12-1-1956

Intensity of Grazing Effect on Livestock and Forage Production

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BULLETIN 459
DECEMBER 1956

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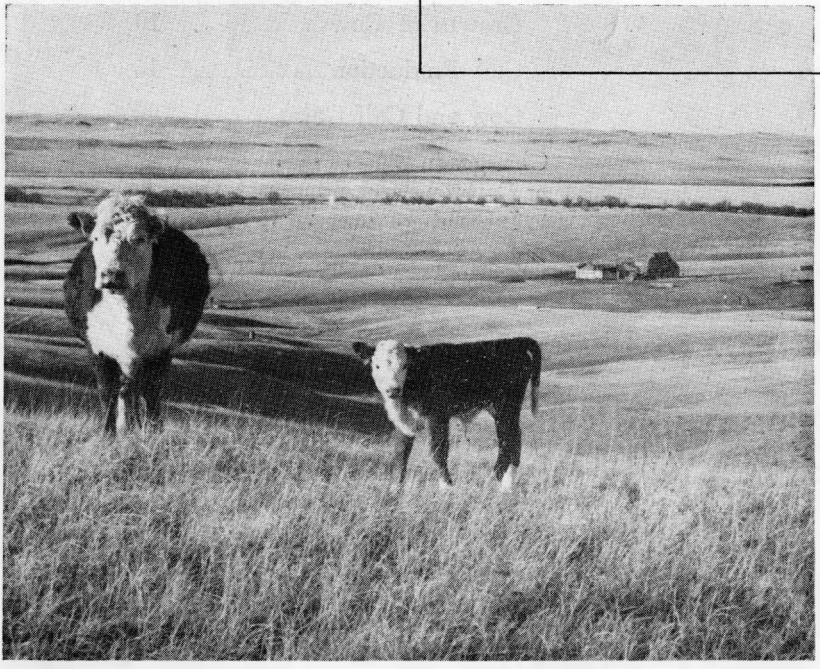

ANIMAL HUSBANDRY DEPARTMENT
AGRICULTURAL EXPERIMENT STATION
SOUTH DAKOTA STATE COLLEGE, BROOKINGS

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7500—4036

intensity of grazing

Its effect on livestock and forage production

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Range beef production is an integral part of the agricultural economy of South Dakota and is especially important in the western portion of the state. Maximum sustained livestock production can be obtained only through proper grazing practices on the range and efficient feeding practices in the feed lot.

Adjusting livestock numbers to prevent overuse of the range resource is the principal problem in securing proper use of South Dakota's rangelands. There is considerable variation in the intensity of grazing of rangelands in the state. It is recognized that if a range is stocked too heavily the native vegetation deteriorates, causing decreased forage and livestock production and often considerable soil erosion. It is equally apparent that too light grazing fails to make efficient use of forage, and total livestock production per unit of land is decreased.

An intensity of grazing experiment was initiated in 1942 at the Cottonwood Range Field Station to study the effects of heavy, moderate, and light grazing on the vegetation and on cow and calf production. Results of the first 9 years of this study were reported in South Dakota Agricultural Experiment Station Bulletin 412 in 1951. These studies have been continued and intensified. The present publication is a progress report on the effects of the intensity of grazing on cow and calf production since 1953 and on the cumulative effects of different grazing intensities on the native vegetation.

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Description of the Experimental Range

The Cottonwood Range Field Station is located in western South Dakota midway between the Black Hills and the Missouri River, 75 miles east of Rapid City on Highway 14.

Experimental Pastures

The experimental pastures consist of six summer and six winter pastures. Three rates of grazing—heavy, moderate, and light—are replicated in the summer series. The two heavily grazed pastures each contain 80 acres, the moderately grazed pastures 133 acres, and the lightly grazed pastures 183 acres. An aerial view of the summer pastures is shown in figure 1.

The winter series comprises six pastures each containing approximately 89 acres. These pastures have been grazed only during the winter (approximately December 1 to April 30) since 1942. In 1955 all of the winter pastures were in excellent condition.

Soil and Topography

Elevation at the station headquarters is 2,414 feet. The summer series of experimental pastures is approximately 25 feet to 132 feet higher than the headquarters. Topography of the experimental pastures is rolling to gently rolling and is essentially composed of long, sloping, somewhat flat-topped ridges. Erosion by an ancient stream has been the most recent factor in developing topographic features.

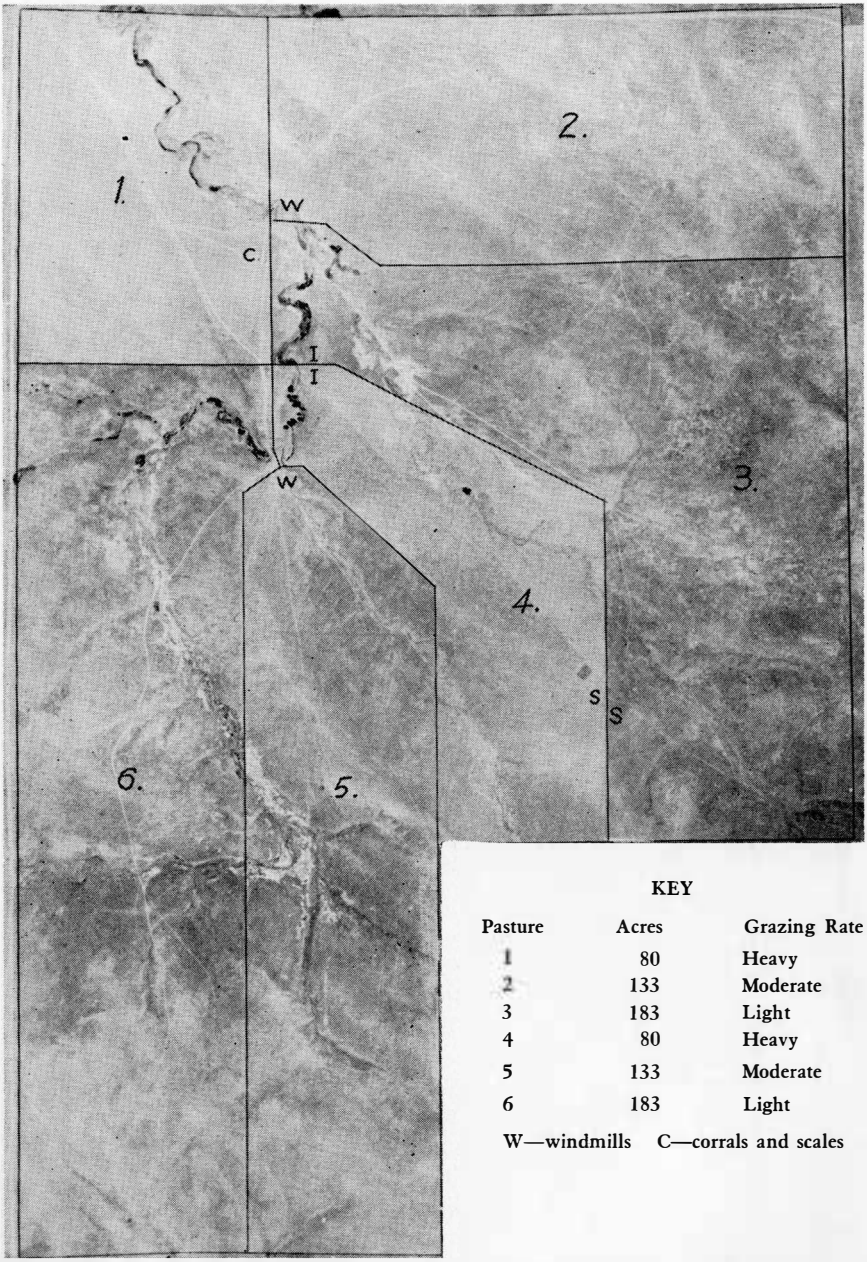
The soils, in general, vary from clay loam to a heavy clay and are slowly permeable, dark brown in color, and relatively thin on the steeper slopes. The parent material of the soils was derived from the Pierre, Foxhills, and Chadron formations.[2] However, the latter two formations have been removed from all but the higher ridgetops. Coarser materials ranging in texture from fine sandy loam to clay loam have been deposited on some of the slopes and ridges.

Climate

Precipitation. The average annual precipitation at the Cottonwood Range Field Station during the 46-year period, 1910 through 1955, has been 14.72 inches—nearly 80 percent is received from April through September. May, June, and July are normally the wettest months of the year, while December, January, and February normally receive the least precipitation. Approximately 25 percent of the autumns (September, October, and November) receive less than 3 inches of precipitation.

Heavy snowfall sometimes occurs during the winter, but as a rule the snow cover is not great. Precipitation for the 5 years, 1951 through 1955, averaged 16.63 inches with a variation from 20.92 inches in 1951 to 13.01 inches in 1954. Table 1 shows monthly precipitation and deviation from normal for this period.

[2] White, E. M. 1956. Unpublished soil survey. South Dakota Agricultural Experiment Station.



KEY

Pasture	Acres	Grazing Rate
1	80	Heavy
2	133	Moderate
3	183	Light
4	80	Heavy
5	133	Moderate
6	183	Light

W—windmills C—corrals and scales

Figure 1. Aerial photograph of the summer series of experimental pastures.

Table 1. Precipitation at the Range Field Station, Cottonwood, for 1951-55

	1951		1952		1953		1954		1955	
	Prec.*	Dev.†	Prec.	Dev.	Prec.	Dev.	Prec.	Dev.	Prec.	Dev.
January	.12	–.25	1.30	.93	1.74	1.37	.12	–.25	.23	–.14
February	1.15	.84	1.44‡	1.13	1.82	1.51	.41	.10	.42	.11
March	1.45	.80	1.80	1.15	1.57	.92	1.68	1.03	.31	–.34
April	.46	–1.39	.14	–1.71	3.33	1.48	.18	–1.67	1.15	–.70
May	1.51	–1.14	3.46	.81	1.24	–1.41	3.39	.74	2.51	–.14
June	4.64	1.98	5.77	3.11	3.41‡	.75	1.89	–.77	1.84	–.82
July	2.41	.41	1.16	–.84	1.50	–.50	.40	–1.60	1.54	–.46
August	3.51	1.91	.27	1.33	1.45	–.15	1.14	–.46	.39	–1.21
September	2.21	1.20	.56	–.45	.07	–.94	.63	–.38	3.89	2.88
October	1.54	.67	.00	–.87	1.98	1.11	2.50	1.63	.08	–.79
November	.09	–.33	.69	.27	.16	–.26	.63	.21	.49	.07
December	1.83	1.50	.12	–.21	.31	–.02	.04	–.29	1.10	.77
Total Annual	20.92	6.20	16.71‡	1.99	18.58‡	3.86	13.01	–1.71	13.95	–.77
Total April 1 to Sept. 30	14.74	2.97	11.36	–.41	11.00‡	–.77	7.63	–4.14	11.32	–.45
Total Warm Season (June, July, Aug.)	10.56	4.30	7.20	.94	6.36	.10	3.43	–2.83	3.77	–2.49
Total Cool Season (Previous Sept. thru May)	—	—	13.81	5.35	11.07	2.61	8.30	–.16	8.42	–.04

*Precipitation.
†Deviation.
‡For these months water equivalent of snowfall was estimated, using a ratio of 10 inches of snowfall equivalent to 1 inch of water.

Temperature. Temperatures at the station are highly variable and exhibit wide ranges in day and night, monthly, and annual temperatures. Temperatures above 100°F. occur frequently during midsummer. High temperatures, accompanied by low humidity in the summer months, have a profound influence on the moisture relationships of the native vegetation. Winter temperatures fluctuate widely but are often high enough to allow growth of vegetation for short periods. The average frost-free season is 136 days, generally from mid May until late September.

Evaporation. The combined effects of high temperature, frequent wind, and low humidity produce evaporation from a free water surface of as much as 16 inches a month during the summer. Only short periods throughout the year experience a complete lack of wind. However, the wind velocity, which averages 8 to 11 miles per hour, is no greater than in many other areas in the Northern Great Plains. Precipitation-evaporation data for 1953 to 1955 are presented in table 2.

Native Vegetation

The Range Field Station at Cottonwood has a nearly continuous cover of mixed-prairie vegetation in which short and medium height grasses are codominant. The principal short grasses and grasslike plants are blue grama, buffalograss, needleleaf sedge, and sandberg bluegrass. The primary mid-grasses (medium height) are western wheatgrass, green needlegrass, needleandthread, sideoats grama, and little bluestem. Western wheatgrass, blue grama, and buffalograss make up more than 75 percent of the annual forage production. Woody plants account for only a small percentage of the vegetation on the station and are represented by only a few species. Western snowberry and species of prickly-pear are the most common woody plants in the experimental pastures at Cottonwood.

Since the study began in 1942 heavy grazing has produced an average utilization of 59 percent of each year's current growth and has resulted in the elimination of most of the mid-grasses. These ranges

Table 2. Evaporation and Precipitation-Evaporation Ratio* at the Range Field Station, Cottonwood, 1953 through 1955

Months	Evaporation			Precipitation-Evaporation Ratio		
	1953	1954	1955	1953	1954	1955
April	—	7.31	7.58	—	.02	.15
May	—	7.30	10.95	—	.46	.23
June	9.88	8.83	10.00	.35	.21	.18
July	10.71	16.20	14.48	.14	.02	.11
August	10.01	12.33	13.65	.14	.09	.03
September	9.34	8.14	8.83	.01	.07	.44
October	6.21	4.09	5.92	.32	.61	.01

*P/E for months noted.

are now an almost continuous sod of shortgrasses. Light grazing (23 percent utilization) has increased the percentage of mid-grasses, while moderate grazing (40 percent utilization) has maintained nearly equal proportions of mid- and short grasses.

Effects of Intensity of Grazing on Livestock Production

Management of Cattle

In the fall of 1952, 54 head of approximately 18-month-old grade Hereford heifers of similar breeding were bought from a neighboring rancher. They were branded, weighed, and permanently allotted at random for their productive life into six pastures, two each of which were grazed heavily, moderately, or lightly from about May 1 through November 30 of each year. Six of the nine heifers in each pasture were termed "record" animals and remained throughout the grazing season on the pasture to which they were assigned. The remaining three head were termed "put-and-take" animals.

The desired levels of forage utilization on the summer pastures were: heavy grazing, over 55 percent; moderate grazing, 35 to 50 percent; and light grazing, less than 35 percent. The put-and-take heifers were placed in their respective pastures at the beginning of each grazing season but were removed if necessary to maintain the desired level of utilization. Thus, each of the six summer pastures was stocked with nine cows, three of which could be removed during the grazing season. Put-and-take cows which were removed were placed in a separate creek-bottom pasture. Since the treatment they received differed from that of the record cows, their records were not included in the cow and calf production data.

The cows were bred on pasture to calve at 3 years of age. The breeding season each year varied slightly, but was generally from June 1 until August 15. The bulls used during the study were half-brothers from the South Dakota Experiment Station herd. When sold in 1955 they weighed 1,580 and 1,590 pounds. One bull bred the cows in replication one (pastures 1, 2, and 3,) while the second bull bred the cows in replication two (pastures 4, 5, and 6.)

During the summer grazing period the cows had free access to water, iodized salt, and a mineral mixture composed of equal parts of salt and dicalcium phosphate.

Winter Supplements. Two record cows and one put-and-take cow from each summer pasture were allotted to one of three (replicated) levels of vitamin A supplementation when they were placed on winter range. Cows in two of the winter lots received no vitamin A in their

supplement, cows in two other lots received 1,000 International Units (IU) per 100 pounds of body weight daily, and cows in the remaining two winter groups received 3,000 IU per 100 pounds of body weight daily. Winter weights of the cows were estimated in order to compute the necessary amounts of vitamin A added to each mix. The cattle were rotated from pasture to pasture each week during the winter to compensate for pasture differences.

Blood samples were taken from the cows at the beginning, about the middle, and near the end of the winter grazing period. These samples were analyzed for carotene and vitamin A.

During the winter grazing period, approximately December through April, the cows received 1 pound of a 38 percent protein supplement per head daily in 1952 and 1953 and 1½ pounds in 1954 and 1955 in addition to grazing. The protein supplement was composed of solvent process soybean oil meal with 5 percent cane molasses, enough dicalcium phosphate to provide approximately 11 grams of phosphorus per head daily, and the Vitamin A supplement.[3]

During the winter of 1953-54, when snow cover prevented grazing, the cows were given all the late-cut hay that they would readily clean up. This hay had been harvested after frost in order to provide emergency winter forage similar in carotene content to standing grass on winter range. No hay was fed during the two winters 1954-55 and 1955-56.

Weights were taken at approximately monthly intervals throughout the year after an overnight shrink and also 1 to 24 hours after calving. The calves were weighed, tattooed, and eartagged, and the bull calves were castrated within 24 hours after birth. Thereafter, they were weighed at approximately monthly intervals until they were weaned (about November 1). When they were approximately 1 month old they were vaccinated for blackleg. Adjusted weaning weights were computed by the use of correction factors developed from growth curves of South Dakota range calves.[4]

Stocking Rates. Stocking rates in all pastures were lower in 1954 than in other years because of drought. Near normal precipitation was received during the growing season in 1953 and precipitation during the preceding winter was above normal (table 1). In 1953 the put-and-take cows remained on the pastures for the entire season, whereas in 1954 and 1955 they were removed in mid- or late summer to control utilization. There was little difference in the average number of animal unit

[3]The Nopco Chemical Company furnished a stabilized vitamin A supplement, NOPCAY 10 Type III.

[4]Johnson, L. E. and C. A. Dinkel. 1951. Correction factors for adjusting weaning weights of range calves to the constant age of 190 days. *J. Animal Sci.* 10:371.

months (AUM) of grazing furnished by the various stocking rates over the 3-year period (table 3). The greatest amount of grazing was furnished by lightly grazed pasture 6 in 1955—55.1 AUM. The least amount of grazing was furnished by heavily grazed pasture 4 in 1954—37.5 AUM.

Growth of Cows

Growth Curves. The yearling heifers which were put on the study were similar in size and type. The average weight for the record animals was 600.5 pounds for heavy grazing, 588.4 for moderate, and 619.0 for light. Growth curves of the cows through May 19, 1956 are shown in figure 2.

The basic pattern of the curves each year indicates that the cows gained rapidly in May, June, and July, gained more slowly in August, and then lost weight until they were placed on deferred winter range in excellent condition and provided a protein supplement.

With an abundance of forage and an adequate protein intake at the beginning of the winter grazing period, the cattle gained rapidly for about a month and then more slowly through February. They lost weight through March and April until placed on summer pastures in early May. These early spring weight losses were partly due to calving and subsequent lactation.

In some years when continuous warm growing weather is delayed, the cattle tend to graze the sparse green grass in preference to the more abundant dry grass and probably do not consume enough dry matter to maintain their body weight. Peak summer weights were reached about September 1 in 1954 and 1955. Weight losses were temporarily arrested during November 1954 and October 1955 by the growth of cool season grasses following favorable rainfall.

The cows from light grazing were the heaviest of the groups at most weighing dates. They were slightly heavier at the beginning of the study and had a greater amount and variety of forage available from which to select their diet. Cows from the moderately grazed pastures were generally the lightest, possibly because they were somewhat lighter when the study began.

In 1955 the cows on heavy and moderate grazing began to lose weight in July, whereas the cattle in the lightly grazed pastures continued to gain until September 1. Cows under light grazing lost weight more slowly in the fall and, following favorable rains, gained weight in November 1954 and October 1955. Because they were in better condition at the end of the summer grazing, these cows gained more slowly at the beginning of the winter than did the cows on heavily grazed pastures. The latter lost weight rapidly during the fall and were in poor condition at the beginning of the winter.

Summer Gains. Over the 3-year period, cows from light grazing made summer gains of approximately 50 pounds more than the cows from moderate grazing and

Table 3. Animal Unit Months of Grazing Furnished, Stocking Rate, and Utilization at the Range Field Station, Cottonwood, for 1953 Through 1955

	Pasture	Heavy Grazing			Moderate Grazing			Light Grazing		
		1	4	Av.	2	5	Av.	3	6	Av.
1953	Grazing Furnished, AUM*	49.9	43.6	46.8	48.7	49.9	49.3	50.5	51.1	50.8
	Stocking rate, acres per AUM	1.60	1.83	1.72	2.73	2.66	2.70	3.62	3.58	3.60
	Utilization, %	60	70	65	52	45	48	25	20	22
1954	Grazing Furnished, AUM	41.6	37.5	39.6	41.1	43.0	42.0	41.6	43.4	42.5
	Stocking rate, acres per AUM	1.92	2.13	2.02	3.23	3.09	3.16	4.40	4.22	4.31
	Utilization, %	66	75	70	50	45	48	25	25	25
1955	Grazing Furnished, AUM	51.9	41.0	46.4	47.0	51.5	49.2	51.9	55.1	53.5
	Stocking rate, acres per AUM	1.54	1.95	1.74	2.83	2.58	2.70	3.53	3.32	3.42
	Utilization, %	70	75	72	60	55	58	30	30	30
All Years	Grazing Furnished, AUM	47.8	40.7	44.3	45.6	48.1	46.8	48.0	49.9	49.0
	Stocking rate, acres per AUM	1.67	1.97	1.82	2.93	2.77	2.85	3.85	3.70	3.78
	Utilization, %	65	73	69	54	48	51	27	25	26

*One animal unit is considered to be a 1,000 pound cow with or without calf. Animal units for animals of different weights were computed by the formula $AU = \frac{W^{0.75}}{1000^{0.75}}$ where W is the average of the monthly weights during the grazing season.

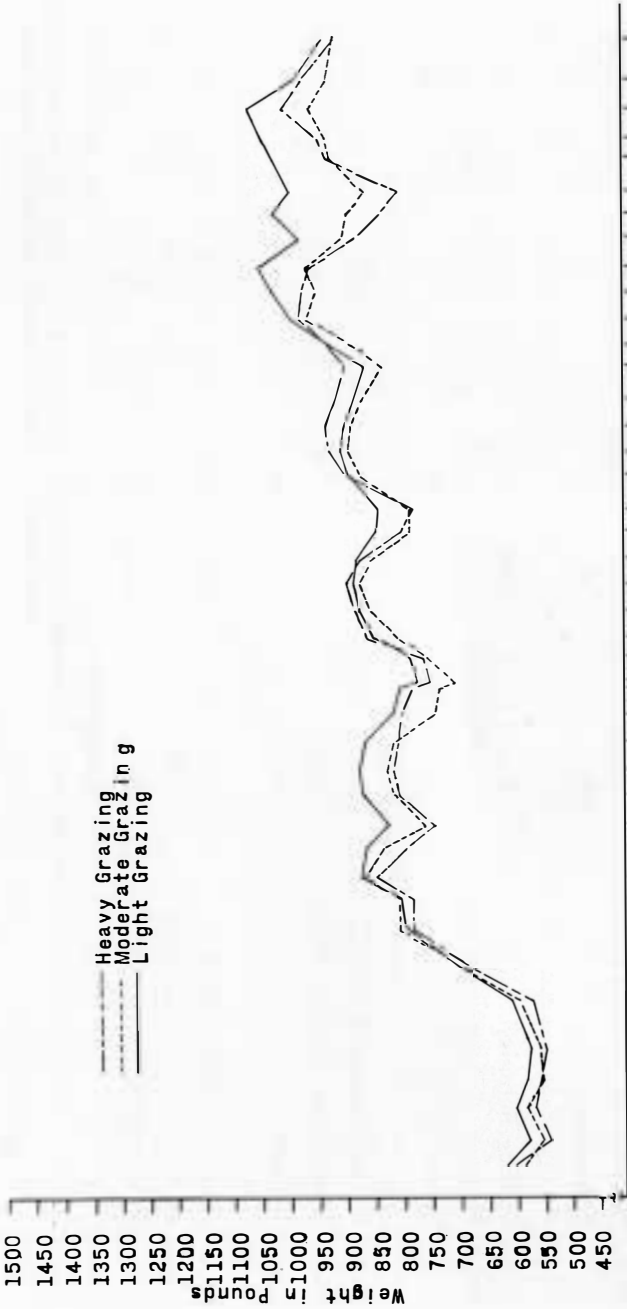


Figure 2. Growth curves for all cows from different rates of grazing

over 100 pounds more than the cows from heavy grazing (table 4). In 1953, when the heifers were not suckling calves, comparable gains were made by heavy and moderate grazing; but light grazing produced summer gains more than 50 pounds per head greater than the other two rates of grazing.

The greatest differences in weight between rates of grazing occurred at the end of the 1955 grazing season when the average weights for cows on heavy, moderate, and light grazing were 792, 887, and 996 pounds. Figures 3 through 5 reveal the marked differences in the condition of the cows at that time. These large differences in cow weights show the effects of different rates of grazing and were intensified by below-normal precipitation in 1955.

The greatest average summer gains for the 3-year period were made in lightly grazed pasture 6, and the smallest gains were made in heavily grazed pasture 4.

Winter Gains. During the winter feeding period, previously described, the cows in all rates of grazing gained weight except during the winter of 1953-54, but that year the heifers were all in high condition at the end of the summer grazing season.

Over the four winter periods studied, cows from heavy grazing

Table 4. Average Difference Between the Weight of the Record Cows 1-24 Hours After Calving and the Weight at the End of the Summer Grazing Season at the Range Field Station, Cottonwood, from 1953 Through 1955*

	Pasture	Replication 1			Replication 2			Average
		Spring	Fall	Gain or Loss	Spring	Fall	Gain or Loss	Gain or Loss
1953	Heavy Grazing	576.7	782.0	205.3	530.5	654.5	124.0	164.6
	Moderate Grazing	563.7	707.3	143.6	584.6	772.8	188.2	165.9
	Light Grazing	611.5	815.3	203.8	606.6	840.8	234.2	219.0
1954	Heavy Grazing	767.8	807.0	39.2	734.0	704.2	–29.8	4.7
	Moderate Grazing	748.3	777.7	29.4	753.8	846.3	92.5	61.0
	Light Grazing	761.5	827.7	66.2	806.5	853.5	47.0	56.6
1955	Heavy Grazing	919.1	844.3	–74.8	826.3	740.0	–86.3	–80.6
	Moderate Grazing	888.5	863.3	–25.2	856.7	911.0	54.3	14.6
	Light Grazing	854.7	949.7	95.0	872.8	1041.3	168.5	131.8
Average	Heavy Grazing	754.5	811.1	56.6	696.9	699.5	2.6	29.6
	Moderate Grazing	733.5	782.9	49.3	741.7	853.3	111.6	80.9
	Light Grazing	742.6	864.3	121.7	862.0	1011.9	149.9	135.8

*Initial weights of dry cows were taken May 5 in 1954, April 1 in 1955, and April 5 in 1956. These dates were the weigh days closest to the average calving dates for the respective years.

made an average gain of 76 pounds, moderately grazed cows gained an average of 36 pounds, and cows from light grazing lost an average of 4 pounds (table 5).

Effects of Calving. The average calving dates for the 3 years were May 5 in 1954, April 1 in 1955, and April 5 in 1956. The first calving had a much stronger depressing effect on cow weights than did the second or third calving period. Calving all 3 years under heavy grazing apparently retarded the growth of the cows.

Average weights at the beginning (November 7, 1952) and at the end of the study (1 to 24 hours after calving in 1956) are presented for the record cows in table 6, with a comparison of the effects of calving all 3 years with calving only 2 years. The cows calving all 3 years made 65 pounds less gain than the cows calving only 2 years.

Replication Differences. There was considerable variation in cow weight gain between pastures grazed at the same rate. Although they were similar in weight when the study began in November 1952, the cows in heavily grazed pasture 4 have been consistently lighter than the cows in heavily grazed pasture 1. Under moderate grazing the pasture 2 cows have been much lighter than the cows in pasture 5. These differences were much greater in 1953 when the heifers were only 2 years old and were growing rapidly.

Differences in pasture production are primarily due to the potential productivity of the soils in the pastures which have resulted in a difference in the kind and amount of forage produced. For several years pastures 2 and 4 have been lower in range condition and have received slightly heavier utilization than their corresponding replicates, pas-

Figure 3. Cows from heavily grazed pastures 1 (left) and 4 (right) at the end of the 1955 grazing season. Cows in pasture 1 lost an average of 74.8 pounds and those in pasture 4 lost an average of 86.3 pounds from calving to end of the season.

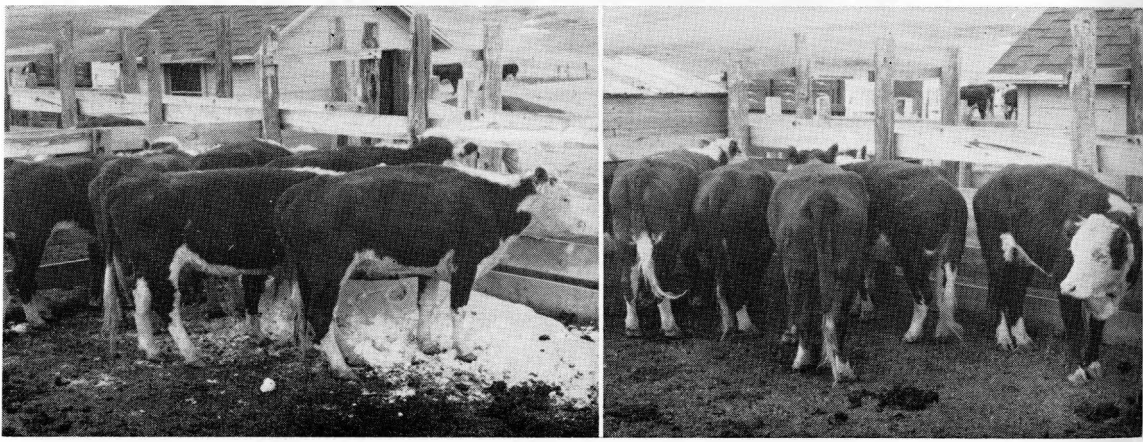


Table 5. Average Difference Between the Weight of Record Cows at the End of the Summer Grazing Season and the Weight 1-24 Hours After Calving in the Following Spring for 1952 Through 1956*

	1952-53			1953-54			1954-55			1955-56			All Years
	Fall	Spring	Gain or Loss	Fall	Spring	Gain or Loss	Fall	Spring	Gain or Loss	Fall	Spring	Gain or Loss	Gain or Loss
Heavy													
Pasture 1	560.0	576.7	16.7	782.0	767.8	–14.2	807.0	919.9	112.2	844.3	959.3	115.0	54.9
Pasture 4	527.5	567.5	40.0	654.5	734.0	79.5	704.2	826.4	122.2	740.0	881.8	141.8	95.9
Average	543.8	572.1	28.3	718.2	750.9	32.7	755.6	873.2	117.2	792.2	920.6	129.6	75.8
Moderate													
Pasture 2	557.5	593.3	35.8	707.3	706.9	–.4	777.7	868.5	90.8	863.3	930.1	66.8	47.7
Pasture 5	567.0	615.8	48.8	772.8	753.8	–19.0	846.3	856.6	10.3	911.0	973.5	62.5	25.7
Average	562.2	604.6	42.3	740.0	730.4	–10.5	812.0	862.6	46.9	887.2	951.8	64.5	35.9
Light													
Pasture 3	570.8	611.6	40.8	815.3	744.8	–70.5	827.7	854.7	27.0	949.7	945.2	–4.5	–1.8
Pasture 6	586.7	606.7	20.0	840.8	806.5	–34.3	853.5	872.8	19.3	1041.3	1011.6	–29.7	–6.2
Average	578.8	609.2	30.4	828.0	775.6	–52.4	840.6	863.8	23.2	995.5	978.4	–17.1	–4.0
All rates	**561.6**	**595.3**	**33.7**	**762.1**	**752.3**	**–10.1**	**802.7**	**866.5**	**62.9**	**891.6**	**950.3**	**56.8**	**35.6**

*Initial weights of dry cows were taken May 5 in 1954, April 1 in 1955, and April 5 in 1956. These dates were the weigh days closest to the average calving dates for the respective years.

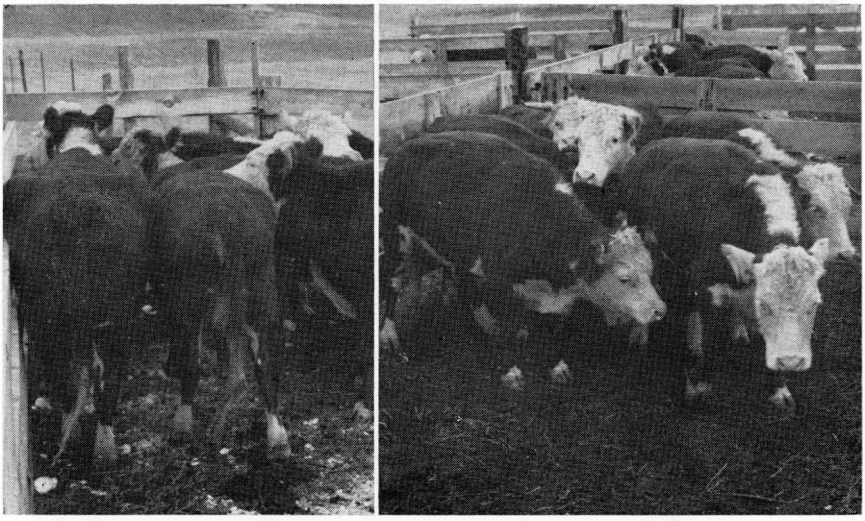


Figure 4. Cows from moderately grazed pastures 2 (left) and 5 (right) at the end of the 1955 grazing season. Cows in pasture 2 lost an average of 25.2 pounds and those in pasture 5 gained an average of 54.3 pounds from calving to the end of the season.

tures 5 and 1. The lightly grazed replicates have been quite similar in range condition, utilization, and cow gains. However, differences in the potential productivity of ranges become more evident as grazing pressure is increased.

Calf Production

Calf Crop. The average calf crop in the lightly grazed pastures was 5 percent greater than the calf crop in the heavily grazed pastures and 10 percent greater than the calf crop in the moderately grazed pastures. Because of the extreme variability in the data it cannot be concluded that light grazing increased the percent calf crop (table 7). More years of study or a larger number of cows are needed to determine the effect of the intensity of grazing on the percent calf crop.

Birth Weights. The cows on moderately and lightly grazed pastures produced calves that were approximately 5 pounds heavier at birth than the calves produced under heavy grazing (table 8).

Calves from replication 1 averaged 4.4 pounds heavier than the calves from replication 2. The bull calves on all rates of grazing averaged 5.6 pounds heavier at birth than the heifer calves.

Calf Growth. Growth curves of calves from different rates of grazing are shown in figure 6. Calves from light and moderate grazing were heavier from birth to weaning than calves from heavy grazing. Although calves from moderate grazing were heavier than calves from light grazing for a short period in midsummer, their rate of gain declined at the end of the summer

Table 6. Average Weight Gains of Record Cows that Calved All 3 Years and Cows that Calved Only 2 Years*

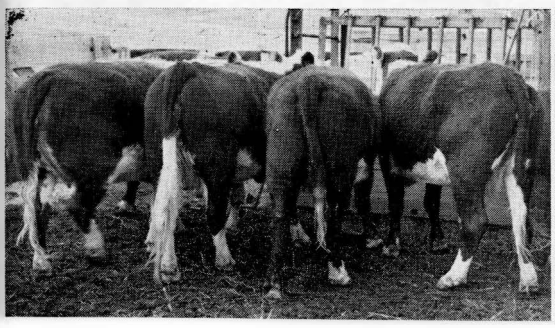
	Grazing Rate	1952	1956	Gain	1952	1956	Gain	Average
		Pasture 1			Pasture 4			
Two calves	Heavy	585	1057	472	608	947	339	392
Three calves	Heavy	633	916	283	598	802	204	263
All cows calving	Heavy	614	972	358	605	899	294	335
		Pasture 2			Pasture 5			
Two calves	Moderate	600	833	233	586	946	360	296
Three calves	Moderate	620	882	262	552	931	379	309
All cows calving	Moderate	616	870	254	569	938	369	305
		Pasture 3			Pasture 6			
Two calves	Light	595	1040	445	615	1018	403	414
Three calves	Light	616	927	311	642	1043	401	336
All cows calving	Light	612	946	333	626	1028	402	365

*Average values represent differences between November 1952 weights and weights taken 1 to 24 hours after calving in 1956.

Table 7. Percent Calf Crop Born at the Range Field Station, Cottonwood, 1954 Through 1956

	Heavy Grazing		Moderate Grazing		Light Grazing		All
Year	Pasture	Calf Crop %	Pasture	Calf Crop %	Pasture	Calf Crop %	Rates
1954	1	83.3	2	83.3	3	100.0	88.9
	4	66.7	5	66.7	6	100.0	77.8
	Average	75.0	Average	75.0	Average	100.0	83.3
1955	1	66.7	2	83.3	3	83.3	77.8
	4	66.7	5	66.7	6	33.3	55.6
	Average	66.7	Average	75.0	Average	58.3	66.7
1956	1	83.3	2	83.3	3	100.0	88.9
	4	100.0	5	50.0	6	83.3	77.8
	Average	91.6	Average	66.6	Average	91.6	83.3
All	1	77.8	2	83.3	3	94.4	85.2
Years	4	77.8	5	61.1	6	72.2	70.4
	Average	77.8	Average	72.2	Average	83.3	77.8

Figure 5. Cows from lightly grazed pastures 3 (left) and 6 (right) at the end of the 1955 grazing season. Cows in pasture 3 gained an average of 95.0 pounds and those in pasture 6 gained an average of 168.5 pounds from calving to the end of the season. Only two of the cows on the right calved in 1955.



grazing season. Calves from lightly grazed pastures maintained the same rate of gain late in the fall as they did earlier in the season.

The rate of gain of calves from heavy grazing dropped sharply in late summer when the green feed supply decreased. The increase in the rate of growth of these calves in the late fall was probably due to green forage produced by late fall rains in 1954 and 1955. Many of these calves were no longer nursing.

Weaning Weights. Differences in the rate of growth of the calves resulted in average adjusted weaning weights of 316.7, 360.2, and 370.2 pounds for calves on heavy, moderate, and light grazing, respectively, for 1954-55 (table 9).

The first calves dropped in 1954 were lighter for all rates of grazing than the 1955 calves. The average difference between the weaning weights in 1954 and 1955 was approximately 25, 80, 93 pounds for the heavily, moderately, and lightly grazed pastures, respectively. The heavier calf weights under moderate grazing in 1955 were accompanied by smaller cow gains.

There was considerable difference between the average weaning weights of calves from pastures grazed at the same rate. The greatest difference between replications was found under moderate grazing. The calves in pasture 5 averaged about 73 pounds heavier than the calves from pasture 2. The greatest difference between pastures in average weaning weights for the 2

Figure 6. Growth curves for calves from heavy, moderate, and light grazing in 1954 and 1955.

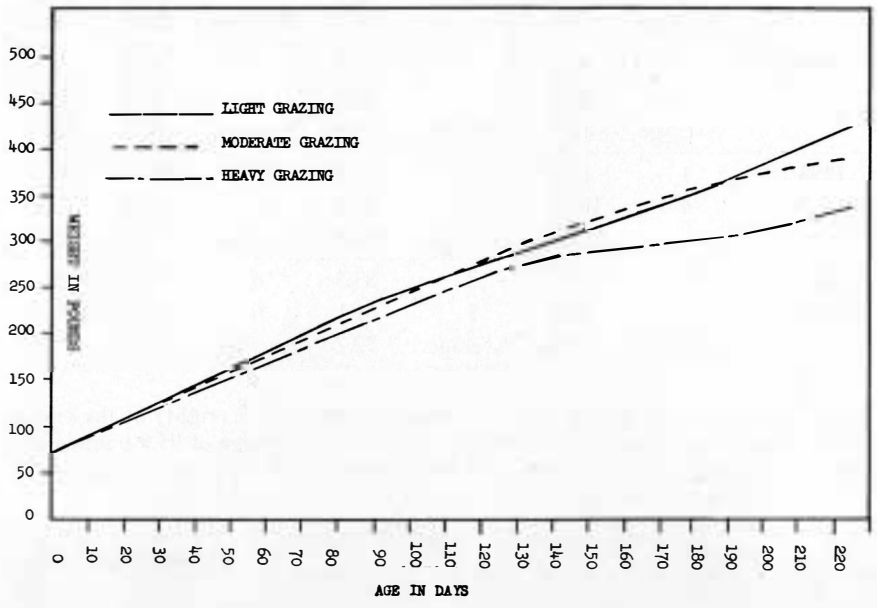


Table 8. Average Birth Weights of Calves for 1954 Through 1956

Year	Pasture	Heavy Grazing Bulls	Heifers	All Calves	Replication	Moderate Grazing Bulls	Heifers	All Calves
	1	76.5	62.3	68.0	2	69.3	64.0	67.2
1954	4	58.3	66.0	60.2	5	76.5	67.5	72.0
	Average	65.6	63.2	64.6	Average	72.2	65.8	69.3
	1	74.5	.....	74.5	2	76.5	68.0	74.8
1955	4	59.0	66.5	62.8	5	78.3	63.0	74.5
	Average	69.3	66.5	68.6	Average	77.3	65.5	74.7
	1	67.0	70.0	69.4	2	82.5	60.0	78.0
1956	4	68.0	69.8	69.2	5	67.0	66.0	66.3
	Average	67.7	69.9	69.3	Average	79.4	64.0	73.6
All	1	74.0	66.7	70.4	2	76.7	64.0	73.3
Years	4	61.3	68.3	64.8	5	75.8	66.0	71.4
	Average	67.6	67.5	67.6	Average	76.4	65.1	72.5

Year	Pasture	Light Grazing Bulls	Heifers	All Calves	Replication	All Rates Bulls	Heifers	All Calves
	3	71.7	77.7	74.7	1	72.0	68.5	70.2
1954	6	73.0	72.0	72.8	2	69.3	68.2	69.0
	Average	72.5	76.2	73.8	Average	70.5	68.4	69.7
	3	72.0	64.0	68.8	1	74.5	65.3	72.6
1955	6	67.5	.....	67.5	2	69.7	65.3	68.4
	Average	70.2	64.0	68.4	Average	72.7	65.3	70.8
	3	84.0	67.0	78.3	1	81.4	67.7	75.4
1956	6	.....	67.4	67.4	2	67.7	68.0	67.9
	Average	84.0	67.3	73.4	Average	78.0	67.9	71.9
All	3	76.7	70.7	74.2	1	76.0	67.7	72.8
Years	6	71.4	68.2	69.9	2	69.2	67.6	68.4
	Average	74.5	69.5	72.4	Average	73.2	67.6	70.8

Table 9. Average Adjusted Weaning Weights of Calves in 1954 and 1955

Year	Heavy Grazing Pasture 1	Pasture 4	Average	Moderate Grazing Pasture 2	Pasture 5	Average	Light Grazing Pasture 3	Pasture 6	Average
1954	331.8	276.8	304.2	286.6	362.8	320.4	335.6	332.7	334.0
1955	346.8	311.5	329.1	368.8	439.0	400.0	413.6	460.5	427.0
Average	339.2	294.1	316.7	327.7	400.9	360.2	374.6	364.6	370.2

years was 183.7 pounds between heavily grazed pasture 4 in 1954 and lightly grazed pasture 6 in 1955.

Type and Condition at Weaning. Table 10 presents the average values for the coded type and condition scores for 1955. Although the calves from light grazing had an average type score 0.7 of a point higher than the calves from moderate grazing and 1.2 points higher than the calves from heavy grazing, these differences were not statistically significant. Differences in condition due to grazing treatment, however, were significant. The calves from light and moderate grazing were in higher condition than the calves from heavy grazing, as shown by the average condition scores of 6.4, 7.6, and 8.1, respectively, for heavy, moderate, and light grazing.

Cow and Calf Gains

Total cow and calf gains are a composite measure of the percent calf crop and the weight gains of the cows and calves. Figure 2 shows that the cows lost weight each fall regardless of grazing rate. In 1954 and 1955 put-and-take cows were removed at different times during the summer and early fall to control utilization on the various pastures. Frequently these cows were removed before weight loss began.

Table 10. Average Type and Condition Scores of Calves at Weaning in 1955

	Coded Type Score	Coded Condition Score
Replicate 1		
Pasture 1	10.0	6.2
Pasture 2	10.6	7.4
Pasture 3	11.0	8.2
Average	10.6	7.3
Replicate 2		
Pasture 4	9.8	6.5
Pasture 5	10.2	7.8
Pasture 6	11.5	8.0
Average	10.3	7.3
Average of Both Replicates		
Heavy Grazing	9.9	6.4
Moderate Grazing	10.4	7.6
Light Grazing	11.1	8.1
All Treatments	10.4	7.3

Table 11. Average Adjusted Cow and Calf Gains in Pounds

Year		Grazing Rate			
		Heavy	Moderate	Light	All Rates
1953	Per Pasture	1585	1741	1970	1765
	Per Animal Unit	225	238	267	243
	Per Acre	19.8	13.0	10.8	14.5
1954	Per Pasture	1353	1778	2092	1741
	Per Animal Unit	224	281	291	265
	Per Acre	17.0	13.4	11.4	13.9
1955	Per Pasture	530	1864	2272	1555
	Per Animal Unit	73	258	289	207
	Per Acre	6.6	14.0	12.4	11.0
All Years	Per Pasture	1156	1794	2111	1687
	Per Animal Unit	174	259	282	238
	Per Acre	14.5	13.5	11.5	13.1

Obviously the inclusion of weight gains of put-and-take cows would have yielded an unrealistic picture of pasture production. Consequently, adjusted cow and calf gains have been calculated by multiplying the total gain of record cows and calves by the total AUM grazing and dividing this by the AUMs grazing furnished to record cows.

Light grazing produced the greatest total gain per animal unit and per pasture each year (table 11). Cow and calf gains per acre have usually been highest under heavy grazing, but have declined steadily due to range deterioration and the resulting reduction in amount and quality of forage consumed.

With the first group of cows studied, cow and calf gains per acre declined from an average of 32 pounds per acre during the first 5 years (1942-46) to 18 pounds (1947-49) to 9 pounds per acre in 1950. When the present herd was placed on the pastures as 2 year olds in 1953, heavy grazing produced 19.8 pounds of gain per acre. It declined to 17.0 pounds in 1954 and to 6.6 pounds per acre in 1955. The sharp drop in 1955 was due to the cumulative effect of overgrazing coupled with 2 consecutive years of drought.

Changes in Blood Plasma Levels of Carotene and Vitamin A Due to Intensity of Summer Grazing

Grazing livestock consume forage containing carotene which is converted into vitamin A and stored in the body. Vitamin A deficiency is sometimes encountered in range cattle following long periods of low carotene intake. This deficiency is most likely to occur in winters following summer drought when cattle are grazed on the range or fed low quality roughage.

Blood plasma analyses for carotene and vitamin A were made for the cows reported in this experiment to determine the status of vitamin A nutrition at different times during the year. Plasma carotene levels fluctuate widely depending upon the carotene intake but give a fairly reliable indication of the amount of carotene recently consumed. However, plasma vitamin A is a better measure of the vitamin A nutrition of the animal than plasma carotene.

Plasma carotene levels of the lightly grazed cows at the end of the summer grazing season each year were considerably higher than the other groups (table 12). The contrast between the plasma carotene levels of cows grazed at different intensities was especially striking in 1954 and 1955. Carotene content of the blood plasma at the end of the grazing season averaged 113.5, 133.2, and 539.8 micrograms percent for heavy, moderate, and light grazing in 1954. In 1955 the corresponding values were 170.0, 264.0, and 486.6.

Plasma carotene values are an indirect measure of the amount of green forage available in the late

Table 12. Spring and Fall Plasma Carotene and Vitamin A Values, 1953 Through 1955

		Pasture Designation	Heavy Grazing 1	Heavy Grazing 4	Heavy Grazing Av.	Moderate Grazing 2	Moderate Grazing 5	Moderate Grazing Av.	Light Grazing 3	Light Grazing 6	Light Grazing Av.
			mcg %	mcg %	mcg %	mcg %	mcg %	mcg %	mcg %	mcg %	mcg %
1953	Carotene	March 12	17.5	16.0	16.8	16.5	19.7	18.1	18.3	15.3	16.8
		Nov. 30	73.5	50.7	62.1	40.8	78.5	59.6	137.8	134.8	136.3
		Change	56.0	34.7	45.4	24.3	58.8	41.6	119.5	119.5	119.5
	Vitamin A	March 12	21.7	20.0	20.8	20.8	21.5	21.2	19.2	22.5	20.8
		Nov. 30	21.7	18.3	20.0	16.5	20.8	18.6	25.4	30.7	28.0
		Change	0.0	–1.7	–0.8	–4.3	–0.7	–2.5	6.2	8.2	7.2
1954	Carotene	March 18	26.3	26.2	26.2	36.3	32.7	34.5	34.2	22.8	28.5
		Nov. 26	135.5	91.5	113.5	73.6	192.7	133.2	651.4	428.1	539.8
		Change	109.2	65.3	87.2	37.3	160.0	98.6	617.2	405.3	511.2
	Vitamin A	March 18	21.3	20.7	21.0	21.3	20.3	20.8	19.7	21.0	20.4
		Nov. 26	28.3	21.7	25.0	21.5	33.5	27.5	59.0	46.7	52.8
		Change	7.0	1.0	4.0	0.2	13.2	6.7	39.3	25.7	32.5
1955	Carotene	March 1	29.8	22.5	26.2	35.2	42.3	38.8	41.0	24.8	32.9
		Nov. 26	210.2	129.8	170.0	170.5	357.6	264.0	546.0	427.3	486.6
		Change	180.4	107.3	143.8	135.3	315.3	225.2	505.0	402.5	453.7
	Vitamin A	March 1	26.3	23.7	25.0	23.5	29.0	26.2	23.5	28.7	26.1
		Nov. 26	28.3	23.3	25.8	25.9	37.6	31.8	49.1	46.5	47.8
		Change	2.0	–0.4	0.8	2.4	8.6	5.6	25.6	17.8	21.7
Average	Carotene	Spring	24.5	21.6	23.0	29.3	31.6	30.5	31.2	21.0	26.1
		Fall	139.7	90.7	115.2	95.0	209.6	152.3	445.1	330.1	387.6
		Change	115.2	69.1	92.2	65.7	178.0	121.8	413.9	309.1	361.5
	Vitamin A	Spring	23.1	21.5	22.3	21.9	23.6	22.7	20.8	24.1	22.4
		Fall	26.1	21.1	23.6	21.3	30.6	26.0	44.5	41.3	42.9
		Change	3.0	–0.4	1.3	–0.6	7.0	3.3	23.7	17.2	20.5

fall. Substantial amounts of precipitation were received in the fall of 1953, 1954, and 1955 (table 1). Following the rains, cool season grasses such as western wheatgrass and green needlegrass made considerable growth each year. However, the winter annual japanese bromegrass increased progressively from a very small amount in 1952 to a major part of the vegetation in 1955 (refer to tables 22 and 23). The cattle were observed grazing this plant in late fall and early spring. Under heavy grazing only very small amounts of cool season perennials and winter annuals were available, while in the moderately and lightly grazed pastures they were quite plentiful.

The vitamin A content of the blood plasma at the end of the grazing season in 1954 averaged 25.0, 27.5, and 52.8 micrograms percent for heavy, moderate, and light grazing respectively. The corresponding values in 1955 were 25.8, 31.8, and 47.8. These differences in plasma vitamin A were not as great as the differences in plasma carotene. Nevertheless, they clearly show differences in the vitamin A nutrition of cows grazed in pastures containing different amounts of cool season grasses. No symptoms of vitamin A deficiency have been observed in any of the cows. However, a deficiency of vitamin A is more likely under heavy grazing than under light or moderate grazing.

Effects of Intensity of Grazing on Native Vegetation

Clipping Studies

Detailed clipping studies have been conducted in the summer pastures since 1952. On the basis of a soil survey conducted in 1950, the soil and topography in the summer pastures was classified into eight rather uniform areas. Two exclosures were located at random on each area in each pasture. Three 1- by 2- foot plots were clipped in each exclosure. Vegetative measurements have been based on clippings from 151 of these plots in 53 exclosures located throughout the summer pastures. Figure 7 shows a view of the type of exclosures used and the location of the plots within the exclosure. The exclosures, approximately 7 feet square, were relocated each year before the beginning of the summer grazing season.

Clippings were made in June, August, and at the end of the growing season. In June and August of 1952, medium-height grasses were clipped to a 1-inch stubble height, and short grasses were clipped to crown height; whereas, in 1953 through 1955 all grasses were clipped just above the first leaf. All plants were clipped to ground level each year after the end of the growing season. The clipped vegetation was oven-dried and weighed to the nearest hundredth of a gram.

Reaction of Individual Species to Grazing

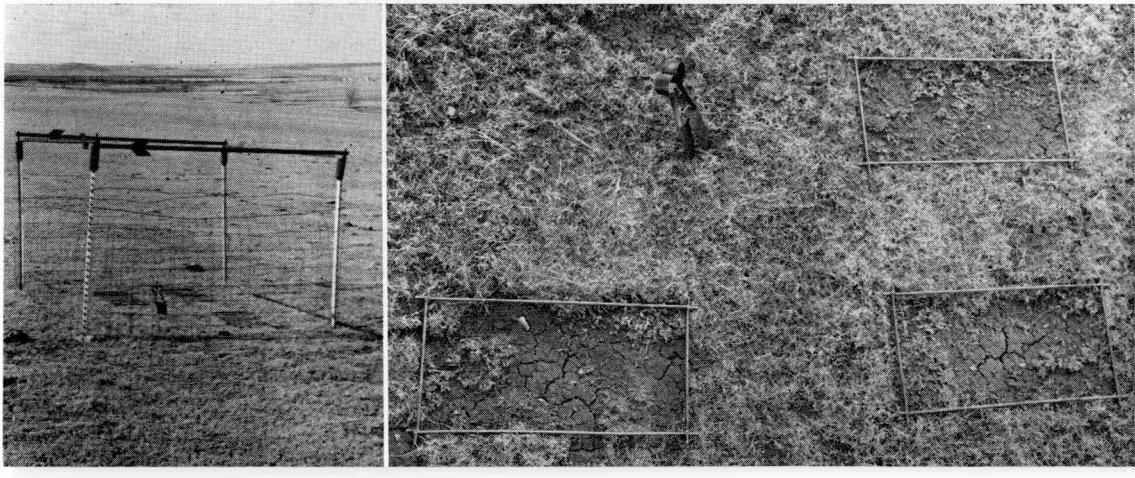
For many years rangemen have

known that heavy grazing causes retrogression. Highly palatable plants are reduced in abundance under intensive grazing (decreasers). The weakening or death of decreaser species due to prolonged abuse allows other native plants to increase in abundance (increasers) because competition for water, nutrients, and light is lessened.

However, under continued intensive use, the increaser species may be reduced in vigor and abundance as they receive the grazing load. Continued heavy use will often weaken the native cover sufficiently to allow an influx of species (invaders) which are not a component of the climax vegetation. As the native species disappear, invaders may spread over the range. Prolonged heavy grazing produces a vegetal cover which escapes grazing by low growth habit, as in the case of buffalograss; by low palatability, as in the case of fringed sagewort and snakeweed; by season of growth, as in the case of sixweeks fescue; or by prevention of grazing by spines, as in the case of various species of cactus.

The reaction of a given species to grazing is dependent upon many factors, especially range site, range conditions, kind of grazing livestock, season of use, and degree of utilization. Under a specific set of conditions any range plant can be placed in one of the three classes—decreasers, increasers, or invaders. On the basis of their response to grazing by cattle since 1942, the plants of the experimental pastures have been tentatively classified as decreaser, increaser, or invader. This classification was based on data from the clipped plots and from observations on and in the vicinity of the station. Plants which have been identified are listed in the appendix according to kind of range plant and its reaction to grazing.

Figure 7. One of the exclosures used in the study and location of plots within the exclosure (right). This shows blue grama and buffalograss on a ridgetop in heavily grazed pasture 4 at the end of the 1955 summer grazing season.



Changes in Range Condition

Range condition is a measure of the state of health of the range. In this publication, range condition is defined as total percent by weight of the present vegetation on a site which is original or climax vegetation for that site. A range site is a combination of climate, soil, and topography that produces a characteristic kind and amount of vegetation.

This method of determining range condition involves studying the climax vegetation of the area by examining relatively undisturbed (relict) areas. Range sites in various stages of retrogression and recovery are also examined and the various plant species are classified as decreasers, increasers, or invaders and the maximum amount of the increaser species in the climax population is estimated.

Range condition is then computed by totaling the percent decreasers and the percent increasers. If the amount of any one increaser species exceeds the maximum amount of that species estimated to be present in the climax population, only the amount estimated to be present in the climax is used in computing range condition. Invaders are not considered to be part of the climax and are not totaled in calculating range condition. A range condition percentage from 0 to 25 is designated as poor, 25-50 as fair, 50-75 as good, and over 75 as excellent.[5]

Visual estimates of range condition and forage utilization are presented in table 13. These estimates have been made by one individual.

The pastures were ungrazed for 3 years before the experiment began. The average range condition in 1942 was 60, 62, and 63 percent, respectively, for heavily, moderately, and lightly grazed pastures. Utilization during the first 5 years of the experiment averaged 42, 23, and 15 percent for heavy, moderate, and light grazing, respectively. These values were rather low under all grazing rates because of favorable rainfall and high forage production.

During the last 9 years, utilization under heavy grazing averaged 69 percent and range condition declined from 46 to 33 percent. This decline was primarily due to a decrease in western wheatgrass accompanied by an increase in buffalograss and blue grama, followed by a replacement of blue grama by buffalograss.

Under moderate grazing, utilization averaged 50 percent for the last 9 years and range condition remained about the same through 1954 and declined in 1955.

Under light grazing, utilization averaged 28 percent from 1947 through 1955 and range condition varied from 66 to 80 percent and averaged 74 percent. The improvement in these pastures was due principally to an increase in western wheatgrass and a decrease in buffalograss. The decline in range condition in both the moderately and lightly grazed pastures in 1955 was

[5]This is the method described by Dyksterhuis, E. J., 1949. Condition and management of range based on quantitative ecology. *J. Range Mgt.* 2:104.

probably due to the effect of 2 years of drought and to an influx of japanese brome.

Utilization in lightly grazed pasture 3 and heavily grazed pasture 4 at the end of the 1955 grazing season is shown in figure 8. Utilization within a pasture has varied considerably due to several factors, particularly distance from water and the species composition of the range. A comparison of utilization in a western wheatgrass-japanese brome area with utilization in an area where sideoats grama was abundant is shown in figure 9. Both of these areas are in the same lightly grazed pasture and are comparable distances from water.

Total Vegetative Production

The lightly grazed pastures produced significantly greater amounts of forage than heavily or moderately grazed pastures (table 14). There were large differences in forage production between different topographic locations and between years. Ridges, the driest of the four topographic areas studied, had less than one-half the production of the draws. Forage production of slopes was intermediate between the production of ridges and draws. Total forage production on north facing slopes was somewhat greater than the production on south facing slopes, probably because north facing slopes had a more moist microclimate.

In 1951 precipitation was 20.92 inches, which is 6.20 inches greater than the long-time average for the station. Forage production in 1952 was the greatest of any of the 3 years studied. The carryover of soil mois-

Table 13. Visual Estimates of Range Condition and Forage Utilization Under Different Rates of Grazing from 1942 Through 1955

	Heavy Grazing			Moderate Grazing			Light Grazing		
Year	Stocking Rate A/AUM	Utilization %	Range Condition %	Stocking Rate A/AUM	Utilization %	Range Condition %	Stocking Rate A/AUM	Utilization %	Range Condition %
1942	1.43	23	60	2.38	14	62	3.23	9	63
1943	1.37	42	51	2.27	25	58	3.12	17	58
1944	1.39	40	50	2.33	21	64	3.23	12	65
1945	1.37	50	53	2.27	28	61	3.12	16	64
1946	1.35	55	51	2.27	26	60	3.12	19	65
1947	1.10	67	46	1.82	48	61	2.50	29	68
1948	1.10	75	44	1.82	58	72	2.50	32	80
1949	1.49	78	40	1.96	58	64	2.50	38	72
1950	2.13	62	41	3.23	45	63	4.00	28	71
1951	1.55	69	38	2.42	46	65	3.33	26	80
1952	1.66	60	39	2.60	38	65	3.50	20	79
1953	1.72	65	36	2.70	48	67	3.60	22	75
1954	2.02	70	31	3.16	48	64	4.31	25	72
1955	1.74	72	33	2.70	58	55	3.42	30	66

ture and plant vigor from 1951, combined with above-normal precipitation in 1952, was responsible for this high yield. Forage production in 1955, a year of below-average rainfall, was only 60 percent of that in 1952.

The vegetation on the ridges responded the least to differences in rainfall between years while the draws produced over one and one-half times as much forage in 1952 as they did in 1955. Forage production in the draws was higher because they received the benefit of added runoff and seepage.

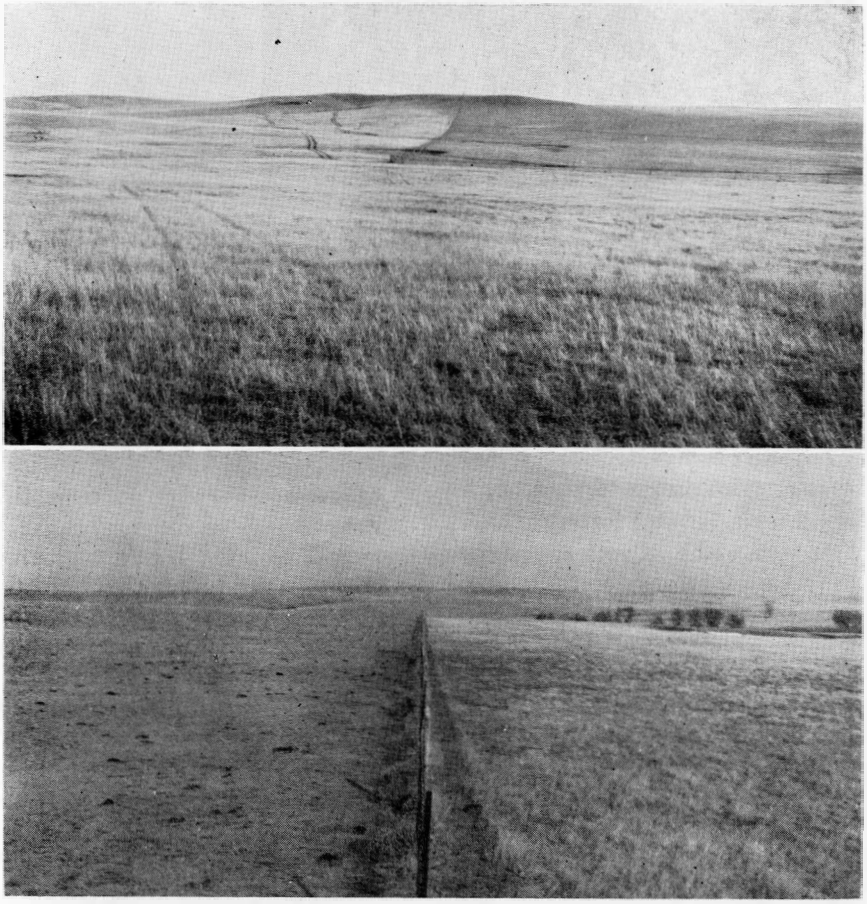


Figure 8. Comparison of lightly and heavily grazed pastures. The upper photo shows lightly grazed pasture 3 on the left and heavily grazed pasture 4 in the upper right. The lower photo shows heavily grazed pasture 1 on the left and lightly grazed pasture 6 on the right.

Figure 9. Utilization of a small area of warm season sideoats grama (left) in a large area of cool season western wheatgrass (right) in the same lightly grazed pasture in 1955.

Reaction of Decreasers

The decreaser grasses that were most often encountered in the plots were green needlegrass, sideoats grama, sand dropseed, and needleandthread. Several forbs, including american vetch, silverleaf scurfpea, tallbread scurfpea, and slimflower scurfpea—all legumes—were encountered frequently. Data in table 15 indicate that decreasers occurred in significantly greater amounts on ridges in lightly grazed pastures than on any other site. Decreasers were least abundant on south facing slopes in those heavily grazed.

Decreaser species accounted for a greater percent of the total weight of forage produced from lightly grazed pastures than from moderately grazed pastures. This was true on all sites except north facing slopes. On north facing slopes, the data showed a greater percent of decreasers produced under moderate grazing than under light grazing. This difference is probably due to inadequate sampling.

Average values of percent decreaser species on silty clay soils for heavy, moderate, and light grazing (table 16) did not vary greatly from the average values for all soil sites. Comparison of data in tables 15 and 16 shows that on north facing slopes, both on silty clay soils and on all soil types, the percent decreasers were the greatest in 1953 and the least in 1952. However, the magnitude of this difference was greater on silty clay soils than on all soil types.

Reaction of Increasers

The major increaser species occurring in the plots were western wheatgrass, blue grama, buffalograss, and needleleaf sedge. Scarlet

Table 14. Average Pounds Per Acre of Total Live Vegetation

	Year*	Ridges	South Slopes	North Slopes	Draws	All Sites
Heavy Grazing	1952	1164	1379	1534	2999	1785
	1953	1218	1202	1152	2956	1522
	1955	825	713	854	1796	1060
	Average	1069	1098	1188	2509	1449
Moderate Grazing	1952	1198	1526	1532	2606	1578
	1953	1164	1288	1636	2364	1488
	1955	664	1087	940	1722	1015
	Average	1009	1300	1343	2231	1353
Light Grazing	1952	1355	1678	1653	3527	1976
	1953	1069	1344	1422	2817	1647
	1955	757	843	1099	2311	1196
	Average	1059	1289	1389	2885	1605
All Rates	1952	1239	1546	1584	3131	1790
	1953	1158	1287	1494	2738	1558
	1955	749	902	987	1988	1096
	Average	1045	1245	1335	2611	1476

*Data for 1954 not available.

Table 15. Average Percent by Weight of Decreaser Species

	Year*	Ridges	South Slopes	North Slopes	Draws	All Sites
Heavy Grazing	1952	2.28	.69	.27	7.01	2.71
	1953	.46	.53	1.13	2.54	.92
	1955	1.28	.12	.35	2.59	1.14
	Average	1.34	.45	.43	4.35	1.66
Moderate Grazing	1952	5.85	.57	4.46	2.20	3.15
	1953	15.38	8.38	5.96	2.30	8.60
	1955	5.54	1.75	5.38	4.39	4.09
	Average	8.92	3.57	5.27	2.96	5.26
Light Grazing	1952	18.44	23.93	3.03	6.18	13.01
	1953	19.09	9.31	5.93	11.08	10.40
	1955	16.70	16.38	4.05	.72	9.61
	Average	17.98	16.54	4.24	6.00	11.03
All Rates	1952	8.86	9.36	2.95	5.72	6.82
	1953	10.96	6.77	5.51	6.75	7.47
	1955	7.84	6.83	3.84	2.20	5.34
	Average	9.17	7.65	3.99	4.76	6.50

*Data for 1954 not available.

globemallow, scarlet gaura, fringed sagewort, cudweed sagewort, and three species of pricklypear (common, plains, and brittle) also occurred frequently.

There was a significant difference in the percent by weight of increasers between rates of grazing (table 17). For the 3-year period more than 90 percent of the vegetation from all sites in the heavily grazed pastures was produced by increaser species. Draws in moderately grazed pastures contained a larger percentage of increaser species than did the ridges, north facing slopes, or south facing slopes. The plots yielding the greatest percent of increasers in the lightly grazed pastures were found on the ridges. However, over all rates of grazing, there was little difference in the percent of increasers from the various topographic sites.

In both the moderately grazed and lightly grazed pastures, increasers accounted for a smaller percent of the total vegetation produced in 1953 than in 1952 and also a smaller percent in 1955 than in 1953. In contrast, in the heavily grazed pastures, the percent of increasers varied only slightly between years.

Differences in the percent of increasers for the various years were influenced by a number of factors. These changes in relative abundance of increasers can best be evaluated by examining the changes in the three major increaser species—buffalograss, blue grama, and western wheatgrass. Average values for these species are shown in tables 18, 19, and 20.

Buffalograss. Buffalograss was found in significantly greater amounts in the heavily grazed pastures than in the moderately or lightly grazed pastures. Buffalograss never accounted for more than 25 percent of the forage produced in lightly grazed pastures; whereas in

Table 16. Average Percent by Weight of Decreaser, Increaser, and Invader Species on Silty Clay Soils on North Facing Slopes

Year* and Classification		Heavy	Moderate	Light	Average
1952	Decreaser	.27	3.35	1.25	1.62
	Increaser	98.25	96.65	96.89	97.26
	Invader	1.48	.00	1.87	1.12
1953	Decreaser	1.13	7.42	11.84	7.79
	Increaser	98.25	89.78	84.84	89.58
	Invader	.63	2.80	3.31	2.64
1955	Decreaser	.35	6.51	2.04	3.32
	Increaser	89.23	73.28	71.89	77.29
	Invader	10.42	21.11	26.07	19.39
All Years	Decreaser	.43	5.98	4.19	3.93
	Increaser	94.38	85.32	84.50	87.51
	Invader	5.19	8.69	11.30	8.55

*Data for 1954 not available.

Table 17. Average Percent by Weight of Increaser Species

	Year*	Ridges	South Slopes	North Slopes	Draws	All Sites
Heavy Grazing	1952	96.93	98.48	98.25	86.77	94.90
	1953	96.56	93.26	98.25	93.42	94.94
	1955	90.24	96.95	89.23	95.50	93.23
	Average	94.57	96.23	94.38	91.59	94.30
Moderate Grazing	1952	94.14	99.22	95.54	95.59	96.51
	1953	83.61	84.95	90.13	91.40	86.92
	1955	92.05	62.56	68.71	86.90	73.87
	Average	89.93	82.24	83.79	91.30	85.54
Light Grazing	1952	81.48	75.51	95.99	80.74	83.90
	1953	78.49	80.18	77.85	77.63	78.69
	1955	82.26	61.46	59.50	43.59	61.46
	Average	80.95	72.39	77.78	67.32	74.54
All Rates	1952	90.85	90.14	96.32	86.12	91.19
	1953	86.92	85.24	85.29	85.02	85.61
	1955	88.18	70.74	69.13	73.02	74.66
	Average	88.70	82.04	83.09	81.13	83.69

*Data for 1954 not available.

Table 18. Average Percent by Weight of Buffalograss

	Year*	Ridges	South Slopes	North Slopes	Draws	All Sites
Heavy Grazing	1952	36.59	64.08	73.38	49.92	54.83
	1953	59.17	46.62	53.45	76.94	57.32
	1955	30.90	37.42	63.65	47.42	43.59
	Average	42.22	49.38	66.36	54.32	51.39
Moderate Grazing	1952	38.28	52.70	50.10	63.37	49.80
	1953	44.88	45.07	39.17	55.94	44.57
	1955	41.39	32.55	32.81	58.44	37.48
	Average	41.51	43.44	40.20	59.25	43.82
Light Grazing	1952	6.36	24.26	21.02	16.16	18.09
	1953	17.57	19.48	22.05	20.50	20.10
	1955	14.82	11.82	12.87	8.66	12.10
	Average	12.49	18.52	18.45	15.11	16.65
All Rates	1952	27.08	44.88	42.62	39.11	39.06
	1953	42.63	35.86	32.69	43.47	38.04
	1955	29.04	25.99	31.00	34.12	29.63
	Average	32.64	35.58	35.53	38.57	35.44

*Data for 1954 not available.

Table 19. Average Percent by Weight of Blue Grama

	Year*	Ridges	South Slopes	North Slopes	Draws	All Sites
Heavy Grazing	1952	41.54	25.77	11.17	4.44	21.37
	1953	22.25	26.76	22.23	.24	19.88
	1955	33.84	41.85	6.70	1.57	21.94
	Average	32.54	31.46	10.84	2.45	21.18
Moderate Grazing	1952	33.80	27.11	17.78	12.12	24.18
	1953	21.33	18.75	14.83	7.26	16.85
	1955	27.55	9.83	9.25	.12	12.50
	Average	27.56	18.56	13.66	6.50	17.74
Light Grazing	1952	42.43	13.75	11.01	5.24	16.96
	1953	20.89	22.37	15.03	3.08	15.80
	1955	25.70	9.79	10.06	4.58	12.01
	Average	30.47	15.30	11.86	4.30	14.89
All Rates	1952	39.26	21.76	13.46	6.29	20.59
	1953	21.54	22.11	15.60	3.41	17.16
	1955	29.03	17.82	9.07	2.48	14.99
	Average	30.18	20.56	12.40	4.11	17.58

*Data for 1954 not available.

Table 20. Average Percent by Weight of Western Wheatgrass

	Year*	Ridges	South Slopes	North Slopes	Draws	All Sites
Heavy Grazing	1952	10.16	5.26	8.32	20.02	11.11
	1953	4.96	14.70	7.38	13.62	10.29
	1955	5.06	15.01	7.92	32.83	15.69
	Average	6.72	11.66	8.02	23.86	12.57
Moderate Grazing	1952	18.36	14.27	22.17	16.66	17.84
	1953	6.78	16.23	19.37	18.65	15.22
	1955	8.54	12.66	18.59	25.64	15.16
	Average	11.23	14.39	19.95	20.32	16.05
Light Grazing	1952	25.62	34.92	59.58	32.45	39.96
	1953	37.41	34.08	37.79	30.64	34.90
	1955	29.92	32.47	31.63	15.51	28.30
	Average	30.40	33.82	43.31	26.17	34.37
All Rates	1952	18.04	19.76	35.24	24.32	24.41
	1953	14.47	22.54	26.65	23.39	21.74
	1955	14.51	20.68	21.68	24.42	20.27
	Average	15.71	20.99	27.79	24.09	22.14

*Data for 1954 not available.

the heavily grazed pastures this grass produced an average of 51 percent of the total weight, and on north slopes produced about two-thirds of the total vegetative production.

During 1952 and 1953 buffalograss was found in significantly greater abundance than in 1955. Below-normal rainfall in the summer months of 1954 and 1955 (see table 1, page 6) was probably the major factor in causing the decline in production of buffalograss. In 1955, the soil moisture supply was largely depleted by cool-season grasses and early growing annuals before buffalograss began growth. These species formed an overstory in the lightly grazed pastures and reduced the light which was available to buffalograss. The increasing abundance of invader species, primarily japanese brome and sixweeks fescue, was associated with a reduced abundance of buffalograss. The regression of the percent weight of buffalograss on the percent weight of invader species was —.93.

Blue Grama. There was more blue grama in the heavily grazed pastures than in lightly or moderately grazed pastures, although this difference was not significant. Site differences had a greater effect on the production of blue grama than on the production of buffalo grass. Over all rates of grazing, buffalograss was found in greatest abundance in the draws and was least abundant on the ridges. In contrast, blue grama accounted for significantly less of the total production in the draws and was most abundant on the ridges. Draws received greater grazing pressure than other sites, and this may have reduced the abundance of blue grama under heavy grazing, since this species has been observed to be more palatable than buffalograss.

Increases in the percent of invaders did not affect the production of blue grama as much as it affected buffalograss. The regression of the percent by weight of blue grama on the percent invaders was —.35.

Western Wheatgrass. Although western wheatgrass has been classified as an increaser, it has been decreasing in abundance on the heavily grazed pastures since the experiment began and was nearly twice as abundant in 1955 on lightly grazed pastures as on heavily grazed pastures. This does not alter its classification because the range condition was estimated to be only 60 percent when the study began. At that time the decreaser species made up only a small part of the vegetation. When a range is subjected to heavy grazing, plants that are classified as increasers will increase in abundance over their normal values in the climax, but under continued overuse these plants may receive greater utilization and be displaced by less palatable increasers or invaders.

Western wheatgrass was most abundant in draws and least abundant on ridges. The percent by weight of this species did not vary markedly between years. The production of western wheatgrass was reduced only slightly by the presence of invaders, probably because

it is a cool-season mid-grass and is better able to compete with early growing annuals than the warm season, short grasses. This is especially true during periods of low summer rainfall.

Reaction of Invaders

A number of invader species have increased considerably in the past few years. Among those of frequent occurrence are japanese brome, cheatgrass brome, sixweeks fescue, and little barley. In addition 25 species of annual forbs were collected in the 1955 plots. Among the most common were rough falsepennyroyal, woolly indianwheat, prairie pepperweed, whitlow-wort, species of spurge, common sunflower, species of stickseed, and venuslookingglass.

Invaders did not contribute greatly to total vegetative production in 1952 but by 1955 accounted for more than half of the forage produced in lightly grazed draws (table 21). The percent invaders was highly variable and appeared to be affected by yearly climatic fluctuations, rates of grazing, and topographic locations, as well as other factors which were not measured in this study.

A series of fall seasons with favorable precipitation followed by warm temperature (1953 through 1955) has probably been the predisposing factor which has permitted japanese brome to compete favorably with the native perennial vegetation. This effect has been intensified by below normal precipitation during two summers, which has restricted the growth of warm season vegetation. In 1955, japanese brome was separated from other invader species and percent by weight was computed (table 22). Japanese brome accounted for nearly four-fifths of the total production of invaders in moderately and lightly grazed pastures but composed only a small part of the invaders in the heavily grazed pastures. A similar relationship was observed in the three previous years. This species is grazed when it is young and succulent, but is unpalatable to cattle when mature. Under heavy grazing, the cows have been forced to consume nearly all of the japanese brome, allowing very little to mature seed (see figure 8).

In 1955 japanese brome was found in significantly greater amounts in draws than on other topographic sites and was practically absent on ridges, probably because of differences in soil moisture and other soil characteristics. Sharp transitions occurring between areas containing a large percentage of japanese brome and areas containing practically none are common in the experimental area. Plant communities composed principally of little bluestem, sideoats grama, cudweed sagewort, and several species of scurfpea are relatively free from this species.

The amount of invaders on silty clay soils on north slopes increased more slowly than on the average of all north slopes (compare tables 16 and 21). Invaders did not make up an important part of the vegetation on silty clay soils until 1955. On silty clay soils on north slopes, the per-

cent invaders increased from 1.12 percent in 1952 to 19.39 percent in 1955; whereas, on all soils on north slopes, the percent invaders increased from 0.74 percent in 1952 to 27.02 percent in 1955.

Changes in Standing Dead Vegetation, Mulch, and Total Cover

Total cover on rangelands is composed of three vegetative components—live, standing dead, and mulch in various stages of decomposition. The amount of standing dead vegetation is primarily dependent on the total vegetative production of the previous growing season and the utilization of that vegetation by livestock, rodents, and insects. Beating rains, heavy snow, and wind also influence the amount of vegetation left standing at the end of a growing season. Standing dead material on the plots was cut and sacked during the June clipping. Mulch was picked up after the end of the grazing season at the time of

Table 21. Average Percent by Weight of Invader Species

	Year*	Ridges	South Slopes	North Slopes	Draws	All Sites
Heavy Grazing	1952	.79	.83	1.48	6.22	2.39
	1953	2.99	6.21	.63	4.04	4.14
	1955	8.41	2.93	10.42	1.87	5.61
	Average	4.06	3.32	5.19	4.04	4.03
Moderate Grazing	1952	.01	.21	.00	2.22	.34
	1953	1.02	6.67	3.90	6.29	4.48
	1955	2.41	35.67	25.88	8.68	22.02
	Average	1.15	14.18	10.93	5.73	9.20
Light Grazing	1952	.09	.56	.98	13.07	3.09
	1953	2.41	10.51	16.21	11.28	10.92
	1955	.88	22.26	36.45	55.69	28.93
	Average	1.01	11.11	17.98	26.68	14.43
All Rates	1952	.30	.49	.74	8.16	1.99
	1953	2.12	8.00	9.20	8.22	6.92
	1955	3.90	22.46	27.02	24.76	19.98
	Average	2.10	10.31	12.92	14.11	9.80

*Data for 1954 not available.

Table 22. Average Percent by Weight of Japanese Brome in 1955

	Ridges	South Slopes	North Slopes	Draws	All Sites
Heavy Grazing	.00	.02	.25	.60	.22
Moderate Grazing	.00	25.17	16.54	6.90	14.67
Light Grazing	.12	17.33	31.66	55.56	25.83
All Rates	.04	15.94	19.33	23.84	14.79

Table 23. Average Pounds per Acre of Standing Dead Vegetation

	Year*	Ridges	South Slopes	North Slopes	Draws	All Sites
Heavy Grazing	1952	122	48	43	82	76
	1953	217	234	260	40	195
	1955	75	64	34	43	555
	Average	138	115	70	58	100
Moderate Grazing	1952	124	162	242	118	171
	1953	472	537	603	319	515
	1955	154	346	260	110	249
	Average	250	348	362	182	311
Light Grazing	1952	370	486	696	383	505
	1953	889	831	832	306	724
	1955	516	481	560	291	474
	Average	564	599	688	327	562
All Rates	1952	205	255	394	210	272
	1953	493	572	676	243	520
	1955	249	326	335	156	279
	Average	311	384	449	200	350

*Data for 1954 not available.

Table 24. Average Pounds per Acre of Mulch

	Year*	Ridges	South Slopes	North Slopes	Draws	All Sites
Heavy Grazing	1952	269	348	188	675	382
	1953	229	274	191	299	255
	1955	12	17	22	135	46
	Average	184	231	117	412	239
Moderate Grazing	1952	454	714	699	604	635
	1953	354	379	509	350	408
	1955	67	76	62	80	69
	Average	292	390	401	397	371
Light Grazing	1952	864	1130	1010	2320	1279
	1953	706	544	697	1209	761
	1955	331	266	364	430	337
	Average	627	647	690	1401	801
All Rates	1952	529	778	722	1319	810
	1953	405	415	565	767	510
	1955	148	140	175	254	169
	Average	365	451	474	844	505

*Data for 1954 not available.

the fall clipping. The yields of standing dead vegetation and mulch are shown in tables 23 and 24.

Over five and one-half times as much standing dead material was left on the lightly grazed as on the heavily grazed pastures. Above-normal precipitation in 1952 was partly responsible for the large amount of standing dead vegetation remaining in 1953.

Heavy utilization in draws was reflected in significantly less standing dead material than on the other sites. Snow pack was deepest and had the greatest duration in some of the draws, which might account for lower weight of standing dead vegetation on this site. North facing slopes were second in production only to the draws but had the greatest amount of standing dead material.

There was significantly less mulch under all rates of grazing in 1955 than in the other 2 years (table 24). A large amount of mulch was washed from the plots by heavy rains in the fall of 1955, especially in the heavily grazed pastures where there was less total cover for protection. There was three and one-third times as much mulch on the lightly grazed pastures as on the heavily grazed pastures.

Variations in total cover are primarily due to the amount of total live vegetation. The soil on all sites in the lightly grazed pastures was protected with 50 percent more vegetation than in the heavily grazed pastures. Variation in total vegetative cover was greater be-

Table 25. Average Pounds per Acre of Total Cover

	Year*	Ridges	South Slopes	North Slopes	Draws	All Sites
Heavy Grazing	1952	1555	1776	1764	3756	2243
	1953	1664	1710	1602	3294	1971
	1955	786	776	910	2096	1142
	Average	1385	1479	1375	3100	1817
Moderate Grazing	1952	1775	2401	2472	3327	2384
	1953	1991	2204	2747	3033	2411
	1955	886	1334	1263	1980	1241
	Average	1551	1979	2105	2940	2012
Light Grazing	1952	2588	3295	3358	6230	3760
	1953	2663	2718	2950	4333	3132
	1955	1604	1591	2023	2717	1908
	Average	2251	2535	2767	4582	2944
All Rates	1952	1973	2580	2700	4660	2872
	1953	2055	2274	2735	3748	2588
	1955	1120	1325	1496	2346	1480
	Average	1724	2075	2258	3720	2325

*Data for 1954 not available.

tween years than between rates of grazing or topographic sites (table 25). Cover was approximately twice as great in 1952 as in 1955. Mulch and total live vegetation were also greatest in 1952. There was a difference in the amount of total cover on different topographic locations. Amount of cover was twice as great in the draws as on the ridges.

Summary and Conclusions

An intensity of grazing study with beef cows and calves on western South Dakota ranges has been conducted since 1942. This publication is a progress report presenting data collected from 1952 through 1955. Heavy, moderate, and light grazing have resulted in the following average stocking rates for the 7-month summer grazing season: 1.82, 2.85, and 3.78 acres per animal unit month. These stocking rates resulted in an average forage utilization of 69, 51, and 26 percent for heavy, moderate, and light grazing, respectively.

Cows on the heavily grazed pastures gained an average of 29.6 pounds between calving and the end of the summer grazing season. Those under moderate grazing gained 80.9 pounds, and those under light grazing gained 135.8 pounds. The cows under heavy grazing were in the poorest condition in the fall and, when placed on excellent condition winter range, made the largest winter gain, 75.8 pounds. Winter gain was 35.9 pounds under moderate grazing, but under light grazing there was a loss of 4.0 pounds.

The average percent calf crop born for 1954 through 1956 for heavy, moderate, and light grazing was 77.8, 72.2, and 83.3 percent. Bull calves were 5.6 pounds heavier at birth than heifer calves, and the calves from lightly and moderately grazed pastures were approximately 5 pounds heavier at birth than the calves from the heavily grazed pastures. At weaning, the calves from lightly grazed pastures were scored higher in condition and were 53 pounds heavier than the calves from heavily grazed pastures and 10 pounds heavier than the calves from moderately grazed pastures.

Total cow and calf gains for heavy, moderate, and light grazing were 14.5, 13.5, and 11.5 pounds per acre. However, production under heavy grazing has been declining since the beginning of the study and averaged only 6.6 pounds per acre in 1955.

Although no symptoms of vitamin A deficiency were observed, plasma carotene and vitamin A values at the end of the summer grazing season were much higher under light than under heavy grazing.

Lightly grazed pastures produced significantly greater amounts of forage than either the moderately or heavily grazed pastures. Ridges were the lightest producers and draws were the heaviest producers of forage over all rates of

grazing. The major decreaser species occurring in the pastures were green needlegrass, sideoats grama, needleandthread, sand dropseed, american vetch, and several species of scurfpea. These species were most abundant in the lightly grazed pastures and on ridges.

The major increaser species were western wheatgrass, blue grama, buffalograss, needleleaf sedge, scarlet globemallow, scarlet gaura, and species of pricklypear and sagewort.

Japanese brome was the principal invader species and was most abundant under light grazing and in the draws. Other invader grasses were sixweeks fescue, little barley, and cheatgrass brome. Some of the most abundant annual forbs included rough falsepennyroyal, woolly indianwheat, prairie pepperweed, whitlowwort, species of spurge, common sunflower, stickseed, and venuslookingglass.

There was significantly less standing dead vegetation remaining at the end of the season in the draws, while north facing slopes had the greatest amount. Although mulch cover was highly variable, there was three and one-third times as much mulch on the lightly grazed pastures as on the heavily grazed pastures. Draws contained significantly greater amounts of mulch than the other sites. Variations in total cover were primarily due to differences in total live vegetation. Total cover was the heaviest in the year 1952 and in the draws of all pastures.

The heavily grazed pastures are showing considerable erosion, whereas, in the lightly grazed pastures, the total vegetative cover is sufficient to prevent any appreciable soil movement.

Under the conditions of this study since 1942, it appears that a utilization of the annual forage production of between 30 and 45 percent from May 1 to December 1 would result in maximum sustained livestock production consistent with maintaining the soil and vegetative resources. This utilization is affected largely by yearly differences in precipitation but may be obtained by an average stocking rate of from 2.50 to 3.00 acres per animal unit month during a 7-month summer grazing season on ranges similar to the Cottonwood Range Field Station.

APPENDIX

Plants Identified in the Experimental Pastures at the Range Field Station, Cottonwood, Tentatively Classified by Their Observed Response on Clayey Range Site to Grazing by Cattle*

COMMON NAME;† SCIENTIFIC NAME	GRAZING REACTION

GRASSES AND GRASSLIKE PLANTS

Perennials

Barley, foxtail; *Hordeum jubatum* L.	Invader
Bluegrass, sandberg; *Poa secunda* Presl.	Increaser
Bluegrass, waxy;§ *Poa glaucifolia* Scribn. and Williams	Decreaser
Bluestem, big; *Andropogon gerardi* Vitman	Decreaser
Bluestem, little; *Andropogon scoparius* Michx.	Decreaser
Buffalograss; *Buchloe dactyloides* (Nutt.) Engelm.	Increaser
Dropseed, tall; *Sporobolus asper* (Michx.) Kunth	Decreaser
Dropseed, sand; *Sporobolus cryptandrus* (Torr.) A. Gray	Decreaser
Grama, blue; *Bouteloua gracilis* (H. B. K.) Lag. ex Steud	Increaser
Grama, hairy; *Bouteloua hirsuta* Lag.	Increaser
Grama, sideoats; *Bouteloua curtipendula* (Michx.) Torr	Decreaser
Junegrass, prairie; *Koeleria cristata* (L.) Pers.	Decreaser
Muhly, sandhill; *Muhlenbergia pungens* Thurb.	Decreaser
Muhly, stonyhills; *Muhlenbergia cuspidata* (Torr.) Rydb.	Decreaser
Needleandthread; *Stipa comata* Trin. and Rupr.	Decreaser
Needlegrass, green; *Stipa viridula* Trin.	Decreaser
Saltgrass, inland; *Distichlis stricta* (Torr.) Rydb.	Increaser
Sandreed, prairie; *Calamovilfa longifolia* (Hook.) Scribn.	Decreaser
Sedge, fescue;§ *Carex brevior* (Dewey) Mack.	Decreaser
Sedge, needleleaf; *Carex eleocharis* Bailey	Increaser
Sedge, plump-seed;§ *Carex gravida* Bailey	Decreaser
Sedge, threadleaf; *Carex filifolia* Nutt.	Decreaser
Switchgrass; *Panicum virgatum* L.	Decreaser
Threeawn, red; *Aristida longiseta* Steud.	Increaser
Wheatgrass, slender; *Agropyron trachycaulum* (Link) Malte	Decreaser
Wheatgrass, western; *Agropyron smithi* Rydb.	Increaser
Wildrye, Canada; *Elymus canadensis* L.	Decreaser

Annuals

Barley, little; *Hordeum pusillum* Nutt.	Invader
Barnyardgrass; *Echinochloa crusgalli* (L.) Beauv.	Invader
Brome, cheatgrass; *Bromus tectorum* L.	Invader
Brome, Japanese; *Bromus japonicus* Thunb.	Invader
Dropseed, puffsheath; *Sporobolus neglectus* Nash.	Invader
Fescue, sixweeks; *Festuca octoflora* Walt.	Invader
Foxtail, water; *Alopecurus geniculatus* L.	Invader
Stinkgrass; *Eragrostis cilianensis* (All.) Lutati	Invader
Tumblegrass; *Schedonnardus paniculatus* (Nutt.) Trel.	Invader
Witchgrass, common; *Panicum capillare* L.	Invader

COMMON NAME;† SCIENTIFIC NAME	GRAZING REACTION
FORBS	
Perennials	
Agoseris, pale; *Agoseris glauca* (Nutt.) Greene	Decreaser
Aster, heath; *Aster ericoides* L.	Increaser
Bahia, plains; *Bahia oppositifolia* (Nutt.) A. Gray	Uncertain
Bindweed, field;‖ *Convolvulus arvensis* L.	Invader
Bladder-pod; *Lesquerella versicolor* Greene	Increaser
Boneset, false;‖ *Kuhnia eupatoriodes* L.	Decreaser
Cinquefoil; *Potentilla spp.*	Increaser
Comandra, common; *Comandra umbrellata* (L.) Nutt.	Uncertain
Dalea, bigtop;§ *Dalea enneandra* Nutt.	Decreaser
Dalea, silktop; *Dalea aurea* Nutt.	Decreaser
Dandelion, common; *Taraxacum officinale* Weber	Invader
Deathcamas, meadow; *Zigadenus venenosus* S. Wats.	Increaser
Deathcamas, Nuttall; *Zigadenus nuttalli* (Gray) S. Wats.	Increaser
Dock, curly; *Rumex crispus* L.	Invader
Dock, Mexican; *Rumex mexicanus* Meissn.	Invader
Dock, tall;§ *Rumex altissimus* Wood	Invader
Dogbane, hemp; *Apocynum cannabinum* L.	Increaser
Echinacea, blacksampson; *Echinacea angustifolia* DC.	Decreaser
Fleabane, hoary; *Erigeron canus* A. Gray	Increaser
Four-o'clock, narrow leaved;§ *Mirabilis linearis* (Pursh.) Heimerl	Decreaser
Gaura, scarlet; *Gaura coccinea* Nutt.	Increaser
Gayfeather, dotted; *Liatris punctata* Hook.	Decreaser
Geranium, Carolina; *Geranium carolinianum* L.	Decreaser
Globemallow, scarlet; *Sphaeralcea coccinea* (Pursh.) Rydb.	Increaser
Goldaster, hairy; *Chrysopsis villosa* (Pursh.) Nutt., ex DC.	Decreaser
Goldenrod, threenerve; *Solidago sparsiflora* A. Gray	Increaser
Goldenweed, ironplant; *Haplopappus spinulosus* (Pursh.) DC.	Decreaser
Gromwell, yellow;§ *Lithospermum incisum* Lehm.	Decreaser
Hymenopappus, fineleaf; *Hymenopappus filifolius* Hook	Decreaser
Larkspur, plains; *Delphinium virescens* Nutt.	Decreaser
Licorice, American; *Glycyrrhiza lepidota* (Nutt.) Pursh.	Increaser
Lettuce, chicory; *Lactuca pulchella* (Pursh.) DC.	Decreaser
Lomatium, yellowflowered;** *Lomatium foeniculaceum* (Nutt.) Coult. and Rose	Increaser
Lomatium, whiteflowered;** *Lomatium orientale* Coult. and Rose	Increaser
Mariposa, segolily; *Calochortus nuttalli* Torr.	Decreaser
Milkweed, green;§ *Asclepias viridiflora* Raf.	Decreaser
Milkweed, plains; *Asclepias pumila* (A. Gray) Vail	Decreaser
Milkvetch, groundplum; *Astragalus crassicarpus* Nutt.	Decreaser
Milkvetch, Missouri; *Astragalus missiouriensis* Nutt.	Increaser
Milkvetch, threeleaf;§ *Astragalus triphyllus* Pursh.	Decreaser
Onion, textile; *Allium textile*	Decreaser
Parsley, wild;‖ *Musineon divaricatum* (Pursh.) Coult. and Rose	Increaser
Penstemon, pale; *Penstemon pallidus* Small.	Decreaser

COMMON NAME;† SCIENTIFIC NAME	GRAZING REACTION

FORBS

Perennials

Penstemon, slender; *Penstemon gracilis* Nutt.	Decreaser
Penstemon, white; *Penstemon albidus* Nutt.	Decreaser
Phlox, plains; *Phlox andicola* (Britton) E. Nelson	Increaser
Polygala, white; *Polygala alba* Nutt.	Decreaser
Prairieclover, purple; *Petalostemon purpureum* (Vent.) Rydb.	Decreaser
Prairieclover, slender white; *Petalostemon occidentale* (Gray) Fernald	Decreaser
Prairieconeflower, upright; *Ratibida columnifera* (Nutt.) Wooton and Standley	Increaser
Pussytoes, rockymountain; *Antennaria aprica* Greene	Increaser
Sagewort, cudweed;‡ *Artemisia ludoviciana* Nutt. *var. gnaphalodes* (Nutt.) T & G.	Increaser
Sagewort, fringed;‡ *Artemisia frigida* Willd.	Increaser
Scurfpea, common breadroot; *Psoralea esculenta* Pursh.	Decreaser
Scurfpea, silverleaf;†† *Psoralea argophylla* Pursh.	Increaser
Scurfpea, slimflower;†† *Psoralea tenuiflora* Pursh.	Increaser
Scurfpea, tallbread; *Psoralea cuspidata* Pursh.	Decreaser
Sensitivebriar, catclaw; *Schrankia nuttalli* DC.	Decreaser
Skeletonplant, rush; *Lygodesmia juncea* (Pursh.) D. Don.	Increaser
Snakeweed, broom; *Gutierrezia sarothrae* (Pursh.) Britton and Rusby	Invader
Soapweed, small; *Yucca glauca* Nutt.	Decreaser
Spiderwort, bracted; *Tradescantia bracteata* Small	Decreaser
Starlily, common; *Leucocrinum montanum* Nutt.	Decreaser
Violet, Nuttall; *Viola nuttalli* Pursh.	Increaser
Vetch, American; *Vicia americana* Muhl.	Decreaser
Verbena, bigbract; *Verbena bracteata* Lag. and Rodr.	Invader
Yarrow, common; *Achillea millefolium* L.	Increaser
Yellowcress, spreading;‖ *Rorippa sinuata* (Nutt.) Hitchc.	Increaser

Biennials

Cryptantha, Bradbury's;** *Cryptantha bradburiana* Payson	Invader
Erysimum, plains; *Erysimum asperum* (Nutt.) DC.	Invader
Gumweed, curlycup; *Grindelia squarrosa* (Pursh.) Dunal	Invader
Salsify, meadow; *Tragopogon pratensis* L.	Invader
Salsify, vegetable-oyster; *Tragopogon porrifolius* L.	Invader
Stickseed, American;§ *Hackelia americana* (L.) I. M. Johnston	Invader
Thistle, bull; *Cirsium vulgare* (Savi) Tenore	Invader

Annuals

Amaranth, redroot; *Amaranthus retroflexus* L.	Invader
Cocklebur, oriental; *Xanthium orientale* L.	Invader
Collomia, slenderleaf;§ *Collomia linearis* Nutt.	Invader
Deervetch, spanishclover; *Lotus americanus* (Nutt.) Bisch.	Invader
Draba, creeping;§ *Draba reptans* (Lam.) Fern.	Invader
Ellisia, waterleaf;** *Ellisia nyctelea* L.	Invader
Euphorbia, netted-seed; *Euphorbia dictyosperma* Fisch. and Mey.	Invader
Euphorbia, ridgeseed; *Euphorbia glyptosperma* Engelm.	Invader

COMMON NAME;† SCIENTIFIC NAME	GRAZING REACTION
FORBS	
Annuals	
Euphorbia, snow-on-the-mountain; *Euphorbia marginata* Pursh.	Invader
Falseflax, bigseed;§ *Camelina sativa* (L.) Crantz	Invader
Falsepennyroyal, American; *Hedeoma pulegioides* (L.) Pers.	Invader
Falsepennyroyal, rough; *Hedeoma hispida* Pursh.	Invader
Flax, grooved; *Linum sulcatum* Riddell	Invader
Fleabane, annual; *Erigeron annuus* (L.) Pers.	Invader
Fleabane, horseweed; *Erigeron canadensis* L.	Invader
Fleabane, daisy;§ *Erigeron strigosus* Muhl. ex Wild.	Invader
Goosefoot, lambsquarters; *Chenopodium album* L.	Invader
Goosefoot, slimleaf; *Chenopodium leptophyllum* Nutt.	Invader
Indianwheat, spiny;** *Plantago spinulosa* Decne.ex DC.	Invader
Indianwheat, wooly; *Plantago purshi* Roem. and Schult.	Invader
Knotweed, prostrate; *Polygonum aviculare* L.	Invader
Knotweed, erect; *Polygonum erectum* L.	Invader
Kochia;‡ *Kochia scoparia* (L.) Schrad.	Invader
Lettuce, prickly; *Lactuca scariola* L.	Invader
Monolepis, Nuttall; *Monolepis nuttalliana* (Schultes) Greene	Invader
Nightshade, buffalobur; *Solanum rostratum* Dunal	Invader
Pennycress, field; *Thlaspi arvense* L.	Invader
Pepperweed, prairie; *Lepidium densiflorum* Schrad.	Invader
Polygala, whorled; *Polygala verticillata* L.	Invader
Purslane, common; *Portulaca oleracea* L.	Invader
Ragweed, common; *Ambrosia artemisifolia* L.	Invader
Rockjasmine, western; *Androsace occidentalis* Pursh.	Invader
Russianthistle, tumbling; *Salsola kali L.*, var. *tenuifolia* Tausch.	Invader
Stickseed, European; *Lappula echinata* Gilib.	Invader
Stickseed, western;** *Lappula redowski* (Hornem.) Greene	Invader
Sunflower, common; *Helianthus annuus* L.	Invader
Transymustard, richardson; *Descurainia richardsoni* (Sweet) O. E. Schulz	Invader
Venuslookingglass, clasping; *Specularia perfoliata* (L.) A. OC.	Invader
Venuslookingglass, slender; *Specularian leptocarpa* (Nutt.) Gray	Invader
WOODY PLANTS	
Perennials	
Amorpha, dwarfindigo; *Amorpha nana* Nutt.	Decreaser
Amorpha, leadplant; *Amorpha canescens* Pursh.	Decreaser
Cactus, pincushions;‡ *Mammillaria missouriensis* Sweet	Decreaser
Chokecherry, black; *Prunus virginiana* L. var. *melanocarpa* (A. Nels.)	Decreaser
Currant, buffalo; *Ribes odoratum* Wendl.	Decreaser
Plum, American; *Prunus americana* Marsh.	Decreaser

COMMON NAME;† SCIENTIFIC NAME	GRAZING REACTION
Pricklypear, brittle; *Opuntia fragilis* (Nutt.) Haw.	Increaser
Pricklypear, common; *Opuntia humifusa* Raf.	Increaser
Pricklypear, plains; *Opuntia polyacantha* Haw.	Increaser
Rose, woods; *Rosa woodsi* Lindl.	Decreaser
Sagebrush, silver; *Artemisia cana* Pursh.	Increaser
Snowberry, western; *Symphoricarpos occidentalis* Hook.	Increaser
Sumac, skunkbush; *Rhus trilobata* Nutt.	Decreaser

*The authors appreciate the assistance of C. A. Taylor of the Botany Department, who identified many of these plants and checked the scientific names in this list.

†Except where noted, common names are from Kelsey, H. P. and W. A. Dayton, *Standardized Plant Names,* 2nd Ed., J. Horace McFarland Co., Harrisburg, Pa., 1942.

‡The common generic name is taken from a reference other than *Standardized Plant Names.*

§The common generic name given in *Standardized Plant Names* is used, but the common specific name was obtained from another reference.

‖The common generic name used is not given in *Standardized Plant Names* so was obtained from another reference.

**The common generic name given in *Standardized Plant Names* is used, but the common specific name used in this list is suggested by the authors.

††This species was considered to be a decreaser during most of this study.