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Effect of Grazing Intensity Upon Vegetation and Cattle Gains on Ponderosa Pine-Bunchgrass Ranges of the Front Range of Colorado

By W. M. Johnson, *range conservationist, Rocky Mountain Forest and
Range Experiment Station,¹ Forest Service*

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INTRODUCTION

Stockmen and managers of western range lands, both public and private, are vitally interested in stocking their ranges on a basis that will assure sustained forage and livestock production at a high level. It is recognized that if ranges are stocked too heavily, the vegetation deteriorates, producing less forage and less livestock. On the other hand, too light grazing fails to make use of forage that is available, and livestock production is less than it should be. This problem of proper stocking is especially important to stockmen and ranchers of the Front Range of Colorado. Many of them graze only a few head of livestock, and it is necessary for them to obtain the best possible

¹ Maintained by the Forest Service, United States Department of Agriculture, in cooperation with Colorado A & M College, Fort Collins, Colo.

income from their relatively small herds. The larger livestock operators that graze in the area also need a basis for proper stocking in order to operate efficiently.

In addition to the needs of the stockmen, ranchers, and larger livestock operators of the Front Range are watershed considerations. The headwaters of the South Platte and Arkansas Rivers are here, and they furnish irrigation water for about 1½ million acres of intensively used Colorado cropland. Proper stocking has a direct bearing on these watersheds in that it improves deteriorated ranges and maintains those already in good condition. Good range conditions provide satisfactory watershed conditions, whereas poor range conditions often do not.

As part of a research program to improve methods of range management, the Rocky Mountain Forest and Range Experiment Station conducted a study to determine the relation of grazing intensity to herbage production, herbage utilization, and amount and value of cattle gains on ponderosa pine-bunchgrass² ranges. The study was made at the Manitou Experimental Forest in the Front Range of the Rocky Mountains 26 miles northeast of Colorado Springs, Colo., from 1941 through 1947. From the basic information collected, it is possible to recommend an intensity of utilization that will maintain forage and watershed values and at the same time make efficient use of available forage for beef production. Since the findings of the study are for ponderosa pine ranges on granitic soils and of moderate topography, they should be useful as a guide to the stocking of similar ranges in the Rocky Mountain area.

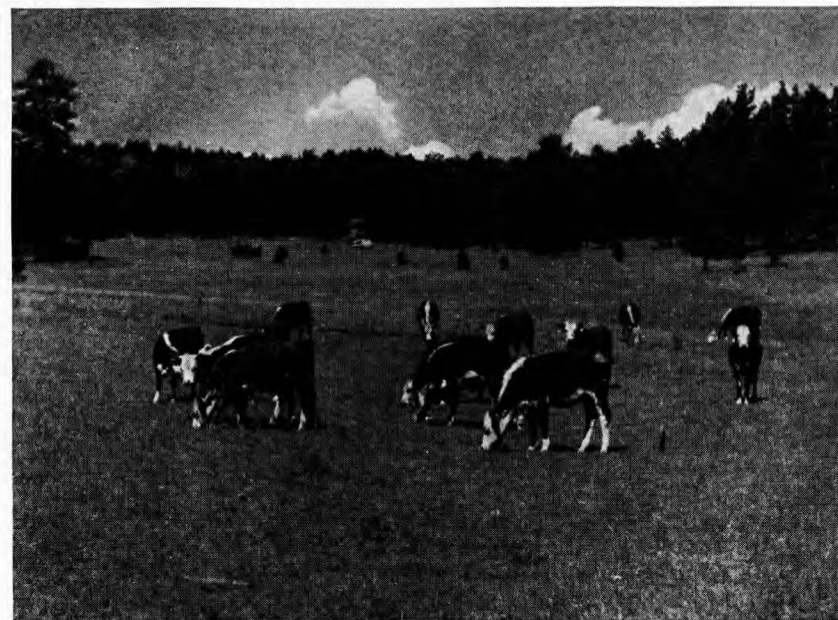
THE EXPERIMENT

THE EXPERIMENTAL AREA

The Manitou experimental area is located in a broad mountain valley characteristic of many in central Colorado (fig. 1). It has a gently sloping east exposure with low, east-west ridges. Near the east side these ridges blend into the intervening valleys and present a uniform, gently sloping topography; on the west, they are more pronounced, sometimes rising rather abruptly 50 to 100 feet. Elevational limits range from 7,600 feet on the east to approximately 8,200 feet on the west.

The soils have developed primarily from Pikes Peak granite, which is characterized by quartz and large orthoclase crystals with mica as an accessory mineral. The surface soils, 12 to 18 inches thick, contain low amounts of organic matter, and are slightly acid, loose, and open, with a sandy-loam texture. Some areas have sandy-clay subsoils, but the most common subsoils are coarse sandy loams that grade into the unconsolidated parent material at a depth of 30 to 40 inches. Although slopes of this valley are commonly less than 20 percent, the soils erode readily when they are not protected by a mantle of vegetation.

² Common and botanical names of species mentioned are listed on p. 35.



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FIGURE 1.—The experimental pastures have a moderate topography. The range consists largely of a mixture of open grassland parks such as this, and open ponderosa pine forests.

The climate is characterized by normally open, dry winters and mild summers. Average annual precipitation at the Manitou Experimental Forest for the period 1937–47 was 16.75 inches. The driest year was in 1939 with 7.99 inches, and the wettest in 1947 with 25.80 inches. More than 75 percent of the precipitation falls during the 6-month period of April through September, when most of the plant growth occurs. Temperatures during the summer are mild, seldom exceeding 85° F. during the day or dropping to less than 40° during the night.

Ponderosa pine ranges as represented on the experimental area may be divided into four types: (1) grassland parks, untimbered (fig. 2, A); (2) open timber, ponderosa pine (fig. 2, B); (3) stands of dense timber with dense canopies; and (4) fields once cultivated but now abandoned.

Prior to 1935 the land included in the experimental pastures was in absentee ownership, and grazing use was very heavy and for a long season. Blue grama was the dominant species but remnant tufts of the original bunchgrass cover remained. In 1935 the Resettlement Administration began purchasing these lands, and some degree of grazing control was begun. Then, in 1937, they were turned over to the Forest Service. During the summer grazing seasons of 1935–38, moderate grazing occurred on the experimental area; this was also true of winter grazing in 1939. In 1940 the area was closed to all grazing, and physical installations, including fences, water developments, corrals, and scales for weighing cattle, were completed.



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FIGURE 2.—A, Grassland park in foreground with open timber in background. These two vegetation types represent the major forage-producing areas of the experimental pastures. Arizona fescue and mountain muhly are the principal forage species. B, An open stand of ponderosa pine. Much palatable bunch-grass forage is produced under proper grazing of range in good condition.

RANGE PASTURES

To study the effect of grazing intensity, six range pastures were established in 1941 (fig. 3). These varied in size from 254 to 309 acres. All were representative of ponderosa pine ranges in the Front Range of the Colorado Rocky Mountains, having moderate topography and granitic soils. They all contained some open timber, grassland parks, and dense timber types, and all but pastures 1 and 6 contained abandoned fields (table 1). The relative proportions of these types varied between pastures but a greater acreage of open timber than of other types occurred in all. The area of open timber in the pastures was relatively consistent, varying from 151 acres in pasture 6 to 213 acres in pasture 4. The area of grassland park varied more widely between pastures from a low of 31 acres in pasture 4 to more than 3 times that much in pastures 1, 3, and 6. The relative amounts of dense timber and abandoned field types in each pasture were small compared to those of the other two types.

TABLE 1.—Acreage by cover types of the six experimental pastures, Manitou Experimental Forest

Pasture No.	Grassland park	Open timber	Dense timber	Abandoned field	Total
	<i>Acres</i>	<i>Acres</i>	<i>Acres</i>	<i>Acres</i>	<i>Acres</i>
1.....	106	158	5	0	269
2.....	74	184	19	32	309
3.....	98	177	11	11	297
4.....	31	213	6	9	259
5.....	81	165	19	10	275
6.....	96	151	7	0	254
Total.....	486	1,048	67	62	1,663

An inventory of the vegetation, using the point-observation method (7)³ and made in conjunction with the establishment of the experimental pastures, showed the plant cover to be relatively sparse. Total average density of the vegetation on all types was less than 10 percent (table 2). The density of the vegetation on grassland parks was nearly twice that on the open timber type and 57 percent greater than that on the abandoned fields. Understory vegetation was sparsest in the dense timber where a large part of the ground was covered with fallen pine needles.

The grasses and sedges were the most abundant vegetation in the grassland parks and open timber types, but in the dense timber they were exceeded in density by weeds (forbs), and in the abandoned fields by both forbs and fringed sagebrush. Of the grasses, mountain muhly was the most abundant on all types and was of highest density in the grassland parks. Blue grama was abundant in the grassland parks, ranking second of the grass species, but it was sparse in the open timber and was not found in the dense timber and abandoned fields. Arizona fescue was the second grass in abundance in the

³ Italic numbers in parentheses refer to Literature Cited, p. 36.

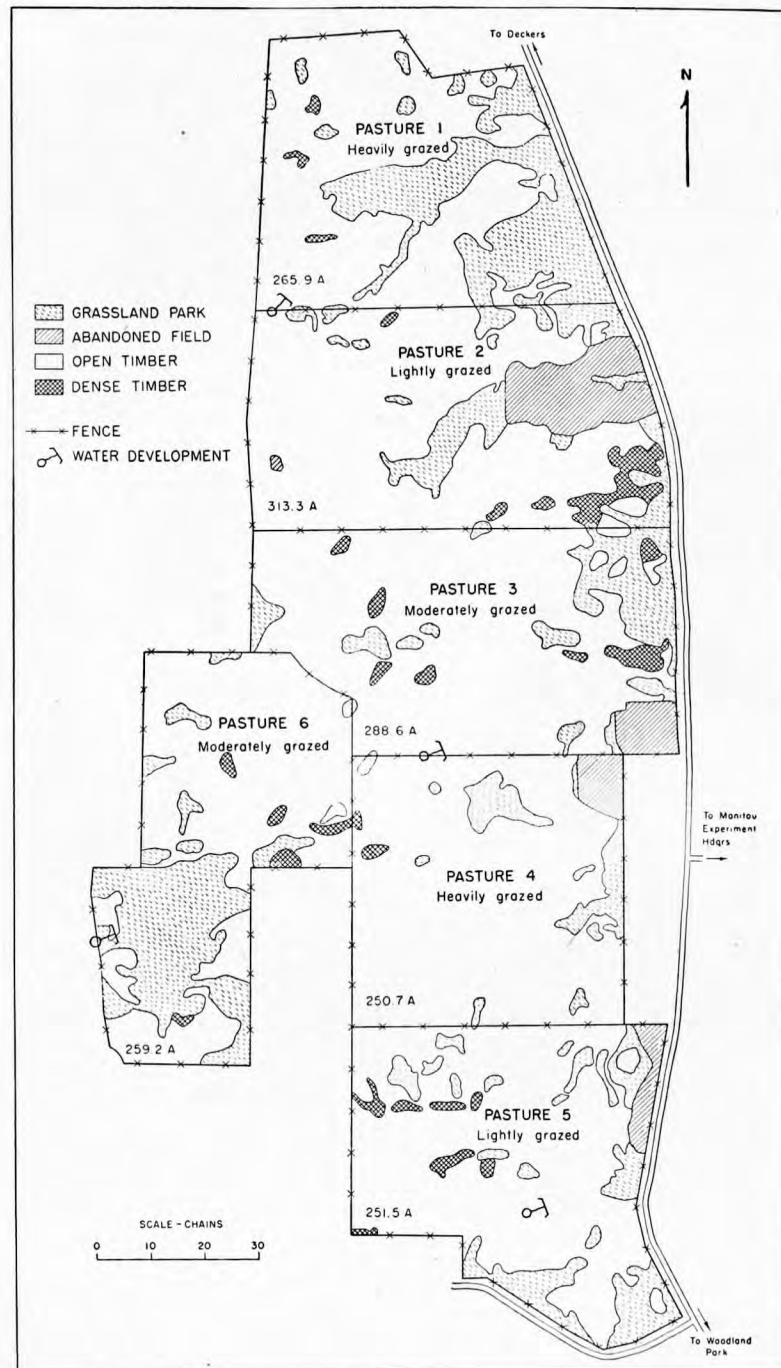


FIGURE 3.—Experimental range pastures, Manitou Experimental Forest.

dense timber type and was exceeded only by mountain muhly and blue grama in the grassland parks. *Danthonia*, a permanent plant in later years, was not observed in 1940. The worthless Rocky Mountain pussytoes and trailing fleabane and the low-valued fringed sagebrush were the only plants other than the grasses and sedges important in number.

In 1938 the herbage yields of palatable species on the experimental area were determined by sampling 87 25-square-foot plots. Each important species was clipped, air-dried, and weighed. The total average herbage yield of important palatable plants was 266 pounds per acre. Grasses and sedges produced 251 pounds per acre, 94 percent of the herbage palatable to livestock. Mountain muhly, by far the most abundant species, produced an average of 119 pounds per acre, and was followed in order by sedge, Arizona fescue, and little bluestem. Geranium and western yarrow, the two palatable forbs present in sufficient quantities to weigh, made up 5 percent of the palatable herbage, and the shrub *Arkansas rose* less than 1 percent.

Livestock used in the study were yearling grade Hereford heifers obtained from local stockmen (fig. 4). Each owner's cattle were distributed among the six experimental pastures, and the same animals stayed on the pastures during the entire grazing season.

TABLE 2.—Average density of vegetation on experimental pastures at Manitou Experimental Forest, 1940

Species	Average density in percent of ground covered			
	Grassland park	Open timber	Dense timber	Abandoned field
Grasses and grasslike plants:	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>
Arizona fescue.....	0.331	0.530	0.180	0.021
Blue grama.....	.929	.064		
Little bluestem.....	.092	.163	.035	
Mountain muhly.....	1.768	1.020	.375	.437
Other grasses.....	.348	.365	.085	.355
Sedges.....	.215	.277	.145	
Total.....	3.683	2.419	.820	.813
Weeds or forbs:				
Geranium.....	.018	.086	.065	
Lupine.....	.071	.058	.075	.021
Nickleaf milkvetch.....	.070	.048	.015	.083
Cinquefoil.....	.180	.038	.020	.062
Rocky-Mountain pussytoes.....	1.356	1.210	.580	.312
Groundsel.....	.144	.050	.020	.084
Trailing fleabane.....	.211	.034	.025	1.333
Other weeds.....	.440	.440	.180	.771
Total.....	2.490	1.964	.980	2.666
Half shrubs: Fringed sagebrush.....	2.384	.312	.068	1.959
Total.....	8.557	4.695	1.868	5.438



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FIGURE 4.—Yearling grade Hereford heifers corraled for weighing. Individual weights were taken at the beginning and end of the grazing season, and pasture group weights at monthly intervals during the season.

To help determine actual grazing capacities, all experimental pastures were stocked in 1941 at a rate proportional to their estimated capacity. Although utilization varied considerably between pastures, none were excessively underused or overused (table 3), and a better basis for determining actual grazing capacity was obtained. Light grazing was considered to be where 10 to 20 percent of the grass and sedge herbage was removed; moderate grazing, 30 to 40 percent; and heavy grazing, 50 percent or more.

As a result of stocking adjustments in 1942, pastures 1, 4, and 6 received moderate grazing; pastures 3 and 5, light grazing; and pasture 2, very light grazing. The stocking was again adjusted in 1943. In that and subsequent years, utilization obtained on pastures 3 and 6 was reasonably close to the utilization goal of moderate grazing. Also, utilization on lightly grazed pastures 2 and 5 was reasonably close to that for light grazing. The utilization goal for heavy grazing was first achieved in 1943 on pasture 4 and in 1944 on pasture 1. Pasture 4 was grazed the heaviest, having more than 70 percent of its grass and sedge herbage removed every year after 1943.

Adjustments in the number of heifers on the experimental pastures to obtain the desired utilization goals are shown in table 3. The greatest adjustments were made on heavily grazed pastures 1 and 4 and moderately grazed pasture 3. Stocking rates of the other pastures were varied by only one or two head of heifers after 1943.

Since the grazing season was from June 1 to October 31 throughout the experiment, the study relates to range use during the late spring, summer, and early fall. Observations of plants on ungrazed sites in pasture 2 in 1941, 1942, 1946, and 1947 showed that the leaf growth

TABLE 3.—Average utilization of grass and sedge herbage on pastures planned for three grazing intensities,¹ and number of cattle grazed, Manitou experimental pastures

Year	Heavy grazing				Moderate grazing				Light grazing			
	Pasture 1		Pasture 4		Pasture 3		Pasture 6		Pasture 2		Pasture 5	
	Heifers	Utili- zation	Heifers	Utili- zation	Heifers	Utili- zation	Heifers	Utili- zation	Heifers	Utili- zation	Heifers	Utili- zation
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
1941	10	28.0	10	34.0	10	25.0	13	40.0	8	42.0	9	23.0
1942	17	40.6	17	36.4	14	16.1	21	30.4	6	8.4	7	15.8
1943	21	43.0	24	55.9	24	42.4	21	31.6	10	16.0	9	15.6
1944	21	50.3	24	74.7	20	38.6	21	29.8	12	10.5	10	14.4
1945	25	55.0	20	72.2	18	39.2	20	32.9	12	21.4	10	18.8
1946	25	60.1	18	72.2	18	39.5	21	29.8	12	13.2	11	18.6
1947	25	64.5	18	71.9	18	37.4	21	29.6	12	13.4	11	20.0

¹ Light grazing, 10 to 20 percent of grass and sedge herbage removed; moderate grazing, 30 to 40 percent; heavy grazing, 50 percent or more.

of Arizona fescue usually began about the first week in April. Leaf growth of mountain muhly started 2 weeks later, and in 3 years of record it had an average maximum leaf height of between 3 and 4 inches. It was even further developed by June 1 of the fourth year. Average maximum leaf height of Arizona fescue at that time was from 7 to 12 inches. Seed maturity of Arizona fescue in the grassland type varied from August 12 to September 12, and that of mountain muhly from August 22 to September 15. The June 1 to October 31 grazing season therefore included most of the active growth period of the two most important forage species.

To determine the effect of grazing intensity on herbage production, measurements were made of unsegregated grass and sedge herbage on randomized plots within each pasture in 1942, and again in 1946 and 1947. On those dates the herbage on the plots was clipped, air-dried, and weighed. The utilization of palatable grasses and sedges by the cattle was estimated each year, 1942-47.

UTILIZATION ACTUALLY OBTAINED

The principal palatable grasses and sedges were considered in estimates of average herbage utilization, particular attention being given to mountain muhly and Arizona fescue because of their importance as forage plants. Some of the other species, which lacked abundance, played only a small part in the over-all use of the pastures. During 1942, utilization was estimated by ocular methods (4) and checked against the percentage of grazed plants found along line transects used in determining herbage production (8). Since the results obtained by the two methods agreed closely, the utilization determined by the line-transect method was accepted as the percentage of use. It was apparent that areas of heavy, moderate, and light use were developing in most of the pastures. Therefore, in 1943 and throughout the remainder of the study, utilization was estimated on the basis of stubble heights (1), and each use area in individual pastures was carefully mapped.

PASTURE AND TYPE UTILIZATION

The irregular patterns of herbage utilization noted in 1942 continued prominent in most pastures to the end of the experiment. Even in the heavily grazed pastures areas of heavy, moderate, and light use (figs. 5-7) were observed during the early part of the study. However, as the vigor of the plants became less and the amount of herbage decreased, the size of the heavily used areas increased until at the end of the experiment all of pasture 4 and 67 percent of pasture 1 were receiving heavy utilization (table 4).

In observing herbage utilization between pastures, it was noted that the higher the grazing rate the more intensive the utilization on all types. In pasture 4, which received the heaviest grazing, the whole area was receiving heavy grazing by 1947. In pasture 1, which on the average received a little lighter use than pasture 4, all the grassland type and about half the open timber type received heavy grazing. The remainder of the open timber type received moderate grazing. At the other extreme, pasture 2, which on the average received the lightest use, had some areas of heavy use; 5 acres of grass-



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FIGURE 5.—Open area in heavily grazed pasture 4 at end of grazing season. Such heavy utilization causes a decrease in the volume of forage produced and the replacement of palatable species by inferior plants.



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FIGURE 6.—A moderately grazed range area in pasture 4 at the end of the grazing season. On this area 40 percent of the available herbage was utilized by the livestock.



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FIGURE 7.—Light grazing in an excellent stand of mountain muhly. Small areas of heavy utilization are intermixed with larger areas of light or no use.

land and 8 acres of open timber, or a total of 4 percent of the pasture, received this kind of utilization. Seventeen percent of the pasture was grazed moderately and the remaining 79 percent was grazed lightly. The other lightly used pasture showed a somewhat similar distribution of use; 22 percent was grazed heavily, 11 percent moderately, and the remainder lightly.

Moderate grazing, which is recommended as a result of this study, had a distribution of grazing intermediate between the heavy and light grazing intensities. In pasture 6, 2 acres, or about 1 percent of the area, was grazed heavily; about 43 percent, predominantly the grassland, was grazed moderately; and 54 percent, all open timber type, was grazed lightly.

The grassland park type of pasture 3 developed into a concentration area in 1943 and was too heavily grazed to meet requirements of the treatment. By fencing out the grassland with an electric fence in 1944, the cattle were forced to use the herbage under the open timber during the first 4 months of the season. The fence was then taken down and the cattle again had access to the grassland park. Under this management, utilization in the open timber was increased and the use on the grassland reduced so that the requirements of the treatment were met. It is believed that if there had been no fencing in 1944 to correct cattle distribution, pasture 3 would have had a somewhat higher percentage of heavily grazed range than pasture 6, but that even so, most of the pasture would have received moderate grazing. The advantage given by the fencing was a more uniform distribution of grazing throughout the pasture.

TABLE 4.—Actual average utilization of palatable grass and sedge herbage, by pasture and cover type, on pastures planned for grazing at three intensities, 1942-47

Pasture and cover type	Actual average use classification	Average area	Utilization					
			1942	1943	1944	1945	1946	1947
			Percent	Percent	Percent	Percent	Percent	Percent
Pasture 1:								
Grassland	Heavy	106	54	59	70	70	75	78
Open timber	{ Heavy	74	47	45	44	55	64	73
	{ Moderate	84	18	21	31	36	38	40
Dense timber		5	0	0	0	0	0	0
Average 1			40.6	43.0	50.3	55.0	60.1	64.5
Pasture 4:								
Grassland	Heavy	31	29	62	85	85	85	83
Open timber	Heavy	213	36	54	73	70	70	70
Dense timber		6	0	0	0	0	0	0
Abandoned field	Heavy	9	72	80	80	80	80	80
Average 1			36.4	55.9	74.7	72.2	72.2	71.9

PLANNED FOR HEAVY GRAZING

Footnote at end of table.

Within a pasture, use areas occurred in about the same places each year. Usually they coincided with range types, but even within types certain areas were grazed more heavily than adjacent areas (fig. 8).

In general the cattle grazed the herbage on the grassland parks and abandoned fields more heavily than that growing in the much larger areas of open timber. This was true for all grazing rates. Under the moderate grazing rate in pasture 6 the grassland type received an average herbage utilization of 38 percent compared with 25 percent for the open timber type over the 1942-47 period. In lightly grazed pasture 5 the 6-year average use of the grassland type was 32 percent compared with 8 percent for open timber. Much the same relative difference between the use of the types was observed in lightly grazed pasture 2 where the use of grassland averaged 21 percent and the open timber 8 percent. Even where the grassland and the open timber types were both heavily grazed, as they were in pastures 1 and 4, the grassland type was grazed much more closely.

The utilization of herbage on the grassland and open timber types was much more alike on moderately used pasture 3, the vegetation on both types being used moderately. However, this was the result of the electric fence restricting the use of the grassland type during part of the year. In 1943, prior to installation of the fence, the grass and sedge herbage in the grassland type was grazed an average of 55 percent compared with 36 percent in the open timber type.

Exclusive of pasture 3, the average grass and sedge utilization on grassland types in 1943 was 41.2 percent compared with 28.5 percent on open timber types. The relative differences in utilization of these two types varied considerably between pastures but this did not appear to be related to grazing intensity. However, within each pasture the difference in utilization between the two types tended to be about the same each year. These results agree with those of other studies (2, 5, 6) which have also shown that range herbage on grassland types is grazed more closely than that on open timber types when cattle movements between the two are unrestricted.

The abandoned fields in all pastures, except pasture 2, were heavily grazed. Vegetation on the abandoned fields differed considerably from that on the rest of the pastures. Much of the cover consisted of forbs such as nickleleaf milkvetch, penstemon, sunflower, aster, trailing fleabane, and the half-shrub, fringed sagebrush. In the afternoons the cattle drifted to these abandoned-field areas, which were small, varying in size from 9 to 32 acres. Their comparatively heavy use may be explained in part by the presence of the forbs that furnished variety to the animals' diet; on the more extensive grassland type native grass species predominated.

In all but the pastures planned for light grazing, utilization of grass and sedge herbage on the abandoned fields exceeded 50 percent in most years. On pasture 2, the average utilization for the 6 years on the abandoned field was only 31 percent, and on pasture 5 it was 45 percent. On pasture 2, plant succession was slightly further advanced and the weed component was much reduced. Instead of palatable weeds, more of the vegetation was composed of relatively unpalatable grasses, such as tumblegrass, sand dropseed, and sleepygrass. This cover was not as attractive to the cattle.

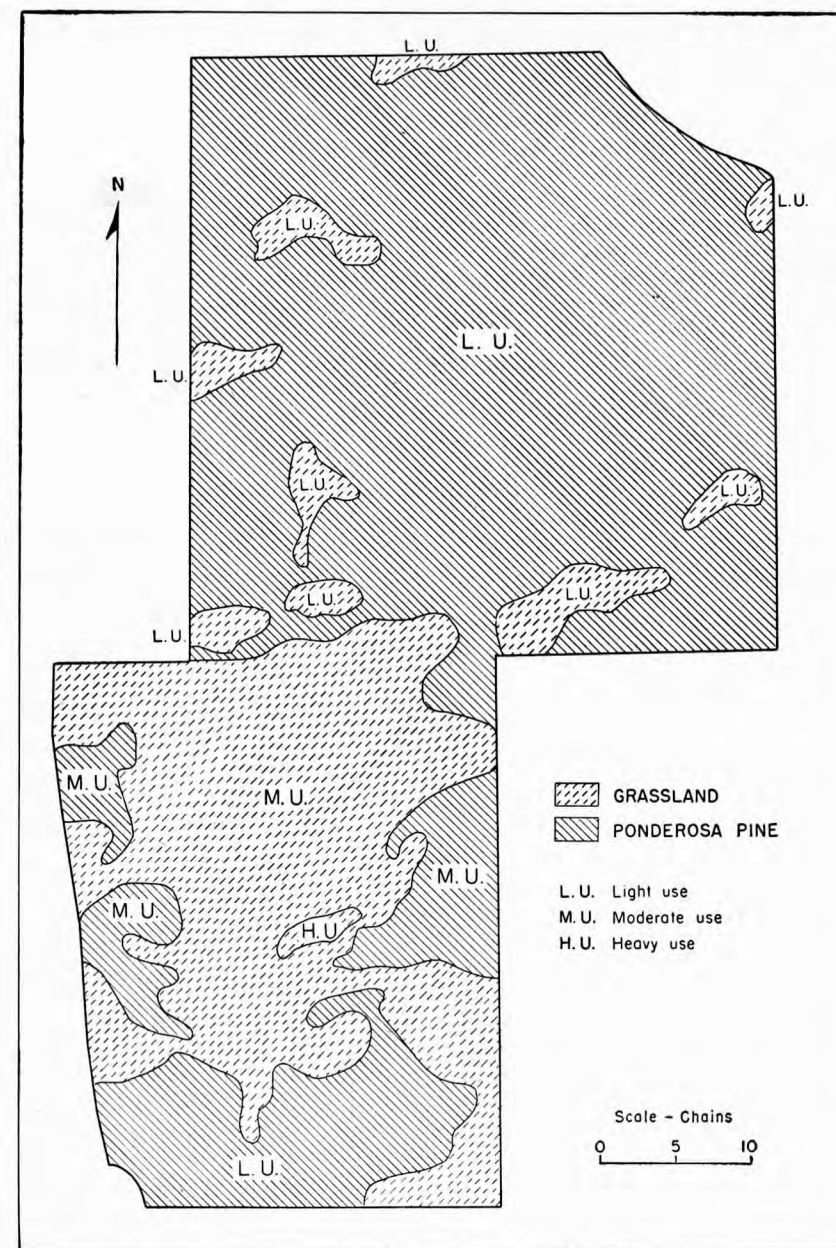


FIGURE 8.—Pasture 6 showing cover types and use areas as they occurred in 1947, Manitou Experimental Forest.

Dense timber types were practically unused under all grazing intensities studied. These types had heavy layers of pine needles over the ground surface and produced only sparse herbaceous vegetation.

Factors other than vegetation types caused irregular use of the pastures. There was some tendency for the heaviest grazing to be concentrated along the lower east side of the pastures, and small areas of concentrated use, generally less than one-fourth acre, occurred around water developments and salt grounds. Also, there was a tendency for cattle to graze heavily in the bottoms of small drainages where the highly palatable Kentucky bluegrass was prevalent. On many areas, however, the reason for use development was unknown.

SPECIES UTILIZATION

The average percentage of herbage removed from the principal species on the experimental range pastures under heavy, moderate, and light grazing intensities are shown in table 5. For the most part, the degrees to which these species were utilized were correlated with the grazing intensity. The notable exception was Kentucky bluegrass which occurred in small amounts and was grazed heavily under all conditions.

TABLE 5.—Average percent of herbage removed from principal species on Manitou experimental pastures, under three grazing intensities, 1942-47

Species	Herbage removed under—		
	Heavy grazing	Moderate grazing	Light grazing
	Percent	Percent	Percent
Bluestem wheatgrass.....	86	72	48
Little bluestem.....	90	43	28
Blue grama.....	48	11	0
Danthonia.....	85	37	16
Arizona fescue.....	63	35	10
Prairie junegrass.....	10	0	0
Mountain muhly.....	60	40	20
Kentucky bluegrass.....	90	90	90
Sedge.....	81	43	37
Western yarrow.....	14	6	0
Nickleaf milkvetch.....	88	53	45
Fremont geranium.....	55	30	12
Fringed sagebrush.....	15	4	0
Arkansas rose.....	61	23	18

Under moderate grazing, an average of about 40 percent of the mountain muhly herbage was removed. This left a stubble of about 1½ to 2 inches at the end of the grazing season. Arizona fescue was grazed an average of 35 percent, an intensity that left an average stubble height of 5 to 6 inches and a large number of plants ungrazed.

About 50 percent of the danthonia plants were closely used and on the average about 37 percent of the herbage produced by this species was grazed. Most of the sedges were grazed to a stubble of 1½ to 2 inches. Blue grama, a species most prevalent on range in poor condition in this area, prairie junegrass, western yarrow, and fringed sagebrush were used only lightly. Of the forbs, nickleaf milkvetch was grazed most, averaging about 53 percent, and Fremont geranium was next heavily utilized.

Under the heavy rates of grazing more of the plants were grazed and the stubble was shorter. Nine-tenths of the Arizona fescue plants were grazed to some extent. Only about 1-inch stems of the young plants were left. Because the older plants were protected by a dense mass of dried stalks, the cattle could not graze closer than 3 to 4 inches. On the average, about 63 percent of the herbage produced by this species was consumed. All plants of mountain muhly and little bluestem were grazed to a 1-inch stubble. Most of the danthonia plants were grazed to a short stubble, representing 85 percent average herbage use. Blue grama was grazed to a 1-inch stubble receiving much heavier grazing than on lightly and moderately grazed areas where it received light or no grazing.

In lightly grazed pastures only the younger and more succulent plants of the more palatable species were grazed. The stubble on the grazed plants was about the same as on the pastures that were moderately stocked, but fewer of the individual plants were cropped. On the basis of relative abundance, the palatability of the different grasses was about the same. Kentucky bluegrass, bluestem wheatgrass, little bluestem, and the sedges received the heaviest use followed by mountain muhly, danthonia, and Arizona fescue.

The preference shown by cattle for the different forage grasses, under all grazing intensities, varied with the time of the year, the relative abundance, and, to some extent, the rate of stocking. When first turned into the pastures in June, the cattle grazed Arizona fescue, Kentucky bluegrass, little bluestem, and the sedges in preference to the other grasses. Mountain muhly was also grazed at this time, but to a lesser extent. As the season advanced, it was grazed more intensively and by the end of the summer grazing it furnished the bulk of the forage. Arizona fescue became dry and harsh, and was not readily grazed. Little bluestem also was grazed less later in the season. Kentucky bluegrass and the sedges were still grazed, but not so conspicuously as earlier in the summer because most of the plants had already been used. Danthonia was grazed most readily during early summer to midsummer. Casual observation would have suggested that this grass was not grazed appreciably, because the noticeable plants at the end of the season were untouched. Generally, however, if a plant of danthonia was grazed at all, it was eaten about as closely as the cattle could crop.

Relative abundance was an important factor affecting the intensity to which a palatable grass was grazed by the heifers. Where a species was less abundant, it tended to be more heavily grazed. For example, Arizona fescue was heavily grazed where it was relatively scarce in a dense stand of mountain muhly. Danthonia was outstanding in this respect.

EFFECT OF GRAZING INTENSITY ON HERBAGE PRODUCTION

The amount of herbage produced by palatable grasses and sedges in the pastures was measured in 1942, the first year that different rates of stocking were applied, and again in 1946 and 1947. These production estimates were obtained by clipping, air-drying, and weighing all of the herbage produced by the palatable grasses and sedges on randomized plots. Because palatable weeds were sparse, they were not clipped. Production was taken only for the grassland and open timber types where the bulk of the forage was produced.

HERBAGE PRODUCTION BY PASTURES

Grass and sedge herbage production on the lightly and moderately grazed pastures was about the same at the close of the study period in 1947 as it was in 1942, but significant decreases occurred on the pastures heavily grazed. As shown in table 6, the air-dry weight of herbage on the pastures moderately grazed averaged 361 pounds per acre in 1942, 325 pounds in 1946, and 331 pounds in 1947. Differences between these yields are well within variations that are to be expected as the result of seasonal differences in plant growth or experimental error in sampling.

TABLE 6.—Average air-dry yield per acre of grass and sedge herbage on pastures grazed at three intensities, 1942, 1946, and 1947

Grazing intensity and pasture No.	1942		1946		1947	
	Herbage produced per acre	Sampling error ¹	Herbage produced per acre	Sampling error ¹	Herbage produced per acre	Sampling error ¹
Heavy:	Pounds	Percent	Pounds	Percent	Pounds	Percent
1-----	408	± 14	212	± 14	240	± 21
4-----	292	± 20	138	± 20	149	± 19
Average-----	351	-----	176	-----	195	-----
Moderate:						
3-----	342	± 17	304	± 17	298	± 14
6-----	384	± 15	350	± 18	370	± 21
Average-----	361	-----	325	-----	331	-----
Light:						
2-----	295	± 20	265	± 21	303	± 24
5-----	341	± 17	244	± 18	303	± 18
Average-----	317	-----	255	-----	303	-----

¹ Sampling errors are 2 standard errors expressed in percent of the mean.

On lightly grazed pastures the production of grass and sedge herbage did not vary in statistically significant amounts over the treatment period even though only 255 pounds per acre of herbage was produced in 1946 as compared with 317 pounds in 1942. The main forage-producing grasses remained vigorous, and there was a very noticeable increase in the amount of herbaceous litter both on the ground and in the grass clumps.

Under heavy grazing herbage production decreased from an average of 351 pounds per acre in 1942 to 176 pounds in 1946 and 195 pounds in 1947. These decreases exceed variations that are to be expected because of seasonal differences in plant growth or error in sampling. Since such large decreases did not occur on the moderately or lightly grazed pastures, it can be concluded that those on the heavily grazed pastures were due to close grazing.

On heavily grazed pasture 4 utilization remained fairly constant at somewhat more than 70 percent of the grass herbage production from 1944 through 1947, even though reductions were made in the number of cattle in the pasture during the course of the study. On the other heavily grazed pasture the number of cattle was maintained at 25 from 1945 through 1947, but the percentage of utilization increased each year. The decrease in herbage production was due to a reduction in plant vigor. As the vigor was reduced, less forage was available, causing the cattle to graze the plants more closely. The injurious effect on the plants was cumulative. By 1947 the grasses that furnished the bulk of the forage were noticeably lacking in vigor; their height growth was depressed and production of seedstalks lowered.

HERBAGE PRODUCTION BY RANGE TYPES AND USE AREAS

The most striking comparison of the effects of grazing intensity on grass and sedge herbage production is made by comparing the production on use areas within range types irrespective of pastures. On all use areas, the grassland type produced much more grass and sedge herbage than the open timber type. The average herbage production increased on the moderately and lightly grazed grassland and was maintained on the moderately and lightly grazed open timber. In contrast, average herbage production decreased greatly in both the grassland and open timber on areas that received heavy grazing (table 7). Grassland moderately grazed produced an average of 2.7 times as much herbage in 1947 as heavily grazed grassland, and 19 percent more than was produced in 1942. On heavily used areas, the 1947 herbage production was only 42 percent of the 1942 production.

In the open timber type, 1947 herbage production was approximately the same as the 1942 production on the moderately and lightly grazed areas, but it was only 44 percent of the 1942 production on the heavily grazed areas. Therefore, it is apparent that herbage production in the open timber type, as in the grassland type, was maintained under light and moderate grazing and reduced where subjected to heavy grazing.

The effect of grazing intensity on herbage production of types as they occurred within the pastures was not so evident as when the production was compared by use areas within types. This is due to

TABLE 7.—Average air-dry yield of palatable grass and sedge herbage, by use areas within cover types, 1942, 1946, and 1947

Cover type and year	Herbage yield on—		
	Heavy-use areas	Moderate-use areas	Light-use areas
	<i>Pounds per acre</i>	<i>Pounds per acre</i>	<i>Pounds per acre</i>
Grassland:			
1942.....	599	566	544
1946.....	318	715	1 906
1947.....	249	673	704
Open timber:			
1942.....	344	273	256
1946.....	142	248	228
1947.....	150	276	255

¹ Only 5 plots available for this average, giving an inadequate sample.

the fact that there is compensation in pasture averages for areas of light, moderate, and heavy grazing that occurred within types. However, even on this basis the differences in herbage production of the grassland and open timber types, resulting from the different grazing intensities, were evident.

From the foregoing it appears that a utilization of 40 percent or less of the grass and sedge herbage is a safe goal from the standpoint of maintaining satisfactory forage production. Utilization of 50 percent or more of the herbage results in lowered production and therefore is not recommended.

EFFECT OF GRAZING INTENSITY ON PLANT GROWTH

Grazing on the pastures continued at the different intensities after 1947, but data are not available on herbage production and utilization. However, the effects of grazing intensity on plant growth and development were observed in 1949-50. Studies of several of the important species in 1949 revealed many of the reasons why herbage yields decreased under heavy grazing. Detailed measurements were made of Arizona fescue, mountain muhly, blue grama, and sedge on areas that had been subjected to the three grazing intensities.

Arizona fescue gave a high yield on the areas grazed moderately and lightly, but on those heavily grazed it produced only about one-tenth as much herbage (table 8). Average height growth at the end of the growing season in that year was only 6 inches on heavily grazed areas as compared with 10 inches on lightly and moderately grazed areas. There were significantly fewer plants of Arizona fescue per plot on heavily grazed plots, but the number of separate leaf tufts on each plant was about the same.

In mountain muhly the differences between the grazing intensities were found to be somewhat similar to differences found in Arizona fescue for both herbage yield and average height growth, but they

TABLE 8.—Detailed measurements for important forage plants in relation to grazing intensity, Manitou experimental pastures, 1949

Species and grazing intensity	Herbage yield per plot ¹	Average height	Plants per plot ¹	Leaf tufts per plant ²
	<i>Grams</i>	<i>Inches</i>	<i>Number</i>	<i>Number</i>
Arizona fescue:				
Heavy.....	21. 5	6. 0	1. 2	5. 2
Moderate.....	342. 6	9. 6	8. 7	3. 7
Light.....	222. 1	10. 0	5. 0	4. 7
Mountain muhly:				
Heavy.....	203. 6	3. 3	28. 6	5. 3
Moderate.....	299. 2	4. 0	28. 1	5. 1
Light.....	338. 8	4. 7	23. 9	5. 6
Blue grama:				
Heavy.....	140. 4	1. 7	27. 7	3. 5
Moderate.....	73. 6	1. 8	26. 3	2. 6
Light.....	12. 2	2. 3	4. 6	2. 1
Sedge:				
Heavy.....	50. 5	2. 9	110. 9	-----
Moderate.....	42. 9	4. 1	47. 4	-----
Light.....	50. 9	4. 2	59. 0	-----

¹ 10 square-foot plots; 1 foot wide by 10 feet long.

² Tufts are living parts of the plant crown separated from other living parts by ½ inch or more.

were not so pronounced. There was more herbage produced and the plants were taller on the moderately and lightly grazed plots than on the heavily grazed plot. The muhly on the moderately grazed area was intermediate between that on the lightly and heavily grazed areas in these respects. On the other hand, there were more plants of mountain muhly on heavily and moderately grazed plots than on those lightly grazed.

Under close grazing, large mountain muhly plants tended to break up into a number of smaller plants and the intervening crown to disintegrate and disappear. This gave the appearance more of a sod type of growth than of the bunchgrass that mountain muhly is. Arizona fescue seems to be more resistant to this disintegration. On heavily grazed plants of both Arizona fescue and mountain muhly, the individual grass tufts produced only sparse leaf and stem growth that was confined to a narrow band around the outside of the crown. On moderately and lightly grazed plants the tufts were larger and top growth was denser and occurred more or less uniformly over the crown of the plant.

In contrast to Arizona fescue and mountain muhly, blue grama, which was very lightly grazed on the moderately and lightly grazed pastures, produced more herbage and more plants per plot on heavily grazed areas than on moderately and lightly grazed areas. On moderately grazed plots, herbage production was intermediate between that on the lightly and heavily grazed areas. Apparently heavier grazing stimulated herbage production, but even so production was relatively low.

Sedge plants were more abundant on heavily grazed areas, but on moderate- and light-use areas their height growth was greater. For

this reason, herbage yields were about the same for the three grazing intensities—all rather low.

Ten plants each of mountain muhly and Arizona fescue were staked out on representative grassland areas of each pasture and measured periodically from May 10 to September 9, 1950. Total leaf growth was considerably less and growth was slower on heavily grazed areas than on those moderately and lightly grazed. As shown in figure 9, maximum leaf growth of Arizona fescue was greatest under light grazing, averaging 13.10 inches. The average maximum leaf growth on moderately grazed areas was 11.67 inches. Under heavy grazing it averaged 6.95 inches, which was only 53 percent of the height growth attained under light grazing and 60 percent of that under moderate grazing. Plants of mountain muhly on moderately grazed areas had slightly less total leaf height growth than those on lightly grazed areas, but growth was more than 50 percent greater than that under heavy grazing.

The effect of grazing intensity on the number of flower stalks and seed heads on mountain muhly and Arizona fescue in 1950 is shown by the following tabulation:

	Percent of plants with flower stalks	Average number of flower stalks per flower-stalk-bearing plant
Mountain muhly:		
Heavily grazed.....	45	6.0
Moderately grazed.....	70	11.0
Lightly grazed.....	95	12.5
Arizona fescue:		
Heavily grazed.....	5	.5
Moderately grazed.....	15	2.5
Lightly grazed.....	20	4.5

On both Arizona fescue and mountain muhly, increased grazing intensity for a period of years resulted in a smaller proportion of plants flowering, and fewer flower stalks per plant on those plants that did flower. On mountain muhly there was an average of 2.7 flower stalks per plant under heavy grazing, 7.7 under moderate grazing, and 11.9 under light grazing. Although Arizona fescue flowered much less profusely than mountain muhly, the effects of grazing intensity were much the same.

These data supplement those on herbage production in showing that heavy grazing does not permit the maintenance of plant vigor of palatable grasses at a desirable level. Blue grama, which is of low forage value under conditions at Manitou, tends to replace the more valuable mountain muhly and Arizona fescue as these are weakened. The over-all result is lowered forage production on the range.

Although moderate grazing had some adverse effects on the plants, it did not materially affect height growth and forage production. Weakened vigor was shown by the lowered flowering of mountain muhly and Arizona fescue. Light grazing on the other hand provided for the best vigor of these two main grasses and also maintained herbage production over the years.

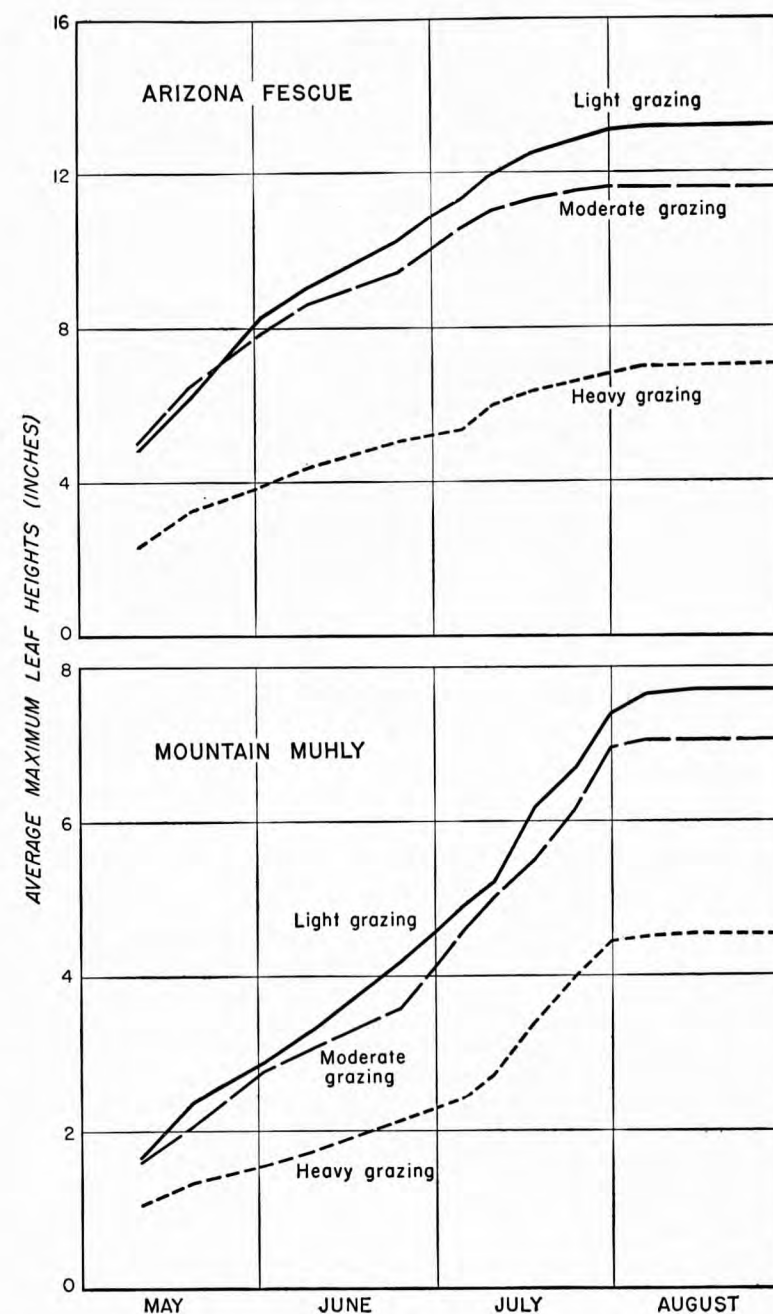


FIGURE 9.—Average growth of Arizona fescue and mountain muhly on grassland types of the pastures grazed at light, moderate, and heavy intensities in 1950.

EFFECT OF GRAZING INTENSITY ON CATTLE GAINS

SEASONAL GAINS

The heifers were weighed individually on June 1 at the beginning of the season and again on October 31 at the end of the season. At monthly intervals they were weighed by pasture groups. To minimize the effect of fill on cattle weights, the animals were brought into the corrals late in the afternoon, held without feed or water overnight, and weighed and returned to the pastures early the following morning.

In 1941 the average gain of all cattle was 230.7 pounds per head for the June 1 to October 31 period. All pastures were grazed at about the same intensity that year and there was no material difference in the average gains made on the different pastures (table 9). This indicated that any major difference in future gains might be expected to be the result of grazing intensity.

In 1942, the first year that stocking rates were adjusted, the average gain of heifers showed some relation to grazing intensity. Beginning in 1943 when utilization goals were more nearly achieved, and each year thereafter through 1947, light and moderate grazing gave greater gains per animal than heavy grazing, as shown in the following tabulation:

	Average gain per animal ¹ (pounds)
Light grazing:	
Pasture 2.....	243.2
Pasture 5.....	229.6
Moderate grazing:	
Pasture 3.....	214.0
Pasture 6.....	232.5
Heavy grazing:	
Pasture 1.....	189.1
Pasture 4.....	170.3

¹ During June 1–October 31 grazing season.

In all years but 1945 the average weight gain per animal on the lightly grazed pastures exceeded gains on the moderately grazed pastures by from 4 to 32 pounds (fig. 10). In 1945 the average gains made under moderate grazing exceeded those under light grazing by 9 pounds per animal. However, differences between gains under these two intensities varied to such an extent on individual pastures that the 1942–47 average gain of 236 pounds per animal under light grazing was not substantially different from the 222 pounds per animal under moderate grazing. The consistently lower gains under heavy grazing permit the conclusion that this grazing intensity significantly reduced cattle gains below those obtained under light and moderate grazing.

On the average, seasonal gains per animal grazed tended to be less as herbage utilization increased. However, the variation in average weight gain per animal was only 11 pounds where the herbage was utilized an average of 14, 17, and 31 percent. Pasture 3, grazed an average of 36 percent, gave somewhat lower gains. This may have been the result of some pasture characteristic, since the cattle on it

TABLE 9.—Average yearly seasonal gains of yearling heifers, in pounds per head, on pastures planned for three grazing intensities¹

Planned grazing in- tensity and pasture No.	1941	1942	1943	1944	1945	1946	1947	Aver- age sea- sonal gains, 1942– 47
Heavy:	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1.....	227.6	189.8	170.5	237.0	179.6	167.6	190.9	188.3
4.....	226.3	179.1	135.1	209.4	181.3	152.5	173.1	171.9
Average..	227.0	184.4	151.6	222.3	180.4	161.3	183.4	180.5
Moderate:								
3.....	220.0	207.8	191.0	249.0	232.0	184.0	214.2	212.6
6.....	245.8	221.9	220.4	256.2	245.2	215.3	225.3	230.6
Average..	234.6	216.3	204.7	252.7	238.9	200.9	220.2	222.1
Light:								
2.....	253.6	224.2	245.2	269.0	229.6	231.9	240.4	241.4
5.....	208.9	235.3	227.0	241.6	229.3	204.6	245.7	230.2
Average..	229.9	230.2	236.6	256.5	229.5	218.8	242.9	236.1

¹ All pastures stocked at approximately the same rate in 1941. Stocking was adjusted in 1942 and then varied by only a few head after 1943.

also made lower gains than average in 1941 when all pastures were stocked at similar rates. However, on the pastures grazed 52 and 64 percent the gains were appreciably less per animal. The degree of grazing that resulted in lowered cattle gains was about the same as that which reduced the production of herbage.

MONTHLY TREND OF GAINS

The overall trend in monthly weight gains was a gradual decrease from a maximum in June to a slight gain or even a loss per animal in October (fig. 11). The average monthly gains per heifer during the period 1942–47 were as follows: June, 72 pounds; July, 54 pounds; August, 46 pounds; September, 41 pounds; while in October there was an average loss of 1 pound.

The intensity of grazing had little effect on June gains. During August and September in most years the cattle on the heavily grazed pastures gained from 5 to 15 pounds less per month than those on other pastures. Where weight losses occurred in October, they were greatest on heavily grazed pastures. From June to October differences in average cattle gains made under light and moderate grazing were small.

Variations from the overall trend of weight gains occurred in certain years as the result of weather fluctuations and seasonal variations in forage quality. In June 1944 the average gain was 90 pounds per head, with the cattle on one pasture gaining more than 100 pounds. High-quality forage resulting from favorable spring growing conditions was responsible.



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FIGURE 10.—Maximum gains on individual heifers were obtained on pastures that were either lightly or moderately grazed. In addition, a vigorous and luxuriant growth of native bunchgrass was maintained.

Weather conditions during the latter part of the grazing season had an important effect on cattle gains. In September 1941 the heifers lost an average of 20 pounds because of a cold, wet snowstorm. October was mild and the cattle gained 10 pounds. Cold, wet snowstorms in October of 1942, 1943, and 1947 also were accompanied by average losses in weight varying from 5 to 20 pounds per head. In all cases, the cattle on heavily grazed pastures lost the most weight. There were no severe storms in 1944, 1945, and 1946, and the cattle did not lose weight except on the heavily grazed pastures in the latter year.

FORAGE QUALITY AND CATTLE GAINS

Since all pastures, even those lightly grazed, produced lower cattle gains in late summer, the downward trend in monthly gains was not caused by a lack of forage. Although lack of forage was a contributory cause to weight loss on the heavily grazed pastures, there was still plenty of grass herbage on the moderately and lightly grazed pastures at the end of the season. The nutritive quality of the forage was partially responsible for this late-season trend. Wide variations in total grazing-season gain, such as between 1943 and 1944, also appeared to be influenced by differences in forage quality.

Chemical analyses of Arizona fescue and mountain muhly were made by J. W. Tobiska, Chemist, Veterinary Pathology Section, Agricultural Experiment Station, Colorado A & M College, Fort Collins. Plants of these species were collected in 1943 when cattle gains were lower than average, and in 1944 when they were above average. Since gains during these 2 years differed widely, the cattle gaining on

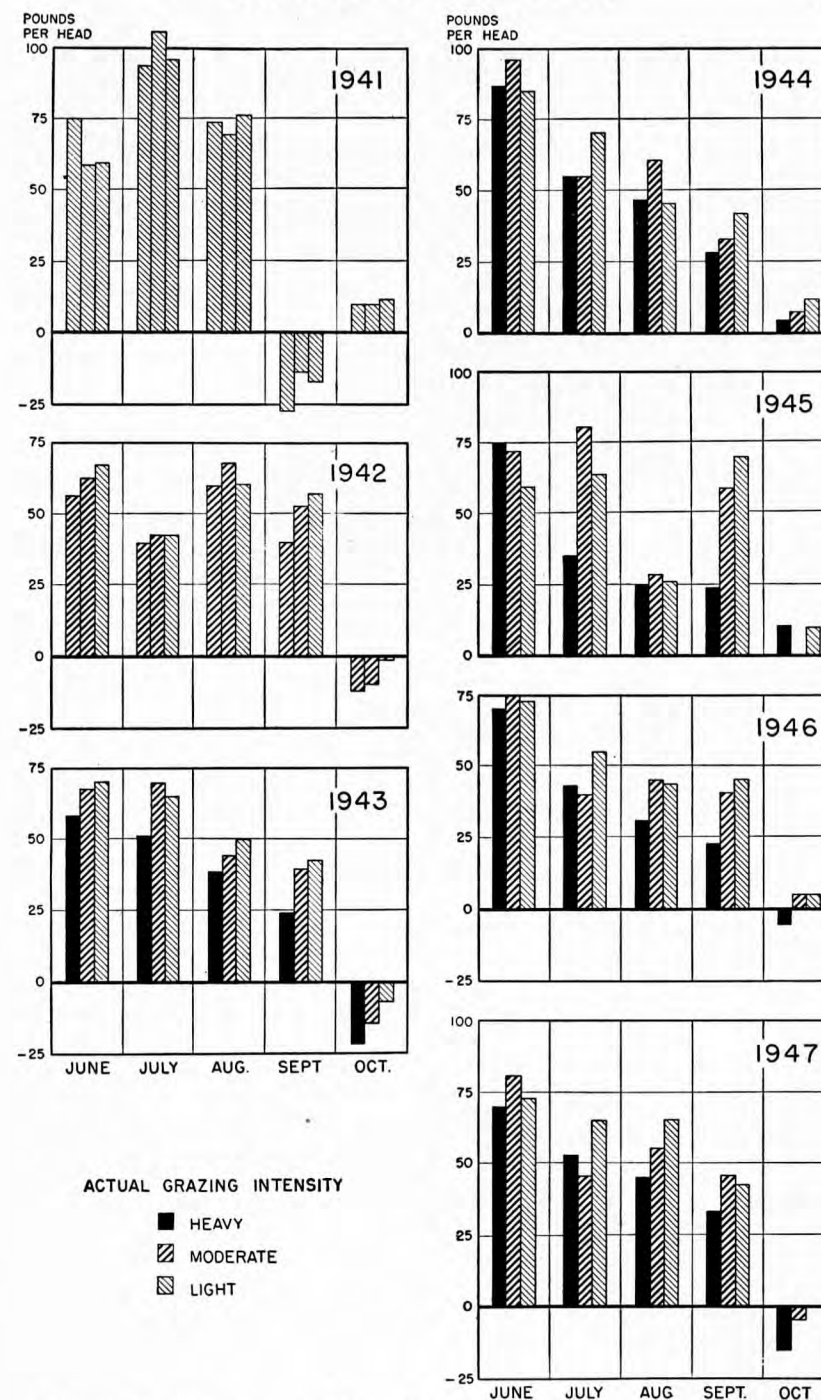


FIGURE 11.—Average monthly cattle gains under three grazing intensities.

the moderately grazed pastures an average of 47 pounds per head more in 1944 than in 1943, the relation between forage quality and cattle gains was more obvious.

The average crude protein content of Arizona fescue in May 1943 was 5.69 percent (fig. 12). It increased to 12.95 percent in June; dropped to 5.86 percent in July; and to 3.76 percent in November. Mountain muhly had 3.02 percent crude protein in May; increased to 5.69 percent in August; and then dropped to 2.80 percent in November. Studies of animal nutrition (3) show that a minimum of 8-percent crude protein is necessary for rapid growth of beef cattle. In 1943 Arizona fescue had more than that amount in June only, while mountain muhly never had as much as 6-percent crude protein in any month.

In 1944 the forage contained more crude protein than it did in 1943. Arizona fescue had an average of 13.85 percent in May and stayed above the 8 percent level until September. Mountain muhly contained an average of 4.46 percent crude protein in May, increased to 11.99 percent in July, and dropped to 7.09 percent in September.

The monthly trend of cattle gains on moderately grazed pastures was correlated with the monthly trend of crude protein. In the early summer when crude protein was highest, the cattle made their best gains during both years, while in late summer both gains and protein content were low.

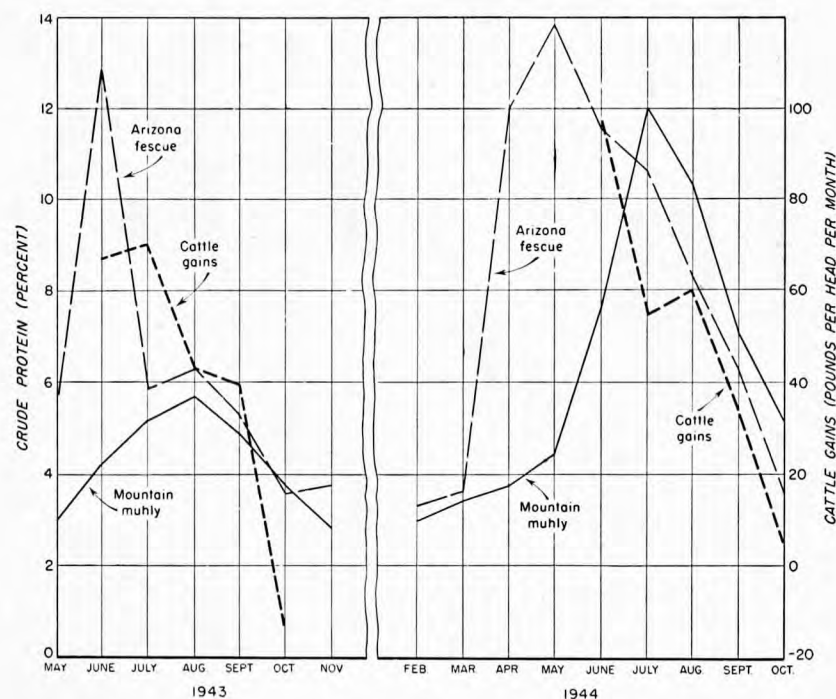


FIGURE 12.—Monthly cattle gains on moderately grazed pastures, and content of crude protein in Arizona fescue and mountain muhly. Manitou Experimental Forest, 1943-44.

Cattle grazed the different kinds of grass when they were most nutritious, and showed a preference for Arizona fescue in June and early July when it contained the greatest amount of crude protein. About the same time that protein in Arizona fescue began to decrease, the cattle showed greater preference for mountain muhly. This shift in grazing preference coincided with a shift in the amount of protein in the two grasses.

PRODUCTION OF BEEF PER ACRE

The intensity of grazing and the amount of gain per animal determine the amount of beef produced. On the average, more beef was produced per acre on moderately grazed pastures than on those heavily grazed (table 10). Moderately grazed pasture 6 outproduced both heavily grazed pastures every year. On the other hand, moderately grazed pasture 3 outproduced heavily grazed pasture 4 in 3 years out of the 5 in which pasture 4 was heavily grazed, and equaled it in production during another year. Heavily grazed pasture 1 outproduced moderately grazed pasture 3 every year but 1943 when both pastures were grazed at about the same intensity. For practical application, therefore, about the same beef production per acre was obtained from the moderately grazed pastures as from the heavily grazed pastures, with the moderate pastures producing 1.2 pounds per acre more on the average.

All of the moderately and heavily grazed pastures consistently produced more beef per acre than either of the lightly grazed pastures largely because of the few cattle on the latter.

TABLE 10.—Effect of grazing intensity on beef production per acre, on pastures planned for three grazing intensities

Planned grazing intensity and pasture No.	1942	1943	1944	1945	1946	1947	Average
Heavy:	<i>Pounds per acre</i>	<i>Pounds per acre</i>	<i>Pounds per acre</i>	<i>Pounds per acre</i>	<i>Pounds per acre</i>	<i>Pounds per acre</i>	<i>Pounds per acre</i>
1-----	12.1	13.5	18.7	16.9	15.8	17.9	15.8
4-----	12.1	12.9	20.0	14.5	10.9	12.4	13.8
Average	12.1	13.2	19.3	15.7	13.4	15.2	14.8
Moderate:							
3-----	10.1	15.9	17.3	14.5	11.5	13.4	13.8
6-----	18.0	17.9	20.8	18.9	17.4	18.3	18.5
Average	13.8	16.8	18.9	16.6	14.3	15.7	16.0
Light:							
2-----	4.3	7.8	10.3	8.8	8.9	9.2	8.2
5-----	6.5	8.1	9.6	9.1	8.9	10.7	8.8
Average	5.3	7.9	10.0	8.9	8.9	9.9	8.5

Over the years, the cattle on the moderately grazed pastures made the most efficient use of the grass herbage of any of the three intensities of grazing. The lightly grazed pastures had too few animals and usable herbage was ungrazed. The heavily grazed pastures had too many animals, too much of the herbage was grazed, forage plants lost vigor, and weight gains per animal were less. Even though more animals were grazed, the lower weight gains per animal reduced the amount of beef produced per acre under heavy grazing.

GRAZING INTENSITY AND INCOME

The estimated net return per section from grazing the experimental range pastures in 1946 and 1947 was computed on the basis of the results of this study. For this comparison, the gross return was the difference between the total initial and final values of the cattle grazed, and the net return was the gross return less the cost (table 11).

The average initial value was based on the average initial weight at a market value of \$11.43 per hundredweight, or the average price of feeder and stocker heifers of similar quality on the Denver market in late May. The average final value per hundredweight was based on actual market appraisals by well-known Colorado cattle feeders. The average appraisals were \$10.00 per hundredweight for cattle

TABLE 11.—Comparison of estimated average returns per section from ponderosa pine-bunchgrass range grazed at three intensities, 1946-47

Item	Heavy grazing	Moderate grazing	Light grazing
Animals per section.....number..	53	47	27
Average initial weight per head...pounds..	331	313	337
Average final weight per head.....do.....	503	524	568
Average gain per head, 5-month season.....do.....	172	211	231
Average initial value per head at \$11.43 per cwt.....dollars..	37.83	35.78	38.52
Total initial value, all animals.....do.....	2,004.99	1,681.66	1,040.04
Average final value per cwt.....do.....	10.00	11.00	11.50
Average final value per head.....do.....	50.30	57.64	65.32
Total final value, all animals.....do.....	2,665.90	2,709.08	1,763.64
Gross return per section.....do.....	660.91	1,027.42	723.60
Costs per section:			
Death losses, 1 percent initial value.....dollars..	20.05	16.82	10.40
Interest on investment, 5 percent—6 months.....dollars..	50.12	42.04	26.00
Salt and miscellaneous at 50 cents per head.....dollars..	26.50	23.50	13.50
Grazing fees, national forest range.....do.....	91.42	81.08	46.58
Total.....do.....	188.09	163.44	96.48
Net return per section.....do.....	472.82	863.98	627.12
Ratio to highest net return.....percent..	55	100	73

from heavily grazed pastures, \$11.00 for those from moderate, and \$11.50 for those from light. The cattle from the moderately grazed pastures were valued at \$1.00 more per hundred pounds, and those from the lightly grazed pastures at \$1.50 more, than the cattle from heavily grazed pastures. The reason for the higher values according to the appraisers, was more bloom, thrift, and condition in the cattle.

Costs deducted to cover the expenses of management and the risks involved were interest on the investment value of the cattle, death loss, grazing fees, salt and miscellaneous costs per head. Death loss, of course, is to be expected in any cattle operation. For this comparison, 1 percent of the initial value of all animals was deducted for each stocking rate. Interest on investment was computed on the basis of 5 percent of the initial value for a 6-month period. Salt and miscellaneous expenses were estimated at 50 cents per head per season. The average fee charged by the Pike National Forest for grazing privileges on the Manitou Experimental Forest was deducted as a cost item.

Of the cost items considered, death loss or risk and interest on investment were greatest on the heavily stocked pastures because of the higher initial investment in cattle. Grazing fees, salt, and miscellaneous costs of management were directly proportional to the number of animals involved.

The average profit for 1946 and 1947 was \$863.98 per section for the moderately grazed pastures, \$627.12 for those lightly grazed, and \$472.82 for the heavily grazed pastures. Moderate grazing, with the correspondingly increased gains, higher market values, and lower overhead costs, was determined to be the most economical method of management. Heavy grazing returned only 55 percent as much income as moderate grazing; and light grazing, which permitted the range herbage to improve most rapidly, was found to give a greater estimated average income than heavy grazing. On this basis, pastures that are not in the best productive condition can be improved through light grazing, and they will give a better financial return than can be expected from heavy grazing and continuing range depletion.

SUMMARY

Grazing western ranges on a basis that will maintain forage and watershed values and at the same time make efficient use of the forage for beef production is especially important to the stockmen, ranchers, and larger livestock operators of the Front Range of Colorado. In 1941 a study of the effect of grazing intensity on ponderosa pine-bunchgrass ranges was begun at the Manitou Experimental Forest. This study, ending in 1947, included the measurement of herbage utilization, herbage production, and cattle gains on six experimental pastures located in the open ponderosa pine zone of the Front Range in central Colorado.

Yearling grade Hereford heifers were obtained from local ranchers and grazed in the pastures from June 1 to October 31 each year throughout the study. This 5-month grazing season included most of the period of active plant growth. Beginning in 1942 the three sets of pastures were grazed with the objective of obtaining three

intensities of grass and sedge herbage removal: heavy, 50 percent or more; moderate, 30 to 40 percent; and light, 10 to 20 percent. The light intensity was obtained beginning in 1942, the moderate in 1942 on one pasture and in 1943 on the other, and the heavy in 1943 on one pasture and in 1944 on the other. After these dates, the utilization goals were achieved each year.

The principal range types in the experimental pastures were grassland parks, open ponderosa pine forest, dense ponderosa pine forest, and abandoned fields. Of these, the grassland parks and open timber were the important forage-producing types. With some exceptions, abandoned fields were grazed the heaviest. Grassland parks received heavier grazing than the open timber type, and the dense timber type was rarely grazed. Under all grazing intensities, however, irregular patterns of use developed. Even in the lightly grazed pastures, areas of moderate and heavy grazing occurred.

Grasses and sedges produced 94 percent of the total palatable herbage. Mountain muhly and Arizona fescue were the most abundant forage species. The use of an individual species was generally proportional to the intensity of grazing on the area on which it occurred. An exception was Kentucky bluegrass, which was grazed very closely wherever it grew. Blue grama was not used in important amounts under light and moderate grazing and was grazed only lightly under heavy grazing. Arizona fescue, little bluestem, Kentucky bluegrass, danthonia, and sedges were grazed most readily in the early summer. Mountain muhly was the most abundant forage in late summer.

Heavy grazing resulted in lowered production of grass and sedge herbage. Under moderate and light grazing herbage production was in general maintained throughout the study. The vigor of mountain muhly and Arizona fescue was best under light grazing, nearly as good under moderate grazing, but was reduced where grazing was heavy. In contrast, blue grama was most productive on the heavily grazed range and least productive under light grazing.

Cattle weight gains were associated with grazing intensity. Average gains from 1942-47, for the 5-month grazing season, were 181 pounds per head in the heavily grazed pastures, 222 pounds in those moderately grazed, and 236 pounds in those lightly grazed. On a per-acre basis weight gains for the grazing season averaged 14.8 from heavy grazing, 16.0 from moderate, and 8.5 from light.

Cattle weight gains were greatest in June and July when the forage was growing rapidly and had the highest protein content. At that time the gains were much the same under all three grazing intensities. As the season advanced and the quality of the forage became poorer, the rate of weight gain decreased and cattle in the heavily grazed pastures made less gains than did cattle in the moderately and lightly grazed pastures. Where weight losses occurred in the fall, the greatest losses were consistently on cattle in the heavily grazed pastures, and the smallest losses on cattle in the lightly grazed pastures. Weight losses of from 10 to 20 pounds per animal usually accompanied early fall storms.

Estimated net returns for the 1946 and 1947 grazing seasons gave an average income per section of \$863.98 from moderate grazing, \$627.12 from light grazing, and \$472.82 from heavy grazing.

As a result of this study, an optimum of 35- to 40-percent utilization of the grass and sedge herbage on pine-bunchgrass ranges is recommended as being a grazing intensity that will maintain forage values and make efficient use of available forage for beef production. To obtain this utilization, Arizona fescue should be grazed to an average height of 5 to 6 inches by the end of the grazing season and mountain muhly to 1½ to 2 inches.

COMMON AND BOTANICAL NAMES OF SPECIES MENTIONED

TREE

Pine, ponderosa..... *Pinus ponderosa*

GRASSES

Bluegrass, Kentucky..... *Poa pratensis*
 Bluestem, little..... *Andropogon scoparius*
 Danthonia..... *Danthonia* sp.
 Dropseed, sand..... *Sporobolus cryptandrus*
 Fescue, Arizona..... *Festuca arizonica*
 Grama, blue..... *Bouteloua gracilis*
 Junegrass, prairie..... *Koeleria cristata*
 Muhly, mountain..... *Muhlenbergia montana*
 Sleepygrass..... *Stipa robusta*
 Tumblegrass..... *Schedonnardus paniculatus*
 Wheatgrass, bluestem..... *Agropyron smithii*

GRASSLIKE PLANT

Sedge..... *Carex* spp.

FORBS, OR WEEDS

Aster..... *Aster* spp.
 Cinquefoil..... *Potentilla* spp.
 Fleabane, trailing..... *Erigeron flagellaris*
 Geranium, Fremont..... *Geranium fremontii*
 Groundsel, Fendler..... *Senecio fendleri*
 Lupine..... *Lupinus* spp.
 Milkvetch, nickleaf..... *Astragalus goniatus*
 Penstemon, oneside..... *Penstemon unilateralis*
 Pussytoes, Rocky-Mountain..... *Antennaria aprica*
 Sunflower..... *Helianthus uniflorus*
 Yarrow, western..... *Achillea lanulosa*

HALF SHRUB

Sagebrush, fringed..... *Artemisia frigida*

SHRUB

Rose, Arkansas..... *Rosa arkansana*

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