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A REVIEW OF RESEARCH RELATED TO DEVELOPMENT OF GRAZING SYSTEMS ON NATIVE RANGES OF THE WESTERN UNITED STATES

by

Carlton H. Herbel[1/]

1/ Range Scientist, Jornada Experimental Range, Plant Science Research Division, Agricultural Research Service, U. S. Department of Agriculture, Las Cruces, New Mexico.

Foreward

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Abstract

Research studies on grazing systems on native range in the 17 contiguous Western States are reviewed. Yearlong-continuous grazing was superior to seasonal grazing on the California annual rangelands. There was only limited success with any grazing scheme other than continuous on rangelands grazed only for a part of the year (seasonal ranges). The deferred-rotation system at Sonora, Texas has resulted in sufficient range improvement to permit a 33% increase in stocking as compared to continuous grazing.

Grazing research should include studies on the entire ecosystem, not just a few of the major species. Livestock performance per unit area may be more important in evaluating grazing studies than individual animal performance. Grazing studies should be flexible to permit consideration of fluctuation in plant attributes due to variations in weather conditions. Much additional study is needed to develop the most productive grazing scheme for each range operation.

Key words: grazing management, grazing systems, continuous grazing, deferred-rotation grazing, rest-rotation grazing, flexible herd management.

Table of Contents

Introduction

This review is concerned primarily with research on grazing systems on native ranges in the 17 Western States. Basic information on climate and vegetation is presented so that results may be interpolated as widely as possible. To keep this paper within space limitations, only studies concerned with grazing systems are considered. Generally, this means that some scheme of livestock manipulation other than continuous grazing was studied. Short-term experiments generally were not considered because the author felt that it takes several years for the treatments to have conclusive effects on vegetation and livestock performance. Other management strategies not considered in this paper are calving or lambing dates, levels of supplemental feeding, methods of obtaining better livestock distribution, and range improvements. Studies are reviewed by major vegetation regions.

Grazing terminology follows that of the American Society of Range Management (37). Deferred-rotation grazing is to leave a range unit, or units, ungrazed for part of a year and to rotate the deferment among range units in succeeding years. Rest-rotation grazing is to leave a range unit, or units, ungrazed for at least one year and to rotate the deferment from grazing among range units in succeeding years.

California Annual Rangeland

In the California valleys and foothills, annual grasses dominate the vegetation. Before white man settled here, the area was probably dominated by perennial grasses, such as Stipa cernua (California needlegrass) Poa scabrella (pine bluegrass), Melica imperfecta (coastrange melic), Sitanion hystrix (bottlebrush squirreltail), and Elymus triticoides (creeping wildrye), (52). Because of fire and heavy grazing, the area is now dominated by the annuals, Avena fatua (wild oat), Bromus hordeaceus, B. mollis (soft brome), B. rubens (foxtail brome), B. rigidus (ripgut brome), B. tectorum (cheatgrass), Hordeum murinum (mouse barley), H. pusillum (little barley), Festuca myuros (rattail fescue), and F. megalura (foxtail fescue). While forbs are not abundant on this type, they are important to the grazing animal. The most important are Medicago hispida (California burclover), Erodium cicutarium (alfileria), and E. botrys (big heronbill). On foothill ranges an open savanna of Pinus sp. (pines), Quercus sp. (oaks), and Ceanothus sp. forms an overstory over the annual grass type (50).

At Hopland, California, about 160 km (100 miles) north of San Francisco and 91 cm (36 in.) average annual precipitation, the annual plants germinate in the fall, grow slowly until early spring, grow rapidly for about six weeks, and are usually mature and dry by June 1 (13). The size of the forage crop is related to weather conditions and may differ over 100% between years. The species composition also varies widely from year to year. The various species mature at different times during the spring. In planning a grazing strategy, several points are important; the short and variable time when species mature, variable maturation dates of desirable and undesirable plants, a wide difference in forage quality as related to available moisture and stage of maturity, and fluctuations in stage of maturity due to site (13).

Light utilization by livestock results in an increase of the tall annual grasses and a decrease of the desirable forbs. Heavy grazing use in the fall reduces plant growth in the winter (4). Heady (42) showed that mulch in excess of about 784 kg/ha (700 lb/a) favored the tallest grasses. With no mulch the vegetation was composed of undesirable

forbs and grasses, and the herbage yields were reduced to about half of the mulch plots. From these studies, Heady (13) concluded that degree of utilization is important in determining the characteristics of the next crop.

Hervey (17) changed the species composition with burning treatments and Heady (13) with seeding and mulch manipulation. There seems little doubt that composition of the annual type can be changed, but the results are temporary and last only as long as the treatment is maintained.

Studies at the San Joaquin Experimental Range in central California (average annual precipitation of 46 cm, 18 in.) showed a consistent advantage of yearlong-continuous grazing over seasonal grazing in breeding cow performance and calf weaning weights. The best balance of seasonally preferred plant species occurred on ranges grazed continuously yearlong (8). Similar results were obtained with sheep at Hopland. One range unit was divided into three divisions. One division was grazed in the early part of the growing season, one in the middle, and the third near the end of the growing season. The stocking period was rotated on an annual basis so that each division was grazed at each time only once in three years. The sheep were allowed to graze all three divisions during the dry season. The average weaning weight of lambs has been consistently higher in the range unit with yearlong-continuous grazing. The grazing treatments did not affect species composition, density, or herbage production (13).

The Pacific Bunchgrass Region

A study conducted at the Burgess Spring Experimental Range in northeastern California during 1936-51 led to the design of a rest-rotation grazing system. The region is mountainous and of volcanic origin. Numerous lava flows and a few high peaks top an extensive plateau with an elevation that ranges from 1068 to 2440 m (3500-8000 ft.). Interspersed among the mountains are many plains and valleys. Some of the valleys are closed or poorly drained. The region is wet and cold in the winter, and warm and dry in the summer. These ranges are grazed from late May to late October (19).

Hormay and Talbot (19) reported that grassland, sagebrush, juniper, and pine types occupy 63% of the total area at Burgess Spring and furnished most of the forage used by livestock. The remaining area, of little use to livestock, was dominated by trees and shrubs. On 97% of the range, the primary species are bunchgrasses and other perennial plants that reproduce from seed. The grassland type is made up of wet meadow, closed basin, drained basin, and terrace sites. The wet meadow sites in good condition are dominated by Deschampsia caespitosa (tufted hairgrass), Poa nevadensis (Nevada bluegrass), P. pratensis (Kentucky bluegrass), Carex pachystachya (chamisso sedge), C. paucicostata (sedge), Sidalcea oregana (Oregon checkermallow), Potentilla gracilis (Northwest cinquefoil), and Trifolium longipes (longstalk clover). Deteriorated sites are invaded by Lomatium leptocarpum (bicolor biscuitroot), Ranunculus alismaefolius (plantainleaf buttercup), R. occidentalis (western buttercup), and shrubby Artemisia sp. (sagebrush). The closed basin sites are inundated for varying periods in the spring and summer. They are dominated by Carex sp. (sedges), Eleocharis palustris (common spikesedge), Juncus balticus (Baltic rush), Sagittaria latifolia (common arrowhead) and Arnica foliosa var. incana (hoaryleaf arnica). The drained basin sites are similar to the closed basin sites, except they have some drainage. Desirable bunchgrasses, such as Deschampsia (hairgrass), Poa (bluegrass), Hordeum nodosum (meadow barley), and Sitanion hystrix (bottlebrush squirreltail), grow together with the sedges and rushes. Carex exserta (shorthair sedge) dominated the terrace sites.

The sagebrush type has sites with Artemisia cana (silver sagebrush), A. arbuscula (low sagebrush), and A. tridentata (big sagebrush). Associated with these shrubs are Poa, Sitanion, Koeleria cristata (prairie junegrass), Festuca idahoensis (Idaho fescue), Wyethia mollis (woolly wyethia), Balsamorhiza sagittata (arrowleaf balsamroot), and Aplopappus bloomeri (rabbitbrush goldenweed).

The pine type consists mainly of Pinus ponderosa (ponderosa pine) and P. jeffreyi (Jeffrey pine) in relatively open stands. Associated with the Pinus sp. (pines) are good stands of Festuca idahoensis (Idaho fescue), Stipa sp., Poa secunda (sandberg bluegrass), Carex rossi (Ross sedge), Wyethia mollis (woolly wyethia), Lupinus laxiflorus

calcaratus (longspur lupine), and Purshia tridentata (antelope bitterbrush), (19).

Cattle grazed season-long in three fenced units; one was representative of cutover pine type, and two were representative of grassland types. The effect of cattle grazing on the vegetation was measured only in the timber type. Species preferences of cattle were recorded for three years. Cattle weights were recorded at biweekly intervals during eight grazing seasons on the pine type and during five seasons on the grassland types.

Annual precipitation during 1935-54 averaged 46 cm (18 in.) at Blacks Mountain Experimental Forest, 19 km (12 miles) from Burgess Spring. On the average, 74% of the total occurred October 1-April 1, primarily as snow; 21% occurred April 1-July 1; and 5% during July 1-October 1. The snowpack averaged 46 cm (18 in.). Average daily temperatures ranged from -5 C (23 F) in January to 14 C (57 F) in July (19).

The average seasonal development of herbaceous vegetation in the pine type was illustrated with Festuca idahoensis (Idaho fescue). Growth began about April 1 after the snowpack melted and ended with seed ripening in early August. Half the seasonal yield of herbage was produced by the end of May and 90% by the end of June. The various plant species developed at different rates during the growing season, some earlier and some later than Festuca. The growth and development of individual species also varied as much as 33 days from year to year. Herbage production varied from 51% below average to 43% above average during the study periods. Flower stalk production varied from year to year. Vegetation development in the grassland type followed the same general trend as that in the pine type except that the plants grew more slowly at the outset. However, an appreciable amount of highly nutritious herbage was available for grazing early in the season. Herbage production in the grassland type was more variable than on the pine type (19).

In both types, cattle grazed certain plants and certain areas more consistently than others. This resulted in a very uneven utilization of the range. The pattern of use was similar from year to year. Nearly all of the plant species in the pine type were grazed. However, 12 species

supplied 95% of the forage consumed by cattle. The degree of use of a species was affected by its abundance, distribution, and the seasonal preference of the cattle.

Clipping Festuca plants 3.8 cm (1-1/2 in.) above ground surface at any time of the season reduced herbage production, basal cover, flower stalks, and height. The effects were more detrimental during periods of rapid growth. Basal area of Festuca plants was reduced about 50% of the year following clipping, even when clipped 50 days following seed ripening. Four years of rest following four years of clipping at the milk stage resulted in little or no recovery of basal area. No flower stalks were produced in the first year of rest, but good production was obtained in subsequent years (19).

The pine type was grazed eight seasons during 1936-46. Use of Festuca averaged only 32% (it was 65% in 1945 and 80% in 1946). However, in 1946 grazed areas had fewer, smaller, and less productive Festuca plants than comparable ungrazed plots.

Yearling heifers grazed the pine and grassland types at Burgess Spring during 1944-48. The average grazing season began May 23 and ended October 21. Gains continued until early October for both groups. The highest weight gains were obtained during the period of rapid Festuca growth, from the prebloom to the mature stages.

Hormay and Talbot (19) concluded that under continuous seasonal grazing, the desirable plants are destroyed by selective grazing. Selective grazing cannot be prevented by adjusting the stocking rate but its harmful effects can be reduced by not grazing the range at appropriate intervals. The improvement of bunchgrass ranges depends on restoring the vigor of desirable plants so that there can be an abundant reproduction of these plants. To obtain reproduction it is necessary to rest the range from grazing for three specific reasons: (1) to restore plant vigor, (2) to insure seed development, and (3) to insure seedling establishment. Based on the information developed at Burgess Spring, Hormay and Talbot proposed a rest-rotation grazing system with the following steps: (1) graze the range unit for maximum livestock production,

(2) rest the range unit until plant vigor is restored, (3) rest the range unit until seed ripens and then graze for maximum livestock production, and (4) rest the range unit until new plants are established. The time required for each of these steps is not fixed but rather depends on the growth requirements of the key species of the range.

The vegetation in the rested units constitutes a forage reserve that can be used in drought years. Range improvements, such as seeding and control of noxious plants, may be scheduled during rest periods. Stocking is based on the utilization of all forage species. Fairly heavy stocking forces greater use of the less palatable forage species and the less accessible grazing areas (19).

A trial of rest-rotation grazing was initiated on the Harvey Valley allotment of the Lassen National Forest in 1954 (18). That area has similar soils, vegetation, and climate as Burgess Spring. Good stands of Bromus inermis (smooth brome), Agropyron desertorum (crested wheatgrass), and A. intermedium (intermediate wheatgrass) were established by seeding and the native grass stands were improved on some areas by controlling the shrubby Artemisia sp. (sagebrush).

There was a drought in Harvey Valley in 1959-61. The precipitation from July 1, 1960 to June 30, 1961 was 27 cm (11 in.) or 59% of average. Ratliff and Rader (39) concluded that forage production was adequate for normal grazing and that the cattle made good gains. However, the stocking in 1961 was 81% of the rated capacity.

Ratliff (38) reported that preferential grazing occurred under rest-rotation grazing at Harvey Valley. He used a combination of fencing, salting, water development, and riding to obtain more even distribution of grazing.

Ratliff and Reppert (40) summarizing results of the grazing study at Harvey Valley after 13 years, concluded that the performance of individual animals was about the same with rest-rotation grazing as with season-long grazing. They indicated that they still have a long way to go to double the capacity of the Harvey Valley allotment. In 1967 the livestock permittee was granted a length of grazing season increase with

no change in permitted numbers. When the trial at Harvey Valley was established, it was expected that the grazing capacity would be doubled in 20 years (18).

Sampson (44, 45) studied the effects of grazing and clipping on the bunchgrass ranges in the Wallowa Mountains of northeastern Oregon. Festuca viridula (green fescue) furnishes a large part of the forage at elevations of 2000 to 2440 m (6500-8000 ft.). Sampson found that deferring grazing until seed ripening provided range improvement. He considered it important to graze after seed ripening to avoid loss of forage through nonuse and to assist reproduction by trampling in the seed. The deferred grazing was rotated among range units so that each unit was deferred every three to five years.

Conifer Forest Ranges

Pinus ponderosa (ponderosa pine) forests are the most important forest grazing area in the Western United States. In Washington and Oregon, approximately ten million ha (25 million acres) of forest grazing land furnishes summer forage for 250,000 cattle and nearly as many sheep (47). Effects of cattle grazing on herbage production were investigated 1954-66 on the Starkey Experimental Forest and Range near La Grande, Oregon. Elevations vary from 1000 to 1500 m (3300-4900 ft.). Annual precipitation averages 54 cm (21 in.). Summer is the driest season. Open stands of Pinus (pines) and Pseudotsuga menziesii (common douglasfir) have an understory of Carex geyeri (elk sedge), Calamagrostis rubescens (pinegrass), and a variety of forbs. Principal species in intermingled grassland openings are Agropyron spicatum (bearded bluebunch wheatgrass), Poa secunda (Sandberg bluegrass), and Danthonia unispicata (onespike danthonia).

Deferred-rotation and season-long grazing at three intensities were compared (47). The grazing period was about June 15 to October 15. Under deferred-rotation, the cattle were placed in half of the range for two months and then moved to the other half. The following year, the early and late pattern was reversed. Systems of grazing did not cause significant difference in production of any major plant group or species in the grassland type. In the forest type, heavy stocking reduced production

of Carex from 455 kg/ha (405 lb/a) to 227 kg/ha (203 lb/a). Carex was very susceptible to grazing. It retained its production during the 12-year period only with light stocking in the deferred-rotation system. There was essentially no difference in reduction of Carex production under deferred-rotation and season-long grazing with moderate and heavy stocking. Skovlin and Harris (47) suggested that herbaceous forest vegetation may have been adversely affected by general reduction in May-July precipitation from 15 cm (6 in.) in 1957 to less than 10 cm (4 in.) in 1966. Initial intensive management practices such as fencing, water development, and salting were effective in increasing cattle use in the forest type (11).

Skovlin (46) studied cow and calf weight trends in 1961 on the Starkey. The summer precipitation in 1961 was 70% of average. Skovlin (46) concluded that cows and calves are not able to maintain summer gains into the fall months during dry years. The amount and distribution of summer precipitation influences the time and rate that these weights decline. To avoid late summer and fall losses during dry years, the rancher should consider marketing his cattle early, providing supplemental feed, or moving the cattle to more nutritious range (46).

Smith et al. (48) compared moderate rotation, heavy rotation, and moderate season-long grazing in the Big Horn Mountains near Burgess Junction, Wyoming. The elevation is 2440 m (8000 ft.). The major forage species is Festuca idahoensis (Idaho fescue), but there is a variety of herbaceous and browse species. The average annual precipitation is 79 cm (31 in.); about 40% occurs April-June. Frost and snow may occur at any time. The grazing season is June 20-September 20. In the rotation units, steers were moved among the three divisions at about monthly intervals. The rotation was such that the same division was not grazed at the same time in consecutive years. The study covered the 1959-64 period. There was no significant difference in daily gain between moderately stocked units (about 0.95 kg, 2.1 lb). The daily gain on the heavy roation unit averaged 0.82 kg (1.8 lb). On soils of granitic origin, production of Festuca was maintained equally well on the three treatments. On soils derived from sedimentary deposits, the

abundance of Festuca declined within the heavy rotation unit. Cover and production of Festuca was best maintained with season-long grazing. However, it generally was not utilized until mid-August on the season-long unit whereas it was moderately utilized as early as late July in the rotation units. In that area Festuca makes little regrowth in the year it is grazed regardless of the time or amount of herbage removal (48). During 1961-63, utilization of Festuca averaged from 20% to 43% for the 3 grazing treatments. However, production declined during the study even though precipitation during the latter part of the study was above average. From the evidence presented, it appears that Festuca is not well adapted to grazing at the rate termed moderate at Burgess Junction.

Intermountain Shrub Region

Season-long grazing was compared with deferred-rotation grazing at the Squaw-Butte Experiment Station in southeastern Oregon during 1938-48 (23). The elevation is 1375 m, and the average annual precipitation is 30 cm (12 in.). Two-thirds of the precipitation occurs as snow in the winter and the remainder as rain during the spring. The major plant species are Artemisia tridentata (big sagebrush), Agropyron spicatum (bearded bluebunch wheatgrass), Festuca idahoensis (Idaho fescue), and Poa secunda (Sandberg bluegrass). Three range units were grazed with cows under a six-year rotation system that included two consecutive years of late spring use (May 1-June 20), followed by one year of early summer grazing (June 20-August 10), two years of late summer grazing (August 10-October 1), and one year of early summer grazing. The growing season usually begins April 1 and ends June 30. A fourth range unit was grazed with cows season-long, approximately May 1 to October 1. The stocking rate was approximately the same under both systems and each year. The cows on the season-long range had an average annual advantage in weight gain of 4.1 kg (9 lb) over those on the deferred-rotation range (23).

Grazing was more evenly distributed under deferred-rotation than under season-long grazing. Even though the season-long range unit was utilized more heavily than the units under deferred-rotation, vegetation density increased 22% under season-long grazing and 20% on the deferred-rotation units. The desirable grasses increased more than twice as much

under season-long grazing as under deferred-rotation grazing. However, most of this increase was in the lightly grazed area in the season-long unit. Hyder and Sawyer (23) concluded that concentrating the cattle on a single unit of the three-unit deferred-rotation system during the growing season for two consecutive years seriously reduced plant vigor. Hyder (22) recognized that the heavy grazing pressure during the growing season placed this deferred-rotation system at a disadvantage.

Fall grazing with sheep was compared with fall plus spring grazing from 1923 to 1948 at the U. S. Sheep Experiment Station near Dubois, Idaho (34). The dominant plant species are Artemisia tripartita (three-tip sagebrush), Agropyron spicatum (bearded bluebunch wheatgrass), and Balsamorhiza sagittata (arrowleaf balsamroot). The average annual precipitation is 27 cm (11 in.). The stocking rate of the fall grazed range unit was 105 sheep days per hectare (42/a). Another range unit was stocked at the rate of 47 sheep days per hectare (19/a) in the spring and 25 sheep days (10/a) in the fall. The two units had similar species composition and production at the beginning of the study. By 1948 the unit grazed only in the fall had a composition of 24% grasses, 29% forbs, and 47% shrubs while the unit grazed in the spring and fall had a composition of 17% grasses, 5% forbs, and 78% shrubs. Mueggler (34) concluded that heavy fall stocking did not markedly affect the range condition. However, spring and fall grazing reduced the range condition from good to poor during the study period. Mueggler suggested that a rotation system in which areas in poor condition are grazed only in the fall may be one method of improving sagebrush-grass range without a reduction in stocking.

In 1950, both the fall grazed unit and the spring plus fall grazed unit at Dubois were cross-fenced (25). Half of each unit was grazed in the spring and the other half was grazed in the fall. Range condition remained essentially unchanged where grazing was continued in the same season as formerly. However, range condition improved from poor to fair on the area grazed in the spring prior to 1950 and in the fall from 1950 to 1957. The area changed to spring grazing in 1950 deteriorated from good to poor condition by 1957. Laycock (25) reported that spring

deferment and heavy fall grazing improved range condition faster than a complete exclusion of livestock. He suggested that a difference in growth periods between shrubs and herbaceous plants may be responsible for the response to grazing. Many of the grasses and forbs complete their growth in the spring while most shrubs continue their growth until fall. Furthermore, the primary use of shrubs by sheep at Dubois is in the fall. Thus, heavy stocking with sheep in the fall actually reduces shrub cover and permits an increase of cover of herbaceous plants.

Salt-Desert Shrub

Winter ranges of the Intermountain region are located at the lower elevations. These areas are grazed from October to April or May. Hutchings and Stewart (21) studied the effects of intensity and season-of-use on the ranges at the Desert Experimental Range near Milford, Utah. The average annual precipitation is 17 cm (7 in.). The major plants are Eurotia lanata (common winterfat), Atriplex confertifolia (shadscale saltbush), Hilaria jamesii (galleta), Oryzopsis hymenoides (Indian ricegrass), Sporobolus cryptandrus (sand dropseed), Artemisia spinescens (bud sagebrush), and Sphaeralcea grossulariaefolia (gooseberryleaf globemallow). Hutchings and Stewart found that the great fluctuations in plant growth due to differences in precipitation from year to year partially obscured the effects of grazing. Early spring grazing was detrimental to some of the desirable plants. Hutchings and Stewart (21) recommended a system which would permit some spring deferment from grazing.

Northern Great Plains

Deferred-rotation and season-long grazing were compared at the Northern Great Plains Field Station during the period 1918-45 (42). The average annual precipitation during this period was 39 cm (15 in.); about half occurred from May-July; and three-fourths from April-September. The dominant plant species are Bouteloua gracilis (blue grama), Agropyron smithii (western wheatgrass), Carex filifolia (threadleaf sedge), and Stipa comata (needleandthread). The experimental range units were stocked with steers from May 16 to October 13. Each of the three divisions in the deferred-rotation system was grazed approximately one-third of the season. The six-year rotation grazing included two consecutive years of

spring use, one year of summer use, two consecutive years of late summer and early fall use, and one year of summer use. Two-year-old steers were used 1918-34 and yearling steers were used 1938-45. The stocking rate on the deferred-rotation units, based on the total acreage in the system, was approximately 2 ha (5 a) per head until 1941 when the intensity was increased to 1.6 ha (4 a) per head. One of the season-long range units was grazed at the rate of 2.8 ha (7 a) per head 1918-40 and 2.2 ha (5-1/2 a) per head 1941-45. The other season-long unit was stocked at 2 ha (5 a) per head 1918-40 and 1.6 ha (4 a) per head 1941-45. Because of a shortage of forage, the steers were not on the latter unit the full grazing season each year (42). The increase in stocking in all units in 1941 was an adjustment for the younger cattle.

Rogler (42) reported that moderate stocking (2.8-2.2 ha, 7-5 1/2 a, per head) was about the correct rate on a season-long basis. At that rate vegetation changes were influenced primarily by differences in precipitation. The vegetation in the heavily stocked unit (2 ha, 5 a, per head) was definitely overgrazed for the 1918-34 period. During the wetter 1938-45 period, the heavily stocked unit was not considered overgrazed in any year. The vegetation in the rotation units did not show the adverse effects of grazing during 1918-34 as the unit grazed season-long at the same rate. There was no evidence that the rotation units benefitted from any natural seeding that theoretically should have occurred in the fall grazed units.

The average seasonal gain of steers on rotation over season-long at the same intensity (2 ha, 5 a, per head) was 16 kg (35 lb) per head for 1918-34. The steers grazed season-long at the moderate rate (2.8 ha, 7 a, per head) gained 20 kg (44 lb) per head more than those on rotation (2 ha, 5 a, per head). During the period of 1938-45 when there was no shortage of forage in any of the range units, the steers in the moderate season-long unit (2.8-2.2 ha, 7-5 1/2 a, per head) gained 13 kg (29 lb) per head per season more than those in the rotation units (2-1.6 ha, 5-4 a, per head). The steers in the heavily-stocked season-long unit (2-1.6 ha, 5-4 a, per head) gained 9 kg (20 lb) per head more than those in the rotation units (42).

Rogler (42) concluded that steer gains could not be increased by using a rotation system when there was sufficient forage for season-long grazing. There would seem to be some merit in a rotation system for improving range that has been damaged by overgrazing. Rogler suggested, however, that complete deferment until the range condition recovers would be a more rapid method of improvement. A rotation system might be used when it is necessary to stock at a high rate during occasional years and with older cattle. One of the advantages of continuous grazing is that cattle have access to all the plants in the range unit when highest in nutritive value. Younger cattle are less likely to gain under a rotation system because they do not utilize the mature forage in the summer and fall units as well as older cattle.

Lodge (27) reviewed other grazing studies in the Northern Great Plains (in the United States and Canada) and concluded that specialized grazing systems based on the exclusive use of natural grassland are no better than continuous grazing. He reported that several workers recognized that the value of a rotation system was the deferment of use in the early part of the growing season. Smoliak (49) of Manyberries, Alberta showed that the weight gains of yearling ewes on a rotation (spring, seeded Agropyron desertorum (crested wheatgrass); summer, native range; and fall, seeded Elymus junceus (Russian wildrye)) were twice as much per unit area as those on native range for the entire season. This combination of seeded and native ranges was also recommended by Rogler et al. (43).

Lewis et al. (26) compared season-long grazing with ewes at three intensities with rest-rotation grazing at a moderate intensity at Antelope Range near Buffalo, South Dakota for the period of 1964-69. The average annual precipitation is 34 cm (13 in.), but it was above average during this study period. Season of use was rotated on the four rest-rotation units and one unit was rested each year. Time of ewe movement was based on utilization (about 50%). Year differences due to blizzards, spring storms, precipitation, and disease have contributed to a greater variation in the results than the grazing treatments. Contrary to results obtained during a dry phase (10), ewe performance

in this wet phase under heavy grazing has been about equal to that of ewes on lightly and moderately grazed units. Rest-rotation grazing resulted in good range improvement. However, ewe and lamb production was lower with rotation grazing than with any of the season-long treatments. Heavy utilization in spots is a problem in all units. Combination stocking with sheep and cattle may alleviate this problem.

Central Great Plains

A stocking rate guide for cattle on Bouteloua gracilis (blue grama) range was developed at the Central Plains Experimental Range northeast of Fort Collins, Colorado by Bement (3). The average annual precipitation is 30 cm (12 in.) and the growing season precipitation (May-September) is 21 cm (8 in.). During 1940-63, three range units were stocked at heavy, moderate, or light rates. Utilization was estimated on the basis of ungrazed herbage remaining at the end of the grazing season. Animal daily gain and gain per hectare were plotted in relation to ungrazed herbage. These curves, combined with average stocking rate, resulted in the stocking rate guide. Maximum average gains of 17 kg/ha (15 lb/a) were obtained when 280 kg/ha (250 lb/a) of air-dry herbage was left on the ground at the end of the grazing season. Maximum average daily gains of 0.66 kg/animal (1.5 lb) were made by leaving at least 392 kg/ha (350 lb/a) of herbage at the end of the season. Bement (3) used a variety of cattle sale prices to show that the greatest return was realized when 336 kg/ha (300 lb/a) of ungrazed herbage remained at the end of the grazing season. This level of ungrazed herbage will maintain good vigor of Bouteloua gracilis (blue grama).

True Prairie Region

Deferred-rotation grazing was compared with season-long grazing during the periods 1916-22 and 1927-36 near Manhattan, Kansas by Aldous (1) and for 1949-55 by Herbel and Anderson (14). The dominant vegetation is Andropogon scoparius (little bluestem) and A. gerardi (big bluestem). The average annual precipitation is 81 cm (32 in.); about 75% occurs during the growing season. For the period of 1916-19, Aldous (1) used a deferred-rotation scheme whereby one unit of three was deferred until after seed maturity, about September 15. He found that the grasses

could maintain a normal ground cover vegetatively if properly utilized, and that the forage value was reduced after maturity. Starting in 1920, the cattle were placed in the deferred unit about June 15. The season-long units were grazed May-October. Aldous (1) found that the deferred system resulted in a 32% increase in carrying capacity, a similar daily gain per animal unit, and a 33% increase in gain per ha when compared to season-long grazing. The increased gain per ha was due to the increased stocking rate on the deferred unit. The vegetation cover decreased on all grazed units from 1927 to 1936 because of a severe drought in 1934. However, the major decreaser species (Andropogon gerardi (big bluestem), A. scoparius (little bluestem), Sorghastrum nutans (yellow Indiangrass), and Panicum virgatum (switchgrass)) were only reduced to 52% of the 1927 average in the deferred unit whereas they were reduced to an average of 31% in the two season-long units (1).

For the period of 1949-55, Herbel and Anderson (14) compared season-long grazing (May-October) at three intensities with deferred-rotation grazing at the moderate rate. Two of the three units in the rotation system were grazed during May and June. On about July 1, all the yearling steers would be shifted to the deferred unit. Toward fall, the steers grazed all three units. Below-average precipitation occurred in the latter part of the study period. On the major range site, loamy upland, there was a slightly greater reduction in range condition under deferred-rotation grazing than with moderate season-long grazing from 1950 to 1955. The average steer gain in 1955 was 48 kg/ha (43 lb/a) with deferred-rotation grazing and 60 kg/ha (54 lb/a) with moderate season-long grazing.

Southern Great Plains

Several grazing systems were compared at the Southern Great Plains Field Station near Woodward, Oklahoma (31). The average annual precipitation is 58 cm (23 in.); 70% of which occurs April-September. The major plants are Artemisia filifolia (sand sagebrush), Bouteloua gracilis (blue grama), Sporobolus cryptandrus (sand dropseed), Eragrostis trichodes (sand lovegrass), Andropogon scoparius (little bluestem), A. hallii (sand bluestem), Panicum virgatum (switchgrass), Paspalum stramineum (sand paspalum), and Leptoloma cognatum (fall witchgrass).

Continuous summer grazing (April-October) was compared with three-division rotation grazing at both heavy and moderate stocking rates (30). The steers were rotated among divisions at two-month intervals in 1942 and at one-month or shorter intervals for 1943-51. Rotation grazing in 1942 reduced steer gains 29 kg (64 lb) per head at the heavy rate and 17 kg (37 lb) at the moderate rate. There was no real difference between gains in the other years when the rotation was shortened. The more desirable tall grasses, and also some of the forbs, increased most under rotation grazing at both rates. The less desirable Paspalum stramineum (sand paspalum), Leptoloma cognatum (fall witchgrass), and Bouteloua hirsuta (hairy grama) increased most under continuous grazing. However, McIlvain and Savage (30) concluded that this type of rotation could not be recommended over continuous grazing as an improved management practice.

McIlvain et al. (29) used cows and calves to compare a two-division rotation with continuous yearlong use. Cattle were confined to one division of the rotation unit from about May 1-June 10. They were then placed in the deferred division for either the remainder of the summer if growth was good, or for about six weeks if the summer was droughty. The cattle in the rotation unit grazed both divisions when the grass was dormant, as in winter or severe drought. After four years there was no difference in cattle gains or vegetation between the two systems.

A rotation system involving a full year's rest was compared with continuous yearlong grazing for four years. The steers on the continuous yearlong grazing system outgained those on the alternate-year rotation by 10 kg (22 lb) per head. At the end of this study, there was little difference in floristic composition of forage production. Above-average moisture conditions near the end of the study period may have contributed to these results. McIlvain and Shoop (31) concluded that the following grazing systems have not proved superior to continuous yearlong grazing at the same stocking rates at Woodward: (1) summer and winter grazing, (2) alternate-year grazing, (3) three-unit rotations with rotations at two-month, one-month, 15-day, and ten-day intervals, (4) two-unit, six-week, one-herd rotation when grass is growing and (5) six-unit, six-day, one-herd rotation. They cited some major reasons

for the success of continuous yearlong grazing in the Southern Great Plains as (1) forage production is primarily dependent upon summer rainfall--and monthly forage production during the summer can vary from 22 to 672 kg/ha (20-600 lb/a), (2) most species are grazed by cattle at one time or another, (3) many of the "increaser" species are excellent grazing plants and they may be very productive under certain conditions, (4) cattle compete with natural losses of forages and with other consumers, (5) young and regrowth forage is more palatable and more nutritious than more mature forage, (6) grazed plants save soil moisture for later green growth, and (7) favorable growing seasons combined with proper management allow ranges to recover a desirable species composition. Some additional reasons for the success of yearlong continuous grazing may be: (1) utilization is light during the growing season under yearlong continuous grazing, and (2) lighter stocking per unit area means less compaction of the soil by livestock when the soil is wet.

Edwards Plateau

Merrill (32) compared continuous yearlong grazing at three intensities with deferred-rotation grazing at a moderate rate near Sonora, Texas. The major forage species is Hilaria belangeri (curlymesquite) with minor amounts of Tridens pilosus (hairy tridens), Aristida sp. (threeawns), Bouteloua curtipendula (sideoats grama), B. hirsuta (hairy grama), Bothriochloa saccharoides (silver bluestem), Andropogon scoparius (little bluestem), Leptoloma cognatum (fall witchgrass), and Stipa leucotricha (Texas needlegrass). There is an overstory of Juniperus sp. (junipers) and Quercus (oaks). There is also a variety of forbs under certain weather conditions. The average annual precipitation is 61 cm (24 in.). The average monthly precipitation is highest in spring and fall. Midsummer can be droughty. In the four-unit rotation system, each unit is grazed twelve months, then rested four months. Thus, during a four-year cycle, each unit is deferred once during each of the four-month periods. Stocking was with a combination of cattle, sheep, and goats. The study was initiated in 1949. After 11 years, the stocking rate of the units in the deferred-rotation system has increased 33% from 12.4 animal units/km^2 (32 animal units/section) to 16.6 animal units/km^2 (43 animal units/section (33). These units carried the increased grazing pressure and at

the same time made greater range improvement than any of the units grazed continuously. Average annual net returns for 1959-65 were $1.78, $2.91, and $1.63 per ha ($0.72, $1.18, and $0.66 per a) with continuous stocking at the rate of 6, 12, and 19 animal units/km^2 (16, 32, and 48 animal units/section). The average net return for the same period on the rotation units was $4.15/ha ($1.68/a) (33).

A two-unit rotation, a four-unit rotation, and yearlong continuous grazing were compared near Barnhart, Texas (20). The most abundant grasses are Buchloe dactyloides (buffalograss), Hilaria belangeri (curly-mesquite), and H. mutica (tobosa). There are also other perennial and annual grasses and forbs, and an overstory of Prosopis juliflora (common mesquite). The mean annual precipitation is about 46 cm (18 in.) with about the same average seasonal distribution as Sonora. The four-unit rotation is the same as the one described by Merrill (32). In the two-unit rotation, the units are alternately grazed and deferred for three- and six-month periods (e.g., one unit is deferred March 1-June 1; grazed June 1-December 1; and deferred December 1-March 1). During a two-year period each unit was deferred twelve months with deferment during each season. All treatments were stocked with cattle and sheep at 10 animal units/km^2 (25.6 animal units/section). During 1959-65, the average annual net returns per animal unit were $30.63, $39.03, and $41.71 for continuous, four-unit rotation, and two-unit rotation grazing, respectively (20). Huss and Allen (20) found that combination use of cattle and sheep was more profitable than grazing either class alone. Merrill (33) also found that combination grazing with cattle, sheep and goats or cattle and goats was more profitable at Sonora than using sheep alone or cattle alone.

Southern Rolling Plains

Fisher and Marion (9) compared rotation and continuous grazing at a moderate rate at Spur, Texas. The major forage species are Buchloe dactyloides (buffalograss), Hilaria mutica (tobosa) and Panicum obtusum (vine mesquitegrass). The average annual precipitation is 54 cm (21 in.). The average monthly precipitation is well distributed from April-October. The remainder of the year is drier. The grazing season was about May 1-

October 1. The rotation system consisted of grazing each of three units for one month and deferring it for two months for the 1942-49 period. Fisher and Marion (9) concluded (1) rotation grazing did not improve the vegetational composition from 1942 to 1947, (2) rotation grazing increased differential use of Buchloe and Hilaria as the season progressed or in drought, and in some instances resulted in less moisture penetration on sites occupied by the more desirable species, and (3) gains of yearling steers grazing on the rotation units were slightly lower than those grazing on the continuous units.

Various grazing systems were compared at the Texas Experimental Ranch near Throckmorton during 1960-68 (24). The major plant species are Stipa leucotricha (Texas needlegrass), Buchloe dactyloides (buffalograss), Bouteloua curtipendula (sideoats grama), Prosopis juliflora (common mesquite) and Condalia obtusifolia (lotewood condalia). There is a wide variety of other plants in the flora. The average annual precipitation is 63 cm (25 in.). There is a tendency for the precipitation to be distributed in the spring and fall with a slight depression in midsummer and in the winter. A moderate stocking rate with cows and supplemental feeding level of 0.7 kg/day (1-1/2 lb/day) of cottonseed cake during winter were used in comparing grazing systems. The three systems were yearlong continuous, two-unit rotation similar to that studied at Barnhart, Texas by Huss and Allen (20), and a four-unit rotation similar to that studied at Barnhart by Huss and Allen and at Sonora by Merrill (32). Calf production per animal unit averaged 200, 208, and 221 kg (441, 458, and 487 lb) for the moderate continuous, two-unit rotation, and four-unit rotation, respectively, for the eight years. Precipitation was near average or above-average during the study.

Semidesert Grassland

A number of studies on the Jornada Experimental Range, 40 km (25 mi.) north of Las Cruces, New Mexico, have contributed to developing a grazing system (16). The major forage species on the light- to medium-textured soils are Bouteloua eriopoda (black grama) and Sporobolus flexuosus (mesa dropseed). Hilaria mutica (tobosa) and Scleropogon brevifolius (burrograss) grow on the heavier soils. Under certain weather conditions, there may be an abundance of a variety of forbs and

annual grasses. The average annual precipitation is 22.5 cm (9 in.). The average precipitation during the summer growing season is 12.5 cm (5 in.). The average annual evaporation from a Weather Bureau pan is 225 cm (90 in.) or ten times the precipitation. However, Herbel and Nelson (16) showed that precipitation averages had little meaning. During 53 years of record, 45% of the years had seasonal precipitation of less than 85% of average and 34% of the years had seasonal precipitation greater than 115% of average. Furthermore, summer rainfall occurs as localized, convectional thunderstorms. Cool night-time temperatures limit growth of some of the warm-season plants in spring and fall when moisture is available. However, since May and June are often very dry, and since spring and fall moisture is unreliable, cool temperatures have little effect on growth of the warm-season plants. High daily maximum temperatures, ranging from 38 to 41 C (100 to 105 F) occur during dry periods in the summer. This places considerable stress on many of the growing plants, and it is particularly harmful to seedlings.

Forty years ago, there were two major vegetation types on the Jornada; one dominated by Bouteloua eriopoda (black grama) and the other dominated by Hilaria mutica (tobosa) and Scleropogon brevifolius (burrograss). Because Hilaria and Scleropogon are more palatable and can withstand moderate grazing during the summer growing season, the grazing system consisted of grazing the Hilaria-Scleropogon type in summer and early fall and then grazing the Bouteloua type from late fall until the next summer (36). However, considerable Bouteloua was lost during the severe drought of 1951-56 and due to a rapid increase of Prosopis juliflora (common mesquite) on sandy soils (6). Now there are other vegetation types made up of a multiplicity of forbs and a few grasses. They can provide a considerable part of the forage crop in some years. Their production is not as reliable as the long-lived perennial grasses, but they have a high nutritive value (35). Herbel and Nelson (15) found that cattle grazed, to some extent, all species available to them, including a variety of forbs and shrub-like species. They also found that there were definite seasonal preferences for some species.

Using weather and plant information, and considering livestock needs, Herbel and Nelson (16) developed the Best Pasture Grazing System. The system consists of establishing an objective for each range unit and stocking accordingly. The system is opportunistic in that the use of forbs and short-lived grasses is maximized. They are of little value to the permanent range resource but contribute much to livestock nutrition. No set stocking plan is established for a specific time period because of considerable variations in weather conditions that affect plant growth. The system involves a rotation scheme where the livestock are moved when the vegetation on another unit can be grazed to the advantage of both plants and animals as compared to the unit being grazed. In the large range units occurring in parts of the West, periodic opening and closing of watering places can be used to rotate grazing pressure to different areas within a range unit (28).

Stocking should be adjusted to compensate for a highly variable forage crop. Flexible Herd Management has been suggested by several workers as the best method for maximizing livestock production without damaging the range resource during droughty periods (2, 5, 36, 41, 51, and others). During average years, the herd is made up of not more than 55 to 60% breeding animals. The remainder of the herd is composed of yearlings and replacement heifers. In years of low forage production, adjustments in the size and composition of the herd are planned to bring the herd within the capacity of the range. Readily saleable animals such as weaners and yearlings are marketed. In the years of above-average precipitation, part or all of the natural increase from the breeding herd can be held over until spring or fall depending on conditions.

Conclusions

Studies on California Annual Rangelands have indicated that yearlong-continuous grazing is superior to seasonal grazing. However, species composition can be manipulated by grazing intensity, burning, and seeding. This may indicate that a highly flexible grazing system, involving some form of manipulation on part of a ranch operation, may provide a higher quality and/or quantity of forage for part of the year.

There was only limited success with any grazing scheme other than continuous on rangelands grazed only for a part of the year. There has only been a modest increase of the grazing period at Harvey Valley following 13 years of rest-rotation grazing, and this may be due to range improvements such as seeding, brush control, fencing, and water development. At the Starkey Experimental Forest, the production of Carex geyeri (elk sedge) was maintained only with light stocking in a deferred-rotation system. However, there was a spring drought during the study and Carex is very susceptible to grazing. At Mandan, the vegetation in the rotation units did not show the adverse effects of grazing during a period of below-average precipitation as the unit grazed season-long at the same rate. However, improvement in range condition would be more rapid under complete deferment for one or two years. At Antelope Range, rest-rotation grazing resulted in good improvement in range condition but sheep production was lower than with season-long grazing. At Manhattan, an earlier study showed an advantage in vegetation response to deferred-rotation grazing but a later study showed no advantage in vegetation by deferred-rotation grazing and a disadvantage in livestock performance.

In the northern part of the West, early plant growth is generally dependent upon winter-spring precipitation and periods of warm weather. It has been recognized by many workers that grazing or clipping during the early part of seasonal growth is detrimental to subsequent plant vigor (e.g., 7, 19). On ranges grazed seasonally, several studies have shown an advantage to spring deferment but this must be balanced against the detrimental effects of concentrating livestock during this critical period of plant growth. At Squaw-Butte, nonuse during the growing season for four years did not overcome the detrimental effects of two

consecutive years of concentrating the stock during the growing season. In the areas with short growing seasons, an important question, often not considered, is: how many of the desirable plants are actually grazed during the critical period of growth under a moderate stocking rate in a continuous system? At Burgess Junction, Wyoming, Festuca idahoensis was not utilized until mid-August on the season-long unit whereas it was moderately utilized as early as late July in the rotation units. It appears that any deferment period on ranges grazed only for part of a year should be brief, and that it should coincide with a critical period of growth. It should be recognized that the dates of this critical period vary from year to year depending on phenological development.

Another important consideration on ranges grazed seasonally is: are range managers trying to maintain the right species? Undoubtedly, we must have species that will maintain the soil resource. However, from the evidence presented in this paper, Festuca idahoensis (Idaho fescue), Carex geyeri (elk sedge), Agropyron spicatum (bearded bluebunch wheatgrass), and possibly others, are poorly adapted to grazing by livestock in some areas. Species that are not well adapted climatically also should not be considered important in many instances. E. g., though Bouteloua gracilis (blue grama) is quite resistant to grazing, its production is low in some high altitude situations in the Southwest.

At Woodward, a number of studies have shown no advantage to rotation grazing over continuous grazing in livestock performance. An early study showed an improvement in floristic composition due to rotation grazing. Later, but shorter, studies showed no change in floristic composition due to grazing system. The Woodward station is located in a broad regional ecotone with considerable fluctuations in floristic composition due to weather conditions. There is a reduction in percentage of tall grasses in the floristic composition in a series of dry years regardless of grazing treatment. Similarly, during a series of wet years, the tall grasses increase rapidly under any grazing treatment other than heavy stocking. This wide fluctuation in floristic composition due to weather conditions is common to some other parts of the West,

and it must be taken into consideration when evaluating grazing treatments. With this fluctuation in composition, a classification of range condition at any point in time must allow for previous weather conditions.

Of the studies reviewed, the deferred-rotation system at Sonora, Texas has shown the most striking results. At that location, a range unit is grazed with a combination of livestock for 12 months and deferred for four months. This infrequency of livestock movement means that the livestock must adjust to new forage conditions only once a year. Livestock are in a given unit for a complete cycle of plant growth. The major species, Hilaria belangeri (curlymesquitegrass), is quite resistant to heavy grazing. Another point is there may be some growth of at least some of the plant species at anytime of the year when there is sufficient moisture. Therefore, a four-month deferment during each third of the year every four years has resulted in a substantial improvement in carrying capacity.

In many grazing studies, the major emphasis has been centered on a few species. The value of all plants growing on an area must be considered. Even minor amounts of a few species may contribute much to animal performance for a brief, but critical, part of the year. Few studies have given attention to forbs and shrubs.

Most studies have shown that livestock production per animal is the same or lower for a rotation system compared to continuous grazing. Generally, there must be an improvement in range condition, and subsequently in carrying capacity, to justify a rotation scheme using livestock performance as a criterion. Animal performance per unit area is more important than performance of individual animals. In some instances, it may take several years to have enough range improvement to justify an increase in stocking.

When a rotation scheme is initiated, range improvements such as seeding, brush control, fencing, and water developments are often not properly credited for observed differences when compared to unimproved ranges. Rather, there is a tendency to credit the rotation scheme for observed improvements in range condition or animal performance. Any

improvement that aids livestock distribution will result in greater productivity. The entire management plan, including both range improvements and grazing scheme is the important consideration. All of the beneficial, economical practices should be integrated into the overall management plan.

Most grazing studies have been established at a fixed stocking rate. Downward adjustments in livestock numbers were made only in severe droughts. A fluctuating forage crop was given little thought to establishing grazing studies. This is probably another reason why many of the grazing studies have failed to show much improvement in range condition. When ranch operators adopt a grazing system, other than continuous grazing, they often allow for a flexibility in time of grazing and deferral, and the number of livestock grazed. This flexibility may be the difference between success or failure of the grazing scheme.

A grazing system must be highly flexible. Plant and animal requirements must be considered. For example, some of the range units in a ranch operation may be manipulated to furnish highly nutritious forage during the time of the year when livestock need a higher plane of nutrition. This may be done at a sacrifice of some of the "highly desirable" range species on those units. Furthermore, it should be recognized that the critical growth stage of plants varies from year to year because of weather conditions. Due to grazing history and weather conditions, it may be more important to defer grazing in some years than others.

Grazing systems should also be tailored to fit a variety of vegetation types, soil types, and herd management plans. This means that there may be considerable variation in specific details from one ranch operation to the next. In some areas, continuous grazing may be the most profitable system. In some instances, it may be desirable to use a certain intensive grazing system to attain a certain measure of improvement and then change to a different system for maximum net returns while maintaining the resource. Flexibility in planning and in the day-to-day operations of a grazing scheme is the key to success. The vagary of weather, particularly drought, is a common problem throughout the West and considerable flexibility must be built into any grazing plan, or for that matter, any activity on rangeland.

Much has been learned about grazing management. However, much needs to be done to develop and adapt the most productive grazing scheme to each ranch operation. Grazing research should include studies on the effects of the treatments on the entire ecosystem, not just the effects on the livestock and a few of the major plant species.

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