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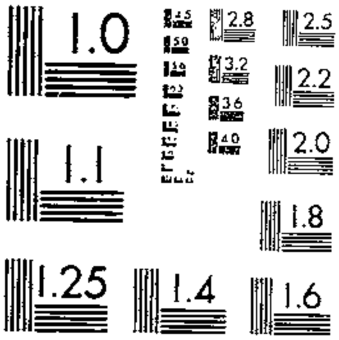

MICROCOPY RESOLUTION TEST CHART
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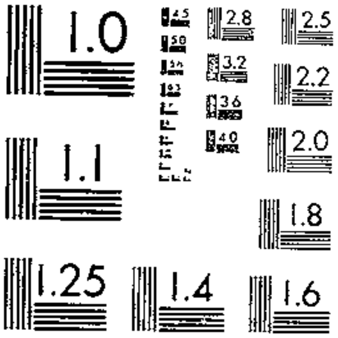

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Vegetation, Soil, and Cattle Responses To Grazing On Northern Great Plains Range

by Merton J. Reed and Roald A. Peterson

TECHNICAL BULLETIN NO. 1252 December 1961

U.S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington 25, D.C. - Price 35 cents

Acknowledgments

The study reported here was conducted cooperatively by the Forest Service; the Animal Husbandry Research Division of the Agricultural Research Service, formerly the Bureau of Animal Industry; and the Montana Agricultural Experiment Station, while Federal research on grazing management of northern Plains ranges was the responsibility of the Forest Service. The cooperation and assistance of many members of these agencies, particularly of numerous Forest Service employees, is gratefully acknowledged.

The authors especially acknowledge the major contributions of Leon C. Hurtt and E. Joseph Woolfolk whose sustained effort and encouragement made completion of the study possible and preparation of this report easier. Mr. Hurtt, Chief of the Division of Range Research of the former Northern Rocky Mountain Forest and Range Experiment Station, developed the original broad study design and provided general supervision; Mr. Woolfolk, in charge of the study for nearly its duration, initiated and recorded many of the observations. The authors also thank Warren C. Whitman, in charge of the study during its final years, for major assistance; and Melvin S. Morris, Head, Department of Range Management, Montana State University Forestry School, for laboratory facilities and assistance in part of the soils analyses.

Contents

Vegetation, Soil, and Cattle Responses to Grazing On Northern Great Plains Range

by Merton J. Reed and Roald A. Peterson [1]

The Problem of Managing Northern Plains Range

Of the approximately 118 million acres of northern mixed-prairie region in the United States, 80 percent or more than 90 million acres is grassland principally devoted to livestock grazing (*50*).[2] By far the larger part of this is native range. A similar large acreage in Canada is also in this category.

Numerous studies of western ranges, including the northern Plains, have amply shown that overgrazing impairs both the range and the livestock. Consequently, to assure full use of the range without damage and loss, guides to proper grazing are important particularly for recognizing when use is harmful. The development of guides to optimum grazing of northern Great Plains ranges has recieved considerable attention, but information is still fragmentary because of the many variables involved.

In developing dependable guides for judging range condition and trend in condition resulting from grazing practices, a comprehensive understanding of the responses of the range to weather and grazing is required. It is indispensable to know what characteristics of the vegetation and soil are visibly affected by each, and in what manner, degree, and sequence. The constancy of these responses and their interrelations must be understood. Most particularly, sensitive indicators of early upward or downward changes in forage yields are needed, or indicators that even foreshadow such changes.

This bulletin reports the responses of vegetation, soils, and cattle to three grazing intensities over a 14-year period, 1932–45. Because these responses were associated with early changes in range condition, they are of particular interest. Also included are estimates of proper stocking and herbage utilization.

In reporting these results, the authors have reviewed the findings from formal grazing trials and other studies of northern Great Plains range, and attempted to relate results. Formal grazing trials with cattle have been conducted near Mandan, N. Dak. (*40, 41*); Ardmore and Cottonwood, S. Dak. (*7, 32*); and Manyberries, Alta. (*2, 13, 15*); and with sheep near Miles City, Mont. (*61*).

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[1] The authors are located at the Pacific Southwest Forest and Range Experiment Station, Forest Service, Berkeley, Calif., and Inter-American Institute of Agricultural Science, Southern Zone, Montevideo, Uruguay. Both authors were employed during the study by the Northern Rocky Mountain Forest and Range Experiment Station, which is now part of the Intermountain Forest and Range Experiment Station, Forest Service.

[2] Italic numbers in parentheses refer to Literature Cited, p. 72.

How the Problem Was Studied

Character of the Range

The study area, located about 5 miles southwest of Miles City, Mont., is in an intermediate precipitation zone of the northern Great Plains (fig. 1). Two pieces of native range on the U.S. Range Livestock Experiment Station made up the area proper. Past use had been mostly conservative since the early twenties.

The amount of cover by all plant species on the various sites, as determined by inventory at the start of the study, ranged from 15 to 80 percent and averaged 40 percent. Perennial grasses and sedges made up approximately three-fourths of the cover. The remainder

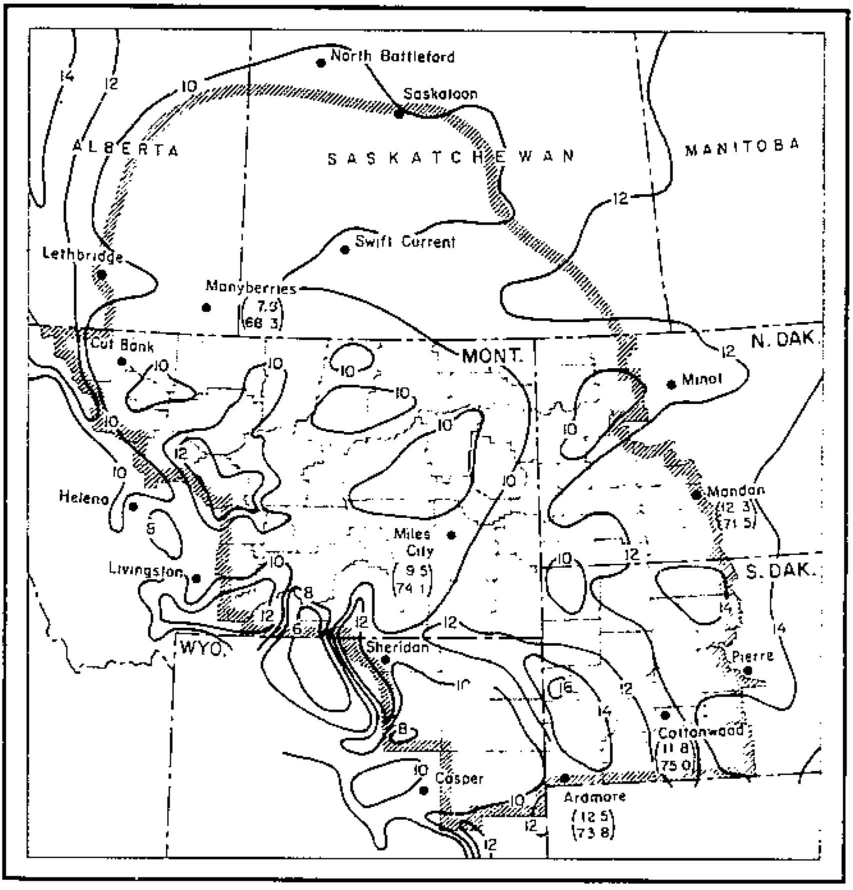

FIGURE 1.—The northern Great Plains (mixed prairie) region, showing lines of equal warm-season, April–Sept., precipitation (*49*). (Those for Canada through courtesy of Meterological Branch, Department of Transport.) Upper figure in parentheses=average April–Sept. precipitation; lower figure=average July temperature. These averages are based on a 24-year record at the Dominion Range Experiment Station, Manyberries, and a 60-year record at Miles City.

was composed largely of shrubs. Perennial forbs and annuals were minor.

Five grasses and one sedge accounted for about 65 percent of the cover and constituted the principal grazing species. These were blue grama,[3] buffalograss, and threadleaf sedge which made up approximately 40 percent; the taller grasses, western wheatgrass, needle-and-thread, and green needlegrass made up the remainder. Growth of threadleaf sedge and the taller grasses normally began during late March or early April, while that of blue grama and buffalograss began from mid- to late April after the days had lengthened and become warmer. Completion of growth was in late June or early July for the sedge, and grass herbage normally was cured by late July or early August. The period of most rapid growth for the grasses was during late April, May, and June. During most falls the cool-weather species made additional growth, but the amount was small.

Other perennial grasses common on the range but of secondary importance because of relative scarcity or low palatability were bluegrasses—Sandberg, big, Canby, and Canada; and alkali sacaton, sand dropseed, prairie Junegrass, tumblegrass, and red threeawn. Frequently, about 15 species of forbs were present.

Distribution of species was limited by topography and soils to form five rather broad but easily recognized plant communities. Important features of these are given in table 1.

Experimental Range Setup and Stocking

Two sets of experimental ranges were fenced on the study area. Each set was made up of six individual ranges. Division fences in each set were built out from a central well, the only source of permanent water. The set of ranges with rougher topography, which provided the most shelter from storms, was used for late fall, winter, and early spring grazing. Normally, experimental cattle grazed here from late October or early November through mid-May. The other set, with more gently rolling topography, provided grazing during the remaining spring, summer, and early fall months (fig. 2). Hereafter as a means of reference to season of stocking these two sets of ranges will be referred to as "winter ranges" and "summer ranges" respectively.

The size of individual ranges varied, because size was based on relative amounts of cover of forage species at the start of the study in order to provide three levels of stocking yearlong. Two ranges of each set were approximately matched to duplicate each level under summer and winter conditions.

Although cover of forage species changed during the period 1932–45 while the ranges were stocked, surface acres were kept constant. During all seasons, all ranges of a set were stocked or unstocked for identical periods. With relatively few exceptions, surface-acre rates and seasons of stocking also were kept constant. Major exceptions were when grazing was lightened because of younger age of cattle or drought, or both, during the summer seasons of 1932, '36 and '37, and the winter seasons of 1934–35 and 1937–38. In addition, the winter ranges remained unstocked during the 1936–37 season.

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[3] A list of common and scientific names of plants mentioned appears on p. 71.

TABLE 1.—*Important features of major vegetation subtypes of the experimental range, Miles City, Mont.*

Subtype	Topography	Soil class	Principal forage species	Common secondary grasses	Common shrubs
Threadleaf sedge—Upland.	Rolling uplands: Ridges and upper slopes.	Gravely to sandy loam.	Threadleaf sedge Blue grama Needle-and-thread	Sand dropseed ---- ----	Big sagebrush. Fringed sagebrush. Plains pricklypear.
Blue grama—Upland	Slopes, mostly gentle.	Sandy loam to sandy clay.	Blue grama Western wheatgrass Needle-and-thread	Sand dropseed Sandberg bluegrass Red threeawn	Big sagebrush. Silver sagebrush. Fringed sagebrush. Plains pricklypear.
Shrubby—Breaks	Breaks: Steep slopes.	Usually eroded clay	Western wheatgrass	Tumblegrass Sandberg bluegrass Red threeawn Alkali sacaton	Black greasewood. Gardner saltbush. Shadscale saltbush. Big sagebrush. Fringed sagebrush. Silver sagebrush.
Western wheatgrass—Bench.	Benches: Gentle slopes to nearly level.	Sandy clay to nearly pure clay (some scabby areas).	Western wheatgrass Buffalograss Blue grama (on sandier areas).	Tumblegrass Sandberg bluegrass ----	Big sagebrush. Fringed sagebrush. Plains pricklypear.
Western wheatgrass—Bottom.	Bottoms: Mostly gentle slopes.	Clay and silty clay	Western wheatgrass Buffalograss Green needlegrass	Tumblegrass Prairie junegrass Canada bluegrass	Silver sagebrush. Plains pricklypear. Western snowberry.

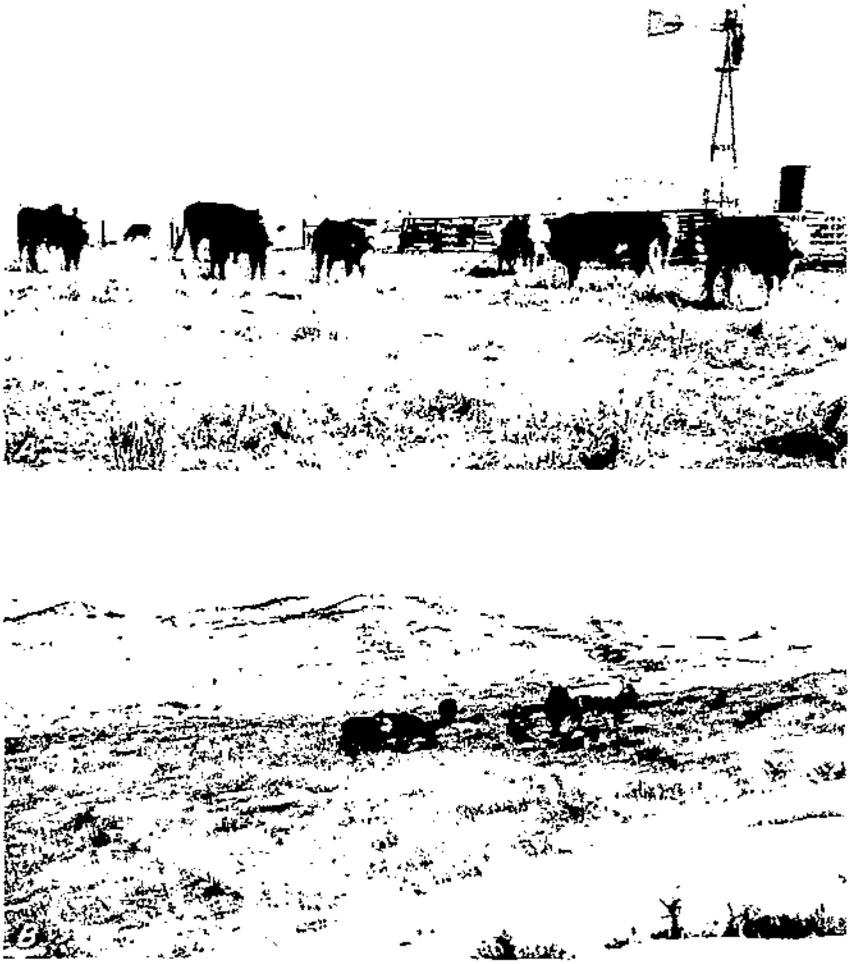

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Figure 2.—Experimental cattle ranges near Miles City, Mont.: *A*, Summer ranges were of gentle rolling topography; *B*, winter ranges were rougher, affording shelter from winter storms.

In the other years, surface-acre allowances under the three levels of stocking approximated 1.8, 2.3, and 3.1 per cow month on the summer range. If calves are considered, allowances were somewhat less than this. On the winter range, allowances approximated 2.0, 2.9, and 3.4 acres per cow month. For a combined 12-month season, surface acres approximated 23.1, 30.5, and 38.8 per cow. Hereafter, these levels of stocking are referred to as the heaviest, intermediate, and lightest, respectively.

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Cattle Management

Two herds of purebred Hereford cows grazed the ranges. The first herd was sold in early August 1936, because drought made the forage supply uncertain. The second herd was started in August 1937 and continued through November 1945 when the cows were sold as open 10-year olds. Ten cows were carried on each range unit in season, making a total of 20 subjected to each level of stocking at any one time. During the study all cows were kept at the same level of stocking in which they started.

Cows were started as uniform 2-year-old heifers that came from the Station herd on conservatively grazed range. The first herd was divided into lots and assigned on the basis of weight and future potentials as judged by an animal husbandman. Assignment of the second herd was purely random.

Throughout the study, original cows were replaced because of disease, crippling accidents, death, failure to calve in two consecutive years, and consistent production of extremely small calves. The replacements were animals of similar breeding and age.

Breeding was to registered Hereford bulls during a 6-week period in June and July. Each lot of cows was furnished one bull except in 2 years when single bulls were moved through all ranges twice each day. In 1935 and from 1939–44, bulls were shifted among ranges one or more times to equalize possible effects of individual bulls. More than 50 bulls were used in the breeding program.

All calves ordinarily had been dropped by the time the cows were moved from the winter range. They remained on summer range until weaned, usually about 2 weeks before the cows were returned to winter range.

The cattle were constantly supplied with a 3:1 salt-bonemeal mixture and adequate water that was warmed during heavy freezing weather. After 1936, protection from storms on the winter range was provided by open-face sheds with southern exposures.

Supplemental feeding was restricted to individual animals or lots of animals as required to maintain them in at least fair condition. Feed was mostly medium-quality alfalfa hay. The amount fed was with rare exception less than that required for maintenance, so a deficiency remained to be furnished by the range.

Areas Sampled on the Experimental Ranges

Most of the studies of grazing effects were carried out on the summer ranges. It was here that reactions were expected to occur first and be of greater magnitude than on the winter ranges because of season of grazing and less supplemental feeding. Since most of the studies on both sets of ranges were made at the end of the trial in 1945 and 1946, the resulting information represents cumulative responses of the vegetation and soils following 14 years of differential grazing.[4]

The terminal studies were restricted to relatively distinct vegetation subtypes. This was done to avoid confusion in comparisons of ranges

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[4] The methods used in various phases of the study are given in the appendix, p. 75.

in any single year that would have resulted from differences in subtype makeup. The subtypes studied were essentially the same for the grazing levels compared. The subtype approach also gave results applicable to relatively well-defined situations. Entire ranges were compared only by computing annual herbage yield on the summer ranges, using cattle weights and herbage utilization.

Entire parts of important grazing subtypes on the summer and winter ranges were sampled to determine mature height growth of grasses at the end of the trial. More comprehensive sampling of vegetation and soil characteristics was done on smaller, more carefully matched parts of subtypes of the summer ranges called test areas. These extended across division fences into ranges stocked at the different levels (fig. 3). The relation of the test areas to the major subtypes is shown in table 2.

Because of the arrangement of ranges and location of subtypes, most of the test areas were on ranges that had been stocked at the heaviest and lightest rates. From 2 to 4 acres were sampled in each range per test area. The parts among which comparisons were made were similar in soils, exposure, and drainage,[5] and vegetation was essentially homogenous for each area at the start of the trial. Topography, fences, and distance from the central well were uniform within each comparison.

Other plots sampled during the trial were permanent. They consisted of 18 pairs of 10- by 12-meter and 29 pairs of 6- by 9-meter plots individually paired among the heaviest and lightest stocked summer ranges, 57 one-square-meter chart quadrats scattered over the summer and winter ranges, and several units of various sizes on conservatively grazed or enclosed, ungrazed range in or adjacent to the study area.

Sampling units, except of sagebrush and cactus, were restricted to locations readily available to the cattle. Such locations varied, depending on the ground cover of Plains pricklypear and big and silver sagebrush. Trails, intact cattle dung, ant hills, and rodent disturbances were avoided. None of the latter three influences became serious enough to require dropping any of the permanent plots.

In 1946, all sampling on the summer ranges was under ungrazed conditions. The 1945 forage crop on these ranges had been grazed 1½ months before sampling and the 1946 crop on the winter ranges 2⅔ months. During the trial, sampling was done while the ranges were being grazed.

Weather Preceding and During the Study

In 1931, immediately preceding the study, precipitation was so limited during all seasons as to cause serious drought; to a lesser extent, this was also true in 1928 (fig. 4).[6] In the intervening years of 1929

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[5] Exposure of the part of Test Area 1 within an intermediately stocked range was more northerly than for the parts within heaviest and lightest stocked ranges. On the latter range, there was a small upland drainage that was not replicated in the other parts.

[6] Precipitation and temperature data from U.S. Weather Bureau records; evaporation data from North Dakota Agricultural Experiment Station at Dickinson (*16*).

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FIGURE 3.—Representative test areas, summer experimental ranges: *A* and *B*, Areas 1 and 4 in 1946 when ranges were ungrazed, looking respectively from heaviest toward lightest grazed part immediately across division fence and, similarly, from lightest toward heaviest grazed part. *C*, Test Area 5 at the end of the 1944 season: *left*, heaviest grazed part and *right*, lightest grazed

TABLE 2.—*Important features of the summer range test areas, Miles City, Mont., experimental range*

Test area	Subtype	Principal forage grasses [1]	Topography	Soil class	Drainage
1	Blue grama—Upland	Blue grama, western wheatgrass, needle-and-thread.	Rolling upland: Gentle slope.	Sandy loam	Excellent.
2	do	Western wheatgrass, blue grama	Very gentle slope	Sandy clay	Good.
3	Western wheatgrass—Bench.	Western wheatgrass	Bench: Gentle slope	Clay	Do.
4	do	Western wheatgrass	Nearly flat	do	Fair.
5	Western wheatgrass—Bottom.	Western wheatgrass, green needlegrass.	Bottom: Gentle slope	Silty clay	Do.
6	do	Western wheatgrass, green needlegrass.	Nearly flat	do	Poor.

[1] In order of herbage yields on lightest grazed part of each area in 1946 when ranges were ungrazed.

and 1930, however, critical spring (April–June) precipitation was nearer normal and growing conditions more favorable.

In 1932 and 1933, April–June and March–May precipitation respectively was about average and growing conditions fairly good. But drought occurred again in 1934 and lasted through 1937. Precipitation was most deficient in 1934 and 1936 when spring rainfall was but 24 and 26 percent of the longtime spring average. Preceding fall through current spring precipitation also was less than half of average. In addition, temperatures were higher during these years: mean for May through July averaged 71.0° and 73.7° F. in 1934 and 1936 respectively as compared with a 60-year average of 65.7°.

Coincident with deficient precipitation was extreme evaporation. At Dickinson, N. Dak., about 150 miles east and north where weather conditions were similar to those in the study area, losses from an open-water surface during April through September in 1934 and 1936 were 13 and 17 inches above a 45-year average of 34.4 inches. In 1935 and 1937 drought conditions were less severe; spring precipitation was approximately 60 percent of average, and May–July mean temperatures were close to average.

Spring precipitation returned to its longtime average in 1938 and remained average or above through 1946. In 3 successive years, 1942–44, it exceeded the average by 2 to 7 inches. Preceding fall through current spring precipitation followed much the same pattern during these years except that it was somewhat below average from 1938–40 and again in the last 2 years. Summer rainfall was sufficiently above average to improve growing conditions in only 2 years—1941, and in 1946 after vegetation studies were completed.

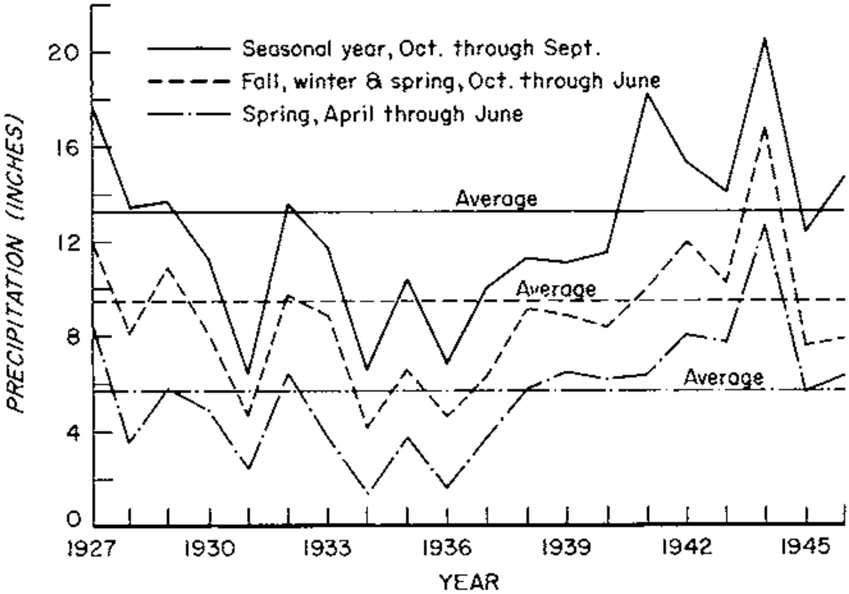

FIGURE 4.—Precipitation at Miles City, Mont., preceding and during the study, by seasons and seasonal years, and averages for 74 years, 1878 through 1951.

Temperatures were also more conducive to lower evaporation during this later period. In 1938–41, May through July means ranged from approximately average to 3° F. above in 1940; in 1942–46, they were from 1° to 4° below normal. Evaporation at Dickinson for April through September in 1941–45 ranged from 2 to 8 inches below average.

Herbage Production on the Sample Areas

At the start of the study, per acre production of palatable herbage on the summer ranges was essentially equal for ranges stocked heaviest and lightest, but about 17 percent greater for those intermediately stocked. During the 1939–45 period, herbage production declined on the heaviest stocked ranges. In those years, yields for lightest and intermediately stocked ranges were constantly higher than for the heaviest stocked, averaging 22 and 40 percent more respectively (fig.5).

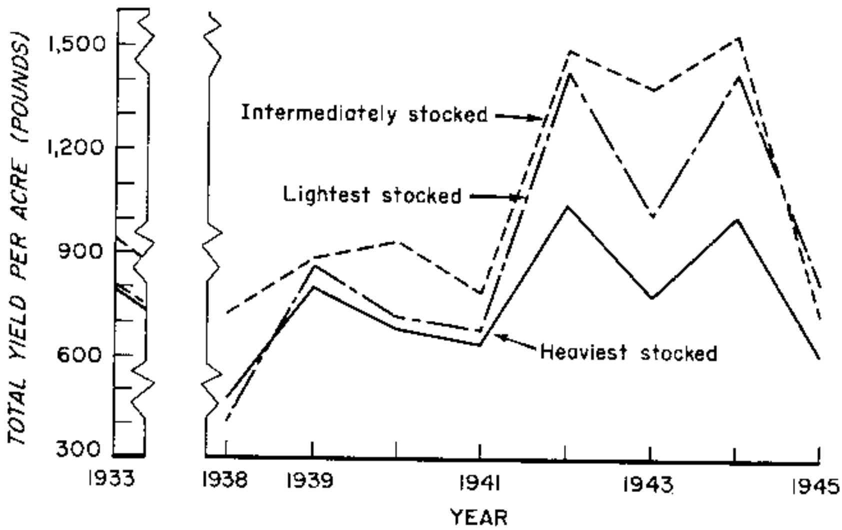

FIGURE 5.—Production of palatable herbage on the summer ranges, based on cattle weights, days of stocking, and herbage utilization, 1938–45. Original relations based on amounts of cover of forage species, 1933. Miles City, Mont., experimental range.

For the ranges stocked intermediately and lightest, herbage production remained about equal when allowance was made for the difference at the start. On the same basis, the difference in average production between the intermediately and heaviest stocked ranges during 1939–45 was approximately equal to that between the heaviest and lightest stocked.

At the end of the trial when ranges were ungrazed, yields of important forage grasses and of all herbage, with one exception, were consistently less on parts of test areas within the heaviest stocked summer ranges than yields from test areas in the intermediately and lightest stocked ranges (fig. 6). The apparent decreases in the production of forage grasses on the heaviest stocked ranges was generally greater than corresponding losses in all herbage. They ranged from 19 to 46 percent and averaged 34 percent for the six areas. On Test Area 4, where equal yields of all herbage were obtained from parts

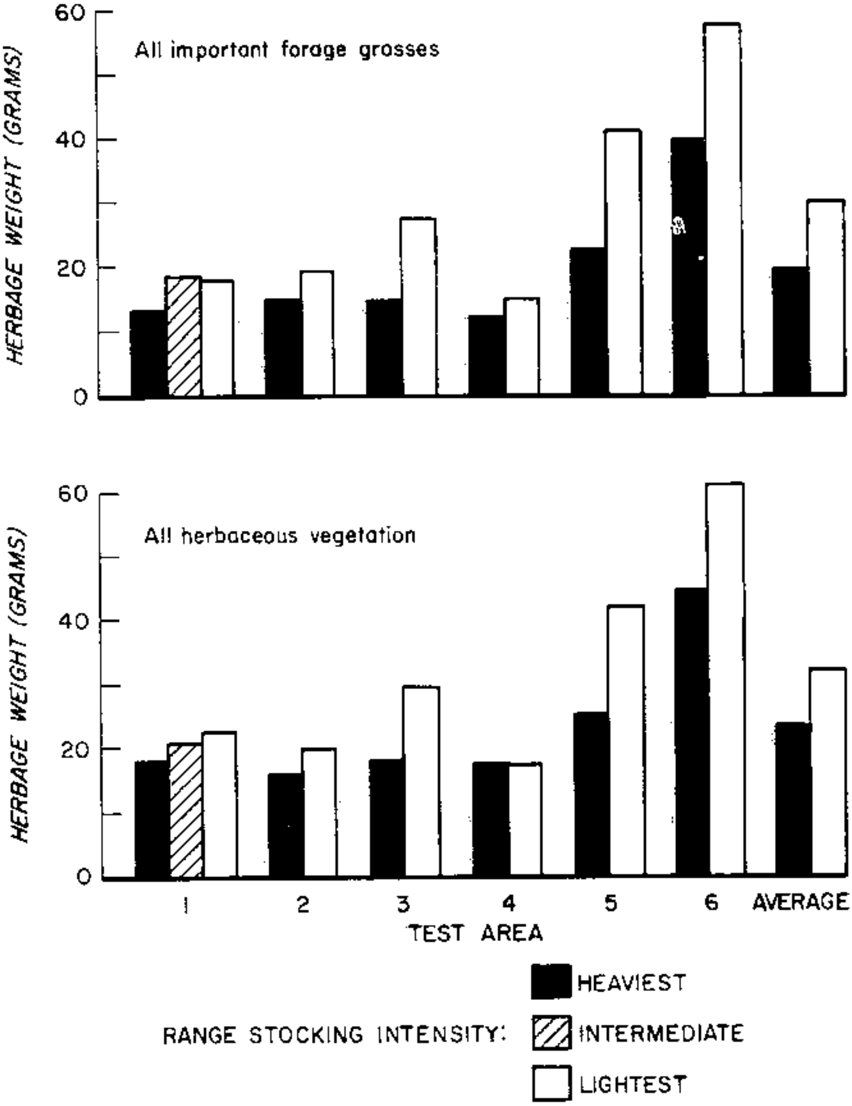

FIGURE 6.—Average yield of mature herbage per 0.1 milacre from parts of test areas on the summer ranges when the ranges were ungrazed, 1946. Based on current growth clipped ½-inch above root crowns and air dried; big and silver sagebrush and cactus species excluded. (Statistically, significantly less under heaviest stocking in all comparisons at the 1-percent probability level, except for all herbaceous vegetation from Test Area 4. Yields can be converted to pounds per acre by multiplying by 22.1.) Miles City, Mont., experimental range.

in the heaviest and lightest stocked ranges, loss in forage grasses under the heaviest rate was offset mainly by greater yields of Sandberg bluegrass, tumblegrass, and fringed sagebrush—plants of limited or no grazing value.

As indexed by production of palatable herbage, then, range condition was lowered by the heaviest intensity of grazing. Reaction of other vegetation and soil characteristics to grazing intensity and their relation to range condition will be discussed in later sections.

Influences of Herbage Utilization

Records of herbage use confirm the conclusion that grazing intensity was responsible for the differences experienced in range condition. Utilization under summer and winter conditions, as would be expected, was consistently greatest on the ranges stocked at the heaviest rate (table 3). On such summer ranges, utilization of the two most widely distributed forage grasses was greater than on the ranges stocked intermediately and lightest—about 15 to 25 percent greater for western wheatgrass and about 10 to 15 percent greater for blue grama. On winter ranges, these differences amounted to about 10 to 15 percent for either grass.

TABLE 3.—*Utilization of important forage grasses*[1] *on cattle ranges stocked at three rates, Miles City, Mont., experimental range, 1939–45*

Grass and stocking intensity	1939	1940	1941	1942	1943	1944	1945	Average
SUMMER RANGES								
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Western wheatgrass:								
Heaviest	44	50	60	37	47	34	56	47
Intermediate	25	34	42	22	24	20	40	30
Lightest	19	30	36	17	23	16	25	24
Blue grama:								
Heaviest	42	33	33	23	29	23	38	32
Intermediate	33	25	23	16	18	11	28	22
Lightest	24	20	24	13	20	10	23	19
Buffalograss:								
Heaviest	74	80	70	85	77	69	87	77
Intermediate	60	62	63	74	64	65	81	67
Lightest	44	47	39	53	46	36	59	46
WINTER RANGES								
Western wheatgrass:								
Heaviest	56	51	66	------	------	------	24	49
Intermediate	47	37	53	------	------	------	18	39
Lightest	36	36	54	------	------	------	17	36
Blue grama:								
Heaviest	53	24	41	------	------	------	19	34
Intermediate	41	13	26	------	------	------	13	23
Lightest	40	13	24	------	------	------	11	22

[1] Proportion of entire weight of western wheatgrass or blue grama herbage removed; proportion of buffalograss mats grazed. Only current growth included on summer ranges; on winter ranges, only that of the immediate preceding growing season.

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On intermediately and lightest stocked ranges, herbage utilization was about equal. Only buffalograss on summer ranges showed substantially greater use under intermediate than lightest stocking. This was because its distribution in the intermediately stocked ranges was restricted to bottoms that were favored by the cattle. Since this grass was not abundant, it was of little consequence in overall herbage use. In 12 of 14 comparisons of western wheatgrass and blue grama on summer ranges, and in 6 of 8 comparisons on winter ranges, utilization under the intermediate rate of stocking was somewhat greater than under the lightest rate.

While only part of the trial was covered, inventories for 1939–45 provide a good index to relative use of the ranges. There is little reason to believe that relative use was dissimilar in the years when inventories were not made. The most probable exception is the severe drought years of 1934 and 1936 when scarcity of forage combined with use by cattle and heavy concentrations of grasshoppers resulted in nearly complete herbage utilization on all ranges.

Recorded utilization would have appeared greater if a part of the grasses next to the ground had been discounted as mechanically ungrazable or if only height of residue had been considered. A large part of grass weight is concentrated in the lower third or quarter of the shoots. Approximately 35 to 55 percent of the dry weight of western wheatgrass shoots usually was present in the lower 3 inches. Consequently, while only 47 percent of its weight was utilized on the heaviest stocked summer ranges, 72 percent of its shoots were grazed to an average stubble of 2.9 inches. Comparable figures for the intermediately and lightest stocked ranges were respectively 55 and 47 percent of the shoots grazed to stubbles of 3.7 and 3.9 inches. Similar relations existed for the other grasses (*28*).

As on entire ranges, use of herbage on important grazing subtypes and test areas was greatest within the ranges stocked heaviest (tables 4 and 5). On matched areas in ranges stocked intermediately or lightest, it was generally close to equal but substantially less than in the heaviest stocked. Somewhat of an exception occurred on the western wheatgrass bottom subtype of the summer ranges. There, use in all years that inventories were made was mostly about 15 to 20 percent greater on intermediately than on lightest stocked ranges.

Relative Impacts of Weather and Grazing on the Vegetation and Cattle

Major trends in nearly all vegetation characteristics were set by the major cycles of weather, and rate of change within these trends was largely influenced by intensity of grazing. Conditions of the cattle was affected similarly, because weather and the rates of stocking affected the amount and quality of forage available. Since the extremes in weather were so great, weather rather than rate of grazing had the greatest influence on responses of the range and cattle.

The spread between the heaviest and lighter rates of grazing was narrowed because more supplemental feed was given under the heaviest rate. With a less adequate feeding program, less satisfactory performance of the range and cattle might logically have been expected. The heaviest rate of stocking was not as heavy as some commonly used on ranges in the vicinity.

TABLE 4.—*Utilization of important forage grasses*[1] *on principal grazing subtypes of cattle ranges stocked at three rates, Miles City, Mont., experimental range, 1939–45*

SUMMER RANGE

Subtype, grass, and stocking intensity	1939	1940	[2]1941	1942	1943	1944	1945	Average
Blue grama—Upland:								
Western wheatgrass:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Heaviest	30	40	------	26	28	17	47	31
Intermediate	19	27	------	14	15	11	34	20
Lightest	20	26	------	17	18	9	20	18
Blue grama:								
Heaviest	37	33	------	21	30	21	42	31
Intermediate	31	25	------	13	17	7	27	20
Lightest	23	25	------	12	20	9	22	19
Western wheatgrass—Bench:								
Western wheatgrass:								
Heaviest	48	50	------	39	59	36	63	49
Lightest	21	30	------	10	23	15	25	21
Buffalograss:								
Heaviest	68	82	------	75	70	57	87	73
Lightest	39	48	------	33	38	33	50	40
Western wheatgrass—Bottom:								
Western wheatgrass:								
Heaviest	51	61	------	45	56	53	61	55
Intermediate	48	57	------	41	54	56	74	55
Lightest	26	42	------	28	40	39	47	37
Buffalograss:								
Heaviest	83	83	------	93	88	81	89	86
Intermediate	87	85	------	88	87	76	91	86
Lightest	67	72	------	68	64	55	77	67

WINTER RANGE

Subtype, grass, and stocking intensity	1939	1940	[2]1941	1942	1943	1944	1945	Average
Blue grama—Upland:								
Western wheatgrass:								
Heaviest	59	52	67	------	------	------	24	51
Intermediate	44	37	52	------	------	------	17	37
Lightest	37	36	53	------	------	------	15	35
Blue grama:								
Heaviest	51	25	43	------	------	------	21	35
Intermediate	37	12	23	------	------	------	11	21
Lightest	43	14	25	------	------	------	11	23

[1] Proportion of entire weight of western wheatgrass or blue grama herbage removed; proportion of buffalograss mats grazed. Only current growth included on summer range; on winter range, only that of the immediate preceding growing season.

[2] Data for the summer range omitted because subtypes were defined differently in the other years.

TABLE 5.—*Utilization of important forage grasses*[1] *on test areas of summer cattle range stocked at three rates, Miles City, Mont., experimental range, 1939–45*

Test area, grass, and stocking intensity	1939	1940	1941	1942	1943	1944	1945	Average
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
(1) Western wheatgrass:								
Heaviest	48	31	43	25	36	10	51	35
Intermediate	18	19	40	15	6	9	24	19
Lightest	16	20	4	16	0	2	20	11
Blue grama:								
Heaviest	22	39	40	36	42	45	35	37
Intermediate	32	17	17	11	4	5	30	17
Lightest	11	22	15	21	12	2	34	17
(2) Western wheatgrass:								
Heaviest	45	40	58	50	15	27	39	39
Lightest	7	21	12	25	29	15	5	16
Blue grama:								
Heaviest	38	59	-----	22	33	26	17	33
Lightest	17	10	19	2	12	3	7	10
(3) Western wheatgrass:								
Heaviest	55	42	73	36	54	13	54	47
Lightest	22	32	39	17	15	3	17	21
(4) Western wheatgrass:								
Heaviest	43	50	45	33	69	49	69	51
Lightest	21	27	39	11	51	30	50	33
(5) Western wheatgrass:[2]								
Heaviest	41	55	54	57	49	43	53	50
Lightest	-----	-----	-----	-----	-----	-----	-----	24
Buffalograss:								
Heaviest	94	45	75	75	86	88	83	78
Lightest	-----	-----	-----	-----	-----	-----	-----	46
(6) Western wheatgrass:								
Heaviest	46	65	72	54	68	48	49	57
Lightest	14	44	34	25	72	33	61	40

[1] Proportion of entire weight of western wheatgrass or blue grama herbage removed; proportion of buffalograss mats grazed. Only current growth included on summer range; on winter range, only that of the immediate preceding growing season.

[2] The lightest stocked part of Test Area 5 adjoined the experimental range and was not included in the herbage utilization surveys; average use values are from the lightest stocked ranges.

Basal Area Response of Grasses and Forbs to Weather, and Implications for Management

The great droughts of 1934 and 1936 reduced the basal cover of herbaceous vegetation to only a fraction of what it was earlier. In addition, the effect of drought was aggravated by severe grasshopper infestations. Combined area of all perennial grasses and sedges on chart quadrats dropped from 28 percent in 1933 to a low of 2 percent in 1937 (fig. 7). After that, there was a steady uptrend with improved weather. But the predrought level was not reached until 1944, 7 years later. Similar trends were shown by all vegetation combined.

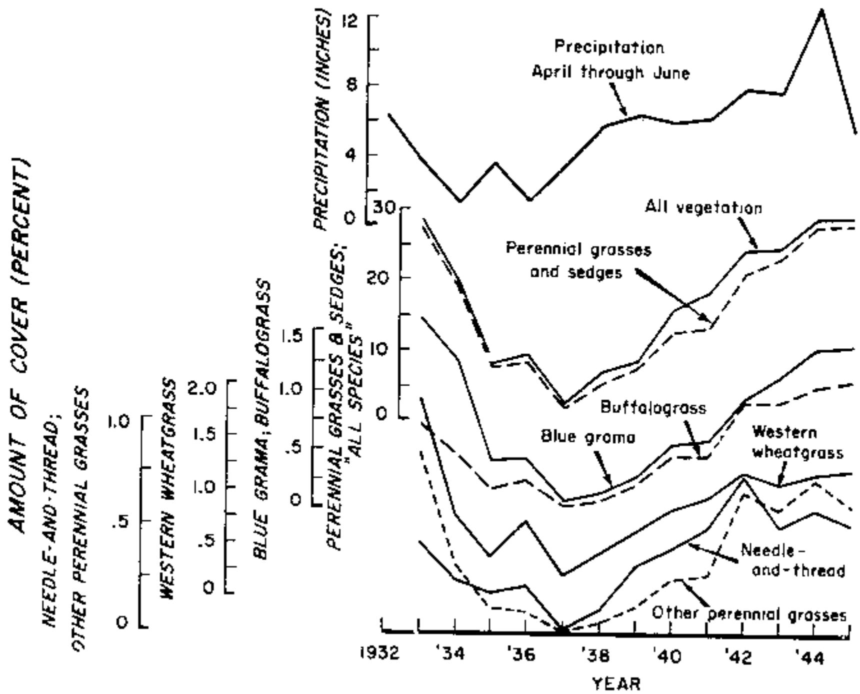

FIGURE 7.—Average basal cover of important grasses and other vegetation 1 inch above root crowns on permanent chart quadrats open to grazing on summer and winter ranges, 1933–45, and April–June precipitation, 1932–45. (Quadrats about equally distributed among heaviest, intermediately, and lightest stocked ranges.) Miles City, Mont., experimental range.

Basal area changes showed a generally delayed response to changes in precipitation. These changes usually were more closely associated with precipitation of the preceding growing season than with that of the current year (fig. 7). Surprisingly, this held also for the relatively late-starting buffalograss and blue grama. However, unusual amounts of precipitation during periods other than the preceding growing season might have modified this general relation. For example, high late-fall moisture in 1941 plus improved spring moisture in 1942 and exceedingly high spring moisture in 1944 may account for much of the increase in cover in 1942 and 1944. Precipitation during the preceding growing seasons did not suggest such changes.

Of the common perennial grasses, only Sandberg bluegrass differed sharply in its response to the drought. Ordinarily a minor constituent of the vegetation, this grass increased rapidly on all ranges during and immediately following the drought (fig. 8). Increase was both by expansion of clumps and establishment of new plants (*21*). By 1938 Sandberg bluegrass covered more area than any other single species and was 4½ times as abundant as in 1933. A steady decline after 1938 lowered it to its predrought level by 1943.

F-347490

FIGURE 8.—Almost complete dominance of Sandberg bluegrass on an intermediately stocked summer range in 1937 after the 1934–36 drought killed most other vegetation. Previously, this site was covered by an almost complete turf of blue grama and buffalograss.

Although all of the principal forage grasses were reduced 90 to 95 percent by the drought, their recovery varied. While threadleaf sedge had decreased only about half as much as needle-and-thread and buffalograss, all three reached predrought levels between 1940 and 1942. By 1945, this sedge and needle-and-thread showed small net gains, and buffalograss occupied 50 percent more area than before the drought. Recovery of blue grama and of western wheatgrass was much slower. By 1945, they occupied only 85 and 64 percent as much area as in 1933.

An increasing spread between the basal cover of all perennial grasses and sedges and of all vegetation is evident following the drought up through 1941 (fig. 7). Large increases in Plains pricklypear and smaller increases of perennial forbs and annuals were primarily responsible. Conversely, the decrease in spread after 1941 is accounted for by a steady decline in pricklypear and a more irregular decline of annuals.

Considerable variation in composition accompanied the changes in plant cover during these years (fig. 9). Near the end of the study, composition was essentially similar to that before the drought: the proportion of buffalograss was somewhat greater, and blue grama and western wheatgrass less, but together these three grasses again predominated; all other grasses made up a minor part.

That material changes in the basal cover of vegetation may result from fluctuations in weather is clear from this and other studies of northern Plains ranges. Such possible influences of weather must be taken into consideration when judging range condition as affected by grazing. Normally, annual changes in basal cover can be expected to be less variable than those in foliar cover (*23*). Abrupt and fundamental changes in the amount and kind of living plant-crown area may

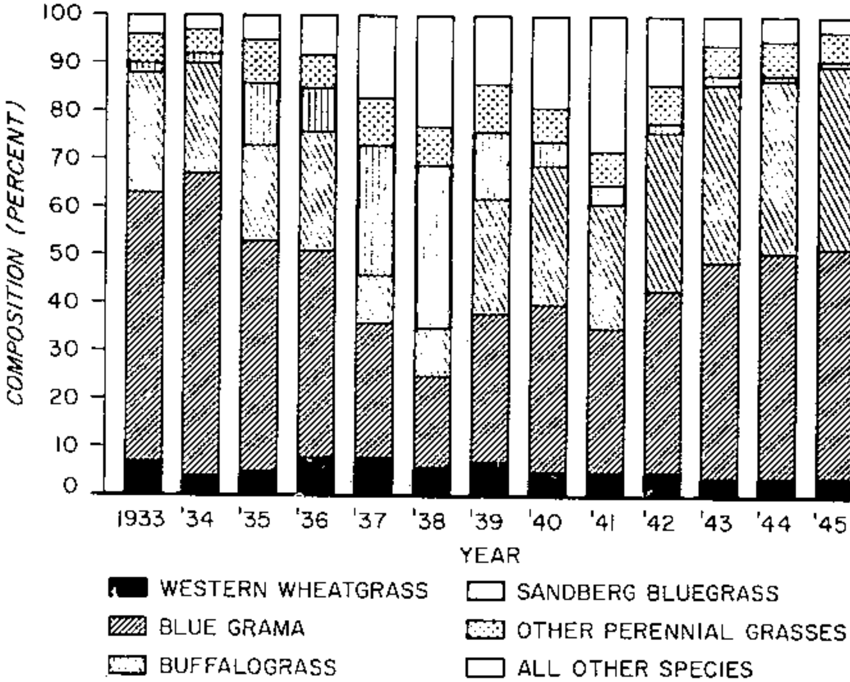

FIGURE 9.—Average composition of vegetation cover 1 inch above root crowns on permanent chart quadrats open to grazing on summer and winter ranges, 1933–45. (Quadrats about equally distributed among heaviest, intermediately, and lightest stocked ranges.) Miles City, Mont., experimental range.

result from severe drought and last longer than ordinarily supposed (*3*, *15*, *41*, *43*, *55*, *59*). Recovery of blue grama and western wheatgrass may be slow, while threadleaf and needleleaf sedges, needle-and-thread, prairie Junegrass (*59*), and buffalograss may be less seriously decreased or recover more rapidly. An ultimate increase in buffalograss as a consequence of drought has never been reported from other locations in the northern Plains. However, such an increase was noted, to a marked degree, on an ungrazed mixed prairie site in Kansas (*3*). The temporary flush of Sandberg bluegrass following decreased competition from other plants apparently is a characteristic response (*15*, *34*, *59*). The same is true of the temporary increase of perennial forbs and annuals (*15*, *59*).

Two or more consecutive years of drought probably are necessary for an appreciable kill of plants and extended subsequent effects. This is suggested by the Miles City results: Drought conditions were approximately as bad in 1931 as in 1934 and 1936. Yet 2 years later, in 1933, basal area of vegetation was as dense and of about the same composition as in 1945, after eight seasons of approximately average or better than average weather.

Unusually favorable cycles of weather may result in peak amounts of perennial cover (*15*, *41*) and perhaps, not unreasonably, in increased proportions of midgrasses. Annual weeds also apparently respond quickly to available soil moisture. They may increase sporadically during intermittent, abnormally good years or particularly after killing drought when probably available nitrogen and moisture are present in relative abundance. In addition, lesser changes in plant cover on silty or clay soils than on coarser textured ones during favorable (*19*) or drought (*15*) periods have been found in Canada.

A close positive relation between foliar cover in a particular year and precipitation of the current seasonal year was found in east-central Wyoming (*34*). This is as would be expected, since height growth of grasses and herbage production at Miles City, Mont., were strongly influenced by current precipitation.

Basal Area Response of Grasses and Forbs to Grazing

Probably the most significant fact concerning the vegetation cover on the study ranges as related to grazing intensity was that principal grasses continued to make up most of the cover after 14 years. Cover did not deteriorate to an unpalatable grass or weed stage under the relatively heavy level of use and the sequence of drought and later favorable weather. The lack of material change shows the considerable tolerance of these range grasses to grazing.

Buffalograss

Basal area of buffalograss was markedly affected by grazing intensity on the summer ranges. On four of six test areas, it was considerably greater after 14 years on heavier than on lighter grazed parts. On two of these four areas, this grass covered more ground on heavier grazed parts than all other herbaceous plants combined (table 6). In contrast, under lighter grazing, buffalograss was only codominant or of minor importance. Reversals of the general trend occurred on two test areas, but these reversals were apparently due to the occurrence of a small upland watercourse on the lightest grazed part of Area 1 and to the highly erratic distribution of buffalograss on this area and Area 4.

Following the drought, buffalograss spread steadily on permanently paired plots in the heaviest stocked summer ranges. By 1941, its basal area on these ranges had increased substantially more than on the lightest stocked.

Similar increases of buffalograss have been reported in the central and southern Great Plains (*11*, *43*, *56*). All available information seems to warrant the conclusion that heavy use generally favors an increased cover of this grass.

Green Needlegrass

This was the only other principal grass to show a definite trend in amount of cover as a result of grazing intensity. In contrast to buffalograss, its area decreased under heaviest grazing. This was shown by both the permanent plots (see above tabulation) and the test areas. On the latter, basal area at the end of the trial was only about half as great as on adjoining lighter grazed parts.

The loss in basal area resulted from decreased numbers of plants. On two test areas, plants averaged 1.2 and 1.2 per 2- by 5-decimeter

TABLE 6.—*Average basal cover [1] of grasses, sedges, and forbs on 2- by 5-decimeter plots on the summer range test areas in relation to cattle grazing intensity, Miles City, Mont., experimental range, 1945*

PRINCIPAL FORAGE GRASSES

Test area and grazing intensity	Buffalograss	Western wheatgrass	Blue grama	Needle-and-thread	Green needlegrass
	Sq. cm.	*Sq. cm.*	*Sq. cm.*	*Sq. cm.*	*Sq. cm.*
(1) Heaviest	37.4	3.6	145.4	5.2	----------
Intermediate [3]	.1	4.5	193.4	17.0	----------
Lightest	80.0	3.3	154.2	5.3	----------
(2) Heaviest	61.2	12.2	51.8	----------	----------
Lightest	28.2	11.8	58.8	----------	----------
(3) Heaviest	[2] **162.2**	**9.3**	**31.6**	----------	----------
Lightest	22.5	16.1	6.0	----------	----------
(4) Heaviest	11.3	11.4	----------	----------	----------
Lightest	34.6	11.5	----------	----------	----------
(5) Heaviest	**120.9**	**10.0**	.2	----------	1.7
Lightest	18.3	14.1	----------	----------	3.3
(6) Heaviest	19.9	23.4	----------	----------	**2.6**
Lightest	.3	20.5	----------	----------	4.2
Average, all areas:					
Heaviest	68.8	11.7	38.2	.9	.7
Lightest	30.7	12.9	36.5	.9	1.3

OTHER PERENNIAL GRASSES; SEDGES

Test area and grazing intensity	Sandberg bluegrass	Other perennial grasses	Threadleaf sedge	Needleleaf sedge
	Sq. cm.	*Sq. cm.*	*Sq. cm.*	*Sq. cm.*
(1) Heaviest	**4.6**	**2.1**	8.1	0.5
Intermediate [3]	5.6	.3	5.6	----------
Lightest	3.8	.6	3.3	.2
(2) Heaviest	2.7	1.2	----------	----------
Lightest	2.7	.3	----------	----------
(3) Heaviest	**6.2**	**3.5**	----------	----------
Lightest	5.4	.6	----------	----------
(4) Heaviest	**9.7**	**8.7**	----------	----------
Lightest	5.4	2.8	----------	----------
(5) Heaviest	.1	**6.1**	----------	----------
Lightest	----------	.2	----------	----------
(6) Heaviest	----------	3.8	----------	----------
Lightest	----------	3.4	----------	----------
Average, all areas:				
Heaviest	3.9	4.2	1.3	.1
Lightest	2.9	1.3	.5	—.1

See footnotes at end of table, p. 22.

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TABLE 6.—*Average basal cover*[1] *of grasses, sedges, and forbs on 2- by 5-decimeter plots on the summer range test areas in relation to cattle grazing intensity, Miles City, Mont., experimental range, 1945*—Continued

ALL HERBACEOUS VEGETATION[4]

Test area and grazing intensity	Perennial grasses, sedges	Perennial forbs	Total perennials	Annual forbs, grasses
	Sq. cm.	*Sq. cm.*	*Sq. cm.*	*Number*
(1) Heaviest	206.9	0.4	207.3	0.7
Intermediate[3]	226.5	.2	226.7	1.9
Lightest	250.7	.4	251.1	.4
(2) Heaviest	129.1	.5	129.6	.4
Lightest	101.8	.4	102.2	.3
(3) Heaviest	212.8	.2	213.0	.7
Lightest	50.6	.5	51.1	.8
(4) Heaviest	41.1	.2	41.3	.6
Lightest	54.3	.3	54.6	1.3
(5) Heaviest	139.0	----------	139.0	.1
Lightest	35.9	.1	36.0	----------
(6) Heaviest	49.7	.1	49.8	.7
Lightest	28.4	.3	28.7	.3
Average, all areas:				
Heaviest	129.8	.2	130.0	.5
Lightest	87.0	.3	87.3	.5

[1] One inch above root crowns, except for annuals.
[2] Boldface figures significantly different statistically from lightest grazing at the 5-percent level. Values not tested statistically for threadleaf sedge; needleleaf sedge; perennial grasses, sedges; total perennials; averages.
[3] Samples in 1946 when ranges were ungrazed.
[4] Excludes all sagebrush and cactus species.

	Change in area 1 inch above root crown, 1937–41		
	Heaviest stocked (percent)	*Lightest stocked (percent)*	*Heaviest compared with lightest stocked (percent)*
Buffalograss	+547	+425	+122
Western wheatgrass	+ 80	+ 67	+ 13
Blue grama	+185	+176	+ 9
Needle-and-thread	+426	+602	−176
Green needlegrass	+306	+480	−174
Sandberg bluegrass	− 54	− 62	+ 8

plot on heaviest grazed parts compared with 1.7 and 2.1 on lightest grazed. In the same comparison, individual shoots averaged 8.7 and 12.8 compared with 15.8 and 21.6 respectively.

Even on lightest stocked ranges, cover of green needlegrass was far below its maximum, as shown by qualitative inspection of a grazing exclosure on Test Area 6. This was apparently due to rather heavy utilization of herbage on bottom land. Green needlegrass is commonly considered sensitive to grazing, being greatly reduced or disappearing with overuse.

Blue Grama

Only on one of three test areas where blue grama was common was there an apparent response to grazing. Here blue grama was most dense where grazing had been heaviest. That this grass was somewhat favored by heaviest summer grazing was suggested also by the response of the permanent plots. On them, its percentage increase from 1937 through 1941 was slightly greater than on lightest stocked ranges.

In other studies, the response of blue grama has been seemingly variable. Increased cover under heavy compared with conservative cattle grazing was found in Canada during the drought (*15*) and in North Dakota over a longer period, including the drought (*41*). Similar results were shown by grazed or mowed compared with ungrazed relict range in South Dakota (*35*). In Nebraska, cover of this grass has been interpreted as generally increasing with decline of mixed prairie and then decreasing (*11*).

In contrast, conservative use favored blue grama cover on cattle ranges going into the drought (*30*) and in recovery on sheep ranges following the drought (*61*). Inconsistent reactions to grazing and protection were found in southwestern Saskatchewan (*36*).

Consequently, a question remains as to the constancy of response of blue grama to grazing. Weather and site, as well as kind of grazing animal may act as modifying influences. The evidence suggests that this grass may be less responsive to grazing than the other principal short grass, buffalograss.

Western Wheatgrass

Basal area response was variable. Following the drought, it increased slightly more by 1941 on permanent plots in the heaviest stocked summer ranges than in the lightest stocked. But in 1945, cover was essentially the same on heaviest and lightest grazed parts of four test areas. On the other two areas, it was less dense under heaviest grazing. These were the same areas on which buffalograss had greatly increased under heaviest grazing (fig. 10).

That western wheatgrass and buffalograss densities may be inversely related was supported by a separate survey. On immediately adjacent sampling points on the same soils, western wheatgrass shoots were three times as numerous where buffalograss was sparse or absent as where buffalograss was dense. From these results it appears that continuation of the trend toward more buffalograss under heavy grazing might inevitably result in a more general decline in abundance of western wheatgrass.

A generally reduced abundance of western wheatgrass under increasing intensity of use has been reported in other studies on the northern Plains (*15, 35, 36, 41, 61*). In North Dakota (*41*) it was noted that while abundance declined, this grass held up better than all other species except blue grama. In all of the above studies, buffalograss was either not present or scarce. Decreasing cover of western wheatgrass has been associated with decline of mixed prairie in Nebraska (*11*).

F-447005

FIGURE 10.—Detail of Test Area 5 in 1946 when summer ranges were ungrazed: *Left*, Short and less dense western wheatgrass and green needlegrass on heaviest grazed part; dominant herbaceous cover of buffalograss also of short growth. *Right*, Taller and more abundant western wheatgrass and green needlegrass, and scanty but taller buffalograss on lightest grazed part. Here yield of palatable herbage 1 inch above the ground averaged about 2½ times as much as on the heaviest grazed part.

Needle-and-Thread

Basal area of needle-and-thread was not affected by grazing intensity on Test Area 1 where this grass was common. This equality on heaviest and lightest grazed parts was shown further by counts of shoots, which were essentially of the same density. On the other hand, clumps of needle-and-thread were slightly more numerous under heaviest grazing. Basal area of the individual clumps, however, was less and each clump had fewer shoots. This lack of difference in needle-and-thread cover existed despite a more rapid recovery in area on the permanent plots in lightest compared with heaviest stocked ranges following the drought. The considerably greater cover of this grass on the intermediately grazed part of Test Area 1 was due to the somewhat more favorable exposure, as explained earlier.

Needle-and-thread has been reported proportionately reduced in area under increasingly heavier levels of use in other controlled grazing trials (*15, 41*). In other studies (*35, 36*), it appeared to be favored by light grazing as compared with nonuse, but considerably reduced by somewhat heavier use.

That needle-and-thread can withstand extremely heavy use under certain conditions was shown by its persistence in a stock driveway near the experimental area. More recent information shows that the plants differed in morphological features, in their response to defoliation, and in the genetic composition of the population as compared to plants in an adjacent long-term protected area. These differences were interpreted as being favorable to its survival under heavy grazing.[7] These observations may help to explain the lack of change in basal area of this species on the heaviest grazed experimental ranges.

Other Perennial Grasses and Sedges

These made up but a small part of the herbaceous perennial cover in 1945.

Because prairie Junegrass was confined to the more moist locations and was sparse even there, its response to grazing was not sampled separately. Other studies report this grass considerably reduced in basal area with declining range condition (*15, 30, 41*).

Sandberg bluegrass cover was somewhat greater on ranges subjected to the heaviest grazing. Its percentage decrease on the permanent plots from a high following the drought to 1941 was slightly less than on ranges grazed lightest. Likewise, in 1945 its cover averaged one-fourth more on heaviest than on lightest grazed parts of the test areas.

On none of the test areas was Sandberg bluegrass cover greatest under lightest grazing. This was due to consistently fewer plants. They averaged 2.4 per 2- by 5-decimeter plot on heaviest stocked ranges compared with 1.8 in lightest stocked on four test areas where this grass was common. Average basal size of individual clumps was essentially equal.

In Canada, the amount of Sandberg bluegrass cover was favored by heavy cattle grazing during the drought (*15, 30*). On the other hand, at Miles City, Mont., the rate of decline following the drought was directly associated with increasing intensities of sheep use (*61*). The difference in these findings may be due to the earliness of the sheep grazing season, and to the inherent closeness of grazing and the greater selectivity of this grass by sheep.

Other secondary grasses, such as tumblegrass, sand dropseed, Canada bluegrass, and red threeawn, were consistently most dense on heaviest grazed parts of the test areas. This was true for individual species as well as for the group. Of these, tumblegrass was most widely distributed and most abundant. Not only was its cover increased under heaviest grazing, but plants were also consistently more numerous. These averaged 1.5 per 2- by 5-decimeter plot compared with 0.4 under lightest grazing on four areas where this grass was common. Basal area of individual plants was apparently not affected.

This latter group of grasses was not much grazed by the cattle, except for Canada bluegrass. Their increased abundance on heaviest grazed summer ranges and particularly that of Sandberg bluegrass, suggests a shift toward a lower successional stage. An increase of tumblegrass, sand dropseed, red threeawn, and other secondary grasses has been associated with deterioration of Plains range to the south (*11*).

Threadleaf and needleleaf sedges were sparse on the summer ranges and grew only on Test Area 1. Differences in basal cover could not be attributed to grazing intensities.

Little has been reported about responses of these sedges to grazing. Canadian reports state that under severe grazing needleleaf sedge

[7] Peterson, Roald A. 1959. Influence of grazing history upon responses of *Stipa comata* Trin. and Rupr. to frequent defoliation and other treatments at Miles City, Montana. Ph. D. Thesis, Univ. Minn., Minneapolis.

gains in density at the expense of grasses (*19*). On the other hand, abundance of mixed needleleaf and penn sedge was favored by light use or nonuse in South Dakota as compared with grazing or mowing (*35*). Concerning threadleaf sedge, one might infer from the lack of comment that it is little changed by grazing. However, its basal area was decreased by severe clipping (*40, 58*).

Perennial Forbs and Annuals

Abundance of these plants was low and not greatly different on the several ranges. Even when shrubs were included, no evidence of a breakdown to a "weed" stage occurred. The scarcity of these plants probably was accounted for by the density of perennial grasses.

Not all species of perennial forbs responded in the same way. Although sparse, American vetch and Plains bahia were three to five times as numerous under lightest grazing as under heaviest. Scarlet globemallow, in contrast, was 1⅔ times as abundant under heaviest grazing. This plant has been reported as increasing with declining condition of central Plains range (*11*). Of the annual forbs and grasses, only six weeks fescue and bottlebrush Indianwheat were consistently favored by heaviest grazing.

All Herbaceous Vegetation

Cover was about 50 percent greater in 1945 on heaviest grazed parts of test areas than on ranges stocked lightest. Reversals of this trend occurred on Test Areas 1 and 4, but they could not be assigned to differences in grazing response.

The generally greater cover associated with heaviest grazing was accounted for principally by buffalograss. Where losses in other forage grasses occurred, they were not great enough to compensate for increases in this short grass. Secondary perennial grasses and annuals generally added to the trend for greater cover. But the area they occupied was small and of little consequence. The small differences in the scanty cover of perennial forbs was also of little importance.

The interpretation of the increased cover of perennial grass agrees in part with that of Branson and Weaver (*11*) in the central Plains. They concluded that such cover increases at first under heavy grazing, principally because of buffalograss or blue grama, and then decreases as deterioration progresses. In contrast are the decreases reported at Manyberries, Alta., under heavy cattle grazing that continued through the drought (*15*), and at Miles City, Mont., under heavy sheep grazing following the drought (*61*). In both of these trials buffalograss was scarce or absent, but blue grama was common. Somewhat intermediate in response are the variable changes suggested at Saskatchewan (*36*) and the lack of change at Ardmore, S. Dak., (*7*).

Implications for Management

From this and other trials (*7, 15, 32, 41, 61*) it appears that responses in amount and composition of vegetation may be relatively insensitive for judging adequacy of management on mixed-prairie ranges over periods as short as 3 to 5 years or perhaps longer. Changes apparently are small and slow in the sense of classical stages of plant succession.

Changes in the amount of perennial grass cover may not always follow a similar simple pattern, as shown by the variable nature of responses described above. Weather, species composition, kind of grazing animal, and possibly other factors may modify reactions. Limited information *(15, 36)* shows that site may be influential.

Although lower ecological stages have not been clearly established under experimental grazing, certain information suggests that they may take place under severe or continued overuse. The small but consistently increased cover of secondary perennial grasses in this study suggests a shift under slow deterioration toward a lower stage. Whether such grasses would ever become clearly dominant over more desirable forage grasses is open to question. In a sense, nearly complete cover of buffalograss or blue grama on ranges capable of supporting at least a fair cover of the better midgrasses might well be taken as a less desirable as well as a lower ecological condition.

Final reduction to a weed stage has been observed in several localities. At Manyberries, Alta., dominance of fringed sagebrush, snakeweed, Plains pricklypear, and Hoods phlox was found on severely grazed range following the drought *(15)*. Scanty grass cover and proportionately greater cover of unpalatable forbs and annuals was interpreted as associated with poor and very poor range condition in Nebraska *(11)*. This shift is supported also by maintenance of nearly complete dominance of annuals following the drought on localized areas where unherded sheep habitually congregated *(61)*. A situation similar to this is frequently seen around stock water, salt grounds, and corrals.

Response of Cactus and Sagebrush to Weather and Grazing

Plains Pricklypear

Abundance of this cactus was greatly affected by weather. While changes were influenced by intensities of grazing, resulting differences were essentially small.

Immediately following the drought, clumps and joints increased rapidly on all ranges (fig. 11), in contrast to most other vegetation *(26)*. By 1940, joints were 2½ times and clumps 1½ times as numerous on plots in heaviest and lightest grazed summer ranges as in 1936 (fig. 12). This rapid increase was shown even by the chart quadrats that originally were located away from cactus and sagebrush in sampling herbaceous vegetation.

Increases were about the same on heaviest and lightest stocked ranges; other perennial vegetation was depleted about equally by the drought, and pricklypear had an equal opportunity to spread. Its increase probably was favored by drier and warmer than average weather for several seasons after the drought.

After 1940, live joints became progressively fewer. The weather was damper and cooler than average and probably less favorable for pricklypear growth. Basal area of other vegetation also was approaching predrought level. The rate of decline was slightly greater under lightest grazing than under heaviest. In 1945, lightest stocked ranges supported 8 percent fewer joints than in 1936, while heaviest stocked ranges supported 16 percent more (fig. 12).

F-456723

FIGURE 11.—Increased Plains pricklypear in 1937 following the severe drought of 1934–36. Note small young clumps recently established and numerous joints in the larger older clumps. Prominent dark tufts are Sandberg bluegrass which also was favored by the drought.

Death of joints resulted in a breakup of clumps. Consequently, clumps continued to steadily increase. By 1945 they were considerably more numerous than before, but they were mostly small and made up of few joints.

Changes in numbers of joints in response to grazing intensity undoubtedly were greater than associated changes in ground surface

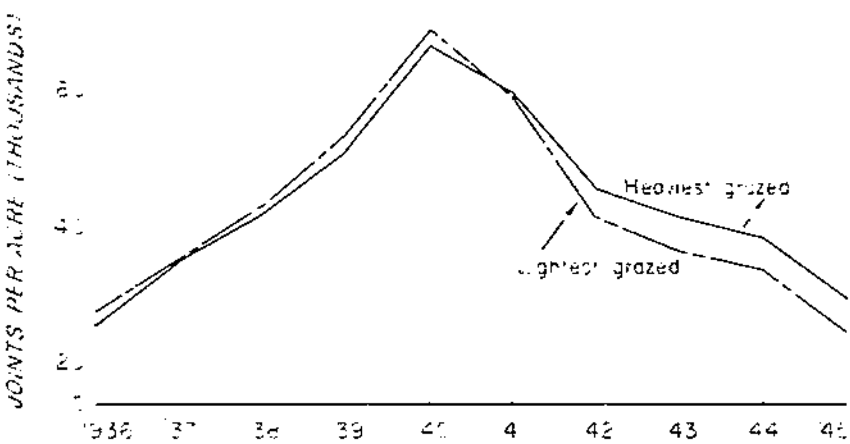

FIGURE 12.—Average number of joints of Plains pricklypear on permanent paired plots on heaviest and lightest grazed summer cattle ranges, 1936–45. Miles City, Mont., experimental range.

occupied by pricklypear. This was because all joints, aerial and basal, were counted. That differences in either case were small was reasonable, since basal area of all principal grasses combined was not reduced under heaviest grazing. Perhaps particulary important here was the increased cover of the mat-forming buffalograss and, to a lesser extent, blue grama.

During the later years, four kinds of insects fed on this cactus: *Chelinidea vittiger* Uhl., *Dactylopius* sp., *Melitara dentata* Grote, and larvae of an unidentified, small gray moth. Infestations were relatively sparse and not of much consequence in pricklypear decline. Proportions of infested clumps were approximately the same in heaviest and lightest stocked ranges.

Big and Silver Sagebrush

Major trends in abundance were set by weather and influenced by grazing. The differences in abundance due to grazing, however, were not obvious through casual inspection because the greatest effect was in numbers of small, young plants. Had these been given time to become taller, differences might have been more apparent.

Silver sagebrush was greatly decreased by the drought. By 1938 the kill ranged from an average of 50 percent on three bottom-land transects on lightest stocked ranges to nearly 100 percent on a north-facing upland on intermediately stocked range. Mortality on uplands, however, was not always this great.

After 1938 this species rapidly reestablished itself on bottom lands. By 1943, about seven times as many well-established bushes as before the drought were present on the transects. Numerous current seedlings were present also. On uplands some, but lesser, reproduction was apparent.

Heaviest grazing favored silver sagebrush as compared with lightest grazing. On two bottom-land test areas in 1946, well-established young bushes were four and seven times as numerous under the heaviest grazing treatment as under the lightest. These were plants established after the drought; seedlings from 1945 and 1946 also were more numerous. These results suggest a trend with continued heavy use toward a shrub stage on bottom lands that support silver sagebrush.

Big sagebrush fared about as badly as silver sagebrush during the drought. By 1938, 64 percent of the bushes were dead on the north-facing transect on intermediately stocked range and 85 percent on a south-facing slope.

Recovery of big sagebrush on uplands, where it commonly grows, was not as rapid as that of silver sagebrush on bottom lands. On plots in heaviest and lightest stocked summer ranges, there was no increase in numbers of established bushes from 1938 through 1943. Exceptionally good crops of seedlings occurred in 1941 and 1942, and a fair number survived through 1943. Some of these continued to grow, as shown by the test areas in 1946.

Unlike silver sagebrush, big sagebrush was handicapped by heaviest grazing. During the period 1938-43, numbers of these two well-established shrubs remained essentially constant on the plots in the lightest grazed ranges, while in heaviest grazed they steadily declined from 93 percent as many to 77 percent. Most of this decrease involved big sagebrush, since 1 percent or less of the stands were made up of silver sagebrush in 1938.

Young plants supported the trend of reduced abundance under heaviest grazing. On two upland test areas where young bushes were common, they were only 75 and 4 percent as numerous in 1946 as on lightest grazed parts. Most of these were 5 or 6 years old, representing 1941 or 1942 seedlings.

Big and silver sagebrush, like other shrubs of low palatability generally are considered to be decreased by conservative grazing and a good cover of grasses and herbs, and conversely, to be increased by heavy grazing and range deterioration. For big sagebrush, this has been shown on sagebrush-grass ranges in Idaho, Utah, and Wyoming (*18*, *20*, *37*, *38*) and on seeded rangelands in Idaho and Utah (*8*, *51*).

A like response of big sagebrush on Plains range has never been measured to the authors' knowledge. Explanation of its decrease on the experimental ranges under heaviest grazing may lie in the range type and condition. Plains range with its mat-forming buffalograss and blue grama, and with strongly rhizomatous western wheatgrass, may offer effective competition to seedlings for a longer period under slow deterioration than bunchgrass ranges do. This seems particularly reasonable if grass cover first increases, as the evidence suggests. In addition, big sagebrush does not sprout, and it is known to be killed by mechanical means. Certainly, trampling was greatest on the heaviest stocked ranges; this could account in part for the responses observed. Direct browsing probably had little effect, because this shrub was seldom grazed.

That the response of silver sagebrush was not the same as that of big sagebrush under the same circumstances may be due to the fact that it sprouts when it is trampled or is otherwise injured, and because it grows most abundantly on drainage bottoms where moisture conditions are more favorable. This sagebrush received heavy use during the drought when other herbage was scarce, but ordinarily was only lightly browsed the other years.

Fringed Sagebrush

Following the drought, this plant became considerably more common on all the ranges. Increases under the different stocking levels were so nearly equal that differences were at no time apparent by ordinary inspection. Sampling near the end of the trail showed that well-established plants were slightly more numerous on heaviest than lightest grazed parts of four of five test areas:

	Plants per 0.1 milacre	
	1944 (*number*)	1945 [1] (*number*)
Test Area 1:		
Heaviest grazed	0.78	0.67
Lightest grazed	.66	1.14
Test Area 2:		
Heaviest grazed		.16
Lightest grazed		.07
Test Area 3a: [2]		
Heaviest grazed	1.04	
Lightest grazed	.30	

See footnotes at end of table, p. 31.

	Plants per 0.1 milacre	
	1944 (number)	1945 [1] (number)
Test Area 4:		
Heaviest grazed	--------	.99
Lightest grazed	--------	.14
Test Area 4a: [2]		
Heaviest grazed	.38	--------
Lightest grazed	.32	--------

[1] Converted from 2- by 5-decimeter plots.

[2] A different part of the subtype than that designated by the primary number; important features and grazing on constituent parts were the same as for the primary area.

A similar response was suggested by herbage yields from some of these areas in 1946. Dry weight of fringed sagebrush averaged slightly more under the heaviest than under the lightest grazing treatment on two out of three areas that supported this plant.

This sagebrush has received considerably more attention than other sagebrush in the northern Plains as an indicator of range deterioration. During the drought it probably was considerably reduced throughout the region, as suggested by studies near Manyberries, Alta. (*15*). After the drought, rapid increases were recorded near Manyberries (*15*) and Mandan, N.Dak. (*40, 41*). Apparently favored by the depletion of other vegetation, these increases took place even on lightly grazed and protected range. However, abundance was strongly favored by heavy grazing during and after the drought at Manyberries and following the drought at Mandan. Under conditions of the Miles City study, the response experienced on the experimental ranges seems reasonable. All ranges were abruptly and about equally depleted by the drought, and during recovery the cover of grasses was not reduced by the heaviest grazing.

Implications for Management

There can be little doubt that natural increases and decreases of pricklypear are caused by weather and can be expected. While heavy grazing is commonly considered to increase pricklypear, changes from this cause may be slow and probably not as great as frequently supposed. This conclusion is also supported by other data (*47*). More rapid or larger changes might reasonably occur on severly depleted ranges. In making qualitative judgments of pricklypear as an index of range condition, however, caution is in order. On the experimental range, for example, the shorter growth of grasses and particularly the close utilization of herbage late in the season magnified the appearance of pricklypear cover on the heaviest stocked ranges as compared with that on the intermediate or lightest stocked (see fig. 14, p. 35).

Undoubtedly spread of pricklypear is hindered by maintenance of a vigorous grass cover. In this connection, insects were found to play an important part in control in the central Plains. Infestations were favored by more luxuriant vegetation under conservative as compared with heavy grazing (*17*).

As indicators of change in range condition, big and silver sagebrush probably are better suited for estimating long- than short-time trends. Since changes in established bushes may be difficult to detect because these species are long lived, young plants may be more sensitive indicators. Further, silver sagebrush may be a more sensitive indicator than big sagebrush because of its sprouting ability.

Indiscriminate use of fringed sagebrush as an indicator of range deterioration seems unwise. From available information, it is evident that abundance of this shrub may be strongly interrelated with weather. Changes should be judged against appropriate standards for the year in which estimates are made. Equally important, the Miles City results show that considerable damage to the range from grazing may take place long before increases in fringed sagebrush are apparent.

Plant Size and Growth Characteristics in Relation to Grazing and Weather

Although total basal area coverage of many grasses was not markedly affected by the heaviest level of grazing, individual plant characteristics changed. The most pronounced and consistent change was reduction in height growth of leaves. For certain grasses, basal area, or size of clumps, or growth habit of herbage also were influenced.

Clump Basal Area and Growth Habit

Basal area of individual needle-and-thread clumps was reduced under heaviest summer grazing. On Test Area 1 where this grass grew, average area was only about two-thirds as large in 1945–46 as on intermediately and lightest grazed parts (2.7 [8] vs. 4.5 and 4.0 cm.^{2} respectively). There were also fewer shoots per clump: an average of 11.4 on the heaviest grazed part compared with 13.8 and 14.4 respectively on the intermediately and lightest grazed parts. In addition, herbage was noticeably finer and shoots tended to be decumbent.

Western wheatgrass was similarly affected. Herbage tended to be decumbent on the heaviest grazed parts of the test areas, particularly during the early part of the season, and basal area or thickness of individual shoots appeared to be thinner there than on the intermediately and lightest grazed parts. This size impression was supported by weight information on individual shoots (p. 39).

Size and growth habit of blue grama clumps were affected in a like manner. On the heaviest grazed parts, cover of this species tended to be made up of numerous, small, closely spaced tufts [9] forming loose, irregular mats. Consequently, the number of well-defined clumps with all parts rising from a common base, were fewer there than where grazing had been intermediate and lightest: 1.1 per 0.1 milacre compared with 1.5 and 1.6 respectively.

The basal area and growth habit of green needlegrass, Sandberg bluegrass, and tumblegrass were not as clearly influenced by grazing intensity as were the three grasses just discussed.

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[8] Significantly smaller statistically than for intermediately or lightest grazed at the 5-percent probability level.

[9] Groups of herbage separated from all other such groups by more than 2 centimeters.

Nothing of the effects of grazing on growth habit of herbage of Plains' species has been published to our knowledge. Smaller basal clump size of needle-and-thread, blue grama, and Sandberg bluegrass has been reported under heavy than under more conservative sheep grazing (*61*), and for needle-and-thread under clipping (*58*). Response of Sandberg bluegrass on the sheep range may have been due partly to inherent differences in the grazing habits of sheep and cattle.

Reduced size of clumps under heavy grazing also has been recorded for Idaho fescue and bluebunch wheatgrass on bunchgrass ranges in Montana (*22*, *25*) and Wyoming (*53*). Perhaps it is significant that in one of the Montana studies (*22*) Sandberg bluegrass failed, as on the experimental range, to show any response in this characteristic. This was on summer cattle range where both other grasses showed strong reactions. Particularly important, both in that study and in Wyoming, responses held constant for different sites.

In contrast, clumps of threadleaf sedge and fringed sagebrush were larger respectively on Plains range under heavy sheep (*61*) and cattle grazing (*41*). For fringed sagebrush, this was ascribed to reduced competition for abundant subsoil moisture during the early years of the trial. Size later decreased as moisture was exhausted.

Killing drought also may cause a considerable flux in basal area of plants on northern Plains range, which may last for a number of years. Following drought, surviving clumps of most grasses were broken up and considerably reduced in size (*3*, *15*, *21*, *40*, *59*). On the other hand, Sandberg bluegrass clumps increased in area during and immediately following drought, apparently because of reduced competition and their early growth habit (*21*). Many seedlings of this and other grasses became established; these and surviving clumps of other grasses increased in size for several years after the drought (*3*, *15*, *21*, *40*, *41*, *59*, *61*). As other species became more abundant, size of Sandberg bluegrass clumps declined.

Height Growth of Leaves and Seedstalks

Response to weather.—Mature height of leaves of western wheatgrass and blue grama varied considerably during the study. Often, changes from year to year were abrupt. Although measurements were of protected plants, the same variation undoubtedly occurred on the range open to cattle. It seems reasonable also that other principal grasses reacted similarly.

Height of both western wheatgrass and blue grama leaves was closely associated with current April through June precipitation (fig. 13). Wheatgrass, which normally started growth in late March or early April, also was more influenced by the preceding fall and winter moisture than was the later starting blue grama.

Probably because of its early growth habit, leaves of western wheatgrass were not reduced as much in height by drought as those of blue grama: in 1934 and 1936 they were about one-half as tall, while blue grama leaves were only about one-fourth as tall, as their maximum during years with above-normal rainfall. The height of blue grama was so meager that it was nearly impossible for the cattle to graze this plant. This emphasizes the importance of maintaining early starting, cool-season midgrasses as partial protection against inevitable dry years.

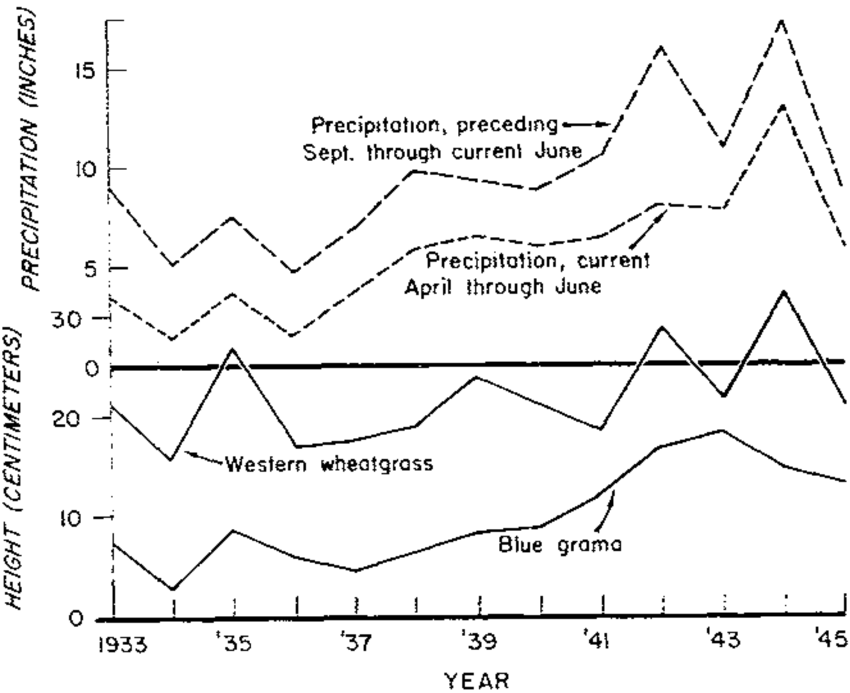

FIGURE 13.—Average mature leaf height of western wheatgrass and blue grama in relation to seasonal precipitation, 1933–45. (Based on tallest leaf per plant of plants protected from cattle grazing, 1933–45; leaves fully extended, seedstalks excluded.) Miles City, Mont., experimental range.

Available information suggests that seasonal plant growth in the northern Plains is determined largely by temperature through April or early May, after which moisture assumes a major role in limiting total height (*15, 24*). Current growing-season precipitation also was found to largely determine mature height of western wheatgrass and green needlegrass in a 3-year trial in northern Colorado (*24*).

Changes in weather, particularly in precipitation, are generally known to produce annual changes in height growth which are roughly proportional. Nearly all common northern Plains grasses and sedges, and many common perennial forbs, are reported to be stunted by dry conditions (*19, 24, 59*). Of these, however, threadleaf and needleleaf sedges, Plains muhly, little bluestem and perhaps others may be less sensitive. As a result of the 1934–36 drought, a drastic reduction in height growth was the most noticeable immediate damage on western North Dakota range where conditions were less severe than in other places (*59*). For some species, the residual effects lasted several years. The significance of this height reduction was evident in that it caused large temporary decreases in carrying capacity.

Response to grazing.—Leaf height growth was consistently reduced under the heaviest grazing on the experimental range. This was shown by the test areas on the summer ranges and by important vegetation subtypes on both summer and winter ranges (table 7, fig. 14). It was also true for short grasses as well as midgrasses. Included were blue grama, buffalograss, Sandberg bluegrass, western

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FIGURE 14. Shorter and less dense growth of western wheatgrass under heaviest stocking (right) than under lightest stocking (left) on Test Area 3 in 1946 when ranges were ungrazed. Ground covered by Plains pricklypear was about equal on the two parts.

TABLE 7. *Average mature leaf height[1] of ungrazed forage grasses on important grazing subtypes of the summer and winter range in relation to intensity of cattle grazing, Miles City, Mont., experimental range, 1946*

SUMMER RANGE

Subtype and grass	Heaviest		Intermediate		Lightest	
Blue grama—Upland:	*Cms.*	*Pct.*	*Cms.*	*Pct.*	*Cms.*	*Pct.*
Western wheatgrass	[2]**14.9**	88	17.2	101	17.0	100
Blue grama	**4.3**	68	**5.9**	94	6.3	100
Needle-and-thread	**9.1**	72	12.9	102	12.7	100
Western wheatgrass—Bench:						
Western wheatgrass	**11.8**	79			14.9	100
Buffalograss	**3.9**	75			5.2	100
Western wheatgrass—Bottom:						
Western wheatgrass	**14.1**	80	**16.5**	94	17.6	100
Green needlegrass	**17.2**	79			21.9	100
Buffalograss	**4.5**	71	**5.2**	83	6.3	100

WINTER RANGE

Subtype and grass	Heaviest		Intermediate		Lightest	
Blue grama—Upland:						
Western wheatgrass	**16.5**	92	17.7	99	17.9	100
Blue grama	**6.7**	80	7.8	93	8.4	100
Needle-and-thread	**12.0**	83	14.0	97	14.4	100

[1] Leaves of seedstalks excluded.
[2] Boldface heights significantly shorter statistically than under lightest grazing and, where appropriate, intermediate grazing at the 5-percent probability level.

wheatgrass, needle-and-thread, and green needlegrass. This reduction in leaf height took place regardless of how other characteristics or basal area of the grasses were affected by grazing. These leaf height reductions suggest that condition was lowered under the heaviest level of grazing on both summer and winter ranges.

Relative effects of the three intensities of stocking were better shown by the survey of important vegetation subtypes than by the smaller test areas. This was particularly true of the intermediate rate that was sampled on only one test area; the subtype survey, on the other hand, covered 50 to 90 percent of all ranges. On ranges that had been stocked heaviest, mature leaf heights of major forage grasses ranged from 71 to 93 percent and averaged 83 percent as tall in 1946 as on those stocked intermediately. Similarly, they ranged from 68 to 92 percent and averaged 79 percent as tall as on lightest stocked ranges. Also, some suppression of growth was suggested for intermediate grazing. In six out of eight comparisons between intermediately and lightest stocked ranges, grasses were 1 to 17 percent shorter on the intermediately stocked. For all comparisons, heights were 95 percent as great.

Growth was stunted throughout the growing season on parts of the test areas as a result of the heaviest grazing. Differences between this growth and that on intermediately and lightest grazed parts were small early in 1946 when ranges were unstocked, but as the season advanced they increased (fig. 15). In most instances, decline in growth rate started earlier on heaviest grazed parts, and in some growth stopped 1 to 2 weeks sooner. On the part of Test Area 1 that had been intermediately grazed, leaves varied from approximately equal to somewhat taller than on the part lightest grazed. This again suggests that the somewhat better potential of the intermediately grazed part helped to offset the slightly heavier use.

The lag in growth under heaviest grazing is exemplified by western wheatgrass, which grew on all four test areas: leaves reached 5 centimeters (approximately 2 inches) about 9 days late; 10 centimeters (4 inches) about 16 days late; and on three areas where leaves finally reached 12 to 13 centimeters, the lag was approximately 32 days. Growth of other forage grasses was similarly repressed.

Measurements early in the season were fairly indicative of relative differences in leaf heights at maturity. Apparently such differences can be expected to persist, and they may be greater by the time the grasses mature.

These results indicate that range forage may be limited throughout the season by retarded growth and shorter leaf heights under heavy grazing. This can be especially important during spring months when need for green herbage may be critical.

That the vigor of the grasses was directly impaired and their ability lowered to take advantage of favorable weather was suggested by comparison of heights in 1945 and 1946 on the test areas. Growing conditions were more favorable in 1945 because of lower spring temperatures and evaporation rates than in 1946. Consequently, leaves grew taller in 1945 on both the heaviest and lightest grazed ranges. But under heaviest grazing, in six out of seven comparisons grasses showed a smaller margin of additional growth compared with their heights in 1946. Differences between the heaviest and lightest used grasses were greater in 1945 than in 1946. Percentagewise, differences for western wheatgrass were similar in the 2 years on four

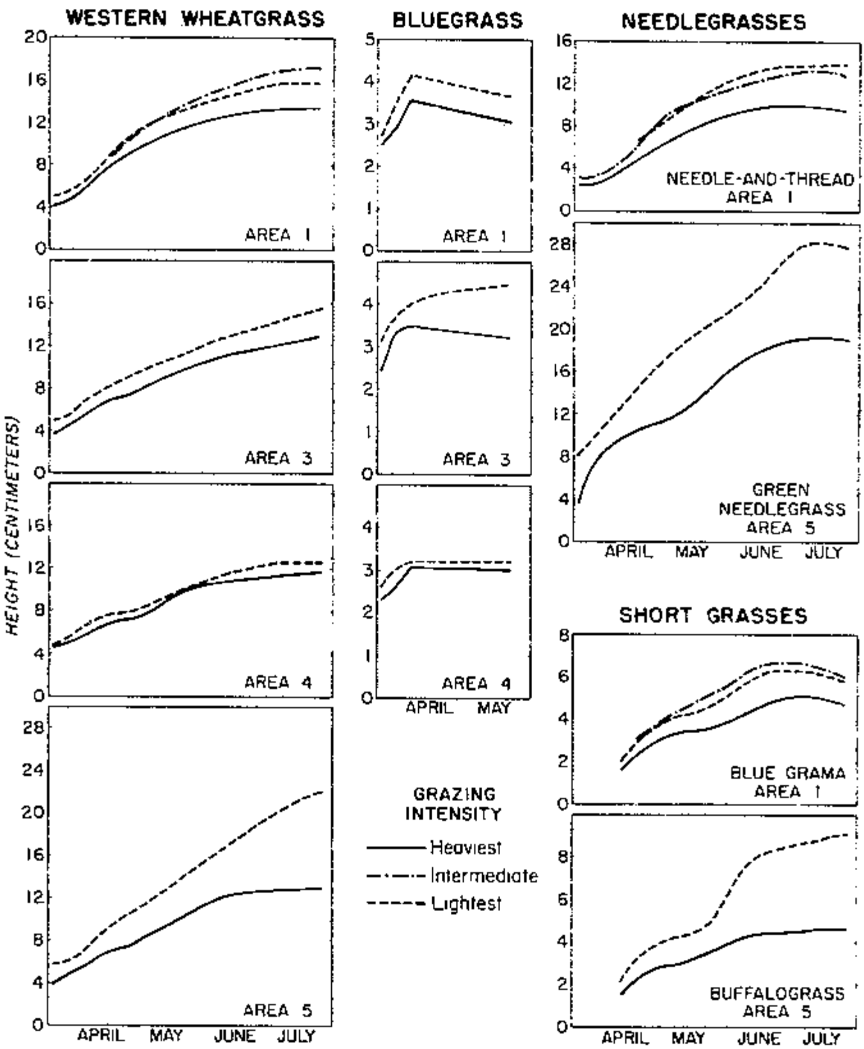

FIGURE 15.—Average growth of leaves of forage grasses on four summer range test areas in relation to intensity of cattle grazing, when ranges were unstocked, 1946. Leaves of flower and seedstalks excluded. Miles City, Mont., experimental range.

of five areas, but they were greater for blue grama and needle-and-thread in 1945 on one area. In terms of actual herbage weight, even a larger loss occurred under heavy grazing in good years than in poor ones. This handicap of the heaviest used grasses also was supported by herbage yields of the heaviest and lightest stocked ranges during the period 1938–45.

Seedstalks were produced by only a few grasses in 1946 when the summer ranges were ungrazed. The stalks of both needle-and-thread and green needlegrass, like their leaf height, were shorter at maturity where grazing had been heaviest. Stalks of sandberg bluegrass, however, unlike its leaves, failed to show a consistent response to grazing intensity:

	Height of seedstalks where grazing had been—		
	Heaviest (*cms.*)	*Intermediate* (*cms.*)	*Lightest* (*cms.*)
Needle-and-thread, Test Area 1	[1] **21.9**	**25.9**	23.8
Green needlegrass, Test Area 5	**40.7**	----	53.2
Sandberg bluegrass:			
Test Area 1	12.4	----	11.3
Test Area 3	10.5	----	11.5
Test Area 4	9.8	----	8.5

[1] Boldface heights significantly different statistically from lightest and, where appropriate, intermediate grazing at the 5-percent probability level.

Several studies, including this one, have shown that the leaves or seedstalks of nearly all common northern Plains grasses and sedges are reduced in height in an amount proportional to severity of grazing or clipping (*24, 27, 52, 57, 58, 61*). This is true for the leaves of blue and sideoats grama, buffalograss, western wheatgrass, needle-and-thread, green needlegrass, Sandberg bluegrass, sand dropseed, little bluestem, and threadleaf sedge; and for the seedstalks of blue grama, western wheatgrass, needle-and-thread, and green needlegrass. Length of buffalograss runners also is reduced (*57*).

A similar response in leaf growth has been found for a number of other perennial grasses on central Plains (*57*) and other western ranges (*9, 22, 52, 53*), and for seedstalks of certain grasses on southwestern ranges (*54*). Also, shorter growth of annuals was reported on California foothill range (*5*) and noted on the experimental range in the final year of this study.

Generally, where it has been investigated, leaf growth has been found to be repressed throughout the growing season. In some cases, growth stopped 1 to 2 weeks earlier under heavy than conservative use. Differences in leaf heights were found in some instances to be the most consistent response to grazing: all major forage grasses showed this response; it was expressed on a great variety of sites regardless of changes in amount of basal cover. For this reason, leaf height appears to be a sensitive indictor of grazing intensity and consequently a readily usable criterion for judging range condition.

The high sensitivity of leaf growth to heavy grazing is further suggested by clipping studies which indicate that such grazing during a single growing season may result in decreased leaf growth the following season. Little is known, however, of the extent to which reductions from grazing or clipping may be cumulative. One study on the experimental range suggested that after a certain point further reduction may be very slow for western wheatgrass and not materially influenced percentagewise by considerably different weather years (*46*).

The maximum amount that leaves can be reduced in length before the plant dies is unknown. On the experimental range for example, reductions up to about 40 percent for western wheatgrass and blue grama and 50 percent for buffalograss occurred. That greater reductions can take place without killing the plants was suggested by qualitative comparisons with a neighboring stock driveway that had been heavily grazed for many years. Also, in western North Dakota, western wheatgrass and blue grama were reduced by drought to approximately 10 percent of their later more normal heights (*59*).

Moisture Content and Curing

Near the time of maturity, moisture content of freshly collected vegetative shoots of forage grasses was consistently lower under heaviest grazing than under the lighter levels on the three summer range test areas that were compared:

	Moisture content of vegetative shoots where grazing was—		
	Heaviest (percent)	*Intermediate (percent)*	*Lightest (percent)*
Test Area 1, July 25:			
Western wheatgrass	27.6	29.0	28.2
Needle-and-thread	24.1	28.5	27.5
Blue grama	24.4	29.1	25.1
Test Area 3, July 25:			
Western wheatgrass	20.9	----------	27.1
Test Area 5, June 21:			
Western wheatgrass	41.1	----------	49.2
Green needlegrass	34.8	----------	45.4

These results are in accord with those that showed earlier termination of growth on heaviest grazed parts. That grass herbage was also less succulent earlier on the heaviest grazed ranges is suggested by the June 21 samples from Test Area 5. Earlier curing of grasses was further shown by early yellowing of individual species and a noticeably drier condition of herbage-yield clips. Obviously, any shortening of the green-feed period reduces the grazing value of a range.

Number of Leaves Per Shoot

In addition to a reduced height for western wheatgrass, leaves produced by its vegetative shoots were fewer. On three summer range test areas in 1946, they averaged for heaviest and lightest grazed parts respectively, 4.2 and 4.9 per stem, 3.9 and 4.3, and 4.4 and 5.6.[10]

Reduced abundance of leaves as a response to grazing intensity has never been reported to our knowledge. However, a decreased width of blades has been reported for six grasses studied in the central Plains (*57*). Among these were western wheatgrass, blue and sideoats grama, and buffalograss.

Weight of Shoots

What decreased height and other changes in shoots of forage grasses, such as reduced number of leaves, mean in terms of herbage yield was shown by dry weights. These were consistently less for the vegetative shoots from heaviest grazed ranges compared with those from the lighter grazed (table 8). Shoots of individual species ranged from 54 to 83 percent as heavy. Consequently, even if shoots had been equally numerous, herbage yield of the heaviest grazed ranges would still be less. The relation between height and weight of shoots was fairly close.

[10] Significantly fewer in all comparisons under heaviest than lightest grazing at the 5-percent probability level.

TABLE 8.—*Average weight and height of individual shoots*[1] *of forage grasses on three summer range test areas in relation to cattle grazing intensity, when ranges were unstocked, Miles City, Mont., experimental range, 1946*

Grass, test area, and date	Weight per 100 shoots where grazing was—			Height where grazing was—		
	Heaviest	Intermediate	Lightest	Heaviest[2]	Intermediate	Lightest
Western wheatgrass:						
Test Area 1:	*Grams*	*Grams*	*Grams*	*Cm.*	*Cm.*	*Cm.*
5–14	4.84	----	6.29	10.6	----	12.6
6–6	8.57	10.27	9.95	13.0	14.7	14.6
6–21	9.35	11.97	12.15	13.3	16.1	15.5
7–25	9.13	13.16	11.67	13.3	17.2	15.2
Test Area 3:						
6–14	6.05	----	6.92	11.3	----	12.7
7–25	8.33	----	11.15	13.0	----	15.5
Test Area 5:						
6–6	5.51	----	8.68	11.3	----	16.1
6–21	6.44	----	10.27	12.5	----	18.1
7–25	6.44	----	15.37	12.9	----	21.9
Blue grama:						
Test Area 1:						
5–14	.83	----	1.30	3.6	----	5.2
6–6	1.26	1.84	1.83	4.1	6.7	6.6
6–21	1.66	2.18	2.10	5.1	7.0	6.4
7–25	1.74	1.98	1.82	5.0	6.4	5.8
Needle-and-thread:						
Test Area 1:						
5–14	1.47	----	2.24	7.8	----	11.1
6–6	2.62	3.67	3.05	9.7	13.3	12.0
6–21	3.24	4.24	4.24	10.1	13.5	13.4
7–25	3.01	5.43	3.73	9.6	14.6	11.2
Green needlegrass:						
Test Area 5:						
6–6	7.27	----	7.88	17.6	----	22.0
6–21	8.20	----	8.56	18.8	----	24.3
7–25	8.36	----	12.19	18.8	----	26.4

[1] Clipped at ground level and air-dried before weighing.
[2] Significantly shorter statistically in all comparisons than under lightest and, where appropriate, intermediate grazing at the 5-percent probability level. Values for weights not tested statistically.

Proportion of Plants Producing Seedstalks

Only three forage grasses produced seedstalks in 1946: needle-and-thread, green needlegrass, and Sandberg bluegrass. For these, differences in the percentages of plants producing stalks under heaviest and lighter summer grazing were not apparent.

Seedstalk production has been reported to decline under heavy grazing or clipping for blue grama, buffalograss, and other grasses in the central Plains (*57*), and for several species common to Intermountain (*9*) or Southwestern (*54*) ranges. In the latter two studies, this response appeared to be a more sensitive indicator of vigor than did height of seedstalks or leaves. Seed heads of blue grama also became smaller (*57*).

On the other hand, production of seedstalks by blue grama was not changed by 7 years of severe clipping in western North Dakota; needle-and-thread seedstalks, however, were progressively reduced under lighter clipping levels but increased under severe (*58*). Similarly, on heavily grazed sheep range near Miles City, Mont., slightly more blue grama and western wheatgrass plants produced stalks than did plants on conservatively used range (*61*). Here the increase probably was caused by less competition for moisture because of lighter density of vegetation. This also may have been the case under severe clipping in North Dakota.

More important than reduced stalk production, seeds of green needlegrass averaged lighter in weight on continuously grazed range than on deferred-rotation range in Colorado, and germination was less than half as great (*24*).

Drought reduced or prevented seedstalk production of most northern Plains' grasses, and the adverse effects carried over into following seasons for western wheatgrass, blue grama, and needle-and-thread (*21*, *59*). However, stalk production by needle-and-thread may not necessarily be closely associated with seed production: a good crop matured in North Dakota in 1935 even though stalk production was not high (*59*). In contrast to other grasses, Sandberg bluegrass fruited abundantly immediately following the drought—another expression of its thrift during these years.

Root Development

On the three summer range test areas examined in 1946, air-dry weight of root material taken from the surface 2 inches of soil was consistently greater for the parts that had been lightest or intermediately grazed:

	Weight of roots per 1,000 cubic centimeters of soil where grazing was--		
	Heaviest (grams)	*Intermediate (grams)*	*Lightest (grams)*
Test Area 1	[1] **0.97**	1.64	1.44
Test Area 3	**.34**	......	.49
Test Area 5	**.95**	......	1.17

[1] Boldface weights significantly less statistically than for lightest and, where appropriate, intermediate grazing at the 5-percent probability level.

These results were converted from 494.2 cubic centimeter sampling units. Obviously the number or size of roots, or both, had been reduced where range condition was lowered by the heaviest grazing intensity. Apparently decreased root development, like decreased top growth, is associated with the early stages of deterioration in condition of northern Plains ranges.

Roots of range grasses have been shown to be as greatly or more adversely affected by heavy grazing or clipping than top growth (*6*, *57*). Included among a number of grasses studied in Nebraska and Kansas were western wheatgrass, blue grama, buffalograss, and sand dropseed. Total combined length of roots, depth of root penetration, degree of branching, and root diameters were all decreased.

More fundamental, the thinner roots showed accompanying reductions in the number and size of water transporting strands (*6*). These changes resulted in a considerable reduction in the volume and weight of roots produced.

Implications for Management

The size and growth characteristics of individual grasses appear to be sensitive and reliable indicators of change in the condition of northern Plains range. Responses of these grasses associated with adverse grazing are for the most part similar in kind to those associated with unfavorable weather or sites. This circumstance requires that the influences of weather and of site be appropriately accounted for in judging grazing effects. Particularly significant, under slow range deterioration resulting from grazing, certain changes in vigor, growth habit, or other characteristics take place before measurable change in either basal area or foliar cover occurs. In addition, these responses appear constant in kind for different sites and under different weather conditions.

Although far from complete, available information for many grasses suggests a general dwarfing of parts of the plants or of the plants themselves, or both, as a result of too heavy grazing. Reduced height as a general, dependable response and one that is easily measured is well established. Significantly, this holds also for buffalograss, blue grama, and Sandberg bluegrass which tend to increase in abundance under heavy grazing—a response that without other information could be construed as implying an upward trend in range condition. For needle-and-thread, size and growth habit appear to be a more reliable index to condition than total cover. On the experimental range, small basal area of clumps of this species, short leaves and seedstalks, fine-appearing herbage, and a tendency toward decumbent growth gave an impression of obviously small plants, or on casual examination of little or no needle-and-thread where condition had deteriorated. Further investigation of the responses of size and growth characteristics of range plants should be productive in developing guides to range condition and trend as a basis for intensive management.

Herbage Production in Relation to Weather and Grazing

Significance of the changes in basal area, height growth, and other vegetation characteristics was shown by herbage yields. This was demonstrated best by the comprehensive studies of species and species groups on the test areas in 1946.

During the study, annual production was usually dependent on current spring precipitation (fig. 16). Only in 1941 was there enough fall rain to provide sufficient stored moisture to markedly affect yields the following year.

The drastic decrease in height and cover of vegetation during the drought reduced production to less than 20 percent of the maximum reached in 1944. This can safely be assumed from the record of yields shown in figure 16, even though quantitative measurements are lacking. The low production was reflected in the number of days of grazing available. Even with close cropping and low cattle weights, the summer ranges could provide only 61 and 43 percent as many days' feed in 1934 and 1936 as they did with more normal utilization between 1938 and 1945.

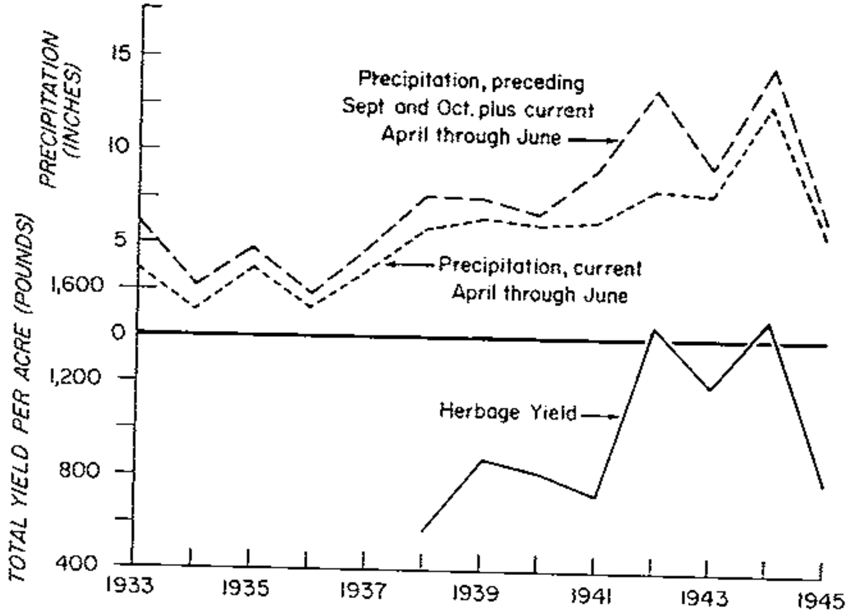

FIGURE 16.—Annual yield of palatable herbage on intermediately and lightest stocked summer ranges combined, in relation to seasonal precipitation, 1938–45, and preceding seasonal precipitation, 1933–37. Based on cattle weights, days of grazing, and herbage utilization. Miles City, Mont., experimental range.

Following the drought, production also fluctuated considerably. Since basal area of grasses and of all vegetation was generally on an upswing through 1944 (fig. 7, p. 17), annual variations in height appear to be largely responsible for the fluctuations. This is supported by the record of leaf heights of western wheatgrass and blue grama (fig. 13, p. 34).

The heaviest level of summer grazing materially reduced production, particularly of principal forage grasses (fig. 6, p. 12). Also suppressed was the ability of the range to take advantage of near optimum weather. During the good years of 1942 through 1944, yields on heavily stocked ranges averaged only 49 percent greater than during the 5 poorer years, 1938–41 and 1945, while on intermediately and lightest stocked ranges increases amounted to 80 to 85 percent (fig. 5, p. 11). Reduced production under heavy grazing during the most favorable years was due mostly to lowered grass vigor and lowered absorption of moisture by the soil. This is shown by the soils studies that are discussed in a later section.

Western Wheatgrass

Although relatively sparse, this grass was one of the top producers. Yields equalled or exceeded those of any other grass on all sampled sites (table 9). Under lightest grazing, with one exception it made up 75 percent or more of the dry weight of all principal forage grasses combined.

Yields were consistently reduced on the heaviest grazed summer ranges. This was true even though basal area occupied by this grass was decreased on only two test areas, 3 and 5. There yields were

TABLE 9.—*Average mature herbage yield per 0.1 milacre*[1] *on summer range test areas in relation to cattle grazing intensity when ranges were ungrazed, Miles City, Mont., experimental range, 1946*

PRINCIPAL FORAGE GRASSES

Test area and grazing intensity	Western wheatgrass	Needle-and-thread	Green needlegrass	Blue grama	Buffalograss	Total
	Grams	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*
(1) Heaviest	[2] **5.05**	**2.28**		**4.86**	0.86	**13.05**
Intermediate	6.49	**5.32**		6.22	.20	18.23
Lightest	6.32	3.92		6.47	1.25	17.96
(2) Heaviest	**12.59**			1.59	.60	**14.78**
Lightest	15.41			2.30	1.38	19.09
(3) Heaviest	**11.02**			**.71**	**2.97**	**14.70**
Lightest	26.79			.17	.46	27.42
(4) Heaviest	**10.67**			.25	1.14	**12.06**
Lightest	14.14				.66	14.80
(5) Heaviest	**14.19**		**1.94**		**6.71**	**22.84**
Lightest	36.54		4.07		.56	41.17
(6) Heaviest	**33.90**		**5.41**		**.52**	**39.83**
Lightest	49.27		8.33		.02	57.62
Average: Heaviest	14.57	.38	1.23	1.23	2.13	19.54
Average: Lightest	24.75	.65	2.07	1.49	.72	29.68

ALL VEGETATION [3]

Test area and grazing intensity	Principal forage grasses	Other perennial grasses and sedges	Browse, mostly fringed sagebrush	Perennial forbs	Annuals	Total
	Grams	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*
(1) Heaviest	**13.05**	**1.88**	2.74	0.40	0.04	**18.11**
Intermediate	18.23	.04	1.42	.15	.90	21.34
Lightest	17.96	.05	3.02	.28	.07	22.28
(2) Heaviest	**14.78**	.77	.43	.07	.04	**16.09**
Lightest	19.09	.53	.16	.04	.05	19.87
(3) Heaviest	**14.70**	**3.05**	----------	.20	.18	**18.13**
Lightest	27.42	1.37	----------	.31	.19	29.29
(4) Heaviest	**12.06**	**3.51**	**1.85**	.10	.05	17.57
Lightest	14.80	1.08	.76	.20	.08	17.52
(5) Heaviest	**22.84**	**2.30**	----------	.08	.01	**25.23**
Lightest	41.17	.75	----------	.27	.04	42.23
(6) Heaviest	**39.83**	3.97	----------	.33	.30	**44.43**
Lightest	57.62	2.43	----------	.46	.31	60.82
Average: Heaviest	19.54	2.58	.84	.20	.10	23.26
Lightest	29.68	1.20	.66	.26	.12	32.00

[1] Clipped at one-half inch and air-dried; can be converted to pounds per acre by multiplying by 22.1.

[2] Boldface yields significantly different statistically from lightest and, where appropriate, intermediate grazing at the 5-percent probability level. Values not tested statistically for perennial forbs; annuals; averages.

[3] Excludes big and silver sagebrush and cactus species.

reduced 60 percent. Where its cover had not been affected, reductions averaged 25 percent. Thus, decreased size of shoots accounted for a considerable part of the reduced yields.

Needle-and-Thread and Green Needlegrass

Yields of these two species were least in all cases on heaviest grazed parts of test areas. For needle-and-thread this was mainly a result of stunted plant size, because cover was approximately equal on heaviest and lightest grazed parts of Area 1. Its largest yield under intermediate grazing was due principally to greater cover resulting from the somewhat more favorable exposure of this part of the test area.

Reduction in green needlegrass resulted from both reduced basal area and dwarfing of shoots. Similarly, even under the lightest level of summer stocking, production appeared to be considerably reduced below that which could be expected under complete protection. For example, yield on the lightest grazed part of Test Area 6 was only one-fifth as much as in an adjoining exclosure.

Blue Grama and Buffalograss

Production of the short grasses was not consistently related to grazing intensity. Where basal cover of buffalograss or blue grama on the test areas increased three or more times with heaviest grazing, yields of these grasses also increased. Where cover increased less or was about equal with that under lightest grazing, yields were reduced. Apparently, unless basal area increases were great enough to compensate, yields were reduced because of decreased size of shoots. From this and the information on shoot size, it may be concluded that yields per unit of basal area of these grasses decreased under heaviest grazing. Although frequent increases in basal area of these grasses partly compensated for this decrease, the resulting herbage yield did not make up for losses in the yields of midgrasses.

Other Components

Grasses of less grazing value, such as Sandberg bluegrass, sand dropseed, and tumblegrass, consistently produced greater yields on the heaviest grazed ranges. This was due to their greater basal area. Combined with these grasses were Canada and Canby bluegrasses, red threeawn, other perennial grasses of little importance, and threadleaf and needleleaf sedges. But these made up a minor part of the yields.

Semiwoody browse, principally fringed sagebrush, usually yielded most on parts of test areas that had been heaviest grazed. This supports the trend of slightly increased abundance of fringed sagebrush under lowered range condition.

Perennial forbs and annuals provided little of the total herbage. On four of the six test areas, perennial forbs yielded most where grazing had been lightest. This yield was associated with greater basal area. Yields of annuals also were without exception greater under the the lightest grazing intensity. This was due to more robust plants and species composition rather than to greater numbers.

Composition of Yields

Under the heaviest grazing, yield of the principal forage grasses on each test area ranged from 4 to 16 percent less than under the lightest intensity. Secondary species of comparatively low value made up correspondingly higher proportions on the heaviest grazed areas.

Available Forage

Important changes in the structure and forage production of grassland vegetation are implied by changes in basal area and height growth of plants. These can be partly visualized from a composite showing distribution of herbage weight in relation to height above the ground for principal forage grasses (fig. 17). Most significant is the consistently greater proportional concentration of plant material nearer the ground where grazing had been heaviest than where it had been lightest. This held even on Areas 1 and 4 where the main difference was reduced size of shoots. Where cover also had been changed—as on Area 5—by an increase in buffalograss and a decrease in midgrasses, the shift was greatly amplified (fig. 10, p. 24).

This shift becomes particularly meaningful when it is considered that cattle seldom graze much below 1 inch (2.54 cm.) (*28*). For practical purposes, herbage below this level may be considered unavailable. Accordingly, weight of palatable herbage above 1 inch on heaviest grazed parts of the three test areas was only about 63, 63, and 40 percent as much as on lightest grazed parts. On the other hand, weight from the ground level was about 79, 90, and 77 percent as much. Thus in terms of estimated forage available to cattle, as much loss was due to concentration of the herbage near the ground as to decrease in total production.

Implications for Management

As previously mentioned, high yield of palatable herbage is one of the most reliable indicators of good range condition. The above insight into production underscores the value of maintaining a good proportion of palatable midgrasses on the range and vigorous growth of all principal forage species.

Logically, for indexing herbage yields, use of basal area or height growth of species alone is inadequate. This is evidenced by the Miles City results and other studies (*9, 15, 48, 54*). The significance of cover changes is generally accepted and is exemplified by information from Manyberries, Alta. (*15*). That of height or size of shoots is less well recognized but is demonstrated by the present study and other information (*27*). Changes in shoot size of individual species account for a major part of shifts in yield when basal areas have not changed appreciably. Conversely, as numbers of shoots and basal areas are progressively affected, these factors account for an increasingly larger part of yield changes. Losses in density, however, may be partly compensated for by recovery in size of shoots after release from grazing pressure or as a result of more favorable weather. Percentages of seedstalks, seed dispersal, and curing of herbage may also influence yields at a given time (*48*).

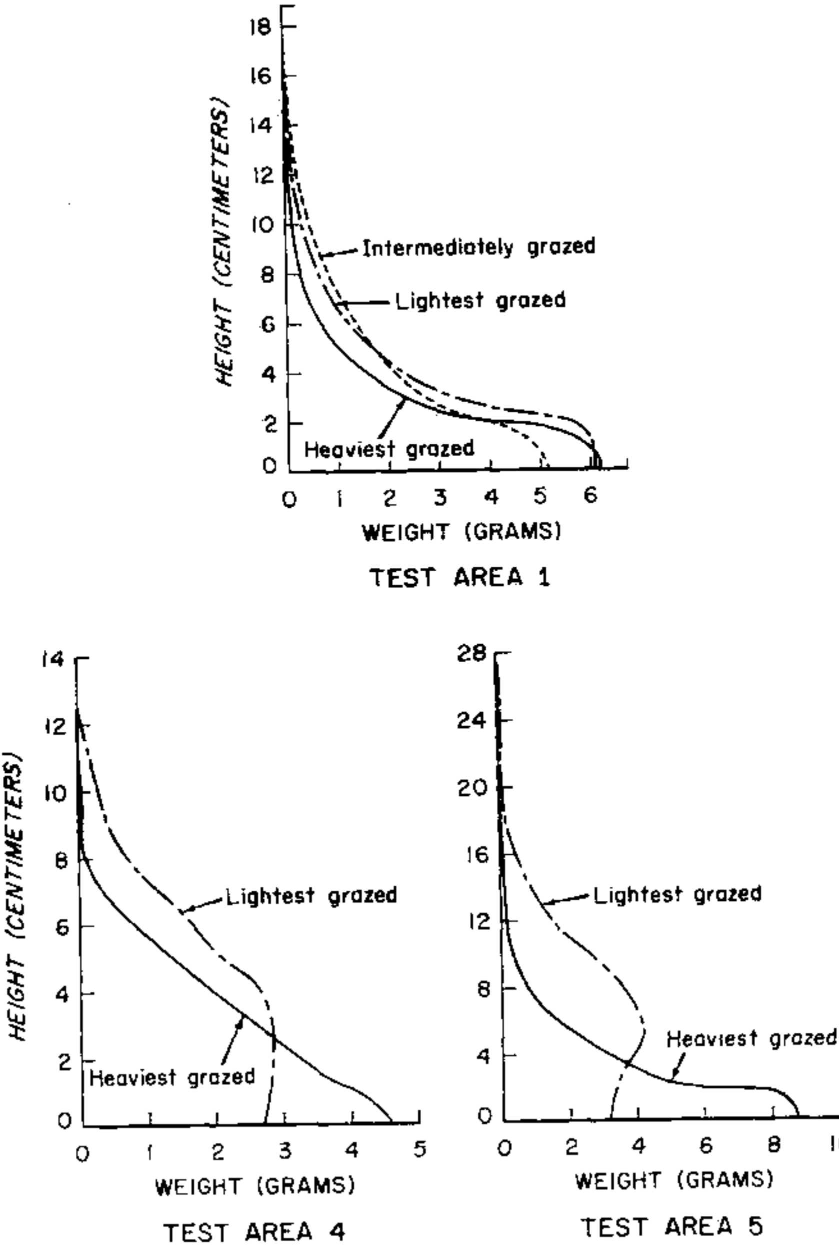

FIGURE 17.—Average air-dry weight of palatable herbage per 0.1 milacre in relation to height above ground and cattle grazing intensity, 1946. Areas under the curves represent weight per plot. Based on a composite of principal forage grasses on each part of three summer range test areas, Miles City, Mont., experimental range.

From this and other studies (*15, 39, 41*), it is clear that the chances of accurately forecasting annual herbage crops are limited; precipitation during the current growing season largely determines production. Only in exceptional years when fall moisture is unusually high can a crop for the following season be forecast with some assurance. But since spring and early summer precipitation normally has a major effect on production, it is possible to know somewhat in advance whether full-season stocking is possible.

Litter and Soil Characteristics in Relation to Grazing

Changes in vegetation characteristics under the heaviest summer grazing intensity were associated with and undoubtedly in part the result of adverse changes in soil characteristics. This was shown by comparing the soil characters that were most likely to influence moisture absorption and retention on the various ranges. At the time of the comparison, the ranges had been unstocked for a full year. Consequently the effect of the three grazing intensities had lasted over this period, but the magnitude had undoubtedly lessened.

Surface Litter

Accumulations on interspaces between grass clumps on two test areas weighed approximately 2 and 2½ times as much under lightest than under heaviest grazing:

	Air dry litter per square foot of interspace (grams)
Test Area 1:	
Heaviest grazed	[1] **4.40**
Intermediately grazed	9.28
Lightest grazed	7.73
Test Area 3:	
Heaviest grazed	**5.03**
Lightest grazed	13.16

[1] Boldface weights significantly less statistically than under lightest and, where appropriate, intermediate grazing at the 1-percent probability level. Yields were converted from 91.1 cm.² plots.

This was due to more of the interspaces having litter as well as to more litter per interspace under lightest grazing.

These results reflect differences in past herbage utilization and in composition and herbage production of vegetation. Similar differences in litter occurred between the heaviest and lightest grazed summer ranges as a whole, as qualitative comparisons showed.

The relatively coarse midgrasses made up a major part of the litter. Consequently, natural differences among sites in the kind of vegetation they can support may be a major factor in determining the amount of litter normally accumulated under conservative management.

From the information on litter and herbage production, it is clear that the combined soil protection provided on the lighter grazed ranges was equal or greater than on the heaviest grazed. This was true despite the trend of greater basal area of plants under heaviest grazing (fig. 18) and was supported by qualitative observations.

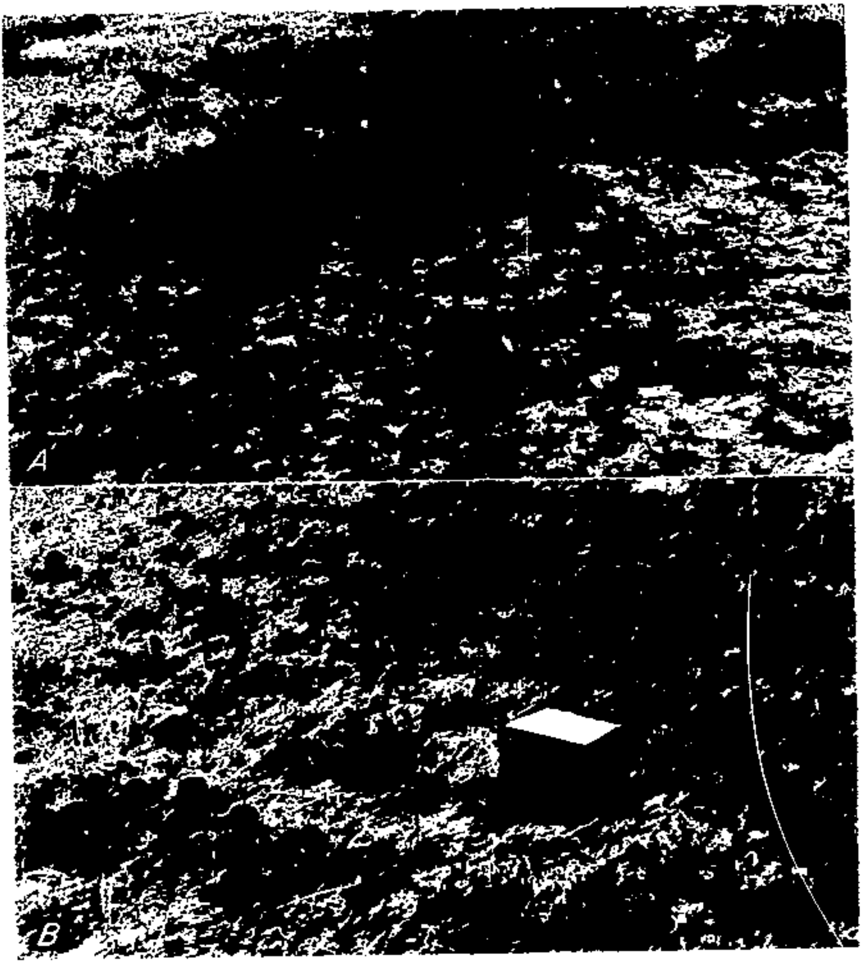

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FIGURE 18. Detail of Test Area 3 at the end of the trial when ranges were ungrazed: *A*, Scanty soil protection furnished by accumulated litter and current herbage growth despite increased basal area of short grasses under heaviest grazing. *B*, Materially greater protection under lightest grazing where western wheatgrass was more vigorous and provided greater cover.

Soil Volume-Weight

On the three test areas sampled, compaction of the surface 2 inches of soil was consistently highest where grazing had been heaviest. Increases in weight per cubic centimeter varied from 4.7 percent on the sandy loam of Area 1 to 9.7 and 3.7 on the clay soil of Areas 3 and 5:

	Weight of soil per cubic centimeter, oven-dry[1] *(grams)*
Test Area 1:	
Heaviest grazed	1.433
Intermediately grazed	1.369
Lightest grazed	1.369
Test Area 3:	
Heaviest grazed	1.289
Lightest grazed	1.175
Test Area 5:	
Heaviest grazed	1.135
Lightest grazed	1.094

[1] Significantly heavier statistically at the 5-percent probability level under heaviest than lightest grazing in all comparisons.

Particles making up these surface soils were essentially similar for the parts of the areas compared. In no case were differences large enough to account for the differences in weights or in other comparisons of porosity and water absorption:

	Mechanical separates of 0–2 inch depth, 2mm. and less			
	Sand (percent)	*Silt (percent)*	*Clay, 0.005–002 mm. (percent)*	*Clay, 0.002 mm. and less (percent)*
Test Area 1:				
Heaviest grazed	63.0	24.0	2.5	10.5
Intermediately grazed	63.5	24.0	2.5	10.0
Lightest grazed	63.0	24.0	2.3	10.7
Test Area 3:				
Heaviest grazed	28.0	33.0	4.0	35.0
Lightest grazed	28.0	28.0	6.0	38.0
Test Area 5:				
Heaviest grazed	13.0	33.0	11.0	43.0
Lightest grazed	11.0	33.0	12.0	44.0

Gravel above 2 mm. was present only on Area 1: 1.7, 1.0, and 1.9 percent of the unseparated sample weights on the average for heaviest, intermediately, and lightest grazed parts respectively.

Porosity

As suggested by volume-weights and texture, porosity of soils was least in each case on heaviest stocked ranges. Practically all reduction occurred in the larger noncapillary pores that are particularly important in water intake. Although reductions ranged from only 1.5 to 6.8 percent, they would be expected to materially lower the rate of water absorption (*4*):

	Pore space, 0–2 inch depth		
	Noncapillary (percent)	*Capillary (percent)*	*Total (percent)*
Test Area 1:			
Heaviest grazed	24.4	21.1	45.5
Intermediately grazed	27.4	20.5	47.9
Lightest grazed	26.8	21.1	47.9

	Pore space, 0–2 inch depth		
	Noncapillary (percent)	*Capillary (percent)*	*Total (percent)*
Test Area 3:			
Heaviest grazed	16.2	35.2	51.4
Lightest grazed	23.0	32.7	55.7
Test Area 5:			
Heaviest grazed	19.4	37.8	57.2
Lightest grazed	20.9	37.8	58.7

Organic Matter

Content of organic matter in the surface 2 inches of soil was least under heaviest grazing for the same three representative but considerably different sites where compaction was tested. Differences between the heaviest and lighter grazed ranges were slight but consistent, suggesting a genuine trend:

	Organic matter expressed on ovendry weight of soil where grazing was—		
	Heaviest (percent)	*Intermediate (percent)*	*Lightest (percent)*
Test Area 1:			
Trial 1	1.65	1.91	1.76
Trial 2	1.64	1.90	1.85
Trial 3	1.62	1.89	1.73
Average	1.64	1.90	1.78
Test Area 3:			
Trial 1	2.16	----	2.23
Trial 2	2.21	----	2.21
Trial 3	2.18	----	----
Average	2.18	----	2.22
Test Area 5:			
Trial 1	2.58	----	2.75
Trial 2	2.64	----	2.71
Trial 3	2.60	----	2.75
Average	2.61	----	2.74

Organic matter analyzed was almost entirely soil humus, because most of the undisintegrated roots were eliminated. Inclusion of roots would have increased the differences, since yields were consistently least under heaviest grazing.

Reduced organic matter under heaviest summer grazing seemed logical to expect. More of the herbage was utilized annually, less litter was returned to the soil, and probably also smaller amounts of roots, at least in the surface 2 inches.

The greater content of organic matter in soil from the intermediately than lightest grazed part of Test Area 1 demonstrates the importance of plant material returned to the soil. Litter and roots were both more abundant on the intermediately grazed part due to more vigorous herbage growth under slightly more favorable site exposure.

Absorption of Water

The reduced soil porosity under heaviest grazing materially slowed down absorption of water. Intake was generally rapid under all grazing intensities, because the soils were dry and the sealing action of rain was absent in the method used to apply the water. In addition, numerous small cracks were present in the clays. Despite these circumstances, more than half again as much absorption time was required for the sandy loam of Area 1 where grazing had been heaviest as where it had been more conservative, and more than twice as much time on the clays of Areas 3 and 5:

	Time for complete absorption of 1 inch of water [1] (minutes)
Test Area 1:	
Heaviest grazed	21.2
Intermediately grazed	13.9
Lightest grazed	13.8
Ungrazed	8.2
Test Area 3:	
Heaviest grazed	26.8
Lightest grazed	12.4
Test Area 5:	
Heaviest grazed	22.6
Lightest grazed	8.9

[1] Significantly longer statistically for heaviest than lighter grazing at the 1-percent probability level, all areas combined. Results are converted from 0.92 inch of water.

Even under conservative grazing, absorption capabilities were apparently reduced; this is shown by the trials on Area 1 which included two exclosures ungrazed by cattle for 7 years or more.

The value of surface litter was shown by other trials. On sandy loam where grazing had been intermediate, absorption on interspaces with fair to good cover took about two-thirds as long as where litter was removed or the soil naturally bare. On clay soil in a lightest grazed range, only about ½ and ¼ as much time was required respectively. This benefit was apparent even though the sealing effect of rain was absent. Tests showed that not more than 3 percent of the water applied was absorbed by the litter itself.

There can be little doubt that improved infiltration of precipitation through greater litter cover on lightest grazed ranges was partly responsible for better vegetation conditions there than on the heaviest grazed. As an aid to water intake, reduced litter under heaviest grazing was not compensated for by the increased basal area of vegetation. Because the increase was due principally to buffalograss sod, comparisons were made between it and adjoining western wheatgrass cover. Absorption was markedly slower on buffalograss on both heaviest and lightest grazed ranges. Under lightest grazing, however, differences were much smaller:

	Time for complete absorption of 1 inch of water [1]	
	Buffalograss sod (minutes)	Western wheatgrass cover (minutes)
Test Area 3:		
Heaviest grazed	43.2	23.8
Lightest grazed	14.1	12.4
Test Area 5:		
Heaviest grazed	73.4	15.7
Lightest grazed	13.3	8.8

[1] Results converted from 0.92 inch of water.

The excessively slow intake on buffalograss under heaviest grazing probably is accounted for by the frequent regrazing and trampling to which that grass was subjected. Regrazing of buffalograss did not occur as frequently on the lightest stocked ranges.

Penetration of Rainfall

Rains were gentle and relatively light during the summer of 1946. Only two were more than 1 inch, and these resulted in little runoff. Unusally heavy rains totaling almost 8 inches fell in September and October. Not until this time did appreciable runoff occur.

Nevertheless, after most of the more important rains, depth of wetting in comparable soils was greater on lightest grazed summer ranges than on ranges that had been grazed heaviest. This was true in seven out nine[11] comparisons, and for sandy loam and clay soils. In no case was penetration greater on heaviest grazed ranges. Because of the gentle nature of most rains and the fact that the ranges remained unstocked until late in the summer, differences undoubtedly were less than what they would normally have been.

Differences were greatest after the abundant fall rains. At that time, wet soil averaged 29.5 cc. deep where grazing had been heaviest compared with 39.1 cc. where it had been lightest on the heavy soils of Test Areas 3 and 5. Measurements were not made in sandy loams.

Average penetration per inch of rain, using all measurements taken, suggested that depth of wetting had been reduced about 8 percent in sandy soils under the heaviest level of grazing and 20 percent in clays for the particular rainfall conditions prevailing:

	Penetration per inch of rain	
	(centimeters)	*(percent)*
Sandy loam:		
Heaviest grazed	16. 7	92
Lightest grazed	18. 1	100
Clay:		
Heaviest grazed	10. 3	79
Lightest grazed	13. 0	100

The decrease for sandy loam probably would have been greater had measurements also been made after the heavy fall rains. These reductions at the most are only suggestive of trends, because of the dependence of differences on the amount and intensity of the rains.

Implications for Management

Specific soils information adequate for management decisions is practically nonexistent. This is particularly true regarding soil interrelations with grazing practices and seasonal and annual weather changes, influences of soil texture and other site features, and the rate at which soil capabilities may deteriorate or recover. However, surface litter, soil porosity, organic matter content, rate of water absorption, and depth of rainfall penetration were all reduced by the heaviest grazing and are apparently indicators of lowered range condition.

[11] In six comparisons, penetration was significantly shallower statistically under heaviest than lightest grazing at the 5-percent probability level.

Adverse responses of these soil characteristics to too heavy grazing appear to be similar in kind for different sites. But actual amounts of litter, organic matter, porosity, and moisture apparently differ. For judging range condition, litter cover probably is the most easily measured of the characteristics studied. Its importance in water relations is well established.

Findings similar to those described here have been reported for northern *(36)* and central Plains range *(11, 24, 29)*. Meager as the information is, it is apparent that heavy compared with more conservative grazing tends to move Plains ranges toward a drier environment. In an already semiarid region, this additional curtailment of moisture for forage growth is of major concern. Also of concern is the increased siltation of reservoirs and streams that is caused by greater runoff.

Particularly significant, the Miles City results make clear that material depreciation of soil-moisture relations occurs during early stages of range deterioration and while changes in vegetation characteristics are not markedly apparent. Further, this disability may carry over at least a full year following complete release from grazing.

Cattle Performance

With one exception, only those cows are considered here that were originally assigned to each stocking rate and remained on the ranges throughout 1932–36 or 1937–45; their calves are included. The exception concerns supplemental feeding. Because feeding was almost entirely by groups, all cows are included, i.e., those originally assigned and their replacements.

Effects of the 1934–36 drought on the first herd were reported earlier *(31)*, as was the growth of calves from all originally assigned cows of the second herd *(62)*. For information on growth, emphasis in the following discussion is placed on results from the second herd because performance of the first was strongly influenced by drought.

Supplemental Feed Required

In the more normal years of 1937–45, necessary feeding was almost entirely in the winter seasons (table 10). During the summer seasons, less than 0.5 percent of the total feed required was fed. This, however, was different in the drought years of 1934 and 1935. About 20 percent of the total was fed during the summer seasons.

Only about one-half as much feed was required by cattle run at the more conservative rates than at the heaviest. Lighter feeding was possible in 9 out of the 12 winters and in each of the 4 summers that feeding was necessary. For both herds, hay consumption per cow year averaged better than a quarter of a ton less under intermediate and lightest stocking. In addition, about one-half ton of cottonseed cake was saved under each of these rates during the winter of 1943–44, compared with requirements under the heaviest level.

Labor of feeding was also substantially increased under heaviest stocking. Cattle had to be fed about twice as long. In 8 of the 12 winters this amounted to more than one-fourth of the days that cattle were on winter range, while in contrast feeding lasted that long during only three winters under the more conservative rates. This difference

TABLE 10.—*Amount of hay or other supplement fed to duplicate groups of cattle*[1] *at three rates of stocking, Miles City, Mont., experimental range, 1932–45*

SUMMER RANGE

Grazing season, inclusive dates[2]	Heaviest stocked	Intermediately stocked	Lightest stocked
	Pounds	*Pounds*	*Pounds*
May 15–Oct. 17, 1934	25,450	16,615	13,898
May 15–Oct. 29, 1935	5,416	----------	----------
May 15–Aug. 6, 1936	12,467	2,308	1,773
Total, 1934–36	43,333	18,923	15,671
May 15–Nov. 13, 1940	1,380	----------	----------

WINTER RANGE

Grazing season, inclusive dates[2]	Heaviest stocked	Intermediately stocked	Lightest stocked
Dec. 1–May 12, 1932–33	8,600	8,600	8,600
Nov. 13–May 14, 1933–34	3,400	3,400	3,400
Oct. 18–May 14, 1934–35	[3] 86,413	[3] 77,826	[3] 72,160
Oct. 30–May 14, 1935–36	36,248	23,596	21,136
Total, 1932–36	134,661	113,422	105,296
Nov. 24–May 16, 1937–38	[4] 25,909 [5] 1,700	[4] 25,613 [5] 1,700	[4] 25,524 [5] 1,700
Oct. 19–June 1, 1938–39	39,478	29,150	29,050
Nov. 16–May 15, 1939–40	16,221	6,440	7,645
Nov. 13–May 15, 1940–41	24,260	2,130	----------
Nov. 14–May 15, 1941–42	22,090	250	3,300
Nov. 13–May 14, 1942–43	20,650	560	1,260
Nov. 12–May 15, 1943–44	17,585 [6] 1,056	8,200 ----------	9,610 ----------
Oct. 30–May 15, 1944–45	9,894	302	1,612
Total, 1937–45	176,087 [5] 1,700 [6] 1,056	72,645 [5] 1,700 ----------	78,001 [5] 1,700 ----------

SUMMER AND WINTER RANGE

Grazing season, inclusive dates[2]	Heaviest stocked	Intermediately stocked	Lightest stocked
Average hay per cow year:			
1932–36	2,222	1,648	1,503
1937–45	1,068	436	470
1932–45	1,444	830	807

[1] Twenty cows under each rate of stocking; spring calves in addition on summer range.
[2] Seasons when feeding was unnecessary are not listed.
[3] 60,556 pounds fed while in dry lot Nov. 23–Apr. 2.
[4] 24,657, 24,575, and 24,664 pounds of hay and all pulp fed under heaviest, intermediate, and lightest rates, respectively, while in dry lot Dec. 23–Mar. 15.
[5] Pulp.
[6] Cottonseed cake.

was even greater when only the more normal years were compared. Feeding was required during more than 25 percent of the days in six of eight winters under heaviest stocking but in only one winter each under the intermediate and lightest rates.

Cow Weights

Only cows that weaned calves in any given year are described here, because dry or open cows varied irregularly among groups and were few in number. Consequently, results are descriptive of bred or wet cows during appropriate seasons (see p. 6).

In nearly all years, some of the cows making up the bred groups had been dry the preceding spring and summer. For this reason, some difference occurred between average fall weights of wet cows and starting winter-season weights of bred cows because of the generally heavier weights of previously dry individuals. Further, a larger number of such cows under any one stocking intensity could result in some distortion in comparisons among intensities during the following months. However, this occurred in an important way in only one year.

Weight trends.—Weights changed in a characteristic manner with the quality and amount of herbage available during different seasons of the year and from year to year throughout the study (figs. 19 and 20). In more favorable years, the most rapid and continuous gains were made during the abundant green-feed period that lasted about 2 months after the cattle were moved to summer range on May 15. This was followed by an irregular tapering off and then fairly rapid losses until the end of the grazing season. Following the weaning of calves and moving of the cows to fresh winter range in November, weights again rose until sometime in January, or occasionally later.

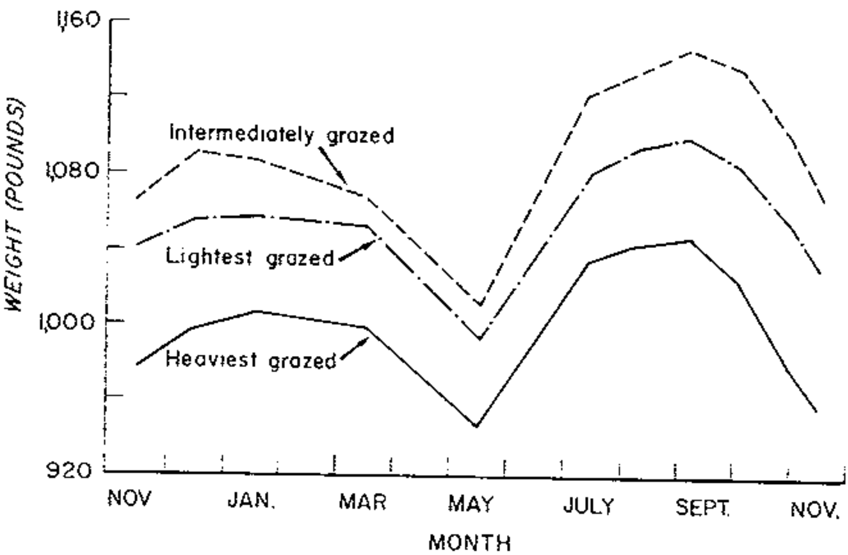

FIGURE 19.—Average seasonal weights of mature bred and wet cows grazed at three intensities during fair to excellent forage years, 1938–45. Dry, mid-November through mid-March—May 15; wet, mid-March—May 15 through mid-November. Based on cows carried continuously at each rate throughout entire period. Weights interpolated where necessary. Miles City, Mont., experimental range.

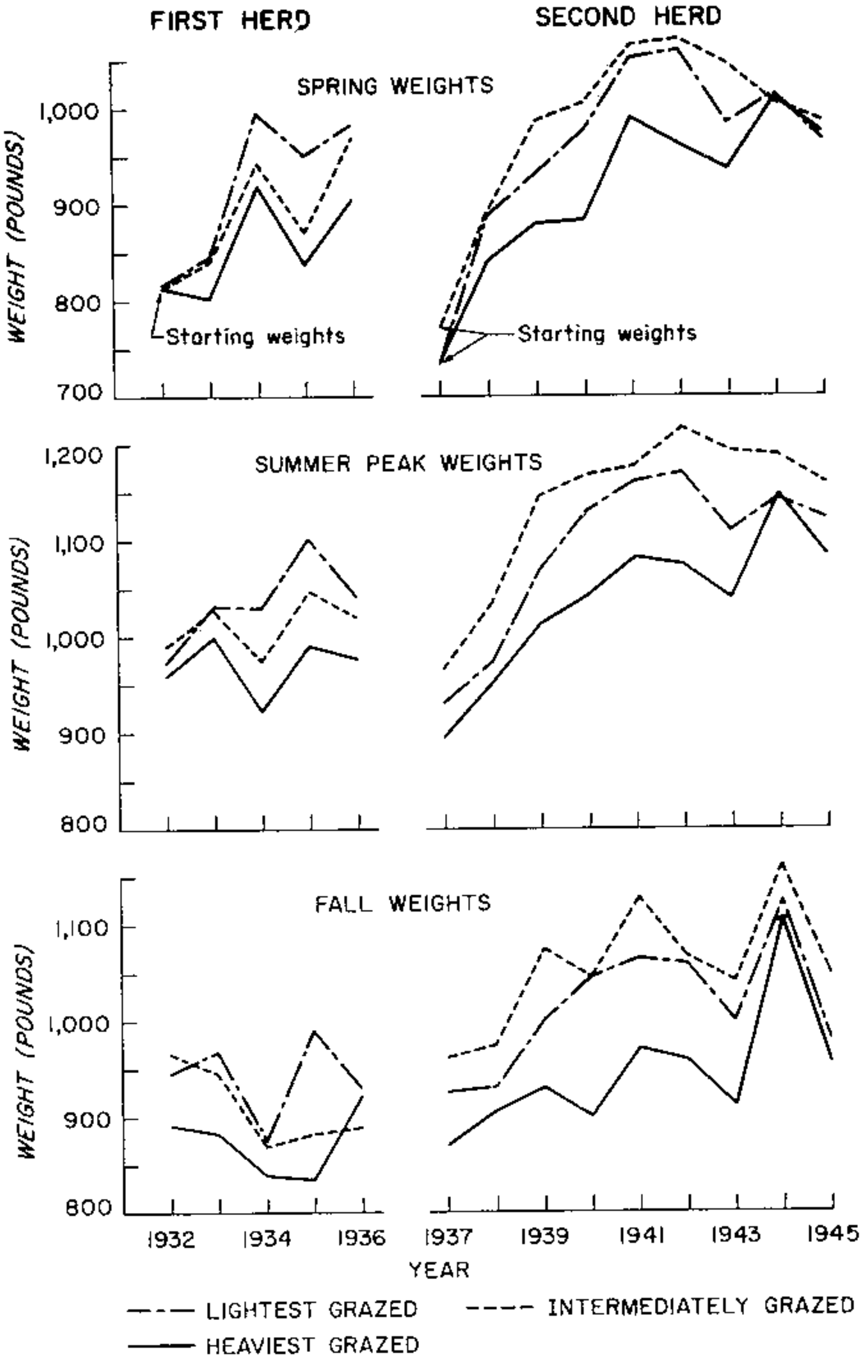

FIGURE 20.—Average spring, summer peak, and fall weights of cows on summer range grazed at three intensities, 1932–45. Two-year-old bred heifers, 1932 and 1937; wet cows in other years. Based on cows carried continuously at each intensity throughout 1932–36 or 1937–45. Miles City, Mont., experimental range.

Weight rise in the winter was usually much less than in the spring, but weights were frequently maintained with only moderate losses up until calving. These trends, of course, were associated with growth of fetuses. Consequently weights did not fully reflect condition of the cows, which was usually lowered because of the reduced quality of herbage and amount available. A sudden and marked weight loss took place with dropping of calves in the spring. Mid-May weights were with few exceptions lowest of the year.

Grazing intensity also had a considerable effect on weight. Under heaviest stocking, with only rare exception weights were lightest in both herds despite additional feeding and wide variations in forage crops (fig. 21). This was true even though starting weights in 1932 were essentially equal among stocking intensities for animals continued through 1936. Also, in 1937 starting weights were nearly identical under heaviest and lightest stocking.

The original weight similarity did not persist long. By the second weighing, 56 days after entering, heifers of both herds on heaviest stocked ranges had fallen below the others. From then on, weight difference was usually least in the spring and greatest in the fall.

Only for the second herd was there an extended period when the weight gap was closed. This occurred at the start of the winter season in 1943–44 and lasted until peak summer weights were reached in 1944. This departure was due to the fact that half of the bred cows on heaviest stocked ranges had been dry the preceding summer compared with only about one-eighth under lightest and none under intermediate stocking. Undoubtedly the exceptionally abundant forage crop in the spring of 1944 also helped keep up weights through early summer under heaviest stocking.

Weights of cows stocked at the intermediate rate generally were somewhat less than those stocked at the lightest rate for the first herd, but generally more for the second. Apparently the reversal was due to a 35+-pound higher average starting weight for the second herd on intermediately than on lightest (or heaviest) stocked ranges. This is supported by the comparisons described below and also by other studies (*12*, *45*).

When final weights were expressed as percentages of initial weights, cows were shown to be slightly favored by lightest grazing throughout the study (fig. 22). This was shown also by percentage gains during the first 4 years:

	Average gain over starting weight	
Stocking rate:	*First herd, 1933–36 (percent)*	*Second herd, 1938–41 (percent)*
Heaviest	1 1	29. 1
Intermediate	15. 7	37. 2
Lightest	20. 0	39. 0

These comparisons confirm the lowest performance under heaviest grazing. Also, it seems reasonable that the more consistent advantage under lightest than intermediate grazing for the first herd probably was due to the less favorable forage conditions during most of the early years. Forage restricted by drought tends to magnify the importance of differences in stocking rates.

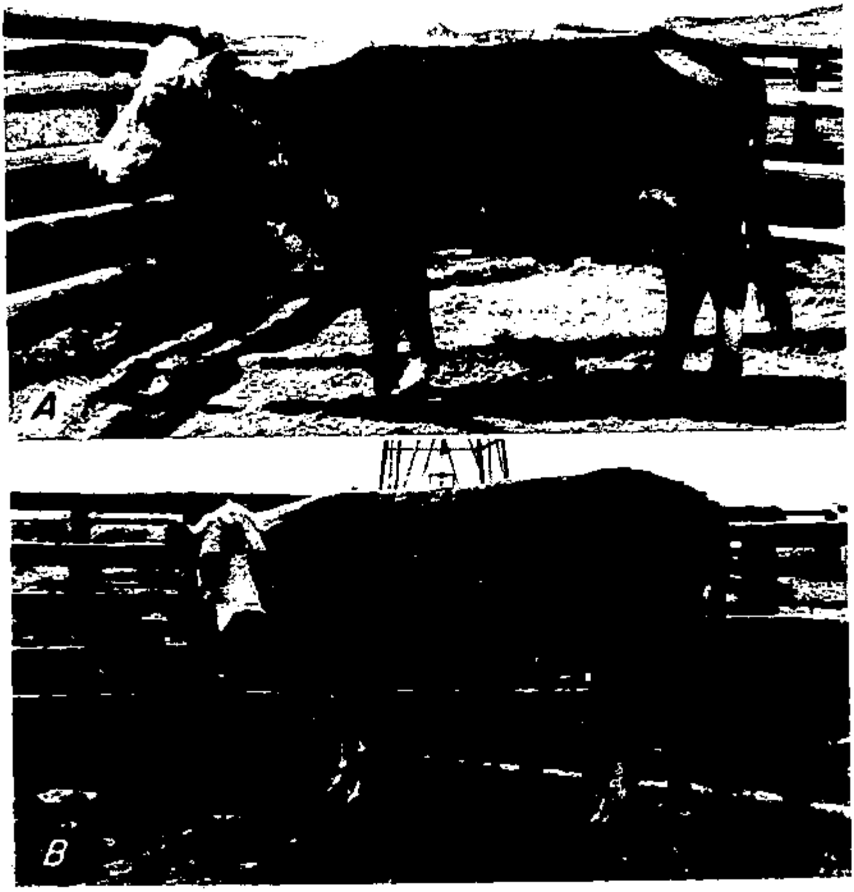

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FIGURE 21.—*A*, Typical unthrifty condition, and *B*, thrifty condition of 10-year-old wet cows grazed continuously since 2 years of age at the heaviest and lightest stocking rates respectively, 1945. Difference is in early May and in spite of materially greater supplemental feeding under heaviest stocking during the preceding winter and abundant herbage from 1944. Condition under the intermediate and lightest rates was about equal. Number brands on left hip were recently clipped.

Gains from spring to summer.—During the severe drought years, gains were least under all rates of stocking. They ranged from only 3 to 72 pounds. Accordingly, they also were highest during the more favorable years, and in a few instances exceeded 180 pounds. More than half the time the second herd was in the study, gains ranged between 120 and 180 pounds.

Cows on the heaviest stocked ranges gained about the same amount as those on the other ranges, even though they weighed less in the spring. Consequently, they did not compensate for their lighter spring weights. For the first herd, gains averaged 108, 111, and 109 pounds from May 15 to summer peak under heaviest, intermediate, and lightest grazing respectively, and 121 and 126 pounds under heaviest and lightest grazing for the second. The larger cows of the

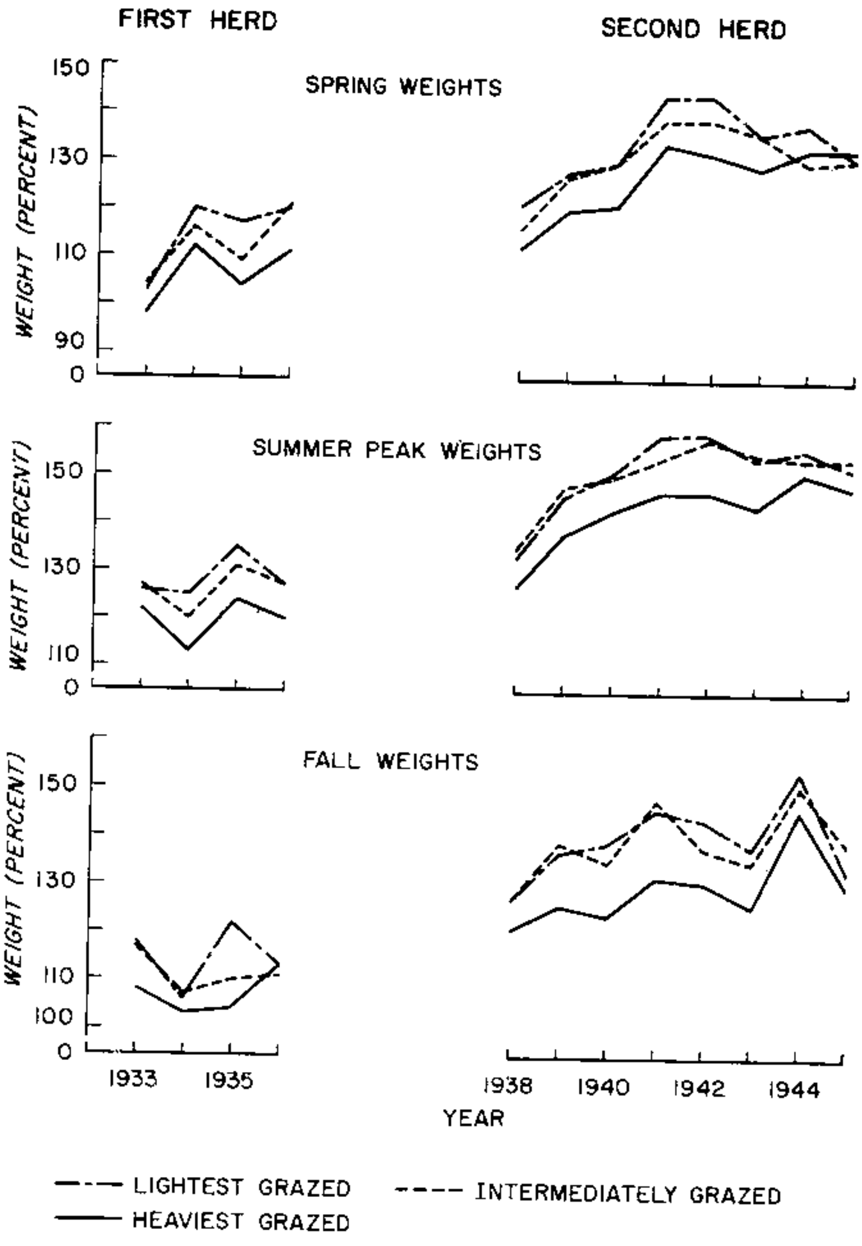

FIGURE 22.—Average spring, summer peak, and fall weights of wet cows on summer range stocked at three rates, expressed as percentages of their initial weights, 1933–36 and 1938–45. Based on two weighings before being started, corrected each year for individuals that were wet; cows carried continuously at each intensity throughout 1932–36 or 1937–45.

second herd on intermediately stocked ranges averaged 153 pounds gain. During the 12 years that cows raised calves, gains under heaviest grazing averaged 140 pounds or more only about one-third of the time. This level was reached in about ⅔ and ½ of the years under intermediate and lightest grazing.

The date at which peak weights were reached varied from year to year and usually was soon after complete curing of the herbage. In any given year the date when peak weights were reached was similar for all grazing intensities. During more normal years, three-fourths of the peak weights were recorded between August 8 and September 5. In the severe drought years, top weights were recorded at the end of the first 28 days on summer range, or about June 12. On the other hand, in unusually favorable seasons, such as in 1944, high weights were maintained through late summer.

All groups usually gained rapidly and in a similar fashion from mid-May through early July. Daily gains for the second herd during this period averaged 1.75 pounds. This dropped to 0.20, 0.48, and 0.34 pounds per day respectively, under heaviest, intermediate, and lightest grazing during the next 56 days. Consequently, under heaviest grazing 90 percent of summer gains was made during the first 56 days on summer range compared with about 80 percent under the more conservative rates. This again shows that forage supply had become limiting after about 2 months of grazing.

Losses from summer to fall.—These were usually greatest under heaviest stocking. During the 8 years that cows of the second herd raised calves, losses were about 100, 90, and 85 pounds respectively under the heaviest, intermediate, and lightest grazing. This amounted to 82, 60, and 67 percent of summer gains under the three rates.

Net summer gains.—The tendency for cows to gain slightly less and lose more during summers under heaviest grazing kept them constantly lighter than the other cattle. For example, net gains during the more favorable years averaged only about half as great under heaviest as under lightest grazing. This difference was ever greater when comparison was made with the originally heavier starting cows under intermediate grazing. Here gains were only about one-third as great. Once the cows on heaviest grazed ranges were behind in weight, winter feeding and even unusually favorable forage years did not compensate for the weight disadvantage.

Growth of young cows consequently was influenced by differences in net gains. Under heaviest grazing, weight increment between 3 and 5 years of age was negligible during the years of fairly normal rainfall. In contrast, 75 pounds or more of body weight was added under intermediate and lightest stocking. This amount of growth compares with that found to be normal on other ranges at the Station *(33)*.

Calf Weights

Results are reported only for weaned calves.

At birth.—Weights were not influenced by weather or intensity of stocking. This was to be expected under differential feeding of the cows as based on their needs.

Growth during summer.—Calves gained at a fairly regular rate through September under all levels of stocking. From then till weaning at the end of October, the rate often dropped 50 percent or more. During more normal years, gains through September about equaled birth weights every 43 days. This amounted to almost 2 pounds per day. Gains were only about half this during October.

Drought reduced average gain in the first herd to about 1.7 pounds daily up to October 2, with the effect being especially marked on calves on heaviest stocked ranges.

Heaviest stocking resulted in lighter calves often after only 1 month on summer range (fig. 23). This undoubtedly was because of a lesser milk supply. Early differences between these calves and calves on the more conservatively stocked ranges generally increased up through weaning. On intermediately and lightest stocked ranges, growth of calves was essentially similar and apparently not influenced by differences in stocking.

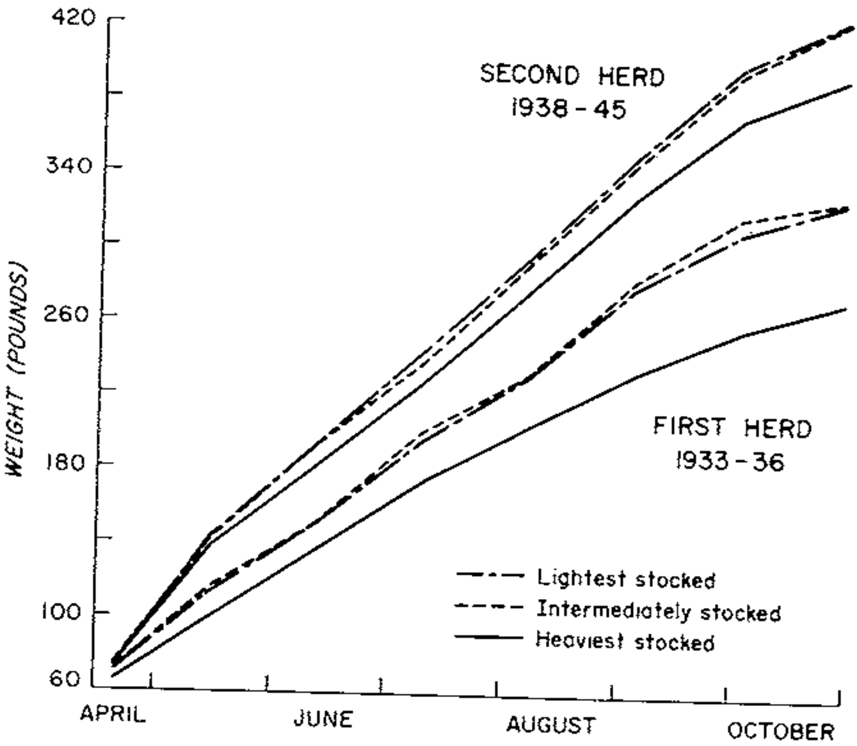

FIGURE 23.—Average weight of calves, birth through weaning, on ranges stocked at three rates, 1933-36 and 1938-45. Based on weaned calves from cows that were run continuously at each rate from 1932 or 1937 throughout either period. Heifer and steer calves combined equally and all years given equal weight; weights interpolated where necessary. Miles City, Mont., experimental range.

At weaning.—Both heifers and steers from heaviest stocked ranges weighed less about 80 percent of the time than those from ranges grazed lighter (fig. 24). Average differences in weaning weight amounted to about 50 pounds for the first herd and 30 for the second:

	Heifers (pounds)	Steers (pounds)
First herd, 1933–36:		
Heaviest stocked	[1] **244**	**252**
Intermediately stocked	292	302
Lightest stocked	294	305
Second herd, 1938–45:		
Heaviest stocked	**378**	**410**
Intermediately stocked	411	437
Lightest stocked	408	443

[1] Boldface weights significantly less statistically at the 5-percent probability level than under intermediate and lightest stocking.

Calf Production

Calf crops.—During the more normal years, 87 percent of the cows weaned calves. This level was apparently reduced by the drought as shown in 1934, 1935, and 1936 when only 73 percent of the cows, or 14 percent fewer, successfully weaned calves.

Rates of stocking did not clearly affect weaned calf crops:

	Cows that weaned calves	
	First herd, 1933–36 (percent)	Second herd, 1938–45 (percent)
Heaviest stocked	75	82
Intermediately stocked	79	90
Lightest stocked	79	89
Average	78	87

This was to be expected, because of the many outside influences that affected number of calves, such as accidents and breeding ability of bulls.

Weaning weight per cow.—Throughout the study, cows under heaviest stocking produced 54.9 pounds less of calf weaning weight per cow per year than under the more conservative rates. This was equivalent to the loss of one 450-pound weaned calf per year for every 8.2 cows.

Implications for Management

Similar results during spring-summer grazing have been shown by other trials on northern Plains ranges (*7, 15, 32, 40, 41*). Further, at Miles City, even though calves from the three grazing levels were maintained together under favorable circumstances after weaning, the weight advantage of the ones from conservatively grazed ranges was retained until they were at least 18 months old (*62*). This appears to agree with findings from critical studies with identical twin beef steers (*60*).

Cattle weights have been amply demonstrated to be early and materially affected by the level of nutrition provided by rate of range stocking. There can be little doubt that a satisfactory rate should provide in most years for normal gains in relation to potentials of the cattle. In addition, under adequate yearlong stocking in the vicinity of Miles City, mature breeding cows normally should require feed during fewer than 25 percent of the days between November 15 and May 15 to maintain themselves in at least fair condition. The necessity to constantly exceed this standard would strongly suggest that

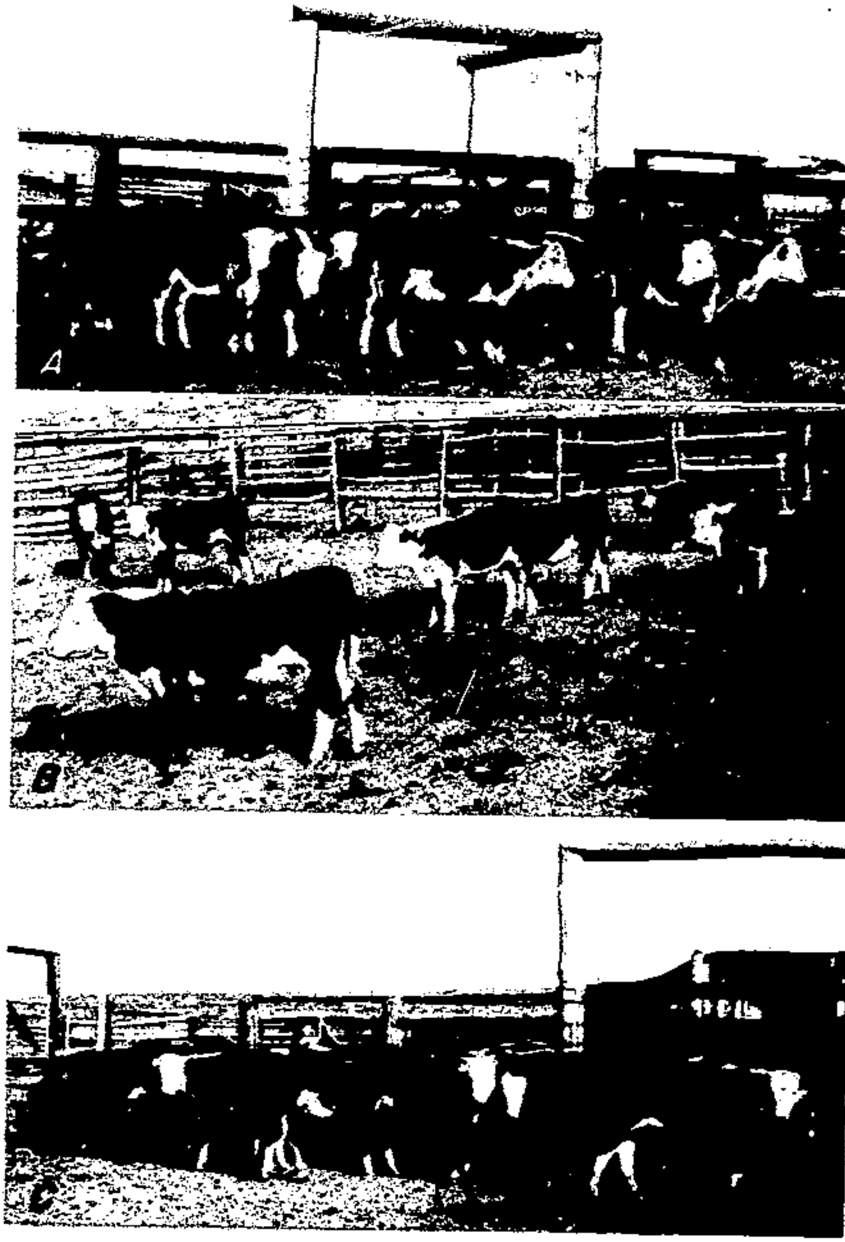

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FIGURE 24.—Representative calves produced by cows grazed at *A*, heaviest, *B*, intermediate, and *C*, lightest intensities, 1943. Average weaning weights of heifers from cows originally assigned in 1937 and carried continuously at each rate amounted to 377, 404, and 443 pounds respectively; and for steers, 434, 454, and 477 pounds.

TABLE 11.—*Stocking capacity of cattle range in good condition at several locations in the northern Great Plains*

Location and reference	Approximate long-time average April-Sept. precipitation [1]	Season	Class of cattle	Approximate rate recommended on the average for satisfactory cattle performance and range productivity [2]
	Inches	*Months*	*Units*	*Acres/month per unit*
Miles City, Mont	9. 5	Jan.-Dec.	Cows w/spring calves	Minimum of 2.6.
Manyberries, Alta. (*15*)	7. 8	April-Oct	do	Slightly over 4.3.
Southwestern Saskatchewan and southeastern Alberta (*14*):				
Drier phase, "short grass prairie".	8–9	April-Oct	1,000-lb. cows	Average of 4.7.
More moist phase, "mixed prairie"	10–11	do	do	Average of 2.8.
Mandan, N. Dak. (*41*)	12. 3	Mid-May—mid-Oct	2-year-old steers	1.4.
		Jan.-Dec	do	Over 2.1 (estimated).
Western South Dakota, exclusive of Black Hills (*1*).	10–14	May-Nov., Dec	1,000-lb. animal unit	Mostly 2.6–2.3.
Cottonwood, S. Dak. (*32*)	11. 8	May-Nov	Cows w/ spring calves	2.3.
Ardmore, S. Dak. (*7*)	12. 5	Mid-May—Sept., Oct	2-year-old steers	Over 1.5.[3]

[1] For U.S. locations, from Weather Bureau records; for Canadian, from Dominion experiment station reports and Canada Dept. Transport climatic summaries.

[2] Supplemental winter feeding in addition, where appropriate.

[3] 1.5 acres was apparently satisfactory for range maintenance but not for steer gains.

range stocking was out of line with grazing capacity. Unusually severe winters or drought would, of course, necessitate more liberal feeding. Particularly important, however, is the fact that there is no assurance nor evidence that a rate of stocking adequate for gains and minimum feeding will at the same time be satisfactory for long-term, sustained high production of forage.

Range Stocking Capacity, Allowable Herbage Use, and Implications for Management

A minimum of 31 acres of range in good condition, as judged against adapted standards, should be provided per breeding cow per year in the vicinity of Miles City under the system of separate summer and winter range. This has been recommended previously by Hurtt (*31*). The approximate average monthly rate of 2.6 acres compares favorably with estimated capacities in other northern Plains localities with similar rainfall (table 11).

The 31-acre rate that was approximated under intermediate stocking approached being proper for the experimental range. However, stocking over a longer period might have shown slow deterioration; this is suggested by the slight decrease in height growth of grasses by the end of the trial. Also, complete relief from grazing was given for a full year under all rates following the second severe drought year, and growing conditions thereafter were essentially favorable.

Based on the intermediate stocking discussed here, guides to the amount of herbage removal that principal forage plants in this vicinity can safely stand (*28*) are shown in table 12. These were supplemented by information from neighboring, conservatively used Station ranges. Percentages of grazed plants were the most distinctive and most easily used single feature distinguishing herbage utilization under the three rates of stocking throughout this study.

Generally, as far as can be judged, guides from other locations provide for heavier herbage utilization than do those from the experimental range. When 55 percent of western wheatgrass shoots on uplands of the experimental range was grazed, about 30 percent of the total herbage weight of that grass had been removed. Similarly, when 40 to 45 percent of blue grama clumps and 55 percent of needle-and-thread plants had half or more of their areas grazed, herbage weight removed amounted to about 25 and 35 percent, respectively.

The Miles City guides may be conservative, since measurements were made during the essentially favorable forage years 1939-45. However, over these years nearly 50 percent of the weight of western wheatgrass herbage was grazed off on heaviest stocked summer ranges. This, with the accompanying utilization of other grasses and associated trampling, prevented as complete a recovery of those ranges from the drought as occurred under conservative grazing and resulted in lowered condition. Also, the importance of maintaining vigorous forage grasses for continued full production argues for conservative use.

Consequently, it is thought that a rate of stocking that results in use near the suggested levels in a slightly better than normal year would also be safe in more normal and drier years. During and following unusually dry years or drought, some adjustment in numbers probably would be desirable as a precaution against unnecessary damage to the range and for satisfactory recovery.

TABLE 12.—*Allowable herbage use by cattle on range in good condition at several locations in the northern Great Plains*

Location and reference	System and season of grazing	Utilization of palatable herbage[1] recommended for satisfactory range and cattle performance
Miles City, Mont. (*28*)	Continuous, mid-May—mid-Nov.	Plants grazed:[2] Western wheatgrass, 55% on uplands, 75% on bottoms; blue grama, 40–45%, 65% similarly; buffalograss, 50–55%, 75% similarly; needle-and-thread, 55–60% on uplands; threadleaf sedge, 50% similarly.
	Continuous, mid-Nov.—mid-May	Western wheatgrass, 65% on uplands, 75% on bottoms; blue grama, 40%, 55% similarly; others, same as mid-May—mid-Nov.
Manyberries, Alta. (*15*)	Continuous, April-Oct.	65% of available herbage.
Swift Current, Sask. (*42*)	Continuous, May-Oct.	50–55% of total weight.
Southwestern Saskatchewan and southeastern Alberta (*14*).	Continuous, April-Oct.	55% of total weight.
Mandan, N. Dak. (*41*)	Continuous, mid-May—mid-Oct.	75–80% of foliage cover.
Western South Dakota, exclusive of Black Hills (*1*)	Rotated, May-Nov., Dec.	To minimum stubble of: 1 in. for short grasses; 4 in. for mid- and tall-grasses.
Cottonwood, S. Dak. (*32*).	Continuous, May-Nov.	40–55% of total weight.

[1] Includes only current growth, except for mid-Nov.—mid-May at Miles City where only the immediate preceding growing season's growth is included.

[2] Individual shoots of western wheatgrass or mats of buffalograss grazed; individual clumps of other species on which one-half or more of the area has been grazed.

Estimates of satisfactory stocking from experimental or other ranges are useful only as a first check or starting point in management, since productivity of ranges may vary considerably within the same locality because of natural features and past use. A more critical evaluation is given by herbage utilization. But, the surest procedure is a continuing check of range condition and trend in condition as judged against adapted standards. Current standards are available from local representatives of land management agencies, Soil Conservation Service, and Extension Service. They should be considered subject to improvement until proved satisfactory for a specific range.

All of the characteristics commonly used as criteria for judging condition, and others less frequently or heretofore not considered, have been discussed in the preceding pages. It is hoped this information will help stimulate continued study in an effort to improve existing condition and trend guides.

It seems reasonable that any system of grazing that provides conservative use during the critical growing season and summer will permit the highest level of stocking and fullest utilization of herbage over the year consistent with maintenance of the range and satisfactory cattle gains. As an example, conservative use on spring-summer-early fall range might be coupled with fairly full use on late fall-winter range. This should give high summer gains with maximum carryover into the fall, minimum required winter feeding, and at the same time adequate protection of the range. Also, alternating moderately conservative summer and winter grazing on individual ranges should help meet these objectives.

Summary

During the period 1932–46, vegetation and soil responses to different intensities of grazing on mixed-prairie cattle range were determined at the U.S. Range Livestock Experiment Station near Miles City, Mont. Included were measurements of cattle responses associated with grazing intensity and estimates of proper stocking and herbage utilization.

Two sets of six native ranges were used; one set was grazed during late spring-summer-early fall (summer ranges) and one during the remaining seasons (winter ranges). Four were stocked heaviest, 23.1 acres per breeding cow, yearlong; four intermediately, 30.5 acres; and four lightest, 38.8 acres.

Principal range subtypes were representative of those making up large expanses of the northern Plains. Most common forage plants were western wheatgrass, blue grama, needle-and-thread, green needlegrass, buffalograss, and threadleaf sedge which made up about 65 percent of the vegetation. The remainder was principally Plains pricklypear and big, silver, and fringed sagebrush.

Two herds of uniform Hereford breeding cows were grazed during the study. These cows were started as bred 2-year-old heifers, and individuals remained throughout the time they were in the study at the same stocking rate to which originally assigned.

Stocking was constant in nearly all years, although herbage utilization varied depending on herbage crops as influenced by weather. Utilization was greater on ranges stocked heaviest than on ranges and comparable parts of ranges stocked intermediately or lightest. Under intermediate stocking, it was only slightly greater than under the lightest rate.

Vegetation and soils were comprehensively studied at the end of the trial on selected parts of important grazing subtypes of the summer ranges. Areas used were essentially comparable except for past grazing intensity. In addition, mature height growth of grasses was sampled on entire areas of principal grazing subtypes within all summer and winter ranges. The above information was supplemented by systematic records from permanent plots on the ranges during the trial.

A primary influence on vegetation was exerted by extreme drought during the period 1934–36, and near normal and much above normal weather during the following years. Basal cover and composition of vegetation, height growth of grasses, and production of palatable herbage were affected. Basal area of principal grasses charted in June and of all herbaceous vegetation combined, were closely associated with precipitation of the preceding growing season. In contrast, mature height of grasses and production of palatable herbage were normally closely associated with current growing season precipitation.

As indexed by herbage production and further evidenced by changes in other vegetation and surface soil characteristics, an early stage of range deterioration resulted under the heaviest level of summer grazing. This condition was characterized by the following changes:

Reduced height growth of vegetative, nonseedstalk-producing shoots of forage grasses was the most consistent vegetation change. It was accompanied by reduced weight per shoot. This was true for both the principal mid- and short grasses throughout growth and at maturity, and for all major sites. It was apparently one of the earliest responses and occurred regardless of how basal area and other vegetation characteristics were affected.

Basal area of all perennial grasses combined and of all herbaceous vegetation was generally increased. The increase was accounted for principally by buffalograss, and to a lesser extent by blue grama, perennial grasses of low or no grazing value, and annuals. Green needlegrass was materially reduced, and western wheatgrass where buffalograss had become abundant. In no instance was there a material invasion of low-value perennial grasses, perennial forbs, or annuals. Abundance of Plains pricklypear and silver and fringed sagebrush was slightly favored. Density of big sagebrush was somewhat reduced.

These changes lowered production of palatable herbage and, in most cases, yield of all herbaceous vegetation. Increases of short grasses and secondary plants usually did not compensate for losses in production of important midgrasses. By decreases in height growth and a shift toward short grasses, a greater proportion of the weight of palatable herbage also became concentrated near the ground where it was less readily available to cattle.

Surface soil characteristics were affected through a reduction in litter cover, volume of roots, and organic matter. Volume weights were increased and noncapillary pore space reduced. These changes lengthened the time required for absorption of applied water and decreased the depth to which rainfall penetrated.

Less change resulted under the heaviest level of winter grazing. This was partly due to the dormant condition of the plants during most of the grazing period and partly to decreased grazing pressure caused by relatively heavy feeding of supplements to the cows. However, height growth of all principal grasses was somewhat reduced.

Growth of young cows was suppressed under heaviest yearlong grazing. Net summer gains were reduced throughout the study and weights generally lowered throughout the year. Growth of spring calves was retarded. Weaning weights were decreased about 50 pounds during the drought period and 30 pounds during the more normal years. On the other hand, hay requirements were increased one-quarter ton per cow per year and length of feeding period extended.

As compared with the heaviest grazing rate, the intermediate and lightest rates maintained cattle performance and range condition at a higher and nearly equal level. This equality was partly caused by a smaller difference in grazing than suggested by the surface-acre stocking rates, because palatable herbage production per acre of the intermediately stocked ranges was higher. Under intermediate grazing, however, height growth of grasses was slightly decreased. This suggests that more serious changes might have developed with continued grazing.

As a starting check on management, a minium of 31 acres of range in good condition should be provided in this vicinity per breeding cow per year under the system of separate summer and winter range tested. A guide to herbage removal is suggested. However, under any intensity of herbage utilization or grazing system, the surest way to satisfactory long-term range maintenance and accompanying high sustained cattle production is a continuing check on range condition.

Common and Botanical Names of Plants Mentioned

GRASSES AND SEDGES

Bluegrass, big	*Poa ampla* Merr.
Bluegrass, Canada	*P. compressa* L.
Bluegrass, Canby	*P. canbyi* (Scribn.) Piper
Bluegrass, Sandberg	*P. secunda* Presl
Bluestem, little	*Andropogon scoparius* Michx.
Buffalograss	*Buchloe dactyloides* (Nutt.) Engelm.
Dropseed, sand	*Sporobolus cryptandrus* (Torr.) A. Gray
Fescue, Idaho	*Festuca idahoensis* Elmer
Fescue, six weeks	*F. octoflora* Walt.
Grama, blue	*Bouteloua gracilis* (H.B.K.) Lag.
Grama, sideboats	*B. curtipendula* (Michx.) Torr.
Junegrass, prairie	*Koeleria cristata* (L.) Pers.
Muhly, Plains	*Muhlenbergia cuspidata* (Torr.) Rydb.
Needle-and-thread	*Stipa comata* Trin. & Rupr.
Needlegrass, green	*S. viridula* Trin.
Needlegrasses	*S. viridula* and *S. comata*
Porcupinegrass, shortawn	*S. spartea* var. *curtiseta* Hitchc.
Sacaton, alkali	*Sporobolus airoides* (Torr.) Torr.
Sedge, needleleaf	*Carex eleocharis* L. H. Bailey
Sedge, penn	*C. pennsylvanica* Lam.
Sedge, threadleaf	*C. filifolia* Nutt.
Threeawn, red	*Aristida longiseta* Steud.
Tumblegrass	*Schedonnardus paniculatus* (Nutt.) Trel.
Wheatgrass, bluebunch	*Agropyron spicatum* (Pursh) Scribn. & Smith
Wheatgrass, thickspike	*A. dasystachyum* (Hook.) Scribn.
Wheatgrass, western	*A. smithii* Rydb.

FORBS

Bahia, Plains	*Bahia oppositifolia* (Nutt.) DC.
Globemallow, scarlet	*Sphaeralcea coccinea* (Pursh) Rydb.
Indianwheat, bottlebrush	*Plantago aristata* Michx.
Phlox, Hoods	*Phlox hoodii* Rich.
Vetch, American	*Vicia americana* Muhl.

SHRUBS

Greasewood, black	*Sarcobatus vermiculatus* (Hook.) Torr.
Pricklypear	*Opuntia*
Pricklypear, Plains	*O. polyacantha* Haw.
Sagebrush, big	*Artemisia tridentata* Nutt.
Sagebrush, fringed	*A. frigida* Willd.
Sagebrush, silver	*A. cana* Pursh
Saltbush	*Atriplex*
Saltbush, Gardner	*A. gardneri* (Moq.) Standl.
Saltbush, shadscale	*A. confertifolia* (Torr. & Frem.) S. Wats.
Snakeweed	*Gutierrezia*
Snowberry, western	*Symphoricarpos occidentalis* Hook.
Winterfat, common	*Eurotia lanata* (Pursh) Moq.

OTHER

Selaginella	*Selaginella densa* Rydb.

Literature Cited

(1) Albee, Leslie R., Klosterman, Earle W., Burkitt, William H., and Olson, Harlan R.
1948. south dakota grasslands: their condition and management. S. Dak. Agr. Expt. Sta. Cir. 70, 39 pp., illus.

(2) Alberta, Manyberries Dominion Range Experiment Station.
1937. results of experiments, 1927–1936, inclusive. Canada Expt. Farms, Manyberries (Alta.) 56 pp., illus.

(3) Albertson, F. W., and Weaver, J. E.
1946. reduction of ungrazed mixed prairie to short grass as a result of drought and dust. Ecol. Monog. 16: 449–463, illus.

(4) Baver, L. D.
1948. soil physics. Ed. 2, 398 pp., illus. New York, London.

(5) Bentley, J. R., and Talbot, M. W.
1945. how many head? West Livestock Jour. 23 (43): 21, 40, 42, 43, illus.

(6) Biswell, Harold H., and Weaver, J. E.
1933. effect of frequent clipping on the development of roots and tops of grasses in prairie sod. Ecology 14: 368–390, illus.

(7) Black, W. H., Baker, A. L., Clark, V. I., and Mathews, O. R.
1937. effect of different methods of grazing on native vegetation and gains of steers in northern great plains. U.S. Dept. Agr. Tech. Bul. 547, 18 pp., illus.

(8) Blaisdell, James P.
1949. competition between sagebrush seedlings and reseeded grasses. Ecology 30: 512–519, illus.

(9) ——— and Pechanec, Joseph F.
1949. effects of herbage removal at various dates on vigor of bluebunch wheatgrass and arrowleaf balsamroot. Ecology 30: 298–305, illus.

(10) Bouyoucos, George John.
1936. directions for making mechanical analyses of soils by the hydrometer method. Soil Sci. 42: 225–229, illus.

(11) Branson, Farrel, and Weaver, J. E.
1953. quantitative study of degeneration of mixed prairie. Bot. Gaz. 114: 397–416, illus.

(12) Clark, R. T., Knapp, Bradford, Jr., Baker, A. L., and Quesenberry, J. R.
1943. performance-testing of beef cattle. Mont. Agr. Expt. Sta. Bul. 417, 12 pp., illus.

(13) Clarke, S. E.
1930. pasture investigations on the short grass plains of saskatchewan and alberta. Sci. Agr. 10: 732–749, illus.

(14) ——— Campbell, J. A., and Campbell, J. B.
1942. an ecological and grazing capacity study of the native grass pastures in southern alberta, saskatchewan and manitoba. Canada Dept. Agr. Tech. Bul. 44, 31 pp., illus.

(15) ——— Tisdale, E. W., and Skoglund, N. A.
1943. the effects of climate and grazing practices on short-grass prairie vegetation in southern alberta and southwestern saskatchewan. Canada Dept. Agr. Tech. Bul. 46, 53 pp., illus.

(16) Conlon, Thomas J., Douglas, Raymond J., and Moomaw, Leroy.
1953. rotation and tillage investigations at the dickinson experiment station, dickinson, north dakota. N. Dak. Agr. Expt. Sta. Bul. 383, 126 pp., illus.

(17) Cook, C. W.
1942. insects and weather as they influence growth of cactus on the central great plains. Ecology 23: 209–214, illus.

(18) Cooper, Harold W.
1953. amounts of big sagebrush in plant communities near tensleep, wyoming, as affected by grazing treatment. Ecology 34: 186–189, illus.

(19) Coupland, Robert T.
1950. ecology of mixed prairie in canada. Ecol. Monog. 20: 271–315, illus.

(20) Craddock, G. W., and Forsling, C. L.
1938. THE INFLUENCE OF CLIMATE AND GRAZING ON SPRING-FALL SHEEP RANGE IN SOUTHERN IDAHO. U.S. Dept. Agr. Tech. Bul. 600, 42 pp., illus.

(21) Ellison, Lincoln, and Woolfolk, E. J.
1937. EFFECTS OF DROUGHT ON VEGETATION NEAR MILES CITY, MONTANA. Ecology 18: 329–336, illus.

(22) Evanko, Anthony B., and Peterson, Roald A.
1955. COMPARISONS OF PROTECTED AND GRAZED MOUNTAIN RANGELANDS IN SOUTHWESTERN MONTANA. Ecology 36: 71–82, illus.

(23) Hanson, Herbert C.
1950. ECOLOGY OF THE GRASSLAND. II. Bot. Rev. 16: 283–360.

(24) ——— Love, L. Dudley, and Morris, M. S.
1931. EFFECTS OF DIFFERENT SYSTEMS OF GRAZING BY CATTLE UPON A WESTERN-WHEATGRASS TYPE OF RANGE NEAR FORT COLLINS, COLORADO. Colo. Agr. Col. Bul. 377, 82 pp., illus.

(25) Heady, Harold F.
1950. STUDIES OF BLUEBUNCH WHEATGRASS IN MONTANA AND HEIGHT-WEIGHT RELATIONSHIPS OF CERTAIN RANGE GRASSES. Ecol. Monog. 20: 55–81, illus.

(26) Holscher, Clark E.
1944. CONTROLLING THE PRICKLYPEAR. West. Livestock Jour. 22 (38): 18, 54, 55, illus.

(27) ———
1945. THE EFFECTS OF CLIPPING BLUESTEM WHEATGRASS AND BLUE GRAMA AT DIFFERENT HEIGHTS AND FREQUENCIES. Ecology 26: 148–156, illus.

(28) ——— and Woolfolk, E. J.
1953. FORAGE UTILIZATION BY CATTLE ON NORTHERN GREAT PLAINS RANGES. U.S. Dept. Agr. Cir. 918, 27 pp., illus.

(29) Hopkins, Harold H.
1954. EFFECTS OF MULCH UPON CERTAIN FACTORS OF THE GRASSLAND ENVIRONMENT. Jour. Range Mangt. 7: 255–258, illus.

(30) Hubbard, William A.
1951. ROTATIONAL GRAZING STUDIES IN WESTERN CANADA. Jour. Range Mangt. 4: 25–29

(31) Hurtt, Leon C.
1951. MANAGING NORTHERN GREAT PLAINS CATTLE RANGES TO MINIMIZE EFFECTS OF DROUGHT. U.S. Dept. Agr. Cir. 865, 24 pp., illus.

(32) Johnson, Leslie E., Albee, Leslie R., Smith, R. O., and Moxon, Alvin L.
1951. COWS, CALVES AND GRASS. S. Dak. Agr. Expt. Sta. Bul. 412, 39 pp., illus.

(33) Knapp, Bradford, Jr., Baker, A. L., Quesenberry, J. R., and Clark, R. T.
1942. GROWTH AND PRODUCTION FACTORS IN RANGE CATTLE. Mont. Agr. Expt. Sta. Bul. 400, 13 pp., illus.

(34) Lang, Robert.
1945. DENSITY CHANGES OF NATIVE VEGETATION IN RELATION TO PRECIPITATION. Wyo. Agr. Expt. Sta. Bul. 272, 31 pp., illus.

(35) Larson, Floyd, and Whitman, Warren.
1942. A COMPARISON OF USED AND UNUSED GRASSLAND MESAS IN THE BADLANDS OF SOUTH DAKOTA. Ecology 23: 438–445, illus.

(36) Lodge, Robert W.
1954. EFFECTS OF GRAZING ON THE SOILS AND FORAGE OF MIXED PRAIRIE IN SOUTHWESTERN SASKATCHEWAN. Jour. Range Mangt. 7: 166–170.

(37) Mueggler, Walter F.
1950. EFFECTS OF SPRING AND FALL GRAZING BY SHEEP ON VEGETATION OF THE UPPER SNAKE RIVER PLAINS. Jour. Range Mangt. 3: 308–315, illus.

(38) Pickford, G. D.
1932. THE INFLUENCE OF CONTINUED HEAVY GRAZING AND OF PROMISCUOUS BURNING ON SPRING-FALL RANGES IN UTAH. Ecology 13: 159–171, illus.

(39) Rogler, George A., and Haas, Howard J.
1947. RANGE PRODUCTION AS RELATED TO SOIL MOISTURE AND PRECIPITATION ON THE NORTHERN GREAT PLAINS. Amer. Soc. Agron. Jour. 39: 378–389, illus.

(40) SARVIS, J. T.
1923. EFFECTS OF DIFFERENT SYSTEMS AND INTENSITIES OF GRAZING UPON THE NATIVE VEGETATION AT THE NORTHERN GREAT PLAINS FIELD STATION. U.S. Dept. Agr. Bul. 1170, 45 pp., illus.

(41) ———
1941. GRAZING INVESTIGATIONS ON THE NORTHERN GREAT PLAINS. N. Dak. Agr. Expt. Sta. Bul. 308, 110 pp., illus.

(42) SASKATCHEWAN, SWIFT CURRENT DOMINION EXPERIMENTAL STATION.
1949. FORAGE CROPS. Canada Expt. Farms, Swift Current (Sask.) Sta. Prog. Rpt. 1937–1947: 35–59, illus.

(43) SAVAGE, D. A.
1937. DROUGHT SURVIVAL OF NATIVE GRASS SPECIES IN THE CENTRAL AND SOUTHERN GREAT PLAINS, 1935. U.S. Dept. Agr. Tech. Bul. 549, 54 pp., illus.

(44) SCHOLLENBERGER, C. J.
1945. DETERMINATION OF SOIL ORGANIC MATTER. Soil Sci. 59: 53–56.

(45) SHELBY, C. E., CLARK, R. T., AND WOODWARD, R. R.
1955. THE HERITABILITY OF SOME ECONOMIC CHARACTERISTICS OF BEEF ANIMALS. Jour. Anim. Sci. 14: 372–385.

(46) SHORT, L. R., AND WOOLFOLK, E. J.
1956. PLANT VIGOR AS A CRITERION OF RANGE CONDITION. Jour. Range Mangt. 9: 66–69, illus.

(47) TURNER, GEORGE T., AND COSTELLO, DAVID F.
1942. ECOLOGICAL ASPECTS OF THE PRICKLYPEAR PROBLEM IN EASTERN COLORADO AND WYOMING. Ecology 23: 419–426, illus.

(48) ——— AND KLIPPLE, G. E.
1952. GROWTH CHARACTERISTICS OF BLUE GRAMA IN NORTHEASTERN COLORADO. Jour. Range Mangt. 5: 22–28, illus.

(49) U.S. DEPARTMENT OF AGRICULTURE.
1941. CLIMATE AND MAN. Yearbook 1941. 1248 pp., illus.

(50) U.S. DEPARTMENT OF COMMERCE, BUREAU OF CENSUS.
1956. UNITED STATES CENSUS OF AGRICULTURE: 1954. I (11): 388 pp. illus.; (27): 196 pp., illus.; (29): 338 pp., illus.

(51) U.S. FOREST SERVICE, INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION.
1955. ANNUAL REPORT 1954. 80 pp. [Processed.]

(52) U.S. FOREST SERVICE, ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION.
1955. ANNUAL REPORT, 1954. 57 pp., illus. [Processed.]

(53) ———
1956. ANNUAL REPORT, 1955. 86 pp., illus. [Processed.]

(54) U.S. FOREST SERVICE, SOUTHWESTERN FOREST AND RANGE EXPERIMENT STATION.
1952. ANNUAL REPORT, 1951. 63 pp., illus. [Processed.]

(55) WEAVER, J. E., AND ALBERTSON, F. W.
1940. DETERIORATION OF MIDWESTERN RANGES. Ecology 21: 216–236, illus.

(56) ——— AND ALBERTSON, F. W.
1944. NATURE AND DEGREE OF RECOVERY OF GRASSLAND FROM THE GREAT DROUGHT OF 1933 TO 1940. Ecol. Monog. 14: 393–479, illus.

(57) ——— AND DARLAND, R. W.
1947. A METHOD OF MEASURING VIGOR OF RANGE GRASSES. Ecology 28: 146–162, illus.

(58) WHITMAN, WARREN C., AND HELGESON, E. A.
1946. RANGE VEGETATION STUDIES. N. Dak. Agr. Expt. Sta. Bul. 340, 43 pp., illus.

(59) ——— HANSON, HERBERT C., AND PETERSON, ROALD.
1943. RELATION OF DROUGHT AND GRAZING TO NORTH DAKOTA RANGE LANDS. N. Dak. Agr. Expt. Sta. Bul. 320, 29 pp., illus.

(60) WINCHESTER, C. F., AND HOWE, PAUL E.
1955. RELATIVE EFFECTS OF CONTINUOUS AND INTERRUPTED GROWTH ON BEEF STEERS. U.S. Dept. Agr. Tech. Bul. 1108, 34 pp., illus.

(61) WOOLFOLK, E. J.
1949. STOCKING NORTHERN GREAT PLAINS SHEEP RANGE FOR SUSTAINED HIGH PRODUCTION. U.S. Dept. Agr. Cir. 804, 39 pp., illus.

(62) ——— AND KNAPP, BRADFORD, Jr.
1949. WEIGHT AND GAIN OF RANGE CALVES AS AFFECTED BY RATE OF STOCKING. Mont. Agr. Expt. Sta. Bul. 463, 26 pp., illus.

Appendix. Methods of Study

Herbage Production

Relative range condition of the study areas was indexed by herbage production which was evaluated by two methods:

(1) For entire summer ranges, estimated yields were computed as follows:

$$\text{Palatable herbage dry weight lbs./acre} = \frac{\text{18 lbs., assumed daily consumption per 1,000 lbs. cattle weight} \times \text{1,000 lbs.-cattle-unit days}}{\text{\% herbage utilization} \times \text{acres per range}}$$

Where

$$\text{1,000 lbs.-cattle-unit days} = \text{Cow days per range} \times \frac{\text{Seasonal average total cow weight}}{1{,}000} + \text{Calf days per range} \times \frac{\text{Seasonal average total calf weight}}{1{,}000}$$

Computations were made for the period 1938–45. For these years, intensive herbage utilization inventories were available. With the exception of 1939, utilization of western wheatgrass—the most widely distributed forage—was taken as the index of palatable herbage use. In 1939, a good blue grama year, utilization of that grass was more representative and was used as the index.

To establish a comparative base, original relations in production among ranges were used. For those intermediately stocked, production in 1933 was raken as equal to that computed for 1940 when weather and herbage growth were similar. Production for the other ranges was then scaled according to differences shown by the 1932 inventory of the amounts of cover of forage species.

(2) On test areas of the summer ranges, herbage produced in 1946 was clipped ½-inch above root crowns on 0.1 milacre plots. These averaged 69 per range per test area and were distributed on a restricted-random basis. Growth from previous years was eliminated by preclipping during the preceding late fall and very early spring; harvested material was left as litter. Yields were air-dried, and weights were corrected for grasshopper damage according to the means of three estimates for each area by three observers.

In addition, distribution of yields with height was computed for principal forage grasses combined, from average clipped yields per species from the test areas, mature heights by species, and distribution of weight by height as determined by segmenting plants of the several grasses.

Herbage Utilization

Percent herbage weight removed by grazing was inventoried by a modified stubble height-weight method. This was done for all principal forage grasses except buffalograss. For buffalograss, proportion of mats grazed was sampled rather than weighed. Inventories were made annually at the end of each grazing season on summer ranges during the period 1938–45,[12] and intermittently on winter ranges. Weight to the ground level was considered, but only for plants away from obstructions to grazing. Observations were restricted to current growth on summer ranges; on winter ranges, to only growth of the immediate preceding growing season. Details of the method, range sampling, and herbage utilization are given in an earlier report (*28*).

Basal Area of Grasses and Forbs

Measurements were made on 57 meter-square quadrats open to grazing on all summer and winter ranges and about equally distributed among stocking levels, and on 10 subplots in each 10- by 12-meter paired plot on heaviest or lightest grazed summer ranges. All test areas within summer ranges were sampled in 1945, except part of Area 1 within an intermediately grazed range. This was done in 1946, when ranges were unstocked. Forty-five to eighty-six 2- by 5-decimeter sampling units were observed in each range per test area, depending on size.

Basal areas of clump and mat-forming perennials were estimated 1 inch above root crowns. On quadrats, they were charted with a pantograph; on the other plots, a grid divided into 4-square-centimeter units was used. Individual shoots of western wheatgrass and single-stemmed perennial forbs were counted and a fixed area allowed for each. Annuals were counted; for quadrats, numbers were converted to area as for single-stemmed perennials. Quadrats were observed between May 15 and July 10—the other plots during late June and July when grasses were mature or nearly so.

Abundance of Cactus and Sagebrush

Numbers of joints and clumps of Plains pricklypear were counted on 15 pairs of permanent 10- by 12-meter plots and 29 pairs of 6- by 9-meter plots.

Big and silver sagebrush bushes were counted on the 15 pairs of 10- by 12-meter plots. Supplemental information was collected from five belt transects on conservatively used range in or adjacent to the summer ranges. These ranged from 91 to 483 meters long and 2 to 4 meters wide. Numbers of young bushes were compared in 1946 on two upland and two bottom-land test areas where big or silver sagebrush was common. Seventy-two to ninety 0.1 milacre plots were examined per individual part of each area; appropriate age classes were judged by size and growth rings.

Fringed sagebrush plants were counted on test areas in 1944 and again in 1945 during the survey of basal area. Sampling frequency was about the same in both years, but units in 1944 were 0.1 milacre.

Height of Leaves and Seedstalks of Grasses

From 1933 through 1945 mature heights of western wheatgrass and blue grama leaves were measured annually within several exclosures

[12] In 1938, only use of western wheatgrass was sampled; the sampling plan differed thereafter.

established in 1932 and 1933 and located on several vegetation subtypes. Ten to twenty-five plants of each per exclosure were measured; these were selected by a restricted-random method. Leaves were extended and the tallest measured from tip to plant crown; leaves of seedstalks were excluded.

In the terminal years, comparisons were made of mature heights of leaves or seedstalks of principal grasses on summer test areas or entire parts of important grazing subtypes of all ranges or both, and growth of leaves at weekly intervals on four test areas. Individual vegetative shoots or seedstalks, as appropriate, closest to a sampling point were measured for each grass. Points were mechanically spaced and selected anew at each examination. Sixty to eighty points were usually observed on each date per test area per range. On subtypes, frequency approximated 3 to 10 points per acre. Other standards of measurement were the same as for exclosures. For seedstalks, heads were extended and measurements made to the tip, including awns or sheaths. In all cases, only ungrazed plants were measured.

Grass Moisture Content and Curing

Individual vegetative shoots of grasses were clipped at the plant crown near the time of their maturity in 1946 when ranges were ungrazed. Only small groups were collected at one time and placed immediately in covered containers. These groups were weighed immediately in the field. Moisture was computed on ovendry weights. Supplemental observations on curing were qualitative.

Number of Leaves Per Shoot

Leaves of individual shoots of mature western wheatgrass were counted; all leaves were tallied, including those that were broken off; shoots with seed heads were excluded. Procedures and frequency of sampling were the same as for height measurements.

Plants Producing Seedstalks

Clumps of mature forage grasses with and without stalks were tallied on four test areas. Sampling procedures and frequency were the same as for heights, except that entire plants were observed. Plants with one or more seedstalks were recorded.

Root Development

Roots within the surface 2 inches of soil were separated from sampling units taken for volume-weight determinations. These units were collected from interspaces among herbaceous plants, not closer than 1 inch from grass clumps or localized concentrations of plants. Soils were dried, granulated, and passed through a 2 mm. sieve; roots, rhizomes, and buried runners were retained. Estimated recovery was about 60 percent.

Surface Litter

All detached plant material other than current growth was collected by hand on plots 91.1 $cm.^2$ in area. Ninety to one hundred samples were taken per sampling area per range. Average recovery was 90 to 95 percent. Attached soil was removed by sifting or soaking and washing; small particles were recovered from the water with a fine screen. All samples were thoroughly air-dried before weighing.

Soil Volume-Weight

All vegetation and litter was cleared from the surface. Sampling units were taken not closer than 1 inch from blue grama and needle-and-thread clumps; dense buffalograss and heavy localized stands of western wheatgrass also were avoided. A smooth brass tube 2½ inches in diameter, with a cutting edge, was carefully driven 2 inches into the soil. The tube with surrounding soil was dug up, excess soil removed, and a clean cut made even with the end of the tube. The soil was than deposited in a paper bag. Ninety to ninety-six units were collected from each sampling area per range. These were composited by threes; each composite had a calculated volume of 494.2 cc. Samples were thoroughly air-dried and weighed; weights were converted to ovendry on the basis of representative subsamples.

Volume-weight samples were granulated, and duplicate composite subsamples for each area per range were analyzed for texture (*10*).

Soil Porosity

Total pore space was calculated from volume-weights and specific gravities (*4*). To approximate capillary pore space, samples of the upper 2 inches of the soils were collected 12 to 16 hours after a half-inch rain while the surface was still moist. At this time, drainage was assumed to have left only the capillary pores filled. Moisture content was determined, and with volume-weights the percent capillary space was computed as equal to volume-weight $\times$ cc. of water in soil-moisture sample $\div$ weight of ovendry soil in soil moisture sample $\times$ 100. Noncapillary pore space was taken as the difference between capillary and total space.

Organic Matter

Composite subsamples of the 2 millimeter and finer fraction of soil volume-weight samples were sieved a second time to further remove roots. Triplicate subsamples were analyzed by a wet combustion method (*44*); probable recovery was about 90 percent.

Absorption of Water

Cylinders with a sharp edge and an area of 91.1 cm.^{2} were driven about 1 inch into the soil after all vegetation and litter had been removed by hand. Locations were systematically alternated between blue grama clumps or buffalograss mats and interspaces or western wheatgrass cover. Two hundred cc. of water, about 0.92 inch, were poured into the cylinders through a screen baffle to break the fall and timed for complete absorption. Little compaction or disturbance was observed in driving in the cylinders, and lateral movement of water into the soil was slight. Twenty to forty readings were taken on representative sections of parts of the test areas that were compared.

In trials of litter influence, cylinders were located in interspaces among grass clumps. Where litter was left in place, about 75 to 110 percent of the surface was covered; where it was removed, similar amounts were originally present and were carefully picked off by hand. To minimize disturbance where litter was left intact, material that would have protruded was carefully trimmed before inserting cylinders.

For other comparisons, the same basic techniques were used.

Penetration of Rainfall

Measurements were made 1 to 2 days after rains and mostly on test areas that were sampled for surface soil characteristics. Nine comparisons were made averaging 16 measurements for each grazing intensity per area.

Supplemental Feed Records

Amounts provided were weighed prior to feeding, and weights and kind of feed were recorded daily during all feeding periods.

Cow and Calf Weights

Individual cows were weighed every 28 days during all summer seasons and irregularly during winter seasons, except in 1944–45 when 28-day weighings were made.

Calves were weighed within 24 hours after birth and every 28 days throughout all summer seasons until weaned.

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