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INTRODUCTION

The California foothills (fig. 1) comprise the most important range area within the State. These lands border the great Central Valley and enclose numerous smaller valleys within the Coast Ranges. Primary use of foothill range lands is production of livestock. This use is closely associated with the highly intensified valley agriculture, which supplies hay, grain, and agricultural byproducts to supplement range forage and furnishes seasonal pasturage for livestock carried part of the year on foothill range. Also, some of the livestock are grazed during the summer in the mountainous lands above the foothills. But by far the greatest part of the State's range grazing capacity is in the foothills.

The foothill area has relatively mild, wet winters and hot, dry summers. Thus, some green forage is available during the fall and winter, plant growth is at its height during the spring, but the plants are dry during the summer and early fall.

Annual plants dominate the herbaceous cover and occur with varying amounts of bunchgrasses and other perennial species. This cover is found over the grass and woodland-grass vegetative types, as well as the more open phases of the chaparral.

[1] Credit is due to two former forest ecologists of the California Forest and Range Experiment Station: F. G. Renner, who was in charge of planning, establishing, and supervising the forage experiments in 1934–35, and H. H. Biswell, in charge of the experiments 1936–40. Assistance in sampling of forage and in compilation and analysis of data was obtained from members of the staff of the California Forest and Range Experiment Station and from many temporary field assistants and members of emergency agencies, particularly Civilian Conservation Corps and Civilian Public Service.

[2] Maintained by the Forest Service, U. S. Department of Agriculture, in cooperation with the University of California at Berkeley, Calif.

FIGURE 1.—Approximate location of foothill range in California.

The foothill range area includes the sloping plains and rolling hills bordering the valleys and extends upward through hills of rolling-to-steep topography; elevation varies from near sea level to about 4,000 feet; the soils are exceedingly diverse; and total annual precipitation ranges from less than 10 inches in the plains at the south end of the San Joaquin Valley to more than 40 inches in the upper foothills at the north end of the Sacramento Valley.

Local demand for livestock products has increased as a result of rapid growth of population, and the California livestock industry is increasingly aware of the need for both the fullest sustained production of forage and the greatest efficiency in its use. The goal is to obtain high livestock production while maintaining or improving the forage cover. The long-time objective of management is to obtain the most productive mixture of the best forage plants, including both perennials and annuals. But over millions of acres the immediate problem of live-

stock operators is how to obtain the most efficient use of the present cover of annual plants.

This circular reports studies of use of foothill range by cattle at the San Joaquin Experimental Range.[3] The studies have shown how range management can be geared to the typical yearly pattern of annual-plant growth, with sufficient flexibility in ranch operation from year to year to meet variations in time of growth and most of the fluctuations in forage yield. The studies have also shown the grazing capacity of different kinds of foothill range, and how plant growth and cattle production are affected by different degrees of grazing. Finally, the studies have developed practical guides for increasing the efficiency of range use.

EXPERIMENTAL AREA AND METHODS

The San Joaquin Experimental Range, a tract of approximately 4,500 acres, is located within the woodland-grass vegetation type in the Sierra Nevada foothills on the east side of the San Joaquin Valley. Elevation of the experimental area is from about 700 to 1,700 feet above sea level. The soils on the slopes, mainly sandy loams, average about 1½ feet in depth and have numerous outcroppings of the granitic bedrock. The bottom-land soils, transported from the slopes above, are of heavier texture and are deeper and more productive.

The herbaceous cover on the experimental range contains a fairly representative mixture of annuals; it includes grasses, grasslike plants, filaree,[4] clovers, other legumes, and numerous miscellaneous species. Soft chess, broadleaf filarees, and foxtail fescue, which occur on most foothill ranges, produce about two-thirds of the herbage. Perennials, mainly rushes in the bottom lands, compose about 3 percent of the herbage yields. The native pine bluegrass, a small early-drying perennial, is common but produces less than 1 percent of the herbage. The more valuable native perennial bunchgrasses, stipas or needlegrasses, are virtually absent on the experimental area.

On some heavier and more productive soils of the foothill area, burclover, alfileria or redstem filaree, and wild oat, highly palatable annuals, are much more abundant than on the experimental range, and the forage is generally considered "stronger;" but the problems of management are similar to those on the experimental range. Problems not experienced in the studies do occur, however, on more arid foothill ranges where average annual precipitation is approximately 5 to 12 inches and forage production fluctuates more widely from year to year.

The guides that were developed from the studies apply in management of the annual-plant portion of the vegetative cover on most foothill ranges. Specific effects of weather and grazing management on growth of individual plant species, however, may apply only in the "Granite

[3] These studies were part of the cooperative interagency research program at the San Joaquin Experimental Range, O'Neals, Calif., during the period 1935–48. In this program the University of California was responsible for the cattle studies, and the California Forest and Range Experiment Station for the studies of range forage production and utilization. Additional information on all phases of this interagency program is given in The San Joaquin Experimental Range (7) (see Literature cited, p. 51).

[4] Common and botanical names of the species mentioned in this circular are listed on p. 50.

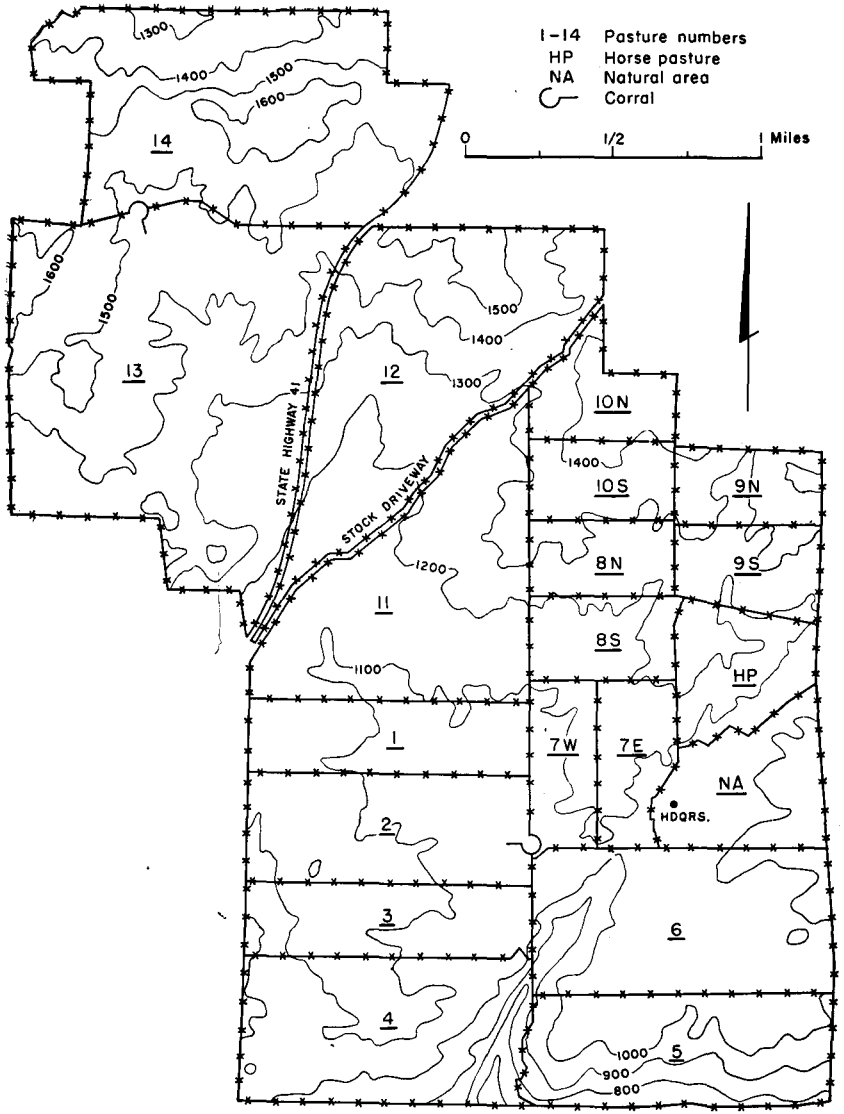

FIGURE 2.—Experimental pasture layout at the San Joaquin Experimental Range.

Area" (most of the foothills on the east side of the San Joaquin Valley, from Madera County southward).

For study purposes the range is subdivided into a number of pastures (fig. 2). Most of the forage studies were made in experimental pastures *1* to *6*, which were devoted primarily to determining the effect of different intensities of grazing on both cattle and range. When not in these grazing-intensity pastures, the cattle were held in pastures *10*, *12*, and *14*. The remainder of the experimental pastures (*7*, *8*, *9*, *11*, and *13*) were used for trials on cattle feeding and for grazing of miscellaneous animals.

Studies of range fertilization, range reseeding, range rodents, and other subjects were made in portions of several pastures. The effects on vegetation of complete exclusion of livestock grazing were studied in an ungrazed "natural area."

Ninety head of breeding cows were used in the grazing-intensity studies. From approximately August 1 to February 1 they were divided into two equal herds. One, the supplemented "A" herd, receiving concentrate feeds in addition to natural forage, was grazed in pastures *10* and *12*. The second, the unsupplemented "B" herd, was grazed in pasture *14* with access only to the natural forage. During the remainder of the year, from approximately February 1 to August 1, none of the cows received supplements; 15 cows with their calves were placed in each of the grazing-intensity pastures *1* to *6*. Pastures *1*, *2*, and *4* each held 8 cows from the "A" herd and 7 from the "B" herd; pastures *3*, *5*, and *6* each held 7 cows from the "A" herd and 8 from the "B" herd. A bull was with each group of cows from January 1 until May 1.

Approximate rates of stocking in the six grazing-intensity pastures were: 10 acres per cow in pastures *1* (154 acres) and *3* (155 acres), 15 acres per cow in pastures *2* (230 acres) and *5* (250 acres), and 20 acres per cow in pastures *4* (309 acres) and *6* (316 acres). The cows were placed in all six pastures in late winter at the time when new green forage over most of the range was judged adequate to maintain a cow with a calf for the remainder of the winter. They remained in these six pastures until after the herbage was mature and dry and were removed when the heaviest-used pasture was judged closely grazed.

Measurements were made each spring to determine (1) the plants that make up the forage, and (2) how herbage production varies with grazing intensity and year-to-year differences in weather. The percent of the ground covered by herbaceous vegetation, plant density, and the percent of the cover made up by each plant species in each of the six grazing-intensity units were estimated on square-foot quadrats: 300 quadrats per experimental pasture in 1936; and 80 to 160 quadrats per pasture in 1938, 1939, 1940, and 1943. Continuity of density records was maintained in 1941, 1942, and 1944 by estimates from 100 quadrats in lightly grazed pasture *2*, and closely grazed pasture *3*. Density measurements were made as nearly as possible at the time of maximum plant density in April, when the early-maturing species first started to dry.

The yield of herbage on slopes was measured in May 1942 on 100 square-foot quadrats in each of pastures *2* and *3*. The vegetation on each quadrat was protected from grazing by small wire "cages" (fig. 3) and was clipped at ½-inch stubble height in May, after almost all the herbage had made full growth and started to dry. Herbage from each quadrat was placed in a paper bag, dried in a greenhouse, and weighed when relative humidity of air was below approximately 30 percent. In 1943, 1944, and 1945 the yield on slopes was measured on 100 quadrats in each of pastures *1*, *2*, and *3* and on swales, or bottom land, on 60 to 100 quadrats in each pasture. The vegetation was protected from grazing, clipped, sorted, and weighed as in 1942. The wire cages were moved to new locations each January.

The total yield of herbage within a ¼-acre area from which cattle and rodents were excluded was measured on 100 quadrats at plant maturity each spring during an 8-year period, 1940–47. In addition, the dry

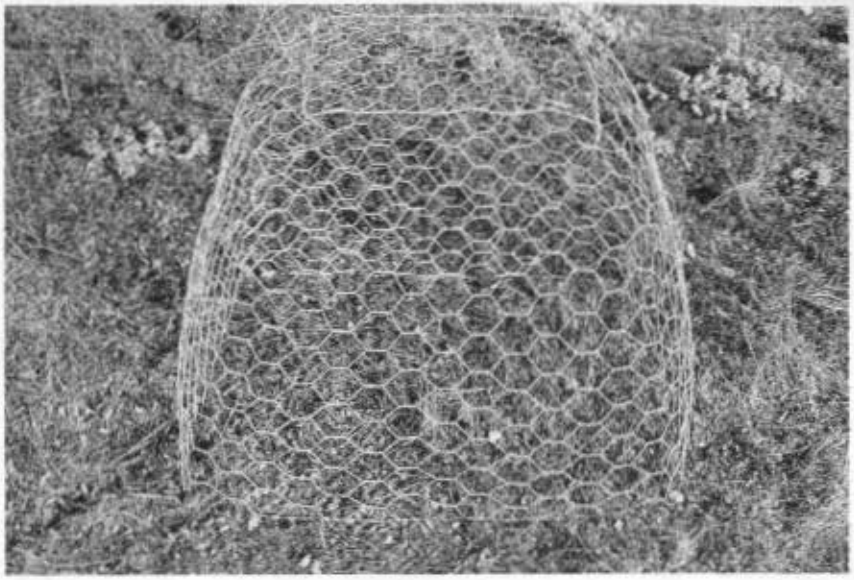

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FIGURE 3.—Cage made of 2-inch mesh poultry netting used to protect vegetation from grazing by cattle.

herbage was measured on another set of quadrats each fall during a 7-year period, 1936–42. This ¼-acre area was located within pasture *1*.

To facilitate comparison of yields between experimental range units with different amounts of waste area, yields were measured only on productive, grazable land. Rocks, brush, and other waste areas were excluded from the samples. Then the amount of waste area was measured in 1942 on 16 transects across each of the six grazing-intensity pastures and subtracted from the total area to determine the grazable acreage. In evaluating the productivity and grazing capacity of different kinds of land, a range site classification was employed. The development of this classification entailed the making, in 1945, of a site-class map of the six grazing-intensity pastures.

Measurements were also made to determine the seasonal pattern of plant growth. During the 1937–45 period, plant density and height were measured at one fixed station in each of the six pastures at intervals of 1 to 4 weeks. The average growth and development of vegetation by sites were determined in each year by observations of plant growth over all of the experimental pastures and by color photographs at selected stations. Detailed observations were made on critical features of plant growth, such as the amount of precipitation required to germinate the seed and start growth of the several species, growth on south slopes contrasted with growth on north slopes, growth at different air temperatures, and the relative dates of flowering, fruiting, and drying of the different species on different sites. Many comparisons of plant heights were made across fence lines between experimental pastures grazed at different degrees and between spots grazed to different degrees within pastures.

TABLE 1.—*Monthly precipitation at San Joaquin Experimental Range, September 1934–August 1948*

Year	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
1934–35	0.00	2.22	3.39	3.64	5.76	3.21	4.85
1935–36	.00	1.63	.52	1.56	3.67	11.20	2.47
1936–37	.00	2.17	.10	5.16	3.22	7.08	4.58
1937–38	.00	.03	.50	6.23	5.99	7.75	8.69
1938–39	.14	1.37	.75	1.28	2.87	2.50	2.89
1939–40	1.28	.86	.03	.64	9.94	5.87	2.15
1940–41	.00	1.56	.10	8.26	3.68	7.50	2.76
1941–42	.00	1.13	1.21	8.11	2.93	2.06	1.98
1942–43	.00	.00	1.98	2.14	4.63	2.23	5.09
1943–44	[1] T	.23	.56	2.37	2.45	4.73	1.05
1944–45	.05	1.05	4.98	2.83	.31	4.48	4.56
1945–46	.07	1.69	1.46	3.83	.91	2.02	3.26
1946–47	.00	1.58	4.26	3.88	.51	1.51	.94
1947–48	.28	1.64	.68	.83	.06	1.34	4.27
14-year mean	.13	1.23	1.47	3.63	3.35	4.53	3.54

Year	Apr.	May	June	July	Aug.	12-month total
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
1934–35	6.33	0.00	0.00	0.00	0.00	29.40
1935–36	1.35	.15	.04	.06	.00	22.65
1936–37	.65	.00	.00	.00	.00	22.96
1937–38	2.69	.02	.00	.19	.00	32.09
1938–39	.26	.03	.14	.00	.02	12.25
1939–40	.43	.00	.02	.00	.00	21.22
1940–41	4.44	.02	.00	.00	.01	28.33
1941–42	2.81	1.31	.00	.00	.00	21.54
1942–43	1.17	.00	.00	.00	.00	17.24
1943–44	1.78	.58	.04	.00	.00	13.79
1944–45	.32	.35	.05	T	.01	18.99
1945–46	.06	.56	.00	T	.00	13.86
1946–47	.44	.57	.03	.00	.00	13.72
1947–48	4.13	1.26	.01	.00	.00	14.50
14-year mean	1.92	.35	.02	.02	T	20.18

[1] T = trace.

Air temperatures, relative humidity, and wind movement were measured at a standard Weather Bureau station at the headquarters, at an elevation of 1,050 feet. Precipitation was measured as an average of readings from two standard rain gages, one at headquarters and one at a rainfall-runoff station in pasture 7 at an elevation of 1,100 feet. The records of precipitation and air temperature are summarized in tables 1 and 2.

TABLE 2—*Monthly mean air temperature at San Joaquin Experimental Range, November 1934-August 1948*

Year	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
	°F.	°F.	°F.	°F.	°F.	°F.	°F.
1934–35			52.1	45.1	44.5	47.4	47.1
1935–36	76.3	60.6	47.3	44.8	47.0	48.5	54.3
1936–37	75.5	64.7	51.7	42.3	36.1	46.7	51.4
1937–38	73.7	64.4	52.1	46.5	43.6	48.3	48.5
1938–39	75.0	60.2	47.6	45.2	42.7	42.5	51.5
1939–40	74.5	60.2	52.9	47.8	46.5	49.0	53.8
1940–41	68.4	61.8	48.0	47.7	46.5	50.5	53.1
1941–42	67.4	56.8	50.0	44.5	44.2	44.2	48.9
1942–43	69.4	61.9	49.2	42.3	42.5	47.1	51.8
1943–44	73.0	60.3	50.7	45.0	44.2	44.4	50.3
1944–45	73.8	63.9	48.6	45.5	41.1	47.3	46.8
1945–46	73.6	63.6	49.0	45.0	40.5	44.1	49.1
1946–47	71.7	55.8	45.7	43.3	37.1	47.9	53.3
1947–48	74.8	61.4	44.9	40.5	45.7	43.9	46.5
14-year mean	[1] 72.9	[1] 61.2	49.3	44.7	43.0	46.6	50.5

Year	Apr.	May	June	July	Aug.	12-month mean
	°F.	°F.	°F.	°F.	°F.	°F.
1934–35	56.0	65.0	77.5	79.9	82.2	
1935–36	60.0	68.4	76.6	84.7	83.5	62.7
1936–37	56.1	69.0	75.6	84.5	82.5	61.3
1937–38	55.9	66.4	76.7	82.9	80.0	61.6
1938–39	61.5	67.1	75.7	81.9	81.5	61.0
1939–40	58.1	69.1	78.7	78.5	78.6	62.3
1940–41	53.8	66.2	70.9	81.5	75.4	60.3
1941–42	54.0	60.4	72.1	81.6	79.0	58.6
1942–43	56.9	65.5	67.2	78.4	74.1	58.9
1943–44	53.1	65.6	68.9	79.1	78.0	59.4
1944–45	56.6	62.6	74.0	84.1	78.3	60.2
1945–46	58.8	64.6	71.7	79.7	79.5	59.9
1946–47	58.8	70.2	74.0	76.9	75.4	59.2
1947–48	54.3	60.1	72.3	78.1	76.1	58.2
14-year mean	56.7	65.7	73.7	80.8	78.9	[1] 60.3

[1] 13-year mean.

The relative degree of herbage utilization — for example, close, moderate, or light — in each of the six grazing-intensity pastures was rated each year according to the amount of unused herbage left on the ground. Ratings were made after the cattle were removed from the pastures, but before the start of fall rains. The method used was to compare the grazed range with standard photographs showing how the range looks with different amounts of unused herbage.

To help determine how different degrees of use affect the condition of the site, in January 1943 the depth and weight of the litter on the soil surface were measured and correlated with the height and yield of new herbaceous growth on 100 quadrats in each of pastures *1*, *2*, and *3*. Many other observations on litter conditions, soil erosion, and plant growth were made at the experimental range and other parts of the foothill area.

Cattle records taken included weights and forage preferences. Each animal was weighed several times: When removed from one pasture to another, at the start of the supplemental feeding period, just before calving, at weaning time, at the end of the green-forage period, and at other times when forage changed noticeably in quality or amount. In the first years of the experiment the cattle were weighed soon after watering in the corrals, but later they were shrunk overnight in a dry lot before each weighing to minimize the differences in "fill" of water and herbage at different times of year.

The manner in which the cattle selected the various plant species at different growth stages was determined by observation of grazing habits and of grazed vegetation. In 1936, R. H. Klugh [5] recorded detailed observations on the preference of cattle for the different plants during the spring. During 1936–40, Kenneth A. Wagnon, resident animal husbandman in charge of University of California cattle-management studies, at daily or weekly intervals collected samples of the forage that cows were grazing. These samples were analyzed for chemical composition. Other observations on use of the vegetation by cattle were made during the course of the studies by other technicians.

FITTING RANCH OPERATIONS TO FORAGE GROWTH

Foremost among the results of this study is a clear understanding of the seasonal growth of foothill forage plants. The availability and nutritive value of the plants, and the species selected by cattle, change during the year as the plants progress through different stages of development. At certain stages, the need for supplemental feeds is critical. Knowledge of these changes is basic to skillful fitting of ranch operations to forage plant growth — and hence to efficient use of the annual-plant cover.

AVAILABILITY OF FORAGE DURING THE YEAR

The characteristic California foothill climate results in three rather distinct plant-growth periods (fig. 4). The first period usually starts in October. Seeds of annual plants start to germinate after the first rains of 0.5 to 1.0 inch. This amount is enough to start germination over most of the range. After the first effective fall rains, however, plant growth is often limited by insufficient soil moisture, unfavorable temperatures, or both. In November mean air temperature for most days of the week usually drops below 50° F. After this, growth is retarded regardless of soil moisture. Plants grow intermittently, during short rainy periods or other occasional periods of mild weather. Cold, dry weather with frequent frosts that stop all growth or freeze back part of the plants can

[5] Formerly Junior Range Examiner, California Forest and Range Experiment Station.

be expected for a few weeks each winter. Hence new green forage is uncertain and not adequate to maintain cattle weights during this entire fall and winter period.

The second period starts by late winter, usually about February 1. At this time the green forage becomes adequate to maintain cattle weights for the remainder of the winter, even though temperatures are still too low for rapid plant growth. During the first early spring weather, when mean temperatures for most days of the week are near 50° F. or above and frosts are infrequent, plant growth is accelerated and green forage begins to grow faster than it is grazed. Later in the spring, usually in April, the temperature rises rapidly and there is a surge of plant growth. Ordinarily most of the plants mature and dry early in May, but a limited amount of herbage remains green for a short time longer.

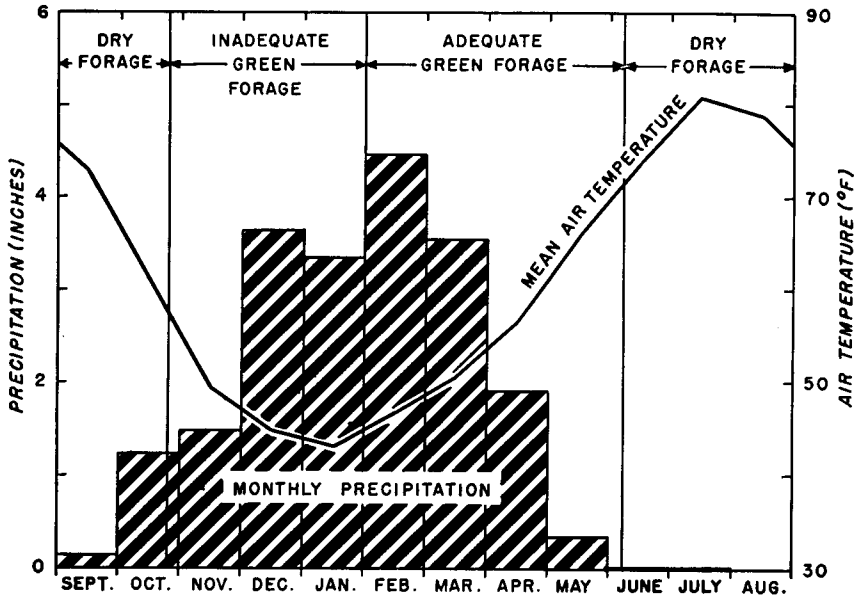

FIGURE 4.—Relation of the three yearly plant-growth periods to monthly precipitation and mean air temperature, San Joaquin Experimental Range (average 14 years, September 1934-August 1948).

By early summer the third period has begun. This is usually in June, when almost all of the plants have dried. The little remaining green leafage is on scattered plants of summer-growing annual species, or perennial bunchgrasses. Most of the cattle forage is dry herbage until fall rains bring new plant growth.

UNCERTAIN GREEN FORAGE IN FALL AND WINTER

The forage preference of cattle shifts from dry grass to the new green plants soon after the seedlings emerge. The new plants are selected when barely one-half inch in height, but cattle are forced to take some old dry roughage as they search for the short new growth. This green

forage they take without discrimination between species. As most of the plant growth occurs during short rainy periods, cattle obtain the greatest amount of green forage immediately following rains. In years with limited fall precipitation or with dry, freezing weather in the winter, for several weeks at a time cattle must depend largely on the old roughage whose value has been lowered through leaching. Because growth of new plants during the fall and winter is so uncertain, it is advisable to have sufficient old grass on the ground in the fall to serve as a source of roughage in the years when it is needed.

Supplemental feeding is necessary in this period of uncertain plant growth. After rainy periods the crude protein in the cattle diet may be above 10 percent; but when new plant growth is retarded and the cattle are forced to eat more old roughage, the percentage of crude protein is lowered (*12*).[6] Also, throughout the fall and winter the total intake of dry matter is reduced because the cattle spend most of their grazing time in search of succulent green forage. Thus, supplemental feeds are needed to supply both protein and carbohydrates. Inadequacy of the forage alone was shown by weights of yearling heifers that did not receive supplemental feeds. As an average for 12 years the heifers weighed almost the same at the end as at the start of this fall-winter period.

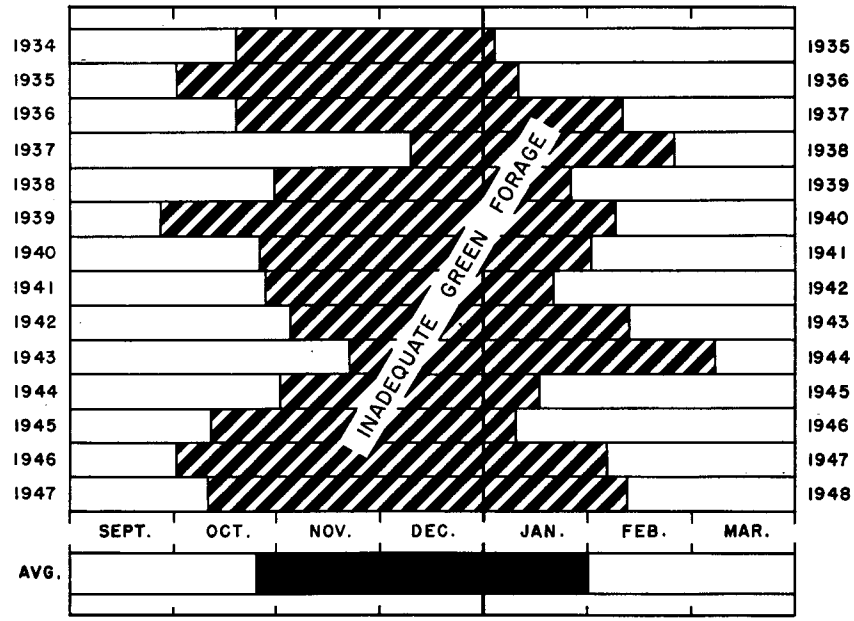

FIGURE 5.—Variations in length of time that green forage was inadequate on foothill range.

The length of time that green forage was inadequate during each plant-growth season at the experimental range is shown in figure 5. Start of the period of inadequate green forage was closely related to the date of the first effective autumn rains of 0.5 to 1.0 inch, or more. End of the period is the date when cattle were placed in the grazing-intensity

[6] Italic numbers in parentheses refer to Literature Cited, p. 51.

pastures, except for 2 years when end of the period was estimated from climatic records: 1935, the year before pastures were stocked, and 1937, when cattle were placed in them about 6 weeks too early.

The starting date for this period, for all 14 years of study, averaged October 24, but differed considerably from year to year. The interval between germination of seed and restriction of plant growth by low temperatures averaged about 3 weeks but varied from 0 to 76 days. Green forage produced during this interval was not sufficient in any year to maintain satisfactory cattle gains during the entire fall-winter period.

In some years, however, forage growth after early rains was sufficient to produce gains of cattle early in the fall. For example, in 1939 — the year with earliest effective rainfall — there was a good start of forage growth after a total of 1.97 inches of rainfall between September 25 and October 7, and the unsupplemented yearling heifers gained in weight. Later, during a drought that extended into January, plant growth was stopped and many plants died. The unsupplemented heifers stopped gaining in weight, but they ended the fall-winter period with a net gain of about 40 pounds each.

There was considerable variation in plant growth and cattle gains in other years, but the poorest fall growth of forage occurred during the 1937–38 and 1943–44 seasons when the first effective rains occurred late in the fall, after mean daily temperatures were below 50°. In these two seasons the unsupplemented heifers lost about 20 to 25 pounds each during the period of inadequate green forage.

Poor growth of forage in the fall also means that green forage will not be adequate in amount until late in the winter. For example, in the 1937–38 and 1943–44 seasons, feeding of supplements was needed until late February or early March.

Even when good growth of forage occurs in early fall, the end of supplemental feeding cannot be predicted with certainty. Cold weather during the winter, often coincident with dry weather, may halt plant growth before the green forage is adequate in amount. Also, part of the available forage may be frozen back after being judged adequate, making it advisable to resume feeding. This happened in two of the five years when feeding was terminated before January 15. However, there seems to be little likelihood of prolonged forage scarcity when supplemental feeding is terminated in February.

DEPENDABLE GREEN FORAGE IN SPRING

The period of most dependable forage is approximately 4 months long, from January or February into June. During this period the vegetation develops from early-leaf stage through seedstalk, flower, and mature-fruit stages. In these stages of plant development the mixed cover of many plant species provides an adequate amount of well-balanced cattle forage.

Several signs can be used in late winter to judge when green forage is adequate in amount. The grasses average 2 to 3 inches high but are considerably taller under trees or in other areas where conditions have been favorable for plant growth. Some plants of early-growing species such as slender oat may be 6 inches high or taller. Filaree is 1.5 to 2.0 inches high on the average and considerably taller on small spots. Young animals usually will have started to gain in weight when the forage has

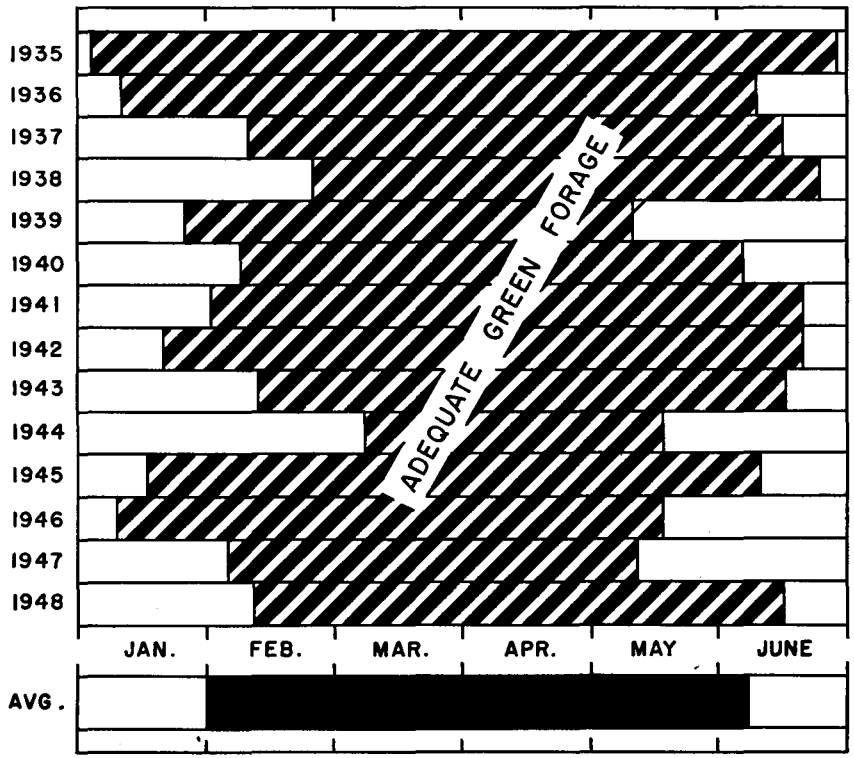

FIGURE 6.—Variations in length of time that green forage was adequate on foothill range.

reached this height. Cattle often will stop coming in to feed when called. This, along with height of vegetation, can be used in deciding when to quit feeding supplements.

The period of dependable green forage (fig. 6) extended until approximately the date when the crude protein content of the forage eaten by cattle dropped sharply below 9-10 percent. For 1936–40 the final date was estimated from the forage samples collected by Wagnon; for other years it was estimated from observations of plant development. The length of period was judged on conservatively stocked range.

Forage preferences of cattle change several times during this period. In late winter cattle continue to graze the different plant species without discrimination wherever they are tall enough to be grazed. All species can still be considered as forage. Most of this forage is provided by the scattered spots of taller plant growth. Such early-growing species as slender oat, ripgut brome, Douglas fiddleneck, and popcorn-flower are taken in considerably quantity. Taller plants of filaree also are grazed. The forage in the early leaf stages is rich in minerals and protein, the crude protein content usually ranging from about 20 to 30 percent (*1, 3*). Cattle start to gain in weight even though the vegetation is still short.

When plant growth is accelerated by rising spring temperatures, cattle still graze most species, but the widely available and early maturing subspecies of broadleaf filaree (*11*) provides the bulk of the forage.

With the midspring surge in plant growth, cattle become more selective. Many of the forbs (broadleaved herbaceous plants) are discriminated against after they flower and are no longer good forage plants. Of the species selected by cattle, soft chess and the late-growing species of broadleaf filaree are the most abundant and in most years provide the bulk of the forage. Seed heads of soft chess, which mature in late spring, are especially sought out in years when heavy heads are produced. The annual grasses and perennial rushes on bottom lands are heavily grazed. The clovers, which make most growth in April or early May, are greedily taken wherever they occur, and in "good clover years" furnish a large part of the spring forage eaten by cattle. During this time of rapid growth, there is an abundance of green vegetation in several stages of development, from full leaf to mature fruit. The forage selected by cattle is well balanced nutritionally, and the most rapid gains of cattle are made at this time of year. Gains of yearling heifers that had not been supplemented during the winter usually ranged from 2 to 2½ pounds per day.

After the herbaceous vegetation starts to dry, cattle can still find an adequate amount of green forage for several weeks. Early maturing species start drying on south slopes by the middle of April in most years. In years of low rainfall drying will start in March, or even as early as February, and the south slopes will have a mottled yellowish-green appearance by the first of April. But the bulk of the herbage does not dry until temperatures rise sharply and the upper soil dries. Then most of the herbage may dry within a few days. This rapid drying usually occurs early in May, but may occur during the last half of April in years of limited late spring precipitation, as in 1939, 1946, and 1947.

Cattle become quite selective in their search for green vegetation at this stage of the spring period. Grazing is concentrated on soft chess, filaree, and littlehead clover on the lower slopes and on whitetip clover, toad rush, grasses, and perennial rushes in the drainage bottoms. Cattle also make considerable use of the green plants under trees; and of the scattered green plants such as late-flowering godetias, summer-growing Spanish-clover, and yellow-tarweed. By such selection cattle can obtain an adequate amount of nutritious green forage for 2 to 6 weeks after the bulk of the range herbage has dried.

In June the cattle are usually forced to graze largely on dry herbage. The crude protein content in their diet drops below the level considered necessary for maintenance of mature cattle. This may occur in May — as in 1939, 1944, 1946, and 1947 — when the supply of late growing species is limited by light total annual or late-spring rainfall. In years of heavy annual and late-spring rainfall (1935 and 1938), adequate green forage is available until late in June. The yearling heifers continued to gain in weight after they were eating considerable dry herbage, but the rate of gain dropped rapidly during June.

DEFICIENT DRY FORAGE IN SUMMER AND FALL

Cattle are forced to graze almost entirely on dry forage for about 5 months during the summer-fall period (fig. 7). Most of the forage is from dry annual grasses. These provide a roughage high in carbohydrates, but they usually contain less than 5 percent crude protein (*1*, *3*). A supplemental feed is needed to supply protein. Heifer calves weaned in

July and not fed supplements usually gained slowly for part of the summer dry-forage period and lost in weight by the end, the net change being a few pounds loss on the average.

The most abundant of the finer-stemmed grasses, soft chess and foxtail fescue, are the most widely grazed. Soft chess is the most valuable of the annual grasses at this time because it retains a considerable amount of unshattered seed. Other small grasses and toad rush are also selected but may be limited in amount. The coarser grasses, such as wild oat and ripgut brome, are less readily grazed after they have dried.

Most of the forbs are of little value after they dry and crumble. Many have coarse, fibrous stems, such as those of the broadleaf filarees, and are not grazed unless cattle are forced to eat them because of a shortage of preferred roughage. Native clovers, redstem filaree or alfileria, and bur-clover are exceptions. The fine-stemmed native clovers have a higher protein content than most dry annual species and are sought by cattle even after the plants start to crumble. Redstem filaree has the highest protein content of any filaree and is often grazed closely after it dries. Mature dry bur-clover, with its nutritious burs, averages about 15 percent protein, an amount more than necessary to meet minimum

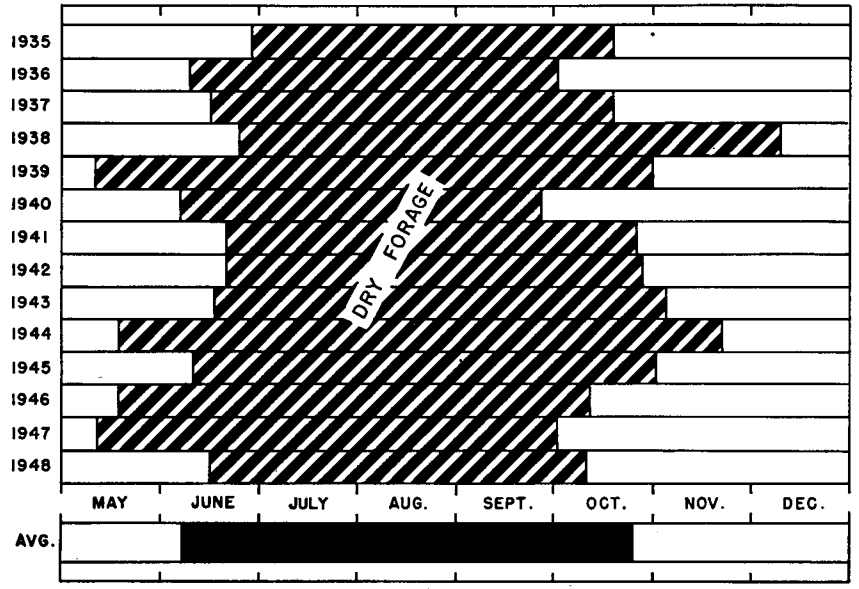

FIGURE 7.—Variations in the length of time that cattle grazed almost entirely on dry forage on foothill range.

requirements of cattle (*2*, *3*). Because it serves as a protein supplement to the other dry plants during the summer and fall, when present in adequate quantity, bur-clover is the most valuable of the annual plants on foothill ranges.

Vitamin A deficiencies may also occur on dry annual-plant range where there is no browse. Phosphorus deficiencies, which may occur in the natural forage, will usually be met by use of concentrates as supplemental feeds (*12*).

Supplementing Range Forage During Critical Periods

Although best adapted for grazing during the approximately 4 months of adequate green forage, foothill ranges are of necessity grazed at other times of the year. Only a limited acreage is used solely in the spring, when the forage would promote most efficient livestock gains. The foothills are the chief source of range forage during the fall and winter. In many operations the livestock are kept on these ranges during the entire year. Whenever foothill grazing extends beyond the green-forage period, the natural range forage is now commonly supplemented during part or all of the time that it is deficient.

A practice of supplementing foothill range forage was developed by the Division of Animal Husbandry, University of California, in their part of the studies at the San Joaquin Experimental Range (*2*, *13*). Here, where there is little bur-clover, the practice is to feed 1 pound of 43-percent cottonseed cake per day per cow while depending on dry range forage during the summer. This amount is increased to 1½ to 2 pounds per day in September or October (before the start of calving), after the better forage species have been removed by grazing through the summer and fall. Rolled barley, at 1 pound per day, is added as a source of energy-producing carbohydrates after the first effective fall rains. Supplements are decreased gradually as new green forage becomes more abundant in late winter. The daily amount of feed is increased slightly in years when there is a low proportion of grass and clovers, when the dry forage is leached by late spring rains, or when cattle weights are below average.

Ranchers must also take into account the year-to-year variations in the length of the period with adequate green forage. During 14 years of study the average length was 127 days, but the period varied from 72 days in 1944, 43 percent below average, to 176 days in 1935, 39 percent above average. Variations between 15 to 30 percent above or below average occurred in four other years. For operations in which cattle are moved onto foothill ranges during the winter and moved off in late spring, the variations can be met by purchasing supplemental feeds, moving to other sources of range forage, or varying the date of buying and selling stockers and feeders. For operations in which the cattle are on foothill ranges the entire year, or from fall until late spring, such variations can be met only by supplying sufficient feed to supplement the deficiencies in the natural range forage.

How the amount of supplements needed may differ from year to year because of variations in the forage crop is suggested by records at the experimental range. Supplemental feeding was started several weeks later than desirable in some years because the cows to be supplemented were mixed with unsupplemented cows in the grazing-intensity pastures until about August 1. Nevertheless, for 10 years (1937–46) the yearly supplement per cow varied from 288 to 462 pounds (*13*).

Supplements increased cattle production. Averages reported for the first 7 years (*2*) show a calf crop of 83.0 percent for the herd fed supplements and 67.6 for the herd not fed supplements; calf weaning weights at about 8 months of age were 470 and 417 pounds, respectively. An average of 365 pounds of supplemental feed yearly produced 108 pounds more calf weight per breeding cow in the supplemented herd.

Thus, although green forage is adequate only about 4 months, foothill ranges can be efficiently grazed during the entire year, provided there is sufficient dry roughage on the range and supplements are fed during the time when the green forage is deficient in quantity or quality.

Ranchers follow several practices to supplement range forage. Dry-land Sudangrass is used in connection with some foothill ranges during the summer. As pointed out by Jones and Love (*8*), this practice is centered in the Sacramento Valley and Coast Ranges and is limited on most ranches by the small acreage suitable for dry-land farming. Another practice is to mow green range vegetation on part of the ranch and to feed the hay out of the windrow or shock during the summer. This method is usually limited to areas that support a good cover of wild oat. Alfalfa hay, or home-grown grain or wild-oat hay, is used as a supplement, occasionally in the summer but more commonly in the fall and winter. Probably the most widespread practice is to feed protein concentrates, particularly cottonseed cake, during the fall and winter — and on some ranches during the summer, too. The cooperative animal husbandry studies have shown that supplementing the dry range forage is an efficient range husbandry practice.

Lengthening the Period of Adequate Forage

A major objective in foothill range management is to devise practices that will provide adequate forage for livestock over the longest possible period. Cultural treatments of the land, such as range reseeding or fertilization, have been used successfully on a trial basis to accomplish this objective. Adapted perennial species established by seeding will produce adequate green forage earlier than annuals and will provide some green leafage during the summer. Also, an increase in production of annual legumes will lengthen the period when foothill range forage is adequate. For example, studies now under way at the experimental range have shown that sulfur-bearing fertilizers will increase native annual legumes on these granitic soils. As a result, yields of dry forage are increased and its nutritive value during the summer is greatly improved, and forage growth during the following winter is stimulated because of the nitrogen added to the soil by the legumes. Cultural treatments to increase soil fertility and establish superior species, combined with management to make best use of the improved range will be more widely used to lengthen the period of adequate forage on foothill ranges.

Results of this study, however, show that there are other means of providing green forage at times when it is critically needed. This can be accomplished on some ranches by using the different kinds of range land at the best time of year. For example, in the early part of the plant-growing season, north slopes are better suited for grazing than south slopes. This is especially true of the steeper north slopes where the soil surface dries slowly after the infrequent rains at that time of year. Hence, the tallest green forage is found on north slopes. Similarly, new green forage is often more abundant in the shade of some tree and shrub canopies than in the open. These effects of shading are particularly important in years when fall-winter rainfall is below average.

By late winter soil moisture is ordinarily not a limiting factor, and the situation is reversed. At this time plant growth is most advanced on warm south slopes; green forage is usually adequate, without supple-

TABLE 3.—*Comparison of herbage per grazable acre from swales and slopes in pasture No. 2, San Joaquin Experimental Range, during four specified years* [1]

Plant group and species	1943		1944		1945		1948	
	Swales	Slopes	Swales	Slopes	Swales	Slopes	Swales	Slopes
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Grasses:								
Soft chess	97	825	151	485	182	531	80	135
Foxtail fescue	552	205	499	181	919	269	760	101
Mediterranean barley	2,542	[2] T	1,621	5	1,683	T	641	T
Other grasses	94	137	69	173	126	140	36	138
Total	3,285	1,167	2,340	844	2,910	940	1,517	374
Grasslike plants:								
Toad rush	56	T	10	T	14	T	T	T
Perennial rushes	381	T	232	3	632	T	33	T
Total	437	T	242	3	646	T	33	T
Forbs:								
Filaree	128	707	204	421	408	622	610	877
Clovers	258	64	112	16	1,094	121	32	23
Other legumes	11	82	18	39	79	158	T	78
Other forbs	263	110	165	87	579	278	33	27
Total	660	963	499	563	2,160	1,179	675	1,005
All species	4,382	2,130	3,081	1,410	5,716	2,119	2,225	1,379

[1] Based on sorting and weighing of herbage clipped at ½-inch stubble height in May on about 100 temporary, protected quadrats on swales and 100 on slopes during 1943–45 and 50 on each site in 1948.

[2] T = species or plant group occurred as a trace or was not found in the sample.

ments, about one month earlier than on the steeper north slopes where the soil may be frozen during the coldest weather. South slopes, however, are not well adapted for grazing in late spring since the plants dry early.

Another means of using different kinds of land at the best time is to defer the grazing of some swales until the supply of green forage on slopes is nearly exhausted. Swales are the last sites to dry, and most of the herbage produced on swales remains green for 2 to 4 weeks longer than the bulk of the vegetation on slopes. Late-maturing species growing on the swales (table 3) help extend the green-forage period there. The late-growing annual clovers, mainly whitetip clover, and two perennial grass-like species, common spikesedge and slimpod rush, produce a heavy crop of forage in most years in the wet swale bottoms. Mediterranean barley makes a heavy growth on the drier swale borders; foxtail fescue, which dries a little earlier, also produces considerable herbage on this site.

Some large swale areas can be fenced; but if this is not practical, many foothill ranches will be able to defer use of entire range units that contain a high percentage of swale sites. Such lands also usually contain the sites that support the best growth of Spanish-clover and other late-maturing slope species. Because of the relatively high production of swales, it should be beneficial to defer even small acreages in order to provide some additional green forage at the end of the green-forage season.

The practice of deferring swales has other advantages, too. Cattle can select the choice forage species and have an improved diet when turned into such deferred range pastures. Thus, even when experimental herds were moved from grazing-intensity pastures to ungrazed range in August, crude protein in their diet increased for a short time after the move (*12*). Also, deferring swales until the soil is no longer soft should reduce soil compaction and increase herbage production.

Several consecutive years of less-than-average precipitation, however, may greatly reduce the extent to which the green-forage season can be lengthened by deferring grazing in swales. The accumulative effect from a shortage of soil moisture in swales is a decrease in production of late-maturing species. This change was observed in 1947, after low rainfall in 1946 and 1947, and was very pronounced in 1948, another dry year. The clover and the rush portions of the total swale production in pasture *2* had each dropped from about 10 percent, as an average for 3 years (1943–45), to about 1.5 percent for each in 1948. Yield of clover dropped from 488 to 32 pounds per acre, and yield of rushes from 442 to 33 pounds per acre. Deferring use of swales, however, may be desirable during a period of several dry years since even a small increase of green forage is especially helpful under such conditions.

Still another way to lengthen the green-forage period is to promote earlier fall and winter growth of the annual plants. This can be done by grazing management that leaves sufficient unused herbage on the grounb, as is shown later by results of grazing-intensity tests. On conservatively stocked range, green forage will become adequate 2 to 6 weeks earlier than on heavily stocked range.

ADJUSTING RANCH STOCKING TO HERBAGE PRODUCTION

Each ranch contains range land with different characteristics of soil, topography, brush cover, and rockiness. These characteristics influence not only time of forage growth, but also total herbage production. Moreover, production of annual-plant species varies considerably from year to year because of differences in weather. By a skillful adjustment of

ranch stocking to these variations, efficiency in use of forage can be increased.

Effect of Site on Grazing Capacity

Classification of the different kinds of range land will aid in making the necessary adjustments. For example, on granitic soils — such as those in the experimental pastures — herbage production is usually greater on the more gentle slopes, apparently because the soils are deeper and finer-textured than on steeper slopes. Obviously, this difference will affect the grazing capacity of the land, and a means of classifying the range according to such differences will improve the estimation of grazing capacity.

In evaluating the grazing capacity of the experimental pastures, it was found that the land could be separated into six readily identifiable site classes. These are:

1. *Swale.*—The swale (drainage bottom) soil is typically a dark grey, sandy clay loam with a fairly good water-holding capacity, as contrasted to the shallow, brownish, sandy loams of low water-holding capacity that are found on the slopes. The swales receive a considerable amount of seepage water; in wet winters some portions remain saturated for several months. Swales (figs. 8 and 9) consist of a heavy, poorly drained phase, or wet swale, and a lighter, better-drained phase, or dry swale, that usually borders the wet swale.

F—355852

Figure 8.—Narrow, ungrazed "wet swale" with exceptionally dense stand of perennial rushes, April 1940.

2. *Gentle slope.*—Located just above the swale, the fine sandy loams of gentle slopes represent the transition from transported soil in the drainages to soil developed in place on the slopes. Gradient is under 10 percent.

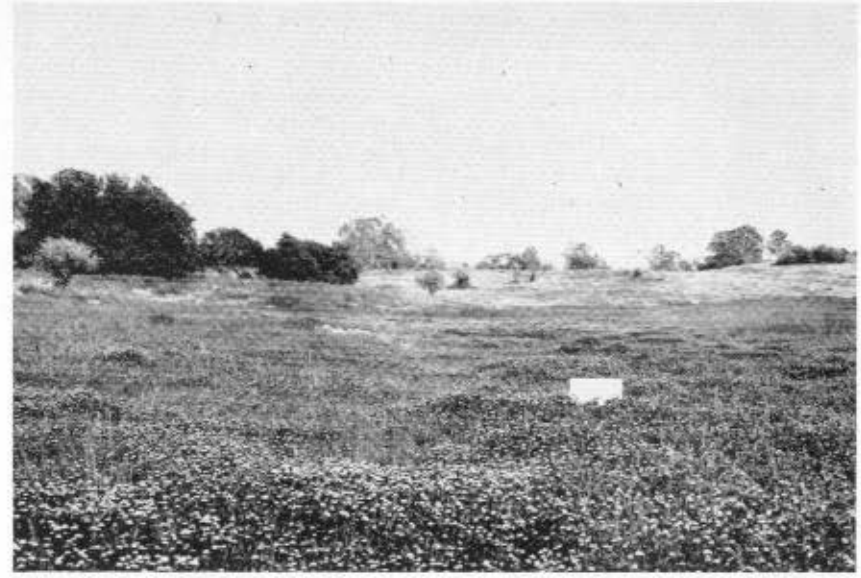

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Figure 9.—Exceptionally heavy growth of whitetip clover in ungrazed swale, April 1935. Dense stand (near backboard) in wet swale and thinner stand at left in dry swale phase. Grazing capacity of swales in the grazing-intensity pastures is 0.5 to 0.7 acre per animal-unit month. Grazing capacity of the narrow border of gentle slope around the swales is 0.8 to 1.1 acres per animal-unit month.

F—460569

Figure 10.—Rolling slope with only occasional trees, shrubs, or rock outcrop. Grazing capacity of this kind of range land is 1.25 to 1.75 acres per animal-unit month.

3. *Open, rolling slope.*—These sites, with a gradient of 10 to 25 percent, have an open cover of trees and shrubs and only scattered rock outcrops (fig. 10). Most of the sandy loams are about 24 inches deep.

4. *Rocky brushy, rolling slope.*—The average gradient of these sites is greater than for the open, rolling slope but the range in gradient, 10 to 25 percent, is about the same. In general, the soils are shallower and coarser and more of the surface is covered by rocks, shrubs, and trees (fig. 11). Such lands comprise more acreage than any other site class within the area of granitic soils.

5. *Rocky brushy, steep slope.*—These sites have a gradient of 25 percent or greater and numerous rock outcrops or many shrubs and trees. The steep areas are not common in the lower foothills; they differ considerably from place to place, including some productive soils as well as thin, sandy soils.

6. *Steep, rocky bluffs.*—These localized areas are small in size and practically unused by cattle.

F-375364

FIGURE 11.—Slope with common occurrence of trees, shrubs, or rock outcrops. Grazing capacity for most of this kind of range land with rolling-to-steep slopes is from 2 to 3 acres per animal-unit month.

The relative herbage production of each site class was estimated from yield measurements made in pastures *1*, *2*, and *3* during the period 1943–45 (table 4). The yield from the best site was almost nine times that from the poorest, and the differences between sites are evidence that the grazing capacity of foothill ranges is related more closely to the sites than to the total acreage of the range unit. Steep slopes were not well represented within the sampling areas, but though not precise the yields estimated for the steep-slope site class are considered indicative of average production on such sites. The differences in yield between north and south exposures were determined from observations extending over 10 years. On north

TABLE 4.—*Relative herbage yields of site classes, San Joaquin Experimental Range*

Site class	Yield per grazable acre [1]	Grazable soil [2]	Yield per surface acre [3]
	Pounds	*Percent*	*Pounds*
Swale	4,400	100	4,400
Gentle slope:			
North exposure	3,200	95	3,040
South exposure	2,800	95	2,660
Open, rolling slope:			
North exposure	2,200	90	1,980
South exposure	2,000	90	1,800
Rocky brushy, rolling slope:			
North exposure	1,400	70	980
South exposure	1,400	70	980
Rocky brushy, steep slope:			
North exposure	900	55	495
South exposure	1,800	70	1,260
Steep, rocky bluffs	.....	0	.....

[1] In evaluating productivity of the several site classes, the average yield of 4,400 pounds per acre for swales in pasture *2* during 3 years of intensive sampling (1943–45) was taken as a base. Yield of each slope site class and for steep slopes in relation to the base yield for swales was estimated from a limited number of sample quadrats for each site class in three pastures in 1945.

[2] Percentage of grazable soil for each site class was estimated from an intensive survey of the land surface actually grazable by cattle in each pasture.

[3] Yield of herbage per surface acre (Land Office acre) was computed for each site class by multiplying the yield per grazable acre by the percentage of grazable soil.

exposures on rolling topography, with thin stands of trees and shrubs, yields were commonly observed to be greater than those on similar south exposures. On steep north exposures, however, the stand of herbage was often thinned by shading from dense tree canopies.

That productivity of range site classes must be taken into account in estimating grazing capacity is also shown by the lack of correspondence between size, productivity, and degree of utilization in each of the six grazing-intensity pastures on the experimental range (table 5).

As a yardstick of productivity the acreage of each site class in each pasture was reduced to its swale-equivalent in herbage production, or "swale-acres." Because pasture *1*, 154 acres in area, contained a relatively great proportion of the more productive site classes (fig. 12), it had a productivity equivalent to that of 60 acres of swale. But pasture *3*, with 155 acres and a different combination of site classes, mostly of lower value, was equivalent to only 43 acres of swale. Similarly, the 230-acre pasture *2* contained 12 more swales-acres than the 309-acre pasture *4*.

Each pasture was stocked with 15 cows along with their calves and a bull for part of the season. This stocking averaged approximately 19 animal units per pasture for a 6-month season. Consequently, the two

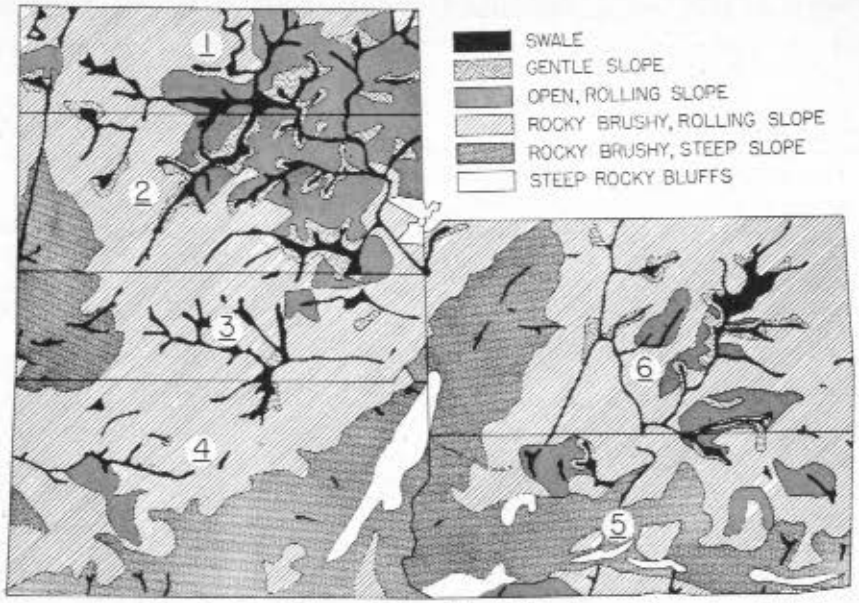


FIGURE 12.—Map showing different kinds of land (site classes) in pastures 1 to 6.

TABLE 5.—*Pasture size, productivity, degree of grazing, and grazing capacity on six pastures*

Range pasture number	Size	Productivity [1]	Degree of grazing obtained [2]	Grazing capacity [3]
	Acres	*Swale-acres*		*Animal units*
3	155	43	Close	12.3
1	154	60	Moderate to close	17.1
5	250	68	Moderate	19.4
4	309	78	Light to moderate	22.3
6	316	89	Light	25.4
2	230	90	----do	25.7

[1] Sum of the acreages of all site classes in the pasture after the acreage of each site class had been reduced to its swale-equivalent in herbage production; based on relative herbage yields shown in table 4.

[2] 11-year average obtained when each pasture was stocked with approximately 19 animal units for an average grazing season of 6 months.

[3] The number of animal units that the pasture would support for 6 months under moderate grazing.

pastures with the lowest productivity were grazed closest and those with the greatest productivity were grazed lightest. All six pastures showed a consistent relation between productivity and degree of grazing.

This consistent relation was also evident when the grazing capacity of each pasture was estimated as the number of animal units that the pasture would support under a moderate degree of grazing for an average 6-month season, from about February 1 until August 1. Stocking at approximately 3.50 swale-acres per animal unit gave moderate utilization; the range was from about 2.25 swale-acres for close utilization to 4.75 swale-acres for light utilization. Using a requirement of 3.5 swale-acres per animal unit for 6 months, the 154-acre experimental pasture would support 17.1 animal units under moderate grazing, and the 155-acre pasture would support only 12.3 animal units.

The grazing capacity of each site class under moderate grazing was calculated from the relative yields per surface-acre shown in table 4. For example, swales with a yield of 4,400 pounds per acre and a capacity of 3.5 acres per animal unit for 6 months required an average of 0.58 acre per animal-unit month. Similarly, south exposures on open, rolling slope, with a yield of 1,800 pounds per acre, required an average of 1.42 acres per animal-unit month. Because of variations in productivity around the average for each site class, a range in grazing capacity was estimated for each. The estimated range in grazing capacity for each site class was:

Site class:	*Acres per animal-unit month*
Swale	0.50–0.70
Gentle slope	.80–1.10
Open, rolling slope	1.25–1.75
Rocky brushy, rolling slope	2.00–3.00
Rocky brushy, steep slope	3.00–5.00

More refinement in criteria is needed for recognition of grazing capacity on steep slopes, but the range in capacity for other site classes is sufficiently narrow for satisfactory use.

The studies show that grazing capacity can be estimated by range land classification. Thus range site classes are of direct use in determining proper ranch stocking. In addition, classification of range sites will bring about more equitable evaluation of the tax base and more uniform loan appraisals on foothill lands.

EFFECT OF ANNUAL PRECIPITATION ON HERBAGE YIELD

Records of how herbage yield on the experimental range fluctuated with annual precipitation show the need for flexibility in stocking. Total herbage production there is typical of other parts of the California foothills where average precipitation is about the same or greater. On soils different from the granitic soils of the experimental range, annual-plant herbage presumably would respond in a similar manner, but the amount of monthly and annual precipitation required for the same plant response might be different.

The total yield at maturity of most species for each year (fig. 13) was estimated as the average for all grazable soil in pastures *1*, *2*, and *3*. The estimates were based on intensive measurements made as follows: 1943–45, all sites in the three pastures; 1948, all sites in pastures *2* and *3*; 1942, all slope sites in pastures *2* and *3*; 1937–48, ¼-acre exclosure in pasture *1*.

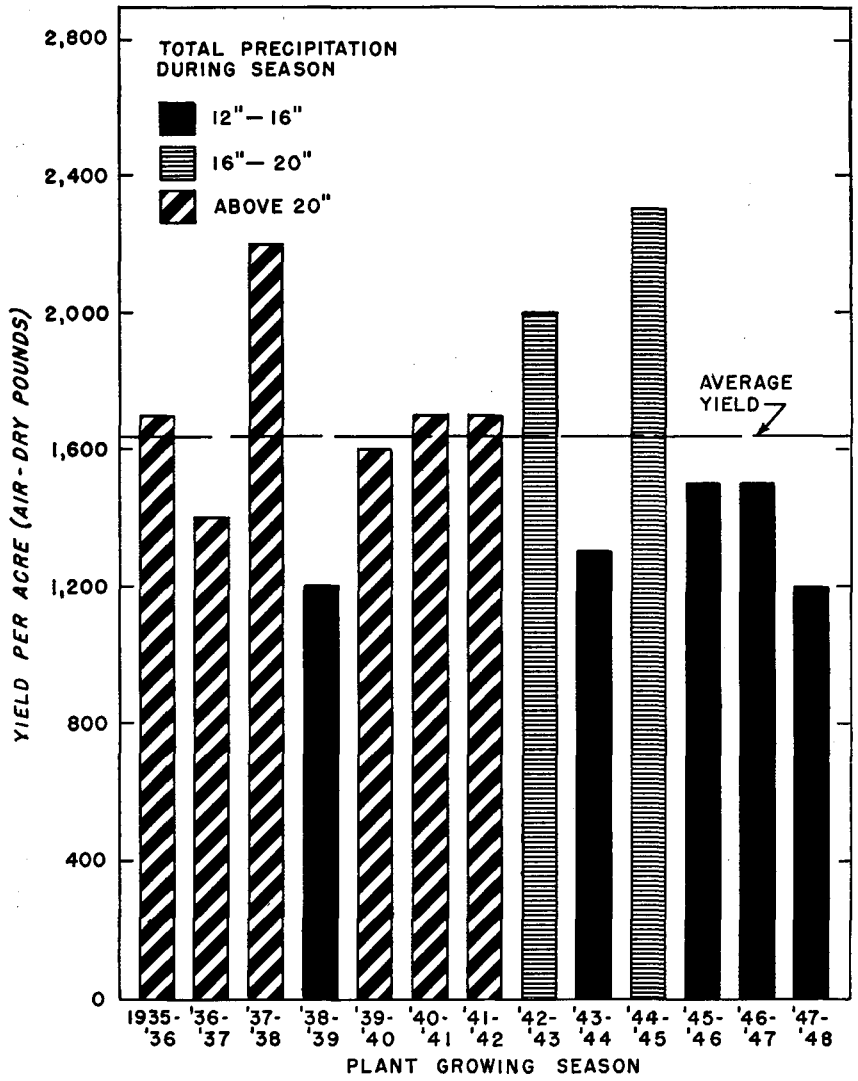


FIGURE 13.—Estimated total production of air-dry herbage per grazable acre, and total precipitation during plant growing season (September of one year to time of plant maturity in next year), San Joaquin Experimental Range, 1935–48.

In years with precipitation greater than 20 inches, the heavy rainfall during the winter months was largely lost by seepage from the upper soil before air temperatures became favorable for plant growth. Shallow-rooted annuals could not take advantage of the excess precipitation except on bottom-land soils, where ample seepage from the slopes provided moisture into the spring months. Thus, total herbage production was approximately average in four of the six seasons when total precipitation was above 20 inches. Greater than average yields were obtained during 1937–38, with 32.09 inches of precipitation, when good rains occurred late in the spring. Exceptional yields were also observed during 1934–35, not shown in figure 13, when precipitation totaled 29.40 inches and good rains occurred in both fall and spring. In 1936–37, however, yields were below average, even though precipitation totaled 22.96 inches, apparently because severe winter temperatures stunted the plants so that full production was not attained later on. Winter temperatures may have more effect on plant yields than is readily apparent because effects of temperature are not easily dissociated from effects of precipitation.

In 1942–43 and 1944–45, with total precipitation of 17.24 and 18.99 inches, respectively, soil moisture was considered adequate during the winter and there was sufficient seepage into the swales to promote good growth on these fertile sites. Yield in each of these 2 years was well above average. These years were near the long-time average of 17 to 18 inches, calculated from isohyetal maps of the U. S. Weather Bureau and from comparison of precipitation records at the experimental range with records of longer duration at other foothill stations. Apparently average or greater yields can be expected in most years when total precipitation at the experimental range is within a range of 16 to 20 inches.

In dry years, with precipitation between 12 and 16 inches, soil moisture was not adequate at all times during the winter, and there was only limited seepage into the bottom lands. Herbaceous vegetation was retarded at some time during the winter or spring by lack of moisture, and total yields were accordingly reduced. In each of the five grazing seasons with total precipitation well below the long-time average, herbage production was measured or estimated to be between 1,200 and 1,500 pounds per acre, as compared to the 13-year average of about 1,640 pounds. Often, half or more of the total herbage in dry years is produced after rains of 1 to 2 inches in late March or April, after some species start to dry at a very short height. This ability to make rapid growth during a short period of favorable weather in the spring allows production of a fair total yield in years that are otherwise unfavorable, and enhances the dependability of annual-plant herbage production. The critical point of annual and monthly precipitation, below which annual-plant production is reduced, will depend on the character of the soil. Observations indicate that plant growth is limited by below-average precipitation to a greater extent on heavy, fine-textured soils than on lighter soils.

In drought years, say with less than approximately 12 inches total precipitation at the experimental range, herbage yields would probably drop below 1,200 pounds; but how far below is speculative: annual rainfall was more than 12 inches throughout the period of study. In fact, study of long-time records at other foothill stations indicates that precipitation at the experimental range may have fallen as low as 8 to 12 inches in only 6 years out of 48; and only two of these occurred in the 40 years from 1909 through 1948.[7] Because the distribution of rainfall in drought years ordinarily does not follow the normal pattern, some drought years may have above-average spring precipitation and a fair total production of herbage. To the knowledge of local ranchers, no

[7] Monthly and annual precipitation at the San Joaquin Experimental Range for period September 1897-August 1934 was computed from U. S. Weather Bureau records for Friant, Calif. (no record 1904–06), by regression equation based on correlation of precipitation at San Joaquin Experimental Range and Friant during the period September 1934-August 1946. Average annual precipitation at Friant was 13.24 inches for the period 1897–1945.

"failure" of herbage production occurred in the vicinity of the experimental range from 1877 to 1948. In years of extremely low precipitation, however, severe forage shortages undoubtedly occurred during a considerable part of the plant-growing season, and a shortage of water for stock limited effective use of the forage after it dried.

Stocking to Meet Forage Fluctuations

To meet the fluctuations in the forage supply and obtain efficient utilization of annual plants, some adjustment in stocking is needed nearly every year. Whether a change in numbers of livestock is needed can be judged in late spring, after almost all plant growth is complete, and again at weaning time in the summer or fall. The extent of adjustment and the classes of stock involved will depend on the type of operation at each ranch.

For ranches keeping the cattle on foothill range during all or most of the year, the desirable flexibility can be had by operation of a breeding-cow herd in which all or part of the calves are generally carried over and sold at the end of the next green-forage season as long-yearlings. Essentially, this practice consists of carrying enough cows and replacements to utilize most of the forage in the years when yields are well below average. During the five dry years at the experimental range, total herbage production was reduced a little more than 25 percent below average in two of the years, but only about 10 percent below in two other years. Probably the cow herd should not take more than 75 percent of the usable herbage in average years.

The extra forage in years of average production is utilized by yearlings. If there is no extra, the young stock can be sold as weaners. In years of above-average herbage production the increased forage yield may either be utilized by bringing in outside animals, or be left on the ground to replace any litter than may have been lost during dry years.

If a year of very low herbage production occurs when maximum numbers of yearlings are being carried, some animals can be sold earlier than usual to save range roughage for use by the cow herd during the summer, fall, and winter. Other adjustments can be made by heavier culling of cows and replacements and possibly by earlier weaning.

Almost yearly changes in stocking are necessary because a reserve of forage cannot be built up on the ground in good years. Dry herbage of annual plants is ruined by leaching during the winter. It appears feasible, however, to keep a reserve of hay above the usual yearly needs (*12*). This hay reserve, often obtainable at a lower cost before the start of a drought, can be stored under cover with little deterioration. Besides filling part of the needs for roughage in years of low grass production, the hay may be needed in other emergencies, as when growth of green forage is greatly delayed in late winter or when grass fires cause sudden loss of dry vegetation.

Experience with both a breeding herd and yearlings at the experimental range indicates that the foregoing method of operation is feasible and will allow the necessary adjustments in livestock numbers in all except the occasional years of extremely low herbage production.

Fluctuations in the composition of the herbage crop should also be considered in stocking foothill ranges. The amount of grass in the plant mixture is of special importance on ranges grazed from summer until

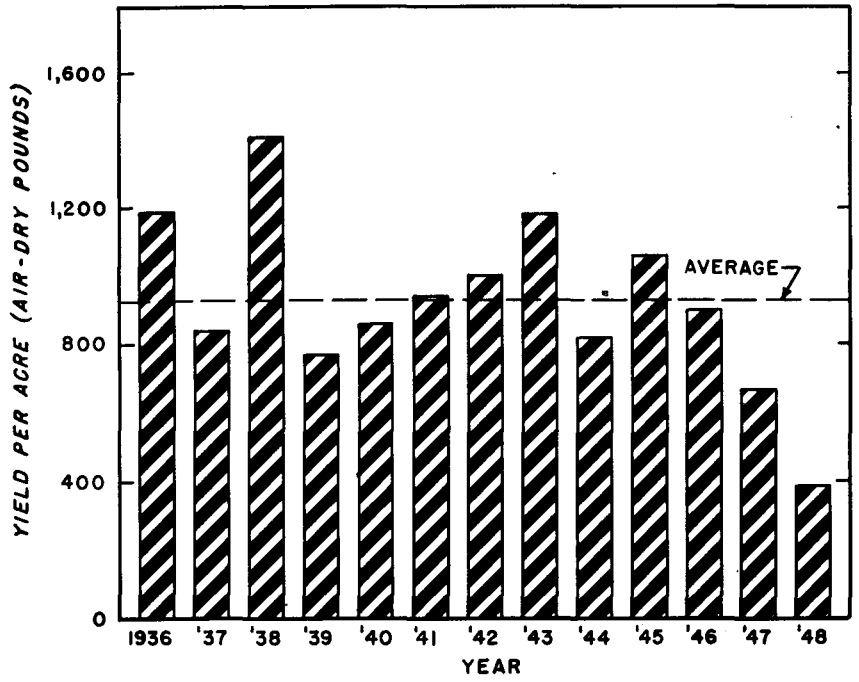


FIGURE 14.—Estimated annual production of air-dry herbage from grasses and grasslike plants per grazable acre, San Joaquin Experimental Range, 1936–48.

winter. Grasses are the chief source of dry forage at that time of year. During the 13 years, 1936–48, the production by grasses and grasslike plants each year in pastures *1*, *2*, and *3* (fig. 14) was estimated from clipped samples, density records, and other field observations. These records show that the yield of grasses and grasslike plants varied less than did total herbage production (fig. 13) up to and including 1946. Livestock adjustments based on variations in total herbage were sufficient in these first 11 years.

After 1946, however, grass yields fluctuated more than total yields, presenting a more critical stocking problem. The proportion of grasses in the herbage was progressively lowered during the dry years after 1946. Filaree dominated the plant cover in 1947 and 1948; consequently, grass yields were lowered much more than total yields. By 1948 grass yields were only about 42 percent of the 13-year average. Under these conditions a greater amount of supplements was needed in the summer to balance the lower quality of the dry roughage, and hay was needed during the fall and winter, even though fewer livestock were grazed.

Nevertheless, most fluctuations in individual species have relatively minor effects on range stocking. Observations on several important forage species bear out this conclusion. In years of high clover yields, for example, the herbage was considered of better forage value than in other years. However, in "good clover years" there is no shortage of forage and the problem may be to increase stocking. Again, because soft chess matures late, its growth and seed production depend on adequate late spring rains. Value of the dry herbage was considered better in the

years when there was a vigorous growth of soft chess with large seed heads; but when yield of soft chess was low, the number of animals that could be carried on dry forage was also limited by total grass production. A third example is afforded by broadleaf filaree. This plant, which is more dependable as a source of green forage early in the spring than any of the other species, usually produced about 25 percent or more of the total herbage at plant maturity. But its yield was low in 1938 because of late fall rains in 1937, followed by prolonged cold rains; it composed only 9 percent of the total herbage production. However, the shortage of filaree in late spring was more than offset by high production of other species.

Thus it is evident that nutritive value of the forage is affected each year by fluctuations in clovers, soft chess, and other valuable forage species, but grazing capacity is affected mainly by variations in total herbage production and total grass production. Both the kinds of land on the range and the annual precipitation need to be considered in adjusting ranch stocking to meet these variations.

SELECTING THE MOST EFFICIENT DEGREE OF GRAZING

To insure both high livestock production and good forage cover, the ranch operator needs to select the degree of grazing that will give the most efficient utilization of the forage over a period of years. Results of the grazing-intensity experiment will aid in this selection by showing how different degrees of grazing affect both cattle and herbage production.

The experiment was planned to determine how closely annual plants can be grazed without adversely affecting either forage growth or cattle production. The stocking dates for each year were:

Year:	*Entry date*	*Removal date*
1936	January 10	August 4
1937	January 2	August 10
1938	February 25	September 2
1939	January 25	August 1
1940	February 8	August 4
1941	February 1	August 13
1942	January 20	August 6
1943	February 12	July 30
1944	March 7	July 20
1945	January 16	August 8
1946	January 9	July 14
1947	February 5	July 1
Average	January 29	August 1

The grazing season in the experimental pastures covered the period of best forage on foothill range and included only a limited period of forage shortage in the most closely grazed pastures. Grazing started in the winter when the plants were still growing slowly and continued through the spring when the plants were growing rapidly. Since cattle could not keep up with the rapid spring growth, there was adequate seed production of the important forage species — at least on most sites. The vegetation was not grazed to the final degree of utilization until after the plants were mature and dry. Effects on vegetation of the different degrees of grazing obtained should be representative of those which would occur under the usual seasons of grazing.

TABLE 6.—*Degrees of utilization in six grazing-intensity pastures, San Joaquin Experimental Range, 1937–47*

Year	Pasture 3	Pasture 1	Pasture 5	Pasture 4	Pasture 6	Pasture 2
1937	Very close	Close	Close	Moderate	Moderate to light.	Light to moderate.
1938	Close	Moderate to close.	Moderate to close.	Moderate to light.	Light	Light.
1939	Very close	Close to moderate.	do	do	do	Do.
1940	Close	Moderate to close.	Moderate	Light to moderate.	Light to moderate.	Do.
1941	do	do	do	do	Light	Do.
1942	do	do	do	do	do	Light to moderate.
1943	do	Moderate	Moderate to light.	do	do	Light.
1944	Very close	Close to moderate.	Moderate	Moderate	Moderate to light.	Light to moderate.
1945	Close	Moderate to close.	Moderate to light.	Light	Light	Light.
1946	do	Moderate	do	Light to moderate.	do	Do.
1947	Very close	Close to moderate.	Moderate	Moderate to light.	Light to moderate.	Light to moderate.
Average	Close	Moderate to close.	Moderate	Light to moderate.	Light	Light.

The planned procedure was to remove the cattle from the pastures at variable dates from year to year, depending on herbage yields, in order to obtain somewhat the same degree of grazing each year in any given pasture. It was found impractical to follow this procedure in all years. In years of low herbage production the pastures were grazed closer than average (table 6), especially in 1937 and 1939 when the cattle were kept in the pastures until August. During the last 5 years (1943–47) the cattle were removed earlier than in previous years; even so, grazing was somewhat closer than average in 1944 and 1947. The experience in stocking emphasized the need for flexibility in ranch stocking if utilization of the fluctuating herbage crop is to be kept within narrow limits.

The utilization of the pastures at the end of the approximate 6-month season for an 11-year average included five different degrees of grazing. There were three basic degrees; close, moderate, and light. When the average utilization of a pasture in any year did not fit one of these three, intermediate ratings were used; for example, "moderate to close" in-

dicated a degree that was nearer to moderate than to close, while "close to moderate" indicated utilization was nearer to close.

Effects of Different Degrees of Grazing on Cattle Production

A brief consideration of how different degrees of grazing affect cattle production will aid in interpreting the effects on sustained forage production. Members of the Division of Animal Husbandry, University of California, who were in charge of the cattle phases of the experiment, have reported the findings for 1937–43 (*4*). Their results, summarized here, show that heavy stocking, even for only part of the year, on annual-plant ranges means lowered efficiency of production from a breeding-cow herd.

Average gains and weaning weights of calves were low in closely grazed pasture *3*, particularly for calves from the "B" herd which received no supplements, but also for calves from the "A" herd which received supplements while out of the grazing-intensity pastures (table 7). Variations in gains and weaning weights of calves in the other five pastures were not related to degree of grazing; the variations were apparently caused by other factors. The lower calf gains in pasture *3* emphasize the importance of having an adequate forage supply for cows during the nursing period.

Table 7.—*Average gains and weaning weights of calves from supplemented and unsupplemented herds grazed in six pastures, 1937–43* [1]

Pasture number	Degree of grazing	Calves from supplemented "A" herd		Calves from unsupplemented "B" herd	
		Gains in pasture	Weaning weight	Gains in pasture	Weaning weight
		Pounds	*Pounds*	*Pounds*	*Pounds*
3	Close	265	459	241	378
1	Moderate to close	292	504	291	447
5	Moderate	281	459	286	432
4	Light to moderate	284	490	285	435
6	Light	268	462	299	453
2	---do	292	493	300	447

[1] Source: Hart, Wagnon, and Guilbert (*4*).

The cows in closely grazed pasture *3*, from the unsupplemented "B" herd, always gained less than did the cows from this herd in the other five pastures and were always thinner at the time they left the pasture (table 8). Cows from the supplemented herd also gained less in the closely grazed pasture than did their mates in the other pastures. For the unsupplemented cows, gains and final weights were also lower in

Table 8.—*Average initial weights, final weights, and gains of cows from both the supplemented and unsupplemented herds grazed in six pastures, 1937–43* [1]

Pasture number	Degree of grazing	Cows from supplemented "A" herd			Cows from unsupplemented "B" herd		
		Initial weight	Final weight	Gain	Initial weight	Final weight	Gain
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
3	Close	838	939	101	725	868	143
1	Moderate to close	857	1,002	145	701	877	176
5	Moderate	872	1,016	144	754	978	224
4	Light to moderate	869	1,023	154	733	927	194
6	Light	871	1,032	161	766	1,026	260
2	---do	819	1,023	204	717	937	220

[1] Source: Hart, Wagnon, and Guilbert (*4*).

Table 9.—*Percentage pregnancies and percentage calf crop of cows from both the supplemented and unsupplemented herds grazed in six pastures, 1937–43* [1]

Pasture number	Degree of grazing	Cows from supplemented "A" herd		Cows from unsupplemented "B" herd	
		Pregnancies	Calf crop	Pregnancies	Calf crop
		Percent	*Percent*	*Percent*	*Percent*
3	Close	91.4	82.8	65.0	60.0
1	Moderate to close	89.2	78.4	70.6	61.8
5	Moderate	86.5	86.5	83.3	77.8
4	Light to moderate	97.4	89.5	85.7	77.1
6	Light	88.2	79.4	80.0	72.5
2	---do	95.0	82.5	85.3	73.5

[1] Source: Hart, Wagnon, and Guilbert (*4*).

pasture *1* under moderate-to-close grazing than in more lightly grazed pastures. Variations in cow gains among the other four pastures, grazed from moderate to light, were not related to degree of grazing. Part of the variation was caused by differences between pastures in the amount of steep south slope, where the forage grew faster in late winter and dried earlier in the spring.

This experiment produced only limited information concerning the effects of degree of grazing on the calf crop. Percentage pregnancies and calf crops for supplemented cows (table 9) did not differ significantly between experimental pastures. Supplements received during the fall and winter apparently offset the effects of differences in degrees of grazing during the remainder of the year. Yet stocking to a degree closer than moderate during late winter, spring, and early summer did affect reproduction from unsupplemented cows. As stated by the animal husbandmen (*4*), there is a good indication "that the lower percentage of pregnancies and calf crop of group B (unsupplemented) cows in pastures *3* (close) and *1* (moderate to close) is related to the lower gains and weights of these cows."

The experiment shows, too, that net gain per acre is not a good expression of efficiency of operation for a breeding herd. The average yearly gain of all cattle per grazable acre was greatest under close grazing and decreased with increase in the amount of grazable land available per animal unit: from 43.1 pounds in pasture *3* to 23.4 pounds in pasture *6*, with pasture *2* as an exception at 32.5 pounds per grazable acre. But, as stated by the animal husbandmen (*4*), "while pasture *3* shows the highest return in pounds of gain per grazable acre, it should not be concluded that this is the most profitable use. The cattle were always thinner, the gains contained less energy because of lack of fat, the calves weighed less at weaning time, had less bloom, and were worth less per pound. Efficiency of production for those not receiving supplemental feed was further reduced because of lower calf crops. . . . Thus there are limitations of greatest return in pounds of beef per acre as a criterion of most profitable rate of stocking. Rather, the criteria should be the maximum returns per acre compatible with maximum gains of the cattle, high percentage calf crops and optimum weaning weights. . . . That animals do not thrive where they do not get enough to eat is not news to most livestock men. Some cling to large numbers poorly fed and thus use too high a proportion of feed resources for maintenance. This leaves too little for production and sacrifices efficiency through lower weights, calf crops, value per pound, and increased death loss."

Effects of Different Degrees of Grazing on Herbage Production

Grazing to a moderate degree which gave efficient cattle production also maintained satisfactory herbage production. On the other hand, close grazing reduced range forage production as well as efficiency of cattle production. The effects of degree of grazing were apparent in the winter growth of forage and in yield of mature herbage.

EFFECTS ON PLANT GROWTH DURING WINTER

Close grazing consistently reduced winter plant growth. Even though the closely grazed range appeared greener, the new plants were shorter than on areas grazed moderately or lightly. This difference was found in measurements made along fence lines and on permanent sample plots in the grazing-intensity pastures, and it is well illustrated by intensive measurements made in January 1943 on 100 square-foot quadrats in

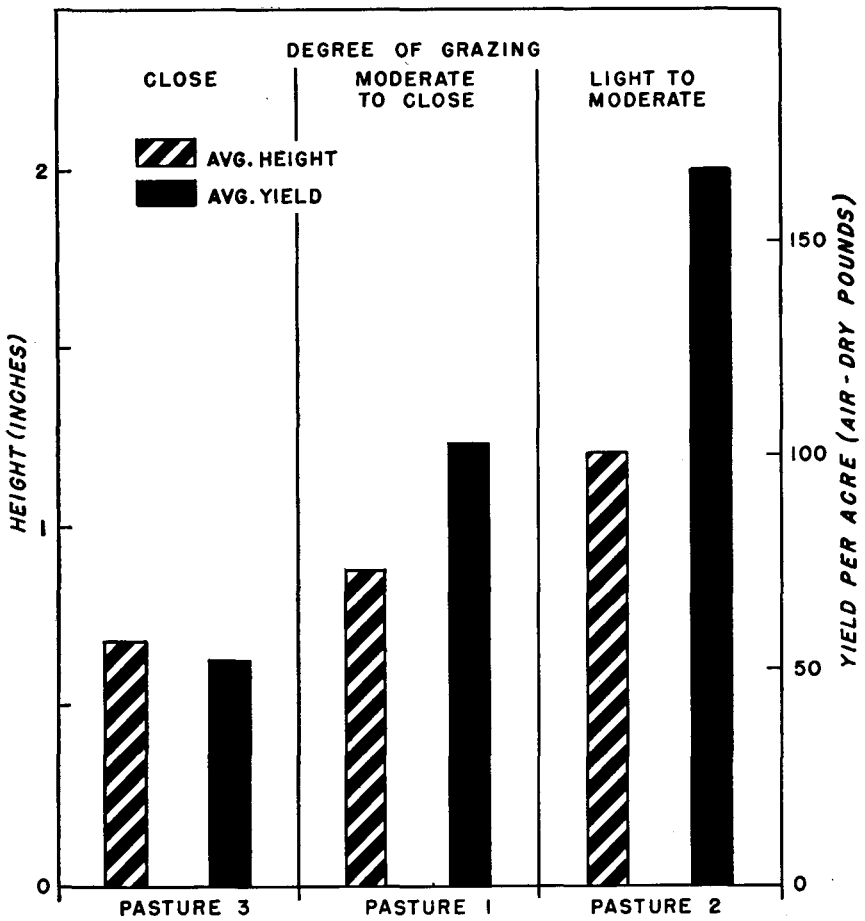


FIGURE 15.—Average height and yield of new vegetation in January 1943 in three range pastures in relation to degree of grazing of each pasture in the preceding year.

each of pastures *1*, *2*, and *3*. These three pastures were chosen for intensive measurements because they were most comparable in kinds of land and included both of the two most closely grazed range pastures, in which degree of grazing was likely to be critical, and one of the lightly grazed pastures.

In the two pastures that had been most closely grazed, the vegetation was hardly tall enough to be grazed on most of the area. The average height of all species in each of these two pastures was between ½ and ¾ inch (fig. 15), with grasses averaging between 1½ and 2 inches. But in pasture *2*, grazed light to moderate in the preceding year, the new plants were tall enough for some grazing over most of the pasture and were readily grazable on about half of the acreage. In this pasture the average height of all species was more than 1 inch, with grasses averaging about 2½ inches.

Because of greater height and increased leafiness, the average yield of plants clipped at ½-inch stubble height during January 1943 in pasture *2*

was three times as great as in pasture *3*, and more than 50 percent greater than in pasture *1*. Production was uniformly low on all sites in the two more closely grazed pastures. Grasses produced about 75 to 90 percent of the available new growth in each of the pastures.

The differences between pastures were only about 50 pounds of air-dry forage per acre, but even such small differences in the production of new forage are important in this period when cattle have difficulty in obtaining sufficient green forage for their minimum requirements. Furthermore, at this stage the forage is a "watery concentrate;" air-dry, it is comparable to many commercial concentrate feeds. Fifty pounds of air-dry forage per acre represent a considerable bulk of green material.

Close grazing also delayed the date when new forage was adequate, thus lengthening the time that expensive supplemental feeding was necessary. Each year when the cattle entered the six grazing-intensity pastures, the new forage was considered adequate in each of the four pastures grazed from moderate to light the previous year. But it was not considered adequate in pasture *3*, grazed close, and pasture *1*, grazed moderate to close in preceding years. Observations during 3 years on some 200 small temporary enclosures that were relocated each year and protected from cattle grazing until May, indicated that the forage in the closely grazed pasture would not have been ready until shortly before the start of the spring growth period. Since spring growth started about the first week in March on the average, close grazing caused an average delay of about 3 weeks in the date when the forage was ready to graze without supplements. The delay in the pasture grazed moderate to close was about half that in the closely grazed pasture.

This delay in growth of late-winter forage was reflected in weight gains of the cows for the first few weeks they were in the pastures. First weighed when they moved into experimental pastures, the cows were weighed again when the forage in all pastures was abundant enough to provide a fill. By that date, averaging March 21 during 9 years, cattle had been in the pastures an average of 51 days. That period included the end of slow winter forage growth and the start of accelerated spring growth. For the entire 51-day period, which included some time when forage was adequate in all six pastures, average gains[8] of cows with calves at side were:

Pasture (degree of grazing):	*Supplemented cows (pounds)*	*Unsupplemented cows (pounds)*
3 Close	2.5	46.5
1 Moderate to close	26.8	65.6
5 Moderate	67.1	117.2
4 Light to moderate	63.9	106.0
6 Light	51.0	100.6
2 ----do	68.1	110.6

Cows which received supplemental feeds before entering the grazing-intensity pastures as well as those that had not been supplemented gained much less in the two pastures that had been most closely grazed than did cows of the same group in more lightly grazed pastures.

Better winter growth of green forage under light or moderate grazing is undoubtedly related to the amount of dry vegetation left ungrazed. The dry vegetation left on the range at the beginning of the fall-winter

[8] From unpublished data in files of Division of Animal Husbandry, University of California, at the San Joaquin Experimental Range.

period promotes the growth of green forage in two ways. First, the upright herbage protects the new plants from drying winds and sun. Second, the decomposing herbaceous material lying flat on the soil surface, and partially intermixed with the mineral soil, conserves moisture and aids establishment and early growth of each year's seedlings. In the grazing-intensity pastures, herbage production during the winter was observed to be consistently greatest on range land with an adequate layer of decomposing litter. Exceptions occurred on small spots recently cultivated by gophers or where moisture accumulated at the base of boulders; but on the whole, plant growth was sparse where there was a shortage of litter on the soil surface.

The layer of old litter was not maintained over most of the soil surface in the two pastures that had been grazed closer than moderate. In pasture *3* (closely grazed), of 99 square-foot quadrats examined in January 1943, about 75 percent had almost no litter; about 15 percent had a thin, spotty cover; and less than 10 percent had a fairly continuous layer of decomposing herbaceous material. In pasture *1* (grazed moderate

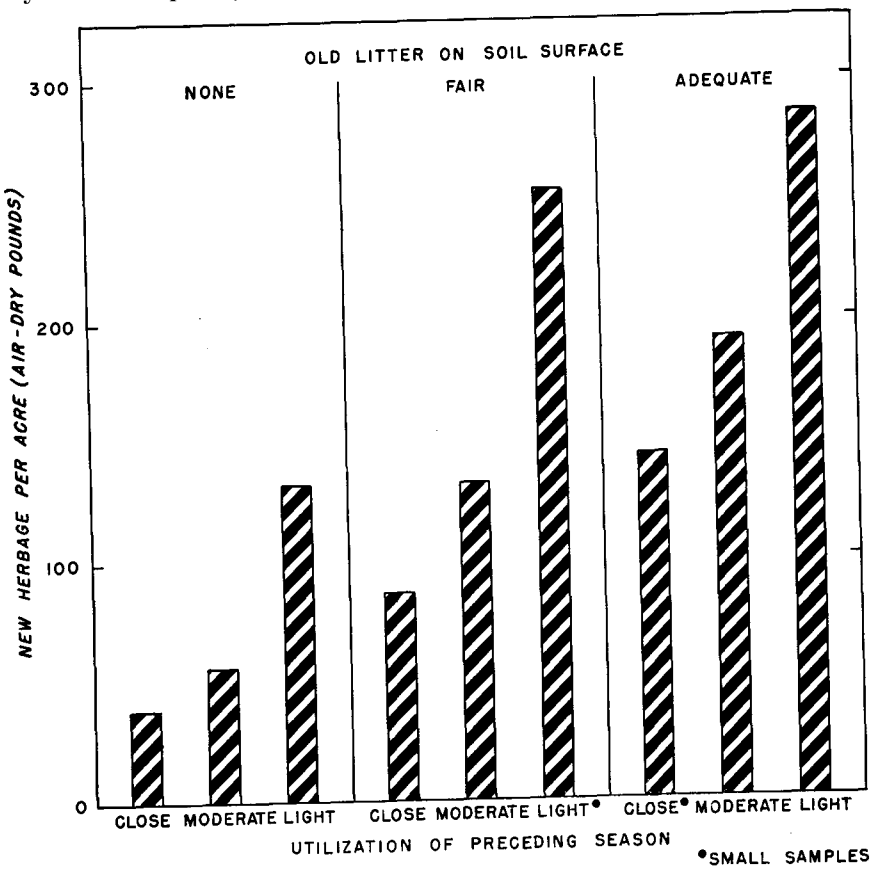


FIGURE 16.—Yield of new green vegetation in air-dry weight pounds per acre, clipped at ½-inch stubble height, as influenced by the layer of old litter lying flat on the soil surface and by the degree of utilization of the preceding season.

to close), half of the quadrats had practically no decaying vegetation on the soil surface; one-fourth had a thin, spotty layer; and the remaining fourth had a continuous layer about ¼ to ½ inch deep. The nearly bare areas were found fairly generally over this pasture on most of the better sites. Soil-surface conditions were better than in the closely grazed pasture but still not satisfactory.

In contrast, there was some old herbaceous litter flat on the soil surface in all parts of the more lightly used pastures. For example, nearly half of the 97 small quadrats examined in pasture *2* (grazed lightly) had a continuous layer of decomposing herbaceous material between ¼ and ½ inch deep, and nearly one-fourth had a thin, spotty layer. The remaining quadrats had almost no old litter, but these quadrats were of scattered occurrence, falling almost entirely on poor, sandy soils, on recent rodent workings, or on closely grazed swale bottoms or livestock trails. Such small local areas of exposed soil can be found on any range, even though it is in satisfactory condition.

Observations within the other lightly or moderately grazed pastures on the experimental range indicated that the soil-surface conditions were similar to those in pasture *2* although more soil without any litter could be found in parts of the moderately grazed pasture. The vigor of plant growth and the general lack of exposed soil during the winter showed that these pastures were in satisfactory condition under the present cover of annual plants.

The importance of unused vegetation and the layer of litter it produces was shown by the yield of herbage in January 1943 from the 295 sample quadrats (fig. 16). A rather continuous layer of the old litter, ¼ to ½ inch deep, was designated as adequate. Where the layer of litter was adequate, on quadrats that had been lightly grazed the preceding season, the yield of new green herbage was nearly 300 pounds per acre, air-dry weight, and on moderately grazed quadrats the yield was nearly 200 pounds. Such yields over a range area would provide sufficient green forage to maintain cattle. With an adequate layer of litter, growth of green forage was nearly sufficient even on the few quadrats that had been closely grazed.

Where the layer of old litter on the soil surface was thin and spotty, designated as fair, growth of green forage was reduced on quadrats that had been grazed moderately or closely during the preceding season. On the few such quadrats that had been lightly grazed, forage growth was satisfactory.

Where there was virtually no layer of old litter, growth of new forage was very greatly reduced, particularly on quadrats that had been grazed moderately or closely during the preceding season. Even on the lightly grazed quadrats, yields averaged less than 150 pounds per acre.

These results show that moderate and light grazing promote winter growth of herbage, but full winter production will be obtained only when an adequate layer of litter has been built up by conservative use in preceding years.

EFFECTS ON MATURE SPRING HERBAGE

The effects of degree of grazing on plant vigor that were readily observed during the winter were not so easily seen later in the season. Differences in grazing during the current season partially obscured the

TABLE 10.—*Average yield at maturity of herbage, by plant group and species, on slopes and swales for the period 1943–45, in three pastures grazed to different degrees from 1936 to 1945*

Plant group and species	Yield per grazable acre on slopes under—			Yield per grazable acre on swales under—		
	Close grazing (pasture 3)	Moderate to close grazing (pasture 1)	Light grazing (pasture 2)	Close grazing (pasture 3)	Moderate to close grazing (pasture 1)	Light grazing (pasture 2)
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Grasses:						
Soft chess	391	473	614	90	117	143
Foxtail fescue	165	234	218	1,053	887	657
Ripgut brome	7	13	67			
Mediterranean barley			2	211	1,172	1,949
Wild oat	6	9	35			
Other	33	54	48	94	55	96
Total	602	783	984	1,448	2,231	2,845
Grasslike plants:						
Toad rush				73	42	27
Perennial rushes			1	252	112	415
Total			1	325	154	442
Broadleaved plants:						
Filaree	316	601	583	222	321	246
Clovers	39	59	67	453	565	488
Other legumes	83	127	93	44	30	36
Smooth cats-ear	31	8	3	16	6	1
Windmill pink	36	12	14			
Pogogyne				109	12	7
Other	139	145	141	214	212	328
Total	644	952	901	1,058	1,146	1,106
All species	1,246	1,735	1,886	2,831	3,531	4,393

effects of past grazing use. The effects on yield and composition of the mature vegetation, however, were apparent from measurements made on the sample quadrats protected from current grazing (fig. 3, p. 6).

Mature herbage yield was lowest under close grazing (table 10), but differences in both productivity of the sites and degree of grazing contributed to the differences in yield between pastures. To illustrate, the productivity of swale soil was uniformly high in all pastures, so the low yield of swales in pasture *3*, in contrast to the swale yields in pastures *1* and *2*, was mainly the result of long-continued heavier grazing. The herbage yield there was only 64 percent of the yield under light grazing, which was most favorable to plant growth. On the other hand, the productivity of slope soils varied considerably, and as pasture *3* had more of the poorer sites than pasture *2* (fig. 12, p. 24), only a part of the reduction in yield on slopes was due to differences in degree of grazing.

That close grazing did reduce the yield from slopes, however, was quite evident. Several comparisons were made of small areas of similar sites across the fence line between pastures *2* and *3* during the years 1943–45; they indicated that the yield on slopes was reduced under close grazing and that the greatest reduction was on the most productive sites. Then, too, in 1944 a fenced plot about 66 feet square was placed astraddle of the fence line between pastures *2* and *3*. It was situated on a highly productive gentle-slope soil, in the only area of appreciable size where comparisons of similar sites could be made directly across the fence line. Yield was measured on three sample transects in each pasture. The average in pasture *2* was 3,624 pounds per acre; in pasture *3* it was 2,254 pounds — a reduction of 38 percent after 8 years of continued close grazing.

When the experiment ended in 1948, yields were measured for these two pastures as a whole. In pounds per grazable acre, herbage yields were 1,379 for slopes and 2,225 for swales in pasture *2*, and 837 for slopes and 1,224 for swales in pasture *3*. On slope sites the yield in the closely grazed pasture was 61 percent of that in the lightly grazed pasture, about the same as in 1943 and 1944. The yield of swale sites, however, was only 55 percent of that in the lightly grazed pasture, slightly lower than in the other years when yields were measured.

Moderate-to-close grazing (pasture *1*) had a measurable effect on total herbage yield only in the swales. The average yield on swale soil in pasture *1* was 80 percent of that in the lightly grazed pasture *2* (table 10). As was the case with pasture *3*, the reduction was caused mainly by heavier grazing. Unlike the case with slopes of pasture *3*, however, the lower yield on slope soil occurred mainly because pasture *1* had a lower proportion of the more productive site classes. Comparisons of yield on similar sites across the fence line between pastures *1* and *2* did not reveal any consistent differences that could be attributed to grazing treatment.

Because the effects of different degrees of grazing on total herbage production were different on each site, the combination of site classes within the pasture had to be considered in judging the extent that production was reduced by close grazing. To do this a "potential yield" for each of three pastures for 1943–45 was computed. First, the acreage of each site class in the pasture was multiplied by the estimated yield per surface acre of this site class (from table 4) to obtain its expected yield. Then the total potential yield for the pasture was obtained by adding the expected yield from each site class. This computed potential yield for pastures *1*, *2*, and *3*, and the measured total yield from sample quadrats in each pasture were:

	Yield	
Pasture and degree of grazing:	*Potential* (*pounds*)	*Measured* (*pounds*)
Pasture 2 (light)	394,276	395,293
Pasture 1 (moderate to close)	262,755	262,836
Pasture 3 (close)	187,815	142,264

For all sites combined, the closely grazed pasture *3* was producing only about three-fourths of its potential herbage production. Each of the other two pastures was yielding near its calculated potential. Although this method of analysis did not show all the differences between pastures, it did show that only in the closely grazed pasture was mature herbage production greatly influenced by degree of grazing.

In these studies high herbage yields were obtained on all sites under light grazing. But this degree of grazing left considerable unused herbage on the ground that might well be grazed by livestock. Grazing to a moderate degree will give efficient livestock production, and it will leave sufficient unused vegetation to maintain satisfactory soil-surface condition and sustained herbage production. It is clearly more efficient use of the available forage.

Although yields of each major plant species on slopes, such as soft chess, foxtail fescue, filaree, and clover, were less in the closely grazed pasture, the percentage of each major species in the herbaceous cover on slopes was not greatly different in pastures that had been grazed at different degrees (table 10). For example, the yield of soft chess in closely grazed pasture *3* was 391 pounds per acre as an average for 1943–45, and the yield in lightly grazed pasture *2* was 614 pounds, the percent of total yield being 31 and 33 respectively in pastures *3* and *2*. In pasture *1*, grazed at an intermediate degree, soft chess composed 27 percent. Foxtail fescue produced about 12 to 13 percent of the yield in each pasture. The differences in proportion of major species on slopes that did occur between pastures — for example, the greater percentage of filaree in pasture *1* — were present at the start of the experiment. Density estimates showed these differences occurred in 1936 and remained until 1943 when yield measurements were started. Measurements in 1948 showed that at the end of the experiment each of the major species composed about the same proportion of the herbage on slope soils in pasture *3* as in pasture *2*.

There were, however, noticeable differences in the abundance of species ordinarily dominant on swale soils. The closely grazed pasture had a much lower yield and a lower percentage of Mediterranean barley and a greater amount of foxtail fescue than the more lightly grazed pastures (table 10). This is not a desirable change because Mediterranean barley in the swales starts growing earlier and dries later than foxtail fescue. In the pasture grazed moderate to close, the amount of Mediterranean barley in the swales was considered adequate even though the yield and percentage were less than in the lightly grazed pasture.

Both yields and proportions of some minor species in the herbage were changed by degree of grazing on both slopes and swales. Two tall-growing grasses (slender oat and ripgut brome) increased slightly but gradually from 1936 to 1943 in lightly grazed pasture *2*. During the period 1943–45, the combined average yield of these species in that pasture was 102 pounds per acre of slope soil. Present in this amount, the two grasses are desirable additions to the winter forage.

Minor forbs of low forage value (particularly smooth cats-ear and windmill pink on slopes and pogogyne in swales) increased under close grazing (table 10). Smooth cats-ear increased in pasture *3* after 1941; by 1944 it made up 12 percent of the total plant density in that pasture. Because of the wide leaved, rosette form of smooth cats-ear (similar to the form of dandelion), its greater abundance under close grazing was very apparent even though it produced only 31 pounds per acre in pasture 3 as an average for 1943–45. The species was not conspicuous in the plant cover on the other pastures.

This study and widespread observations show that when grazing use is too light on California foothill range, tall-growing annual grasses crowd out filaree, clover, and other valuable low-growing plants. This change to a less desirable mixture is most rapid — and most complete — on fertile soils and with fairly high rainfall. On the experimental range virtual nonuse was required to bring about this undesirable increase in tall grasses; the change has been observed under light use on more productive soils. The conclusion is that even though complete protection from grazing for 1 or 2 years may be justified to restore a litter cover on a depleted range, continued very light grazing will not maintain a satisfactory forage plant mixture on annual-plant ranges.

As to herbage composition, then, a satisfactory mixture of annual plants was maintained under degrees of grazing ranging from a little closer than moderate to light. Under close grazing there was some increase in weedy species. Moderate grazing has maintained a satisfactory forage mixture and yield under all conditions that have been observed on foothill range.

Recognizing Satisfactory Range Utilization

The lack of pronounced changes in the composition of the herbaceous cover during the grazing-intensity studies emphasized that relying on the percentage of any annual-plant species as an indicator of grazing use has definite limitations on these granitic soils. Also, the plant mixture under each degree of grazing changed in species composition from year to year, as is typical on foothill ranges. The only conspicuous change in the mixture to indicate the effects of close grazing was the appearance of smooth cats-ear in pasture *3*. This species has also been observed growing on other relatively bare soils, including soils derived from sedimentary and igneous rocks, under a wide range of precipitation. Under these variable conditions, however, the lack of old litter on the soil surface was ample indication of close grazing without reference to composition of the plant mixture.

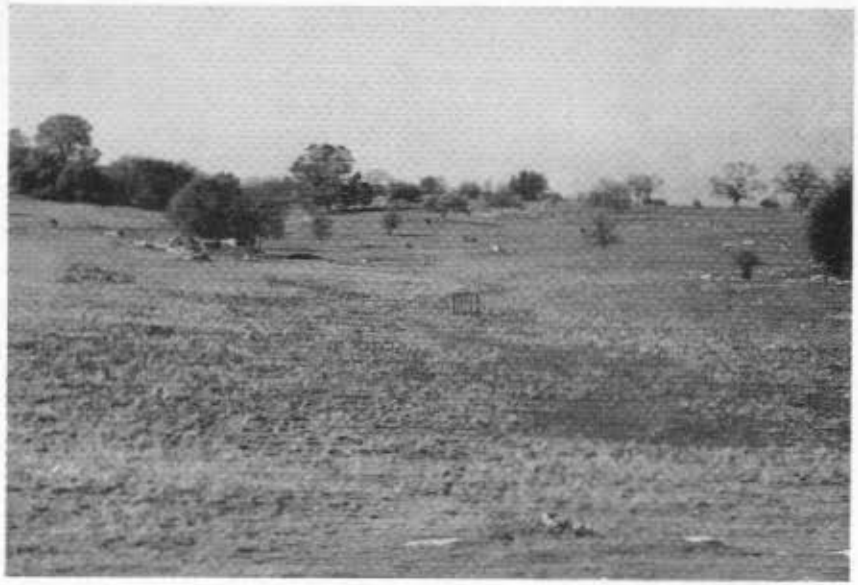
In fact, without reference to the condition of the soil, appraisal of annual-plant forage production on the range is both difficult and apt to be misleading. The level of herbage production cannot be judged merely by the general appearance of the plant cover in the spring. Yields, for example, were different between range pastures having about the same percentage of each dominant species in the cover. Similarly, differences in yields at plant maturity cannot be evaluated readily by general observations because the vegetation is grazed at different intensities during its growing season. The only exception to this principle that could be seen in the experiment was the noticeably reduced vigor of the forage plants in the swales of the most closely grazed pasture.

The studies at the San Joaquin Experimental Range have provided two useful guides to satisfactory utilization of annual-plant range. The first is a simple means for judging adequacy of old litter on the soil surface. The second is a practical method for rating the degree to which herbage of the current year has been utilized.

Judging Adequacy of Old Litter

Full production of forage depends upon an adequate layer of old decomposing litter lying flat on the soil surface. The extent and thickness

of the old litter, or condition of the soil surface, is best observed during the winter, when the beneficial effects of a protective soil covering are most apparent (fig. 17). The layer of litter is not so readily observable



F—40765

Figure 17.—Appearance of foothill range in January—the time of year when condition of the soil surface is best rated.

during the spring because it is more completely masked from view by vegetation. Then, too, differences in grazing during the preceding months affect plant height in the spring so as to obscure the effects of soil-surface condition on plant vigor. During the winter months, however, both the litter layer and the vigor of new plant growth can be considered as indicators of the productive condition of California foothill ranges.

A foothill range with unsatisfactory soil-surface condition has very little decomposing herbaceous material on the soil surface, and the sparse and stunted plant growth provides only a thin vegetative cover. Mineral soil is readily apparent during the winter months over all of the range in unsatisfactory condition. The hard, exposed soil surface inhibits the establishment and growth of annual-plant seedlings.

There are other indicators of unsatisfactory conditions. The mineral soil is commonly covered with a short growth of moss, lichen, or plants of similar appearance. The thin, black humic layer that ordinarily covers the mineral soil may disappear after the overlying herbaceous layer is lost. A miniature erosion pavement is often formed as a result of loss of organic matter and possibly of some fine mineral soil. After heavy rains, local movement of soil particles is evident in the tiny terraces that are formed even on gently rolling slopes, and particularly on south slopes.

Even so, accelerated erosion may not be readily apparent on foothill ranges with unsatisfactory soil-surface condition. Close examination may reveal slow insidious movement of the soil, as in closely grazed pasture *3*,

which had more small spots with broken soil surfaces, and more unstable soil in drainage channels and slopes than the more lightly grazed pastures. Yet in general this pasture showed no conspicuous evidences of accelerated erosion.

A supplementary study on nine 1/40-acre plots found no significant surface runoff of precipitation or erosion from either close grazing, moderate grazing, or nonuse (*10*) although unsatisfactory soil-surface conditions with local movement of soil particles developed on the closely grazed plots. The infiltration capacity of the soil was significantly reduced as compared to the moderately grazed plots, and very significantly reduced as compared to the ungrazed plots. Still, the infiltration capacity of the soil on all plots remained high enough to absorb the rainfall that occurred during the study. This finding helps explain the relative scarcity of conspicuous soil erosion on rolling foothill lands closely similar to the San Joaquin Experimental Range.

The usual patterns of precipitation and plant growth in this locality also helps the explanation. Characteristically, the first fall rains are fairly gentle. Germinating and growing quickly, dense stands of annual plants, particularly the flat rosettes of filaree, form a protective cover over much of the soil surface. Winter rains are seldom torrential. Consequently, under the usual rainfall pattern the porous soils of granitic origin absorb most of the precipitation as it falls. Where soils are less permeable or the annual-plant cover is scant, however, the hazards of runoff and erosion are greater.

A range unit with satisfactory soil-surface condition will have a layer of old litter on most sites in all parts of the area. In general, the moist ground in winter will feel soft and springy under foot. The thin layer of decomposing herbaceous material and the relatively thick, even, and vigorous growth of green plants will leave almost no bare soil apparent to observers walking or riding over the range during the winter. These conditions will be found in all but the rare winters when weather conditions are so severe that plant growth is very sparse regardless of past utilization.

As explained previously, moderate grazing will maintain a satisfactory layer of litter over most of a range unit. Under this degree of utilization the litter may be thin on limited areas of livestock concentration, such as wet swale bottoms, but the soil surface on these sites will be stable, though somewhat compacted. On ranges with an unsatisfactory layer of old litter, a lighter degree of grazing will often be needed. How long this lighter grazing must be continued to build up the litter on ranges that have been closely grazed for a number of years is not known. It has been observed, however, that where the reduction in litter is limited, satisfactory conditions may be restored by light grazing during a single year of heavy forage growth.

RATING USE OF EACH YEAR'S HERBAGE

The degree of grazing of the current year is rated from the amount of unused herbage of that year. On foothill ranges utilization is best rated at the time of the first fall rains to determine how much plant material is left to provide dry roughage and promote new green growth during the fall and winter.

The basic set of utilization standards (*9*, *5*) consists of three photographs illustrating light, moderate, and close utilization, with descriptions of the kind of grazing typical of each degree of utilization. A numerical index scale (*6*) was also developed to simplify recording of intermediate degrees, but for practical ranch operation the three photographs are sufficient.

By comparing the appearance of the grazed range with the three photographs, the degree of grazing obtained that year can be readily recognized. Two criteria should guide the ratings: (1) the pattern of grazing over the different sites, and (2) the extent to which the soil surface and small ground objects are masked from view by ungrazed herbage. The first criterion is usually adequate for rating the degree of grazing, but attention to the second helps evaluate the amount of herbage left to protect the soil.

Under light utilization (fig. 18), grazing appears uniform over the slopes; most spots are lightly cropped, but a few spots are cropped as closely as 2-inch stubble height. The swale bottoms (wet-swale sites) are closely cropped, often to a stubble height of less than 1 inch; swale margins (dry-swale sites) show little use or a patchy use (fig. 19). Low-hanging shrub canopies, fallen branches, and the edges of rocks are mostly obscured by ungrazed herbage. The soil surface and small objects on the ground are almost completely masked from view at distances of 20 feet or more. The landscape has a yellowish or straw-colored cast from ungrazed grass at the time of the first fall rains.

Under close utilization (fig. 20) grazing appears very uniform; few lightly grazed tufts above 2-inch stubble height remain. Both the swale bottoms (wet-swale sites) and the swale margins (dry-swale sites) are uniformly grazed. Low-hanging shrub canopies, fallen branches, and the edges of rocks stand out in bold relief, and the soil surface and small objects on the ground are everywhere visible through the short stubble. There is generally a brownish cast over the slopes from ungrazed filaree and other broadleaved herbs at the time of the first fall rains.

Under moderate utilization (fig. 21) grazing appears very patchy; lightly cropped spots are intermixed with spots cropped to about 2-inch stubble height. The swale bottoms (wet-swale sites) are cropped to less than 1-inch stubble height; swale margins (dry-swale sites) show patchy use. Low-hanging shrub canopies, fallen branches, and the edges of rocks are partially obscured by ungrazed herbage. The soil surface and small objects on the ground are partially masked from view at distances of 20 feet or more. The yellowish cast of ungrazed grass is dulled in the closely grazed spots by the brownish undertones of dry broadleaved herbs at the time of the first fall rains.

These photographic standards for recognizing and rating degree of grazing of annual-plant vegetation, evolved by group effort of the range staff, were tested in the experimental pastures and have proved adaptable for use on almost all kinds of California foothill range.

SUMMARY

Annual plants, which dominate California foothill ranges, grow from fall until spring. Growth starts with the first effective rains (0.5 to 1.0 inch), usually in October, but is limited during the fall and winter by intervals of low temperature or insufficient precipitation. Plants grow

F-447499

FIGURE 18.—Light utilization. This degree of grazing on California annual-plant range maintains a good soil condition, early forage growth during the winter, and full yields of a good plant mixture in the spring. Under very light grazing on some ranges, however, wild oat or ripgut brome may increase to an undesirable amount. While favorable for plant growth, light grazing leaves herbage that could be used efficiently by cattle.

F-460562

FIGURE 19.—Pattern of swale utilization in lightly grazed range. The clovers and rushes in the rather narrow swale bottom (wet swale) have been cropped to less than 1-inch stubble height; the heavy growth of grass (principally Mediterranean barley) at the margin of the swale (dry swale) shows patchy use.

F-447500

FIGURE 20.—Close utilization. This uniformly close utilization of annual-plant vegetation reduces the litter layer on the soil surface; conditions become distinctly unfavorable to plant growth. Growth during the winter is retarded and total yields in the spring are reduced, particularly on the very closely utilized bottom lands. The percentage of the dominant species in the plant cover may not be greatly changed, except in the swales; but minor weedy species increase on all sites. This degree of grazing is too close for efficient cattle production.

F-447498

FIGURE 21.—Moderate utilization. This patchy use of annual-plant vegetation maintains satisfactory soil conditions and a good plant mixture, without evidence of deterioration in either. Winter growth of forage and total yields in the spring are satisfactory although not as great as under lighter grazing. This is an efficient degree of utilization that provides satisfactory cattle production without waste of herbage.

rapidly from February or March until the rains cease in April or May. Then they mature rapidly and are dry during the hot, dry summers.

Thus, annual-plant range has three rather distinct forage periods: (1) inadequate green forage during part of the fall and most of the winter; (2) ample green forage during the spring; and (3) dry forage during the summer and early fall.

Fitting ranch operation to forage growth.—The range is grazed in other periods than during the four spring months when there ordinarily is an adequate, well-balanced forage supply. The foothills are the chief source of grazing for cattle in California during most of the fall and winter, and in many operations cattle are kept yearlong on foothill range. Efficiency in use of the range can be increased by feeding of supplements during the periods when the forage is deficient in quantity or quality and by adopting management practices aimed at increasing the length of the green-forage period.

The length of the critical forage period of fall and winter and the needs for supplemental feeds usually cannot be predicted far in advance. The average termination date for supplemental feeding, according to the study, was near February 1; however, in years when rains sufficient to start forage growth were delayed until mid-November, feeding was needed until late February or early March.

The length of the adequate green-forage period is variable. For example, this period at the experimental range varied in length from 72 to 176 days, with an average of 127 days for 14 years.

Most of the herbage is usually dry in June; occasionally in May. The dry roughage consumed, mainly annual grasses, provides sufficient energy but a supplemental feed is needed to provide protein. Bur-clover, perennial bunchgrasses, or other plants, may serve as a partial supplement during the summer on some ranges.

A management objective is to lengthen the period during which foothill ranges provide well-balanced forage. Cultural practices for this purpose are being developed for some soil and climatic conditions. Such practices include reseeding or fertilization, to provide earlier green forage in the winter and improved forage during the summer. Forage will be adequate over a longer period if sufficient dry vegetation is left each year to promote early plant growth and if each kind of range is grazed at a time when it produces especially needed green forage. Deferring grazing of some range units, or portions of a single unit, until the end of the spring growth period will allow cattle to select an improved diet at that time and should delay the date when supplements are needed. Deferring areas with considerable acreage of swales should be most effective.

Adjusting ranch stocking to herbage production.—As an aid in stocking, herbage production and grazing capacity can be estimated by a simple classification of the different range sites. For example, in six experimental pastures the grazing capacities estimated from classification of the sites agreed closely with actual grazing results. The site classes were recognized by characteristics of soil, topography, and waste area. This method of land classification can be used in appraisal of California foothill range.

Swales are the most productive of the site classes. In acres required per animal-unit month, the grazing capacity of each site class in the experimental pastures is as follows: swales, 0.5 to 0.7; gentle slopes bordering the swales, 0.8 to 1.1; rolling slopes with few rock outcrops, trees, or shrubs, 1.25 to 1.75; rolling to steep slopes with numerous rock outcrops, trees, or shrubs, 2.0 to 3.0; and steep slopes with numerous rock outcrops, trees, or shrubs, 3.0 to 5.0. The lowest grazing capacity was found on steep north slopes with a heavy canopy of trees and shrubs.

Ranch stocking must also consider the characteristic yearly fluctuations in herbage production. On granitic soils at the experimental range, in the 2 years with near-average total precipitation (16 to 20 inches), herbage yields were average or greater. In wet years (more than 20 inches of precipitation), total yields were somewhat similar to those in average years; most of the excess moisture was lost through seepage.

In dry years (12 to 16 inches of precipitation), rapid plant growth during a short interval of favorable weather in the spring produced yields that were only about 9 to 27 percent below the estimated 13-year average of 1,640 pounds per acre. The effects of the occasional extreme drought year (with less than 12 inches total precipitation) were not encountered during the studies.

Fluctuations in the quantity of forage make advisable some adjustments in livestock numbers nearly every year. The extent of needed adjustments can be judged in late spring after most of the plant growth for the year is complete. Changes in number of livestock will depend on the average stocking and type of operation at each ranch.

Adjustments can be made by several measures in a mixed breeding-cow and feeder operation. Enough cows and replacements can be carried to utilize the herbage produced in dry years. The extra herbage in years of average production is utilized by weaners. In years of above-average production the increased yield can either be utilized by bringing in outside animals or be left on the ground to replace any litter that may be lost during dry years. This type of operation will permit the necessary adjustments in livestock numbers in all except the occasional years of extremely low forage production.

Most fluctuations in individual forage species exert relatively minor effects on range stocking. The amount of grass in the plant mixture, however, is of special importance on ranges grazed from summer until winter. In years of very low grass production, stocking should be reduced from average or hay should be provided in addition to the short supply of dry grass.

A reserve of range forage cannot be carried over from year to year because dry herbage of annual plants is ruined by leaching during the winter. It appears desirable and feasible, therefore, to keep a reserve of hay above usual yearly needs.

Selecting most efficient degree of grazing.—Overstocking foothill range lowers efficiency of production from a cattle breeding herd, according to the conclusion of animal husbandmen of the University of California, in charge of the livestock phases of the cooperative grazing-intensity experiment. The objectives of efficient production — high calf crops and optimum weaning weights — could not be met in the pasture under heavy stocking for about 6 months (February to August), even with moderate stocking for the remainder of the year. In the pasture stocked slightly heavier than moderate, production was also reduced for unsupplemented cows but was not lowered for cows fed supplements during the 6 months they were out of the grazing-intensity pastures. Cattle produc-

tion was satisfactory in all four of the experimental pastures grazed from moderate to light from February to August.

Close grazing was clearly inefficient from the standpoint of forage production also. Plant growth was always short during the winter on range closely grazed during the preceding year, and in late winter forage became adequate about 3 weeks later than on range grazed moderately or lightly. Total herbage yield was also lower at plant maturity, particularly on the very heavily grazed bottom lands, the most productive part of the range. Yield of each major species on slopes was lower, but each composed about the same proportion of the total yield as under moderate or light grazing. There was some increase in weedy species of low value under close grazing. Most important in the long run, close grazing did not maintain sufficient litter on the soil surface to promote full forage production year after year, and it produced other indications of soil deterioration.

Light grazing resulted in the best soil-surface conditions and winter growth of forage. It also maintained highest production of soft chess, filaree, clovers, and other valuable forage species. But it left on the ground a considerable bulk of herbage that could have been grazed to increase cattle production.

An intermediate degree of grazing, between close and light, was the most efficient. It maintained a satisfactory litter cover without apparent soil deterioration. Winter growth of forage was also satisfactory, and there was no significant decrease in amount of desirable forage species. Keeping to a moderate degree of grazing on the average, with all practicable flexibility in numbers of livestock, appears feasible as a means of obtaining efficient production from the fluctuating quantity of forage on foothill ranges.

Condition of the soil surface on annual-plant range is best judged during the winter. Where the layer of old herbaceous material is nearly absent or of spotty occurrence over most of the range at this time of year, the mineral soil will be readily apparent through a thin cover of new plants. Conversely, under satisfactory conditions a fairly continuous thin layer of litter and a thick carpet of vigorous new plants will leave almost no bare soil apparent on most of the range. Accordingly, the extent of herbaceous litter on the soil surface and the vigor of plant growth during the winter are dependable guides to maintenance of satisfactory production from the present cover of annual plants.

Photographic standards for judging degree of grazing of annual-plant vegetation, developed and tested during the experiments, have been used successfully in rating utilization on almost all kinds of California foothill range.

COMMON AND BOTANICAL NAMES OF SPECIES MENTIONED

Common name	*Botanical name*
Alfileria, redstem filaree	*Erodium cicutarium* (L.) L'Her.
Barley, Mediterranean	*Hordeum gussonianum* Parl.
Bluegrass, pine	*Poa scabrella* (Thurb.) Benth.
Brome, ripgut	*Bromus rigidus* Roth.
Bur-clover, California	*Medicago hispida* Gaertn.
Cats-ear, smooth	*Hypochoeris glabra* L.
Chess, soft	*Bromus mollis* L.

Clovers	*Trifolium* spp.
Clover, littlehead	*Trifolium microcephalum* Pursh
Clover, whitetip	*Trifolium variegatum* Nutt.
Fescue, foxtail	*Festuca megalura* Nutt.
Fiddleneck, Douglas	*Amsinckia douglasiana* DC.
Godetias	*Godetia* spp.
Heronbill, big; broadleaf filaree	*Erodium botrys* Bertol.; *E. botrys* Bertol. f. *montanum* Brumhard
Oat, slender	*Avena barbata* Brot.
Oat, wild	*Avena fatua* L.
Pogogynes	*Pogogyne* spp.
Popcorn-flower	*Plagiobothrys nothofolvus* A. Gray
Rush, slimpod	*Juncus oxymeris* Engelm.
Rush, toad	*Juncus bufonius* L.
Silene, French ("windmill pink")	*Silene gallica* L.
Spanish-clover	*Lotus americanus* (Nutt.) Bisch.
Spikesedge, common	*Eleocharis palustris* (L.) Roem. & Schult.
Stipas; needlegrasses	*Stipa* spp.
Sudangrass	*Sorghum sudanense* (Piper) Stapf. Hitchc.
Yellow-tarweed; hemizonia	*Hemizonia virgata* A. Gray

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