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EFFECTS OF STOCKING RATES ON RANGE VEGETATION AND BEEF CATTLE PRODUCTION.

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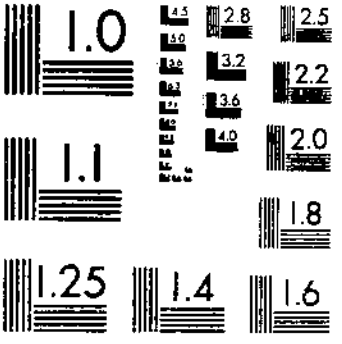

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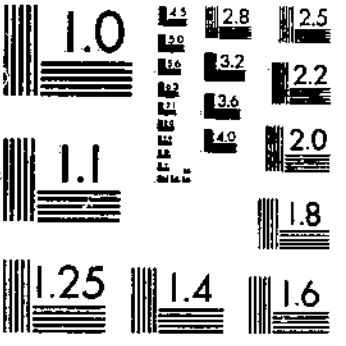

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EFFECTS OF STOCKING RATES ON RANGE VEGETATION AND BEEF CATTLE PRODUCTION IN THE NORTHERN GREAT PLAINS

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Special acknowledgment is due Larry S. Short, formerly of the U.S. Forest Service, who supervised establishment of the study.

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EFFECTS OF STOCKING RATES ON RANGE VEGETATION AND BEEF CATTLE PRODUCTION IN THE NORTHERN GREAT PLAINS

By WALTER R. HOUSTON, *range scientist, Crops Research Division,* and R. R. WOODWARD, formerly [1] *animal husbandman, Animal Husbandry Research Division, Agricultural Research Service*

Range-livestock production is the chief agricultural enterprise in the Northern Great Plains. Over 80 percent of the 118 million acres of this northern mixed-prairie region is primarily devoted to this use (*22*).[2]

Land administrators and economists generally agree that range-livestock production is the highest feasible use for most of this vast range area. For most successful operation and sustained high economic return, it is necessary that these ranges and the livestock using them be managed for maximum productivity without deterioration of the basic land and forage resource. Attainment of this goal depends on the development of sound management systems from thorough study of the range vegetation-soil-grazing-animal complex and the influences and interactions of weather.

The semiarid climate with normally large variation in both amount and distribution of precipitation strongly influences all operations. Although drought has occurred at Miles City, Mont., near the center of the region, on an average of once in every 5 years, actual duration of the cycles varies greatly.

Of the environmental factors that may be influenced by man, the degree of forage utilization is probably the most easily manipulated by controlling either the number of animals or period of grazing. This in turn may influence the range vegetation, animal performance, and economics of the livestock enterprise. In addition, it may modify or magnify the impact of weather extremes.

As a basic consideration livestock and rangeland managers should know the effects of various levels of grazing pressure on the range and how to recognize them promptly. They should know the long-term relationships between degree of forage utilization and the efficiency of livestock operations and how these relationships may be influenced by prevailing weather.

This bulletin reports responses of range vegetation and beef cattle productivity to different stocking rates from 1950 through 1957 on the U.S. Range Livestock Experiment Station near Miles City. Its purpose is to provide a basis for management decisions regarding

[1] Resigned.

[2] Italic numbers in parentheses refer to Literature Cited, p. 47.

stocking levels. This report supplements the previous publication of a similar study on the same areas for the period 1932–45 (*17*).

The selection of different experimental stocking rates varies widely from area to area. It depends upon the experience and objectives of the investigator. Stocking levels that could be called heavy, moderate, or light depend on climate and weather, soils, quantity and quality of vegetation, topography, quantity and distribution of water, and many other factors (*21*). While heavy, moderate, and light rates in general fit a theoretical curve of gain per head by stocking level (*9*), considerable local variation is possible.

OTHER INVESTIGATIONS

Despite differences in time, location, and even classes of animals, several grazing-intensity studies in the Northern Great Plains have shown similar results. Sarvis (*18*), Clarke and coworkers (*4*), Johnson and coworkers (*12*), Smoliak and Peters (*20*), Lewis and coworkers (*14*), and Reed and Peterson (*17*) have found from South Dakota to Alberta that midgrasses generally decrease under heavy utilization levels and short-grass species increase. Other increasing species indicated were fringed sagewort,[3] plains pricklypear, and broom snakeweed. Lewis and coworkers (*14*) found decreases in blue grama grass, a short-grass species, under heavy stocking. Clarke and coworkers (*4*) showed increased damage to forage from prairie gophers (*Citellus richardsonii*) as a result of heavy stocking.

Reed and Peterson (*17*) also showed significant reductions in vigor of vegetation, litter cover, root volume, and the soil properties of organic matter, pore space, rate and depth of moisture infiltration, and increased volume weight under heavy grazing.

Several investigators have indicated that the responses of vegetation are strongly influenced by site (Lewis and coworkers (*14*); Lodge (*15*); Reed and Peterson (*17*)). Holscher and Woolfolk (*10*) found that different sites are often grazed differently.

Reduced animal gains per head have been found without exception to result from heavy stocking. No investigator in the region yet has found reduced gain per acre from heavy stocking; although Johnson and coworkers (*12*) did show a loss in grazing capacity during drought.

Reed and Peterson (*17*) also showed the strong interrelations of weather and stocking rates.

On yearlong range using breeding cows both Clarke and coworkers (*4*) and Reed and Peterson (*17*) found increased winter hay requirements traceable to poorer condition of cows under heavy stocking.

Reed and Peterson (*17*) found a decrease in calf crop weaned as a result of heavy stocking. However, Clarke and coworkers (*4*), Johnson and coworkers (*12*), and Lewis and coworkers (*14*) did not indicate this response with cows and calves.

EXPERIMENTAL AREA

The study area is typical of the semiarid southwestern portion of the northern Great Plains. This area has fewer midgrasses and more

[3] Common and botanical names of plants mentioned are listed in Appendix, p. 49.

short-grass vegetation than the subhumid Dakotas and Canadian part of the region.

The experimental range units consisted of two separate areas of native range. They differed considerably in topography, soils, and vegetation. The area of rougher topography providing the better winter shelter, which included eroded, rough breaks and steep, shale buttes to rolling uplands, was used from about November 1 to mid-May. The other unit of mostly gently sloping benchlands to nearly level bottomlands was grazed during the remaining months of the year.

The size of pastures varied at each range unit to provide a gradient in average stocking levels. Relative sizes were based on forage inventories in 1932 and 1944. Each summer pasture was paired with one of similar size on the winter unit.

One central water source was provided at each unit.

The experimental ranges used are the same as those described by Reed and Peterson (*17*). Grazing use during this study was somewhat lighter than they reported.

The vegetation consisted of about three-fourths perennial grasses and sedges with most of the remainder comprised of pricklypear, woody, and semiwoody shrubs. Perennial forbs and annual species were only a minor portion of the plant cover.

The principal forage species, which made up about two-thirds of the plant cover, were threadleaf sedge, the short-grasses blue grama and buffalograss, and the midgrasses western wheatgrass, needle-and-thread grass, and green needlegrass. Secondary grasses were Sandberg bluegrass, sand dropseed, alkali sacaton, tumblegrass, needleleaf sedge, saltgrass, and red threeawn.

Principal shrubs were big sagebrush, silver sagebrush, western snowberry, and plains pricklypear.

The most common forbs were textile onion, Hood's phlox, and scarlet globemallow.

Soils on the summer range were identified by Gieseker (*7*) as undifferentiated, terrace, slope, upland, and bottomland soils. On the winter range only slope, upland, and bottomland soils were indicated. Twelve different range sites were present on the experimental pastures. These are basically keyed to soil texture and drainage, although other factors are recognized.

EXPERIMENTAL METHODS

Vegetation Study Procedures

Pasturewide utilization was determined each fall on the summer range and in the spring of 1958 on the winter range. Utilization was measured by percentage of plants grazed and stubble heights for the three major forage species western wheatgrass, blue grama, and needle-and-thread grass. Pasturewide utilization (the product of percentage of plants grazed X average stubble height X average mature heights of plants with and without seedstalks weighted by proportions of plants bearing seedstalks (*10*)) was compared with appropriate height-weight curves to obtain the utilization by weight.

A vegetation inventory was conducted in 1956 on both range units. Total plant basal cover and composition of cover were estimated visually on 1- by 2-foot plots located at 33-foot intervals on spaced lines concentric to the central wells. The personnel conducting this survey were trained intensively on the point-plot method of measuring basal cover prior to and concurrent with the survey. The training data were used as a standard during the survey.

Two studies on the effects of stocking rate on height growth were made. In one study, heights of western wheatgrass, needle-and-thread grass, and blue grama were determined at maturity—late July to early August—from 1948 to 1957. Currently ungrazed plants were measured in three pastures representing a variety of stocking rates. Both plants bearing seedstalks and plants without seedstalks were measured along paced transects on similar sites in pastures grazed at stocking rates of 1.85, 2.94, and 3.53 acres per animal-unit-month.

In the second study currently ungrazed plants (with no differentiation between those plants bearing seedstalks and those without) of western wheatgrass and blue grama were measured on the summer range at approximately weekly intervals during the spring of 1957. These measurements were also made along paced transects on upland-range sites in three pastures grazed at rates of 1.85, 2.94, and 3.14 acres per A.U.M.

In 1958 a range-site and range-condition evaluation based on the official U.S. Soil Conservation Service range guide for the area was conducted on the experimental ranges. Herbage production was also obtained at this time.

Stocking Procedures

The cattle used in the present study were selected as yearling heifers in the spring of 1948. The heifers were divided into six groups of approximately equal weights and lines of breeding.

Each pasture was stocked with a basic herd of 10 cows. Numbers of cows were constant throughout the study. This resulted in lower utilization during years of above-normal precipitation and high forage production and close utilization in dry years. In 4 unusually dry years during the study period all animals were moved from summer range to reserve pastures 4 to 8 weeks before the normal end of the summer grazing period. These removals were primarily due to low forage production and poor condition of cows in the two most heavily grazed pastures during these years. When forage became limited and utilization severe in these pastures all animals were removed in order to continue the differential stocking levels. On the winter range low forage productivity was compensated by increased feeding of hay.

The resulting pasture-stocking rates during the summer grazing period were different from the animal-stocking rates. This difference was also present in the yearlong animal-stocking rates. In this bulletin vegetational responses are related to the pasture-stocking rates (table 1) and animal responses to the animal-group-stocking rates (table 2). For this study the animal-unit factor used was determined as follows: 1 cow over 30 months old, 1.0 A.U.; calf 1 month old to weaning, 0.2 A.U.; yearling bull, 1.0 A.U.; older bull, 1.25 A.U.

Cattle Management

Beginning in 1949 Hereford bulls were assigned one to each group of cows and rotated weekly between groups. Bulls were selected as much as possible on the basis of uniform breeding, age, and gain indices. The breeding season began June 15 and continued for 6 to 7 weeks.

Each year beginning in 1952 two of the older cows were removed from each group and two 2-year-old heifers originally born in the group were returned to the group. These heifers were rated on average birth weight and birth date for all heifer calves from that group in the year of birth. The heifers closest to the group averages were used as replacements.

Several years two heifers were not available as replacements for a group because of low number of heifers born, injury, disease, or accidental breeding as yearlings. It then was necessary to use one or more animals from the group with the most-comparable-stocking rate.

The heifers selected as replacements were bred separately as 2-year-olds to a bull selected for similarity in breeding and gain to those bulls used for the other groups.

Supplemental feeding of fair to poor quality grass-and-alfalfa hay was fed only when needed on the winter range. The hay was usually 1 year old, but occasionally 2 years old, when fed. Only a maintenance amount was fed daily to all groups during the feeding period. When heavy range utilization, cold weather, and poor condition of cows in the heavily grazed groups showed that they required supplemental feed for minimum maintenance, the same amount of hay was given separately to all groups in order to maintain the differential grazing pressure on the range (fig. 1). All groups made full use of the supplemental feed except during several years in early spring. In those years feeding was terminated for the individual groups as soon as the

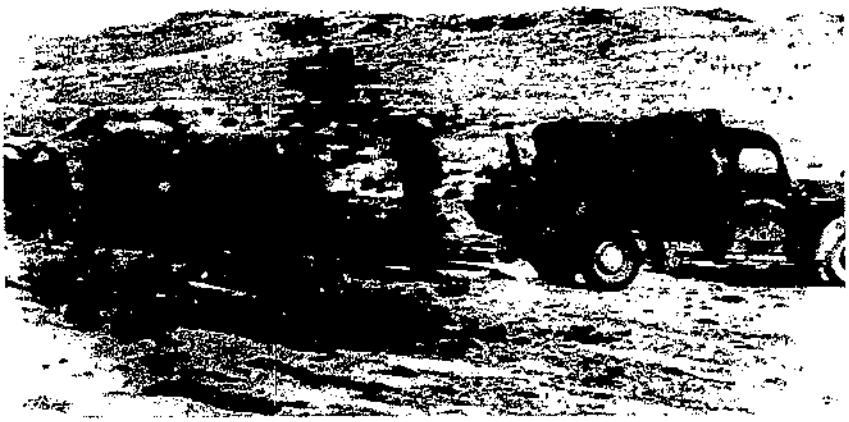

FIGURE 1.—Winter feeding at Lone Pine winter range in T pasture, February 1955. Bales were weighed off truck and broken.

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Table 1.—*Pasture areas* [1] *and animal-unit-months (A.U.M.) of stocking on summer- and winter-range pastures, by years, 1948–57*

[Animal-unit-conversion factor: 1 cow over 30 months old, 1.0 A.U.; calf 1 month old to weaning, 0.2 A.U.; yearling bull, 1.0 A.U.; older bull, 1.25 A.U.]

Year	Summer range, pastures—											
	E		A		D		C		B		F	
	Acres	A.U.M.	Acres	A.U.M.	Acres	A.U.M.	Acres	A.U.M.	Acres	A.U.M.	Acres	A.U.M.
1948	96. 6	46. 9	92. 7	46. 9	147. 2	46. 9	155. 7	46. 9	165. 4	46. 9	188. 8	46. 9
1949 [2]	96. 6	23. 5	92. 7	23. 5	147. 2	23. 5	155. 7	23. 5	165. 4	23. 5	188. 8	23. 5
1950	96. 6	64. 2	92. 7	57. 3	147. 2	62. 9	155. 7	63. 2	165. 4	61. 8	188. 8	63. 1
1951	96. 6	61. 7	92. 7	57. 4	147. 2	62. 7	155. 7	59. 6	165. 4	61. 7	188. 8	61. 7
1952 [2]	96. 6	46. 0	92. 7	45. 2	147. 2	46. 7	155. 7	46. 0	165. 4	46. 0	188. 8	46. 7
1953	96. 6	59. 6	92. 7	59. 6	147. 2	62. 5	155. 7	63. 8	165. 4	63. 7	188. 8	63. 7
1954 [2]	96. 6	49. 1	92. 7	51. 6	147. 2	51. 9	155. 7	52. 0	165. 4	51. 8	188. 8	52. 6
1955	96. 6	67. 3	92. 7	63. 7	147. 2	63. 9	155. 7	67. 3	165. 4	67. 0	188. 8	68. 3
1956 [2]	96. 6	40. 2	[3] 100. 3	40. 7	147. 2	41. 5	155. 7	40. 2	165. 4	39. 6	188. 8	39. 6
1957	96. 6	65. 9	[3] 100. 3	64. 5	147. 2	66. 9	155. 7	66. 9	165. 4	64. 7	188. 8	68. 2
Average	96. 6	52. 4	94. 2	51. 0	147. 2	52. 9	155. 7	52. 9	165. 4	52. 7	188. 8	53. 4
Acres/A.U.M	1. 84		1. 85		2. 78		2. 94		3. 14		3. 53	

Year	Winter range, pastures [1]—											
	Q		T		R		S		U		V	
	Acres	A.U.M.	Acres	A.U.M.	Acres	A.U.M.	Acres	A.U.M.	Acres	A.U.M.	Acres	A.U.M.
1948–49	110. 6	40. 2	138. 9	40. 2	163. 8	40. 2	168. 9	40. 2	192. 3	40. 2	227. 0	40. 2
1949–50	110. 6	16. 9	138. 9	19. 0	163. 8	21. 9	168. 9	21. 9	192. 3	21. 7	227. 0	21. 7
1950–51	110. 6	52. 9	138. 9	55. 9	163. 8	57. 0	168. 9	56. 7	192. 3	57. 4	227. 0	57. 1
1951–52	110. 6	39. 6	138. 9	39. 6	163. 8	40. 1	168. 9	39. 6	192. 3	40. 4	227. 0	40. 1
1952–53	110. 6	43. 4	138. 9	43. 6	163. 8	46. 0	168. 9	45. 8	192. 3	45. 8	227. 0	46. 0
1953–54	110. 6	48. 7	138. 9	49. 8	163. 8	49. 6	168. 9	49. 8	192. 3	49. 5	227. 0	49. 8
1954–55	110. 6	40. 4	138. 9	41. 6	163. 8	41. 6	168. 9	41. 6	192. 3	41. 6	227. 0	41. 6
1955–56	110. 6	49. 3	138. 9	49. 3	163. 8	49. 3	168. 9	49. 3	192. 3	49. 3	227. 0	49. 3
1956–57	110. 6	36. 7	138. 9	37. 2	163. 8	38. 9	168. 9	38. 8	192. 3	38. 9	227. 0	38. 7
Average	110. 6	40. 9	138. 9	41. 8	163. 8	42. 7	168. 9	42. 6	192. 3	42. 8	227. 0	42. 7
Acres/A.U.M.	2. 70		3. 32		3. 84		3. 96		4. 49		5. 32	

[1] Surface acres weighted by forage acres per pasture from 1944 survey.
[2] Animals moved to reserve pastures before end of summer-grazing season.
[3] Pasture enlarged in spring of 1956.
[4] Grazing use is total A.U.M. on pastures less A.U.M. of hay fed at 600 pounds of hay per A.U.M.; calves excluded.

Table 2.—*Animal-stocking rates on summer range and yearlong, by animal groups and years, 1948–57*

[Animal-stocking rates on winter range are same as pasture-stocking rates there; see table 1]

Year	Summer range, animal group—											
	E		A		D		C		B		F	
	Acres [1]	A.U.M.[2]	Acres [1]	A.U.M.[2]	Acres [1]	A.U.M.[2]	Acres [1]	A.U.M.[2]	Acres [1]	A.U.M.[2]	Acres [1]	A.U.M.[2]
1948	96. 6	46. 9	92. 7	46. 9	147. 2	46. 9	155. 7	46. 9	165. 4	46. 9	188. 8	46. 9
1949 [3]	262. 2	60. 3	258. 3	60. 3	312. 8	60. 3	321. 3	60. 3	331. 0	60. 3	354. 4	60. 3
1950	96. 6	64. 2	92. 7	57. 3	147. 2	62. 9	155. 7	63. 2	165. 4	61. 8	188. 8	63. 1
1951	96. 6	61. 7	92. 7	57. 4	147. 2	62. 7	155. 7	59. 6	165. 4	61. 7	188. 8	61. 7
1952 [3]	193. 8	67. 6	188. 5	66. 5	246. 2	68. 7	252. 9	67. 6	262. 6	67. 6	287. 8	68. 7
1953	96. 6	59. 6	92. 7	59. 6	147. 2	62. 5	155. 7	63. 8	165. 4	63. 7	188. 8	63. 7
1954 [3]	144. 3	59. 7	141. 3	62. 4	196. 7	62. 9	205. 2	63. 0	214. 9	62. 8	239. 2	63. 9
1955	96. 6	67. 3	92. 7	63. 7	147. 2	63. 9	155. 7	67. 3	165. 4	67. 0	188. 8	68. 3
1956 [3]	194. 2	61. 9	197. 9	62. 4	248. 0	63. 9	253. 3	61. 9	262. 0	61. 3	286. 4	61. 3
1957	96. 6	65. 9	100. 3	64. 5	147. 2	66. 9	155. 7	66. 9	165. 4	64. 7	188. 8	68. 2
Average	137. 4	61. 5	135. 0	60. 1	188. 7	62. 2	196. 7	62. 0	206. 4	61. 8	230. 1	62. 6
Acres/A.U.M	2. 23		2. 25		3. 03		3. 17		3. 34		3. 68	

Year	Yearlong,[4] animal group—											
	AQ		ET		CS		BR		DU		FV	
	Acres [1]	A.U.M.[2]	Acres [1]	A.U.M.[2]	Acres [1]	A.U.M.[2]	Acres [1]	A.U.M.[2]	Acres [1]	A.U.M.[2]	Acres [1]	A.U.M.[2]
1948–49	368. 9	100. 5	401. 1	100. 5	490. 2	100. 5	494. 8	100. 5	505. 1	100. 5	581. 4	100. 5
1949–50	203. 3	74. 2	235. 5	83. 2	324. 6	85. 1	329. 2	83. 7	339. 5	84. 6	415. 8	84. 8
1950–51	203. 3	110. 3	235. 5	117. 6	324. 6	116. 3	329. 2	118. 7	339. 5	120. 1	415. 8	118. 8
1951–52	299. 1	106. 1	332. 7	107. 2	421. 8	107. 2	426. 4	107. 7	438. 5	109. 1	514. 8	108 8
1952–53	203. 3	103. 0	235. 5	103. 2	324. 6	109. 6	329. 2	109. 7	339. 5	108. 3	415. 8	109. 7
1953–54	251. 9	111. 1	283. 2	109. 5	374. 1	112. 8	378. 7	112. 4	389. 0	112. 4	466. 2	113. 7
1954–55	203. 3	104. 1	235. 5	108. 9	324. 6	108. 9	329. 2	108. 6	339. 5	105. 5	415. 8	109. 9
1955–56	308. 5	111. 7	333. 1	111. 2	422. 2	111. 2	426. 8	110. 6	440. 3	113. 2	513. 4	110. 6
1956–57	210. 9	101. 2	235. 5	103. 1	324. 6	105. 7	329. 2	103. 6	339. 5	105. 8	415. 8	106. 9
Average	250. 3	102. 5	280. 8	104. 9	370. 1	106. 4	374. 7	106. 2	385. 6	196. 6	461. 6	107. 1
Acres/A.U.M.	2. 44		2. 68		3. 48		3. 53		3. 62		4. 31	

[1] Includes areas of reserve pastures grazed.
[2] Includes A.U.M. of grazing on reserve pastures.
[3] Animals moved to reserve pastures before end of summer-grazing season.
[4] Grazing year is from November 1 of previous year to October 31.

cows failed to rapidly utilize the daily ration. During several years some of the cows in the two most heavily grazed groups were in very poor condition and had inadequate milk supply for their calves at birth. These animals were separately fed high-quality alfalfa hay for 7 to 10 days.

No mineral supplements other than common salt were available to the animals on the experimental ranges at any time. Noniodized, ground salt was always available in the pastures at one-fourth to one-half mile from the central water source.

Calves were dropped on the winter range, beginning the latter part of March. Pastures were inspected daily. Calves were weighed, ear-tagged, paste-dehorned, and ear-cropped within 24 hours of birth (fig. 2).

Cows were weighed at 28-day intervals throughout the year. Calves were weighed at 28-day intervals beginning in mid-May and continuing until weaning time about November 1.

Cows and calves were driven 2 miles from winter to summer range in mid-May. Occasionally, slowness of forage growth on the heavily grazed pastures at summer range caused the movement to be delayed for 7 to 10 days.

Calves were branded, castrated, tattooed, and vaccinated against blackleg and malignant edema usually during late June.

At weaning time, calves were separated, cull cows removed, and replacement heifers added. The experimental animals were then

FIGURE 2.—Applying dehorning paste on newborn calf.

moved to the winter range. At weaning time during the last 3 years of the study, all calves were graded by an experienced animal husbandman into appropriate feeder grades.

All calves were wintered near the station headquarters on a liberal ration of good-quality hay and salt-bonemeal mixture. The following spring those heifers chosen as replacements for the two most heavily grazed groups were placed in small, heavily grazed pastures. They remained in these pastures until they entered the experimental pastures except for the breeding season when 2 years old. For that period they were removed to a separate breeding pasture. The heifers chosen as replacements for the four most lightly grazed groups were placed with other yearling heifers and carried at a moderate-to-light rate of stocking until they reached breeding age.

In analyzing the animal data birth weights, average daily gains, and weaning weights of calves were corrected for sex by the procedure outlined by Brinks and coworkers (*2*), weaning weights also were corrected to 180 days of age, and birth weights, average daily gains, weaning weights, and weaning grades corrected for age of dam by the procedure of Koch and Clark (*13*). Cow weights were corrected for age by the procedures outlined by Clark and coworkers (*3*) and Brinks and coworkers (*1*).

PRECIPITATION

Records from Miles City, Mont., and from headquarters of the U.S. Range Livestock Experiment Station approximately 4 miles northwest of the study areas showed an 80-year mean-annual precipitation of 12.94 inches, of which 9.33 occurred as growing-season precipitation—April 1 to September 30. These figures may be compared with averages of 11.50 and 8.75 inches annual and seasonal precipitation, respectively, during the period of study (table 3).

VEGETATION RESPONSE

Because this study followed a previous grazing-intensity study by Reed and Peterson (*17*) on the same areas, many differences resulting from differential stocking levels were already present in the vegetation and in the soil. Much of the data published here then reflects accumulative effects of the various stocking rates since 1932.

Utilization

Percentage of Plants Grazed

On the summer range the percentage of plants grazed of western wheatgrass differed materially between stocking rates (table 4), but was not correlated overall with stocking rate nor with precipitation (table 5). Percentage of plants grazed of blue grama was correlated with stocking rate but not with precipitation. That of needle-and-thread grass was correlated with both stocking rate and precipitation.

Table 3.—*Monthly, growing-season (April–September), and annual precipitation, in inches, at U.S. Range Livestock Experiment Station, Miles City, Mont., 1948–57 and 10- and 80-year averages*

Year	Precipitation													
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Growing season	Annual
1948	0.42	0.74	0.61	1.09	1.64	5.49	4.53	0.66	0.66	0.02	0.61	0.36	14.07	16.83
1949	.86	.51	.36	.29	1.06	1.05	1.63	.05	.17	1.55	.04	.11	4.25	7.68
1950	.25	.53	1.12	1.08	.98	2.92	.66	.29	1.74	.40	.40	.30	7.67	10.67
1951	.07	.27	.17	.36	1.12	2.43	1.49	3.12	1.38	.51	.28	1.03	9.90	12.23
1952	.31	.73	.87	.18	1.53	1.84	.78	.49	.47	.00	.45	.15	5.29	7.80
1953	.67	.43	.60	1.96	2.93	2.38	1.33	.85	.23	1.88	.03	.24	9.68	13.53
1954	.39	.19	.35	.88	.78	2.40	.69	2.44	.85	.29	.09	.07	8.04	9.42
1955	.16	.51	.24	1.43	5.55	2.30	.60	.14	.31	.71	.67	.45	10.33	13.07
1956	.33	.10	.11	.30	2.37	1.08	1.94	2.26	.24	.51	.81	.29	8.19	10.34
1957	.58	.29	.73	1.82	1.84	3.10	1.39	1.21	.72	.58	1.18	.01	10.08	13.45
Average, 1948–57	.40	.43	.52	.94	1.98	2.56	1.50	1.15	.68	.64	.46	.30	8.75	11.50
Average, 1879–1957	.55	.44	.78	1.04	1.99	2.70	1.49	1.12	.99	.86	.50	.48	9.33	12.94

Table 4.—*Utilization of three key forage species, in percentage of plants grazed at end of grazing season, on summer range, by average stocking rates and years, 1948–57*

Species and year	Percentage of plants grazed under average stocking rates (acres/A.U.M.) of—					
	1. 84	1. 85	2. 78	2. 94	3. 14	3. 53
Western wheatgrass:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1948	65. 3	78. 4	70. 1	65. 2	58. 4	39. 0
1949	96. 5	91. 3	82. 5	80. 7	79. 9	73. 3
1950	86. 2	82. 6	46. 1	41. 7	33. 6	41. 2
1951	78. 8	55. 7	44. 8	32. 4	44. 7	35. 2
1952	69. 3	53. 5	50. 8	36. 8	34. 2	43. 3
1953	85. 9	79. 1	72. 3	51. 1	49. 4	48. 7
1954	82. 0	75. 6	53. 7	54. 8	44. 4	46. 1
1955	75. 7	58. 7	45. 9	45. 0	41. 0	41. 0
1956	80. 6	86. 4	64. 6	74. 4	64. 1	60. 8
1957	86. 3	67. 1	62. 7	64. 8	44. 1	59. 2
Average	80. 7	72. 8	59. 4	54. 7	49. 4	48. 8
Blue grama:						
1948						
1949	58. 2	99. 9	99. 9	99. 9	99. 9	99. 9
1950	58. 2	67. 3	38. 2	41. 6	40. 6	36. 7
1951	81. 3	62. 0	35. 3	39. 1	38. 2	31. 2
1952	66. 0	77. 2	54. 9	32. 8	50. 3	46. 2
1953	96. 2	96. 6	60. 0	83. 4	74. 1	78. 7
1954	47. 3	69. 0	48. 3	54. 5	50. 0	42. 8
1955	87. 8	82. 1	62. 5	81. 2	74. 3	70. 6
1956	71. 9	79. 8	74. 5	70. 6	65. 2	74. 4
1957	63. 8	68. 3	51. 0	55. 7	43. 9	38. 9
Average	70. 1	78. 0	58. 3	62. 1	59. 6	57. 6
Needle-and-thread:						
1948						
1949	92. 5	92. 6	94. 4	96. 2	96. 4	79. 3
1950	84. 0	99. 9	68. 8	72. 8	66. 2	47. 1
1951	63. 3	10. 3	45. 5	34. 2	45. 2	19. 2
1952	80. 0	70. 0	78. 6	79. 2	62. 5	66. 7
1953	83. 3	86. 4	70. 5	64. 1	54. 2	37. 5
1954	73. 3	81. 2	55. 1	56. 7	55. 4	40. 9
1955	80. 0	61. 9	43. 3	59. 4	40. 9	32. 3
1956	87. 1	97. 0	82. 3	91. 1	80. 2	77. 3
1957	66. 7	76. 5	58. 3	70. 6	58. 8	29. 6
Average	78. 9	75. 1	66. 3	69. 4	62. 2	47. 8

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Table 5.—*Correlations of percentage of plants grazed for three key forage species on summer range with annual stocking rates and with precipitation, in inches, for selected periods*

Species	d.f. (n–2)	Correlation coefficients (r)			
		Stocking rate (acres/ A.U.M.)	May–June precipitation	April–Sept. precipitation	Nov.-1–Oct. 31 precipitation
Western wheatgrass	58	−0.061	−0.196	−0.156	−0.040
Blue grama	52	−.301*	.091	−.193	−.023
Needle-and-thread	52	−.256*	−.397**	−.561**	−.409**

*Significant at 5-percent level.
**Significant at 1-percent level.

The regression of percentage of plants grazed for the three species on stocking rates and total precipitation during selected periods (May–June, April–September or growing season, and November of previous fall through October of current year) may be shown by regression equations.

The regression equation used is the standard one: $\hat{Y}=a+bX_1+cX_2+dX_3+eX_4$; a, b, c, d, and e are derived data; and the X_{1-4} are substituted data, i.e., X_1=stocking rate in acres per A.U.M., X_2=May–June precipitation, X_3=April–September precipitation, X_4=November–October precipitation.

The regression equations for percentage of plants grazed are as follows: western wheatgrass, $\hat{Y}=53.77-2.01X_1-3.12X_2-6.20X_3{}^{**}+7.08X_4{}^{**}$ (multiple R 0.398*); blue grama, $\hat{Y}=23.94+4.01X_1+5.25X_2{}^{*}-8.46X_3{}^{**}+6.95X_4{}^{*}$ (multiple R 0.551**); and needle-and-thread, $\hat{Y}=116.13-3.75X_1-0.84X_2-10.19X_3{}^{**}+4.51X_4$ (multiple R 0.619**).

These equations show that precipitation for the summer growing season is an important influence on percentage of plants grazed for all three species when stocking rate and precipitation effects are considered together. These data differ somewhat from the simple correlations shown in table 4. The April–September total precipitation averages about 70 percent of the annual precipitation.

On the winter range during the winter of 1957–58 percentage of plants grazed for only blue grama was significantly correlated with stocking rate (table 6).

[4] Asterisk indicates the individually significant elements of the regression equation: *, significant at 5 percent; **, significant at 1 percent.

Table 6.—*Utilization of three key forage species, in percent of plants grazed and stubble heights, at end of 1957–58 winter grazing season, by winter-stocking rates, and correlations with stocking rate*

PERCENTAGE OF PLANTS GRAZED

Species	Utilization under average stocking rates (acres/A.U.M.) of—						Correlation coefficient (d.f.4)
	2.08	2.60	3.06	3.16	3.59	4.24	
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	
Western wheatgrass	58	78	47	53	66	48	−0.388
Blue grama	68	67	50	48	58	39	−.844*
Needle-and-thread	53	58	37	44	63	51	.009

STUBBLE HEIGHTS

	Cm.	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	
Western wheatgrass	5.8	5.8	6.8	7.1	7.1	8.4	0.957**
Blue grama	2.2	2.2	2.3	3.1	2.3	2.4	.231
Needle-and-thread	2.5	2.9	4.0	2.9	3.8	3.7	.724

*Significant at 5-percent level.
**Significant at 1-percent level.

Stubble Heights

On the summer range stubble heights for all three major forage species—western wheatgrass, blue grama, and needle-and-thread grass—differed between stocking rates (table 7) and were, in most cases, correlated with both stocking rates and precipitation (table 8). The effects of stocking rates and of precipitation during selected periods on stubble heights also are shown by regression. For western wheatgrass the regression equation is, $\hat{Y}=-0.40+0.60X_1+0.51X_2{}^{**}-0.10X_3+0.38X_4{}^{*}$ (multiple R 0.811**); for blue grama, $\hat{Y}=0.86+0.01X_1+0.11X_2{}^{*}+0.17X_3{}^{*}-0.05X_4$ (multiple R 0.713**); and for needle-and-thread grass, $\hat{Y}=-2.35+0.18X_1+0.28X_2{}^{**}-0.16X_3+0.47X_4{}^{**}$ (multiple R 0.738**).

These equations show that total precipitation during May and June is probably the most important influence on stubble heights of these species. Again, the regression data are at variance with the simple correlations shown in table 8.

On the winter range for the winter of 1957–58, average stubble height of only western wheatgrass was significantly correlated with stocking rate (table 6).

Table 7.—*Utilization of three key forage species, in stubble heights at end of grazing season, on summer range, by average stocking rates and years, 1948–57*

Species and year	Stubble heights under average stocking rates (acres/A.U.M.) of—					
	1.84	1.85	2.78	2.94	3.14	3.53
Western wheatgrass:	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*
1948	7.2	5.4	8.4	9.3	8.8	8.2
1949	2.6	1.9	3.3	2.7	2.9	3.3
1950	4.8	4.3	6.7	5.9	6.1	6.4
1951	3.1	3.3	3.8	4.1	4.2	5.3
1952	3.7	3.2	4.1	4.7	4.9	5.0
1953	6.2	5.9	7.1	7.7	8.1	8.9
1954	3.9	3.8	4.9	5.1	5.8	5.8
1955	6.6	6.5	6.8	6.3	8.2	7.3
1956	4.8	3.9	5.2	4.8	5.3	5.1
1957	6.1	6.6	7.4	7.2	8.6	8.1
Average	4.9	4.5	5.8	5.8	6.3	6.3
Blue grama:	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*
1948						
1949	1.9	0.9	1.1	1.0	1.1	1.2
1950	1.9	1.6	2.1	2.0	2.2	2.2
1951	1.8	1.7	2.2	2.3	2.1	2.3
1952	1.9	1.7	1.9	2.0	2.3	2.2
1953	2.4	2.2	2.6	2.7	2.1	3.2
1954	2.3	2.1	2.9	2.9	3.3	2.7
1955	3.0	2.4	2.9	2.7	2.9	2.9
1956	2.0	1.9	2.3	2.1	2.1	2.2
1957	2.3	2.2	2.8	2.2	2.7	3.5
Average	2.2	1.9	2.3	2.2	2.4	2.5
Needle-and-thread:	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*
1948						
1949	2.2	1.4	2.4	2.3	2.4	3.2
1950	3.0	1.8	3.4	2.8	4.2	3.7
1951	1.8	1.5	2.0	2.8	2.8	2.4
1952	2.4	1.5	2.1	2.1	3.4	2.7
1953	5.0	2.8	4.4	3.8	5.1	3.7
1954	2.1	1.9	2.5	2.2	3.4	2.7
1955	4.8	3.0	3.7	4.3	4.0	4.3
1956	3.3	2.4	3.0	2.7	3.3	1.9
1957	4.2	3.6	5.1	4.0	5.5	6.9
Average	3.2	2.2	3.2	3.0	3.8	3.5

Utilization by Weight

For the period of 1948–57, the average pasturewide utilization by weight of western wheatgrass under the heaviest stocking rate did not exceed 50 percent and it was much lower for blue grama and needle-and-thread.

Table 8.—*Correlations of stubble heights for three key forage species on summer range with annual stocking rates and with precipitation, in inches, for selected periods*

Species	d.f. (n–2)	Correlation coefficients (r)			
		Stocking rate (acre/A.U.M.)	May–June precipitation	April–Sept. precipitation	Nov. 1–Oct. 31 precipitation
Western wheatgrass	58	0.293*	0.765**	0.720**	0.759**
Blue grama	52	.468**	.623**	.682**	.582**
Needle-and-thread	52	.193	.590**	.508**	.660**

* Significant at 5-percent level.
** Significant at 1-percent level.

The following tabulation shows percentage utilization by weight for the three major forage species:

Species:	*Average percentage of weight removed under stocking rates (acres per A.U.M.) of—*		
	1.84 *Percent*	2.94 *Percent*	3.53 *Percent*
Western wheatgrass	49.5	36.3	31.0
Blue grama	23.6	17.1	12.3
Needle-and-thread	37.5	32.8	22.2

These data show a distinct response to the different stocking rates. However, these utilization levels were lower than that found in most other stocking-rate studies.

Vegetation Cover

Basal cover of total vegetation and basal cover of individual species on charted plots were considerably changed between 1945 and 1956. Other basal-cover data obtained only in 1956 showed many differences in total cover and cover of individual species between range sites and between pastures after 25 years of differential pasture stocking rates. There were also differences in species response to stocking rate by sites between summer and winter use ranges.

Between 1945 and 1956 the total charted basal cover of vegetation was considerably reduced on most sites at the summer range. At the winter range many reductions also occurred, but these were usually smaller and not so consistent.

Basal cover of most individual species also decreased during this period on the summer range. However, threadleaf sedge, Sandberg bluegrass, and big sagebrush generally increased in basal cover on most sites in most pastures at the summer range. Many species showed different responses according to site at both the summer and winter range.

In 1956, after 22 years of differential grazing, the estimated total basal cover at the summer range was highest under the intermediate pasture-stocking rates, both pasturewide and on the overflow site, and under intermediate-to-light rates on the silty site (appendix, table 28). On clayey and pan-spot sites, total plant-basal cover was highest under the lightest pasture-stocking rates. On the thin-breaks site at the summer range it was highest at each end of the stocking gradient. However, at the winter range no general response of total basal cover to stocking rate was evident (appendix, table 29).

Average basal cover of blue grama at the summer range was generally highest under the intermediate or intermediate-to-light stocking rates. At the winter range no general response was evident. On the thin-breaks site at the summer range, cover of this species was slightly higher under heavy stocking; on the clayey and pan-spot sites at the summer range and on the thin-breaks site at the winter range it was lowest under this stocking rate.

The effects of stocking level and site on the percent-composition of basal cover may be shown by the following tabulation of response of blue grama at the summer range:

	Average percent composition of blue grama on two sites at summer range under stocking rates (acres per A.U.M.) of—				
Site:	1.85 *Percent*	2.78 *Percent*	2.94 *Percent*	3.14 *Percent*	3.53 *Percent*
Overflow	4	3	16	64	7
Silty	57	55	65	64	75

On the overflow site this component comprised a large proportion of total cover at intermediate-to-light stocking rate, but a small proportion at the heaviest and lightest rates. On the silty site it composed a larger proportion of cover at the lightest stocking rate than it did at any heavier rates.

Basal cover of western wheatgrass was highest, pasturewide, under light stocking on the summer range and under intermediate rates on the winter range. On the clayey sites at the summer range and on the overflow site at the winter range, it was highest under heavy stocking. On most other sites, cover of this species was highest under intermediate-to-light stocking levels.

Cover of buffalograss was generally highest under heavy grazing on the summer range, but no overall differences between stocking rates were evident at the winter range. This species was most abundant on the overflow site at both ranges. At the summer range on this site the highest level of buffalograss was found under intermediate stocking rates and on the winter range under heavy stocking.

Neither needle-and-thread grass nor green needlegrass cover differed materially between stocking rates on the winter range nor did green needlegrass on the summer range. However, needle-and-thread cover was most abundant under intermediate stocking rates on the summer range. This response of needle-and-thread was evident on most sites. Green needlegrass exhibited both increaser and decreaser responses to differences in stocking rates according to site. However, cover of green needlegrass was usually low.

Cover of threadleaf sedge, needleleaf sedge, and sand dropseed tended to be highest under intermediate or intermediate-to-light stocking levels on both the summer and winter ranges.

Sandberg bluegrass showed essentially no overall response to stocking rates at either seasonal-range unit.

False buffalograss was most abundant on most sites under the heavier stocking levels.

The highest levels of basal cover of bluebunch wheatgrass were generally found under the intermediate stocking rates on the winter range, although a decreaser response was observed on several sites.

Cover of both saltgrass and winterfat showed the highest levels of basal cover under the intermediate stocking rates at both the summer and winter range.

Tumblegrass cover was very sparse at the summer range. The few plants found were present only on the most lightly grazed pasture there. This species was most abundant under intermediate or heavy stocking on most sites at the winter range.

Cover of red threeawn grass was highest under intermediate stocking rates on the silty and thin-breaks sites at the summer range. At the winter range both increaser and decreaser response were observed according to the site.

Cover of both silver sagebrush and big sagebrush tended to be highest under heavy stocking at the summer range and big sagebrush under heavy stocking at the winter range. Silver sagebrush was most abundant on the overflow site at both ranges. On this site at the summer range the highest basal cover was under intermediate stocking and at the winter range under heavy stocking.

Fringed sagewort cover was highest under intermediate stocking levels at the summer range. At the winter range the highest amount of cover was found under either the heaviest or intermediate levels according to the site.

Cover of plains pricklypear on the summer range was highest under intermediate or heavy stocking levels according to the site. There was no distinct overall response to stocking rate on the winter range. Amount of this species varied widely between sites at both areas.

Cover of broom snakeweed generally was higher under the heavier stocking levels on the summer range and under the intermediate levels on the winter range. Cover of the species was very low.

Cover of Hood's phlox tended to be higher under heavy stocking levels on the summer range and under intermediate levels on the winter range.

Both shadscale and greasewood were found only at the winter range. The greatest amounts were present under the intermediate stocking rates on most sites.

Scarlet globemallow responded both as an increaser and a decreaser according to site at both ranges.

Plant Heights

Plant Heights at Maturity

The effects of long-term different average stocking rates on mature plant heights were different for each of the species observed (table 9).

However, responses of the plants bearing seedstalks and those not bearing seedstalks of the same species were similar. Average heights of ungrazed western wheatgrass plants on pastures stocked at the rate of 2.94 acres per A.U.M. differed little from those on pastures stocked at 3.53 acres per A.U.M. However, average heights of this species were distinctly lower at a heavier rate of stocking. This difference was more noticeable for the vegetative plants than for culmed ones.

Table 9.—*Average ungrazed plant heights of culmless and culmed plants of three key forage species at maturity, on summer range, by average stocking rates and years, 1948-57*

CULMLESS PLANTS

Year	Plant heights by species and average stocking rates (acres/A.U.M.) of—								
	Western wheatgrass			Blue grama			Needle-and-thread		
	1.85	2.94	3.53	1.85	2.94	3.53	1.85	2.94	3.53
	Cm.	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*
1948	15.6	21.0	17.6						
1949	12.7	15.6	17.5						
1950	13.8	16.0	17.4	5.3	5.4	5.4	11.1	17.1	16.4
1951	11.6	13.6	14.2	4.7	5.4	5.5			
1952	9.2	12.1	13.0	3.8	4.1	4.2	7.8	9.1	10.0
1953	20.9	23.5	23.4	10.9	12.4	11.2	18.4	20.9	26.4
1954	12.4	16.5	15.2	5.9	7.5	7.1	11.5	13.0	14.0
1955	15.6	19.5	20.6	5.7	5.5	5.2	13.6	13.8	16.2
1956	12.0	14.2	13.1	4.5	5.1	5.0	7.9	9.9	13.4
1957	15.6	12.1	21.0	5.3	7.1	6.9	15.5	16.5	18.6
Average	13.9	17.3	17.3	5.8	6.6	6.3	12.3	14.3	16.4

CULMED PLANTS

1948									
1949									
1950	31.7	37.7	42.0				29.5	35.9	34.7
1951				8.3	10.6	15.2	9.3	18.5	23.8
1952									
1953	37.7	47.2	46.2	18.9	18.2	17.9	38.5	32.5	55.0
1954	23.2	25.1	26.8	10.7	12.1	12.2	22.9	27.0	25.3
1955	32.4	40.2	44.2	17.1	20.8	23.3	27.8	39.3	44.7
1956				14.0	9.5	8.0			
1957	39.4	48.1	48.3	16.5	20.5	20.8	29.2	36.3	36.7
Average	32.9	39.7	41.5	14.2	15.3	16.2	26.2	31.6	36.7

In contrast, average ungrazed heights of needle-and-thread grass were considerably higher on pastures stocked at 3.53 acres per A.U.M. than on pastures stocked at 2.94 acres and heavier. For this species, there was much less effect on plant heights at heavier stocking rates.

Although both culmed and culmless plants responded similarly to stocking rate, culmed plants averaged about 14 to 20 centimeters taller.

Mature-leaf lengths of blue grama were not appreciably affected by the long-term stocking rates.

Plant Heights During Spring

The effects of long-term stocking rates on plant height growth during the spring of 1957 were varied (table 10). On upland sites of the three pastures ungrazed height growth of western wheatgrass was significantly affected by differences in the average stocking rates. The regression of average heights on time was significantly different between all pastures. Although heights of this species in early April were similar under all stocking rates, as the season progressed height growth progressively differed between the three stocking rates (fig. 3). During April and the first half of May height growth was rapid. After mid-May it was much slower. Growth ceased in the most heavily grazed pasture about June 6, but it continued in the more lightly grazed pastures.

Leaf elongation of blue grama grass during the spring of 1957 was only slightly different between the pastures under different stocking rates. These differences paralleled those of western wheatgrass, but for this species were not significant. It was apparent that blue grama also made most of its growth prior to mid-May. There is some evidence that this species ceased growing in the heavily grazed pasture after this date but made further growth in the other pastures.

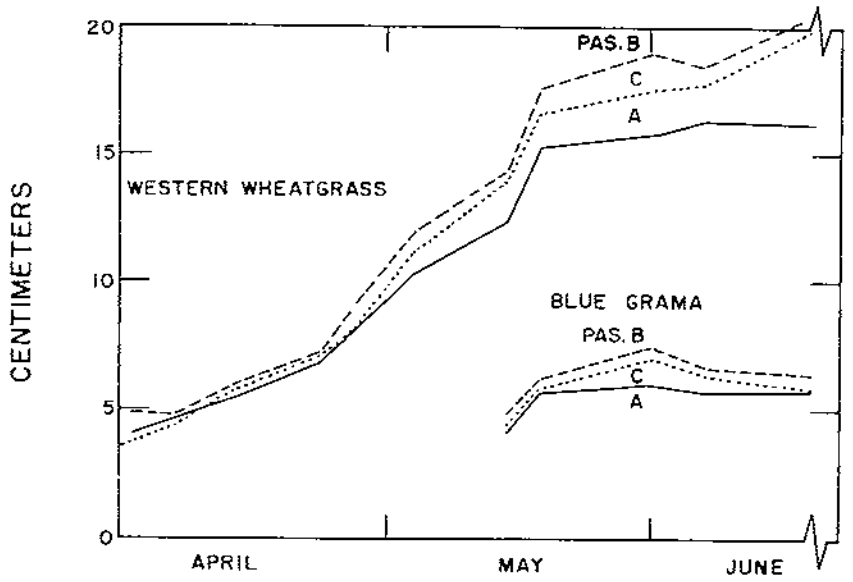

FIGURE 3.—Height growth of western wheatgrass and blue grama during the months of April, May, and part of June 1957, by pastures. Average pasture-stocking rates were: pasture A, 1.85 acres per animal-unit-month; pasture C, 2.94 acres; and pasture B, 3.14 acres.

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Table 10.—*Average ungrazed plant heights of two major forage species on upland site at summer range, by average stocking rates, April through mid-June 1957*

Date	Plant heights by species and average stocking rates (acres/A.U.M.) of—					
	Western wheatgrass			Blue grama		
	1.85	2.94	3.14	1.85	2.94	3.14
	Cm.	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*
Apr. 1	4.09	3.36	4.94			
Apr. 5	4.68	4.44	4.77			
Apr. 12	5.47	5.83	6.03			
Apr. 22	6.86	7.09	7.28			
Apr. 26	8.18	8.25	9.13			
May 3	10.40	11.15	11.95			
May 14	12.39	13.95	14.36	4.08	4.45	4.79
May 18	15.30	16.69	17.56	5.73	5.89	6.20
May 31	15.75	17.63	19.04	6.02	7.04	7.53
June 6	16.29	17.76	18.52	5.66	6.41	6.74
June 19	16.10	19.96	20.38	5.72	5.82	6.45

Range Condition

The range-site and range-condition-class survey of the experimental pastures was conducted by personnel of the U.S. Soil Conservation Service in 1958 (*24*) in accordance with the current Soil Conservation Service range guide (*23*). The underlying principles of these guides have been described by Dykesterhuis (*6*).

As used in this bulletin, range condition is defined as total percentage, by weight, of vegetation on a site that is the original or climax kinds for that site. A range site is a specified combination of climate, soil, and topography that is associated with a characteristic kind and amount of vegetation.

Summer Range

On the summer range the correlation between pasture-range condition rating in 1958 and average stocking rate for the period 1948–57 was high (+0.819*, d.f. 4). At stocking rates of 2.78 acres per A.U.M. and heavier the response of condition to increased stocking rate was slight (fig. 4). However, at lighter rates of stocking than 2.78 there was a rapid increase in condition rating with the progressively lighter average stocking rates.

Winter Range

On the winter range correlation between long-term stocking rates and average pasture-range condition rating was not significant (+0.514, d.f. 4). However, there was a slight overall trend for lower range condition with heavier stocking rates.

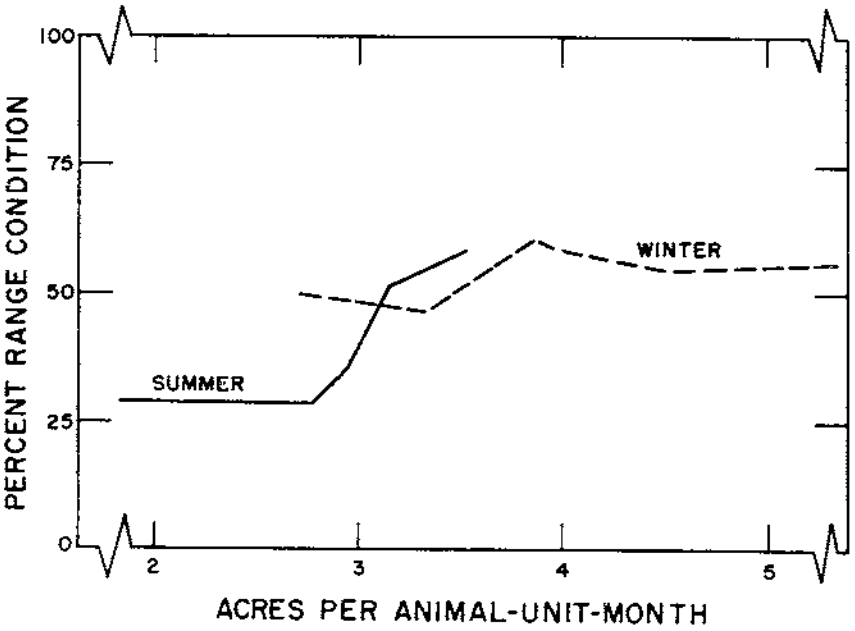

FIGURE 4.—Average pasture-range condition rating for 1958 in percent, on summer and winter ranges, by average stocking rates in acres per animal-unit-month.

Herbage Production

Several of the major sites were sampled for production in 1958 in two to four pastures representing a gradient in average stocking rates. In several instances small exclosures or adjacent very lightly grazed, nonexperimental pastures were also sampled. Because of small size of exclosures, only a few plots could be sampled in them.

On the summer range, long-term stocking rates had a distinct influence on total herbage production as measured in 1958. Under light stocking, total production was greater on the overflow, silty, and clayey sites in direct relation to improved range-condition class (table 11). Total production was high in exclosures on the silty and saline upland sites. Total production was lower in exclosures on the overflow and dense clay sites than on some grazed areas.

On the winter range, total production was greatest under the lighter stocking levels on the overflow, sandy, and one of the pan-spots sites (table 12). On the shallow sites and the second pan-spots site long-term stocking rates had no effect on total herbage production. Total production was greatest in exclosures on one pan-spots site at the winter range, but was not on the overflow and sandy sites.

Production of western wheatgrass was usually higher under the lighter stocking levels at both range units. However, lower production was found under the lightest stocking level or in exclosures on

Table 11.—*Herbage production, in pounds per acre (air-dry), of major forage species and plant groups on summer range in 1958, by range sites and average stocking rates. Shrubs not included*

Range site [1]	Average stocking rates (acres/A.U.M.)	Condition rating [1]	Herbage production				
			Western wheatgrass	Blue grama	Other perennial grasses	Annual species	Total production [2]
			Lb./acre	*Lb./acre*	*Lb./acre*	*Lb./acre*	*Lb./acre*
Overflow	1. 84	Poor-fair	266	6	166	6	444*a*
	2. 78	Poor	256	0	159	0	415*a*
	3. 53	Good	498	14	207	11	796*b*
	Exclosure [3]		271	0	94	10	377
Silty	1. 84	Poor–fair	48	180	193	15	460*b*
	2. 78	Fair	34	161	107	11	324*a*
	2. 94	Fair	9	294	93	1	400*ab*
	3. 14	Fair	30	250	124	3	446*b*
	BAI [4]	Good	15	361	622	0	1, 016*c*
	Exclosure [3]		70	444	366	9	935
Clayey	1. 84	Poor	29	217	125	0	378*a*
	3. 53	Fair	40	238	88	0	365*a*
	BAI [4]	Good	26	485	100	80	690*b*
Dense clay	1. 84	Poor	75	162	192	0	429*a*
	3. 14	Poor	381	0	5	0	387*a*
	Exclosure [3]		347	0	13	0	360
Saline upland	1. 84	Fair	323	0	11	22	367
	Exclosure [3]		487	0	0	12	505

[1] From survey by Van Cleave and coworkers (*24*).
[2] Numbers on the same site followed by the same letter are not significantly different at the 5-percent level (*19*).
[3] Livestock exclosures fenced since 1932.
[4] Nonexperimental range; very lightly grazed.

Table 12.—*Herbage production, in pounds per acre (air-dry), of major forage species and plant groups on winter range in 1958, by range sites and average stocking rates. Shrubs not included*

Range site [1]	Average stocking rates (acres/A.U.M.)	Condition rating [1]	Herbage production				
			Western wheatgrass	Blue grama	Other perennial grasses	Annual species	Total production [2]
			Lb./acre	*Lb./acre*	*Lb./acre*	*Lb./acre*	*Lb./acre*
Overflow	3. 32	Poor	0	474	10	0	484*a*
	5. 32	Fair	363	534	538	0	1, 435*b*
	Exclosure [3]		736	217	437	3	1, 393
Shallow	3. 32	Good	31	199	133	1	405*a*
	5. 32	Good	116	138	71	0	353*a*
Sandy	3. 32	Fair	0	248	358	36	645*a*
	3. 96	Good	2	179	980	63	1, 254*b*
	Exclosure [3]		0	255	891	46	937
Pan spots	2. 70	Good	85	328	65	21	506*a*
	3. 84	Good	40	470	56	2	589*a*
	Exclosure [3]		277	245	0	40	684
Pan spots	3. 32	Fair	5	374	0	18	397*a*
	4. 49	Good	2	526	113	2	644*b*
	5. 32	Good	43	489	135	6	673*b*

[1] From survey by Van Cleave and coworkers (*24*).
[2] Numbers on the same site followed by the same letter are not significantly different at the 5-percent level (*19*).
[3] Livestock exclosures fenced since 1932.

several sites at the summer range as compared with some heavier grazed areas.

The blue grama component of production was generally higher under light grazing on the overflow, silty, and clayey sites at the summer range and under heavier grazing on the dense-clay site. On several sites at the winter range blue grama production was highest at intermediate stocking levels.

Production of other perennial grasses varied in their response to stocking levels according to the site examined. On the overflow site at both range units, the silty site at the summer range, and the sandy and one pan-spot site at the winter range, production of these plant groups was usually highest under the lighter stocking levels. On several sites at each unit the opposite response was observed.

EROSION

A large gully has formed over the years in the overflow area of the most heavily grazed summer pasture. This gully did not exist during the 1930's. The undercutting, deep erosion, and headward progress has accelerated over the years. In 1960 the gully was over 400 feet long, 60 feet wide, and 10 to 16 feet deep (fig. 5).

Although the formation and rapid enlargement of the gully only in this pasture is not conclusive evidence, this strongly suggests another response to heavy stocking.

FIGURE 5.—Head of gully in heavily grazed pasture E, showing active cutting. In the spring of 1960 this gully progressed headward approximately 40 feet and crossed the fence line into an adjacent lightly grazed pasture.

ANIMAL RESPONSE

Animal-stocking rates differ from pasture-stocking rates because in 4 years it was necessary due to drought to remove animals from the summer pastures to reserve pastures. On the winter range shortage of forage was compensated by increased hay feeding.

Birth Dates of Calves

The date of birth of calves during the period 1950–57 inclusive did not differ significantly between stocking rates (table 13). However, it was correlated with the summer-stocking rate over the period of study (table 14). The negative relationship with summer-stocking rate indicated that later births were associated with heavier grazing (decreased acreage allowances). This probably resulted from the cows in the heavier grazed groups having later estrus than those in the lighter grazed groups.

Table 13.—*Average birth dates of calves, by average stocking rates and years, 1950–57.*

[Date in number of days since beginning of year; April 10, 100 or 101 in 1952 and 1956]

Year	Average birth date under average stocking rates (acres/A.U.M.) of—						Average [1]
	2. 44	2. 68	3. 48	3. 53	3. 62	4. 31	
1950	115	97	97	108	107	102	104*ab*
1951	103	125	113	103	108	110	110*b*
1952	99	102	101	96	103	99	100*a*
1953	106	96	98	100	98	105	101*ab*
1954	111	105	101	99	98	99	102*ab*
1955	104	103	98	103	102	106	103*ab*
1956	107	104	97	96	101	96	100*a*
1957	99	99	106	106	116	105	105*ab*
Average [1]	106*a*	104*a*	102*a*	101*a*	104*a*	103*a*	

[1] Numbers in the same column or same row followed by the same letter are not significantly different at the 5-percent level (*19*).

The multiple regression of calf birth dates on three expressions of stocking rates and five of precipitation—summer-stocking rate (X_1), the previous-summer-stocking rate (X_2), winter-stocking rate (X_3), May–June precipitation (X_4), May–June precipitation of the previous year (X_5), April–September, or growing-season, precipitation (X_6), April–September precipitation of the previous year (X_7), and precipitation during the grazing year from the previous November 1 through October 31 (X_8)—indicated that together they accounted for about 34 percent of the total variation in birth date. The regression equation for birth date of calves is, $\hat{Y}=98.59-1.50X_1-3.13X_2+1.86X^3-2.00X_4{}^*-1.41X_5+2.87X_6+0.55X_7-0.36X_8$ (multiple R 0.580**).

Table 14.—*Correlations of beef-cattle-production factors with seasonal-stocking rates (acres/A.U.M.) and with precipitation, in inches, for selected periods of the year*

Production factor	d.f. (n–2)	Summer-stocking rate	Previous-summer-stocking rate	Winter-stocking rate	Precipitation for—				
					May–June	Previous May–June	Apr.–Sept.	Previous Apr.–Sept.	Nov. 1–Oct. 31
Birth date of calf	46	−0.381**	−0.054	−0.042	−0.035	−0.173	0.263	−0.144	0.136
Birth weight of calf	46	.427**	.058	.054	.115	.095	.029	.183	−.012
Daily gain of calf	46	.552**	.257	.291*	.287	.002	−.135	.020	−.157
Weaning weight of calf	46	.563**	.240	.272	.282	.021	−.125	.044	−.153
Feeder grade of calf	16	.004	−.541*	−.490*					
Percent calf crop	46	.449**	.196	.308*	.059	.025	−.288*	.055	−.232
Spring weight of dry cows	16	.405	.039	.045					
Fall weight of dry cows	16	.533*	.372	.381					
Spring weight of wet cows	46	.396**	−.007	−.070	.079	−.060	−.103	.251	.017
Fall weight of wet cows	46	.485**	.453**	.380**	.056	−.106	−.149	−.131	−.067

*Significant at 5-percent level.
**Significant at 1-percent level.

When year effects were removed mathematically from regression, no significant regression or correlation of birth date with stocking rates were evident; and when effects of stocking-rate treatments were removed, no significant relationships between birth date and precipitation were observed. From these it would seem that the significant effects of precipitation on calf birth dates are due to the strong interaction with stocking rate and not to either influence alone.

Birth Weights of Calves

Birth weights of calves were significantly influenced by both stocking rates and years. Birth weights were overall correlated with the current-summer-stocking rate but not with precipitation (tables 14 and 15). However, the multiple regression equation for birth weight ($\hat{Y} = 48.16 + 5.04X_1{}^{**} - 2.20X_2 + 1.00X_3 - 1.22X_4{}^{**} - 2.01X_5{}^{**} + 1.95X_6{}^{**} + 0.40X_7 + 0.61X_8$—multiple R 0.698**) indicates a significant relationship between birth weights and current-summer-stocking rate, May–June and growing-season precipitation, and May–June precipitation of the previous year.

Table 15.—*Average birth weights of calves (corrected for sex and age of dam), by average stocking rates and years, 1950–57*

Year	Average birth weight under average stocking rates (acres/A.U.M.) of—						Average [1]
	2.44	2.68	3.48	3.53	3.62	4.31	
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1950	62	69	67	72	72	75	70*a*
1951	66	77	73	77	77	78	74*ab*
1952	71	66	75	74	73	79	73*ab*
1953	73	75	72	73	72	72	73*ab*
1954	70	75	74	76	74	78	75*b*
1955	66	68	71	74	75	76	72*ab*
1956	69	68	74	70	73	75	72*ab*
1957	65	69	73	74	72	79	72*ab*
Average [1]	68*a*	71*ab*	72*bc*	74*bcd*	74*bcd*	77*d*	

[1] Numbers in the same column or same row followed by the same letter are not significantly different at the 5-percent level (*19*).

When the effects of stocking-rate treatments were removed mathematically from regression, no significant effects of precipitation were found. When year effects were removed, the regressions of birth weight on previous-summer- and winter-stocking rates were both significant, and the multiple correlation coefficient was increased (R 0.784**). The differences between and the correlation with stocking rates indicated that heavy stocking reduced birth weights. This was probably because heavy stocking reduced forage production and quality and thus caused lower weights and poorer condition of cows.

The difference in birth weights of calves due to the extremes of average stocking rates of this study was about 9 pounds.

Daily Gains of Calves

Daily gains of calves between birth and weaning differed significantly between stocking rates and between years. They were correlated overall with both summer- and winter-stocking rates (tables 14 and 16). Heavy stocking reduced gains of calves. The difference in calf gains due to the average stocking extremes was about one-third pound per day. This difference occurred mostly during the last 5 to 6 weeks before weaning.

Table 16.—*Average daily gains of calves from birth to weaning (corrected for sex and age of dam), by average stocking rates and years, 1950–57*

Year	Average daily gain under average stocking rates (acres/A.U.M.) of—						Average [1]
	2.44	2.68	3.48	3.53	3.62	4.31	
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1950	1.60	1.69	1.81	1.90	1.82	1.91	1.79*a–e*
1951	1.65	1.73	1.93	2.14	1.94	2.01	1.90*f*
1952	1.63	1.71	1.91	1.88	1.90	1.97	1.83*ef*
1953	1.57	1.65	1.84	1.82	1.90	1.89	1.78*a–d*
1954	1.51	1.71	1.86	1.91	1.92	2.00	1.82*b–f*
1955	1.48	1.67	1.72	1.77	1.80	1.77	1.70*a*
1956	1.55	1.73	1.76	1.83	1.79	1.90	1.76*abc*
1957	1.46	1.67	1.82	1.85	1.77	1.85	1.74*ab*
Average [1]	1.56*a*	1.70*b*	1.83*c*	1.89*cd*	1.86*cd*	1.91*d*	

[1] Numbers in the same column or same row followed by the same letter are not significantly different at the 5-percent level (*19*).

The regression of daily gains on stocking rates and precipitation ($\hat{Y} = 1.21 + 0.24X_1{}^{**} - 0.06X_2 + 0.02X_3 - 0.06X_4{}^{**} - 0.09X_5{}^{**} + 0.09X_6{}^{**} - 0.01X_7 - 0.01X_8$—multiple R 0.874**) accounted for 76 percent of the variation in daily calf gains. When year effects were removed, the multiple correlation was unchanged (R 0.873**). However, in this instance only the overall stocking-rate effect was significant; no one of the three expressions of stocking rate (summer, previous summer, or winter) was significant. When the effects of the stocking-rate treatments were removed mathematically, only the May–June precipitation and that of the previous growing season had significant effects on the daily gain of calves.

Weaning Weights of Calves

Weaning weights of calves were strongly influenced by both stocking rates and years (table 17). They were highly correlated overall with summer-stocking rate (table 14). Heavy stocking significantly reduced weaning weights (fig. 6). The maximum range in average

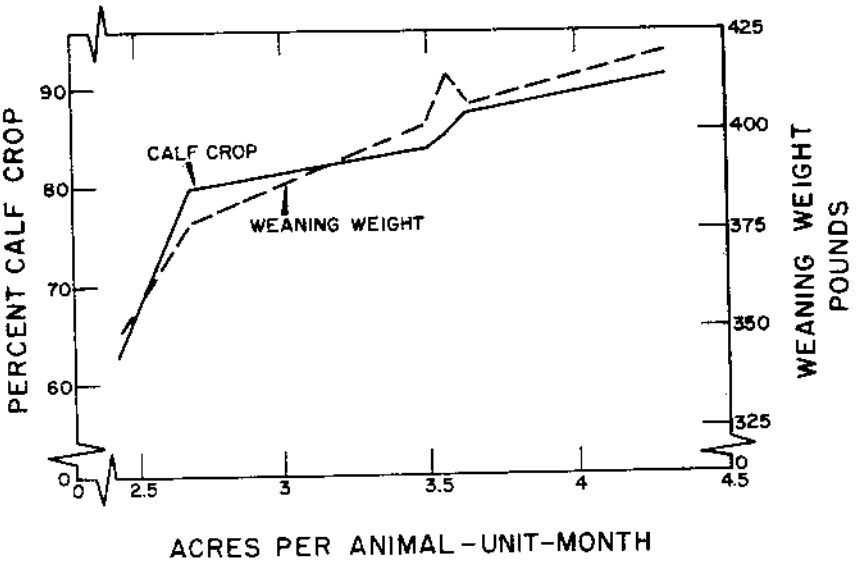

FIGURE 6.—Average percent calf crop at weaning and average weaning weight of calves, in pounds, at stocking rates of 2.44 to 4.31 acres per animal-unit-month, 1950–57.

Table 17.—*Average weaning weights of calves (corrected for sex, age of dam, and to 180 days of age), by average stocking rates and years, 1950–57*

Year	Average weaning weight under average stocking rates (acres/A.U.M.) of—						Average [1]
	2.44	2.68	3.48	3.53	3.62	4.31	
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1950	350	373	394	416	400	418	375*a*
1951	363	388	420	462	426	440	416*f*
1952	365	374	418	412	414	435	403*def*
1953	355	371	402	402	414	412	393*a–e*
1954	342	383	409	419	419	438	402*c–f*
1955	332	369	380	392	399	394	378*ab*
1956	348	380	392	400	396	418	389*a–d*
1957	328	369	399	406	391	410	384*a–c*
Average [1]	348*a*	376*b*	402*c*	414*cde*	407*cd*	420*e*	----------

[1] Numbers in the same column or same row followed by the same letter are not significantly different at the 5-percent level (*19*).

weaning weights due to stocking extremes was approximately 72 pounds.

The multiple regression equation for weaning weights ($\hat{Y}=270.44+48.09X_1^{**}-12.69X_2+4.48X_3-11.88X_4^{**}-17.33X_5^{**}+17.57X_6^{**}$

$-1.63X_7-0.15X_8$—multiple R 0.876**) accounted for 77 percent of the variation in weaning weights found during the study. As with the average daily gains of calves, when year effects were removed mathematically the multiple correlation of summer-, previous-summer-, and winter-stocking rates with weaning weights was essentially unchanged (R 0.887**), and, again, it was only the overall stocking-rate effect that was significant. When the effects of stocking-rate treatments were removed, only the May–June precipitation and that of the previous growing season had significant effects on weaning weights.

Feeder Grades of Calf at Weaning

The feeder grades of the calves at weaning over the 3 years, 1955, 1956, and 1957, differed significantly between stocking rates and between years (table 18). They were significantly correlated overall with both the previous-summer- and winter-stocking rates (table 14). The differences in feeder grades between stocking levels and the correlations with stocking rate indicated that heavy stocking depressed feeder grade of calves. The correlations also indicated that the feeder grade of the calf tended to be influenced by the previous-summer- and winter-stocking rates but not by the current-summer-stocking level. This would seem to be related to the longtime depressing effect of heavy stocking on condition of the dam. The range in calf feeder grade due to the extremes of average stocking rates was about two-thirds of a grade.

Only 3 years of data were available for analyses of feeder grades. When the effects of stocking-rate treatments were removed mathe-

Table 18.—*Average weaning grades of calves (corrected for sex and age of dam), by average stocking rates and years, 1955–57*

[Weaning grades: Fancy, 1.0; select, 2.0; low select, 3.0; top choice, 4.0; choice, 5.0; low choice, 6.0; top good, 7.0; good, 8.0; low good, 9.0; top medium, 10.0; medium, 11.0; low medium, 12.0]

Year	Average weaning grade under average stocking rates (acres/A.U.M.) of—						Average [1]
	2.44	2.68	3.48	3.53	3.62	4.31	
1955	8.9	8.0	7.2	6.2	5.3	6.0	6.9*b*
1956	8.4	7.2	6.2	6.5	6.0	6.9	6.9*b*
1957	6.7	5.2	4.7	4.7	5.4	4.6	5.2*a*
Average [1]	8.0*b*	6.8*ab*	6.0*ab*	5.8*ab*	5.6*a*	5.8*ab*	

[1] Numbers in the same column or same row followed by the same letter are not significantly different at the 5-percent level (*19*).

matically from regression analysis, no significance was found. When year effects were removed, the multiple correlation was highly significant (R 0.787**). Because only 3 years of data were available and no significant regression of feeder grade on precipitation was found, the regression equation shown here includes only stocking-rate effects: $\hat{Y}=10.15+0.45X_1-0.99X_2-0.52X_3$. Only the combined effect of these three seasonal stocking rates was observed to have a significant influence on feeder grades.

Percentage Calf Crop at Weaning

The calf crop at weaning time is probably the most important single-production factor influencing profit of the cow-calf enterprise. In this study the percent calf crop was significantly influenced by stocking level (table 19). It was not significantly different between years, but overall it was directly correlated with previous-winter- and current-summer-stocking rate and inversely with growing-season precipitation (table 14). It is apparent that heavy grazing significantly reduced the calf crop at weaning time (fig. 6). The range in calf crop due to extremes of stocking rates was about 28 percent.

Table 19.—*Percent calf crop at weaning, by average stocking rates and years, 1950–57*

Year	Percent calf crop under average stocking rate (acres/A.U.M.) of—					
	2.44	2.68	3.48	3.53	3.62	4.31
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1950	54.5	100.0	81.8	81.8	90.9	90.0
1951	40.0	80.0	60.0	80.0	90.0	80.0
1952	70.0	90.0	90.0	90.0	100.0	100.0
1953	60.0	60.0	100.0	100.0	90.0	100.0
1954	80.0	70.0	90.0	100.0	88.9	100.0
1955	60.0	90.0	90.0	90.0	60.0	100.0
1956	80.0	80.0	80.0	80.0	100.0	70.0
1957	60.0	70.0	80.0	60.0	80.0	90.0
Average [1]	63.0*a*	80.0*ab*	84.0*b*	85.2*b*	87.5*b*	91.4*b*

[1] Numbers followed by the same letter are not significantly different at the 5-percent level (*19*).

The regression of percent calf crop on stocking rates and precipitation was significant, but accounted for only 32 percent of the total variation ($\hat{Y}=46.67+11.69X_1$*$-4.61X_2+3.50X_3+1.39X_4-1.66X_5-1.03X_6-0.86X_7+1.66X_8$—multiple R 0.570**). When the effects of stocking-rate treatments were removed mathematically from regression, only the influences of the May–June and growing-season pre-

cipitation were significant. When year effects were removed, only the combined influence of stocking rates significantly affected calf crops.

Calving Difficulty and Death Losses

Differences in stocking rates influenced several other production factors affecting profits. During the course of the study there were eight deaths of calves between birth and weaning from all causes at the heaviest stocking rate and only one at any other stocking rate (3.62 acres per A.U.M.). Three cows from the heaviest stocking rate were found in too poor condition to nurse calves or to have sufficient milk supply for the calf at birth. No other cows were found in this condition at any other stocking rate. These cows required extra care and extra amounts of high-quality feed. However, this extra care was not always sufficient. In 1955 one of these cows and her calf died despite the extra care (*11, fig. 3*).

Total Calf Production

Total pounds of calf produced at each stocking rate was directly related to the yearlong stocking rates (table 20). The lowest total

Table 20.—*Total pounds of calf (corrected weights) produced at weaning, by average stocking rates and years, 1950–57*

Year	Pounds of calf produced at weaning under average stocking rates (acres/A.U.M.) of—					
	2.44	2.68	3.48	3.53	3.62	4.31
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1950	1,908	3,730	3,223	3,403	3,636	3,800
1951	1,452	3,104	2,520	3,696	3,834	3,520
1952	2,555	3,366	3,762	3,708	4,140	4,350
1953	2,130	2,226	4,020	4,020	3,726	4,120
1954	2,736	2,681	3,681	4,190	3,725	4,380
1955	1,992	3,321	3,420	3,528	2,394	3,940
1956	2,784	3,040	3,136	3,200	3,960	2,926
1957	1,968	2,583	3,192	2,442	3,128	3,690
Average [1]	2,191*a*	3,006*b*	3,369*bc*	3,523*bc*	3,568*bc*	3,841*c*
Average pounds of calf per breeding cow per year	216.4	300.6	332.7	348.0	356.8	384.1

[1] Numbers followed by the same letter are not significantly different at the 5-percent level (*19*).

Table 21.—*Total pounds of calf (corrected weights) produced per acre at weaning, by average stocking rates and years, 1950–57*

Year	Pounds of calf produced per acre under average stocking rates (acres/A.U.M.) of—						Average [1]
	2.44	2.68	3.48	3.53	3.62	4.31	
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1950	9.4	15.8	9.9	10.3	10.7	9.1	10.9*b*
1951	7.1	13.2	7.8	11.2	11.3	8.5	9.8*ab*
1952	8.5	10.1	8.9	8.7	9.4	8.4	9.0*ab*
1953	10.5	9.5	12.4	12.2	11.0	9.9	10.9*b*
1954	10.9	9.5	9.8	11.1	9.6	9.4	10.0*ab*
1955	9.8	14.1	10.5	10.7	7.1	9.5	10.3*ab*
1956	9.0	9.1	7.4	7.5	9.0	5.7	8.0*a*
1957	9.3	11.0	9.8	7.4	9.2	8.9	9.3*ab*
Average [1]	9.3*ab*	11.5*b*	9.6*ab*	9.9*ab*	9.7*ab*	8.7*a*	

[1] Numbers in the same column or same row followed by the same letter are not significantly different at the 5-percent level (*19*).

production was at the heaviest stocking rate, and the greatest production was at the lightest.

Prorating production on a per-breeding-cow and on a per-acre basis showed different relationships to stocking rates (tables 20 and 21). Average pounds of calf produced per breeding cow varied from 216.4 pounds for the most heavily grazed group to 384.1 pounds for the lightest grazed group. This was a difference of approximately 168 pounds. On a per-acre basis, the greatest average pounds of calf was produced by the second most heavily grazed group and the lowest production by the most lightly grazed one.

Average values of calf production both per pound and per calf closely corresponded to stocking-rate differences (table 22). Although grade differences and corresponding market prices indicated a difference between stocking rates of less than 1 cent per pound, total value per calf differed considerably. Average value per calf varied from $67.68 at the heaviest stocking rate to $85.64 at the lightest stocking rate, a difference of almost $18.00 per calf.

Average value of calf production on a per-acre and per-breeding-cow basis closely paralleled average pounds of calf produced on the same basis (table 23).

Table 22.—*Average calf value per hundredweight and per animal, by average stocking rates, sex, and years, 1955–57*

VALUE PER HUNDREDWEIGHT[1]

Sex and year	Average calf value under average stocking rates (acres/A.U.M.) of—					
	2.44	2.68	3.48	3.53	3.62	4.31
Male:	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
1955	18.40	18.42	19.13	19.10	19.70	20.09
1956	17.23	17.87	18.50	17.99	18.67	18.22
1957	26.00	26.00	26.62	26.00	26.33	26.33
Average	20.54	20.76	21.42	21.03	21.57	21.55
Female:						
1955	14.88	15.46	15.69	16.85	16.67	16.39
1956	14.40	14.72	15.07	15.57	15.07	14.00
1957	21.67	22.25	22.25	22.60	22.00	22.58
Average	16.98	17.48	17.67	18.34	17.91	17.66
Overall average	18.76	19.12	19.54	19.68	19.74	19.60

VALUE PER ANIMAL[2]

Male:						
1955	67.59	74.56	79.33	83.51	89.24	86.59
1956	60.99	72.19	78.07	85.75	87.23	88.09
1957	95.77	108.06	116.93	103.74	109.88	109.36
Average	74.78	84.94	91.44	91.00	95.45	94.68
Female:						
1955	51.44	61.88	66.50	70.26	69.88	67.91
1956	56.50	61.19	65.08	65.33	63.05	60.90
1957	73.82	88.22	92.33	99.39	91.08	101.01
Average	60.59	70.43	74.64	78.33	74.67	76.61
Overall average	67.68	77.68	83.04	84.66	85.06	85.64

[1] Based on market prices at Billings, Mont., for weaning grades.
[2] Average calf weaning weight (not corrected) times average value per pound.

Table 23.—*Average value of calves produced per acre and per breeding cow at weaning, by average stocking rates*

Average stocking rates (acres/A.U.M.)	Value of calves at weaning	
	Per acre [1]	Per cow [2]
	Dollars	*Dollars*
2.44	1.73	42.54
2.68	2.14	60.27
3.48	1.91	70.17
3.53	1.91	71.89
3.62	1.90	73.81
4.31	1.71	79.46

[1] Average value per hundredweight 1950–57 for average feeder grades 1955–57 times pounds of calf produced per acre 1950–57.

[2] Average value per hundredweight 1950–57 for average feeder grades 1955–57 times pounds of calf produced per breeding cow 1950–57.

Spring and Fall Weights of Dry Cows

Weights of dry cows (nonpregnant or open cows) in late October were found to be correlated overall with summer-stocking rates (table 14). No significant effects of precipitation on spring or fall weights of dry cows were found. Only the regression of fall weights on the combined effects of the current-summer-, previous-summer-, and winter-stocking rates was significant ($\hat{Y}=797.00+161.86X_1 -27.57X_2+27.70X_3$—multiple R 0.649**). For this reason and because of absence of dry cows in some groups in some years only the effects of stocking rates were included in the regression equation.

The average weights of dry cows at 28-day intervals throughout the year indicate several interrelationships of stocking rate, season, and management (table 24). Average weights of dry cows in the two most heavily stocked groups were similar throughout the year and both were much lower than the other groups. The average weights directly reflect the summer-stocking rates of these groups. In general, except for the most lightly grazed group, average dry cow weights were progressively greater as average summer-acreage allowances were increased. The average weights of the most lightly stocked group were similar to those of the intermediately stocked groups.

Table 24.—*Average yearlong weights of dry cows, at 28-day intervals, by average stocking rates and dates*

Date	Average weights under average stocking rates (acres/A.U.M.) of—					
	2.44	2.64	3.48	3.53	3.62	4.31
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Nov. 1	880	878	990	1,098	1,008	1,004
Nov. 29	896	904	962	1,056	1,039	994
Dec. 27	874	877	942	1,024	1,006	982
Jan. 24	835	834	891	976	972	931
Feb. 21	854	834	915	986	978	920
Mar. 21	856	826	904	974	952	941
Apr. 18	838	828	911	979	928	948
May 16	876	868	970	1,026	965	982
June 13	960	966	1,057	1,122	1,076	1,094
July 11	1,006	955	1,096	1,168	1,124	1,135
Aug. 8	1,066	1,056	1,158	1,226	1,195	1,171
Sept. 5	1,036	1,022	1,144	1,244	1,186	1,194
Oct. 3	1,044	1,018	1,180	1,249	1,213	1,187
Oct. 31	1,002	968	1,164	1,257	1,194	1,207

All groups lost weight on the winter range until January when winter feeding usually began. During the following 12 weeks some groups lost weight progressively while others initially gained and then lost weight. After the middle of April all groups gained weight. This weight gain continued after movement to the summer range, normally in mid-May, until early August. After early August the four most lightly grazed groups either maintained their weights or continued to gain slowly but the two most heavily grazed groups lost weight rapidly. The average gains in weight between mid-April and early August were similar in all groups regardless of stocking rate.

Spring and Fall Weights of Wet Cows

Both mid-May and late-October weights of wet cows (cows weaning calves) were correlated overall with one or more expressions of summer- and winter-stocking rates (table 14), and spring weights were significantly different between years (table 25).

The regression of spring weights of wet cows on stocking rates and precipitation accounted for 58 percent of the variability in weights ($\hat{Y} = 679.66 + 89.12X_1{}^{**} - 20.16X_2 - 2.11X_3 - 4.66X_4 - 44.43X_5 - 0.52X_6 + 13.62X_7 + 25.74X_8{}^{*}$—multiple R 0.760**). When the effects of stocking-rate treatments were removed mathematically from regression, only the combined effect of precipitation was significant. When the year effects were removed, only the combined effect of stocking rates was significant.

The regression of fall weights of wet cows on stocking rates and precipitation accounted for essentially the same amount of variability—62 percent—as did that of spring weights ($\hat{Y} = 1015.19$

Table 25.—*Average spring weights (corrected for age) of cows weaning calves, by average stocking rates and years, 1950–57*

Year	Average weights under average stocking rates (acres/A.U.M.) of—						Average[1]
	2.44	2.68	3.48	3.53	3.62	4.31	
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1950	857	964	922	1,052	995	970	960*a*
1951	1,027	1,060	1,014	1,064	1,057	1,079	1,050*b–f*
1952	1,067	1,052	1,137	1,175	1,113	1,166	1,118*f*
1953	921	1,016	1,129	1,173	932	1,163	1,006*abc*
1954	955	1,046	1,020	1,032	999	1,050	1,017*b–e*
1955	999	1,016	1,064	1,093	1,053	1,084	1,052*b–f*
1956	974	953	1,005	1,024	1,093	1,007	1,009*a–d*
1957	924	977	1,090	1,086	1,089	1,132	1,005*ab*
Average[1]	966*a*	1,010*ab*	1,035*abc*	1,075*c*	1,041*bc*	1,069*bc*	

[1] Numbers in the same column or same row followed by the same letter are not significantly different at the 5-percent level (*19*).

$+ 95.33X_1{}^{**} + 39.31X_2 - 24.54X_3 - 3.74X_4 - 23.21X_5{}^{*} + 13.99X_6 - 11.40X_7 - 10.21X_8$—multiple R 0.788**). When the effects of stocking-rate treatments were removed from regression, only the single effect of previous-summer precipitation significantly influenced fall weights. When year effects were removed, only the single effect of previous-summer-stocking rate was significant, although the combined effect of current-summer-, previous-summer-, and winter-stocking rates was highly significant. However, for this latter regression, the combined correlation was the same as when precipitation was included ($\hat{Y}=787.96+26.78X_1+102.43X_2{}^{*}+18.99X_3$—multiple R 0.791**).

The differences in average weights of wet cows between stocking rates were of about the same magnitude and at about the same rate throughout the year (tables 25 to 27 and fig. 7). Most groups initially gained weight upon entry at the winter range. They then lost weight during late December and January. They gained weight when winter feeding began and then lost weight when calving started during late March. The lowest weights were reached in mid-May. All groups then gained weight until early August. After that date all groups lost weight through late October. The greatest weight losses during late summer and fall were in the two most heavily grazed groups.

Wet cows were usually lighter than dry cows in the same group. Other differences between wet and dry cows were: wet cows reached their lowest weights in May—1 month after the dry cows; wet cows were calving in April and May; wet cows lost less weight upon entry at the winter range; all groups of wet cows lost weight after August, but dry cows continued to gain slowly; and wet cows gained for several months after winter feeding started, but only a few groups of dry cows did.

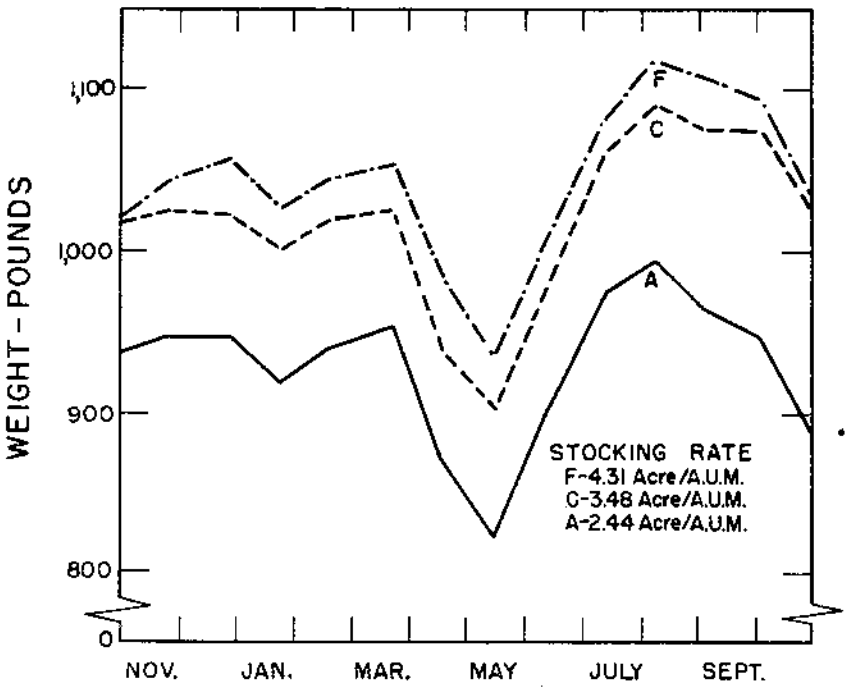

FIGURE 7.—Average 28-day weights of wet cows (uncorrected for age) grazed at three stocking rates (acres per animal-unit-month).

Table 26.—*Average fall weights (corrected for age) of cows weaning calves, by average stocking rates and years, 1950–57*

Year	Average weights under average stocking rates (acres/A.U.M.) of—					
	2. 44	2. 68	3. 48	3. 53	3. 62	4. 31
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1950	986	1, 089	1, 135	1, 215	1, 174	1, 126
1951	974	926	1, 116	1, 184	1, 128	1, 177
1952	1, 052	1, 059	1, 152	1, 200	1, 102	1, 151
1953	996	1, 102	1, 144	1, 228	1, 088	1, 157
1954	980	1, 076	1, 126	1, 145	1, 062	1, 114
1955	1, 006	1, 054	1, 077	1, 154	1, 129	1, 054
1956	975	948	1, 118	1, 160	1, 188	1, 113
1957	919	998	1, 115	1, 140	1, 137	1, 118
Average[1]	986*a*	1, 032*b*	1, 123*c*	1, 178*c*	1, 126*c*	1, 126*c*

[1] Numbers followed by the same letter are not significantly different at the 5-percent level (*19*).

Table 27.—*Average yearlong weights of cows weaning calves, by average stocking rates and dates*

[Weights taken at 28-day intervals]

Date	Average weights under average stocking rates (acres/A.U.M.) of—					
	2.44	2.68	3.48	3.53	3.62	4.31
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Nov. 1	939	972	1,020	1,057	1,020	1,023
Nov. 29	949	1,006	1,027	1,058	1,028	1,044
Dec. 27	948	1,005	1,025	1,068	1,038	1,056
Jan. 24	920	982	1,002	1,032	1,014	1,029
Feb. 21	942	1,000	1,021	1,055	1,027	1,045
Mar. 21	954	996	1,027	1,059	1,022	1,054
Apr. 18	870	941	938	970	965	984
May 16	825	887	903	946	907	937
June 13	913	972	993	1,032	993	1,018
July 11	979	1,047	1,063	1,109	1,072	1,084
Aug. 8	997	1,074	1,093	1,145	1,114	1,117
Sept. 5	965	1,047	1,078	1,125	1,105	1,109
Oct. 3	947	1,011	1,077	1,125	1,098	1,094
Oct. 31	891	952	1,027	1,091	1,042	1,036

Weights of wet cows in the most lightly grazed group were usually similar to or below that of the next most lightly grazed group. It is possible that these weights were reduced because more of the cows in this group had weaned calves during previous years and were consequently at lower weights or that some attribute of forage associated with light grazing, possibly composition, reduced cow weights. The former seems the most likely.

Mature Size of Cows

Two abnormally small cows were observed—one in each of the two most heavily grazed groups of cows—during the latter part of the study. One entered the study in the fall of 1954 and the other in 1955 as replacements. These cows were the smallest in each group and weaned the smallest calves. Even at 6 to 7 years of age their mature weights never exceeded 900 to 925 pounds at the late-summer peak. Their weights after calving were, several times, under 750 pounds.

These small cows maintained their fertility. Each produced a calf every year through 1958.

Although not conclusive the low weights and small stature at maturity of these animals and those of several other small cows suggest an accelerated depressing effect on successive generations from the heavy stocking.

Mineral Deficiency

Throughout the study many of the cattle in the heavily grazed pastures and a few in the intermediately grazed ones exhibited symptoms commonly believed to indicate a lack of phosphorous. These symptoms were thin flesh, humped backs, and occasionally restricted gait (*16, fig. 20*). As indicated, no supplemental phosphorous was provided at any time during the study.

During the early years of this study Marsh and coworkers (*16*) investigated the effects of the different stocking rates on animal phosphorous among other nutritional elements. In 1954 they found slightly higher blood phosphorous in cattle from the heavily grazed pastures, but no differences in bone phosphorous (*16, tables 10 and 18*). However, some reduction in bone growth of cattle from the intermediately and heavily grazed pastures was observed (*16, fig. 21*).

These differences, although far from conclusive, did suggest a slight deficiency of phosphorous for bone growth, but only under the heavier grazing rates. None were noted under the lighter stocking levels.

DISCUSSION AND CONCLUSIONS

This study largely confirms the results of earlier work that heavy stocking levels depress productivity and growth of both range vegetation and the beef cows and calves grazing it and gives additional detailed information on specific changes and influences not previously available. In many instances greater reductions in vegetation and animal production were found than in previous studies.

Precipitation during the study period was 10 to 12 percent below the longtime average. This may be compared with approximately 10 to 15 percent above average precipitation during an earlier study—1939 to 1946—on these pastures (*17*).

As several objectives and methods were the same for the two studies some of the data may be compared. However, the differences between the two studies in weather and in the time intervals since differential stocking levels were begun must be considered.

Pasturewide utilization indices for the three most abundant forage grasses were not well correlated with stocking rates. Even when a significant relationship was found, the correlations and coefficients of determination were usually low. A strong effect of weather or precipitation on the utilization indices was observed. Other utilization determinations during the course of study indicated wide differences in utilization between sites within the same pasture. This has also been observed by Dwyer (*5*).

The data on utilization of vegetation by weight showed lower levels of utilization than those in other western range areas commonly associated with maintaining range and livestock productivity. Apparently, under the conditions of this study, the long-term average utilization of both western wheatgrass and needle-and-thread grass should not have exceeded 33 to 37 percent by weight for optimum productivity of the range resource and livestock using it.

Often, wide differences in basal cover of a single species and differences in range-condition class were found within a pasture. In

several instances the relationships between stocking rate and total cover or cover of individual species differed considerably between sites on the same seasonal range unit.

These differences between sites reaffirm the importance of site designations when studying vegetation on the heterogenous soils and topography of the northern Great Plains. This was also previously found by Reed and Peterson on these pastures (*17, tables 4 and 6*) for the period of 1939 to 1946 and by Dwyer (*5*) in Oklahoma.

The reduction of mature plant height and the slowing down of spring-height growth by heavy grazing were also indicated by Reed and Peterson (*17, table 7*). They pointed out the strong interaction of site and stocking levels found in 1946 (*17, fig. 15*). On several sites they found the most rapid and greatest total vegetation growth under intermediate stocking levels. In contrast, the results indicated here on one major site show the most rapid and greatest total-plant growth under the lightest stocking levels.

The range-condition classification of 1958 showed the three most heavily stocked pastures on the summer range at about the same reduced level of range condition. However, on the three most lightly stocked summer pastures a rapid increase in range condition with decreased average stocking levels was evident.

These ranges appear resistant to extreme reduction in range condition due to heavy stocking. It would seem that the composition and vigor of the native vegetation under prolonged heavy grazing and below-normal precipitation are considerably reduced, but then they tend to stabilize at a low but fairly constant level. At this level, competition is still sufficient to prevent large-scale replacement by invader species. The increase of sod species under heavy stocking is probably the primary reason for this.

The increase in acreage of the heavily grazed pasture *A* of approximately 8 percent in the spring of 1956 also suggests range deterioration. This increase was necessary in order to prevent loss of animals during the average summer-grazing season and to carry them for the full period.

Varied stocking levels during winter and early spring had little effect on range-condition classification. In the range of 2.7 to 3.5 acres per animal-unit-month, a rapid change in range condition was found on summer range but practically no change was evident on winter range.

The effects of stocking level on herbage production are strongly influenced by site. Differential utilization between sites and varying areas of particular sites under the different stocking levels no doubt influences this response. However, in most instances total herbage production is closely and directly related to range-condition classification.

The influence of stocking levels on calf performance during this study was slightly greater than that shown by Reed and Peterson for the period 1938–45. Under the heaviest stocking, the average calf-weaning weights were approximately 16 pounds lower during 1950–57 than for the previous period; under intermediate stocking levels, the weights were 5 pounds lower; and under the lightest stocking, the weights were 10 pounds higher.

Under heavy stocking, percentage calf crop at weaning was 10 percent lower during 1950–57 than for the previous period; under intermediate stocking it was 4 percent lower; and under the lightest stocking it was 1 percent lower. The difference in average percent calf crops between the two most heavily grazed groups and the two most lightly grazed groups was 7 percent for the period 1938–45 (82 to 89 percent) and 17 percent for the period 1950–57 (71.5 to 88.3 percent).

The correlations of precipitation shown with various plant-utilization indices and animal-production characteristics are almost uniformly low. However, the correlations of precipitation with utilization are higher than with the animal responses. Only when the effects of stocking rates and precipitation were considered together in regression were appreciable effects of precipitation observed.

All the significant regression elements for the measures of animal production on May–June precipitation were negative, both for the current and preceding year. The significant regressions of animal production on growing-season precipitation and the one instance on grazing-year total precipitation were positive. It appears that some effect of May–June precipitation tends to reduce animal production in years of high rainfall and improve animal production in years of low rainfall. Apparently, the opposite response occurs if precipitation is concentrated more in April or during July through September. The mechanism through which precipitation during these periods influences animal production is probably related to the effects on forage quality as well as quantity and on grazing habits. Whether the precipitation effects are due to changes in stem-leaf ratios of plants, midsummer to late-summer regrowth of plants, leaching nutrients from forage (*8*, *25*), or decreasing grazing during cold, wet spring weather is unknown.

SUMMARY

In 1948 a study was initiated at the U.S. Range Livestock Experiment Station near Miles City, Mont., to determine long-term effects of different intensities of grazing on range vegetation and beef-cattle production.

The study was conducted in an area of mixed-grass prairie typical of the semiarid southwestern part of the northern Great Plains. The topography, vegetation, and soils are similar to those over a large part of this region.

At each of two separate areas, six pastures of native range were grazed each at a different stocking rate. One area was grazed from mid-May until about November 1 and the other during the rest of the year. The pastures had previously been grazed since 1932 at about the same stocking rates.

Purebred, high-quality, Hereford cattle were used in the study.

The cattle were kept in the study during most of their productive life. Some animals were replaced annually by daughters from the same stocking-rate group. Low-quality hay was fed as necessary on the winter range, and calves were born there. Purebred bulls were placed with the cows for 7 weeks on the summer range. Calves were weaned at the end of the summer-grazing period.

A continuous record was maintained of animal weights and production, and periodic vegetation surveys were made.

During the course of the study, 1948–1957, average pasture-stocking rates on the summer range were from 1.84 acres per animal-unit-month to 3.53 acres. On the winter range, stocking rates were from 2.70 to 5.32 acres.

On both the summer and winter ranges several utilization indices of key forage species were significantly correlated with stocking rates and with precipitation. Regression equations were constructed to allow use of these indices to estimate utilization.

Total basal cover of vegetation decreased between 1945 and 1956 on the summer range; whereas, it generally remained constant or increased slightly on the winter range. By 1956 significant differences in total cover of vegetation were found to exist between stocking rates. Large differences in the amount of various plant species were also found between stocking rates and between range sites.

Material differences in average height and growth rate of two key species were found between stocking rates.

Range-condition ratings on the summer range were significantly correlated with stocking rate by 1958. However, on the winter unit, condition ratings were not correlated, although a slight difference was evident between several stocking rates.

Total herbage production and most components of production were closely related to range condition. However, considerable differences between sites were present. On some sites total production was apparently reduced by exclusion of domestic livestock.

Birth weight of calves, rate of gain, weaning weight, calf-weaning grade, and cow fertility were significantly reduced by heavy stocking. These production characteristics often were correlated with summer- or winter-stocking rates or with precipitation during selected periods of the year.

Spring and fall weights of both wet and dry cows were significantly reduced by heavy stocking.

Calf-weight production and value of calves produced per breeding cow were reduced materially by heavy stocking rates. Animal production per acre of grazing land has been reduced at the heaviest stocking rate below its previous (1932–45) level, but it has not been reduced below the current level of lighter stocking rates.

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APPENDIX

Table 28.—*Average total plant basal cover and basal cover of chief species in 1956 on summer range, after 22 years of different stocking rates, by range sites and average stocking rates*

[Average stocking rate is for 1948–57; T indicates cover of 0.0049 percent or less; blanks indicate range site or species are not present in pasture]

TOTAL PLANT COVER

Site (24)	Average stocking rates (acres/A.U.M.) of—					
	1.84	1.85	2.78	2.94	3.14	3.53
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Overflow	3.00		4.80	7.70	2.40	1.10
Silty	3.20	3.30	4.00	5.20	4.60	3.40
Clayey		2.40			2.50	3.40
Pan spots		2.50			2.90	2.90
Thin breaks	2.70		1.40		2.20	2.20
Pasture average	2.70	2.40	3.90	5.10	3.40	2.50

BLUE GRAMA GRASS

Overflow	.11		.13	1.26	1.54	.08
Silty	1.87	1.84	2.19	3.36	2.94	2.54
Clayey		.66			1.30	1.70
Pan spots		.26			.79	1.06
Thin breaks	.82		.15		.57	.28
Pasture average	.71	.60	1.60	3.00	1.52	.75

WESTERN WHEATGRASS

Overflow	.34		.49	.27	.01	.50
Silty	.02	.18	.13	.06	.09	.14
Clayey		.45			.38	.38
Pan spots		.59			.68	.55
Thin breaks	.30		.14		.12	.53
Pasture average	.23	.41	.21	.15	.39	.68

BUFFALOGRASS

Overflow	1.44		2.67	4.82	.52	.02
Silty	.00	.26	.14	.11	.13	.17
Clayey		.37			.21	.52
Pan spots		.48			.24	.48
Thin breaks	.30		.00		.02	.20
Pasture average	.80	.34	.55	.47	.32	.28

Table 28.—*Average total plant basal cover and basal cover of chief species in 1956 on summer range, after 22 years of different stocking rates, by range sites and average stocking rates*—Continued

Site (24)	Average stocking rates (acres/A.U.M.) of—					
	1.84	1.85	2.78	2.94	3.14	3.53
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
NEEDLE-AND-THREAD GRASS						
Overflow	.03	----	.12	.00	.00	T
Silty	.41	.12	.26	.64	.61	.22
Clayey	----	.03	----	----	.10	.08
Pan spots	----	.07	----	----	.01	.05
Thin breaks	.18	----	.06	----	.31	.10
Pasture average	.09	.03	.21	.48	.20	.04
GREEN NEEDLEGRASS						
Overflow	.25	----	.46	.00	.00	.34
Silty	.00	.04	T	.00	.01	.00
Clayey	----	.00	----	----	.01	.03
Pan spots	----	.00	----	----	.01	.03
Thin breaks	.05	----	.01	----	.17	.38
Pasture average	.13	T	.08	.01	.03	.13
THREADLEAF SEDGE						
Silty	.06	.20	.59	.36	.32	.00
Clayey	----	.06	----	----	.00	.12
Thin breaks	.05	----	.00	----	.14	.00
Pasture average	.04	.05	.39	.25	.10	.02
NEEDLELEAF SEDGE						
Overflow	.03	----	.00	.35	.00	.00
Silty	.00	.02	.01	.01	.01	.00
Clayey	----	T	----	----	.01	.05
Thin breaks	.02	----	.00	----	.00	.00
Pasture average	.01	.01	.01	.05	.01	.01
SAND DROPSEED						
Overflow	.07	----	.09	.00	.00	.08
Silty	.03	.01	.08	.01	.02	.03
Clayey	----	.06	----	----	.02	.11
Pan spots	----	.13	----	----	.02	.11
Thin breaks	.03	----	.06	----	.00	.12
Pasture average	.04	.05	.09	.01	.02	.07
SANDBERG BLUEGRASS						
Overflow	.14	----	.18	.08	.06	.01
Silty	.03	.05	.04	.08	.07	.09
Clayey	----	.07	----	----	.08	.08
Pan spots	----	.05	----	----	.32	.10
Thin breaks	.00	----	.00	----	T	.08
Pasture average	.08	.16	.05	.07	.14	.07

Table 28.—*Average total plant basal cover and basal cover of chief species in 1956 on summer range, after 22 years of different stocking rates, by range sites and average stocking rates*—Continued

Site (24)	Average stocking rates (acres/A.U.M.) of—					
	1.84	1.85	2.78	2.94	3.14	3.53
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
FALSE BUFFALOGRASS						
Silty	.01	.01	.02	.00	.00	.00
Clayey		.05			.00	.00
Pan spots		.14			.01	.04
Thin breaks	.01		.00		.00	.00
Pasture average	.02	.07	.02	.02	T	.02
BLUEBUNCH WHEATGRASS						
Pasture average	.00	.00	.00	.00	.00	T
SALTGRASS						
Pasture average	.00	T	.08	.00	T	.01
TUMBLEGRASS						
Silty	.00	.00	.00	.00	.00	.03
Pan spots		.00			.00	.01
Thin breaks	.00		.00		.00	.02
Pasture average	.00	.00	.00	.00	.00	T
RED THREEAWN GRASS						
Silty	.00	.00	.04	.01	.00	.00
Clayey		.00			.00	T
Pan spots		.01			.02	.00
Thin breaks	.00		.08		.00	.00
Pasture average	.00	T	.05	.01	.01	T
SILVER SAGEBRUSH						
Overflow	.34		.38	.89	.00	.05
Silty	.00	.06	.00	.04	.01	.00
Clayey		.07			.00	.02
Pan spots		.03			T	.03
Thin breaks	.24		.02		.00	.12
Pasture average	.19	.05	.06	.10	.02	.03
BIG SAGEBRUSH						
Silty	.13	.05	.11	.00	.02	.06
Clayey		.21			.10	.03
Pan spots		.32			.32	.09
Thin breaks	.00		.04		.00	T
Pasture average	.02	.32	.08	T	.13	.06

Table 28.—*Average total plant basal cover and basal cover of chief species in 1956 on summer range, after 22 years of different stocking rates, by range sites and average stocking rates*—Continued

FRINGED SAGEWORT

Site (24)	Average stocking rates (acres/A.U.M.) of—					
	1.84	1.85	2.78	2.94	3.14	3.53
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Overflow	.02	-------	.00	.00	.00	.00
Silty	.01	.02	.06	.08	.02	.00
Pan spots	-------	.02	-------	-------	.01	.00
Thin breaks	.00	-------	.00	-------	.00	.02
Pasture average	.01	.01	.04	.05	.01	T

PLAINS PRICKLYPEAR

Overflow	.02	-------	.04	.00	.00	.00
Silty	.36	.39	.19	.37	.25	.13
Clayey	-------	.16	-------	-------	.18	.13
Pan spots	-------	.26	-------	-------	.26	.15
Thin breaks	.12	-------	.12	-------	.03	.01
Pasture average	.11	.16	.16	.27	.21	.15

WINTERFAT

Pasture average	.00	.01	.00	.02	.02	T

BROOM SNAKEWEED

Clayey	-------	.01	-------	-------	.00	.00
Pan spots	-------	.01	-------	-------	.00	.00
Thin breaks	.06	-------	.00	-------	.00	.00
Pasture average	.01	T	.00	T	.00	.00

HOOD'S PHLOX

Overflow	.02	-------	.00	.00	.00	.00
Silty	.00	.00	.02	.01	.00	.00
Clayey	-------	.02	-------	-------	T	.01
Pan spots	-------	.03	-------	-------	.00	.00
Thin breaks	.00	-------	.00	-------	.08	T
Pasture average	.01	.01	.01	T	T	T

SCARLET GLOBEMALLOW

Overflow	T	-------	.01	.08	.14	T
Silty	.00	.02	.02	.04	.03	.01
Clayey	-------	.08	-------	-------	.04	.01
Pan spots	-------	.01	-------	-------	T	.06
Pasture average	.01	.03	.02	.05	.04	.08

Table 29.—*Average total plant basal cover and basal cover of chief species in 1956 on winter range, after 22 years of different stocking rates, by range sites and average stocking rates*

[Average stocking rate is for 1948–57; T indicates cover of 0.0049 percent or less; blanks indicate range site or species are not present in pasture]

TOTAL PLANT COVER

Site (24)	Average stocking rates (acres/A.U.M.) of—					
	2. 70	3. 32	3. 84	3. 96	4. 49	5. 32
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Overflow	3. 40	4. 90	2. 30	2. 00	3. 10	3. 20
Silty		4. 00			4. 90	3. 60
Clayey	2. 80	4. 10	3. 30	3. 60	3. 30	3. 80
Pan spots	3. 20	3. 90	3. 20	3. 00	3. 50	3. 40
Thin breaks	1. 80		2. 20			2. 10
Shallow	3. 50	3. 30	3. 40	3. 50	3. 00	3. 00
Shale	1. 50	1. 20	2. 20	2. 00	2. 70	2. 10
Pasture average	2. 70	3. 80	2. 80	2. 90	3. 60	3. 00

BLUE GRAMA GRASS

Overflow	1. 21	2. 78	. 78	. 77	1. 35	1. 76
Silty		2. 80			3. 18	2. 43
Clayey	1. 64	2. 93	1. 88	2. 07	1. 72	2. 08
Pan spots	1. 85	2. 58	1. 39	1. 61	2. 10	2. 11
Thin breaks	. 49		. 64			1. 13
Shallow	1. 61	1. 90	2. 20	1. 68	1. 39	1. 46
Shale	. 36	. 46	. 51	. 57	1. 17	. 83
Pasture average	1. 28	2. 35	1. 16	1. 35	1. 85	1. 61

WESTERN WHEATGRASS

Overflow	. 80	. 46	. 28	. 31	. 13	. 35
Silty		. 01			. 08	. 14
Clayey	. 07	. 11	. 20	. 20	. 50	. 29
Pan spots	. 15	. 31	. 28	. 18	. 26	. 20
Thin breaks	. 23		. 24			. 08
Shallow	. 43	. 05	. 24	. 21	. 18	. 21
Shale	. 17	. 24	. 36	. 18	. 28	. 17
Pasture average	. 21	. 15	. 28	. 24	. 24	. 22

BUFFALOGRASS

Overflow	. 34	. 84	. 06	. 03	. 19	. 18
Silty		. 08			. 11	. 06
Clayey	. 11	. 08	. 12	. 06	. 06	. 18
Pan spots	. 15	. 20	. 14	. 04	. 02	. 02
Thin breaks	T		. 03			. 00
Shallow	. 07	. 01	. 05	. 14	. 02	. 13
Shale	. 00	. 00	. 04	. 03	. 00	. 02
Pasture average	. 08	. 12	. 08	. 06	. 07	. 10

Table 29.—*Average total plant basal cover and basal cover of chief species in 1956 on winter range, after 22 years of different stocking rates, by range sites and average stocking rates*—Continued

Site (24)	Average stocking rates (acres/A.U.M.) of—					
	2.70	3.32	3.84	3.96	4.49	5.32
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
NEEDLE-AND-THREAD GRASS						
Overflow	.00	.15	.10	.09	.21	.03
Silty	------	.25	------	------	.30	.17
Clayey	.08	.04	.03	.14	.10	.10
Pan spots	.08	.06	.12	.10	.26	.02
Thin breaks	.04	------	.04	------	------	.08
Shallow	.12	.20	.02	.13	.19	.14
Shale	.07	.05	.07	.03	.05	.14
Pasture average	.08	.18	.09	.10	.19	.11
GREEN NEEDLEGRASS						
Overflow	.03	.00	.01	.00	.01	.04
Clayey	.00	.00	.00	.00	.01	.06
Pan spots	.03	.00	.00	.00	.01	.01
Thin breaks	.04	------	T	------	------	T
Shallow	.03	.00	.00	.02	.01	.02
Shale	.02	.00	.00	.01	.00	T
Pasture average	.03	.00	T	.01	.01	.02
THREADLEAF SEDGE						
Overflow	.00	.09	.03	.04	.18	.00
Silty	------	.60	------	------	.88	.26
Clayey	.10	.20	.16	.37	.07	.26
Pan spots	.16	.14	.11	.25	.11	.14
Thin breaks	.02	------	.03	------	------	.11
Shallow	.41	.35	.11	.37	.27	.22
Shale	.07	.01	.04	.09	.00	.15
Pasture average	.14	.38	.07	.22	.34	.20
NEEDLELEAF SEDGE						
Pasture average	T	.01	.01	T	T	T
SAND DROPSEED						
Overflow	.21	.00	.10	.21	.01	.13
Silty	------	.01	------	------	.09	.01
Clayey	.01	.03	.05	.09	.05	.05
Pan spots	.07	.04	.08	.07	.07	.02
Thin breaks	.01	------	.07	------	------	.01
Shallow	.00	.03	.17	.09	.03	.06
Shale	.01	.03	.03	.03	.10	T
Pasture average	.03	.03	.08	.08	.05	.05

Table 29.—*Average total plant basal cover and basal cover of chief species in 1956 on winter range, after 22 years of different stocking rates, by range sites and average stocking rates*—Continued

Site (24)	Average stocking rates (acres/A.U.M.) of—					
	2.70	3.32	3.84	3.96	4.49	5.32
SANDBERG BLUEGRASS						
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Overflow	.05	.10	.01	.02	T	.08
Silty		.01			.05	.07
Clayey	.03	.05	.07	.05	.04	.04
Pan spots	.04	.06	.04	.04	.05	.06
Thin breaks	.01		T			T
Shallow	.02	.01	.04	.01	.01	.04
Shale	T	.02	.02	.01	.00	T
Pasture average	.02	.04	.03	.03	.02	.04
FALSE BUFFALOGRASS						
Silty		.00			.02	.02
Clayey	.02	.01	.00	T	.00	.00
Pasture average	.01	T	.00	T	.01	.01
BLUEBUNCH WHEATGRASS						
Overflow	.00	.00	.11	.00	.25	.02
Clayey	.05	.00	.08	.04	.05	.19
Pan spots	.04	.00	.05	.03	.00	.07
Thin breaks	.12		.16			.02
Shallow	.02	T	.01	.10	.19	.10
Shale	.12	.01	.14	.20	.06	.20
Pasture average	.07	T	.11	.11	.13	.08
SALTGRASS						
Overflow	.14	.01	.12	.22	.02	.01
Clayey	.05	.07	.06	.04	.08	.06
Pan spots	.07	.04	.10	.07	.00	.00
Thin breaks	.10		.08			.00
Shallow	.14	.04	.10	.08	.03	.02
Shale	.04	.02	.06	.07	.10	.03
Pasture average	.07	.03	.11	.07	.04	.02
TUMBLEGRASS						
Overflow	.00	.00	.01	.00	.00	.02
Silty		.00			.00	T
Clayey	.05	.01	.11	.01	.02	.03
Pan spots	.06	.01	.10	.01	.00	.03
Thin breaks	.06		T			.00
Shallow	.00	.02	.00	.02	.02	.01
Shale	.04	.02	.00	.02	.00	T
Pasture average	.05	.01	.04	.01	.01	.01

Table 29.—*Average total plant basal cover and basal cover of chief species in 1956 on winter range, after 22 years of different stocking rates, by range sites and average stocking rates*—Continued

Site (24)	Average stocking rates (acres/A.U.M.) of—					
	2.70	3.32	3.84	3.96	4.49	5.32
RED THREEAWN GRASS						
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Overflow	.00	.00	.02	.00	.04	.00
Clayey	.00	.02	.01	.00	.06	.12
Pan spots	.02	T	.04	T	.00	.03
Thin breaks	.02		T			.00
Shallow	.06	.03	.00	.00	.04	.04
Shale	T	.02	.10	.00	.00	.06
Pasture average	.02	.01	.03	T	.03	.04
SILVER SAGEBRUSH						
Overflow	.08	.15	.03	.02	.02	.04
Pan spots	.02	.01	.02	.01	.00	.09
Thin breaks	.00		.01			.00
Shallow	.00	.04	.00	.00	.01	.01
Pasture average	.01	.02	.01	T	.01	.01
BIG SAGEBRUSH						
Overflow	.12	.16	.05	.14	.01	.03
Silty		.00			.01	.07
Clayey	.14	.00	.08	.08	.00	.00
Pan spots	.13	.00	.11	.14	.00	.00
Thin breaks	.34		.14			.05
Shallow	.04	.05	.00	.12	.02	.02
Shale	.16	.03	.25	.17	.10	.08
Pasture average	.18	.03	.11	.12	.03	.04
FRINGED SAGEWORT						
Overflow	.00	.00	.02	.00	.01	.00
Clayey	.01	.04	.00	.01	T	.00
Pan spots	.02	.02	.01	.01	.01	.00
Thin breaks	T		.01			.00
Shallow	.02	.04	.01	.01	.01	.00
Shale	.03	.00	.00	.00	.00	.00
Pasture average	.02	.02	.01	.01	.01	.00
PLAINS PRICKLYPEAR						
Overflow	.09	.05	.03	.00	.05	.10
Silty		.02			.09	.18
Clayey	.06	.28	.10	.16	.09	.06
Pan spots	.11	.22	.18	.15	.23	.17
Thin breaks	.03		.04			.04
Shallow	.17	.10	.01	.08	.06	.08
Shale	.04	.00	.08	T	.34	.01
Pasture average	.09	.15	.09	.09	.10	.09

Table 29.—*Average total plant basal cover and basal cover of chief species in 1956 on winter range, after 22 years of different stocking rates, by range sites and average stocking rates*—Continued

Site (24)	Average stocking rates (acres/A.U.M.) of—					
	2.79	3.32	3.84	3.96	4.49	5.32
WINTERFAT						
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Overflow	.00	.00	.01	.00	T	.01
Clayey	.00	.05	.06	.02	.00	.01
Pan spots	T	.05	.04	.02	.02	.00
Thin breaks	.00		.01			.00
Shallow	.00	.02	.04	.02	T	.01
Shale	.00	.02	.02	.00	.02	.00
Pasture average	T	.02	.02	.01	T	T
BROOM SNAKEWEED						
Overflow	.00	.00	.05	.01	.02	.00
Clayey	.00	T	.01	T	.05	T
Pan spots	.00	T	.02	T	.00	.00
Thin breaks	.03		.03			.00
Shallow	.00	.02	00	.00	.03	T
Shale	.00	.03	.06	T	.01	T
Pasture average	T	.01	.04	T	.03	T
HOOD'S PHLOX						
Overflow	.00	.00	.01	.00	.03	.00
Silty		.02			.00	.00
Clayey	.00	.07	T	.01	.05	.01
Pan spots	.03	.04	.01	.01	.01	T
Thin breaks	.00		T			.02
Shallow	.03	.03	.00	.02	.05	.01
Shale	.02	.08	.00	.03	.27	.02
Pasture average	.02	.03	.01	.02	.06	.01
SHADSCALE						
Overflow	.00	.00	.08	.00	.00	.03
Clayey	.15	.60	.02	.08	.00	.00
Pan spots	.10	.00	.03	.06	.00	.00
Thin breaks	.10		.10			.00
Shallow	.00	.05	.08	.08	.02	.03
Shale	.09	.07	.13	.12	.10	.00
Pasture average	.08	.02	.07	.09	.01	.02
BLACK GREASEWOOD						
Overflow	.00	.00	.14	.00	.12	.05
Silty		.14			.00	.00
Pan spots	.03	.04	.04	.05	.00	.00
Thin breaks	.00		.14			.00
Shallow	.00	.02	.08	.00	.08	.04
Shale	.06	.00	.04	.14	.10	.00
Pasture average	.02	.03	.09	.05	.05	.02

Table 29.—*Average total plant basal cover and basal cover of chief species in 1956 on winter range, after 22 years of different stocking rates, by range sites and average stocking rates*—Continued

SCARLET GLOBEMALLOW

Site (24)	Average stocking rates (acres/A.U.M.) of—					
	2.70	3.32	3.84	3.96	4.49	5.32
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Overflow	.02	.03	.04	.01	.05	.09
Silty	------	.01	------	------	.01	.01
Clayey	T	.03	.03	.02	.05	.04
Pan spots	.02	.04	.02	.01	.02	.01
Thin breaks	.03	------	.03	------	------	.00
Shallow	.01	.01	.03	.01	.05	.03
Pasture average	.02	.02	.03	.01	.04	.03

Common and Botanical Names of Plants Mentioned

Grasses and Sedges

Bluegrass, Sandberg	*Poa secunda* Presl.
Buffalograss	*Buchloe dactyloides* (Nutt.) Engelm.
Buffalograss, false	*Munroa squarrosa* (Nutt.) Torr.
Dropseed, sand	*Sporobolus cryptandrus* (Torr.) A. Gray
Grama grass, blue	*Bouteloua gracilis* (H.B.K.) Lag. ex Sted.
Needle-and-thread grass	*Stipa comata* Trin. & Rupr.
Needlegrass, green	*Stipa viridula* Trin.
Sacaton, alkali	*Sporobolus airoides* (Torr.) Torr.
Saltgrass, desert	*Distichlis stricta* (Torr.) Rydb.
Sedge, needleleaf	*Carex eleocharis* L. H. Bailey
Sedge, threadleaf	*Carex filifolia* Nutt.
Threeawn, red	*Aristida longiseta* Steud.
Tumblegrass	*Schedonnardus paniculatus* (Nutt.) Trel.
Wheatgrass, bluebunch	*Agropyron spicatum* (Pursh) Scribn. & Smith
Wheatgrass, western	*Agropyron smithii* Rydb.

Forbs

Globemallow, scarlet	*Sphaeralcea coccinea* (Pursh) Rydb.
Onion, textile	*Allium textile* Nels. & Macbr.
Phlox, Hood's	*Phlox hoodii* Rich.

Shrubs

Greasewood, black	*Sarcobatus vermiculatus* (Hook.) Torr.
Pricklypear, plains	*Opuntia polyacantha* Haw.
Sagebrush, big	*Artemisia tridentata* Nutt.
Sagebrush, silver	*Artemisia cana* Pursh
Sagewort, fringed	*Artemisia frigida* Willd.
Shadscale	*Atriplex confertifolia* (Torr. & Frem.) S. Wats.
Snakeweed, broom	*Gutierrezia sarothrae* (Pursh) Britt. & Rusby
Snowberry, western	*Symphoricarpos occidentalis* Hook.
Winterfat	*Eurotia lanata* (Pursh) Moq.

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END