Grazing Systems on Native Range

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When we place livestock or wildlife on native range, we are attempting to maximize animal production as well as to maintain or improve the plant and soil resources. If we abuse these resources, we will change the species composition of the plant communities, reducing both productivity and soil protection. Continued abuse results in soil erosion problems. This is not to imply that proper grazing is destructive. Most of our native range communities have evolved over thousands of years along with grazing use by native animals. However, I would hasten to add that the plant communities that have evolved are not always the most productive under intensive livestock grazing.

This review is concerned primarily with research on grazing systems on native ranges in the 10 Great Plains States. Basic information on climate and vegetation is presented, so that results may be disseminated and adapted as widely as possible. To keep this paper within space limitations, only studies concerned with specialized grazing systems are considered. Generally, this means that some scheme of livestock manipulation other than continuous grazing was studied. Short-term experiments generally are not considered, because the author feels 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 Society for Range Management (Range Term Glossary Committee, 1964). Deferred-rotation grazing means 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 means 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.

Conifer Forest Ranges

Ponderosa pine (*Pinus ponderosa*) forests are among the most important forest grazing areas in the western United States. Smith et al. (1967) compared moderate-rotation, heavy-rotation, and moderate season-long grazing in the Big Horn Mountains near Burgess Junction, Wyoming. The elevation is 8,000 feet. The major forage species is Idaho fescue (*Festuca idahoensis*), but there is a variety of herbaceous and browse species. The average annual precipitation is 31 inches; 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 during the same period in consecutive years. The study covered the years 1959-64. There was no significant difference in daily animal gain between moderately stocked units (2.1 lb) that were rotation-grazed and gains on similarly stocked units grazed season-long. The daily gain on the heavy-rotation unit averaged 1.8 lb. On soils of granitic origin, production of Idaho fescue was maintained equally well on the three treatments. On soils derived from sedimentary deposits, the abundance of Idaho fescue declined within the heavy-rotation unit. Cover and production of Idaho fescue was best maintained with season-long grazing. However, it generally was not grazed until mid-August on the season-long unit, whereas it was moderately used as early as the later part of July in the rotation units. In that area, Idaho fescue makes little regrowth in the year it is grazed, regardless of the time or amount of herbage removal (Smith et al., 1967a). During 1961-63, use of Idaho fescue averaged from 20% to 43% for the three 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 Idaho fescue is not well-adapted to grazing at the rate termed moderate at Burgess Junction.

Northern Great Plains

Deferred-rotation and season-long grazing were compared at the Northern Great Plains Field Station during the period 1918-45 (Rogler, 1951). The average annual precipitation during this period was 15 inches; about half occurred from May-July; and three-fourths from April-September. The dominant plant species are blue grama (*Bouteloua gracilis*), western wheatgrass (*Agropyron smithii*), threadleaf sedge (*Carex filifolia*), and needle-andthread (*Stipa comata*). 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 for about one-third of the season. The six-year-rotation grazing included two consecutive years of spring use followed by 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 about 5 acres per head until 1941, when the intensity was increased to 4 acres per head, or an average of 1.5 acres/animal-unit-month (AUM). One of the season-long range units was grazed at the rate of 7 acres per head 1918-40 and 5-1/2 acres per head 1941-45, or an average of 2.1 acres/AUM. The other season-long unit was stocked 5 acres per head 1918-40 and 4 acres per head 1941-45, or an average of 1.5 acres/AUM. Because of a shortage of forage, the steers were not on the latter unit the full grazing season each year (Rogler, 1951). The increase in stocking in all units in 1941 was an adjustment for the younger cattle.

Rogler (1951) reported that moderate stocking (about 2.1 acres/AUM) 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 (about 1.3 acres/AUM) was definitely overgrazed for the 1918-34 period. During the wetter 1938-45 period, the heavily stocked unit (about 1.7 acres/AUM) was not considered overgrazed in any year. The vegetation in the rotation units did not show adverse effects of grazing during 1918-34, as did the unit grazed season-long at the same rate. There was no evidence that the rotation units benefited 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 (1.3 acres/AUM) was 35 lb. per head for 1918-34. The steers grazed season-long at the moderate rate (1.9 acres/AUM) gained 44 lb per head more than those on rotation (1.3 acres/AUM). 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 (about 2.1 acres/AUM) gained 29 lb per head per season more than did those in the rotation units (about 1.5 acres/AUM). The steers in the heavily stocked season-long unit (about 1.5 acres/AUM) gained 20 lb per head more than those in the rotation units (Rogler, 1951). For the 25 years, average annual gains per acre were about 44 lb for moderate season-long stocking, 51 lb for heavy season-long stocking, and 54 lb for heavy-rotation stocking (calculated from data presented by Rogler, 1951).

Rogler (1951) 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 each is highest in nutritive value. Younger cattle are less likely to gain under a rotation system, because they do not use the mature forage in the summer and fall units as well as older cattle.

Lodge (1970) reviewed other grazing studies in the Northern Great Plains (including 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 (1968) of Manyberries, Alberta, showed that the weight gains of yearling ewes on a rotation (spring, seeded crested wheatgrass (*Agropyron desertorum*); summer, native range; and fall, seeded Russian wildrye (*Elymus junceus*) were twice as much per unit area as gains of those on native range for the entire season. This combination of seeded and native ranges was also recommended by Rogler et al. (1962).

Lewis et al. (1970) 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 13 inches, 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 about 50% use of forage. Year differences caused by blizzards, spring storms, precipitation, and disease caused greater variation in the results than differences in the grazing treatments. Contrary to results obtained during a dry phase (Gartner et al., 1965), 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 use 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 blue grama (*Bouteloua gracilis*) range was developed at the Central Plains Experimental Range northeast of Fort Collins, Colorado, by Bement (1969). The average annual precipitation is 12 inches, and the growing season precipitation (May-September) is 8 inches. 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 acre were plotted in relation to ungrazed herbage. These curves, combined with average stocking rate, resulted in the stocking-rate guide. Maximum average gains of 15 lb/acre were obtained when 250 lb/acre of air-dry herbage was left on the ground at the end of the grazing season. Maximum average daily gains of 1.5 lb/animal were made by leaving at least 350 lb/acre of herbage at the end of the season. Bement (1969) used a variety of cattle sale prices to show that the greatest return was realized when 300 lb/acre of ungrazed herbage remained at the end of the grazing season. This level of ungrazed herbage will maintain good vigor of blue grama.

To distinguish the effects of seasonal grazing, Hyder and Bement (1973) studied 12 seasons of heavy grazing by individual months. Blue grama, the dominant species, increased in frequency with heavy grazing in April, June, and July, and decreased with heavy grazing in February and September. However, considering the entire ecosystem, no season of heavy grazing caused major changes in plant frequency. However, the animal-days of grazing were considerably reduced by repeated heavy grazing in June and July. Hyder and Bement (1973) concluded that deferment, or no more than moderate grazing, would be most beneficial during May, June, and July. In a grazing system requiring a short period of heavy grazing, they found that heavy grazing in August or September would: result in use of some of the less desirable species, promotote more uniform grazing, and harvest maximum nutrients per unit area. However, they indicated that continuous moderate grazing is appropriate on the shortgrass area of the Central Great Plains, because there is no serious sacrifice of preferred species or sites.

True Prairie Region

Deferred-rotation grazing was compared with season-long grazing during the periods of 1916-22 and 1927-36 near Manhattan, Kansas, by Aldous (1938), for 1949-55 by Herbel and Anderson (1959), and for 1950-66 by Smith et al. (1967b). The dominant vegetation is little bluestem (*Andropogon scoparius*) and big bluestem (*A. gerardi*). The average annual precipitation is 32 inches; about 75% occurs during the growing season. For the period of 1916-19, Aldous (1938) 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 used, 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 (1938) 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 acre when compared to season-long grazing. The increased gain per acre was caused by 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 decreasing species (big bluestem, little bluestem, yellow Indiangrass (*Sorghastrum nutans*), and switchgrass (*Panicum virgatum*) were reduced only 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 (Aldous, 1938).

For the period of 1949-55, Herbel and Anderson (1959) 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 of 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.

Smith et al. (1967b) compared steer gains for 1950-66 in the same pastures studied by Herbel and Anderson (1959). The average steer gain was 197 lb with deferred-rotation grazing, and 233 lb with moderate season-long grazing. Moderate season-long grazing on pastures burned in late spring gave average steer gains of 259 lb. By 1966, the vegetation on the pasture burned in late spring was in a higher range condition than that in the pasture moderately grazed season-long or in the pastures with deferred-rotation grazing.

Southern Great Plains

Several grazing systems were compared at the Southern Great Plains Field Station near Woodward, Oklahoma (McIlvain and Shoop, 1969). The average annual precipitation is 23 inches; 70% of which occurs April-September. The major plants are sand sagebrush (*Artemisia filifolia*), blue grama, sand dropseed (*Sporobolus cryptandrus*), sand lovegrass (*Eragrostis trichodes*), little bluestem, sand bluestem (*Andropogon hallii*), switchgrass, sand paspalum (*Paspalum stramineum*), and fall witchgrass (*Leptoloma cognatum*).

Continuous summer grazing (April-October) was compared with three-division rotation grazing at both heavy and moderate stocking rates (McIlvain and Savage, 1951). 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 64 lb per head at the heavy rate and 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 sand paspalum, fall witchgrass, and hairy grama (*Bouteloua hirsuta*), increased most under continuous grazing. However, McIlvain and Savage (1951) concluded that this type of rotation could not be recommended over continuous grazing as an improved management practice.

McIlvain et al. (1955) 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 6 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 4 years. The steers on the continuous yearlong grazing system outgained those on the alternate-year rotation by 22 lb/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 (1969) 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 10-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 primarily depends on summer rainfall--and monthly forage production during the summer can vary from 20-600 lb/acre, (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) use 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 (1954) compared continuous yearlong grazing at three intensities with deferred-rotation grazing at a moderate rate near Sonora, Texas. The major forage species was curlymesquite (*Hilaria belangeri*), with minor amounts of hairy tridens (*Tridens pilosus = Erioneuron pilosum*), threeawns (*Aristida* sp.), sideoats grama (*Bouteloua curtipendula*), hairy grama, silver bluestem (*Bothriochloa saccharoides*), little bluestem, fall witchgrass, and Texas needlegrass (*Stipa leucotricha*). There is an overstory of junipers (*Juniperus* sp.) and oaks (*Quercus* sp.). There is also a variety of forbs under certain weather conditions. The average annual precipitation is 24 inches. The average monthly precipitation is highest in spring and fall. Midsummer can be droughty. In the four-unit rotation system, each unit is grazed 12 months, then rested 4 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 32 animal units/section to an average stocking of 43 animal units/section (Merrill, 1969). These units carried the increased grazing pressure and at the same time made greater range improvement than any of the units grazed continuously. Currently, the major forage species in the deferred rotation units are sideoats grama and silver bluestem. Average annual net returns for 1959-65 were $0.72, $1.18, and $0.66 per acre with continuous stocking at the rate of 16, 32, and 48 animal units/section. The average net return for the same period on the rotation units was $1.68/acre (Merrill, 1969). Merrill et al. (1957) found the highest population of white-tailed deer, one per 6.7 acres, on the rotation units that were moderately grazed by cattle, sheep, and goats. The next highest population, one deer per 7.3 acres, was on units grazed continuously at a light rate by cattle only. This is an important consideration, because of the increased value of deer in recent years.

A two-unit rotation, a four-unit rotation, and yearlong continuous grazing were compared near Barnhart, Texas (Huss and Allen, 1969). The most abundant grasses are buffalograss (*Buchloe dactyloides*), curlymesquite, and tobosa (*Hilaria mutica*). There are also other perennial and annual grasses and forbs, and an overstory of mesquite (*Prosopis juliflora*). The mean annual precipitation is about 18 inches, with about the same average seasonal distribution as that of Sonora. The four-unit rotation is the same as the one described by Merrill (1954). In the two-unit rotation, the units are alternately grazed and deferred for three- and six-month periods (for example, 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 12 months, with deferment during each season. All treatments were stocked with cattle and sheep at 25.6 animal units/section. During 1959-65, the average annual net returns per animal units were $30.63, $39.03, and $41.71 for continuous, four-unit rotation, and two-unit rotation grazing, respectively. Huss and Allen (1969) found that combination stocking with cattle and sheep was more profitable than grazing either class alone. Merrill (1969) also found that combination grazing with cattle, sheep, and goats or with cattle and goats was more profitable at Sonora than using sheep alone or cattle alone.

Southern Rolling Plains

Fisher and Marion (1951) compared rotation and continuous grazing at a moderate rate at Spur, Texas. The major forage species are buffalograss, tobosa, and vine mesquitegrass (*Panicum obtusum*). The average annual precipitation is 21 inches. The average monthly precipitation is 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 (1951) concluded: (1) rotation grazing did not improve the vegetational composition from 1942-47, (2) rotation grazing increased differential use of buffalograss and tobosa 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 gains of those grazing on the continuous units.

Various grazing systems were compared at the Texas Experimental Ranch near Throckmorton during 1960-68 (Kothmann et al., 1970). The major plant species are Texas needlegrass, buffalograss, sideoats grama, mesquite, and lotewood condalia (*Condalia obtusifolia*). There is a wide variety of other plants in the flora. The average annual precipitation is 25 inches. 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 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 (1969), and a four-unit rotation similar to that studied at Barnhart by Huss and Allen and at Sonora by Merrill (1954). Calf production per animal unit averaged 441, 458, and 487 lb for the moderate continuous, two-unit rotation, and four-unit rotation, respectively, for the 8 years. Net return per animal unit was: $62.06 for moderate continuous grazing, $66.11 for two-unit rotation, and $73.64 for four-unit rotation grazing (Kothmann et al., 1971). Net return per acre was: $3.03 for moderate continuous, $3.22 for the two-unit rotation, and $3.81 for the four-unit rotation. Although returns per acre were highest from heavy continuous stocking ($5.28), Kothmann et al. (1971) doubted that they could be sustained at that level. Precipitation was near average or above average during the study.

High-Intensity, Short-Duration Grazing

A rotation system, using as many as 16 units, each grazed 2 weeks or less by one or two herds, has been studied in South Africa and Rhodesia (Roberts, 1967, and Goodloe, 1969). Livestock are not moved at any set time, nor are the units necessarily stocked in sequence. At the time of year when plants are growing rapidly, the livestock should be moved frequently, perhaps as often as every 5 days, to prevent injury to plants. When the plants are dormant, livestock movement may be determined by nutritive requirements of the livestock.

In evaluating grazing systems in South Africa, Roberts (1967) reported: (1) slow rotation systems do not eliminate selective grazing; (2) using 16 units in a high-intensity, short-duration system, 12 are grazed once for about a 2-week period each 6 months, and the four extra units may be used as reserve grazing in dry years or given a full year's rest in years of average precipitation; (3) high-intensity short-duration grazing was designed primarily to combine sufficient rests with efficient use so as to allow rapid restoration of denuded veld--there was less advantage on veld in good condition; (4) veld restoration may be retarded, and intensified abuse may occur, if stocking intensity is increased more rapidly than indicated by herbage production; (5) with variable precipitation, no system can eliminate selective grazing if set grazing periods and stocking rates are maintained, but high-intensity short-duration grazing reduces selective grazing; and (6) the relatively high capital investment required to implement high-intensity short-duration grazing may be justified by the increased carrying capacity. High-intensity short-duration grazing is an intensive system possibly requiring more labor, fencing, and water development. A form of short-duration grazing is being studied at Sonora and Throckmorton, Texas, and Muskogee, Oklahoma.

Semidesert Grassland

A number of studies on the Jornada Experimental Range, north of Las Cruces, New Mexico, have contributed to developing a grazing system (Herbel and Nelson, 1969). The major forage species on the light- to medium-textured soils are black grama (*Bouteloua eriopoda*) and mesa dropseed (*Sporobolus flexuosus*). Tobosa and burrograss (*Scleropogon brevifolius*) 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 9 inches. The average precipitation during the summer growing season is 5 inches. The average annual evaporation from a Weather Bureau pan is 90 inches, or 10 times the precipitation. However, Herbel and Nelson (1969) 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 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 black grama, and the other dominated by tobosa and burrograss. Because tobosa and burrograss are more palatable and can withstand moderate grazing during the summer growing season, the grazing system consisted of grazing the tobosa-burrograss type in summer and early fall, and then grazing the black-grama type from late fall until the next summer (Paulsen and Ares, 1962). However, considerable black grama was lost because of the severe drought of 1951-56 (Herbel et al., 1972), and because of a rapid increase of mesquite on sandy soils (Buffington and Herbel, 1965). 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 that of the long-lived perennial grasses, but they have a high nutritive value (Nelson et al., 1970). Herbel and Nelson (1966) 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 (1969) 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 variation in weather conditions that affect plant growth. The system involves a rotation scheme in which the livestock are moved whenever the vegetation on another unit can be grazed to better advantage for both plants and animals than can the unit being grazed. In the large range units used 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 (Martin and Ward, 1970).

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 (Ares, 1952; Boykin, 1967; Paulsen and Ares, 1962; Reynolds, 1954; and Stubblefield, 1956). 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 salable 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

The research related to the development of grazing systems on native ranges for the 17 Western States was previously reviewed (Herbel, 1971). Some of the pertinent conclusions derived from research in areas not covered in this paper are included here.

Hyder and Bement (1973) listed three requirements for a grazing system: (1) stock the ranges to achieve not more than moderate use in the growing season every year, to maintain a satisfactory botanical composition and productivity of herbage and livestock; (2) include deferment from grazing during the growing season at some interval of time among years to renew the vigor and productivity of preferred plants; and (3) include a period of heavy grazing in the dormant season at some interval of time among years to reduce unpalatable or ungrazed plants, equalize plant composition, and promote more uniform grazing. Alternatives to heavy grazing during the dormant season are discussed in the next paragraph. In some situations, deferment from grazing during the growing season is not necessary, because under moderate season-long or yearlong stocking, not all plants will be grazed during the short growing seasons in arid and semiarid areas. Because of this factor, and the preference for ephemerals that is common during a growing season, the grazing pressure on the perennial plants is very light during the growing season. For these reasons, moderate stocking during the grazing season should maintain or improve range conditions on most range ecosystems. Exceptions to this would be where all the desirable plants have been greatly reduced or eliminated from the area, and also where undesirable woody plants dominate an area. In the latter situation, little improvement will be obtained by manipulating the grazing until the undesirable plants have been controlled.

A study conducted at the Burgess Spring Experimental Range in northeastern California led to the design of a rest-rotation grazing system (Hormay and Talbot, 1961). These ranges are grazed from late May to late October. One of the key species is Idaho fescue. Rest-rotation grazing has the following sequence: (1) graze the range unit all season for maximum livestock production, which may result in a reduction of plant vigor; (2) rest the range unit one or two seasons until plant vigor is restored and there is some accumulation of litter; (3) rest the range unit until seed ripens, then graze the remainder of the season to trample the seed into the soil and for maximum livestock production; and (4) rest the range unit one or two seasons until new plants are established. A trial of rest-rotation grazing was initiated on the Harvey Valley allotment of the Lassen National Forest in 1954 (Hormay and Evanko, 1958). There has been only a modest increase of the season of grazing at Harvey Valley after 13 years of rest-rotation grazing (Ratliff and Reppert, 1968), and this may be a result of range improvements such as seeding, brush control, fencing, and water development. In a 4-unit rest-rotation scheme, the livestock concentration is 4.0 times, and the AUM (animal unit months) quota is 2.0 times as much as would occur if all units were grazed simultaneously throughout the grazing season (Hyder and Bement, 1973). The AUM quota is the livestock concentration, multiplied by the proportion of time that a unit is grazed (for example, pasture 1 has all the livestock for the four units for half the time). For the growing season, an AUM quota of 0.5 or less should be considered a desirable stocking rate (Hyder and Bement, 1973). There is no apparent justification for leaving a range unit ungrazed for an entire year. Can we then justify this rotation plan in terms of seed production, seed planting by trampling, and seedling establishment? On most range ecosystems, the climax species are long-lived perennials. Often these plants are poor seed producers and do not reproduce readily from seed. If these desirable species are depleted by overgrazing or drought, it is often difficult, if not impossible, to obtain recovery by manipulating the grazing. Therefore, it is extremely hazardous deliberately to overstock an area during the growing season. The primary purpose in management is to eliminate excessive grazing, especially in the growing season, in order to increase the vigor and productivity of existing plants (Hyder and Bement, 1973). An alternative to heavy grazing to obtain use of less desirable species is to graze a unit during the time of the year when the less desirable species are more palatable than the preferred species. Another possibility is to use an alternate kind of livestock, or wildlife, as a temporary measure to reduce the less desirable plants.

There was only limited success with any grazing scheme other than continuous on rangelands grazed only for a part of the year. At Mandan, the vegetation in the rotation units did not show as much adverse effect from 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 1 or 2 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 from deferred-rotation grazing and a disadvantage in livestock performance.

In the northern part of the West, early plant growth generally depends on 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 (Crider, 1955; and Hormay and Talbot, 1961). On ranges grazed seasonally, several studies have shown an advantage in spring deferment, but this must be balanced against the detrimental effects of concentrating livestock during this critical period of plant growth. At Squaw-Butte, Oregon, nonuse during the growing season for 4 years did not overcome the detrimental effects of 2 consecutive years of concentrating the stock during the growing season (Hyder and Sawyer, 1951). 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, Idaho fescue was not used until mid-August on the season-long unit, whereas it was moderately used 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 and morphological development.

An 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. Some of the major species growing in the Rocky Mountains, and west of the Rocky Mountains, did not evolve under grazing pressure, as did those species growing in the Great Plains. Idaho fescue, elk sedge (*Carex geyri*), bearded bluebunch wheatgrass (*Agropyron spicatum*), and possibly others, are poorly adapted to grazing by livestock. Species that are not well adapted climatically also should not be considered important in many instances. For example, though blue grama is quite resistant to grazing, its production is low at some high altitudes in the Southwest.

At Woodward, a number of studies have shown no advantage in rotation grazing over continuous grazing in livestock performance. An early study showed an improvement in floristic composition as a result of rotation grazing. Later, but shorter, studies showed no change in floristic composition resulting from the grazing system. The Woodward station is located in a broad regional ecotone where weather conditions cause considerable fluctuation in floristic composition. The percentage of tall grasses in the floristic composition is reduced 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 because of weather conditions is common to some other parts of the West, and it must be considered 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 4 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, curlymesquitegrass, is quite resistant to heavy grazing. Another point is that there may be some growth of at least some of the plant species at any time of the year when there is sufficient moisture. Therefore, a 4-month deferment during each third of the year every 4 years has resulted in a substantial improvement in carrying capacity. The livestock concentration is 1.33 times, and the AUM quota is 0.89 or 1.33 times, as much as would occur if all units were grazed simultaneously for the year (Hyder and Bement, 1973).

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 that uses livestock performance as a criterion. Therefore, the only way a rotation system can show an advantage is by allowing heavier stocking so that animal performance per unit area is greater. 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 a 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. Fluctuations in the forage crop were given little thought in 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. Because of grazing history and weather conditions, it may be more important to defer grazing in some years than others. Range units should be grazed when the key species are damaged least by grazing and when the forage best meets the nutritional requirements of the livestock. This often means grazing in no set or predetermined sequence.

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. At Manhattan, deferred-rotation grazing did not increase herbage production because the range was already in excellent condition. Flexibility in planning and in the day-to-day operations of a grazing scheme is the key to success.

The vagaries of weather, particularly drought, are common problems throughout the West, and considerable flexibility must be built into any grazing plan, or for that matter, any activity on rangeland. Because of these requirements for flexibility, it is difficult to design studies to compare grazing systems. Hyder and Bement (1973) suggested that research scientists should be satisfied with bringing out the fundamental considerations. However, the difficulty with this approach is that it is a problem to interpret research results properly for all the various situations that arise in actual ranching. Modeling of the various ranch situations, using all available information, may be a useful approach to range management. Initial inputs for each ranch would include a description of the physical facilities and the soil, plant, and animal resources. The driving force for the model would be weather conditions. Outputs would be stocking, range-improvement, and herd-management plans. For example, if weather and economic conditions are favorable, the model may suggest a brush-control and seeding program, along with a stocking guide, to maximize benefits from these improvement practices. If a drought occurs, the model might suggest culling the least productive animals.

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.

For increased livestock production in the 1980's, each ranch unit must be as productive as economically feasible. In the vicinity of Mandan, this may mean seeding part of the ranch unit with Russian wildrye and crested wheatgrass, and using fertilizer on both native and introduced species. West of Mandan, this strategy may be less successful. In the prairies of eastern Nebraska, Kansas, and Oklahoma, the highest production for a given ranch unit may include judicious burning of native range and plowing up the native sod on some of the better sites and seeding wheat or smooth bromegrass. On the Southern Great Plains, the best strategy may include seeding some sites on a ranch unit with weeping lovegrass (*Eragrostis curvula*). In the Southwest, range productivity could be greatly increased by brush control and seeding. In some instances, species composition may be manipulated to improve wildlife habitat, while at the same time maintaining or improving livestock productivity. Partial confinement of livestock may offer some possibilities of maintaining productivity during drought, or other periods when livestock performance on range is low. The profitability, or what is economical, is changing with the increased prices of livestock and wildlife. My final plea is for ranchers, and technicians working with ranchers, to be flexible and innovative in planning a ranch operation for greater productivity. What will work well on one ranch unit may not work as well on the ranch next to it, or on a ranch in the next county. We have a long way to go in realizing the potential productivity of our range resources.

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