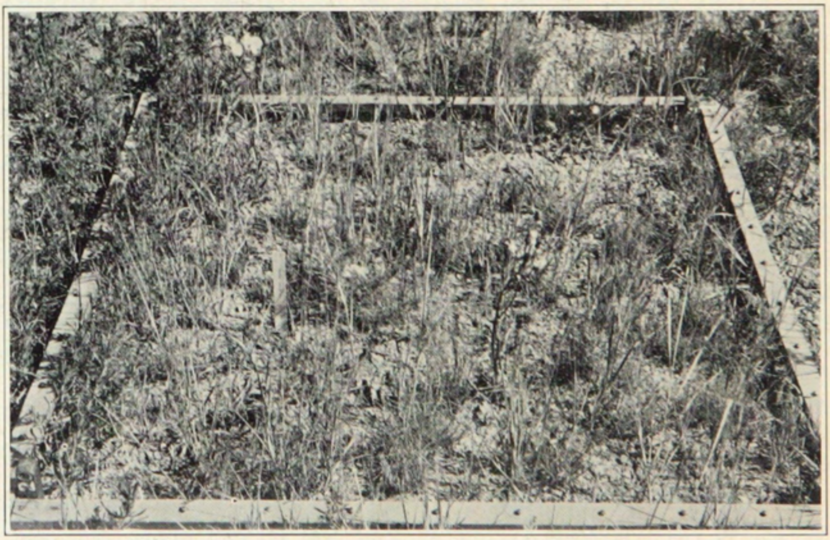

Fig. 34. Quadrat 20, June 16, 1930. The abundance of *Agropyron* changed but little. *Helianthus pumilus* (prominent in foreground in Fig. 32) decreased, while *Aster* and *Aristida* increased.

CONCLUSIONS.—*Agropyron* and *Schedonnardus* remained about the same; *Bulbilis* and *Artemisia gnaphalodes* increased; *Sophora* decreased.

QUADRAT 32. OPENED TO GRAZING IN 1928.

Effect of a change from protection to deferred and rotation grazing upon a stand composed chiefly of *Agropyron, Schedonnardus, Aster* and other forbs.

PRINCIPAL SPECIES.—*Agropyron.*—Decreased somewhat from 1927 to 1928; increased slightly from 1928 to 1930; 1 flower stalk in 1927, 0 in 1928, 1 in 1930. Total stalks in 1930, 540.

Schedonnardus.—153 sq. cm. in 1927, 65 in 1928, 150 in 1930.

Aster.—28 stalks in 1927, 17 in 1928, 92 in 1930.

Astragalus hypoglottis.—Increased; 1 stalk in 1928, 47 in 1930.

LESS IMPORTANT SPECIES.—*Sophora.*—About 22 stalks in 1927, 11 in 1928, 4 in 1930.

Artemisia gnaphalodes.—9 stalks in 1927, 3 in 1928, 23 in 1930.

Astragalus drummondii.—1 stalk in 1927, 3 in 1928, 15 in 1930.

Senecio perplexus.—18 stalks in 1930.

Liatris.—Increased; 27 stalks in 1930.

INFREQUENT TO SCARCE.—*Gaura, Helianthus pumilus, Lesquerella, Linum, Musineon, Eriogonum effusum, Viola, Yucca, Tragopogon.*

ABSENT.—*Bulbilis, Psoralea, Iva, Stipa, Malvastrum.*

CONCLUSIONS.—The abundance of *Agropyron* and *Schedonnardus* changed but little; *Aster, Astragalus hypoglottis, A. drummondii, Artemisia gnaphalodes* and *Liatris* increased; *Sophora* decreased.

QUADRAT 33. CLOSED TO GRAZING IN 1929.

Effect of a change from deferred and rotation grazing to protection upon a stand composed chiefly of *Agropyron, Bulbilis, Schedonnardus, Artemisia gnaphalodes* and other forbs.

PRINCIPAL SPECIES.—*Agropyron.*—Increased in abundance about 25 percent from 1928 to 1930; 3 flower stalks in 1928, 7 in 1930. Total stalks in 1930, 525.

Bulbilis.—309 sq. cm. in 1928, 604 in 1930.

Schedonnardus.—193 sq. cm. in 1928, 62 in 1930.

Artemisia gnaphalodes.—25 stalks in 1928, 54 in 1930.

LESS IMPORTANT SPECIES.—*Sophora.*—16 stalks in 1928, 22 in 1930.

Senecio perplexus.—29 stalks in 1930.

INFREQUENT TO SCARCE.—*Musineon, Psoralea, Lesquerella, Allionia, Astragalus missouriensis, A. hypoglottis, Pentstemon, Lactuca, Liatris, Euphorbia glyptosperma, Gutierrezia.*

ABSENT.—*Aristida, Aster, Iva, Helianthus pumilus, Stipa, Astragalus drummondii, Malvastrum.*

CONCLUSIONS.—Increases occurred in *Agropyron, Bulbilis, Artemisia gnaphalodes* and *Sophora.* A decrease occurred in *Schedonnardus.*

QUADRAT 34. OPENED TO GRAZING IN 1929.

Effect of a change from protection to deferred and rotation grazing upon a stand composed chiefly of *Stipa viridula, Aristida, Agropyron, Aster* and other forbs.

PRINCIPAL SPECIES.—*Agropyron.*—Decreased more than 50 percent from 1928 to 1930; 134 stalks in 1930.

Stipa viridula.—339 sq. cm. and 16 flower stalks in 1928, 542 sq. cm. and 24 flower stalks in 1930.

Aristida.—182 sq. cm. in 1928, 86 in 1930.

Aster.—46 stalks in 1928, 65 in 1930.

LESS IMPORTANT SPECIES.—*Iva.*—18 stalks in 1928, 21 in 1930.

Artemisia gnaphalodes.—10 stalks in 1928, 24 in 1930.

Astragalus drummondii.—Decreased; 8 stalks in 1930.

Malvastrum.—17 stalks in 1928, 14 in 1930.

Opuntia.—115 sq. cm. in 1928, 95 in 1930.

Astragalus hypoglottis.—19 stalks in 1928, 93 in 1930.

Gaura.—15 stalks in 1928, 3 in 1930.

Senecio perplexus.—4 stalks in 1930.

INFREQUENT TO SCARCE.—*Linum, Musineon, Yucca, Liatris, Lavauxia, Draba, Lithospermum, Anogra.*

ABSENT.—*Bulbilis, Psoralea, Helianthus pumilus.*

CONCLUSIONS.—This is one of the very few quadrats where *Agropyron* was less important than other species. *Stipa,* the chief species, increased considerably while *Agropyron* decreased more than 50 percent. Decreases also occurred in *Aristida, Astragalus drummondii, Malvastrum* and *Gaura.* Increases occurred also in *Aster, Astragalus hypoglottis, Iva* and *Artemisia gnaphalodes.*

QUADRAT 35. CLOSED TO GRAZING IN 1930.

Grazing was deferred on this quadrat in 1929, but not grazed in 1930.

PRINCIPAL SPECIES.—*Agropyron.*—616 stalks in 1929, 645 in 1930. There were 40 flower stalks in 1929, 12 in 1930.

Bulbilis.—1,054 stalks in 1929, 1,501 in 1930.

Stipa viridula.—56 sq. cm. and 7 flower stalks in 1929, 107 sq. cm. and 20 flower stalks in 1930.

Senecio perplexus.—33 stalks in 1929, 25 in 1930.

LESS IMPORTANT SPECIES.—*Schedonnardus.*—0 in 1929, 21 stalks in 1930.

Musineon.—60 stalks in 1929, 15 in 1930.

INFREQUENT TO SCARCE.—*Gaura, Sophora, Lesquerella, Yucca, Allionia, Stanleya, Astragalus hypoglottis, Sophia, Artemisia gnaphalodes, Eriogonum, Malvastrum, Mamillaria, Psoralea, Polygonum douglasii, Draba, Quincula, Lithospermum.*

ABSENT.—*Aristida, Aster, Iva, Helianthus pumilus, Astragalus drummondii.*

CONCLUSIONS.—Increases occurred in *Agropyron, Bulbilis, Stipa* and *Schedonnardus;* decreases in *Senecio* and *Musineon.*

QUADRAT 36. OPENED TO GRAZING IN 1930.

There was no change in the grazing on this quadrat because grazing was deferred in 1930.

PRINCIPAL SPECIES.—*Agropyron.*—104 stalks in 1929, 101 in 1930.

Stipa viridula.—In 1929 the area covered by the clumps was 974 sq. cm., in which there was a total of 135 live stalks, 16 of which were flower stalks. In 1930 the area was 481 sq. cm.; total live stalks 254, of which 9 were flower stalks.

Fig. 35. Quadrat 20, not grazed since 1920. Sept. 3, 1926. See Figs. 36 and 37.

Bulbilis.—502 stalks in 1929, 657 in 1930.

Artemisia gnaphalodes.—13 stalks in 1929, 47 in 1930.

LESS IMPORTANT SPECIES.—*Aster.*—19 stalks in 1929, 27 in 1930.

Senecio perplexus.—24 stalks in 1929, 20 in 1930.

INFREQUENT TO SCARCE.—*Musineon, Gaura, Linum, Sophora, Pentstemon, Lesquerella, Iva, Gutierrezia, Lactuca, Aristida.*

ABSENT.—*Schedonnardus, Psoralea, Astragalus drummondii, Malvastrum.*

CONCLUSIONS.—The abundance of *Stipa, Bulbilis, Artemisia gnaphalodes* and *Aster* increased; that of *Agropyron* and *Senecio* was slightly reduced.

QUADRAT 30. NOT GRAZED SINCE 1920 (FIGS. 35, 36 AND 37).

Effect of total exclusion of livestock upon a stand composed chiefly of *Agropyron, Stipa* and forbs.

PRINCIPAL SPECIES.—*Agropyron.*—About 350 stalks in 1921, about 340 in 1928, and 411 in 1930.

Stipa viridula.—336 sq. cm. in 1921, 1,048 in 1926, 305 in 1928, 145 in 1930. In 1926 there were 53 flower stalks, 0 in 1928 and 1930.

LESS IMPORTANT SPECIES.—*Schedonnardus.*—19 sq. cm. in 1921, 97 in 1926, 16 in 1928, 25 in 1930.

Aster.—2 stalks in 1926, 4 in 1928, 21 in 1930.

Helianthus pumilus.—Increased from 1926 to 1928, decreased from 1928 to 1930. There were 16 stalks in 1930.

Artemisia gnaphalodes.—2 stalks in 1926, 8 in 1928, 20 in 1930.

Senecio perplexus.—24 stalks in 1930.

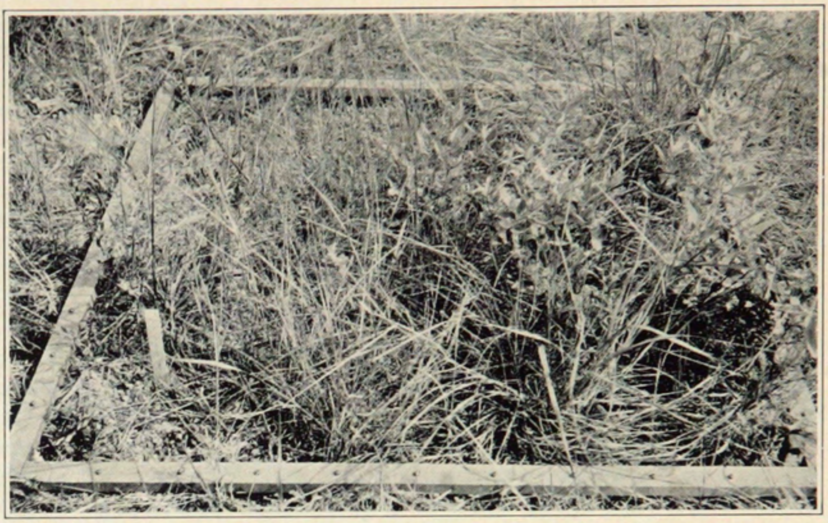

Fig. 36. Quadrat 30, July 28, 1928.

INFREQUENT TO SCARCE.—*Sophora, Astragalus drummondii, A. hypoglottis, Iva, Linum, Musineon, Gaura, Yucca, Liatris, Bahia, Lavauxia, Malvastrum, Lithospermum, Draba, Gutierrezia, Cryptantha.*

ABSENT.—*Bulbilis, Aristida.*

CONCLUSIONS.—The abundance of *Agropyron* varied somewhat from year to year. The number of stalks was greater in 1930 than in the other 3 years

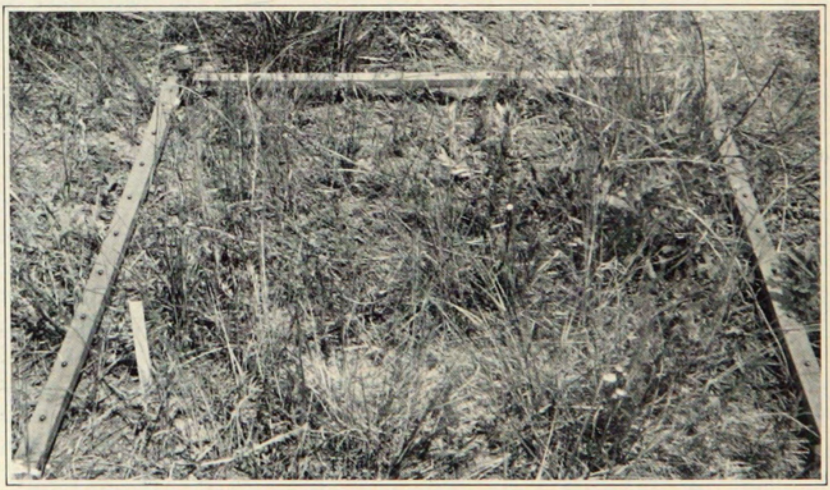

Fig. 37. Quadrat 30, June 21, 1930. The fluctuations in abundance of *Agropyron, Stipa viridula* and forbs appear to be due chiefly to changes in the competition pressure of associated species.

when records were made. *Stipa* showed a considerable increase in 1926 compared to 1921, but decreased greatly in 1928 and even more in 1930. This decrease in *Stipa* may have made possible the increase in *Agropyron* due to lessened competition and because *Agropyron* suffered less from unfavorable soil-moisture conditions than *Stipa*. *Aster* and *Artemisia gnaphalodes* increased from 2 each in 1926 to 21 and 20, respectively, in 1930. *Schedonnardus* and a large number of forbs showed minor fluctuations. The variations in the composition of the vegetation in this quadrat appear to be due to increase or decrease in the competition pressure of various species as modified by favorable or unfavorable climatic or soil conditions, principally soil moisture.

TEN-METER-SQUARE QUADRATS IN CONTINUOUS AND IN DEFERRED AND ROTATION PASTURES.—On account of the apparently greater number of certain weed-like forbs in the continuously grazed pastures, two 10-meter-square quadrats, one in each pasture, were located and marked by permanent stakes in 1926 in order to secure quantitative data. These quadrats were located on very similar soil, close to each other, but separated by the fence dividing the pastures. The results of the counts are given in Table 12.

Table 12.—Number of Plants in Each 10-Meter-Square Quadrat in 4 Years.

Species	Deferred and Rotation Pasture				Continuous Pasture			
	1926	1927	1928	1930	1926	1927	1928	1930
Psoralea tenuiflora	53	46	90	128	40	94	97	165
Carduus undulatus	0	0	0	0	13	11	6	2
Argemone intermedia	6	3	6	8	7	7	8	5
Senecio spartioides	0	0	0	0	4	4	5	5
Opuntia spp.	4	5	5	6	4	7	6	12
Gutierrezia longifolia	..	..	18	70	..	..	4	50
Stanleya pinnata	..	1	1	0	..	0	0	4
Artemisia frigida	7	6	..	1	4	2	..	2
Yucca glauca	1	1	1	1	0	0	0	0
Astragalus drummondii	..	..	1	161	..	..	0	27
Helianthus pumilus	..	..	12	16	..	..	34	37

All of the species in Table 12, except the last two (*Helianthus* and *Astragalus*) were usually not grazed by the cattle, but the last two were usually closely grazed. Both of these desirable species increased in both pastures, and the increase from 1 to 161 plants of *Astragalus* in the deferred and rotation pasture between 1928 and 1930 is particularly noteworthy. *Psoralea* and *Opuntia*, both very undesirable from a grazing viewpoint, increased more rapidly in the continuous pasture; but *Gutierrezia*, which is also very undesirable, increased more rapidly in the deferred and rotation pasture.

The effects of the differences in the grazing systems upon these species is conflicting. It seems that the desirable grazing plants should increase more rapidly where deferred and rotation grazing

Table 13.—Abundance of Selected Species on Quadrats 16 by 16 Feet Square Within the 20-by-20-Feet Areas Opened or Closed to Grazing in 1927. Isolation Transect, Continuous Pasture. Figures are Number of Stalks Unless Otherwise Indicated. Ab, Abundant; F, Frequent; I, Infrequent; S, Scarce.

Species	Area Opened to Grazing			Area Closed to Grazing		
	1927	1928	1930	1927	1928	1930
Bulbilis, sq. dcm	108	91	112	137	123	162
Bouteloua, sq. dcm	6.5	7.5	9.0	22.3	17.6	25.6
Aster	35	78	126	205	190	339
Iva	0	0	0	. .	F	405
Psoralea	. .	77	103	. .	48	58
Gutierrezia	. .	5	30	2	6	6
Liatris	15	25	67	20	18	53
Linum	6	. .	18	28	. .	35
Artemisia gnaphalodes	126	153	271	35	43	76
A. frigida	6	. .	1	. .	. .	. .
Gaura	. .	22	23	. .	93	64
Yucca	5	2	4	4	7	9
Astragalus hypoglottis	. .	197	475	. .	174	773
Lygodesmia	3	1	5	49	48	83
Petalostemon	3	9	23	23	. .	141
Evolvulus	18	33	63	62	83	134
Allionia	1	3	8	13	6	5
Sophora	. .	3	5	. .	41	37
Helianthus pumilus	14 (cl.)	46	58 (st.)	20 (cl.)	39	150 (st.)
Bahia	. .	25	55	. .	19	14
Erysimum	. .	1	23	. .	. .	3
Euphorbia robusta	. .	3	2	. .	15	40
Opuntia	. .	. .	1	. .	1	6
Agropyron	Ab	Ab	Ab	Ab	Ab	Ab
Aristida	F	F	F	F	F	F
Schedonnardus	S	S	S	I	S	S
Stipa	S	S	. .	. .	O	S
Astragalus drummondii	. .	. .	. .	. .	. .	3
Malvastrum	. .	. .	4	29	28	25
Astragalus missouriensis	. .	12	24	. .	27	69

is practiced, but the evidence is not convincing that such is the case. It also seems that under continuous grazing the desirable plants which are cropped at all seasons of the year would be replaced by undesirable plants, but again the data are conflicting. Some undesirable species did increase, but others, just as undesirable, decreased. In order to secure clearer evidence, quadrat counts of this sort should be extended over at least a 10-year period and detailed studies should be made of the life history of every important species in each quadrat.

MAJOR QUADRATS IN ISOLATION TRANSECTS IN THE CONTINUOUS PASTURE.—The vegetation in each of the 4 areas (20 by 20 feet square) opened and closed to grazing in 1927 and in 1928 was studied intensively in 1927, 1928 and 1930 for the first two, and in 1928 and 1930 for the last two. A strip, 4 feet wide, was discarded in each area because of the effect of cattle extending their heads

Table 14.—Abundance of Selected Species on Quadrats 16 by 16 Feet Square Within the 20-by-20-Feet Areas Opened or Closed to Grazing in 1928. Isolation Transect, Continuous Pasture. Ab, Abundant; F, Frequent; I, Infrequent; S, Scarce.

Species	Area Opened to Grazing		Area Closed to Grazing	
	1928	1930	1928	1930
Bulbilis, sq. dcm.	89	195	25	23
Bouteloua, sq. dcm.	0	0	5.0	7.2
Aster	71	192	414	578
Iva	..	..	1	2
Psoralea	103	122	42	9
Gutierrezia	25	63	3	4
Liatris	14	41	32	87
Linum	79	81	16	19
Artemisia gnaphalodes	110	204	113	139
A. frigida	2	1	..	..
Gaura	21	35	77	80
Yucca	13	11	4	3
Astragalus hypoglottis	48	118	98	313
A. missouriensis	7	6	22	34
A. drummondii	..	3	..	..
Lygodesmia	1	1	13	18
Petalostemon	78	53	56	75
Evolvulus	133	159	27	99
Allionia	11	4	..	..
Sophora	13	13	..	5
Helianthus pumilus	27	24	30	79
Bahia	..	..	15	31
Erysimum	..	11	..	1
Euphorbia robusta	7	11	12	21
Opuntia	3	2	1	..
Agropyron	Ab	Ab	Ab	Ab
Aristida	Ab	F	F	F
Schedonnardus	S	S	I	I
Stipa	0	0	S	S
Malvastrum	..	..	16	8

thru the fence and grazing. The size of the quadrats was therefore 16 by 16 feet. Each quadrat was permanently marked with an iron stake in each corner. The results of the listing and mapping for the quadrats in the areas opened in the early spring of 1927 and 1928 and the areas closed at the same times are given in Tables 13 and 14. Data are given for only selected species because there was insufficient time to count or map all of the species on such large areas.

Analysis of Tables 13 and 14 reveals a few definite changes that appear to be due to opening or closing of the areas to grazing. A few species, *Psoralea, Gutierrezia* and *Artemisia gnaphalodes* increased on both areas opened to grazing and decreased in abundance or increased less on both areas closed to grazing. Two species, *Petalostemon oligophyllus* and *Helianthus pumilus,* increased less, or actually decreased, on the areas opened to grazing than on the areas closed

Table 15.—Dry Weights (Oven Dried at 100-110°C.) of Grasses and Forbs of 8 Square-Meter Quadrats Located in Various Types of Grassland, Clipped Once a Year at the Close of the Growing Season.

Quadrat		1927, Grams	1928, Grams	1929, Grams	1930, Grams
	Grasses	266.1	310.3	132.2	173.7
1. *Agropyron*, dense stand	Forbs	0	56.4	57.3	0.6
	Totals	266.1	366.7	189.5	174.3
	Grasses	115.5	88.4	15.7	21.3
2. *Agropyron*, medium dense stand	Forbs	21.0	44.3	58.0	42.3
	Totals	136.5	132.7	73.7	63.6
	Grasses	54.7	51.4	26.8	22.7
3. *Agropyron*, open stand	Forbs	32.2	46.2	56.3	23.5
	Totals	86.9	97.6	83.1	46.2
	Grasses	...	80.7	45.9	29.6
4. *Bulbilis*, dense stand	Forbs	...	19.5	16.0	16.3
	Totals	131.4	100.2	61.9	45.9
	Grasses	98.7	111.4	43.3	32.2
5. *Stipa viridula*, medium dense stand	Forbs	39.7	30.7	28.5	15.8
	Totals	138.4	142.1	71.8	48.0
	Grasses	181.6	57.0	33.7	39.1
6. *Andropogon scoparius*, medium dense stand	Forbs	14.2	19.5	9.3	4.8
	Totals	195.8	76.5	43.0	43.9
	Grasses	123.7	58.7	37.4	39.4
7. *Andropogon furcatus*, medium dense stand	Forbs	15.3	25.7	7.9	12.1
	Totals	139.0	84.4	45.3	51.5
	Grasses	38.6	34.1	27.7	5.7
8. *Bouteloua*, dense stand	Forbs	18.5	39.0	60.6	24.0
	Totals	57.1	73.1	88.3	29.7

to grazing. The first three of these five species were usually not grazed, the second two, especially *Helianthus*, were grazed. It appears, then, that increases in the abundance of *Psoralea* and *Gutierrezia* especially, and decreases in *Helianthus pumilus*, indicate deterioration of this range. Decreases in *Psoralea* and *Gutierrezia* and increases in *Helianthus pumilus* indicate range improvement. These species appear to be fairly sensitive indicators of range management. Some of the species in the tables increased under both conditions (closing or opening), some decreased, and other species did not show consistent results. These species may be less sensitive to changes in grazing or other factors may obscure the effect of grazing or protection from grazing. In order to secure further definite conclusions it is necessary to extend the investigation over a longer period of time as well as to include additional areas.

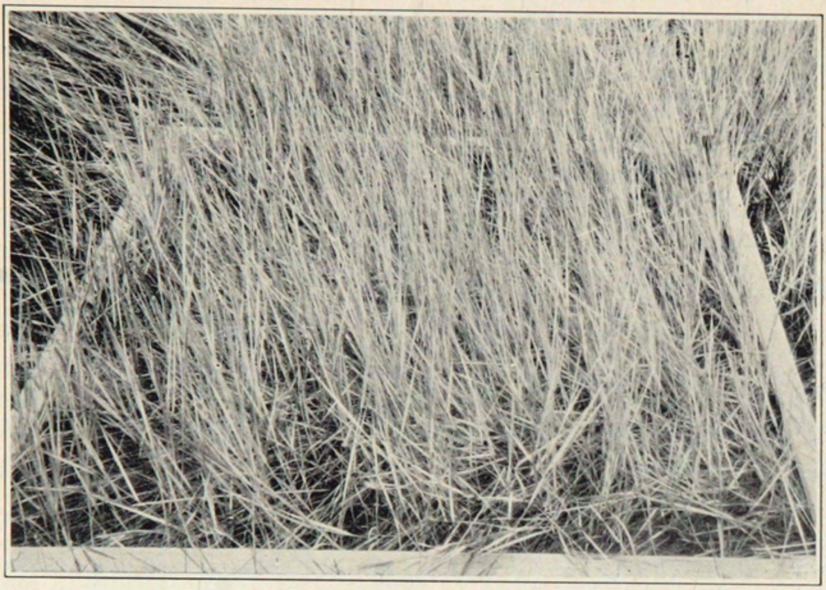

Fig. 38. Quadrat C1 on July 30, 1927, not grazed but clipped once a year at height of 3 inches when plants were mature. See Figs. 39, 40 and 41. Photographs taken just before clipping.

Fig. 39. Quadrat C1, August 4, 1928.

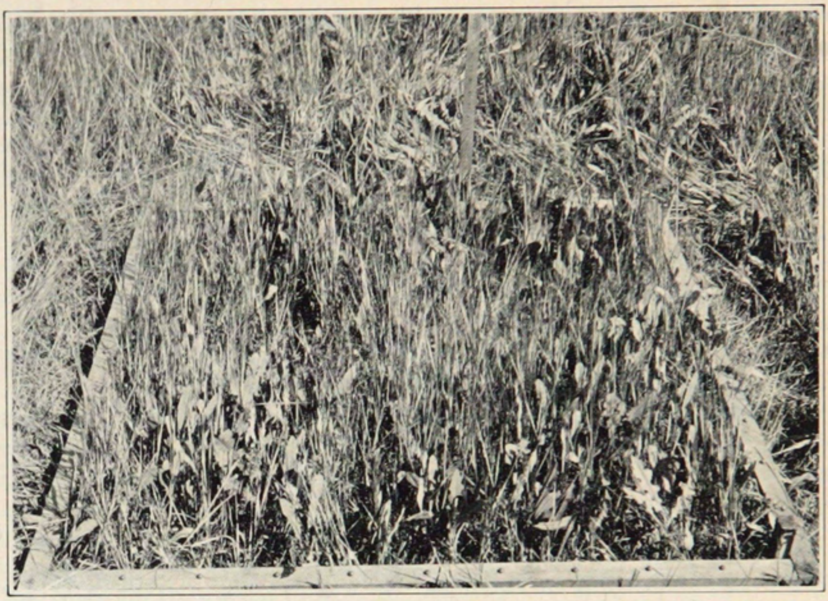

Fig. 40. Quadrat C1, July 9, 1929.

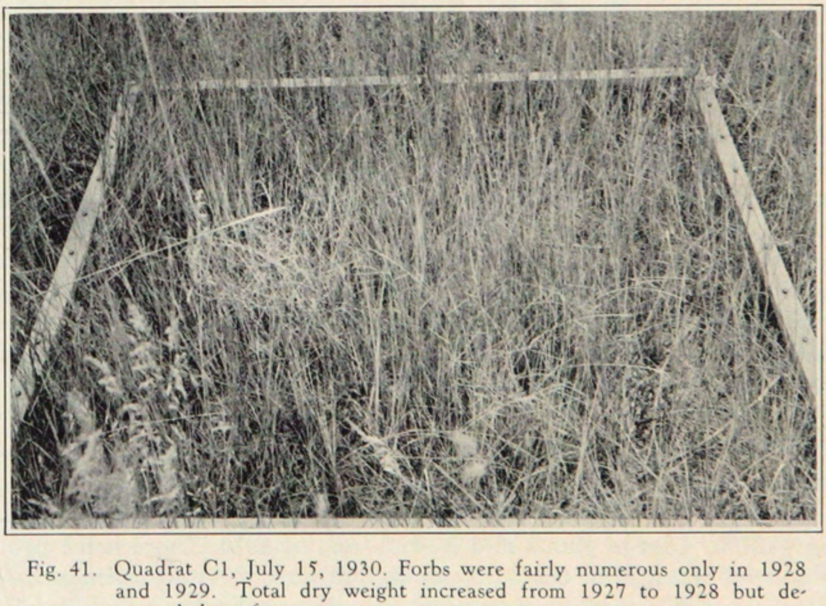

Fig. 41. Quadrat C1, July 15, 1930. Forbs were fairly numerous only in 1928 and 1929. Total dry weight increased from 1927 to 1928 but decreased thereafter.

CLIPPED QUADRATS.—Eight square-meter quadrats were established in different types of grassland to measure the dry weight of the forage produced each year. Each quadrat was located in an area not open to grazing. The vegetation was clipped at a height of 3 inches, except in the *Bulbilis* and *Bouteloua* quadrats, where the height was 1 inch, and in *Stipa,* where it was 4 inches. The clipping was done after growth had been completed and before the seeds began to fall. The plants were separated after clipping into forbs or grasses, and the dry weights (at 100-110° C.) of each secured. These data are given here because they may be of some importance in interpreting the other quadrat data as well as to indicate variations from year to year in the amount of forage available to the livestock. The results are tabulated in Table 15.

The chief significance of the data presented in Table 15 appears to be that the forage production in 1929 and in 1930 was much below that of 1927 and 1928. In most cases less forage was produced in 1930 than in 1929. These decreases appear to be due to the unfavorable moisture conditions during these 2 years. This conclusion may not be warranted by the data because there is a progressive decline in dry weight in half of the quadrats from 1927 to 1930. The declines may be due to the effects of clipping, but this appears unlikely because the vegetation was cut so high (1 to 4 inches) and after the close of the growing season.

Quadrat 1 (Figs. 38, 39, 40 and 41) was particularly interesting. It was located in as dense and pure a stand of *Agropyron Smithii* as could be found in the area under study. In 1927 no forbs were present. In 1928 a rather large number of forbs (56.4 g. dry weight) had invaded. These were *Leptilon canadense, Helianthus annuus, Lactuca* and *Iva axillaris.* In 1929 there was about the same dry weight of forbs, but *Lactuca* was the chief one. *Iva* and *Tragopogon* were also present but scarce. In 1930 the forbs had practically disappeared (weighed only 0.6 grams). The causes of this invasion and disappearance were not studied, but there was no relationship to grazing because this quadrat was located in a fairly large exclosure. The chief factors involved appear to be those associated with migration, establishment of seedlings, and competition of *Agropyron.*

The results in Quadrat 3 were contrary to expectations. *Agropyron* decreased from about 75 percent of the stand in 1927 to less than 10 percent in 1930. *Stipa viridula* increased from 3 small plants in 1927 to 4 large plants and 1 small one in 1930. There were pronounced changes in the forb population also. *Artemisia dracunculoides* and *Malvastrum* decreased greatly, while *Artemisia gnaph-*

alodes increased considerably. In Quadrat 5, also, *Stipa* increased in vigor and abundance, while *Agropyron* decreased.

If variations as these appear from year to year in vegetation in clipped quadrats under protection from grazing, similar variations, not caused by grazing, may be expected in vegetation that is being grazed. If the vegetation were being grazed, however, and such variations appeared, there would be a tendency to ascribe them to some phase of grazing, as too frequent or too close cropping, changes in the grazing system, etc. It should be emphasized that changes in the vegetation should not be ascribed to the influence of any one factor until ample, clear evidence is at hand.

SUMMARY OF QUADRATS.—The data from most of the quadrats in the isolation transects indicate that the abundance of *Agropyron Smithii* increased under continuous grazing and decreased under total protection from grazing. There appears to be an important relationship in some of the increases of *Agropyron* to the abundance of *Aristida*. The isolation transect was located on soil that contained considerable gravel. Under protection this soil was more favorable for the growth of *Aristida* than for the growth of *Agropyron*. When grazed continuously, however, *Aristida* usually decreased, while *Agropyron* increased, because the tufts of *Aristida* were, more or less, cut, kicked or pulled out of the soil by the cattle. *Agropyron* was not damaged in any of these ways and the lessened competition of *Aristida* would favor its spreading.

In some quadrats, however, there were decreases under protection and increases under continuous grazing in the abundance of *Agropyron* when no *Aristida* was present. There were increases in the numbers of forbs under both conditions. In these quadrats it appears that moderate intensity of continuous grazing, as was practiced here, on the gravelly clay type of soil, was more favorable for the production of stalks of *Agropyron* than was total protection from grazing.

When opened or closed to deferred and rotation grazing, there were more quadrats that showed decreases than increases in the abundance of *Agropyron*. This soil was much less gravelly than in the isolation transect in the continuous pasture. The results for the quadrats closed to deferred and rotation grazing were similar to those for the quadrats opened to this method of grazing. It appears, then, that entire protection from grazing has little or no advantage over deferred and rotation grazing in promoting increases in abundance of *Agropyron*.

Hard and fast conclusions regarding the behavior of *Agropyron* cannot be derived from the quadrats in the isolation transects because of the small numbers, short period of time (1926-1930) that they were under investigation and because of the variations in soils and competing species from quadrat to quadrat. The data of each quadrat must be interpreted on the basis of the particular conditions; especially soil and climatic factors, grazing methods and competing species, that prevail on each quadrat thruout the period of study. This requires intensive methods, not merely measuring areas or counting stalks once a year.

The species that appear to have given the most severe competition to *Agropyron* were: *Stipa viridula, Aster, Psoralea, Artemisia gnaphalodes, Bulbilis, Aristida, Bouteloua, Astragalus* spp., *Iva* and *Malvastrum*. Brief statements regarding the behavior of a number of these species may aid in determining the effects upon the vegetation of the grazing systems and of changes in grazing.

Stipa viridula gave surprising results in a number of quadrats. In the quadrats opened to grazing in 1924 and 1929, located in the isolation transect in the deferred and rotation pasture, *Stipa* increased while *Agropyron* decreased. In some of the quadrats closed to grazing, *Stipa* increased somewhat, but in the one not grazed since 1920, *Stipa* decreased considerably while *Agropyron* increased. In the clipped quadrats, 3 and 5, *Stipa* increased in abundance while *Agropyron* decreased, even tho the plants were clipped only once during the season and after vegetative growth had been completed. Since *Stipa* is a bunch grass and *Agropyron* a sod former, opposite results would have been expected.

The area occupied by *Bulbilis* in each quadrat usually increased from 1926 to 1928 and from 1928 to 1930. There were more quadrats in the continuous pasture that had *Bulbilis* than in the deferred and rotation pasture. The results in the 16-by-16-feet quadrats that were opened or closed to grazing in 1927 and in 1928, were conflicting. In the *Bulbilis* quadrat that was clipped once a year at a height of 1 inch, the yield decreased each year from 1927 to 1930. In all of these changes soil-moisture conditions, as determined largely by precipitation, probably had greater influence than grazing.

Aristida was present in all 14 of the quadrats in the isolation transect in the continuous pasture but present in only 3 in the deferred and rotation pasture. This was probably due to the more gravelly soil in the former transect. Most of the quadrats that were opened to grazing showed increases in *Aristida* from 1926 to 1928 and from 1928 to 1930, but a few showed considerable decreases. Most of the quadrats that were closed to grazing showed small decreases from 1926 to 1930.

The abundance of *Schedonnardus* fluctuated considerably in every quadrat where it was present. There were more quadrats, however, that showed decreases than showed increases from 1926 to

1930. There were more increases than decreases in the quadrats opened to grazing, but more decreases than increases in those closed to grazing. Fluctuations as these occurred. In the quadrat opened to deferred and rotation grazing in 1922 there were 358 square centimeters in 1926, 155 in 1928, 284 in 1930; in the quadrat opened to deferred and rotation grazing in 1924 there were 164 square centimeters in 1926, 56 in 1928, 42 in 1930. Chief factors causing these changes were the abundance of the seed crop, seeding conditions as trampling by stock, conditions affecting germination and growth of the seedlings and the short duration of life of the plants.

In almost every quadrat where *Aster hebecladus* occurred it increased in abundance from 1926 to 1928 and from 1928 to 1930. It increased also in each of the large quadrats, 16 by 16 feet square, and was more abundant in the areas that had been grazed than on those that had been protected. Usually the increase from 1928 to 1930 was greater than that from 1926 to 1928. More of the quadrats opened to grazing contained *Aster* than those closed to grazing and there were greater numbers of stalks in the former than in the latter. *Aster* was usually not grazed at all by the cattle and has shown considerable resistance to drought.

Psoralea tenuiflora was present in more of the quadrats in the transect in the continuous pasture than in those of the other transect. In the major quadrats it increased more from 1927 or 1928 to 1930 in the areas opened to grazing than in those closed to grazing. In the 10-meter-square quadrats located in the continuous pasture it increased more from 1926 to 1930 than in the deferred and rotation pasture. So it appears that *Psoralea* is a sensitive indicator of grazing practices.

Artemisia gnaphalodes, not grazed by cattle, increased from 1926 to 1930 in most of the quadrats in which it occurred. It increased somewhat more in the major quadrats (16 by 16 feet) that were opened to grazing than in those closed to grazing.

Senecio perplexus was much less abundant in the continuous pasture than in the deferred and rotation pasture. Decrease in numbers of this plant appears to be a sensitive method of determining improper grazing methods.

Helianthus pumilus (closely grazed by the cattle) increased in more quadrats, and decreased in fewer, under deferred and rotation grazing than under continuous grazing. When protected from continuous grazing it increased more than when subjected to continuous grazing. Protection from deferred and rotation grazing had about the same results as when grazed. In the major quadrats (16 by 16 feet) it increased more in the areas closed to continuous grazing than in those opened to grazing. This species then is favored by deferred and rotation grazing or protection as compared to continuous grazing.

Sophora sericea increased in more quadrats and decreased in fewer quadrats under continuous grazing than under deferred and rotation grazing or total protection. This species is not grazed by cattle.

Astragalus hypoglottis, usually not grazed, increased more from 1927 or 1928 to 1930 in the major quadrats (16 by 16 feet) closed to grazing than in those opened to grazing, altho the increases were large under both conditions. In nearly every quadrat, where it was present, in the isolation transects this species showed increases. Changes in grazing had little effect upon this plant, so other factors, especially drier conditions causing decreased competition from other species, must have caused the increases.

Astragalus drummondii (closely grazed) was present in many more quadrats in the deferred and rotation pasture than in the other pasture. In the 10-meter-square quadrats it was over five times more abundant in the former pasture than in the latter. The abundance of this species, therefore, is favored by the deferred and rotation system of grazing.

GENERAL SUMMARY AND CONCLUSIONS

The purpose of this experiment was to determine the effects of two different systems of grazing, the continuous system and the deferred and rotation system, upon the range vegetation near Fort Collins, Colorado.

The range was located at an elevation of 5,100 feet, 4 miles west of Fort Collins. The experiment was started in 1921 and the data presented in this bulletin are based chiefly upon investigations during the period from 1926 to 1930 inclusive. The vegetation consisted chiefly of western wheat grass *(Agropyron Smithii)*. Other important species were blue grama grass *(Bouteloua gracilis)*, buffalo grass *(Bulbilis dactyloides)*, porcupine grasses *(Stipa* spp., especially *S. viridula)*, three-awn grass *(Aristida longiseta)*, Texas crab-grass *(Schedonnardus paniculatus)* and a number of forbs, chiefly *Sophora sericea, Gaura coccinea, Aster hebecladus, Musineon divaricatum, Malvastrum coccineum, Senecio perplexus, Astragalus drummondii, A. hypoglottis, Psoralea tenuiflora* and *Iva axillaris.*

Data were secured for the following environmental factors: precipitation, evaporation, humidity, soil and air temperature, soil profiles, soil moisture and mechanical and chemical analyses of the soil at various depths.

The mean annual precipitation during a period of 41 years was 15.06 inches and the annual variation was from 7.11 to 27.57 inches.

The months in which most precipitation falls are April and May; least in November, December, January and February.

The average daily evaporation for the season, based on losses from Livingston cylindrical atmometers during four seasons, was about 20 cubic centimeters per day, ranging from 6 to 61 cubic centimeters per day (average of weekly periods). The average annual evaporation from a free-water surface for a period of 40 years was 43.49 inches, the greatest losses occurring in June, July and August.

The average humidity during winter was about 72 percent; that of summer about 60 percent.

The mean annual temperature was 46.5° F. The range in average weekly maxima during winter was 25 to 55° F.; during summer 80 to 90° F. The range in average weekly minima during winter months was 0 to 25° F; during summer, 45 to 58° F. The frostless period averaged 138 days, from May 8 to September 27. During winter the average weekly soil temperature at a depth of 4 inches ranged from 25 to 35° F.; during summer, 68 to 80° F.

The soil is classified as alluvial, modified by colluvial material, and consists of about 80 percent of clay and silt down to a depth of at least 2 feet. The nitrogen and lime contents of this soil are extremely high. Hardpan is present at about 2 feet.

Soil moisture in the upper 2 feet was usually ample from the latter part of March to the first part of June, but during the rest of June and extending into September it was frequently deficient, especially in the surface foot during July. Available moisture was usually not present below 2 feet.

The seasonal development of the vegetation was studied during 4 years. Earliest growth usually began about the middle of March. During May the season's growth was most rapid. In June the blooming of the vegetation was at its height. In July drying began in several species and by the first part of August many species had dried and disappeared. Ripening and drying continued thruout August and September and a few late summer species bloomed.

In early spring the growth rates of grasses was retarded by low temperatures. *Stipa viridula* was less sensitive than *Agropyron Smithii* and both of these were less sensitive than *Bouteloua*, *Bulbilis*, *Schedonnardus* or *Aristida*. Vegetative growth was usually completed by the latter part of June, when soil moisture usually was depleted. *Bouteloua* and *Bulbilis*, however, renewed vegetative growth later in the summer if soil moisture became ample, due to showers.

The effects of the two systems of grazing upon the vegetation were not as pronounced as would have been the case if the intensity of grazing had been greater. The effects of the different systems of grazing may be obscured by variations in climatic factors, especially soil moisture, and by variations in the competition pressure of numerous species which may be favored or hindered by changes in climatic factors. Quadrat data, therefore, cannot always be readily interpreted. The most reliable data are secured from large numbers of quadrats and from quadrats that have been under observation for long periods of time.

The most valuable data on the effects of the grazing systems upon the vegetation in this study appear to be those secured from the 30 list quadrats (2 meters square) systematically distributed in each of the pastures. In 1929 there was an average of 912 ± 75.23 stalks per quadrat (2 meters square) in the deferred and rotation pasture, and 597 ± 50.48 stalks per quadrat in the continuous pasture. This great difference (53 percent more stalks in one than in the other) appears to be due chiefly to the different systems of grazing in operation for 9 years. This is the chief effect that was found.

Bouteloua gracilis, Psoralea tenuiflora, Artemisia gnaphalodes, Aster hebecladus and *Artemisia frigida* were among the species that had greater abundance and frequency in the continuous pasture than in the deferred and rotation pasture. *Bouteloua* was the only one of these species that was grazed to any extent. Some of the species in addition to *Agropyron Smithii* that had greater abundance and frequency in the deferred and rotation pasture were *Eurotia lanata, Schedonnardus paniculatus, Senecio perplexus, Stipa viridula* and *Aristida longiseta.* All of these species were grazed by the cattle. The total number of stalks of desirable species that could be counted was 54 percent greater in the deferred and rotation pasture than in the continuous one, the total number of stalks of undesirable species was 18 percent less and the stalks of immaterial species was 27 percent greater.

In 1926 and in 1927 the average heights of flowering stalks of *Agropyron Smithii* and *Stipa viridula* were greater in the deferred and rotation pasture than in the continuous one. The weight and percentage of germination of seeds from *Stipa viridula* plants growing in the deferred and rotation pasture were greater than of those from the continuous pasture.

The data secured from the quadrats in the isolation transects, clipped quadrats and major quadrats (10 by 10 feet, and 16 by 16 feet) were less decisive. For the period of time during which the quadrats were under study (1926-1930), *Agropyron* increased more under continuous grazing than under total protection from grazing. Deferred and rotation grazing had effects similar to total protection. These results are not considered as reliable as those that are based upon the large number of list quadrats, mentioned above, because of the smaller number, the shorter period over which each kind of grazing extended, and the smaller portions of the pastures that were covered.

It appears from these data, however, that increasing abundance of *Psoralea*, *Artemisia gnaphalodes* and *Sophora sericea* (none grazed) and decreasing abundance of *Senecio perplexus*, *Helianthus pumilus* and *Astragalus drummondii* (all grazed) may be used as delicate indications of grazing methods that are not suitable for the maintenance of the kind of vegetation best suited to cattle. Many changes that developed in these quadrats, particularly in the case of *Schedonnardus*, appear to be due more to environmental conditions, or to competition pressure, than to differences in the grazing systems.

IN CONCLUSION.—In intensive studies on the relation of range management to vegetation it is essential to know the life history and habits of all of the important species and how these life histories and habits may be modified by variations in soil and climatic conditions and competition pressure from neighboring plants, in addition to the direct effects of grazing. To acquire this knowledge it is necessary to study the vegetation and the environment week in and week out during the year. Examinations or quadrat studies once or twice a year are very inadequate for thoro understanding of these complicated interrelations.

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