

# Proper Utilization—A Problem in Evaluating the Physiological Response of Plants to Grazing Use: A Review<sup>1</sup>

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Sampson (1952) in his discussion of range utilization poses two important questions: "How closely may a range area be grazed without damage to forage stand and soil?" and "How may one determine how closely a range unit has been grazed?" Obviously, standards of use which are implied in the first question cannot be answered unless reliable methods for measuring various degrees of use are developed.

Several reviews and comparisons of methods for measuring range use have been published (Pechanec and Pickford, 1937; Clark, 1945; Heady, 1949; Brown, 1954; Ragsdale, 1956). However, Heady stated that the real problem is not the measurements of use but the interpretation of those measurements. This conclusion is supported by Harris (1954) who reported that for a ten-year period on the Starkey Range in northeastern Oregon yearly utilization of bluebunch wheatgrass (*Agropyron spicatum*) varied from 38 to 69 percent, yet the average for the period was close to 50 percent. He concluded that any adjustments in stocking rate on a basis of year to year use would not be justified.

Since methodology used in appraising range utilization has been the subject of most earlier papers, this article will be primarily concerned with interpretations of these measurements in terms of plant and animal responses. Specifically, the purpose of this paper is twofold: (1)

to point out the basis for developing proper use standards applicable on both native and improved forage plants, and (2) to consider some of the important factors influencing forage use.

## Historical Development

Early graziers did not consider their range or pasture to be fully utilized until all the growth had been consumed. However, when public administrators were charged with the problem of regulating grazing, they soon realized that some growth had to be left each season to maintain forage vigor and range productivity (Jardine and Anderson, 1919). These workers pointed out that ranges used after seed maturity could be grazed more heavily than those used during the growing season.

A number of methods for deciding upon the approximate amount of forage removed have been developed. These determinations of range use generally fall into two categories—estimation and measurement. Methods using estimate techniques include: general reconnaissance; ocular estimates, both by average of plots and average of plants within plots; primary forage plant method, and photographic. Those involving measurements are: Weight by clipping grazed and ungrazed plots, height measurements, growth form or height-weight relationships, stem count, and per cent of plants grazed. Good descriptions of the foregoing methods together with examples of their use are found in Sampson (1952) and Stoddart and Smith (1955).

The Joint Committee of the

American Society of Agronomy, American Dairy Science Association, American Society of Animal Production, and American Society of Range Management (1952) states that measurements of the percentage of herbage that has been consumed are particularly useful in the rangelands of the dry west where overstocking is to be avoided. They point out that before and after grazing weight estimates and stubble-height methods are both used for the purpose of measuring utilization on rangelands. They further add that in trying to judge utilization on the range the best we can hope for is to estimate the amount of herbage that is left after grazing. Using this residue figure an attempt is made to calculate how much has been removed.

Hyder (1953, 1954), recognizing the futility of reconstructing the amount of herbage consumed when forage production varies widely among years, has suggested the establishment of residue standards for evaluating range use on sagebrush-bunchgrass ranges in central Oregon. In his opinion, approximately 50 percent of the production on good condition ranges or 160 pounds of air-dry forage should be left on the ground at the end of the grazing season.

A similar approach has been used successfully on annual ranges in California for a number of years (Hormay and Fausett, 1942; Grover, not dated; Bentley and Talbot, 1951). Hormay and Fausett, as did Bentley and Talbot, recommended grazing moderately or until the range residue takes on a patchy appearance. According to Grover about 600 pounds of herbage should be left at the end of the grazing season on moderately grazed annual ranges.

Cook and Stoddart (1953a) have indicated the difficulty of expressing forage removal in percent. Their work with crested wheatgrass indicated that per-

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centage utilization could vary from 50 to 80 percent, depending upon whether percent removed is based on production from clipped or unclipped plants. They concluded that utilization measurements in plant response studies should consider (a) the portions of the plant being utilized, and (b) whether or not the plants were grazed during the growing season, after maturity, or both.

### Physiological Response of Plants to Grazing

Grazed plants must serve a dual role. Not only do they have to supply their own needs, but they also have to provide food for livestock. It is important that livestock men know the needs of plants in addition to the nutritive requirements of their animals. The physiological reaction of plants to grazing should form the basis for development of sound grazing management practices. More than forty years ago Sampson (1914) pointed out the importance of managing rangelands based on the growth requirements and life histories of the principal forage plants. Stoddart and Smith (1955) state that man knows little of how much grazing use a plant can withstand without undue injury. Yet, according to them this knowledge is basic to proper range management.

Influence of grazing, or top removal, on the plant is dependent upon several important variables. These include the intensity or amount, frequency, and season of removal. All of these factors are important in determining standards of use for pasture and range plants. Many investigators have studied the influence of clipping at different intensities, frequencies, and seasons (Parker and Sampson, 1931; Lang and Barnes, 1942; Stoddart, 1946; Blaisdell and Pechanec, 1949, Cook and Stoddart, 1953b). A number of workers have followed carbohydrate reserves in relation to clipping and grazing (Grabner, 1931;

McCarty and Price, 1942; Weinman, 1948; Sprague, *et al.*, 1952).

In general too heavy, too early, and too frequent removal has resulted in a marked decline of forage vigor. In addition, the greatest damage to valuable pasture and range plants occurs during periods of minimum food storage. The influence of clipping or grazing practices on root growth precedes the visible effect on the top and may be immediate and long lasting (Parker and Sampson, 1931; Biswell and Weaver, 1933).

Crider (1955) has accumulated a wealth of material from greenhouse and nursery studies on the effects of clipping on root growth. His data were obtained by clipping pasture and range grass species to different volumes of top removal. Results from clipping many species over a period of years conclusively demonstrated the harmful influence of removing too much of the top. Single clippings that removed more than 50 percent of the top by volume stopped root growth over a period of several days to several weeks depending on the percentage taken. When 40 percent or less was removed, even clipping three times weekly did not markedly influence root elongation or proliferation. Crider also found by clipping portions of the top of a grass plant that root growth below the undisturbed part was not affected. In his opinion, this discovery indicates the desirability of animals grazing only part of the plant crown. This discovery may help to explain why grazing is generally not as damaging to the physiology of plants as clipping, especially on dryland ranges where regrowth is limited by inadequate soil moisture.

### Proper-Use Standards of Some Important Native Forage Plants

A common way of evaluating the effect of grazing on range plants is to first divide them into three major groups: grasses, forbs, and browse. Arnold (1955) suggested eight life-form group-

ings for vegetation in the ponderosa pine zone in northern Arizona. These are: (1) long-lived trees and shrubs, (2) perennial tall grasses, (3) perennial mid-grasses, (4) perennial short grasses, (5) perennial tall, mid- and short forbs, (6) perennial prostrate forbs, (7) short-lived half shrubs, and (8) annuals. This classification is a further refinement of the one based solely on growth form or stature and includes consideration of life span. He suggests that other important life-form characteristics which should be considered are propagation, seasonal growth habits, and protective devices.

Grasses are generally regarded as being the most resistant to the influence of livestock use (Sampson and Chase, 1927). Various reasons have been advanced to explain the persistence of grasses under heavy grazing. Basal meristem, tufted bunch or rhizomatic growth habit, development of basal buds, and reproductive to vegetative stem ratio are several characteristics advanced to account for resistance of a grass plant to grazing pressure.

Cook and Stoddart (1935b) believe that a grass leaf behaves very much like a leaf of a forb or shrub following grazing. Branson (1953) pointed out that the height of the growing point above ground may determine the susceptibility of grasses to grazing injury. However, if the grasses most resistant to grazing are used to guide standards on grass ranges, tall heavy yielding plants may be largely eliminated. Therefore, proper use of grass ranges will depend upon the growth habits including morphological characteristics, and life histories of the principal forage plants as pointed out 40 years ago (Sampson, 1914).

### Proper Use Guides for Mid and Tall Grass Ranges

Most investigators have used leaf length or stubble height as measures of proper use. Crafts (1937) proposed a range from 3

to 5 inches in stubble heights of bunchgrasses in the Southwest to obtain proper grazing use. These general guides are substantiated by Pickford and Reid (1942) on green fescue (*Festuca viridula*) range in northeastern Oregon. These investigators found that 50 percent removal of green fescue herbage should leave a stubble averaging 3 inches high after grazing.

On mountain meadows in eastern Washington and Oregon, Reid and Pickford (1946) found that approximately 55 percent removal of tufted hairgrass (*Deschampsia caespitosa*) by weight constituted proper use and left an average leaf stubble of 3 inches. These same workers (Pickford and Reid, 1948) found that the proper use of bluebunch wheatgrass (*Agropyron spicatum*) should not exceed 55 to 60 percent removal of herbage during the grazing season. Other less palatable plants were used more lightly and total herbage removal amounted to only 23 percent, since the range was in fair to poor condition.

McIlvain, *et al.* (1955) suggest a guide for determining when tall grass range in the southern Great Plains is properly grazed. They state that a stubble height of at least 1 inch should be left on short grasses; midgrasses should have a minimum stubble height of at least 2 inches at the close of the grazing season; tall grasses, 3 to 5 inches. These workers further add that animals should not be forced to eat large quantities of coarse or unpalatable forage, and brush should not be badly broken apart by grazing animals searching for forage.

#### Use Guides for Shortgrass Ranges

In the Southwest, Crafts and Glendening (1942) state that where it is dominant, blue grama (*Bouteloua gracilis*) is a key indicator of range utilization. In their opinion, the stubble height of blue grama after grazing ordinarily should not be less than 2

inches at the end of the grazing season; and, in addition, 25 or 30 percent of the flower stalks should be left ungrazed. This intensity of use seems to occur when between 40 and 50 percent of the forage volume has been cropped.

In the central Great Plains, blue grama and buffalograss (*Buchloe dactyloides*) are the dominant species. Costello and Turner (1944) recommend that the minimum final stubble height for blue grama in years of high forage production should be 1¾ inches. According to these workers this means utilizing approximately 50 percent of the total volume of herbage produced and leaving untouched the coarse and fibrous bases resulting from the rank growth. For years of low forage production their recommended minimum is 1¼ inches which ordinarily means 40 percent or less use of the seasonal herbage production.

Holscher and Woolfolk (1953) prepared guides for proper use of important forage plants on northern Great Plains ranges. Figures prepared by these workers, based on percent of plants to be grazed, are summarized in the accompanying table reproduced from their publication. According to their figures,

Species	Summer range			Winter range		
	Upland	Hills	Bottom	Upland	Hills	Bottom
	subtype	subtype	subtype	subtype	subtype	subtype
	Percent	Percent	Percent	Percent	Percent	Percent
Bluestem wheatgrass	55	55	75	65	65	75
Blue grama	40	45	65	40	40	55
Needle-and-thread	55	60	....	55	60	....
Buffalograss	55	50	75	55	50	75
Threadleaf sedge	50	50	....	50	50	....

with the exception of the bottomland, there is little difference among sites or between seasons of use except for bluestem wheatgrass, which is obviously more valuable in the winter than low growing species. Holscher and Woolfolk recognize the variation in use to be expected from year to year and point out that one out of every five is a drought

year. This means that if use standards are to be followed in dry years, the grazing season must be shortened and large amounts of supplements fed, or livestock numbers drastically reduced.

Campbell and Crafts (1939), working on the Jornada range in New Mexico and the Santa Rita experimental range in Arizona, found that proper grazing utilizes about 50 percent of the total growth of black grama (*Bouteloua eriopoda*). This means that the grazed stubble should not be cropped closer than 2 or 3 inches above ground. They further qualify this standard of use by stating that 1/5 of the flower stalks and most of the stolons should be ungrazed.

#### Proper Use Guides on Forb and Browse Ranges

Only where forbs or browse make up a relatively low but important percentage of the composition, such as on sheep and big game ranges, would these plants be used for determining proper range use. On spring-fall sheep ranges in southern Idaho, Pechanec and Stewart (1949) found that deferred grazing especially favors perennial weeds (forbs), since these species are not taken readily except in the

spring. These workers further added that during the years of deferment the weeds or forbs receive almost complete rest from grazing. If early grazing is practiced, 40 to 60 percent of the more desirable grasses and weeds should remain ungrazed at the end of the spring season.

Talbot and Biswell (1942) reported that light, moderate, and

heavy grazing intensities had no great influence on composition of California annual ranges. However, they did find that grazed and protected areas differed greatly in the percentage of forbs—principally the filarees (*Erodium* spp.), bur clover (*Medicago hispida*)—and grasses. The grasses increased at the expense of the forbs on protected areas. From these results they concluded that not only can annual type ranges be grazed too closely, but some areas can be grazed too lightly—at least from the standpoint of maintaining a high percentage of forbs.

Several workers have studied the response of range shrubs or browse to clipping. Julander (1937) developed standards of use for two browse plants on the Kaibab National Forest in Utah. Aspen was considered as the key species on summer range. He concluded that aspen browse deteriorated if used 75 percent or more, was maintained with 70 to 75 percent use, and improved when used only 65 to 70 percent. Cliff rose, the key species on winter range in his study, if grazed more than 80 percent would deteriorate, would barely be maintained at 75 to 80 percent, would be adequately maintained at 70 to 75 percent, but for maximum recovery should not be grazed heavier than 45 to 65 percent. Although Julander did not state clearly his basis for percentage utilization, he did imply that it was based on current shoot production.

Young and Payne (1948) recommended that cropping up to 60 percent of the current twig growth of redstem ceanothus (*Ceanothus sanguineus*) was satisfactory for this species and other highly palatable browse plants in northern Idaho. Hormay (1943) concluded that about 40 percent of the season's twig growth should be left on bitterbrush (*Purshia tridentata*) to maintain satisfactory vigor and seed production. Garrison (1953), after clipping a number of im-

portant big game browse plants in the Northwest, stated that this treatment generally stimulated twig production to the detriment of flower and fruit production. As a result of his study, Garrison suggested some levels of use for sustained shrub production on winter ranges in Oregon and Washington. These standards varied from 50 to 60 percent removal on the more valuable browse and from 35 to 50 percent for the less preferred species.

Cronmiller (1953) reported on the value and management of deerbrush or sweet birch (*Ceanothus integerrimus*) in California. His report was based on a number of observations made on deerbrush plants browsed heavily for periods up to 35 years. According to him heavily grazed plants in open areas on the Plumas Forest appeared thrifty at the age of thirty years, but five years later were mostly dead. Biswell, *et al.* (1952) found that heavy browsing by deer kept mixed chaparral sprouts and seedlings in a low and productive condition. Under these conditions heavy browsing after the first couple of years is not particularly damaging, since new growth is protected by the old woody stems.

#### Use Standards for Improved Forage Species Grasses

Standards of use on improved pasture plants will depend both upon the growth habit and the season of growth as in native plants, except that more flexibility exists depending upon cultural treatments used. For example, fertilization and irrigation practices can both be used to greatly enhance productivity of improved forage grasses during periods of normally slow growth.

Orchardgrass (*Dactylis glomerata*) is a good example of an improved pasture grass whose productivity can be greatly enhanced by cultural practices.

Robinson and Sprague (1952) reported that dry matter production in July and August in Pennsylvania could be trebled by nitrogen alone, quadrupled by irrigation alone, and increased from 490 pounds under no treatment to 2830 pounds per acre, or nearly six times as much, when both nitrogen and irrigation were added.

Ahlgren (1956) groups the principal improved grass species into several categories depending on their adaptation and performance. He states that bluegrass (*Poa pratensis*), unlike taller grasses and legumes, may be closely and continuously grazed without serious injury to the sod, if it is limed and fertilized according to its needs. In contrast to this reaction of bluegrass, Ahlgren points out that brome grass (*Bromus inermis*) under frequent clipping or heavy grazing thins out and disappears. For example, in New Jersey tests cutting brome grass every time it reached a 5-inch height quickly reduced the stand and lowered the yield. Under this management bluegrass and weeds replaced the brome grass.

Orchardgrass is commonly grown in combination with legumes, particularly Ladino clover (*Trifolium repens*). Under these conditions, rotation grazing is usually practiced and the grass is rarely damaged. In fact, the usual difficulty experienced is in maintaining the legume, especially when nitrogen fertilizer is used. Workers generally recognize that the stand of orchardgrass may be reduced by continuous close grazing, but not as readily as with brome grass or timothy (*Phleum pratense*).

Few studies have been conducted on the proper use standards for improved or introduced species on range land. Frischknecht, *et al.* (1953) reported results of a grazing trial on crested wheatgrass (*Agropyron desertorum*) in Utah. This study was set up to measure cattle gains under

three intensities of grazing and four systems of grazing. Their planned intensities of use were: light, 50 percent; moderate, 65 percent; and heavy, 80 percent of the current year's growth. Their calculations were based on plants protected from grazing beneath cages. According to Cook and Stoddart's work (1953a) this means that percent removal would be lower on grazed plants than on the ungrazed used as a basis for comparison in this experiment. Frischknecht, *et al.* reported light and moderate intensities of use more satisfactory than heavy, and, if their figures are corrected to a grazed plant basis, moderate use would probably imply no heavier than 50 percent removal of the current season's growth.

#### Legumes and Grass-legume Mixtures

Although legumes are seldom grown in pure stands for grazing, it is important to consider their growth requirements in order to maintain them in a grass-legume mixture. Sprague (1952) found legumes to differ from grasses in that more of the carbohydrate reserves are stored in the roots and stolons of legumes rather than in the lower leaf sheaths or stubble, as in grasses. This means that the height of clippings is not as critical in legumes as is the frequency and season of defoliation. This is especially true for alfalfa (*Medicago sativa*) which requires a practice of intermittent grazing followed by an adequate time for recovery.

Dotzenko and Ahlgren (1951) studying an alfalfa-bromegrass mixture in New Jersey stated that frequent and early cutting reduced the yields as did delaying harvest beyond the one-half bloom stage for alfalfa. They concluded that cutting at the one-half bloom stage gave the maximum return in yield and quality without reducing or injuring the alfalfa-bromegrass stand.

Many workers have studied

the influence of time and height of cutting and fertilization on Ladino clover and various grasses. Sprague and Garber (1950), reporting on work with Ladino clover in mixtures with orchardgrass and bromegrass, state that the time of removal of the first crop in the spring was an important factor in determining the persistence of Ladino clover. This first crop, according to them, should be removed when it reaches a height of 8 to 10 inches. They further added that higher yields and more clover were obtained when cuttings were made closer to ground level. In their studies a 2-inch stubble height was more satisfactory than a 3-inch one.

Robinson, *et al.* (1952) studied the influence of irrigation, fertilizer, and clipping treatments on the persistence of Ladino clover in a Kentucky bluegrass sod. These workers used three clipping heights:  $\frac{1}{2}$ , 1, and 2 inches. Although highest average yields for a 4-year period were obtained by clipping to  $\frac{1}{2}$  inch, they noted that this clipping treatment was too severe for maintenance of a good sod of Kentucky bluegrass. They concluded that clipping to 1 inch gave high average yields and at the same time resulted in the maintenance of a good sod. An illustration used in their paper showed that Ladino clover persisted even under high nitrogen fertilization, where the herbage was clipped to 1 inch when 4 to 5 inches high.

From the limited examples cited here it is evident that the growth requirements of legumes and grasses are not fully compatible and that mixtures containing both must be grazed carefully to maintain a proper balance of the two. If it were not for bloat problems on high yielding legume pastures and nitrogen fixation to aid grass production, it is doubtful that graziers would be justified in trying to maintain fairly well balanced mixtures of grasses and legumes.

Indeed, it might be easier to maintain high producing grass swards apart from good legume stands. This practice may be followed eventually in our drier non-irrigated sections of the West. Under present management crested wheatgrass is recommended for good early forage, native bunchgrasses for the highest quality mid-season forage, and alfalfa for the most nutritious grazing in late summer and fall, when the grasses have dried and lost most of their protein content.

Sprague (1952) points out that in the humid and irrigated pasture areas maintenance of the legume is a primary objective in pasture management. According to him, in grass-legume associations grown for use as hay or silage, for use as pasture, or for dual use, the date of the first cutting in the spring, the height at which herbage is removed, and the length of recovery period should be such as to favor the legume. Use standards for these mixtures will depend upon the species used and the interactions of the management practices mentioned with fertility, irrigation, and weather factors. Regardless of the intensity of management and production involved on pastures containing improved forage species, grazing use must permit the forage plants to maintain enough photosynthetic leaf surface for adequate root growth and food storage in the stem bases and roots.

#### Important Factors Influencing Forage Use

Some of the important factors and their relationship to use standards have already been pointed out. Among these are: associated forage species, site, season of use, and kind and distribution of livestock which are most important on range lands, and compensating factors, such as fertilization, irrigation, and mechanical harvesting which are common to pastures.

### On Ranges

The relationship of use standards to life forms of the forage plants was discussed under consideration of native forage plants. The same problem is important in improved pastures where legumes and grasses are grown in mixtures. An additional problem is presented by differences in palatability of plants belonging to the same life form. For example, Campbell and Crafts (1939) state that where black and blue grama occur in mixture, utilization is satisfactory as soon as either one is properly grazed; usually the first to be so utilized is the blue grama. These same workers report that on run-down black grama ranges use will have to be considerably less if black grama is to be restored to dominance. They indicate that under these conditions only 30 percent of the grass by weight should be taken by the end of the season compared with 50 percent on good condition ranges.

Site may have important influences on use standards for range forages. Cook and Harris (1950), as a result of their studies in Utah, conclude that site conditions and stage of growth were important factors affecting the nutritive value of range forage. According to them, sites indirectly affected the chemical content of plants and plant parts through soil and plant development, water runoff, intensity of shade, and other environmental factors. In this writer's opinion, this supports the contention that a thorough knowledge of both soils and vegetation is necessary to provide the ecological background necessary for evaluating the influence of site on standards of use.

Regional ecological studies furnish suitable bases for development of range condition and trend studies if the reaction of plants to grazing is understood. The decreaser, increaser, and invader categories based on response to grazing pressure en-

able range operators and administrators to select the plants most useful in determining use standards. Generally speaking, range use as a whole will be determined by the impact of grazing on the decreaser and increaser species. If the ecology of the area is reasonably understood, this approach may be further simplified by selecting a key species upon which to base proper use. Decreaser species, such as bluebunch wheatgrass in the *Agropyron* zones of the Pacific Northwest or little bluestem (*Andropogon scoparius*) in the midgrass ranges of the Great Plains, are examples of typical key species used in determination of range utilization.

Nearly all of the investigators concerned with use standards of forage plants emphasize the importance of seasonal use in arriving at appropriate levels of grazing. For example, Craddock and Forsling (1938) state that serious range depletion occurred on four 80-acre range areas where for nine years from 19 to 68 percent of the available forage was utilized in the spring followed by the removal of 25 to 66 percent in the fall, or a total for the year of 82 to 93 percent. The degree of depletion on the four ranges was approximately directly proportional to the intensity of spring use. These same workers found that on another 80-acre range area on which 83 percent of all available forage was utilized in the fall and none in the spring the range definitely improved.

Pechanec and Stewart (1949) conclude that it is not necessary to have as much of the current herbage production of perennials left ungrazed at the end of the fall grazing season as at the end of the spring. They emphasize that, even though plants can stand heavier use in the fall than in the spring, fall grazing must be conservative. Similar results were obtained by Hedrick (1956) who reported on grazing use of tall fescue (*Festuca arundinacea*)

in August on nonirrigated pasture in western Oregon. Where this use varied between 25 and 50 percent, production the following April was reduced by one-half as compared with areas unused or very lightly grazed.

Currier (1956) studied range readiness of two grasses—crested wheatgrass (*Agropyron desertorum*) and Whitmar beardless wheatgrass (*Agropyron inerme*)—in central Oregon. He concluded that both grasses were ready to graze when about 35 percent of their total weight had developed. For crested wheatgrass this occurred when it had developed 5 inches of new height growth. Whitmar beardless wheatgrass did not reach this same stage until new growth was 10 inches high. The range readiness stage for crested wheatgrass was reached three weeks earlier than for Whitmar beardless wheatgrass. These data help explain the value of crested wheatgrass for early spring grazing. Perhaps crested wheatgrass is no more resistant to grazing, provided the native bunchgrass is allowed to reach range readiness before cropping is begun.

Range and pasture investigators have long recognized the difference in use standards applicable to important forage plants when grazed by different kinds of livestock. In general, horses have been recognized to be grass eaters; cattle choose grass, forb, and browse in that order; sheep prefer forbs and browse but also eat young and low growing grasses; and goats eat browse more effectively than other livestock. Most livestock producers on improved pastures adjust their seedings to fit the animals used. Range livestock graziers are not as fortunate in that they must adjust livestock to fit the native vegetation for most efficient use.

Cook (1954) found that on a summer range in Utah common use resulted in more uniform utilization than is obtained by single use. In order to prevent



overuse or double use he stated that the combined numbers of each kind of animal must be commensurate with forage production. Hopkin (1954) applied an economic analysis to Cook's data and found that the optimum combination of sheep and cattle on a given range is obtained by equating both physical and price relationships. This approach should be useful in making decisions about the proportions of kinds of livestock to use on a given range unit.

Davies (1952) concludes that mixed grazing has certain advantages over grazing with only one class of stock from the viewpoint of maximum production of livestock products. His conclusion is substantiated by graziers in New Zealand and Australia who use beef animals to consume coarse grass and other roughage unsuitable for sheep.

Humphrey (1949) points out that a range long overgrazed by sheep gradually changes in composition. He cites as an example heavy use of Sandberg's bluegrass (*Poa secunda*) and Idaho fescue (*Festuca idahoensis*) on a Palouse bunchgrass range grazed by sheep in the Northwest. Mature plants of bluebunch wheatgrass were lightly grazed but seedlings failed to develop since they were palatable to sheep. Also noticeably absent on these ranges heavily used by sheep are Sandberg's bluegrass and arrowleaf balsamroot, a valuable forb. Under these conditions, considerable sheet erosion may occur even though old, coarse bunchgrasses remain ungrazed. In contrast, on similar ranges heavily grazed only by cattle, balsamroot may be abundant as would Sandberg's bluegrass and Idaho fescue but bluebunch wheatgrass would be markedly reduced. On ranges like these, mixed grazing at a lighter intensity should undoubtedly provide a greater total amount of livestock products and still keep the soil surface well protected from excessive runoff and erosion.

The importance of livestock distribution in application of use standards on ranges has been recognized by a number of workers. Campbell (1943) reported utilization of black grama on southwestern ranges to vary directly with distance from stock water. Holscher and Woolfolk (1953) present data that illustrate how utilization of Northern Great Plains ranges varies in relation to the location of stock water. They noted heavy utilization with 200 yards of water on both winter and summer range and recommended more and smaller watering facilities placed closer together to reduce this concentration at any one place.

Harris (1954), reporting on fluctuations in forage utilization over a ten-year period on the Starkey Range in northeastern Oregon stated that use of elk sedge was increased from 20 to 38 percent by better distribution of cattle, by improved salting and riding practices. This range was made up of a mixture of grassland and timbered types. When not fenced separately, Harris considered the grassland to be the key area, since cattle graze the grasslands more closely than the timbered range. According to him unused forage in timbered areas may indicate the need for additional or different salt ground locations; the need for distributing a group of cattle in the area at the beginning of the grazing season; additional range riding throughout the season; or the need for additional water developments.

Although irrigation is generally considered a suitable treatment for high value cropland only, ranch operators are making remarkable range improvements through water spreading. Gift (1956) has increased production of dry rangeland covered principally with western juniper (*Juniperus occidentalis*), big sagebrush (*Artemisia tridentata*), and cheatgrass (*Bromus tectorum*) from 10 pounds to 250 pounds of beef per acre. He has

accomplished this change after irrigation and aerial seeding with improved grasses and legumes. This tremendous improvement enabled Mr. Gift to use a 7-day grazing rotation which is much more intensive use than can be practiced on comparable sites supporting only native range.

#### On Pastures

In pasture areas cultural treatments may be used advantageously to overcome problems of under and overgrazing by livestock. It has been recognized in the management of irrigated pastures that applications of nitrogen may serve as an effective means of increasing the grass component at the expense of the legume. This response may be a valuable aid in controlling bloat but generally will be less economical than depending on good grazing management to keep the proper balance between grasses and legumes.

Removal of heavy stands of forage by mechanical harvesters is another way of modifying pasture utilization. This method has two distinct advantages over the grazing animal as the only way to remove pasture herbage. In the first place it is not practical for most livestock producers to make significant seasonal changes in their stocking rate. Yet most forages produce a large bulk of their total production in a relatively short period. By taking off silage or hay crops surplus forage can be stored for periods of slack growth. Semple (1951) illustrates how New Zealanders fit their livestock production to the growth curve of the grass. Silage and hay which is cut from pastures during the flush growth is fed during periods of poor pasture growth in mid-winter and mid-summer.

Another advantage is the opportunity that mechanical harvesting offers in the control of undesirable plants. Animals graze selectively and grazing pressure must be carefully regulated in order to keep the less

preferred species from gaining dominance. Occasionally even good forage species form "wolf" plants that are lightly grazed. Under these conditions clipping may be helpful in obtaining more uniform utilization.

### Proper Use and Special Grazing Systems

Much controversy has developed over the merits of certain grazing systems, particularly rotation grazing where applied to range grasses (Sampson, 1951). There are two general conclusions regarding the merit of deferred-rotation grazing systems. Most of the favorable reports have been from bunchgrass ranges in the Northwest characterized by winter precipitation. Results from experiments in the Great Plains and Southeast where rainfall occurs during the growing season have generally shown continuous or season-long grazing to be more satisfactory.

Exceptions have been noted in both areas. Hyder and Sawyer (1951) reported season-long grazing to be more satisfactory for sagebrush-bunchgrass ranges in central Oregon than rotation grazing. Hyder (1952) recognized that too early grazing put deferred-rotation at a disadvantage in terms of seasonal balance of cropping. Hence, the failure of deferred-rotation grazing under these conditions might have been caused by too early grazing. Puckett (1956), reporting on his ranch operations in western Texas during seven years of drought, states that no tool available to the ranch manager gets the same results as deferred and rotation grazing in pastures. The success of his management is probably accounted for by his use of flexible periods depending on weather and amount of use. He pointed out a dual advantage of stocking fewer pastures—it keeps a maximum area vacated and cuts operational costs. Similar advantages to a flexible two-pasture system of rotation in the brush country of south Texas

have been noted by the writer.

On improved pastures intensive systems of grazing have been commonly used. Recently considerable attention has been directed toward the use of daily ration or strip grazing. McMeekan (1956) reported on the results of three experiments conducted in New Zealand to evaluate strip versus paddock grazing. Although he pointed out that strip or "break-feeding" may be advantageous during periods of limited forage, there was no marked superiority of the break (strip) over the paddock (rotational) grazing system during the main period of pasture growth.

In conclusion, it seems to the writer that most controversies have developed over the value of special systems *per se* rather than the opportunities which they offer to effectively reconcile requirements of plant growth with livestock needs. The real value of any grazing system should be the degree of flexibility that it affords the livestock producer and grazing administrator in securing proper forage use.

### Summary

A review of literature on the physiological aspects of range and pasture use was made with two purposes in mind: (1) to point out the basis for developing proper use standards applicable on both native and improved forage species, and (2) to consider some of the important factors influencing forage use.

Tracing the historical development of philosophies toward range use a change from accent on forage removal to forage remaining was noted. This latter approach recognizes the futility of reconstructing herbage removal when production varies widely among years, sites, and condition classes.

Although the importance of managing rangelands based on the growth requirements and life

histories of the principal forage plants was emphasized by Sampson in 1914, lack of knowledge on the response of individual plants to grazing is still hampering the application of proper range and pasture management.

How grazing or top removal influences the plant is dependent primarily on the intensity, frequency, and season of use. In general too heavy, too early, and too frequent removal has resulted in declining forage vigor. The greatest damage occurs during periods of minimum food storage and markedly influences root growth prior to any visible effect on the top. Crider's work (1955) supports the viewpoint that standards of use are similar for both native and improved forage species.

Use standards for native ranges supporting grass, forb, and browse forage were reviewed. Influences of growth form, site, season of use, range condition, and climatic variations on these guides were pointed out. In discussing standards for improved forage species it was found that these differed from native species only in the degree of flexibility afforded by interaction of cultural treatments and the specific problems involved in the maintenance of legume-grass mixtures.

Important factors influencing forage use could be broken into two groups—those most important on rangelands and those common to pastures. The fact that these groups are not exclusively limited to ranges and pastures was emphasized. The successful use of irrigation and seeding on otherwise undisturbed native range was cited as an example of using cultural practices on rangeland. On the other hand, failure of irrigation and fertilizer practices as a substitute for proper grazing management on improved species was pointed out.

Examples were given to illustrate that special grazing systems provide no panacea in grazing



management but, if used intelligently, do offer opportunities for better reconciling plant and livestock needs.

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