TB 1371 (1967) USDA TECHNICAL BULLETINS UPDATA
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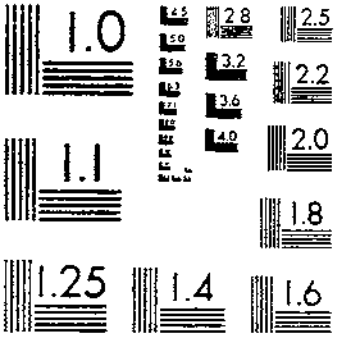

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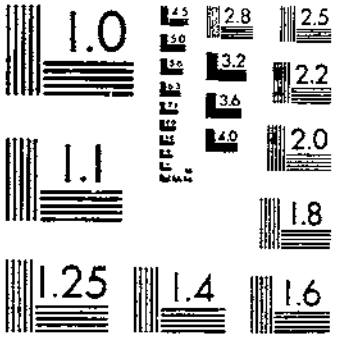

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Effects of Cattle Grazing on a Ponderosa Pine-Bunchgrass Range in Colorado

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Technical Bulletin No. 1371 **July 1967**

U.S. Department of Agriculture **Forest Service**

(This publication replaces USDA Circular 929, issued December 1953.)

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C., 20402 • Price 40 cents

ACKNOWLEDGMENT

The author is indebted to Dr. W. M. Johnson, Range Scientist, Forest Range and Watershed Laboratory, Laramie, Wyo., who conducted the grazing studies reported herein from 1940 through 1955. Dr. Johnson reported results for 1942–47 and part of 1950 in USDA Circular 929 (published in 1953). In this bulletin 1940-59 data are presented, and these results are used in a re-evaluation of the earlier findings.

CONTENTS

INTRODUCTION

A growing population is requiring more and more products from the land. As demand for beef and other rangeland products increases, so does the need for more intensive management.

Stockmen and other managers of private and public rangelands in the West are concerned with stocking the range to restore and maintain satisfactory forage production and quality, soil stability, and livestock production. For economic reasons the rancher grazing cattle on his own land must know how to maintain high forage production and how to produce maximum yields of high-quality beef. The goal of managers of public range is also to improve and maintain the range resource while obtaining maximum beef production.

From 1860 to 1910, virtually all commercial stands of ponderosa pine along the Front Range of the Colorado Rockies were cut. Numerous logging and access roads were constructed. Thousands of acres were burned. Many areas were cultivated, eventually abandoned, and left to return slowly to natural cover. In other areas, ponderosa pine[1] rangelands in Coloado were grazed too long, too heavily, or both. These practices and the probable absence of good management procedures resulted in extensive deterioration of native vegetation and excessive soil erosion.

In Colorado, the needs of men employed in mining, the first important enterprise in the State, provided the earliest incentive for growing crops and raising cattle and horses. The most rapid expansion of the cattle industry occurred between 1880 and 1890. Settlement of ponderosa pine land reached a peak before 1900; then the population began dwindling. However, the number of cattle grazing on National Forest land in Colorado increased until 1918, and it was not until the midthirties when animal months of grazing declined appreciably as efforts to manage forage resources and to stabilize the cattle industry were intensified.

In the West, ponderosa pine-bunchgrass range is one of the important vegetation types on which cattle graze. In Colorado it has provided forage for livestock for nearly 100 years. However, the optimum level of grazing still was not known by 1940. To determine that level, plant and animal responses to three grazing intensities were investigated on ponderosa pine ranges on the Manitou Experimental Forest from 1940 to 1959. The broad aim of this study was to help answer the question, "How closely can a ponderosa pine-bunchgrass range be grazed and still maintain maximum sustained production of forage and beef?" More specific questions concerned the relationships of three intensities of cattle grazing to: (1) Range utilization, (2) herbage production, (3) other plant responses, (4) soil conditions, and (5) cattle weight gain.

[1] Common and scientific names of species mentioned in this bulletin are listed on p. 57.

EXPERIMENTAL AREA

The Manitou Experimental Forest, on the Pike National Forest, occupies 25 square miles 28 miles northwest of Colorado Springs, Colo.

The Experimental Forest is representative of much of the ponderosa pine land along the eastern front of the Rockies in Colorado, both in characteristics of the land and history (fig. 1). The experimental area for this study consisted of 1,663 acres divided into six ranges of 254 to 309 acres.

Past Land Use

White man's use of the experimental area began about 100 years ago when a man named Bergen settled on what is now part of the experimental forest.[2]

[2] Information about past land use is based on material assembled by Professor Gordon Parker, Director of the former Colorado School of Forestry, Colorado College, Colorado Springs, Colo. Unpublished partial report, 1930 (with supplements through 1933), on file at Rocky Mountain Forest and Range Exp. Sta., U.S. Forest Serv., For Collins, Colo.)

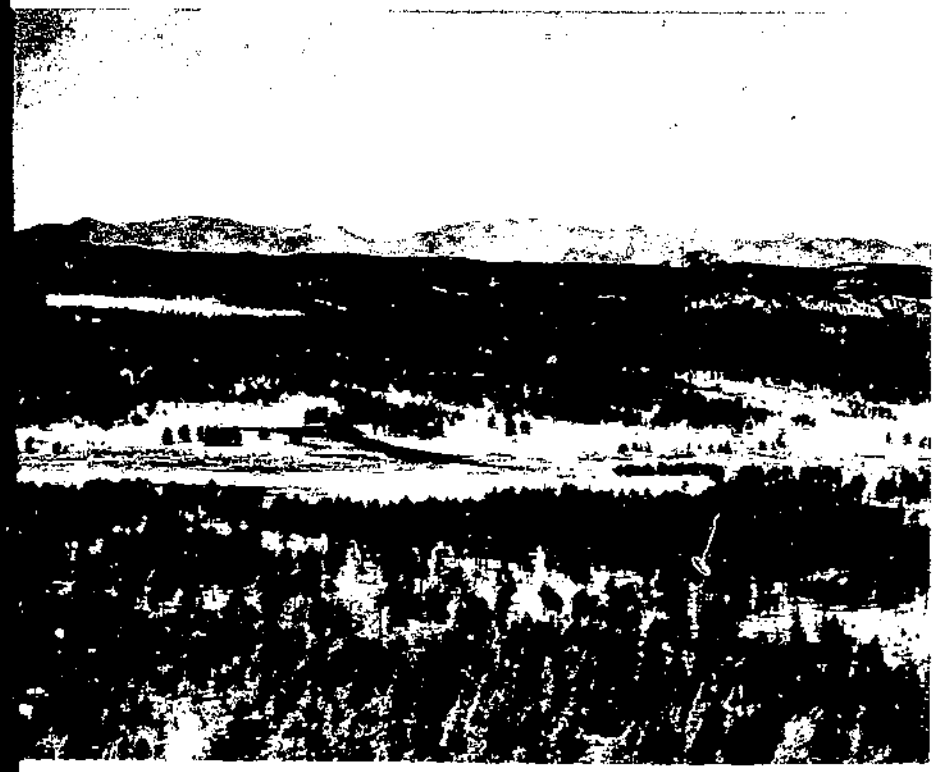
Figure 1.—A panorama

Between 1880 and 1885, all virgin ponderosa pine timber down to about 12 inches d.b.h. was cut from the area of this grazing study. Some of the land was cultivated in the late 1800's and early 1900's, but it was later abandoned. Rather sketchy records indicate that from 1912 through 1933 Colorado College lands were grazed by 225 to more than 300 head of cattle and horses, generally from May 1 to December 15. Considering the area grazed, grazing apparently was generally heavy. By 1935, when the Resettlement Administration began purchasing these lands, all of the area had been grazed. During the summers of 1935–38 and the winter of 1938–39, the whole area was moderately grazed.

All lands were transferred to the Forest Service in 1937. In 1940 the area was closed to grazing while fences, water developments, corrals, and other installations were completed. Experimental grazing began in 1941, but desired utilization levels were not attained until 1943.

Topography

The experimental ranges are in a broad mountain valley drained by Trout Creek, a tributary of the South Platte River. Elevations vary from 7,600 feet on the east to 8,200 feet on the west.



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Topography varies considerably within the experimental units. The western one-third of the area is fairly rough and irregular; slopes vary from 2 to 50 percent. Gently sloping benchlands and drainageways predominate over the eastern two-thirds; slopes range from 1 to 30 percent. Most of the land slopes eastward. The steepest slopes are from the tops of alluvial fans to the drainageways. Dense stands of timber occupy many of these slopes.

Geomorphology and Soil

Within the experimental area alluvium has been deposited as three sets of fans, one above the other.

The youngest fans are at the lower elevations in small pockets and along the drainageways as narrow bands. These fans received most of the early-day cultivation. The larger native grassland parks of the area also are found on these young fans.

Intermediate fans occur above the young fans and below the old ones. They occupy more than three-fourths of the experimental ranges. These fans are mostly large, smooth-surfaced benchlands, where slopes seldom exceed 10 percent. On these benchlands are open stands of ponderosa pine and their understory of bunchgrasses and forbs which typify much of the eastern slope of the Colorado Rockies.

The oldest fans, highest in elevation, are mostly in the western portions of the experimental area. They occupy about 15 percent of the total range area. Soils on old alluvial fans attain maximum development on level ridgetops. Ponderosa pine often grows in thick stands on these ridges. There usually is only a sparse understory of grass and forbs under the trees, but pine needles in most places form an effective erosion-preventing litter.

Soils within the experimental ranges were developed primarily from alluvial deposits of Pikes Peak granite (fig. 2). Principal components are quartz, orthoclase, and microcline. Biotite is an accessory mineral (Retzer 1949).[3]

Although soil characteristics vary with age of alluvium, soils within the experimental area are similar in many respects.

Surface soils are normally 12 to 18 inches deep. They are reddish-brown, low in organic matter, slightly acid, loose, and vary from sandy loam to loam. Despite gentle topography, surface soils erode readily when disturbed or not protected by adequate ground cover.

Where soils are better developed, the 6- to 12-inch-thick subsoil has a moderately developed structure and a sandy clay texture. Subsoils commonly are sandy loams that grade into unconsolidated gravelly parent material at depths of 30 to 40 inches.

Climate

The "dry subhumid" climate at the Manitou Experimental Forest is characteristic of most eastern slope areas in Colorado (Thornthwaite 1941). Influences of the distinctly continental climate are apparent. Winters are dry and often cold for long periods. Summers are cool and most precipitation occurs then (fig. 3). Winds are common during all seasons but seldom are strong.

[3] Names and dates in parentheses refer to Literature Cited, pp. 58–60.

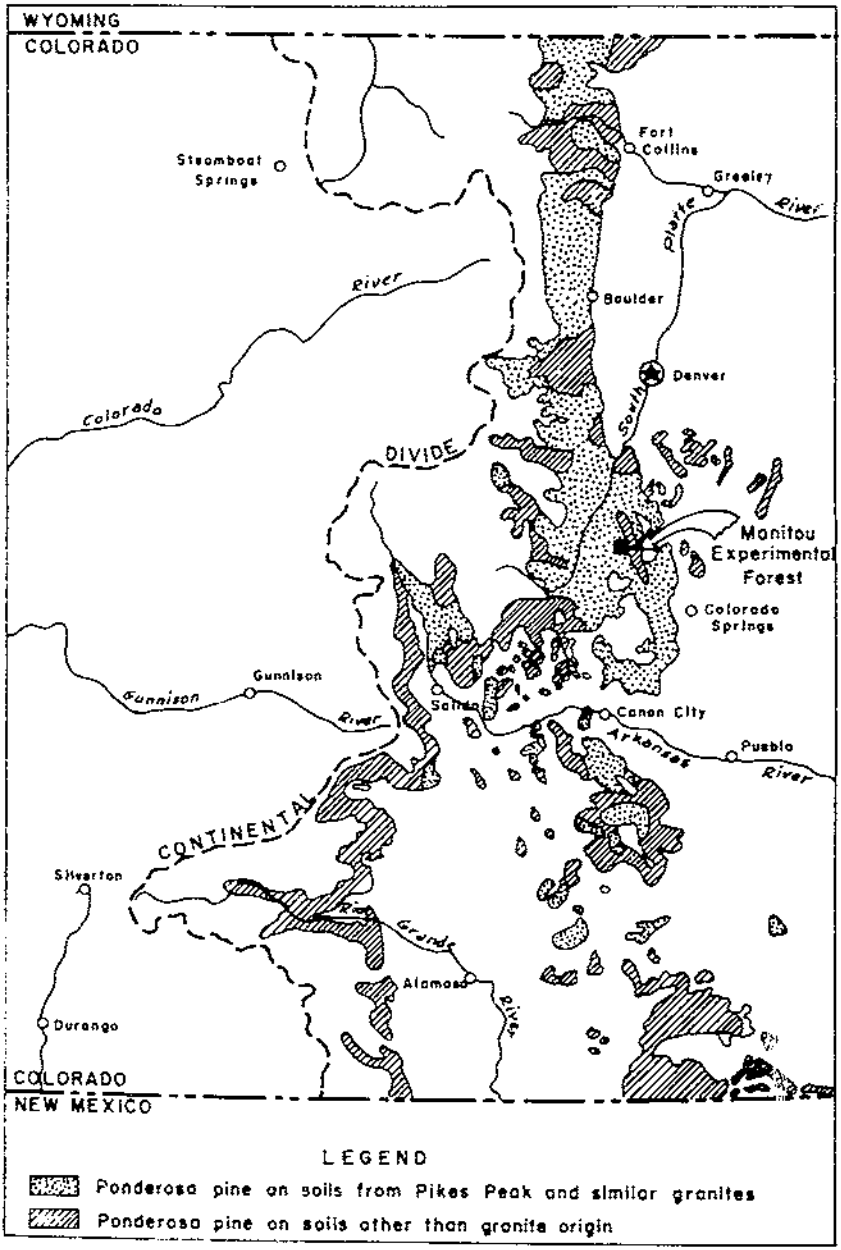

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Figure 2.—Extent and location of ponderosa pine ranges along the eastern flank of the Rockies in Colorado as related to soil origin.

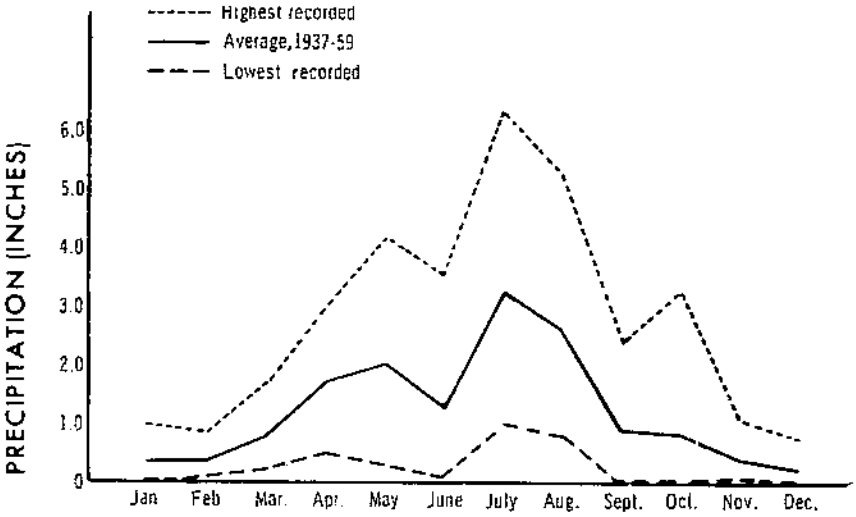

Figure 3.—Means and extremes of monthly precipitation, Manitou Experimental Forest, 1937-58.

Climatological data reported here are from a weather station at Manitou Experimental Forest headquarters (7,740 feet in elevation). The station is within 3 miles of all points in the experimental area. Precipitation records cover 23 years (1937 through 1959), and temperatures were recorded for 18 years (1942 through 1959).

Annual precipitation averaged 15.4 inches, but varied from 7.6 inches in 1939 to 23.6 inches in 1947. Seventy-three percent of the precipitation fell in the 5-month period between April 1 and August 31. Snow may fall between late September and late May, but only about 30 percent of the annual precipitation falls as snow. Snow usually melts within a few days on south slopes and level areas. Peak rainfall occurs in July and August. High-intensity storms, which may produce runoff and erosion, occur most frequently during these 2 months. However, such storms have been recorded each month from May through September (Dunford 1954).

Yearly temperatures at Manitou Experimental Forest averaged 40.6 °F. Mean monthly temperatures varied from 23.0° F. in January to 60.8° F. in July (fig. 4). Assuming that mean daily temperatures of 40° F. or higher are required for growth of aerial portions of most range grasses (Chapline and Cooperrider 1941; Clarke et al. 1947), the effective growing season averages about 180 days, from early April until late October.

Vegetation

Four types of vegetation are recognized within the experimental ranges (figs. 5, 6). They are: (1) *Dense timber*, mostly ponderosa pine with a closed canopy and little besides litter in the understory; (2) *open timber*, an open forest of pine with a ground cover of herbaceous vegetation and pine litter; (3) *grass-*

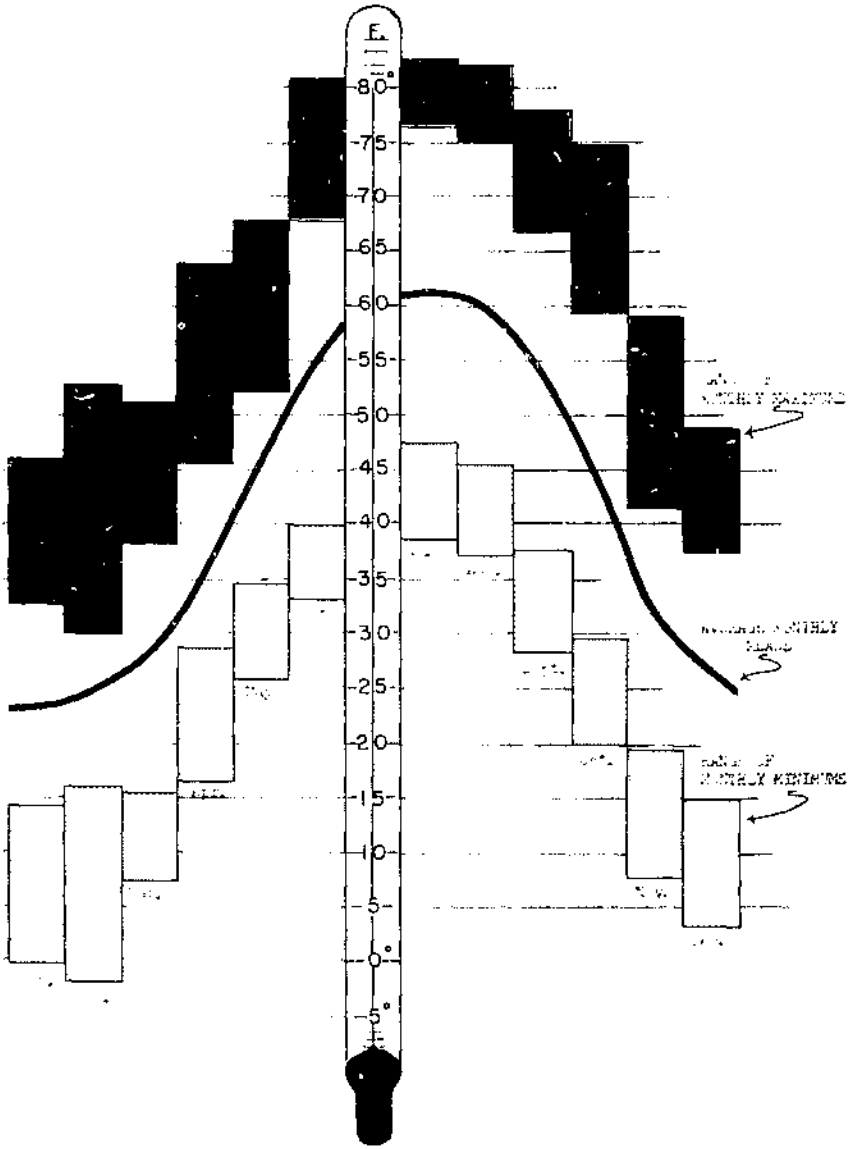

Figure 4.—Monthly mean temperature, and ranges of average monthly maximum and minimum temperatures, Manitou Experimental Forest, 1942–58.

land, parks or openings in the forest that are dominated by native bunchgrasses, have never been cultivated, and have a minimum diameter of more than 1 chain; and (4) *abandoned fields*, areas once cultivated, then abandoned, and now slowly returning to native cover.

Vegetation at the beginning of the study was fairly uniform throughout each cover type. However, among cover types vegetation differed considerably. Mountain muhly, Arizona fescue, and blue grama generally were the most abundant perennial

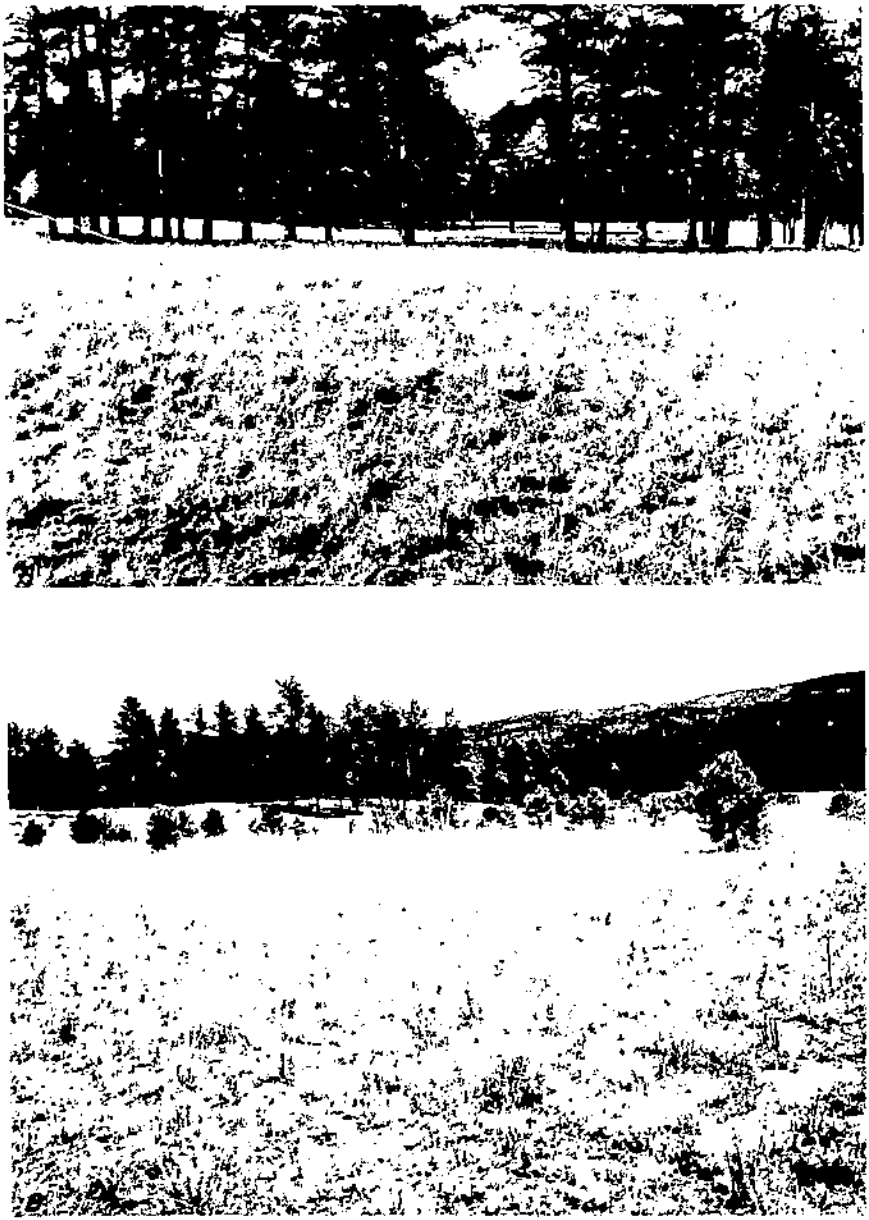

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Figure 5.—*A*, Grassland openings with open timber in background. The grasslands provide highest yields of forage on the experimental ranges. Arizona fescue and mountain muhly are the principal grasses. *B*, An abandoned field last cultivated about 30 years ago. Unpalatable sleepygrass and fringed sagebrush are conspicuous, but associated palatable forbs and grasses make these fields important grazing areas for cattle. Scattered pines are remnants of a reforestation attempt.

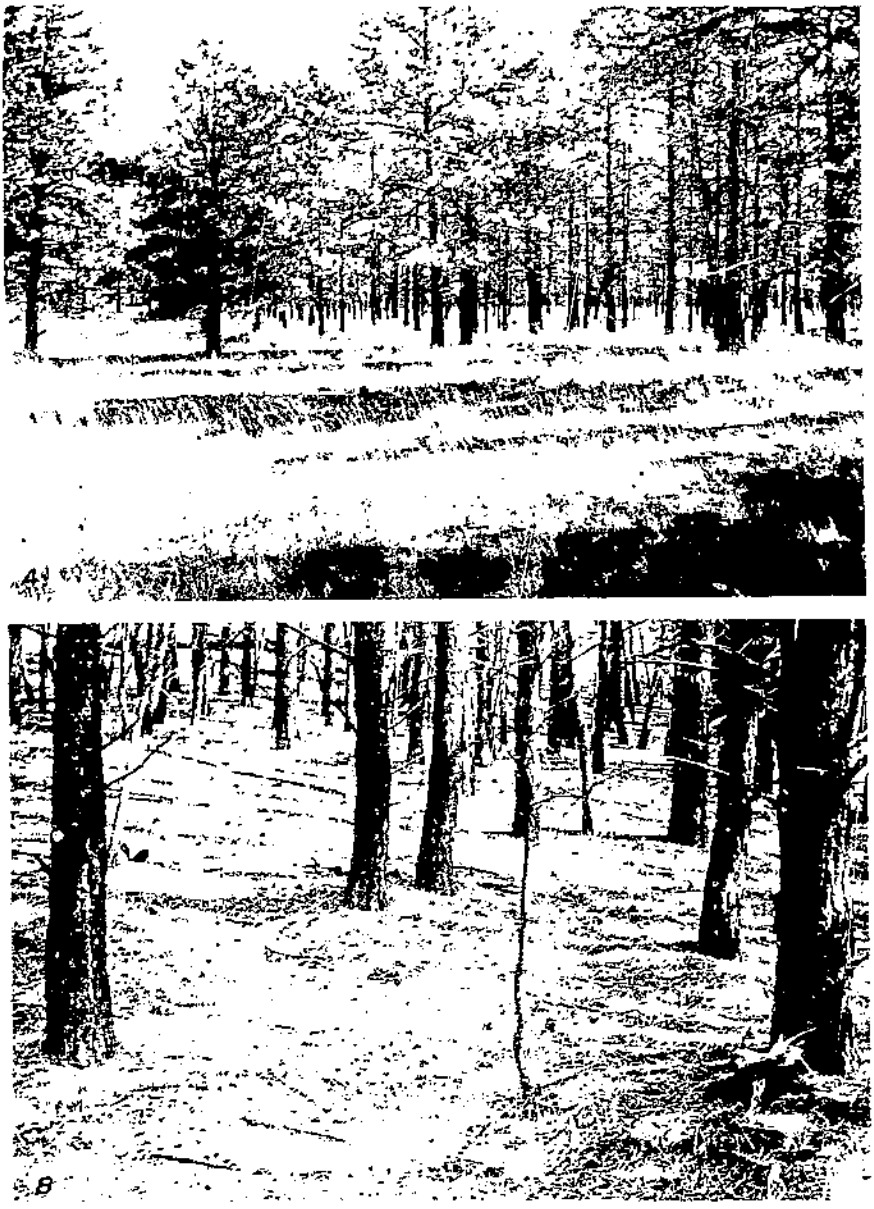

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Figure 6. — *A*. An open stand of ponderosa pine. Such stands occupy about 65 percent of the experimental ranges, but they produce only one-third to one-half as much forage as grasslands. *B*. A dense stand of ponderosa pine. Located mostly on ridges, these areas produce little forage but abundant litter.

grasses. Sun sedge was abundant and quite uniformly distributed within all cover classes. Sleepygrass was common, particularly on abandoned fields or other disturbed areas. Fringed sagebrush was most common on abandoned fields, and least under stands of timber. Rocky Mountain pussytoes, which provided the most ground cover of any forb, was abundant everywhere except on abandoned fields. Little bluestem and Parry danthonia were important grasses, but were restricted almost exclusively to the understory of dense or open timber stands. Shrubs were relatively scarce; the most common was bearberry, which was found only under stands of ponderosa pine.

THE EXPERIMENT

Design

The six experimental ranges were divided into two blocks. Block A contained ranges 1, 2, and 3; block B, ranges 4, 5, and 6. Three grazing intensities were assigned at random within each block. Ranges 2 and 5 were to be grazed the lightest; 3 and 6, moderately; and 1 and 4, the heaviest. In 1940, prior to the start of grazing treatments, two 2-acre exclosures were randomly located within each experimental range. Thus, ungrazed areas and those grazed at three intensities could be compared when evaluating responses to treatment.

Utilization goals, based on perennial grasses and sedges, were:

Light grazing—10 to 20 percent removal of herbage produced.

Moderate grazing—30 to 40 percent removal of herbage produced.

Heavy grazing—more than 50 percent removal of herbage produced.

These treatments were selected because it was believed they would include the optimum level of use. The principal species considered in utilization estimates were mountain muhly and Arizona fescue; however, utilization of all perennial grasses and sedges was considered.

The location and identification of various sampling units was simplified by establishing a coordinate grid system in each range. This grid consisted of permanently marked reference points established at 5-chain intervals along east-west compass lines 5 chains apart.

Comparisons Among Ranges

Table 1 compares cover types among ranges to be grazed at three intensities and between the two ranges that make up each treatment. Herbage production and plant cover are similarly compared in table 2.

Ranges 2 and 5 were grazed at the light intensity. Topography and proportions of vegetation cover types for these ranges were similar. Most grasslands occupied lower elevations along the gently sloping eastern portions of both ranges. Smaller grassland openings occasionally interspersed open stands of ponderosa pine in the rolling central and steeper western portions.

Ranges 3 and 6 were grazed at the moderate intensity.

Range 3 was characterized by generally rolling terrain. Small grassland parks were scattered throughout the range. A fairly large area of grassland, containing islands of open and dense ponderosa pine stands, was in the northeast corner. An 11-acre abandoned field in the southwest corner had been planted with ponderosa pine seedlings 3 or 4 years before the start of experimental grazing.

Table 1.—*Acreage, by cover type, on experimental ranges on Manitou Experimental Forest*

Grazing treatment and range number	Grassland	Abandoned field	Open timber	Dense timber	Total
	Acres	*Acres*	*Acres*	*Acres*	*Acres*
Light:					
2	71	35	184	19	309
5	73	18	165	19	275
Moderate:					
3	98	11	177	11	297
6	73	23	151	7	254
Heavy:					
1	82	24	158	5	269
4	31	9	213	6	259
Totals	428	120	1,048	67	1,662

Table 2.—*Herbage production in 1942 and plant cover in 1940 on Manitou Experimental Forest*

Grazing treatment and range number	Herbage production	Plant cover			
		Grass and grasslike plants	Forbs	Shrubs	Total
	Lbs 'a.	*Percent*	*Percent*	*Percent*	*Percent*
Light:					
2	295	1 8	2 5	1 0	5.3
5	341	2.0	2 2	.6	4.8
Moderate:					
3	342	2.0	3 1	.8	5.9
6	384	3.6	4 0	3	7.9
Heavy:					
1	408	2 4	3 0	1	5.5
4	292	3 0	2 6	.5	6.1

Table 3.—*Animal months grazed by yearling heifers on each range, 1941–58*

Year	Light use		Moderate use		Heavy use	
	Range 2	Range 5	Range 3	Range 6	Range 1	Range 4
1941	40	45	50	65	50	50
1942	30	35	70	105	85	85
1943	50	45	120	105	105	120
1944	60	50	100	105	105	120
1945	60	50	90	100	125	100
1946	60	55	90	105	125	90
1947	60	55	90	105	125	90
1948	60	55	90	105	125	90
1949	55	55	90	105	115	85
[1]1950	46	42	70	81	97	66
[1]1951	24	22	36	42	32	22
[1]1952	48	44	72	84	100	72
[1]1953	49	49	76	94	107	76
[1]1954	50	46	76	89	105	76
[1]1955	49	45	74	86	102	74
[1]1956	48	44	72	84	100	72
1957	50	45	70	85	100	70
1958	55	43	82	96	98	66

[1] Heifers taken off ranges early due to lack of forage.

The northern three-fifths of range 6 was characterized by rolling ridges covered with open timber stands, except for a few steeper slopes that supported dense stands of pine. Gently sloping grassland occupied most of the southern two-fifths of range 6; 23 acres had been cultivated in the 1870's. Although the plant composition still differed from natural grassland openings, this area in 1940 produced about the same amount of herbage as undisturbed grassland.

Ranges 1 and 4 were grazed at the heaviest intensity.

Range 1 was bisected by a broad drainageway that supported mostly grassland vegetation. This drainageway headed above the western boundary and extended across the entire range. In the eastern one-third of range 1, both sides of the drainageway were gently sloping benchlands occupied primarily by grassland and abandoned fields, and secondly by open stands of ponderosa pine. To the west, benchlands were predominately open pine; a small area of densely timbered steep terrain was near the southwest corner. There was 106 acres of grassland and abandoned fields.

Range 4 had two grassland parks totaling 31 acres and one 9-acre abandoned field. The latter was badly depleted and mostly planted to pine. Except for 6 acres of dense timber, the remainder of range 4 was classed as open timber. However, much of this was a fairly close stand. These conditions resulted in generally low herbage production.

Methods of Study

Grazing Treatment

It was planned to graze the experimental ranges with yearling heifers for 5 months, June through October. This procedure was followed in 11 years from 1941 through 1958; in 7 years of low herbage production when utilization goals were met before the end of the season, the cattle were removed earlier than scheduled. Stocking of the ranges for the 18-year period is shown in table 3.

In most years only Herefords were grazed, but during the 1950's a few Aberdeen Angus heifers were included. Heifers, furnished by local ranchers, were ear tagged and distributed proportionately by ownership among the six ranges. Heifers were weighed individually at the beginning and end of the grazing season. Prior to 1957 they were weighed monthly by pasture groups; thereafter, individual weights were recorded each month. To minimize the influence of fill, heifers were corraled late in the afternoon and held without food or water until weighed early the following morning.

Spring water was available to the cattle on three ranges during wet seasons and on two ranges in dry years. Water was hauled to the remaining units. Salt grounds, one to each range, were well away from water.

Utilization Measurements

The ocular-estimate-by-plot method (Pechanec and Pickford 1937) and the method described by Wilm et al. (1944) based on a line transect were used to estimate utilization during the first 2 years of investigation. Results obtained by the two methods agreed closely, and utilization determined on the line transects was accepted as the percentage of use. During the remainder of the study, utilization was estimated by the height-weight ratio method (Crafts 1938).

Total utilization of each range was measured each year during 1943–47 and again in 1957. Use areas were mapped from these data. To determine the average utilization for each range, the percentage of use was weighted according to size of use areas.

The intensive studies of utilization conducted during the early years provided a background of data and experience which guided the estimation of use during 1948–56. In these years, utilization of only certain key areas was estimated as a basis for removing the cattle. Since the ranges were not fully sampled, quantitative data on average use of each range are not available.

In evaluating utilization, abandoned fields and natural grasslands were combined and called grasslands.

A special investigation of utilization of individual plant species was carried out in 1950 and 1952. In both years plots were selected at random on areas grazed consistently at each of the three rates of grazing. Estimates, by plant species, were made in mid-July, mid-August, and late September by the ocular-estimate-by-plot method.

Herbage Production Measurements

Herbage production was measured by harvesting 100 to 121 temporary 1- by 2-foot plots within each range. Utilization was estimated on each plot in order to base production data on ungrazed conditions. These plots were located by a restricted randomization method in which each plot to be clipped was located completely at random within a 5- by 5-chain area.

Desirable grasses and sedges were clipped at ground level, air-dried, and weighed. Weights, in grams, were converted to pounds per acre. Species clipped were:

Arizona fescue	Needle-and-thread
Blue grama	Parry danthonia
Bluegrasses (all species)	Pine dropseed
Bottlebrush squirreltail	Prairie Junegrass
Little Bluestem	Sun sedge
Mountain muhly	Wheatgrasses (all species)

Additional production data for grasslands only were provided by 1- by 10-foot belt transects clipped in conjunction with condition classification studies carried out in 1954, 1955, and 1959. All plants were clipped by species in these plots.

For all herbage production determinations, plots were harvested shortly after the major grass species reached maturity. This generally was during the last 2 weeks of August or early in September.

Plant Cover Measurements

All information related to plant cover and most data concerning species composition were provided by the square-foot density method (Stewart and Hutchings 1936). In 1940, a 100-square-foot circular plot was established at alternate reference stakes within a permanent grid system established throughout the experimental area. This provided 322 plots, or about 1 plot for each 5 acres. The number of plots was doubled in subsequent years when 50-square-foot circular plots were estimated at each stake. Estimates were made by individual plant species.

Changes in plant cover estimates, caused by utilization and plant growth during the period of measurements, were confounded among treatments by rotating periods of measurement among all six ranges until sampling was completed.

Plant Growth Measurements

During several years of the study, maximum leaf lengths of Arizona fescue and mountain muhly were measured along paced transects within each range shortly before grazing began on June 1. During the 1950 and 1957 growing seasons, development of the same two grasses were recorded weekly. Inside a temporary exclosure on each range, 10 plants of each species were selected at random for weekly phenologic observation and measurement.

Grazing effects on plant growth were studied intensively in 1949 and 1950. In both years measurements and observations were made at 12 grassland locations. Three sites were fenced on each of three areas where past grazing had been average for light,

moderate, and heavy rates of grazing. Three additional plots were sampled inside exclosures that had not been grazed since 1939. Ten 1- by 10-foot sample plots were established at random within each fenced area. Average height growth, number of seedlings, number of plants, herbage yield, and litter accumulation were determined for major species. The average number of seedstalks and tufts per plant were counted for the grasses.

Relationships of roots to grazing intensity were investigated in 1958. Measurements included: (1) Depth of penetration, (2) lateral spread, and (3) root weights. Species studied were: Mountain muhly, Arizona fescue, blue grama, fringed sagebrush, and Rocky Mountain pussytoes.

Three sample areas were located at random within grassland areas of each range grazed moderately or heavily. Two areas also were located inside the ungrazed exclosure within grassland portions of ranges 1, 3, and 4. A trench was dug in each sample area, and two root monoliths were extracted by a modification of the method described by De Roo (1957) and several others. One monolith was excavated to a 36-inch depth, the other to 72 inches. Most of the roots occurred in the upper 36 inches. Therefore, only half as many of the more costly 72-inch samples were taken. Specially constructed pin boards, 3 feet high, 2 feet wide, and 3 inches deep, were used to extract the monoliths. These boards effectively held the roots in their natural position while the soil was being washed away.

Infiltration and Erosion Measurements

Infiltration rates were measured with a rainfall simulator, the Rocky Mountain infiltrometer (Dortignac 1951).

Using this instrument, artificial rain is applied to a 40-square-foot area which includes the 2.5-square-foot infiltrometer plot. About 24 hours after the soil has been prewet, about 4.5 inches per hour of rainfall is applied for a test period of 50 minutes. Erosion results are based on soil loss during this period. Infiltration results presented refer to the average infiltration rate during the last 20 minutes of the 50-minute rainfall application.

In locating infiltrometer plots an attempt was made to reduce sampling errors caused by variations in soil, cover, and topography by dividing each range into three strata based on topography. Then three sites, representing the major cover types, were selected at random within each stratum. Two infiltration plots were located at each sampling site. Thus, 18 infiltrometer plots were measured in each of the 6 ranges.

UTILIZATION

Grazing Treatments Obtained

In the first 2 years of stocking (1941 and 1942), utilization generally was lighter than planned on the experimental ranges. The established goals were attained, however, in most years from 1943 to 1958.

As explained under "Methods of Study," utilization of each range was completely sampled only during 1943–47 and 1957. The number of cattle was reduced in 1957, however, and desired use was not obtained. Thus, the 1943–47 averages are the best data available for describing use levels on each range. These values are diagrammed in figure 7.

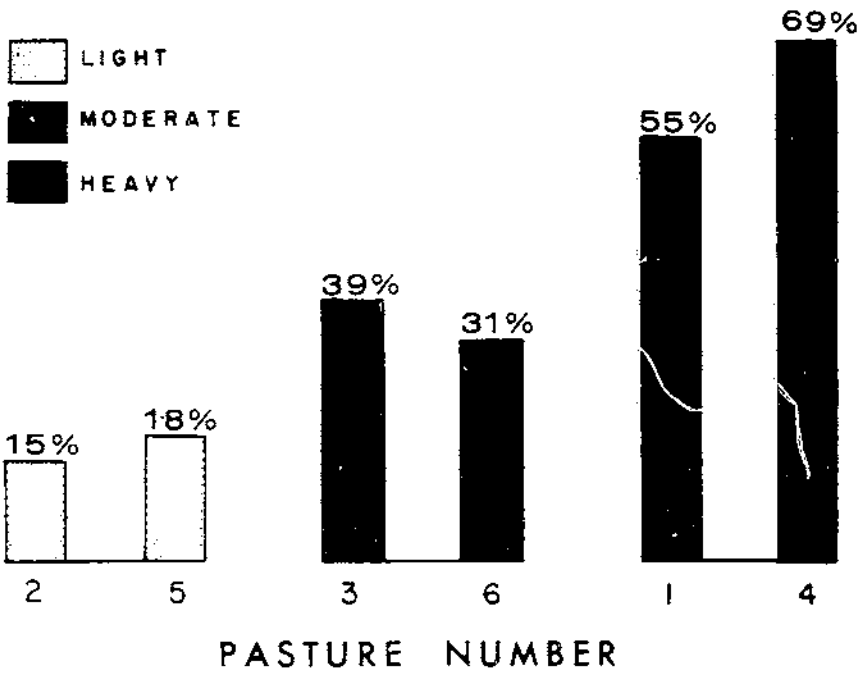

Figure 7.—Average utilization of perennial grasses and sedges on the six experimental ranges, 1943-47.

Percentage utilization, under the intensities of grazing tested, was more closely related to the number of plants grazed than to the extent to which the individual plants were cropped. For example, in 1957, heights of grazed and ungrazed plants were measured, and utilization was estimated from height-weight curves. The stubble height of each grazed plant was about the same, regardless of grazing intensity. The percentage of plants grazed increased markedly, however, as utilization increased from light to moderate to heavy. Figure 8 demonstrates these differences.

Grazing Patterns

Irregular patterns of grazing were noted early in the study. Such patterns were characteristic of all ranges. Though location of stock water and salt grounds had some effect, grazing patterns were influenced mainly by vegetation cover type.

The influence of physical developments and cover types on grazing distribution in moderately grazed range 3 is shown in figure

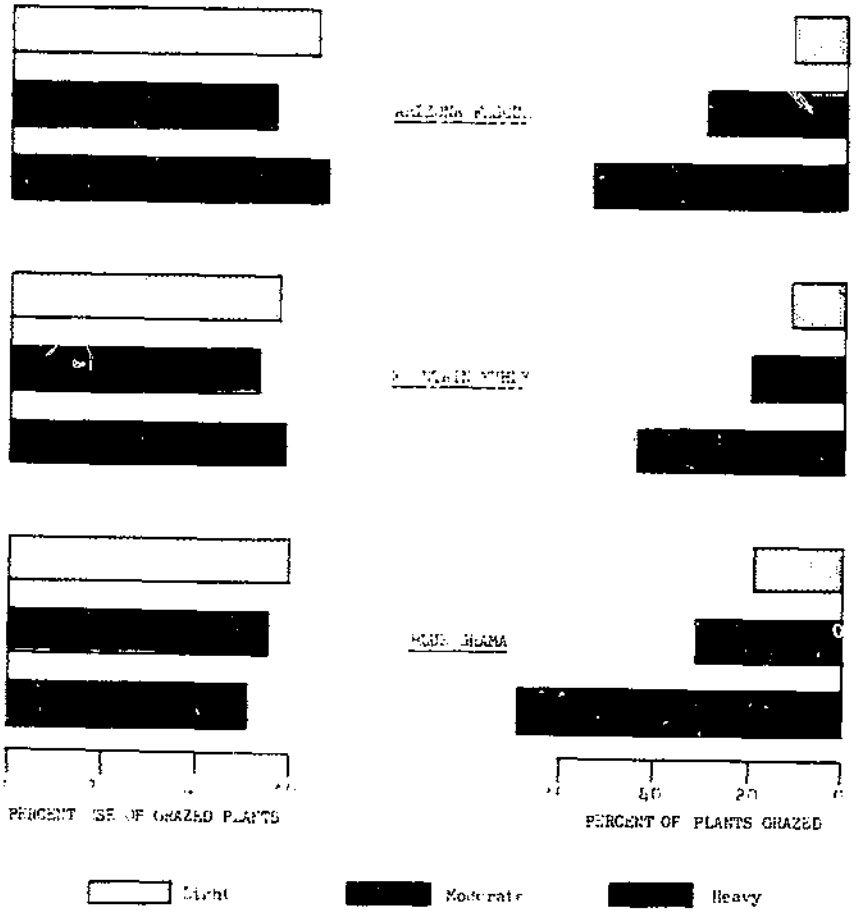

Figure 8.—Average use of grazed plants compared with percent of plants grazed under three intensities of grazing, 1957.

9. Use throughout the range averaged little more than 20 percent in the year illustrated. Herbage in dense timber was essentially ungrazed, however, while use of desirable bunchgrasses on an abandoned field and native grasslands averaged as high as 65 percent.

Table 4 shows how different vegetation cover types were grazed under the different treatments during 1943–47 and 1957. In general, use within timbered types became proportionately greater as average use of the range increased.

Figure 10 illustrates that Arizona fescue is utilized most heavily on grasslands under all levels of grazing and that use becomes more uniform among cover types as grazing increases.

Limited areas on which the highly palatable Kentucky bluegrass occurred were heavily grazed by cattle. These areas often were small, moist swales or drainage bottoms surrounded by timbered range. Yet the cattle readily located these choice grazing

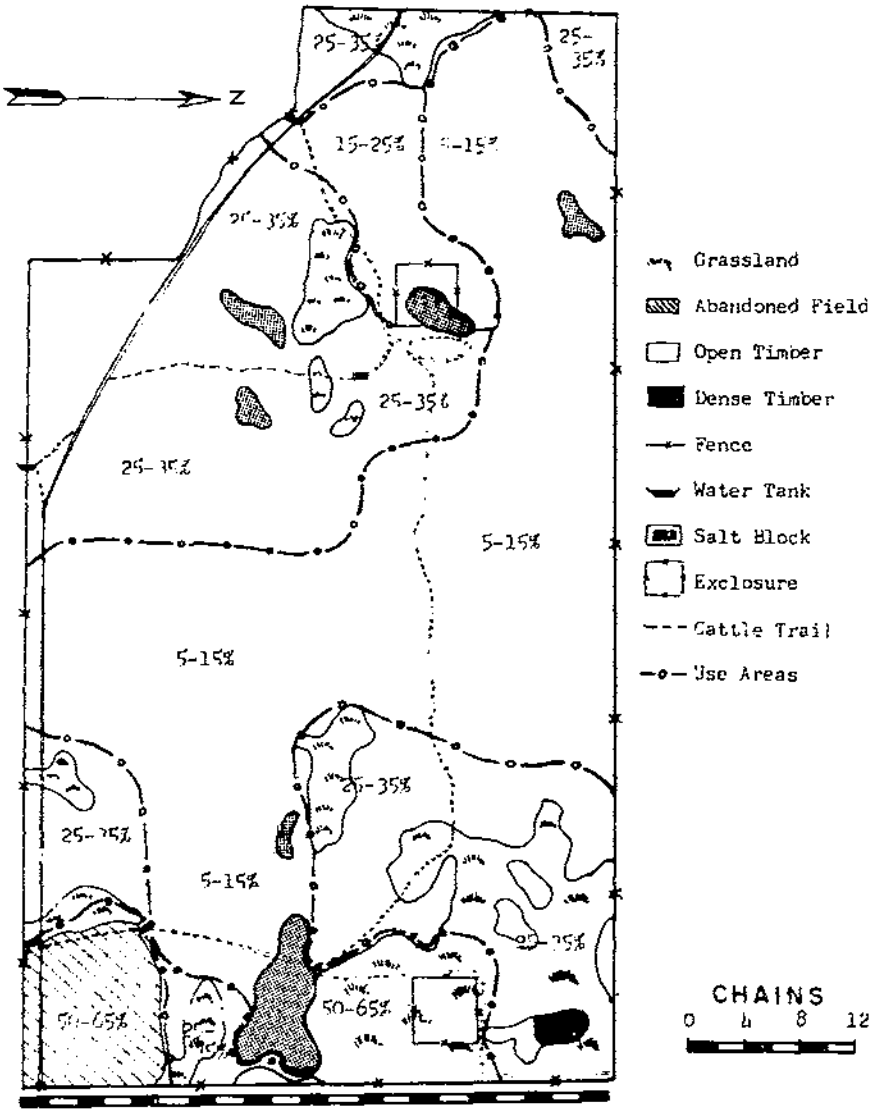

Figure 9.—Pattern of grazing on range 3 in 1957.

spots and utilized up to 90 percent of the bluegrass plus a high proportion of associated plants.

Heavier grazing in open grassland than under stands of timber does not occur only on the Manitou Experimental Forest. Similar relations have been described for other pine-grassland ranges (Arnold 1950; Crafts 1938; Glendening 1944; Pickford and Reid 1948). In fact, larger range units with steeper topography, such as the Elk Ridge Allotment in central Colorado (Reid and Love 1951), may have much greater disparity in grassland and timberland use than the Manitou.

Table 4.—*Utilization as influenced by vegetation cover types*

Year and cover type	Light use		Moderate use		Heavy use	
	Range 2	Range 5	Range 3	Range 6	Range 1	Range 4
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1943:						
Grassland	23	32	53	40	59	66
Open timber	12	8	36	24	32	55
Dense timber	0	0	0	0	0	0
1944:						
Grassland	18	29	36	41	70	84
Open timber	6	6	40	20	37	73
Dense timber	0	0	0	0	0	0
1945:						
Grassland	47	40	38	36	70	84
Open timber	7	7	40	29	45	70
Dense timber	0	0	0	0	0	0
1946:						
Grassland	24	42	43	38	75	84
Open timber	7	7	38	22	50	70
Dense timber	0	0	0	0	0	0
1947:						
Grassland	25	42	37	38	78	82
Open timber	7	8	38	22	55	70
Dense timber	0	0	0	0	0	0
1957:						
Grassland	8	29	35	24	41	54
Open timber	10	6	13	11	33	30
Dense timber	3	1	3	4	13	14

Use of Plant Species

An effective range manager must know which plants make up the forage, their relative value as forage, their ability to withstand grazing, and how they are grazed. The grazing of individual species in the grassland type was studied in 1950 and 1952, when the experimental ranges had been grazed at three intensities for 6 and 8 years, respectively. This differential grazing had created marked differences in range conditions. The appearance of ranges grazed at three levels is compared in figure 11.

Herbage composition, based on weight of herbage produced, was estimated on thirty 25-square-foot plots randomly located within one of the two ranges grazed at each intensity. Utilization of important species plus "other grasses" and "other forbs" was estimated on July 18, August 15, and September 26, 1950. Estimates were repeated on the same plots in 1952.

Only six of the species were sufficiently abundant or palatable to warrant separate consideration. These were Arizona fescue, mountain muhly, little bluestem, sun sedge, blue grama, and fringed sagebrush. The most abundant grasses, Arizona fescue and mountan muhly, furnished 94 percent of the forage provided

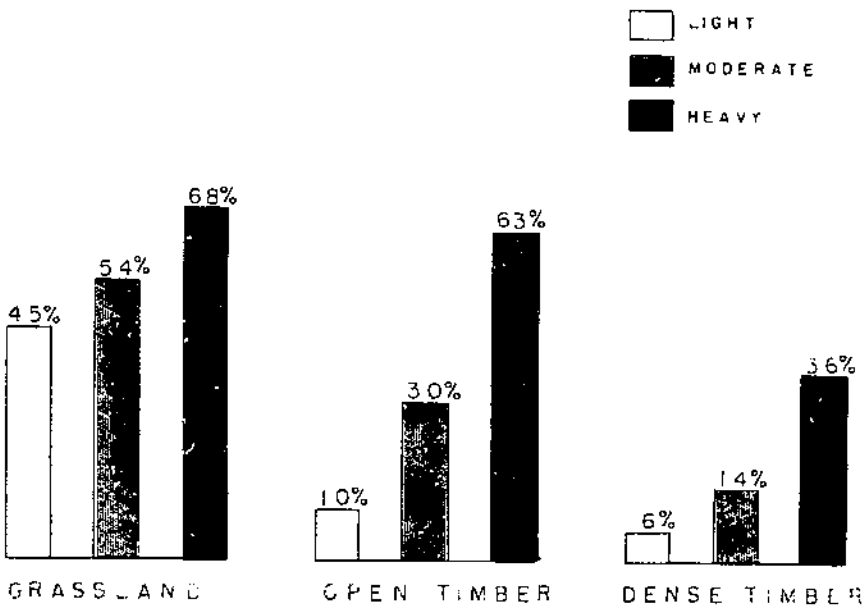

Figure 10.—Relation of percent of Arizona fescue plants grazed to cover type and grazing intensity, 1957.

by the six species on both lightly and moderately grazed ranges (table 5). Little bluestem and sedge produced 5 percent of the forage. These four species were the most palatable plants under all intensities of grazing. Blue grama was grazed sparingly under both levels of use, and fringed sagebrush was not used at all where grazing was light and received only 3-percent use where it was moderate.

Although not considered in the special study because of their scarcity, such species as Parry danthonia, prairie Junegrass, Canby bluegrass, wheatgrasses, and purple milkvetch were grazed eagerly under all grazing levels wherever they occurred.

Table 5.—*Utilization of important plants under three grazing intensities, and their relative contributions to forage supply, average of 1950 and 1952*

Species	Lightly grazed		Moderately grazed		Heavily grazed	
	Utilization	Forage composition	Utilization	Forage composition	Utilization	Forage composition
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Arizona fescue	20	28	38	44	74	15
Mountain muhly	17	66	36	50	70	53
Little bluestem	22	3	27	1	48	6
Sun sedge	12	2	20	4	42	6
Blue grama	3	1	8	1	24	14
Fringed sagebrush	0	0	3	0	29	6

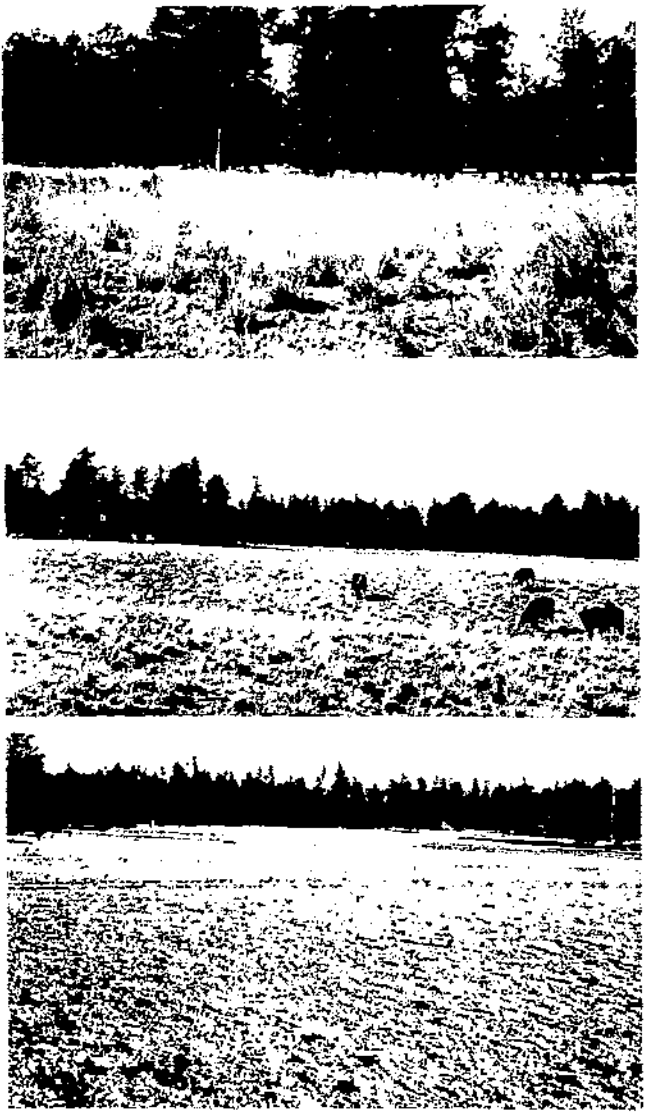

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Figure 11.—Top, Lightly grazed grassland park. This area was stocked with one heifer per 25.5 acres (including timbered areas) for 5 months. Arizona fescue and mountain muhly furnished about 95 percent of the forage. Palatable grasses and sedges on lightly grazed grasslands yielded about 800 pounds per acre. Middle, Moderately grazed grassland. This range was stocked with one heifer per 14.5 acres. Arizona fescue and mountain muhly still made up nearly 95 percent of the forage. Bottom, Heavily grazed grassland. Average stocking rate was one heifer per 12.5 acres. Composition of plant cover and vigor of plants deteriorated. Unpalatable forbs such as Rocky Mountain pussytoes increased, and Arizona fescue and mountain muhly comprised only 68 percent of the forage.

Utilization of all six species on heavily grazed areas was greater than that on more lightly cropped ranges. Arizona fescue and mountain muhly received the most use—74 and 70 percent. However, they furnished only 68 percent of the forage—much less than on moderately or lightly grazed ranges. Mountain muhly was the outstanding species; Arizona fescue was considerably reduced by prolonged close grazing.

Together, little bluestem and sedge furnished 12 percent of the forage on heavily grazed range during the 1950 and 1952 seasons. Measurements and observations in other years showed that these highly palatable species may receive 80 percent or more use in some years.

Although blue grama under heavy grazing was utilized only about 24 percent, it furnished as much forage as Arizona fescue. Fringed sagebrush was utilized slightly more than blue grama and produced about 6 percent of the forage.

Sun sedge was palatable under all intensities of use, particularly early in the season. However, its season-long use was not excessive. When mountain muhly and Arizona fescue were grazed about 70 percent, for example, sedge was grazed only 40 percent.

Seasonal Effects

Utilization of individual forage species varied within the grazing season as well as with intensity of grazing (fig. 12). The effect of season on forage preference was demonstrated in a study of cattle grazing habits in eastern Colorado. In reporting on this study, Reppert (1960) stated that "preference for certain species was very definite and varied considerably at different times of the year."

On areas grazed most lightly, Arizona fescue was utilized at an almost uniform rate throughout the 117-day season. In contrast, on moderately grazed ranges cattle consumed 64 percent of the total fescue used during the first 48 days. Rate of use then declined from mid-July to mid-August, and was still lower during the final 6 weeks of the season. On heavily grazed ranges, cattle consumed 57 percent of the total fescue used during the first 48 days. Throughout the remainder of the season it was grazed less.

Mountain muhly was grazed mostly during the latter part of the season. Under all intensities of grazing, more than half the muhly that was used was grazed during the last 6 weeks.

Grazing of little bluestem and sedges followed the same trend as for fescue on heavily and moderately grazed areas. On lightly grazed ranges, bluestem was grazed mainly during the middle of the summer.

Blue grama and fringed sagebrush were relatively unpalatable, as shown by the light use they received, even on heavily stocked ranges. Of the six species studied, these two were utilized least consistently. The grama on lightly and moderately grazed areas received the most use during late July and August. On heavily grazed areas, the greatest use occurred even later in the season.

In general, plants were grazed most readily during the period of fastest growth. Arizona fescue, little bluestem, and sedge

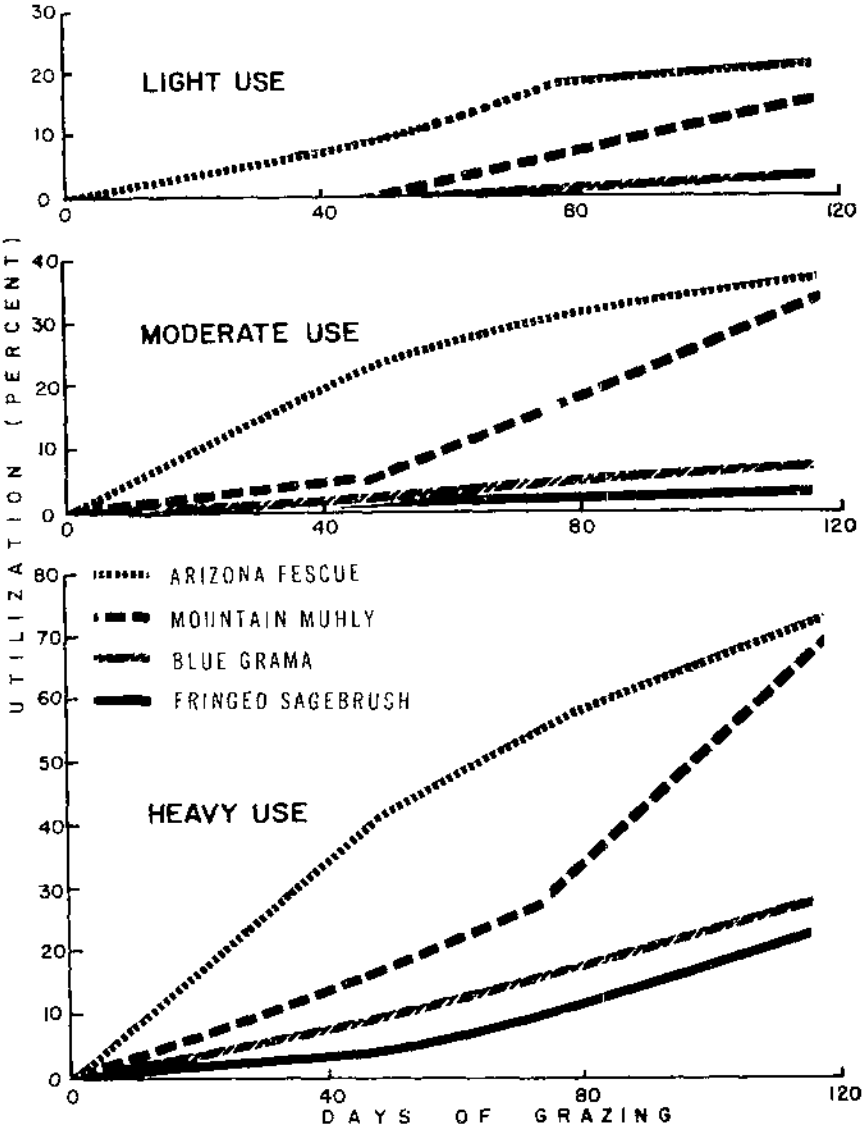

Figure 12.—Seasonal use of major forage species on pine-bunchgrass ranges, average of 1950 and 1952.

grew early in the season, and were grazed most then. The period of rapid growth for muhly and grama was later, and these species were grazed later. Measurements taken on moderately grazed ranges in 1950 illustrate how plant growth is related to cattle preference. By July 1, Arizona fescue had made 90 percent of its height growth and had furnished 72 percent of the forage it was to supply that year. However, mountain muhly had attained only 60 percent of its full height and received only 29 percent of its total use by July 1.

PLANT RESPONSES TO GRAZING INTENSITY

Plant responses to grazing were studied by comparing levels of grazing as to: (1) Changes in plant cover from beginning to end of the treatment period, (2) total growth of leaves and flowerstalks in 1957, (3) leaf growth as of the last week in May during later years of the study, (4) phenological development in 1950 and 1957, (5) depth, lateral spread, and amount of roots in 1958, and (6) herbage production from beginning to end of the study.

Plant Cover Changes

From 1940 to 1957, important vegetation changes resulted from the grazing treatments applied. The following discussion is concerned mainly with these changes. However, in some areas vegetation was advancing through successional stages on fields that were cultivated and abandoned before this study began. Also, a 7-year drought in the 1950's apparently was responsible for other alterations in plant cover.

Total plant cover increased inside exclosures that were protected from cattle use and also on ranges grazed lightly. It decreased slightly on moderately grazed ranges and markedly on heavily grazed ranges.

When all cover types are considered, sedge and perennial grass cover remained about the same from 1940 to 1957 under light and moderate intensities of use, but decreased significantly on ranges grazed heavily (table 6). Perennial forb [4] cover did not change appreciably under any intensity of grazing.

Changes in plant cover will be discussed first as related to classes of vegetation, and then with reference to important species.

Changes by Vegetation Type

Grasslands.—Grass and sedge cover nearly doubled from 1940 to 1957 when grasslands were grazed lightly, increased almost one-third under moderate use, and decreased nearly one-half under heavy grazing. Forb cover increased slightly under light use, but decreased in composition because of the larger increases in grass and sedge cover. Total vegetation cover increased from 6 percent in 1940 to 7.6 percent in 1957 on grassland grazed at the lightest intensity. On grasslands grazed moderately, forbs were reduced substantially. The total plant cover changed little. Forbs decreased markedly on heavily grazed ranges. However, their relative composition increased from 55 to 63 percent because of the decrease in grass and sedge cover. Total plant cover dropped from 10.8 to 7.7 percent.

Cover within the exclosures protected from grazing for 18 years was nearly twice as dense as on any of the grazed ranges. In 1957, perennial grasses and sedge made up 59 percent of the cover inside exclosures compared with 51, 51, and 34 percent on lightly, moderately, and heavily grazed grasslands. The fences were erected in 1940; however, measurements of cover inside the

[4] Fringed sagebrush, a half-shrub, is included in the perennial forb category.

Table 6.—*Plant cover and composition in 1940 (before treatment) and in 1957 (after 16 years of cattle grazing at 3 intensities)*

Vegetation Classes	Year	Grassland				Abandoned field			Open timber				Dense timber			All cover types		
		Not grazed	Light use	Moderate use	Heavy use	Light use	Moderate use	Heavy use	Not grazed	Light use	Moderate use	Heavy use	Light use	Moderate use	Heavy use	Light use	Moderate use	Heavy use
PLANT COVER																		
		Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Perennial grasses and sedge	1940	.	2.1	3.8	4.8	1.3	4.6	0.6	. . . .	2.1	2.6	2.4	1.2	0.9	1.8	1.9	2.8	2.7
	1957	8.9	3.8	4.9	2.6	4.1	8.4	1.8	2.2	1.6	2.0	.9	.6	.6	.3	2.0	2.6	1.3
Perennial forbs[1]	1940	.	3.2	0.5	5.9	3.4	7.2	5.2	.	2.5	2.8	1.8	1.2	1.2	1.6	2.3	3.5	2.8
	1957	5.4	3.6	4.4	5.9	3.7	3.6	5.4	3.0	2	62.9	1.7	1.1	1.2	1.4	2.6	3.0	2.6
All others	1940	.	.7	2	.1	.3	.8	.3	. . . .	.9	.8	.4	1.4	.7	1.0	.9	.6	.3
	1957	.7	2	.3	.2	.5	.5	1.0	.7	.7	.6	.1	.7	.2	.0	.6	.5	.1
Totals	1940	.	6.0	10.5	10.8	5.0	12.6	6.1	.	5.3	6.2	4.6	3.8	2.8	4.4	5.1	6.9	5.8
	1957	15.0	7.6	9.7	7.7	8.3	12.5	8.2	5.9	4.9	5.5	2.7	2.4	2.0	1.7	5.2	6.1	4.0
PLANT COMPOSITION																		
		Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Perennial grasses and sedge	1940	.	35	36	44	25	37	9	. . . .	40	43	53	32	33	42	37	41	46
	1957	59	51	51	34	49	67	22	37	32	37	34	24	33	19	38	42	32
Perennial forbs[1]	1940	.	53	62	55	67	57	85	. . . .	43	45	40	32	44	35	45	50	48
	1957	36	47	46	63	45	29	66	52	53	52	63	44	59	77	50	49	64
All others	1940	.	12	2	1	8	6	6	. . . .	17	12	7	36	23	23	18	9	6
	1957	5	2	3	3	6	4	12	11	15	11	3	32	8	4	12	9	4

[1] Includes *Artemisia frigida*, a half-shrub.

exclosures were not made until 1947. Thus, cover within the exclosures at the beginning and end of the study could not be compared.

Abandoned fields.—Total plant cover increased considerably on abandoned fields under both light and heavy treatments, but remained the same on moderately grazed ranges. Perennial grasses and sedge also increased substantially on all treatments, both in cover and composition. Actual cover of forbs declined only on ranges grazed moderately; under all intensities of grazing, however, the proportion of forbs was substantially lower in 1957 than in 1940. This suggests that plant succession had advanced on abandoned fields.

Cattle were attracted to abandoned fields, possibly by the variety of forbs. Consequently, such areas were used quite heavily under all grazing treatments. Nevertheless, large increases of perennial grasses, contrasted to small increases or to losses on the grassland type, further indicate that succession was largely responsible for changes in plant cover on abandoned fields during the study period.

Timbered ranges.—Understory plant cover within both open and dense stands of timber decreased under all intensities of grazing, particularly heavy. Perennial grasses and sedge declined more than forbs, both in cover and percent composition, at all grazing levels and within both timber types. The area occupied by forbs was essentially the same in 1957 as in 1940. Though crown cover of pine was not measured, comparison of photos taken in 1958 with similar ones taken in the early 1940's showed a substantial closure of the canopy. This change alone would be expected to reduce the understory vegetation.

Total plant cover within exclosures in the open timber type averaged little more than on comparable areas grazed lightly or moderately, but considerably more than on ranges utilized heavily. Composition of cover varied little between grazed and ungrazed areas.

Changes by Plant Species

Eighteen years of grazing at known intensities on Manitou experimental ranges has permitted the observation of the ecology of important plants as related to different intensities of grazing, and to suggest species to use as indicators of effects of grazing. Of 186 species identified, representing 132 genera and 40 families, only 21 species were common or abundant enough to warrant detailed evaluation. Covariance analyses were used to evaluate changes in cover of these species.

Plants were grouped into three categories: (1) Plants favored by lighter grazing; (2) plants favored by heavier grazing; and (3) plants not affected by grazing intensity. Plant cover and composition data are also grouped in these three categories in tables 7 and 8. Two additional groups are discussed: plants that (1) increased and (2) decreased following protection of formerly grazed area. Conclusions are supported by comparisons with the earliest data taken on the protected exclosures in 1947, and by comparisons with estimates of cover on immediately adjacent grazed ranges.

Table 7.—*Plant cover of major species on grassland, open timber, and all types combined at beginning and end of the study*

Species	Grassland						Open timber						All types combined					
	Light		Medium		Heavy		Light		Medium		Heavy		Light		Medium		Heavy	
	1940	1957	1940	1957	1940	1957	1940	1957	1940	1957	1940	1957	1940	1957	1940	1957	1940	1957
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Plants favored by lighter grazing:																		
Mountain muhly	1.39	2.12	1.86	1.23	2.75	1.03	0.92	0.76	1.20	0.96	0.87	0.47	0.97	1.00	1.19	0.94	1.21	0.59
Arizona fescue	.19	.14	.62	.57	.60	.05	.28	.30	.68	.56	.48	.07	.23	.21	.60	.50	.46	.06
Blue grama	.16	1.26	.60	2.40	.88	1.09	.06	.06	.07	.06	[1]	.05	.07	.30	.32	.60	.16	.31
Bottlebrush squirreltail	.02	.02	.07	.01	.02	[1]	[1]	[1]	.02	.01	[1]	0	.01	.02	.03	.01	.01	[1]
Lupines	.06	.02	0	[1]	.23	.02	.06	.06	.05	.03	.08	.01	.05	.04	.06	.02	.10	.01
Bearberry	.06	0	0	0	0	0	.61	.47	.54	.45	.16	0	.53	.36	.42	.33	.19	0
Arkansas rose	.36	.03	0	[1]	0	0	.04	.03	.08	.03	.07	[1]	.10	.03	.07	.02	.06	[1]
Plants favored by heavier grazing:																		
Tumblegrass	.22	0	.02	.01	0	.01	[1]	0	0	0	0	0	.05	[1]	[1]	.01	.01	.02
Rocky Mountain pussytoes	.66	.77	2.58	1.05	2.11	1.91	1.12	1.11	1.54	1.34	.81	.98	.88	.84	1.51	1.16	1.04	1.15
Groundsels	.17	.08	.21	.02	.10	.08	.07	.09	.06	.08	.02	.06	.09	.08	.08	.07	.03	.06
Goosefoot	.04	.04	.03	.06	.01	.05	.04	.03	.02	.04	.01	.03	.04	.03	.03	.04	.01	.04
Plants not affected by grazing intensity:																		
Sun sedge	.17	.13	.28	.16	.25	.25	.23	.20	.26	.18	.34	.19	.19	.16	.24	.16	.29	.18
Fringed sagebrush	1.34	1.45	2.48	2.25	2.42	1.73	.30	.28	.42	.40	.27	.11	.52	.59	.92	.74	.82	.65

[1] Less than 0.005 percent cover.

Table 8.—*Plant composition of major species at beginning and end of study on all cover types combined.*

Species	Light use		Moderate use		Heavy use	
	1940	1957	1940	1957	1940	1957
	Per-cent	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*
Plants favored by lighter grazing:						
Mountain muhly	19.1	19.4	17.2	15.4	20.8	14.6
Arizona fescue	4.5	4.1	8.7	8.2	8.0	1.5
Blue grama	1.3	5.8	4.6	9.8	2.8	7.7
Bottlebrush squirreltail	1	.4	.4	.2	.2	(1)
Lupines	1.0	.8	.9	.4	1.6	.3
Bearberry	10.4	6.9	6.0	5.4	3.3	0
Arkansas rose	2.0	.6	1.0	.4	1.0	(1)
Plants favored by heavier grazing:						
Tumblegrass	1.0	1	(1)	1	1	.6
Rocky Mountain pussytoes	17.3	16.2	21.8	19.0	17.9	28.5
Groundsels	1.7	1.6	1.1	1.1	.6	1.5
Goosefoot	.7	.7	.5	.7	.2	1.0
Abundant plants not affected by grazing intensity:						
Sun sedge	3.7	3.2	3.5	2.7	4.9	4.5
Fringed sagebrush	10.2	11.3	13.3	12.1	14.1	16.1

[1] Less than 0.05 percent.

Plants Favored by Lighter Grazing

Perennial grasses constitute most of the cattle diet on ponderosa pine-bunchgrass ranges, though they provide less than one-half of the herbaceous cover on grassland and less than one-third on open-timber ranges.

Mountain muhly.—Of the perennial grasses on the experimental ranges, mountain muhly is the most important forage producer. Palatable, yet quite resistant to grazing, this grass remained widely distributed regardless of rates of grazing. When averages for all vegetation types are considered, mountain muhly cover changed little between 1940 and 1957 on ranges utilized lightly or moderately, but decreased to less than one-half on ranges grazed heavily. This change was highly significant.[5]

On grasslands, mountain muhly cover increased more than 50 percent from 1940 to 1957 on lightly utilized areas; it decreased about 35 percent under moderate use and 63 percent under heavy use, from 2.75 to 1.03 percent of the cover. Like most perennial grasses, mountain muhly increased on abandoned fields under all grazing intensities and decreased under all intensities under open stands of timber, with the greatest decline on heavily grazed ranges.

Arizona fescue.—Arizona fescue, a highly palatable grass, was

[5] In this bulletin highly significant and significant mean significant at the 0.01 and 0.05 probability levels, respectively.

more sensitive to heavy grazing than mountain muhly. On the total range, fescue decreased only slightly when utilized at light and moderate intensities. However, fescue cover was reduced in 1957 to one-eighth that in 1940 where cattle use was heavy.

On grasslands, light and moderate use did not affect fescue significantly, but where grazing was heavy, fescue decreased from 0.60 percent cover in 1940 to 0.05 percent in 1957. On open timber ranges, light and moderate grazing did not result in significant changes. However, under heavy grazing fescue cover in 1957 was only one-seventh as great as in 1940. This decrease was highly significant.

Blue grama.— Cover of blue grama in this study increased under all intensities of grazing. It was abundant only in the grassland type. Here it increased eight times on lightly grazed ranges, four times on those moderately grazed, and one and one-fourth times on heavily grazed ranges.

In the open timber type, blue grama was not abundant and its quantity did not change significantly.

The April-August periods in 1939 and 1940 were among the driest on record at Manitou. The 1957 growing season was the second wettest recorded. At least part of the increase in cover of blue grama on grazed ranges may have resulted from favorable moisture conditions in 1957.

Blue grama has been reported to increase as a result of continued heavy grazing (Arnold 1950; Costello and Schwan 1946; Reid and Love 1951; Johnson and Reid 1958). Albertson and Weaver (1944) and Albertson et al. (1957) recognized that grazed stands of this grass had a tremendous ability to withstand extraordinarily long and severe drought; the grass merely reduced aerial growth during these stress periods. On short-grass prairies in Canada, Clarke et al. (1947) found that blue grama withstood drought and responded quickly when adequate soil moisture became available. Weaver and Clements (1938) suggest that grama dominance on the short grass plains may constitute a disclimax due to prolonged overgazing. Turner and Klipple (1962) reported that grama in northeastern Colorado responded quickly to both favorable and unfavorable amounts of moisture. Klipple and Costello (1960) found that blue grama on the Central Plains became more abundant under all grazing levels when growing conditions became favorable following drought.

Bottlebrush squirreltail.—Bottlebrush squirreltail decreased under heavy grazing. Though sparse, squirreltail cover doubled where use was light, dropped to one-third where use was moderate, and was only one-fifth as great on ranges grazed heavily.

Lupines.—The lupines were represented by silvery and lodgepole lupine. Decreases in lupines during the study period were noted for all grazing intensities. The smallest reduction was under light use, the greatest under heavy use.

Silvery lupine, which was more common, was more frequent under open pine stands than in grassland parks. Losses of both lupines were greater on grasslands than in open timber. Silvery lupine was not recorded on any abandoned field plots in 1957.

Bearberry.—The most abundant shrub within open and dense timber stands in 1940 was bearberry. Though it is generally con-

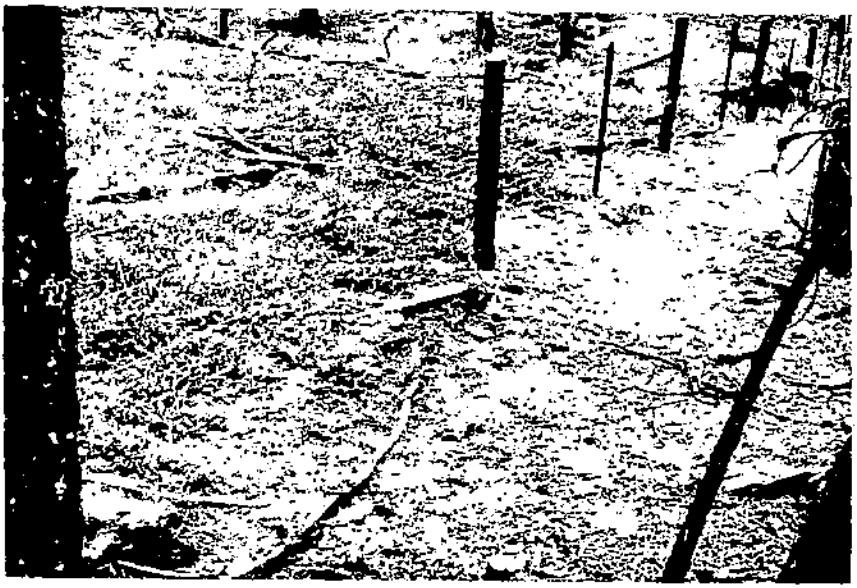

Figure 13.—Presence of bearberry under light grazing (left) and absence under heavy grazing (right). Note that bearberry is also absent in the lightly grazed area in a 12- to 18-inch band along the fence. Cattle could reach that far under the fence from the heavy-use side; thus, grazing, not trampling or soil compaction, resulted in the loss of bearberry.

sidered unpalatable to cattle, bearberry was almost absent on heavily grazed ranges by 1957, and its cover has decreased substantially on lightly and moderately used areas. Figure 13 illustrates that bearberry has remained under light use on one side of a fence while it has been eliminated by heavy use on the other side.

Arkansas rose.—This rose was sensitive to cattle use, being sharply reduced at all intensities and within all cover types. It was nearly eliminated where grazing was heaviest. This rose occurred less frequently than bearberry, but it was more uniformly distributed throughout all cover types.

True mountainmahogany.—Within open timber types on lightly grazed ranges, true mountainmahogany cover (not included in tables 7 and 8 because of its scarcity) averaged 0.12 percent in 1940 and 0.05 percent in 1957. Where grazing was moderate, the decrease was from 0.05 to 0.02 percent. Under both grazing intensities, mountainmahogany plants were severely hedged. Mountainmahogany was not recorded on heavily grazed range in 1940 and 1957. True mountainmahogany is a highly palatable shrub that occurred principally in sparse stands under open timber.

Plants Favored by Heavier Grazing

Tumblegrass.—During the 1940–57 period, tumblegrass diminished under the lightest use and increased when grazed at the intermediate and highest grazing rates (tables 7, 8).

This annual grass invaded abandoned fields and other disturbed areas, was inconspicuous or absent on natural grasslands, and was absent under timber.

Rocky Mountain pussytoes.—At both the beginning and end of this study, Rocky Mountain pussytoes constituted more than one-third of all forb cover. Table 7 shows some decrease in cover of this forb on lightly and moderately grazed ranges and an increase under heavy grazing. Plant composition changes were more pronounced, especially on heavily grazed ranges, where the cover increased from 17.9 percent in 1940 to 28.5 percent in 1957 (table 8).

The cover of pussytoes on grassland was similar to that under timber stands. Cover on abandoned fields was only about one-third as great as on other vegetation types.

Pussytoes often forms large mats, but it produces very little herbage and is practically worthless as forage. Reproduction is by rootstalks and stolons. Consequently, it is seldom weakened by trampling or close cropping. Because of its persistence, it becomes more conspicuous as other plants are reduced. Pussytoes, therefore, is a useful indicator of overgrazing.

Groundsels.—Both Fendler and lambstongue groundsel were present; the former was more prevalent. It occurred most on heavily grazed areas and least on areas protected from grazing. Plant cover and composition of the groundsels on lightly and moderately grazed ranges remained similar from 1940 to 1957, but both increased where grazing was heaviest (tables 7, 8).

Goosefoot.—Lambsquarters and slimleaf goosefoot were most common on dry, disturbed areas. Lambsquarters goosefoot responded differentially to grazing intensity. As shown in tables 7 and 8, its cover decreased slightly on lightly grazed ranges, increased slightly under moderate use, and increased markedly on heavily grazed ranges. It did not change on ranges protected from grazing.

Plants Not Affected by Grazing Intensity

Sun sedge.—This was one of the most uniformly distributed species. Sedge cover was quite similar for the three levels of grazing in 1957. All were slightly lower than in 1940, but no significance could be attributed to treatment effects. Sedge cover within both grassland and open timber exclosures showed small increases, but it represented considerably smaller proportions of the composition than under grazing.

Sedge cover on grassland and under open timber was generally similar, although percentage composition was 2.1 for the former type and 4.3 for the latter. Under dense timber, sedge cover was somewhat less, but it made up 5.8 percent of the total vegetation. It was least abundant on abandoned fields, constituting only 0.5 percent of the composition.

Fringed sagebrush.—This half-shrub has been described (Sarvis 1923 and 1941) as a plant that increases under heavy grazing. Klipple and Costello (1960), on the plains of north-central Colorado, found fringed sagebrush to increase somewhat under all grazing treatments, particularly light or moderate. Sarvis (1941), working in the northern Great Plains, reported that

fringed sagebrush plants increased greatly during the first 10 years of heavy grazing but diminished in the next 15 years. After 25 years their number was similar to that on lightly grazed ranges.

In this study, neither plant cover nor composition of fringed sagebrush was significantly affected by the three grazing intensities.

In 1940, more than one-fifth of the total plant cover consisted of fringed sagebrush. In 1957, cover of the sagebrush within grazed grasslands was about the same as in 1940. Under open stands of ponderosa pine, the sagebrush decreased significantly under all treatments. This general decline was common, however, for most understory species within timbered areas. Ungrazed timbered exclosures had little or no sagebrush. Within grassland exclosures, sagebrush cover was essentially the same in 1957 as in 1947. However, percent composition was considerably lower in 1957; other species were more abundant.

Sagebrush produces large quantities of seeds. Germination tests in the Southwest (Wilson 1931) have shown fringed sagebrush to germinate poorly at first, but to break dormancy many years later. This characteristic may account for its continued abundance inside ungrazed exclosures.

Plants That Increased Following Protection of Formerly Grazed Areas

Mountain muhly.—Cover of mountain muhly was by far the densest inside grassland exclosures, where estimates in 1957 ranged from 3.06 to 3.47 percent. Cover on adjacent grasslands that were grazed lightly, moderately, and heavily was 2.12, 1.23, and 1.03 percent.

Arizona fescue.—Ungrazed exclosures within the lightly and moderately grazed ranges had up to three times more Arizona fescue cover than adjacent grazed areas. On heavily grazed ranges, fescue inside exclosures provided 11 to 15 times more cover than on nearby grazed areas.

Little bluestem and Parry danthonia.—These two grasses were prominent only locally. Each contributed 2 to 5 times more to the composition of the herbaceous vegetation under open and dense stands of timber than on grasslands.

Little bluestem cover averaged about 0.10 percent on the experimental area in 1940. By 1957, cover of bluestem was only about 40 percent as great on the grazed areas. The decline was similar under all levels of use. On ungrazed sites, however, bluestem cover was markedly higher than on grazed ranges within the same vegetation type.

Parry danthonia was not recorded in 1940; however, it may have been present because it was widespread in 1947. In 1957, danthonia cover within ungrazed exclosures was twice as great as on comparable grazed ranges.

Bottlebrush squirreltail.—Because of its prolific seeding, bottlebrush squirreltail increased markedly on depleted ranges protected from cattle use. Squirreltail inside exclosures on the light, moderate, and heavily grazed ranges provided 0.52, 1.93, and 0.08

percent cover, respectively. Corresponding values for adjacent grazed areas were 0.02, 0.05, and 0.01 percent.

Squirreltail normally produces abundant seed, but it is relatively short-lived. It is quite palatable to cattle early in the season before its seed matures. Early grazing is sufficient to prevent the maturation of seed on many plants. Thus, old plants die and are not replaced by young ones.

Sleepygrass.—Total protection from grazing resulted in rather large increases of sleepygrass. This large, coarse grass has low palatability, but its quantity apparently was not affected by the levels of grazing tested.

Its involvement in important plant succession changes was apparent. On native grasslands, sleepygrass increased somewhat between 1940 and 1957, but the increase within abandoned fields was many times greater. It produces much seed, and it readily invaded abandoned farmland and other areas where the soil surface had been disturbed.

Goldasters.—The goldasters—*Chrysopsis fulcrata* and *C. villosa*—are woody, relatively unpalatable forbs. The latter provided the most cover.

Ungrazed plots had much more goldaster cover than adjacent grazed areas.

Goldasters were most frequent on grasslands, but they were present in about one-fourth of all plots within abandoned fields and open timber types.

Milkvetches.—Purple and timber milkvetch, the most common milkvetches, were little affected by different grazing intensities, but they increased when protected from cattle use.

The two milkvetches were palatable and provided a little forage. The high palatability of purple milkvetch was demonstrated during 1942–47 when, for the three levels of grazing, its estimated use was 45, 53, and 88 percent. Though use of timber milkvetch was not estimated, considerable cropping was observed.

Under timber stands, cover of timber milkvetch was about 2.5 times that of purple milkvetch. On grasslands and abandoned fields, purple milkvetch cover was 30 times that of timber milkvetch.

Beath et al. (1934) in Wyoming and Bruce (1927) in British Columbia found timber milkvetch to be highly palatable forage.

Although some milkvetches are poisonous, no ill effects were observed in this experiment.

Plants That Decreased Following Protection of Formerly Grazed Areas

Blue grama.—Blue grama cover within ungrazed exclosures was reduced from 1.82 in 1947 to 0.98 in 1957, perhaps because many plants may have died during the prolonged 1950-56 drought. Studies by Klipple and Costello (1960) revealed that mortality of this grass was highest on ungrazed areas, presumably because moisture was most rapidly exhausted within luxuriant stands. Another possibility is that competition from the greatly increased cover of mountain muhly and Arizona fescue

could have been an important factor in reducing blue grama cover inside the ungrazed exclosures.

Rocky Mountain pussytoes.—In 1957, Rocky Mountain pussytoes provided more than twice as much cover on grazed grasslands as inside the ungrazed exclosures. On open timber ranges, where grazing was generally lighter, its cover was 53 percent greater on grazed ranges than within ungrazed exclosures.

Fendler sandwort.—Fendler sandwort was considerably less abundant within both grassland and timbered exclosures than on adjacent ranges grazed at any of the three intensities. On grazed grasslands, sandwort occurred on 39 to 51 percent of all sample plots. Only 8 percent of the plots on ungrazed grasslands contained sandwort. Comparable figures for the open timber type were 44 to 56 percent where grazed, and 33 percent of the plots where not grazed.

Sandwort occurred on only about one-fifth as many plots on abandoned fields as on the other cover types.

Plant Growth

Leaves and Flower Stalks

Growth attributes influenced by levels of grazing were leaf height [6], flower stalk height, number of flower stalks, and percentage of plants bearing flower stalks. These attributes indicate the vigor of a plant. Also, as shown in this and other studies (Albertson et al. 1957; Blaisdell 1958; Bredemeir 1958; Clarke et al. 1947; Rogler and Haas 1957; Turner and Klipple 1952), they may reflect short-term weather or long-term climatic effects.

Leaf heights of several important plants varied between 1949 and 1950 (table 9), presumably because of the more favorable moisture during the 1949 growing season. Height growth was similarly related to intensity of grazing in both years.

Leaf heights of blue grama, Arizona fescue, mountain muhly, and sedge were greatest in ungrazed exclosures and least on the most heavily grazed ranges. Only one of the forbs measured, the palatable purple milkvetch, responded the same way. Pussytoes and trailing fleabane made about the same growth under all treatments. Height of fringed sagebrush, influenced little by level of utilization, was nearly 60 percent greater on ungrazed areas.

The relationship of leaf height to grazing was investigated further in 1957 for Arizona fescue and mountain muhly. In addition, height of flower stalks, number of flower stalks on flower stalk-producing plants, and number of plants producing flower stalks were considered.

Sixteen years of heavy and moderate grazing reduced leaf height and development of flower stalks of Arizona fescue. Reduction in growth caused by heavy grazing greatly exceeded that from moderate use. The effects of different grazing intensities on mountain muhly also were apparent, but were not so great as on the fescue.

[6] Height measurements refer to the height of the plant, or its component parts, when held erect.

Table 9.—*Average leaf heights of major species, 1949 and 1950 (from Johnson 1956)*

Species	Grazing treatment							
	No use		Light		Moderate		Heavy	
	1949	1950	1949	1950	1949	1950	1949	1950
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
Grasses:								
Arizona fescue	10.0	10.1	10.0	9.4	9.6	8.2	6.0	3.2
Blue grama	3.0	2.0	2.3	1.5	1.8	1.3	1.7	1.1
Little bluestem	2.4	3.0	3.8	2.9	---	---	3.0	1.8
Mountain muhly	6.3	4.4	4.7	3.6	4.0	3.2	3.3	2.1
Parry danthonia	6.5	9.8	4.9	4.2	---	---	3.4	---
Sedge:								
Sun sedge	5.8	4.2	4.2	2.8	4.1	3.2	2.9	2.4
Forbs:								
Fringed sagebrush	4.1	3.5	2.5	2.4	2.9	2.3	2.5	1.9
Purple milkvetch	5.7	3.1	5.7	1.7	4.2	2.1	4.4	1.5
Rocky Mountain pussytoes	.7	.5	.5	.5	.5	.5	.5	.5
Trailing fleabane	1.1	.5	1.0	.8	1.0	.7	1.0	.8

Figure 14 illustrates that increased grazing progressively inhibited plant growth, that the greatest difference in growth was between moderate and heavy use, and that reproductive potential of both Arizona fescue and mountain muhly diminished seriously under the heaviest rate of grazing.

Further evidence that plant growth was reduced at high intensities of grazing was furnished by supplementary measurements taken during a utilization study in the fall of 1957. Observations included the measurements of leaf and flower stalk heights of ungrazed plants and determination of the percentage of ungrazed plants that produced flower stalks. Table 10, which summarizes records from about 2,700 plants, shows that flower stalk and leaf heights decreased as grazing increased.

Past heavy grazing influenced height growth and flower stalk production long after grazing was discontinued (table 11). In this study, a plot was fenced from grazing each year from 1950 through 1959. This provided 10 plots that had been ungrazed for 0 to 9 years. Within each plot, 10 plants each of Arizona fescue and mountain muhly were selected at random for measurements. Perennial grasses in the open grassland site had been grazed an average of about 70 percent from 1943 until the plots were fenced. Leaf height of Arizona fescue increased fastest during the first 3 years of protection. After 3 years, flower stalk production had essentially recovered. Mountain muhly leaf heights and number and height of flower stalks had recovered fairly well by the third year of protection from grazing.

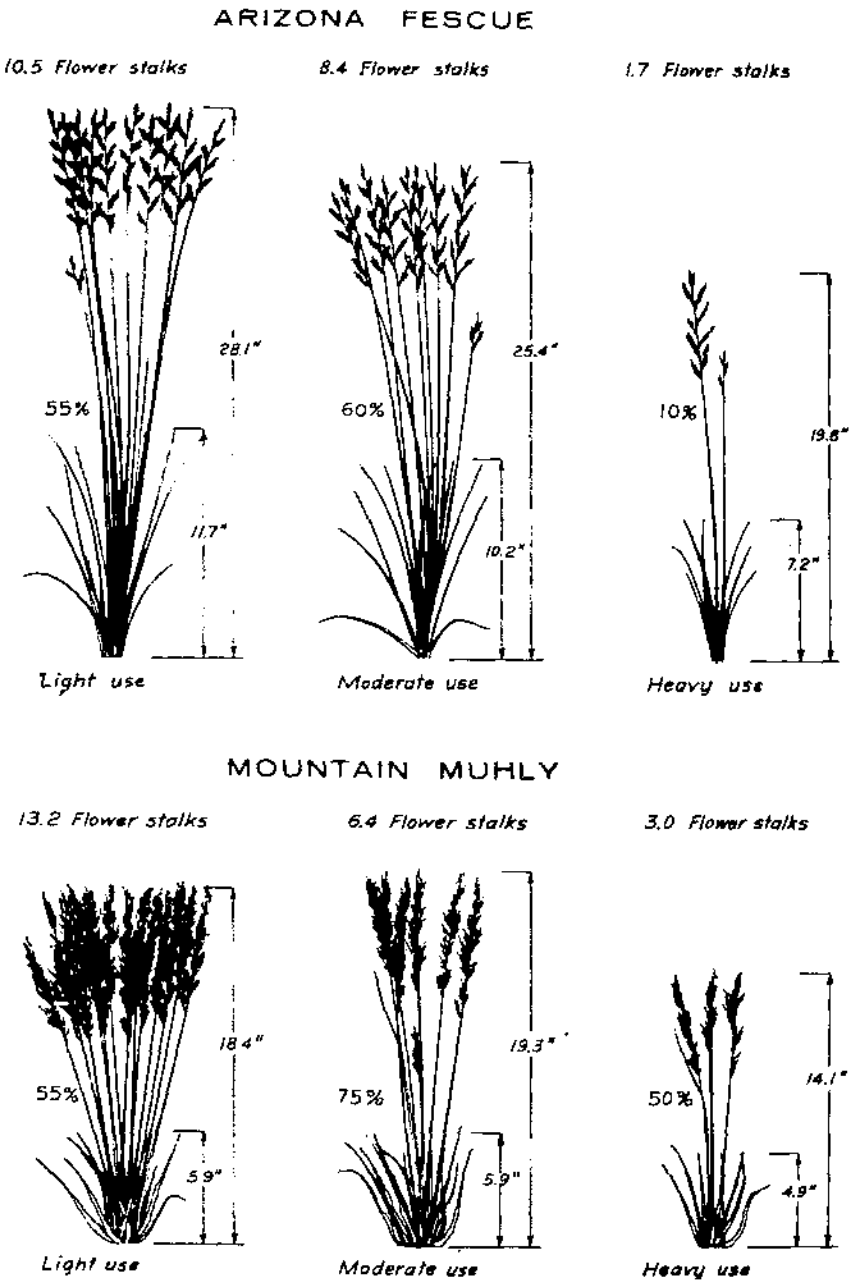

Figure 14.—Top growth of two important grasses under different grazing intensities, 1957. Percentages refer to proportion of plants producing flower stalks.

Table 10.—*Height growth and flower stalk development of three grasses grazed at three grazing intensities, 1957*

Species and grazing intensity	Flower stalk height			Leaf height			Plants bearing flower stalks		
	Grassland[1]	Open timber	Dense timber	Grassland	Open timber	Dense timber	Grassland	Open timber	Dense timber
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*Pct.*	*Pct.*	*Pct.*
Arizona fescue:									
Light use	28.9	29.4	29.8	11.6	11.5	11.6	54	61	76
Moderate use	26.8	28.0	27.2	9.9	10.9	10.2	63	61	77
Heavy use	—	22.1	23.4	5.4	7.4	10.1	0	22	52
Mountain muhly:									
Light use	21.2	20.7	18.5	7.6	6.8	4.7	78	79	84
Moderate use	18.7	19.6	18.6	6.8	6.9	6.6	78	78	82
Heavy use	13.0	15.6	16.8	4.8	5.6	5.1	56	45	52
Blue grama:									
Light use	11.7	15.8	—	4.6	4.4	—	71	68	—
Moderate use	11.3	14.6	—	3.5	3.9	—	76	77	—
Heavy use	8.4	13.0	—	2.2	2.2	—	42	20	—

[1] Grassland type includes abandoned fields.

On plots protected 5 to 9 years, growth did not improve consistently, but leaf and flower stalk heights and number of flower stalks of both species were greatest within the exclosure not grazed for 9 years. In plots fenced 8 and 9 years, the number of flower stalks was still greater than in plots with fewer years of protection. Thus, complete recovery may not have been attained within the study period.

Table 11.—*Height growth and flower stalk development of Arizona fescue and mountain muhly plants protected from grazing for 0 to 9 years. All measurements were made in 1959.*

Years ungrazed (number)	Arizona fescue			Mountain muhly		
	Leaf height	Flower stalk height	Average number of flower stalks	Leaf height	Flower stalk height	Average number of flower stalks
	Inches	*Inches*	*Number*	*Inches*	*Inches*	*Number*
9	14.0	26.8	13.4	9.5	18.9	36.2
8	13.9	23.3	9.6	8.2	18.0	31.6
7	11.9	21.2	12.8	7.4	11.8	20.0
6	12.6	18.4	8.8	6.3	10.6	18.8
5	12.4	25.6	8.4	9.3	16.4	20.1
4	10.7	22.8	11.1	6.8	18.8	26.4
3	11.0	21.3	10.4	6.6	13.4	19.6
2	9.1	23.1	6.6	5.7	13.1	6.2
1	4.8	—	0	4.6	5.9	.7
0	5.0	—	0	3.6	5.3	.2

Roots

Root development also was influenced significantly by grazing intensity. The number of branch rootlets, root depth, lateral spread, weight, and abundance in the plant community all decreased as grazing intensity increased.

That vigor of root systems affects the aerial growth of plants has been established by many investigators. Sturchie (1930) found, for example, that plants beginning the growing season with a well-developed system of rootstalks produced at least 50 percent more top growth than those with poorly developed systems. There is abundant evidence, too, that defoliation results in diminished root growth. Robertson (1933) found root development of grass seedlings to be restricted twice as much as top growth by frequent clipping, and that these effects to roots were almost immediate. In fact, studies by Crider (1955) revealed that grass roots stopped growing within 24 hours after 40 percent or more of the tops were removed. The time required for

resumption of growth varied directly with the degree of foliage removal. Weaver (1950) reported that, as grazing intensity increased, depth and amount of root materials decreased, and that desirable grasses were replaced by undesirable grasses and forbs.

In this study the total weight of roots differed among intensities of use. Roots weighed more under moderate use than under heavy use, and root systems within ungrazed enclosures were heavier than root systems within moderately or heavily grazed ranges. The differences were due to the grass root component. Weights of nongrass roots were not significantly different among treatments.

Concentration of roots in the upper soil is illustrated in figure 15. Root weight in the surface foot of a 2-foot-wide, 3-foot-long, 3-inch-thick soil monolith varied from 78 to 86 percent of the total weight. Analysis of grass-root weights showed a significant interaction between depth and intensity of use.

The primary effect of top treatment on root morphology and the secondary influence of root system changes on plant composition were investigated by Ruby and Young (1953). They discovered that frequent and close cropping diminished both quantity and length of roots, and that such plants were unable to reach deep soil moisture. Consequently, those plants were most likely to die during drought.

There was no significant difference in root depths between moderately grazed ranges and ungrazed exclosures in this study (table 12). Except for Rocky Mountain pussytoes, however, root depth for all species was significantly less where grazing had been heavy than where there had been moderate or no use.

Although lateral spread of grass roots appeared to decrease as grazing intensity increased, analyses failed to show significant differences. Lateral spread of fringed sagebrush and pussytoes roots was considerably greater where grazing was moderate than on ungrazed or heavily grazed areas.

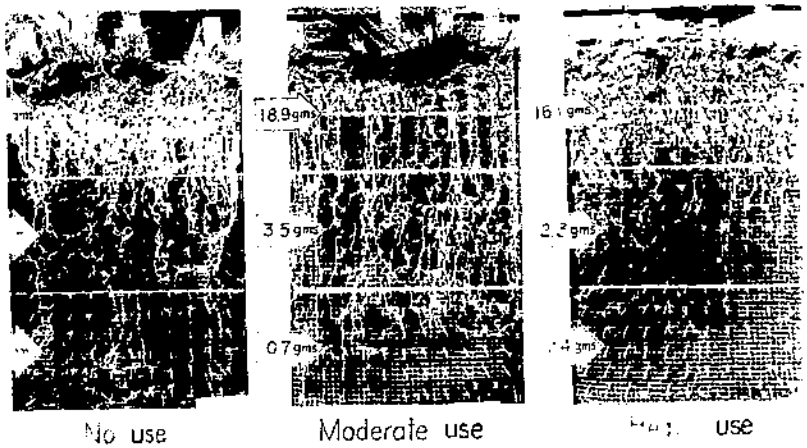

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Figure 15.—Root systems of plants on ranges grazed at different intensities, 1958. Roots shown occurred in a 2-foot by 3-foot by 3-inch monolith of soil. Weights of roots in each vertical foot of the monolith are listed.

Table 12.—*Depth and lateral spread of roots as related to intensity of grazing, 1958* [1]

Species	Average maximum depth			Average maximum lateral spread [2]		
	No use	Moderate use	Heavy use	No use	Moderate use	Heavy use
	In.	*In.*	*In.*	*In.*	*In.*	*In.*
Arizona fescue	44.5	44.1	31.3	12.0	11.3	8.0
Blue grama	37.8	42.8	36.0	9.3	7.4	7.1
Fringed sagebrush	38.2	38.7	26.4	6.4	8.8	6.1
Mountain muhly	50.8	44.1	32.1	11.4	8.9	6.8
Rocky Mountain pussytoes	14.0	14.0	19.0	5.0	10.5	5.8

[1] Adapted from Schuster (1963). Averages are based on 13 samples for no use, 12 samples for moderate use, and 12 samples for heavy use.
[2] Measured from a vertical line projected through the center of the plant.

Root systems of mountain muhly and Arizona fescue responded similarly to grazing. As intensity of use increased, diameter and strength of primary roots and the number of branch rootlets decreased. Blue grama root systems were similar under moderate and no use, but on ranges grazed heavily the roots were less branched and much smaller in diameter. Fringed sagebrush plants from moderately utilized ranges had essentially the same root systems as plants with no use, but lateral spread was greater. Roots from heavily grazed ranges were smaller in diameter than those of plants taken from ungrazed exclosures. Diameters of pussytoe roots, however, were similar within all grazed and ungrazed areas examined.

A summary of major findings concerning the effects of grazing on roots follows:

1. Heavy use reduced root penetration of all species except pussytoes.

2. Spread of the grass roots consistently decreased as grazing increased. However, the reduction could have resulted from variability among the samples. Under moderate use, fringed sagebrush and pussytoes increased their root spread, but under heavy use, lateral spread was similar to that under no grazing.

3. Grass roots weighed significantly more under moderate use than under heavy use, and root systems within ungrazed exclosures were significantly heavier than root systems within heavily or moderately grazed ranges. Nongrass root weight did not vary significantly.

4. The greatest reduction in root weight due to intensity of grazing was in the surface foot of soil. However, proportionately greater declines in root weights occurred at deeper levels on heavily grazed areas than on moderately grazed or protected areas.

5. Root morphology of all three grass species was affected by heavy grazing. Besides being shorter, individual roots were

weaker, smaller in diameter, and contained fewer branch rootlets. The same effects, though less pronounced, were observed on moderately used range; however, roots of blue grama were well developed under that level of grazing.

6. Root patterns of the plant community were changed by grazing. The extensiveness of Arizona fescue and mountain muhly root systems was inversely related to grazing intensity. Roots of blue grama were well developed on moderately grazed ranges, but deteriorated under heavy grazing. The two nongrasses maintained or extended their relative position in the underground system under moderate grazing, but fringed sagebrush roots appeared to decline with heavy grazing. The net effect on the total root pattern was a thinner, less extensive system as grazing was intensified.

These findings agree with the statement of Cook et al. (1958) that, "It appears that any herbage removal reduces total root production."

Seasonal Development

The rate of plant development was affected by grazing. Leaf heights of Arizona fescue and mountain muhly at different periods of the year and under different grazing intensities are shown in figures 16 and 17. The influence of climate upon seasonal leaf elongation is also illustrated.

Leaf measurements taken late in May 1957, 1958, and 1959 show that heavy grazing was detrimental to early leaf growth (fig. 16). Except for mountain muhly in 1958, leaves of fescue and muhly on lightly and moderately grazed ranges were significantly longer than those on heavily used areas.

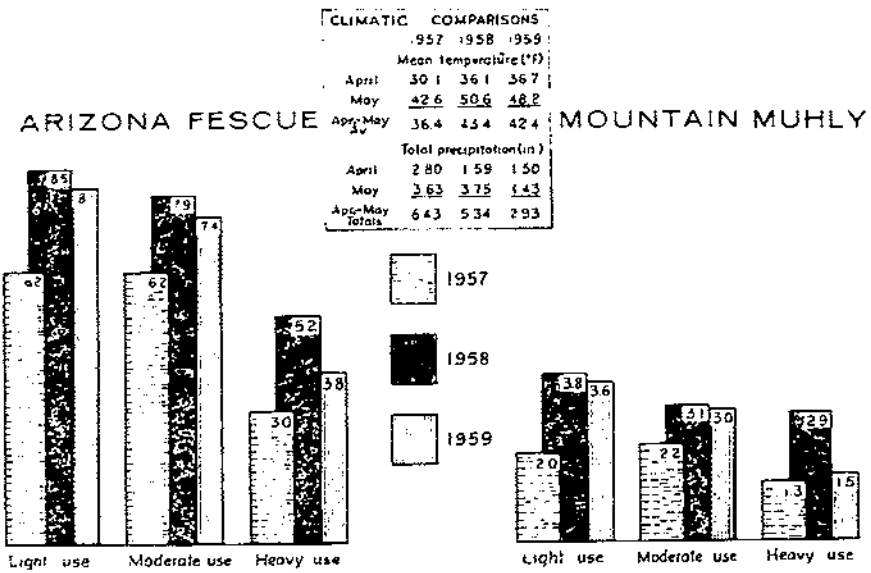


Figure 16.—Average maximum leaf height, in inches, of Arizona fescue and mountain muhly at beginning of the grazing season under different grazing intensities, 1957–59.

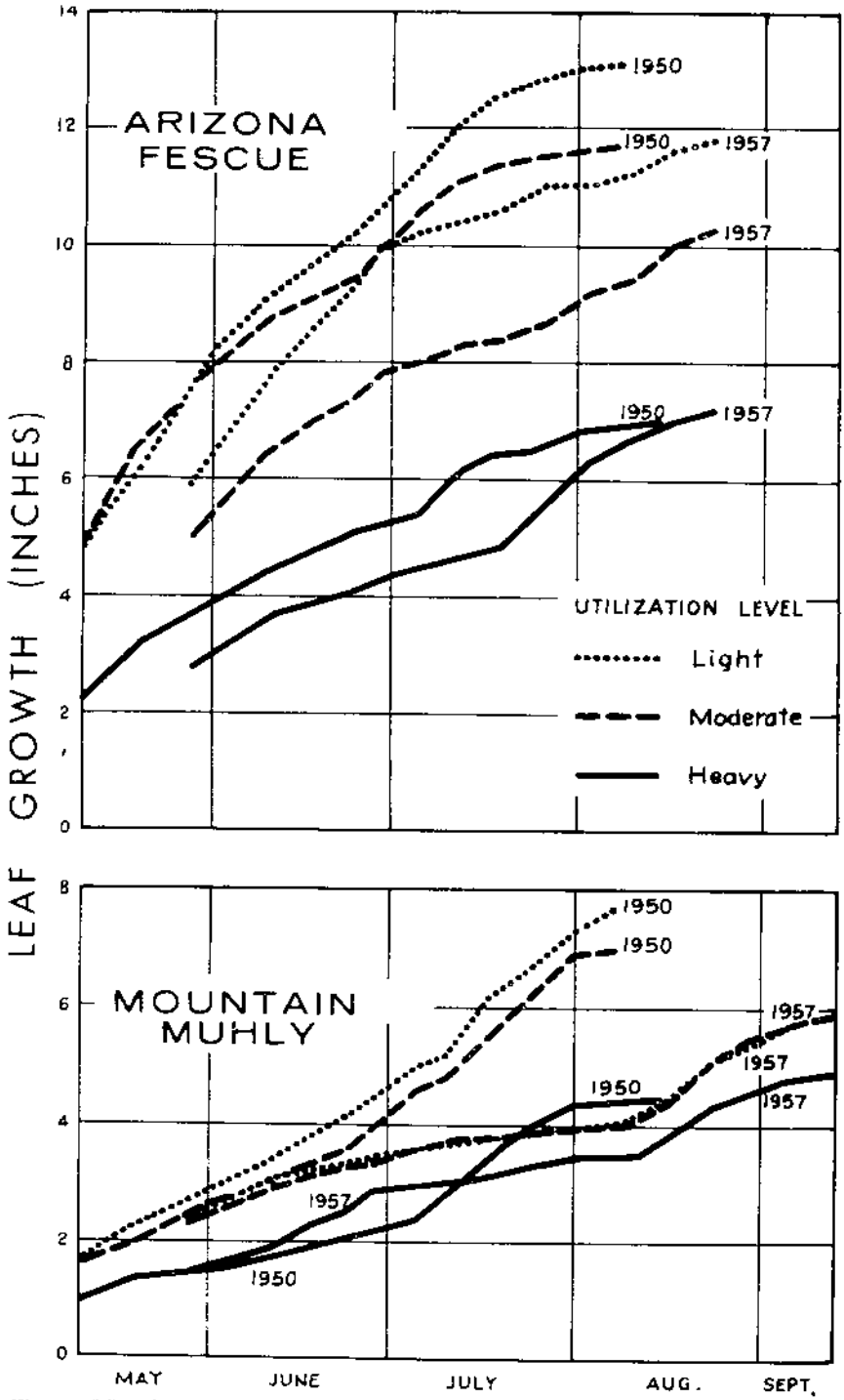


Figure 17.—Seasonal leaf growth of Arizona fescue and mountain muhly under different grazing intensities, 1950 and 1957.

Figure 17 illustrates two principal conclusions: (1) Arizona fescue develops earlier in the season than mountain muhly and (2) light and moderate grazing resulted in more rapid growth of grass and greater total growth than heavy grazing.

Differences in temperature and amount of rainfall probably were responsible for the annual variations in height growth shown in figure 16.

Average temperatures for the April-May period in 1957 were quite low, but precipitation was above average. For the same period in 1958, precipitation was normal and temperatures were above average. In 1959 precipitation was very light, but average temperature was relatively high. Blaisdell (1958) concluded that early plant growth is controlled mainly by high temperatures. This would account for rapid leaf growth in 1958 and 1959 and slower growth in 1957, despite higher rainfall.

However, the prolonged period of growth during the July-September period of 1957 probably was related to higher rainfall. According to Blaisdell (1958) and Nelson (1934), development during the latter part of the growing season seems to be more closely related to precipitation than to temperature.

Herbage Production

Herbage production on areas occupied by the experimental ranges was first measured in 1938. Production of palatable grasses and sedges over the entire area then averaged 251 pounds, air-dry, per acre. About 45 percent of the herbage was produced by mountain muhly.

Grass and sedge herbage, when clipped again in 1942, averaged 344 pounds per acre. This increase was not surprising because, although precipitation was similar in 1938 and 1942, grazing had been reduced to a moderate rate in 1938 and 1939, eliminated entirely in 1940, and was relatively light on all ranges in 1941.

Nongrazed Areas

Production of grasses and sedges on grasslands protected from cattle grazing increased markedly between 1947 and 1957. Meanwhile, production of ungrazed open-timber ranges remained essentially unchanged:

	Air-dry herbage	
	1947	*1957*
	Lbs./a.	*Lbs./a.*
Exclosures in grassland	804	1,616
Exclosures in open timber	337	331

Precipitation during the preceding winter (October-March) and the summer growing season (April-August) was greatly above average for both years. Therefore, the doubling of yields on grassland sites apparently was largely a response to protection from grazing and not to differences in available moisture.

There are two possible reasons why production of grasses and sedges did not increase on ungrazed open-timber areas. First, cattle use on grassland was consistently greater than in open-timber areas. Therefore, open-timber areas on the previously

grazed experimental ranges may have been in better condition than grasslands at the beginning of the study period. Thus, they would not be expected to improve as much as the protected grasslands. Second, production may not have increased because of a gradual closing of the forest canopy during the study period.

Grazed Ranges

Grass and sedge production on lightly grazed ranges averaged about the same at the close of the grazing treatment in 1957 as in 1942 (fig. 18). Where use was moderate, yield remained similar between 1942 and 1947 but increased somewhat in 1957. On ranges grazed heavily, production decreased substantially in 1947 and still further in 1957.

Based on observations of lightly and moderately grazed ranges in 1947, the main forage-producing species remained vigorous, and plant composition was little changed. Under heavy grazing, the vigor of many forage plants was reduced markedly, although

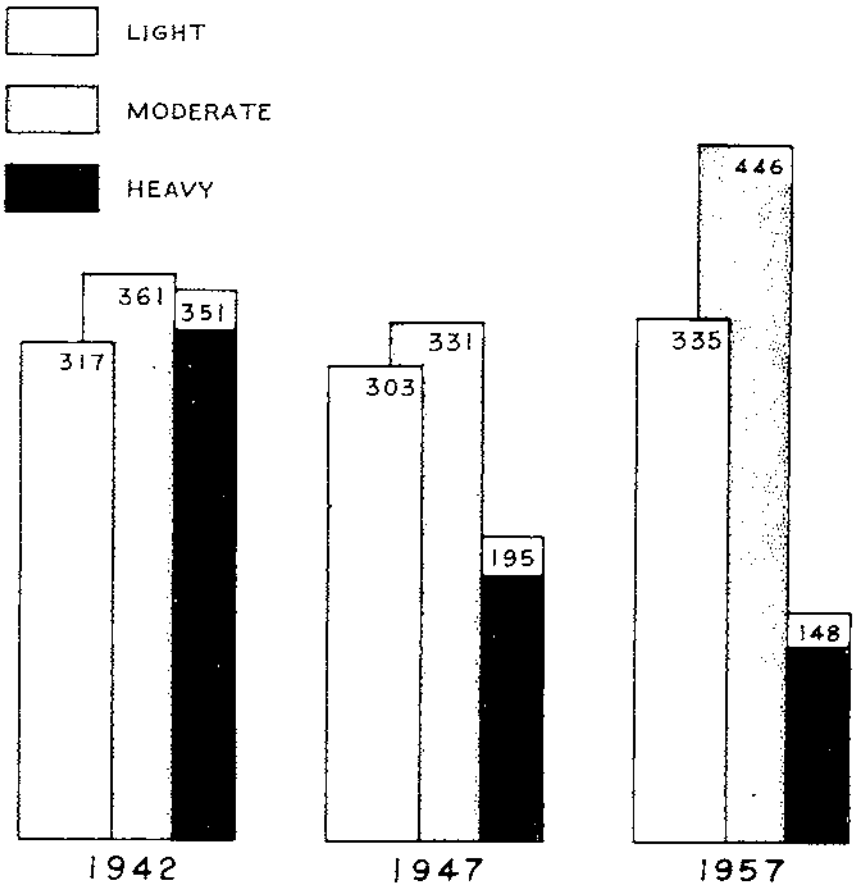


Figure 18.—Grass and sedge yields (in pounds) as affected by grazing intensity.

no important changes in plant composition had occurred. Lower yields resulted from loss of plant vigor rather than from a change in species composition.

Average yields on light- and moderate-use ranges were somewhat higher in 1957 than at the beginning of the study or in 1947. The trend on heavily grazed ranges was different. Production dropped from 351 pounds per acre in 1942 to 195 pounds in 1947, and to 148 pounds in 1957. Plant vigor had been reduced sharply by 1957, and composition of the plant cover had deteriorated.

In summary, light and moderate grazing maintained satisfactory production of grasses and sedges throughout the period of the study, while heavy grazing greatly reduced production.

Cover Types

Grasslands yielded two to three times more grass and sedge herbage in 1957 than the open-timber type under all intensities of grazing (fig. 19). Abandoned fields were included with grassland for these comparisons.

Production under open stands of ponderosa pine was four to six times greater than under dense stands. The small proportion of dense timber type, combined with its low degree of use, renders it of little consequence as a forage producer on these ranges.

Trends in grass and sedge production on grassland and open-timber types from 1942 to 1957 followed patterns described previously for average range conditions. Yields under dense stands of timber declined under all grazing intensities.

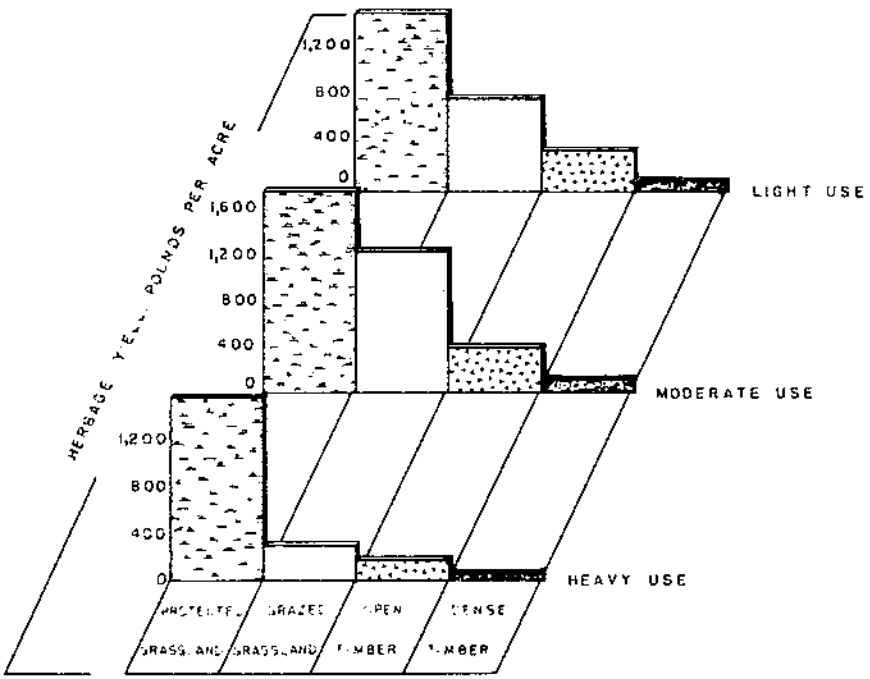


Figure 19.—Grass and sedge yields by vegetation cover types and grazing intensities, 1957.

SOIL RESPONSES TO GRAZING INTENSITY

Infiltration studies were conducted on the six experimental ranges during the summers of 1941, 1942, 1946, and 1952, and in the 2-acre cattle exclosures during 1941, 1947, and 1954. Erosion as well as infiltration was studied on the grazed ranges in 1952 and in the exclosures in 1954. These studies have been reported in more detail previously (Dortignac and Love 1960; Dortignac and Love 1961; Love 1953; Love 1958; Renner and Love 1955).

Infiltration rates in 1952 were about the same as in 1941 (table 13); under moderate grazing the rates remained high; under heavy grazing they stayed low. The large variation in infiltration among spots within each pasture before the experiment prevented full evaluation by pasture of the effect of cattle grazing on infiltration.

Table 13.—*Average infiltration rates in 1941 and 1952 and erosion rates in 1952 on ranges grazed at three intensities*

Year, grazing intensity, and range	Infiltration rate			Erosion rate		
	Grassland	Open timber	Average	Grassland	Open timber	Average
	In./hr.[1]	*In./hr.*[1]	*In./hr.*[1]	*Lbs.*[2]	*Lbs.*[2]	*Lbs.*[2]
1941:						
Light:						
Range 2	1.84	1.76	1.80	—	—	—
Range 5	2.16	2.13	2.15	—	—	—
Average	2.00	1.94	1.97	—	—	—
Moderate:						
Range 3	2.16	2.23	2.19	—	—	—
Range 6	2.47	2.09	2.28	—	—	—
Average	2.32	2.16	2.24	—	—	—
Heavy:						
Range 1	1.66	1.34	1.50	—	—	—
Range 4	1.61	2.21	1.91	—	—	—
Average	1.64	1.77	1.70	—	—	—
1952:						
Light:						
Range 2	1.88	2.08	1.98	112	57	84
Range 5	1.48	1.97	1.72	266	171	219
Average	1.68	2.02	1.85	189	114	152
Moderate:						
Range 3	1.76	1.92	1.84	264	37	150
Range 6	1.71	2.35	2.03	115	69	92
Average	1.74	2.14	1.94	190	53	121
Heavy:						
Range 1	1.29	1.54	1.42	198	63	131
Range 4	1.41	1.89	1.65	375	373	374
Average	1.35	1.72	1.53	286	218	252

[1] The infiltration rate is expressed as the average rate during the last 20 minutes of a 50-minute rainfall application on prewetted soils.

[2] The erosion rate is expressed as lbs./a. of soil loss per inch of surface runoff.

In 1952, erosion rates, as determined by the infiltrometer method, were higher under heavy grazing than under moderate or light use; however, individual range values were variable (table 13). Nevertheless, summaries of plot studies (Dortignac and Love 1961; Dunford 1954; Renner and Love 1955) tend to substantiate the conclusion that surface erosion under heavy grazing is nearly double that under moderate and light use.

In 1941, infiltration was measured inside recently completed exclosures and on outside ranges that were to be grazed experimentally. There was then no significant difference between infiltration inside and outside the exclosures. Infiltration measurements also were made inside the exclosures in 1947 and 1954. Combined infiltration rates inside the exclosures increased as the result of protection from grazing:

	Grassland	*Open timber*	*Combined*
1941	1.95	1.59	1.77
1947	2.27	2.91	2.59
1954	3.26	2.60	2.82

In contrast, infiltration rates on grazed ranges were about the same at the beginning and end of the study (fig. 20). Thus, the main effect of cattle grazing was to prevent an increase or recovery in infiltration rates.

Comparisons of erosion rates between exclosures and adjacent grazed ranges in 1954 illustrate the influence of grazing intensity on erosion (table 14). Although the variation between infiltration plots was large, it was apparent that erosion inside the exclosures was of minor consequence. Outside, erosion was much greater on ranges grazed heavily than on those grazed lightly. This relationship has been substantiated by other studies (Dortignac and Love 1960; Dunford 1954; Renner and Love 1953). The magnitude of erosion, however, about 400 pounds per acre per inch of runoff, would not be considered excessive by Dortignac and Love (1960). These investigators state that relatively small amounts of soil will be washed from ponderosa pine ranges when erosion rates, as determined by the infiltrometer method, are less than 500 pounds per acre.

CATTLE RESPONSES TO GRAZING INTENSITY

Weight gains of yearling heifers were inversely related to intensity of grazing. Most gain was made during the first 3 months of the June 1-October 31 grazing season. Cattle on lightly and moderately grazed ranges made proportionately larger gains in September and October than those on ranges grazed heavily. Beef production per acre was greatest where use was moderate and least where it was light.

Seasonal, Monthly, and Daily Gains

Heifers on lightly used ranges gained an average of 10 pounds more during the 11 full grazing seasons than those on moderately grazed ranges and fifty-five pounds more than heifers on heavily grazed ranges.

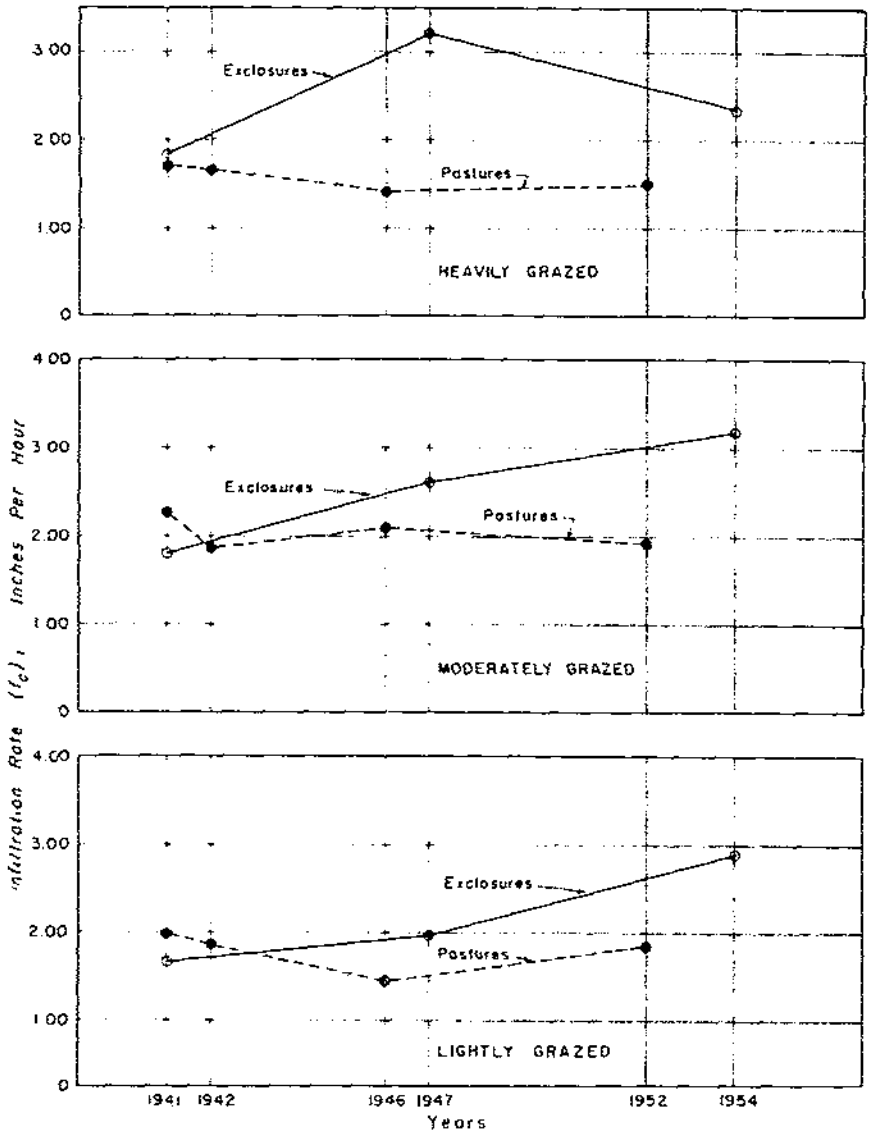


Figure 20.—Comparison of infiltration trends in exclosures with those on grazed ranges for open timber and grassland types combined (from Dortignac and Love 1961).

In 1941, when all pastures were grazed at about the same intensity, heifers gained an average of 231 pounds from June 1 to October 31; gains were similar among cattle on all six ranges. Desired utilization levels were sought but not attained in 1942; however, they were generally achieved in 1943 and later years. Starting in 1942 heifers grazing light- and moderate-use ranges gained significantly more than heifers on heavy-use ranges (fig. 21).

Table 14.—*Average erosion rates*[1] *for plots inside and outside exclosures (open timber and grassland combined), 1954*

	Light grazing			Moderate grazing			Heavy grazing		
	Range 2	Range 5	Average	Range 3	Range 6	Average	Range 1	Range 4	Average
Ungrazed range	3	13	8	46	45	45	56	42	49
Grazed range	94	70	82	85	141	113	418	397	407

[1] Erosion rate expressed as pounds of soil loss per acre per inch of surface runoff.

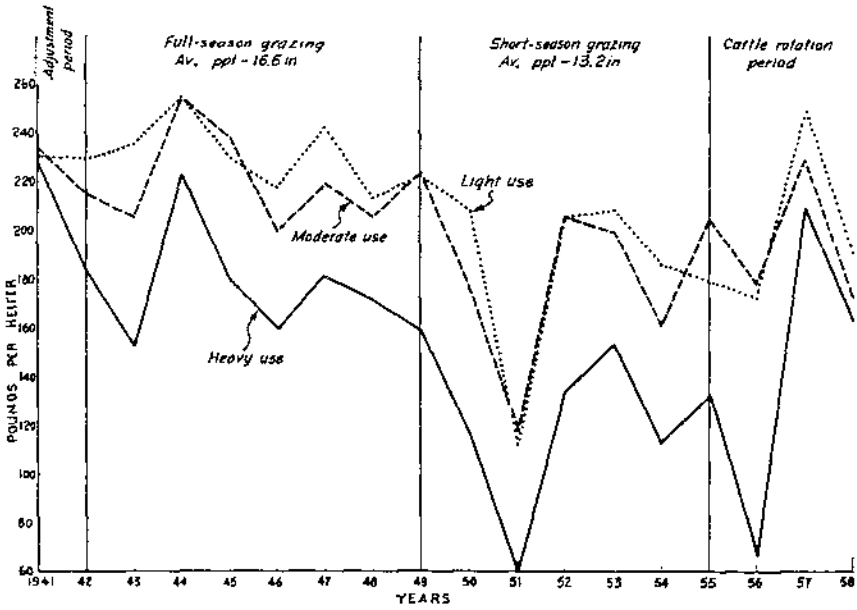
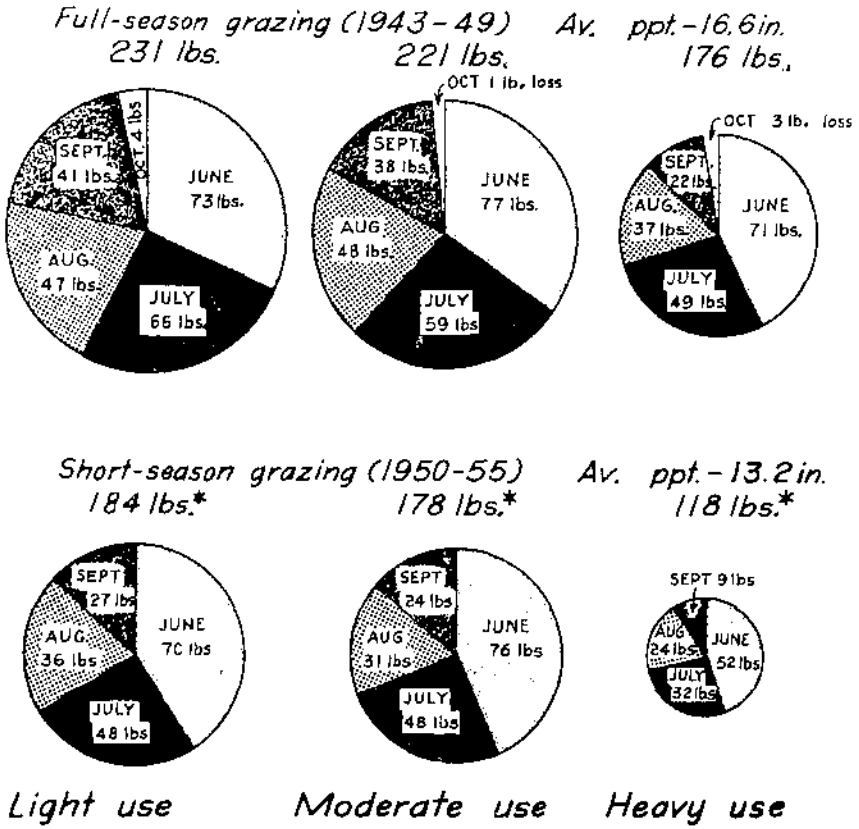


Figure 21.—Seasonal weight gains of heifers during different periods and under different grazing intensities, 1941–58. Cattle grazed a full 5-month season from 1941 through 1949. In the drier years (1950–55), the grazing period varied from a little more than 1 month to 4½ months.

Higher precipitation resulted in greater beef production per unit area (table 15) and higher gains of individual animals at all levels of grazing (fig. 22). From 1943 through 1949, annual precipitation averaged 16.6 inches, 1.2 inches above the 23-year mean of 15.4 inches. Cattle grazed the full 5-month season, and average seasonal gains under light, moderate, and heavy use were 231, 221, and 176 pounds, respectively (fig. 22). The 1950–55 period was characterized by drought; precipitation averaged only 13.2 inches. Seasonal gains were 184, 178, and 118 pounds.

Weight gains on heavily grazed ranges had become so unsatisfactory by 1956 that ranchers refused permission to graze their cattle throughout the season at the heaviest intensity. To maintain treatment effects, cattle were rotated among ranges in 1956–58 so that no one heifer remained on heavily utilized ranges for 2 consecutive months. Consequently, weight gains for 1956–58 are confounded and are not comparable with gains during prior years.

Regardless of rainfall, cattle gained most during the first 2 or 3 months of the grazing season, when the nutritional value of the vegetation was highest. The heavier the grazing, the higher the proportion of gain made early in the season. During the relatively wet period of 1943–49, gains made during the first 2 months of the grazing season were 60, 62, and 68 percent of the seasonal gain under light, moderate, and heavy grazing, respectively. Comparable percentages for the drier 1950–55 period were 64, 70, and 71 percent.



Sum of monthly gain does not equal seasonal gain because monthly gains were not recorded for all years.

Figure 22.—Average monthly and seasonal weight gains of heifers during full-season and short-season grazing periods and under different intensities of grazing.

Intensity of grazing had little effect on June gains during the 1943–49 period. Heifers gained an average of 73, 77, and 71 pounds on light, moderate, and heavy use ranges. In the drier years of 1950–55, however, heavy-use ranges produced June gains of only 52 pounds, compared with 70 and 76 pounds for light- and moderate-use ranges.

Late-season performance of the cattle depended on both grazing intensity and weather. In dry years they were removed from experimental ranges prior to October. In years when they grazed the entire season, their exposure to cold, wet snowstorms in October frequently resulted in lost weight, especially on heavily utilized ranges.

In general, average daily gains of about 1.5 pounds can be expected during a 5-month grazing season on ranges grazed lightly or moderately, compared with a gain of little more than 1 pound per day on heavily grazed ranges.

Beef Production

The amount of beef produced by a unit of rangeland depends upon the number of animals grazed and the weight gained by those animals. As long as satisfactory gains are maintained, beef production will increase with the increase in the number of animals. Production may continue to rise, however, even after gain per animal begins to decline and the range begins to deteriorate. In many studies (Beetle et al. 1961; Klipple and Costello 1960; Sarvis 1941) total beef production per acre was greatest where grazing intensity was highest. However, heavy grazing generally harmed the range and was not recommended. Furthermore, in a study of cattle grazing in Wyoming it was reported that, "total pounds of gain per acre lost some of its significance because animals from heavily grazed pastures sold for less per cwt. than animals from moderately grazed pastures" (Beetle et al. 1961).

At Manitou, moderately grazed ranges produced more beef per acre than heavily grazed ranges. During favorable growing seasons, beef production averaged 9.4, 16.7, and 14.8 pounds per acre for light-, moderate-, and heavy-use ranges, respectively. For dry years, comparable figures were 7.6, 13.2, and 10.2 pounds per acre.

This deviation from the findings of most cattle grazing studies is best interpreted by considering individual ranges. Moderately grazed range 6 produced more beef per acre than the other five ranges in all 18 years of the study. Second in production was heavily grazed range 1. These ranges had the highest percentages, 38 and 39, respectively, of grassland and abandoned field types. These same two ranges yielded the most herbage in 1942, when production was first measured. Range 3, moderately grazed and with 37-percent grasslands and abandoned fields, was the third highest herbage producer in 1942. Heavily grazed range 4 had the lowest percentage of grasslands and abandoned fields (15 percent), was producing the least herbage in 1942, and produced less beef per acre than the other moderately or heavily grazed ranges.

Because of these differences among ranges, it is difficult to compare beef production between treatments on a per acre basis. However, moderate grazing produced much better gains per animal than heavy use, and such gains resulted in total beef production at least equal to that on heavily grazed ranges. The greatest gains per heifer were made on lightly grazed ranges, but the least beef per acre was obtained. During the dry years of 1950–55, beef production was lower on all ranges, dropping least under light use and most under heavy use (table 15).

SUMMARY AND CONCLUSIONS

This bulletin helps answer the question, "How should a ponderosa pine-bunchgrass range be grazed to maintain maximum sustained production of forage and beef?" It reports a study of the relationships of three intensities of cattle grazing on this range type to: (1) Range utilization, (2) herbage production, (3) other plant responses, (4) soil conditions, and (5) cattle weight gains.

The experimental area is on the Manitou Experimental Forest, 28 miles northwest of Colorado Springs, Colo. It varies in elevation from 7,600 to 8,200 feet. Soils, developed primarily from Pikes Peak granite, are unstable and low in organic matter. The climate is characteristic of that along the eastern slope of the central Rocky Mountains. Winters are dry and often cold. Summers are relatively cool. Average annual precipitation during the 23 years (1937–59) was 15.4 inches; 73 percent fell in the 5-month period between April 1 and August 31.

The most extensive vegetation types within the experimental ranges are open timber and grassland. In addition, there are small areas of dense timber and a fourth class, abandoned fields—areas once cultivated, then abandoned, and now slowly returning to native cover. Two perennial bunchgrasses, Arizona fescue and mountain muhly, are the most abundant and the most important forage producers.

Studies were conducted from 1941 through 1958 within six fenced ranges of 254 to 309 acres. These ranges were grazed by yearling Hereford heifers except for a few seasons when some Aberdeen Angus heifers were present. The grazing season generally was June 1 through October 31. Three levels of grazing tested were: (1) Light—10–20 percent removal of the current growth of dominant forage grasses, (2) moderate—30–40 percent, and (3) heavy—more than 50 percent.

The principal findings from this study are:

1. Grazing intensity varied with vegetation cover type. Abandoned fields and grasslands, in that order, were grazed most. Open timber range was grazed much less than grasslands, and dense timber stands were scarcely grazed.

2. Cattle diet changed with grazing intensity. Few plants other than the more palatable species were taken under light and moderate grazing. Heavy use resulted in increased consumption of less desirable species such as blue grama and fringed sagebrush, especially late in the season.

3. The time a species was grazed depended largely on: (1) intensity of grazing and (2) phenology and palatability of the species. For example, Arizona fescue, little bluestem, and sedge grew early in the season and were grazed most then. Mountain muhly and blue grama made their main growth later and were grazed later.

4. For a given grass species, the number of plants grazed increased as grazing intensity increased. However, removal of foliage from individual plants tended to be the same, regardless of grazing intensity.

5. Plant cover increased when the range was either protected from cattle use or grazed lightly, and remained about the same when grazed moderately. Heavy grazing markedly reduced total plant cover, and the proportion of undesirable species increased.

6. Vegetation responded to grazing differently within different cover types. On grasslands, for example, perennial grass and sedge cover nearly doubled from 1940 to 1957 under light use, increased almost one-third when grazed moderately, and was reduced nearly one-half by heavy use. Forb cover changed little under light use, but was reduced substantially on ranges grazed

Table 15.—*Beef produced und r different intensities of grazing and during different grazing periods, 1941–58* [1] [2]

Year	Light use		Moderate use		Heavy use	
	Range 2	Range 5	Range 3	Range 6	Range 1	Range 4
	Lbs. gain/a.	*Lbs. gain/a*	*Lbs gain/a.*	*Lbs. gain/a*	*Lbs. gain/a.*	*Lbs. gain/a.*
1941	6 5	7 3	7 7	12.3	7.9	8 0
1942	4 6	6 4	10 2	18 9	12.2	12 0
Average	5 6	6 9	9 0	15 6	10 1	10 0
1943	8 5	8 0	16 0	18 7	13 6	12 8
1944	11 1	9 4	17 4	21 8	18 9	19 9
1945	9 5	9 0	14 6	19 9	17 0	14 3
1946	9 6	8 8	11 6	18 3	15 9	10 8
1947	9 9	10 6	13 5	19 2	18 1	12 3
1948	8 8	9 2	12 4	18 3	16 5	12 0
1949	9 0	9 1	12 3	21 7	13 4	11.1
Average	9 5	9 2	14 0	19 7	16 2	13.3
1950	7 5	8 5	9 5	15 3	11.3	7 0
1951	4 8	4 7	7 2	10 3	5 1	4 4
1952	7 6	9 8	12 4	18 2	12 6	9 6
1953	7 5	9 5	12 2	16 5	16 4	9 8
1954	7 8	8 6	11 3	16 7	14 5	9 4
1955	6 9	8 3	12 6	17 6	13 7	8.5
Average	7 0	8 2	10 9	15 8	12.3	8.1
1956	5.4	5 6	9 5	14 8	11 6	7.2
1957	9 4	8 8	10 7	17 2	16 9	11.5
1958	7 9	8 3	10 8	14 8	15 1	12.0
Average	7 6	7 6	10 3	15 6	14 5	10 2

[1] 1941–42=adjustment period for determining stocking rates; 1943–49=years of good forage growth (5-months grazing); 1950–55=drought years (cattle removed when utilization goals achieved); and 1956–58=years when cattle were rotated monthly among treatments.

[2] Densely timbered areas produced little herbage, and were seldom grazed. Therefore, acreage of dense timber was not included in beef production calculations.

moderately and heavily. On abandoned fields, perennial grasses and sedge increased substantially under all intensities of grazing. Although total cover of forbs was reduced only under moderate use, the proportion of forbs dropped considerably under all inten-

sities. This indicates continued plant succession on abandoned fields under all treatments. Within open and dense stands of ponderosa pine, understory plant cover, particularly bunchgrasses, decreased at all levels of grazing. Closure of the tree canopy during the study appeared responsible.

7. Mountain muhly and Arizona fescue are by far the most important forage producers on ponderosa pine-bunchgrass ranges. Of the two, the fescue is most sensitive to grazing.

8. Cover of blue grama did not appear to be affected by the rates of grazing tested in this study; it declined somewhat, however, when protected from grazing for several years.

9. Little bluestem and Parry danthonia, highly palatable grasses on timbered ranges, were exceptionally sensitive to grazing.

10. Sleepygrass, a low-quality grass, increased manyfold on abandoned cropland under all intesities of grazing, but increased little on the grasslands.

11. Fringed sagebrush, often reported to increase under heavy use, was not changed by grazing intensities tested in this study. It was less abundant, however, on areas ungrazed for 18 years than on grazed ranges.

12. Rocky Mountain pussytoes, a common but low-value forb, became more conspicuous on heavily grazed ranges as better plants were reduced, although actual cover of the plant changed very little. Total protection from grazing markedly reduced pussytoes.

13. Bearberry was essentially eliminated from ponderosa pine ranges by heavy grazing.

14. Growth responses of dominant grasses, found to be closely related to intensity of grazing, were leaf height, flower stalk height, number of flower stalks, and percentage of plants bearing flower stalks. These responses were somewhat reduced on moderately grazed ranges as compared with those lightly grazed. Growth was greatly curtailed on heavily grazed ranges.

15. Following heavy grazing, Arizona fescue and mountain muhly recovered vigor most rapidly during the first 3 years of protection, but still appeared to be improving after 8 years of protection.

16. Root development was influenced significantly by the levels of grazing tested. Root depth, root weight, number of branch rootlets, and relative root abundance of desirable species in the plant community decreased with an increase in grazing.

17. Root patterns of the plant community were changed by grazing. The vigor and weight of Arizona fescue and mountain muhly roots declined as grazing increased. Blue grama roots appeared to increase on moderately grazed ranges but diminished under heavy grazing. Fringed sagebrush and pussytoes roots maintained or extended their relative position in the underground system under moderate or heavy use. The net result of heavy grazing was a thinner, less extensive total root system.

18. Grazing affected both seasonal plant development and total growth. Heavy grazing not only delayed early growth but retarded later growth.

19. Total yields of grasses and sedges were maintained by light

and moderate grazing. Yields were reduced significantly by heavy use.

20. Grasslands yielded two to three times more grass and sedge herbage than open timber stands, which produced 4 to 6 times more herbage than dense timber stands.

21. Protection from cattle grazing increased infiltration rates from 1941 to 1952. In contrast, they remained about the same under the three rates of grazing tested.

22. Erosion rates, as measured by the infiltrometer, were two to four times higher under heavy grazing than under light grazing. The highest rate of soil loss was only 418 pounds per acre per inch of surface runoff.

23. Average weight gain of yearling heifers was inversely related to the intensity of grazing. During the 5-month grazing season, heifers gained an average of 231, 221, and 176 pounds per heifer on ranges grazed lightly, moderately, and heavily. Comparable figures for the drier 1950–55 period were 184, 178, and 118 pounds.

24. Heifers gained most during the first 2 to 3 months of the June-October grazing season. The heavier the grazing, the higher was the proportion of gain made early in the season. Heifers seldom produced additional gain after the end of September.

25. Overall, best results were obtained by utilizing 30 to 40 percent of the dominant bunchgrass herbage by the end of the season on ponderosa pine-bunchgrass range. This intensity of grazing is recommended. While these results apply specifically to the combination of soil, vegetation, and topographic situations evaluated at Manitou, the general principles developed and conclusions drawn confirm those of other workers on widely different range types in western North America.

BOTANICAL AND COMMON NAMES OF PLANTS MENTIONED

PERENNIAL GRASSES	
Agropyron smithii Rydb.	western wheatgrass
Andropogon scoparius Michx.	little bluestem
Bouteloua gracilis (H.B.K.) Lag.	blue grama
Danthonia parryi Scribn.	Parry danthonia
Festuca arizonica Vasey	Arizona fescue
Koelaria cristata (L.) Pers.	prairie Junegrass
Muhlenbergia montana (Nutt.) Hitchc.	mountain muhly
Poa canbyi (Scribn.) Piper	canby bluegrass
P. fendleriana (Steud.) Vasey	mutton bluegrass
P. pratensis L.	Kentucky bluegrass
Sitanion hystrix (Nutt.) J. G. Smith	bottlebrush squirreltail
Stipa comata Trin. & Rupr.	needle-and-thread
S. robusta (Vasey) Scribn.	sleepygrass
ANNUAL GRASSES	
Schedonnardus paniculatus (Nutt.) Trel.	tumblegrass
GRASS-LIKE PLANTS	
Carex heliophila Mackenz.	sun sedge
PERENNIAL FORBS	
Antennaria parvifolia Nutt.	Rocky Mountain pussytoes
Arenaria fendleri	Fendler sandwort
Artemisia frigida Willd.	fringed sagebrush
Astragalus agrestis Dougl.	purple milkvetch
A. campestris	timber poisonvetch
Chrysopsis fulcrata Greene	goldaster
C. villosa (Pursh) Nutt.	hairy goldaster
Lupinus argenteus Pursh	silvery lupine
L. parviflorus Nutt.	lodgepole lupine
Senecio fendleri A. Gray	Fendler groundsel
S. integerrimus Nutt. (1818)	lambstongue groundsel
ANNUAL FORBS	
Chenopodium album L.	lambsquarters goosefoot
C. leptophyllum Nutt.	slimleaf goosefoot
SHRUBS	
Arctostaphylos uva-ursi (L.) Spreng.	bearberry
Cercocarpus montanus Raf.	true mountainmahogany
Rosa arkansana Porter	Arkansas rose
TREES	
Pinus ponderosa Lawson	ponderosa pine

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