PERENNIAL GRASS COMPOSITION AS AN INDICATOR OF CONDITION OF SOUTHWESTERN MIXED GRASS RANGES

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INTRODUCTION

Events usually record their own history. Main results stand forth boldly, but the signs which foreshadow them often are unnoticed. So it is with the marks left by good and poor range management. Realizing that the range can tell its own story best, range managers have come to rely on "indicators" that may be observed on the ground and which reflect the condition of the range (Talbot, '37).

Among the commonly noted indicators of the condition of the range are density of forage plant cover, whether unpalatable and noxious plants occur in normal or abnormal abundance, and the absence or presence of accelerated soil erosion. Usually these indicators are evidence of a condition already existing. In the Southwest often they fail to indicate early stages of range recovery or to forewarn of impending range deterioration. For example, unpalatable deep-rooted shrubs are less important in indicator value than perennial grasses because they may move in slowly on overused ranges and often persist even though the grass cover has improved under good range management.

Investigations conducted on the Santa Rita Experimental Range [2] show that the native grasses exhibit marked individuality in their response to various intensities of grazing and thereby indicate the early stages of trend either toward range recovery or toward range deterioration. This phenomenon is possible because the perennial grasses bear the brunt of grazing and therefore show an earlier response than do lightly grazed or non-grazed associated plants.

The present condition of grazing lands indicates that there is a serious need for additional guides or criteria on which needed changes in range management can be made.

The purpose of this article is twofold:

1. To present data regarding the floristic composition of perennial grass population as indicators of range recovery and range deterioration on mixed grass ranges of southern Arizona;

2. To portray the characteristic perennial grass patterns resulting from different grazing treatments on two specific range types on the Santa Rita Experimental Range in order to aid in the recognition of similar relationships on comparable ranges.

The vegetation of the Santa Rita Experimental Range includes three common southern Arizona plant associations, namely, the desert shrub, the mesa type (mesquite grassland), and the foothill type (or mixed grama grassland). The desert shrub and mesquite grassland associations are described in detail by Shantz ('24). All of these associations are included in the "lower Sonoran" life zone according to Merriam's ('98) classification. However, only the mesa and foothill forage types, which together form the bulk of the grasslands on the Santa Rita, are considered herein. Botanical names of plants referred to in this article are in accordance with the taxonomy of Kearney and Peebles ('42).

[1] Maintained by the Forest Service, U. S. Department of Agriculture, for Arizona, New Mexico, and West Texas, with headquarters at Tucson, Ariz.

[2] Branch of the Southwestern Forest and Range Experiment Station located 38 miles south of Tucson, Ariz.

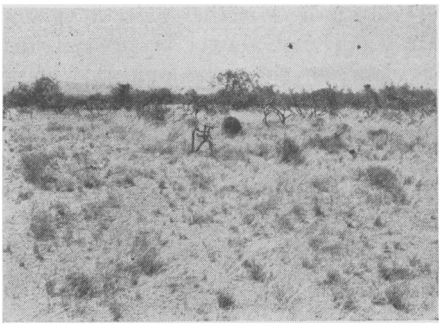

FIG. 1. Mesa type range in good condition. Note the abundance of bunchgrass and the few scattered burroweed plants, cholla cactus, and the mesquite in the background. These noxious plants spread and increase more rapidly in abundance as the perennial grass cover is thinned out by heavy grazing use than under moderate use which permits the maintenance of a good grass cover.

THE MESA TYPE RANGE

Description

The mesa forage type (fig. 1) is confined to the relatively level tablelands above the valley rims and below the foothills which skirt the Santa Rita mountains. According to Shreve ('15) this type would occur primarily in the upper desert with some overlapping into his lower bajada subdivisions of the desert region.

The elevational range of this type is from 3000 to 4000 feet. Vegetational development varies at the upper limits with the distribution of rainfall, characteristic topography, and soils.

Annual rainfall ranges from 12 to 17 inches with a mean for the type of about 13.5 inches.

Topography is generally flat or rolling with a moderate westward slope broken by numerous arroyos and minor drainage channels.

Soils of the Comoro series (Youngs et al., '31) are the most extensive soil types occurring on the Santa Rita Experimental Range. The mesa forage type occurs chiefly in the Comoro coarse sandy loam and a lesser amount in the Comoro sandy loam soils. The upper horizons of Comoro coarse sandy loam are usually 1½ to 2½ feet deep. The subsoil is a loose, coarse sandy loam. Parent materials from which this soil was derived are granite, syenite, and associated igneous rocks. These Comoro soils are similar in general structure to the Comoro sandy loam, being derived from finer grained igneous rocks and having a finer textured medium sandy loam surface layer.

As a general rule the fertility of the mesa soils is relatively high but they rarely attain their potential productivity because of low rainfall. Exposed topsoil is eroded easily by both wind and water once the vegetational cover is broken down.

Formerly the vegetation of the mesa type was primarily grassland with scattered shrubs and trees. Shrubs and half shrubs are now more prevalent. On ranges in good condition the following grasses named in order of abundance are the chief forage species: Arizona cottongrass (*Trichachne californica* (Benth.) Chase), black grama (*Bouteloua eriopoda* Torr.), threeawn grasses (*Aristida* spp., principally *A. glabrata* (Vasey) Hitchc. and *A. hamulosa* Henr.), bush muhly (*Muhlenbergia porteri* Scribn.), Rothrock grama (*Bouteloua rothrocki* Vasey), tanglehead (*Heteropogon contortus* (L.) Beauv.), and sideoats grama (*B. curtipendula* (Michx.) Torr.). Other grasses, of which individual species are generally less than 1 per cent of the total stand, are an important part of the perennial grass population. On conservatively grazed ranges these grasses in the aggregate represent as much as 10 per cent of the total grass cover. The more prominent of these grasses are slender grama (*B. filiformis* (Fourn.) Griffiths), sprucegrama (*B. chondrosioides* (H. B. K.) Benth.), hairy grama (*B. hirsuta* Lag. var. Cienc.), vine mesquite (*Panicum obtusum* H. B. K.), curlymesquite (*Hilaria belangeri* (Steud.) Nash), plains bristlegrass (*Setaria macrostachya* H. B. K.) and dropseed grasses (*Sporobolus contractus* Hitchc., *S. cryptandrus* (Torr.)

A. Gray and *S. airoides* Torr.). Numerous other grasses are still more rare in their occurrence.

Much of the better forage-producing area is characterized by stands of native grasses with velvet mesquite (*Prosopis velutina* Woot.) and other shrubs restricted to the margins of drainage channels. Several forms of cacti are always present.

Perennial grass indicators for mesa type range

Perennial grasses of the mesa type that are most important as indicators include the following: Rothrock grama, Arizona cottongrass, bush muhly, threeawn grasses (chiefly *Aristida glabrata*), and a variety of other species, none of which equals as much as 1 per cent of the total forage cover. These "other grasses" include hairy grama, vine mesquite, curlymesquite, dropseed grasses, and plains bristlegrass.

Identical composition percentages of any one grass should not be expected on different ranges, regardless of how nearly the ranges may appear to be alike in their general aspect. Furthermore, a specific grass, which is known to be an outstanding indicator for the type in general, locally may not always be present in the abundance or show the abnormal scarcity expected of it; but when all signs are considered, the sum of the botanical analysis is significant.

The percentages of composition of the principal grasses as they occur in the mesa type under different grazing treatment at the Santa Rita Experimental Range are presented in table I. Data for this table were obtained from the following sources: Range depletion, column 1, is based on 127 meter square quadrats which had been charted annually from 1915 to 1935. Range recovery under conservative grazing, column 2, is based on three samplings using the line interception method made each June 1941 to 1943, inclusive. Short time protection, column 3, is based on 19 exclosures 50 by 75 feet protected from livestock grazing for 5 years; and long time protection, column 4, is based on the results obtained from 17 exclosures 50 by 75 feet protected for 25 years. All exclosures were intensively sampled one time only with the line interception method (Canfield, '41). Area of mesa type pastures over which the samples were spread was ap-

TABLE I.—*Percentages of principal grasses which are characteristic of mesa type range conditions*

Indicator grasses	Range depletion after heavy grazing	Range improvement		
		Conservatively grazed for 5 years	Protected for 5 years	Protected for 25 years
	Per cent	*Per cent*	*Per cent*	*Per cent*
Threeawn (*Aristida* spp.)	10	23	24	14
Slender grama (*Bouteloua filiformis*)	5	11	0	1
Black grama (*Bouteloua eriopoda*)	15	8	16	26
Rothrock grama (*Bouteloua rothrocki*)	64	8	7	7
Sideoats grama (*Bouteloua curtipendula*)	Trace	3	2	2
Tanglehead (*Heteropogon contortus*)	3	2	7	3
Arizona cottongrass (*Trichachne californica*)	2	22	19	26
Bush muhly (*Muhlenbergia porteri*)	Trace	12	16	11
Other grasses [1]	1	11	9	10
Total per cent	100	100	100	100

[1] Occasional plants of many grasses, no species of which is ever abundant (less than 1 per cent of total grass) but which, when good range management prevails, occur sparsely on the better sites. This group contains hairy grama, curlymesquite, dropseed grasses, plains bristlegrass, and a few even less abundant grasses.

proximately 15,500 acres. The data in table I represent the average conditions found under the indicated grazing practice and periods of protection. Observations made at the Southwestern station and more comprehensive tests made by Anderson ('42) show that, in general, the density obtained from charted quadrats and that obtained by sampling with the line interception method agree closely.

As may be observed in table I, percentage composition of nearly all the grasses is affected by grazing and by protection from grazing. Usually there is a logical explanation for the differences. Some of the variation in composition apparent between the columns is due to the inherent peculiarities of the plants. For example, tall threeawn grasses are likely to be prominent grasses during the first years of range recovery because of their ability to occupy available space quickly. They are also present on deteriorating ranges and on ranges that are presumably in top condition after years of protection. Some of the reasons why tall threeawn grasses are prominent components of the mesa type are as follows: These grasses reproduce from an awned seed that is readily transported by wind and by clinging to the coats of animals, which gives them a wide range of dispersal. Awns and sharp-pointed seeds, which injure the grazing animal's mouth, make threeawn forage less preferred during the period of seed production and until after seed dispersal. This period of nongrazing favors both the parent plant and seed production. A further advantage possessed by the threeawn grass is that its pointed seeds are forced into the ground by any slight movement from wind or the movement of their hygroscopically sensitive bristles; thus they are self-planting.

The increase in the percentage of threeawn grasses, shown in the second and third columns of table I, which occurred with range improvement under conservative grazing and total protection for 5 years is explained by: (1) a fairly high percentage of established threeawn plants at the beginning the 5-year periods; (2) improving site conditions which probably increased survival rate of both old and new plants; (3) capacity to occupy and hold ground against less well established competing plants.

The percentage composition of threeawn on the long-time protected plot is about one-half as great as that occurring in areas that are still in the process of recovery. This decrease in percentage composition of threeawn grass with 25 years of protection (column 4) may be explained by the competition from robust, well established plants of other species, especially black grama and Arizona cottongrass. Although after 25 years of protection from livestock grazing the threeawn grasses become secondary in importance to black grama and Arizona cottongrass, they are still an important constituent of the composition. Hence, the common occurrence of tall threeawn grasses is characteristic of mesa ranges in good condition.

Slender grama is probably a subclimax species in the mesa type. As shown in columns 3 and 4 of table I, it cannot survive competition from the taller more robust grasses under protection. On the other hand, this grass is highly resistant to grazing. As is indicated in columns 1 and 2 of table I, slender grama is common on deteriorated range and is capable of a substantial degree of expansion while the range is improving during the first years of conservative grazing. Slender grama is able to survive heavy use chiefly because it is a prolific seeder and reproduces vigorously when moisture conditions are favorable and unoccupied ground is available.

Black grama is definitely a member of the climax in the mesa type and on the Santa Rita is one of the moderately relished grasses. However, this grass is commonly found on deteriorated mesquite grassland ranges (column 1 of table I). Field observations indicate that under de-

teriorating range conditions black grama survives because it is less susceptible to adverse conditions of either overgrazing or drought. However, on ranges with sandy soils subject to easy movement by wind this species is easily killed out by heavy use and subsequent covering with wind-deposited sand.

Comparisons made between the percentages of black grama occurring on conservatively grazed range (column 2) during a period of range recovery and on deteriorated range (column 1) give the impression that during a period of range recovery a severe loss of black grama may occur on conservatively grazed range. This loss is only apparent. When the two percentages are compared on a weighted basis (per cent ground cover multiplied by per cent composition), little or no reduction in the actual amount of black grama occurs. What does happen is that in the early stages of range recovery black grama may show little change in abundance while the total amount of ground occupied by other perennial grasses increases greatly. Contrary to superficial appearances, black grama does not increase under overgrazing. It merely persists and remains as a remnant of the former grass cover. This is especially true on firm soils.

Another characteristic peculiarity of this grass is that during the period of range recovery under total protection black grama increases in abundance at a faster rate than it does under conservative yearlong use (table I, column 3). Why this difference should occur in the case of black grama while the other principal grasses of the climax do almost as well under conservative grazing as they do under total protection is accounted for by their different methods of reproduction. Black grama reproduces mainly vegetatively by means of stolons—the other principal grasses from seed. Although black grama also produces seed as other grasses do, a black grama seedling is relatively rare. New plants of black grama in the majority of instances spring from the rooting joints of the prostrate stems. However, the existence of ungrazed stolons is not all that is required for the production of new plants. The stolons must not be torn from the soil while the process of rooting is taking place. A top layer of loose, friable, water-retaining sandy soil high in organic matter presents conditions that are most favorable for black grama reproduction. Complete protection of the range in the summer greatly favors regeneration of black grama. Hence, deferred and rotation grazing instead of yearlong use can be practiced to advantage especially on deteriorated mesa type range. Protection from grazing during the growth season favors reproduction of other desirable perennial grasses and promotes increased plant vigor.

Rothrock grama reproduces from seed and has a definite propensity for expansion only in seasons of exceptionally favorable rainfall or when the competition from grasses higher on the scale of succession is reduced either by excessive grazing or drought. Consequently, it does not become permanently a major species as judged by its relative abundance, except on range that has deteriorated (column 1, table I). The fact that this grass is a short-lived perennial which relies on frequent replacement by new plants to maintain or to increase its stand is demonstrated by the marked reduction in relative abundance on ranges that are improving under conservative use or under total protection (columns 2, 3, 4, table I). It appears to be generally accepted that Rothrock grama is the principal grass species of the lower successional stages (Whitfield and Beutner, '38).

Sideoats grama is seldom sufficiently abundant in the mesa type to be regarded as an important forage species. When the range is in poor condition, no more than a trace of this grass is to be found, although when the range is in good condition, 2 or 3 per cent of the perennial grass population is likely to be sideoats grama. Usually it is confined to the

north exposures of drainage channels but an occasional plant may be found on other sites wherever soil and moisture conditions are favorable.

Tanglehead is a tall, robust bunchgrass which appears to maintain a fairly consistent degree of relative abundance regardless of range condition. An exception is the marked increase in abundance during the first years of protection from grazing (column 3, table 1).

Arizona cottongrass is found only in remnant amounts on mesa ranges in unsatisfactory condition. On overstocked ranges it is commonly grazed to ground level, soon becomes confined to the protection of shrubs, and eventually is reduced to a low percentage. On the other hand, the increase in abundance of Arizona cottongrass is the most conspicuous if not the first sign of range recovery under either conservative grazing or total protection.

Bush muhly is another grass which practically disappears when the range becomes deteriorated. It is also a substantial component of the mesa type range in process of recovery. Conspicuous tufts of this grass growing in the open are a good sign (Wooton, '16).

Composition patterns which indicate range conditions in the mesa type

Characteristic composition of range in unsatisfactory condition.[3] The example of deteriorated range shown in section "A" of figure 2 illustrates the characteristics of the perennial forage cover on mesa type ranges that are in unsatisfactory condition.

This example represents but a single range and a single stage in range deterioration. In field application of the information, variation in the composition

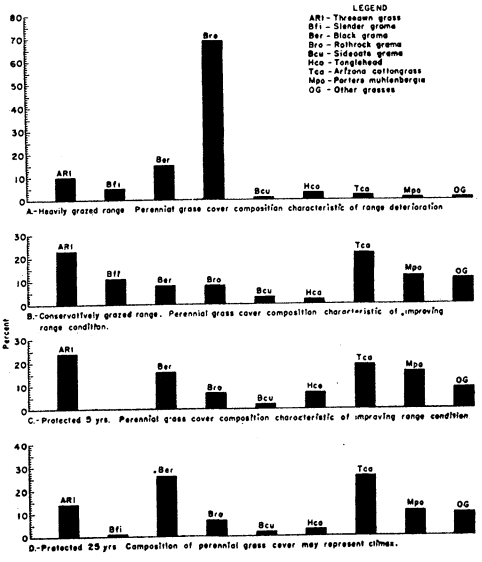

FIG. 2. Percentage distribution of perennial grass species on mesa type range under grazing use and protection.

of population patterns must be expected. Different degrees of deterioration will accentuate one part and obscure another part of the population pattern depending on the extent to which the harmful processes have progressed. Therefore, it is essential that the range examiner study the general overall pattern of the perennial grass composition rather than exact percentages of individual species. A proper interpretation of the sum of the following signs indicates the range to be in unsatisfactory condition:

1. Rothrock grama is the predominant grass, even in years of extreme drought.
2. Arizona cottongrass is a minor species that is far outstripped in abundance by Rothrock grama and perhaps is even less abundant than tanglehead. (On ranges in good condition it should be one of the principal forage species and by far the most conspicuous one.)
3. "Other grasses"—a very important indicator group composed of numerous species of relatively rare and less hardy grasses—are almost

[3] "Range condition" as used herein refers mainly to the phase represented by the floristic composition of the grasses. Unsatisfactory condition is indicated when the vegetation is dominated by grasses characteristic of the lower stages of plant succession. On the other hand, satisfactory condition is indicated by the prevalence of robust climax or subclimax species.

entirely absent on the deteriorated range. Much weight should be given to the less-than-normal number of different grasses in appraising range conditions.

4. Bush muhly is present in very small amounts. Such clumps as have survived are sheltered by shrubs or cacti. Practically no tufts of this grass are growing in the open where they can be grazed.
5. Threeawn grasses are less abundant than black grama and Rothrock grama.
6. Black grama, owing to its high degree of resistance to grazing damage, is likely to be the second most abundant grass. However, the plants are conspicuously aged remnants of much larger tufts.
7. Slender grama is present as small and new tufts but is less abundant than either threeawn or black grama.
8. Sideoats grama is not a particularly strong indicator grass and on overgrazed ranges its occurrence is restricted to the less accessible areas. (However, some of it should be present in places accessible to grazing when the range is in good shape.)
9. Tanglehead is present in small amounts, probably as relics of old tufts.

In summing up the perennial grass pattern which indicates deteriorated mesa type range, the critical points are the overabundance of Rothrock grama, the relative scarcity of Arizona cottongrass and bush muhly, and the almost total absence of the several rare but important indicator species. It may be confidently stated that the range is deteriorated when these occur in combination—especially when the findings are supported by other circumstances such as signs of continuous heavy utilization, low forage plant vigor and accelerated erosion.

Characteristic composition of conservatively grazed range in satisfactory condition. Relative abundance of perennial grasses as they occur on conservatively grazed mesa range that is well advanced toward recovery is shown in section "B" of figure 2. Obviously ranges in various stages of recovery may be expected to vary somewhat in composition from that shown. A number of points which deserve particular attention as indicators of satisfactory condition and range recovery on mesa type ranges are as follows:

1. The threeawn grasses surpass black grama in abundance.
2. Slender grama, although it is not a prominent grass in the climax stage, may also have an abundance that is equal to or greater than that of either Rothrock grama or black grama.
3. Black grama, because of its slower rate of reproduction, may appear from the composition percentage to lose ground during the early stages of range recovery. However, range improvement is indicated by increased vigor of individual black grama plants.
4. Rothrock grama is about equal in abundance to black and slender grama. It is no longer the dominant grass and drops precipitously in relative abundance when the range is recovering.
5. Sideoats grama increases in abundance with range recovery.
6. Tanglehead shows more vigorous growth but little change in relative abundance.
7. Arizona cottongrass increases in a spectacular manner. This grass is likely to be equal to threeawn in abundance during the early stages of range recovery and to equal or exceed any two of the grama grasses in the more advanced stages of range recovery.
8. Bush muhly grows out in the open instead of growing only under the protection of bushes or other ob-

structions to grazing. It will tend to equal or exceed black grama in abundance as range recovery progresses.

9. Other grasses begin to occur in quantities that provide a substantial addition to the forage crop. One of the best and earliest indications of range recovery is the increase in the number of different kinds of grasses that can be listed. The more complete the range recovery, the easier it is to find more of the minor forage grasses.

Rate of range recovery under nongrazing. Data contained in section "C" of figure 2 were obtained from 19 plots 50 by 75 feet which had been fenced to exclude grazing by domestic animals for a period of 5 years. The perennial grass population pattern indicates that on the average the rate of range recovery was very satisfactory. A comparison between the population pattern of the protected range in section "C" and the conservatively grazed range presented in section "B" indicates, on the surface, that in this particular example there was but little general gain from total protection. With 5 years' protection there was a definite improvement in the composition in the form of an increase in the percentage of black grama and the virtual disappearance of the slender grama. Otherwise, the perennial grass population patterns are substantially the same for both the conservatively grazed and the 5-year protected range. However, this one example taken from a range with its basic soil mostly intact does not rule out total protection as a valuable method for regenerating badly deteriorated ranges. Wooton ('16) found that a lightly grazed range took twice as long to recover to the same degree as a protected range. However, the concept of "light grazing" in 1916 would very likely be considered as of heavier intensity according to present-day standards. In many instances it has been demonstrated that recovery of range in very poor condition is slowed down when even moderate grazing is permitted.

Stabilized condition on mesa type range. The exact composition of the perennial grass population of the climax stage on mesa type range is not definitely known. The example in section "D" of figure 2 shows the population pattern of perennial grass cover after protection from livestock grazing for 25 years. Although this pattern may not represent the original climax before domestic livestock was introduced, it does furnish a starting point from which approximations of degree of range deterioration and degree of range recovery may be measured. Using this example as a basis, the earmarks of the composition pattern for a stabilized condition are:

1. Black grama and Arizona cottongrass are the most abundant species, together making up about one-half of the total forage cover. Although these grasses are about equally abundant, the tall cottongrass will appear to dominate the range and during years of favorable rainfall the aspect will be one of a mid-grass association. In abundance they exceed the threeawn grasses.
2. Slender grama, although a desirable forage species, has become an inconspicuous part of the perennial grass population.
3. Rothrock grama is a relatively minor species.
4. Bush muhly will be found growing in the open, beyond the protection of shrubs and in abundance about equal to that of the tall threeawn grasses.
5. Various species herein designated as "other grasses" are present in substantial quantities which collectively equal about 10 per cent of the total grass cover. The more common of these grasses found on mesa type ranges are dropseed grasses, bristlegrass, vine mesquite, and traces of hairy grama and curlymesquite.

The Foothill Type Range

Description

The foothill type range (figs. 3 and 4) begins at the upper margin of the mesa type and extends up the lower slopes and over the foothills to the lower edges of the Encinal region which is characterized by evergreen oaks. Elevations of the foothill type are generally between 4000 and 4500 feet.

Rainfall ranges from 17 to 22 inches annually with a mean for the type of about 18.5 inches.

Fig. 3. A fenced foothill plot showing the general aspect of the vegetation. Note the heavy stand of coarse-stemmed grasses growing on the inside of the enclosure, which are characteristic of foothill range in good condition but ungrazed for 25 years. These grasses are largely lacking on range in poor condition.

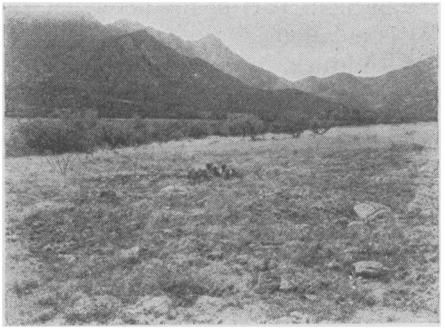

Fig. 4. Foothill type range with a good stand of bunchgrass moderately grazed but in good condition. Note the normally sparse pricklypear in the center, and the mesquite restricted to a narrow strip along the watercourse. This photograph was taken near the end of the grazing year.

Soils of the Tumacacori series, principally the Tumacacori coarse sandy loam, are the prevailing soils (Youngs et al., '31). These soils differ from the soils of the mesa type in that they are darker in color and generally have a higher content of organic materials. The Tumacacori coarse sandy loam is characterized by a surface layer of dark brown, coarse, sandy, or gravelly loam ranging from a few inches to a foot in thickness. Near the mountains broken rock and boulders are common. Parent materials are largely granite and syenite. Soils of the foothill type erode readily after the grass cover is broken down.

Vegetation is generally similar to that of the mesa type. It differs, however, in several specific points. Cacti and half-shrubs are rare. Perennial grass cover is greater in density; measurements show that the percentage of ground occupied by grass is, on the average, almost double that of the mesa type.

Floristic composition of the perennial grass population is also a point of difference between the two types. Named in order of relative abundance as they occur on range in good condition they are Arizona cottongrass, slender grama, sideoats grama, threeawn grasses (chiefly *Aristida hamulosa*), black grama, tanglehead, hairy grama, and Rothrock grama. Minor species which occur in small amount individually but in the aggregate make up a substantial amount are Cane beardgrass (*Andropogon barbinodis* Lag.), spike dropseed (*Sporobolus contractus*), sand dropseed (*S. cryptandrus*), Texas timothy (*Lycurus phleoides* H. B. K.), green sprangletop (*Leptochloa dubia* H. B. K.), plains lovegrass (*Eragrostis intermedia* Hitchc.), bush muhly, and curlymesquite.

Shrubs and half-shrubs are usually present along the arroyos. Mesquite and catclaw (*Acacia greggi* A. Gray) are abundant in the arroyos and along their margins. Under grazing use and protection from fire these plants escape from the drainage channels and invade the

adjacent grasslands. Cactus is mostly the sprawling pricklypear (*Opuntia engelmanni* Salm-Dyck. ex Englm.). Rarely is an arborescent species of cactus found in the type.

Perennial grass indicators for foothill type ranges

The chief perennial grasses of the foothill type include the principal genera and most of the species of the mesa type. There is, however, a great difference in both the density of the forage cover and the relative abundance of the species.

Greater rainfall and soil differences are doubtless responsible for the characteristic vegetation which makes possible the differentiation between the mesa and foothill types. On undeteriorated ranges the perennials occur in the following order of abundance: Arizona cottongrass, "other grasses," slender grama, sideoats grama, threeawn grasses, black grama, tanglehead, hairy grama, Rothrock grama, and a small amount of curlymesquite.

"Other grasses"—the group of several species none of which represents as much as 1 per cent of the total grass stand—include such grasses as: Texas timothy, green sprangletop, plains lovegrass, sand dropseed, and bush muhly. The greater the number of different grasses found on a mixed grass type the better the indications are that good range management exists thereon. Examples, representing approximately 17,000 acres of foothill ranges, which show how the perennial grass composition is affected by heavy and conservative grazing and by short and long periods of protection from livestock are presented in table II.

The manner in which the data shown in table II were obtained is the same as that described for the mesa type. Annual chartings of meter-square quadrats made each year from 1915 to 1935 are the basis of the composition percentages in column 1 under the heading "range depletion." The data in column 2 were obtained in pastures "conservatively grazed 5 years" by the line interception method of sampling. Columns 3 and 4 represent data obtained in a like manner from 38 fenced plots 50 by 75 feet. Half of the plots had been fenced for 5 years and the other half for a longer period (approximately 25 years).

Differences in grass composition between deteriorated foothill range, the stages of range recovery under conservative grazing, and range protected from livestock are, in the main, similar to

TABLE II. *Percentages of principal grasses which are characteristic of foothill type range conditions*

Indicator grasses	Range depletion after heavy grazing	Range improvement		
		Conservatively grazed for 5 years	Protected for 5 years	Protected for 25 years
	Per cent	*Per cent*	*Per cent*	*Per cent*
Threeawn grasses (*Aristida* spp.)	5	11	15	9
Slender grama (*Bouteloua filiformis*)	49	44	27	15
Black grama (*Bouteloua eriopoda*)	5	5	10	7
Hairy grama (*Bouteloua hirsuta*)	2	3	3	3
Rothrock grama (*Bouteloua rothrocki*)	12	3	2	2
Sideoats grama (*Bouteloua curtipendula*)	6	14	18	10
Curlymesquite (*Hilaria belangeri*)	13	4	2	1
Tanglehead (*Heteropogon contortus*)	1	2	2	5
Arizona cottongrass (*Trichachne californica*)	6	6	11	31
Other grasses [1]	1	8	10	17
Total	100	100	100	100

[1] A grouping of many grasses, no species of which is ever abundant (in our examples less than 1 per cent per individual species) but which when good range management prevails contribute substantially to the forage crop and are key indicator species of good condition.

those shown for the mesa type. Certain exceptions to this general response should be noted. For example, the slender grama is the most abundant grass on deteriorated foothill range. It is also present in substantial abundance in the foothill type even after years of protection. On the other hand, Rothrock grama, although of less abundance in the foothill type, responds to grazing pressure about as it did in the mesa type.

Composition which indicates deteriorated range and that which indicates range recovery in the foothill type parallel similar conditions in the mesa type. Grasses such as slender grama and Rothrock grama which are short lived and reproduce readily from seed, or curlymesquite which grows matlike close to the ground, are the principal grasses of deteriorated foothill type ranges. Composition which indicates range recovery in the foothill type includes with one exception the same tall robust grasses that have been cited as indicators of range recovery in the mesa type. The exception is bush muhly. This grass does not grow well under any condition of use in the foothill type.

The minor species included in the table under the term "other grasses" increase in abundance as grazing practice and the range improve.

In general each grass or group of grasses of the foothill type has its place in the normal composition pattern. A changing pattern indicates good or poor range management depending on whether the direction of change is toward or away from the climax pattern.

Composition patterns which indicate range conditions in the foothill type

Examples of perennial grass population patterns representing one stage of range depletion in progress and three stages of range recovery are presented in figure 5.

Characteristic composition of range in unsatisfactory condition. An example of the perennial grass composition pattern associated with deteriorated mixed grass foothill range is shown in section A of figure 5. Although the process of range deterioration has not reached an extreme stage in this example, the downward trend is clearly indicated by the relative abundance of the forage grasses. Points which aid in identifying certain details of this composition pattern are:

1. Where slender grama either approaches or exceeds 50 per cent of the perennial grass stand, the range condition should be viewed with suspicion. However, the relative abundance of a single species is not always sufficient to determine the direction of trend. For example, when slender grama becomes established in quantity it is slow to recede from this dominant position as the trend in range condition begins an upward swing. If slender grama is the principal perennial grass, the observer should be on the alert for more definite indicators of trend. When the trend is downward, conditions which are described in the following paragraphs will be apparent.

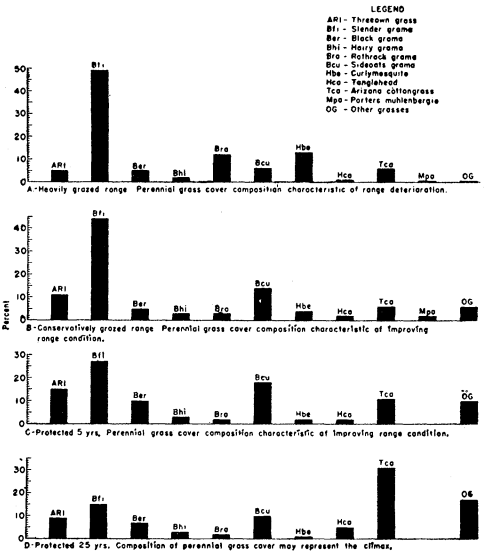

FIG. 5. Percentage distribution of perennial grass species on foothill type range under grazing use and protection.

2. Curlymesquite is the next most abundant grass, making up about 13 per cent of the total perennial grass cover. This grass produces good quality forage, is highly relished by livestock, reproduces readily from stolons and seed, and forms a good protective cover for the soil. However, the volume of forage produced is lower than that of the taller grasses which become relatively more abundant under conservative grazing use.

3. Rothrock grama is about equal in abundance to curlymesquite and is likely to exceed the combined percentages of black grama and Arizona cottongrass. Under the more favorable moisture conditions of the foothill type range, Rothrock grama meets greater competition from other grasses and seldom becomes as abundant as in the lower, drier mesa type.

4. Tall threeawn grasses (principally *Aristida hamulosa*), sideoats grama, and Arizona cottongrass are all minor species and each is about one-tenth as abundant as slender grama and only about one-third as abundant as Rothrock grama or curlymesquite. As deterioration progresses, these minor grasses will, doubtless, become less and less abundant.

5. Tanglehead and "other grasses" are reduced to little more than a trace when the trend in condition of the foothill range is downward.

Stages of range deterioration below that indicated in the pattern shown in section A, figure 5, very likely would have a greater relative abundance of slender grama or perhaps in the later stages some increase in Rothrock grama and curlymesquite although the latter is generally regarded as a desirable forage species. It also seems likely that any increase in the relative abundance of these grasses would be made at the expense of further reduction in the relative abundance of black grama, sideoats grama, and Arizona cottongrass. Isolated instances in the data indicate that such would be the case.

Characteristic composition of conservatively grazed range in satisfactory condition. An example of the composition pattern of a foothill type range in satisfactory condition that is improving is shown in section B, figure 5. The upward trend is indicated by the following relative abundance of the various grasses.

1. Threeawn grasses (chiefly *Aristida hamulosa*) are one-fourth as abundant as slender grama and about three times as abundant as either Rothrock grama or curlymesquite.

2. Sideoats grama, by a slight margin over threeawn, is the second most abundant grass with 10 to 15 per cent of the total perennial grass cover. Even smaller percentages of sideoats indicate range recovery when it is scattered generally over the range instead of being restricted to arroyo banks.

3. Improvement is also indicated when Arizona cottongrass and "other grasses" each exceed all grasses excepting slender grama, threeawn, and sideoats.

4. Curlymesquite is about equal to black grama, Arizona cottongrass, and "other grasses." From the standpoint of livestock production this would favor a better balanced diet throughout the year.

5. "Other grasses" during the early stages of improvement in range rise in percentage from the trace that is characteristic of deteriorated range to an abundance equalling that of Arizona cottongrass and exceeding that of black grama.

Rate of range recovery under nongrazing. The speed of range recovery toward the climax condition is illustrated in section C of figure 5. There is a fairly wide difference between this population pattern and the one obtained by conservative grazing. The more important points are the marked difference in the rate of decrease in relative abundance of slender grama and the sharp increase in cottongrass on areas protected 5 years. However, the direction of change is the same in both cases. The pattern for the 5-year protected areas is obviously further advanced toward the climax but the trend is identified by the same signs in both

cases. From the evidence at hand it may be assumed that the general character of change is the same but the velocity of approach toward the climax is somewhat greater under protection than it is under conservative grazing.

Stabilized condition on foothill type range. As in the case of mesa type range, the exact composition of the foothill type climax stage is not definitely known. The evidence presented in section D of figure 5 demonstrates the composition pattern of a range condition that probably approaches nearer to the climax than any of the other conditions that have been studied and measured in the type under consideration. By using the pattern shown in section D and the previously discussed patterns as datum points it is possible to chart the progress of range recovery and range deterioration in the foothill type. As illustrated in figure 4, the shift in relative abundance from short grasses to the tall robust leafy-stemmed grasses is the most significant characteristic of the composition pattern induced by long-time total protection from livestock.

When the foothill type is approaching the climax the following characteristics of the composition pattern are present:

1. Arizona cottongrass is the dominant species, greatly surpassing every other grass in abundance and equalling approximately one-third of the total composition.
2. "Other grasses" rate second place in relative abundance. At least they, as a group, are approximately equal in abundance to slender grama and surpass any other species except slender grama and Arizona cottongrass.
3. Threeawn and black grama each are approximately one-half as abundant as slender grama.
4. Rothrock grama is a minor species, probably exceeded in relative abundance by every other grass except curlymesquite.
5. Curlymesquite is among the minor grasses found on the protected foothill type range.

Shrubs as Indicators

Invading shrubs are a definite menace to range values and indicate range deterioration when they are increasing in abundance. However, shrubs and like plants on the semidesert ranges cease to be reliable indicators once they become established. The permanent nature of shrub cover which limits its indicator value is worthy of discussion.

In the semidesert grasslands, vegetation commonly referred to as "shrub cover" is composed principally of trees, true shrubs, half-shrubs, and several species of cacti. In this type the principal plants are: velvet mesquite, false mesquite (*Calliandra eriophylla* Benth.), burroweed (*Aplopappus tenuisectus* Greene), and cacti (*Opuntia* spp.). Other shrubs which occur are: catclaw, *Baccharis* spp., ocotillo (*Fouquieria splendens* Engelm.), and a number of species that are encountered with greater rarity. Field observations indicate that mesquite and burroweed invasions are greatly accelerated by too heavy grazing. Both burroweed and mesquite are undesirable on the range mainly because their presence prevents maximum production of grass forage. On the other hand, false mesquite is considered a good forage plant and it provides good spring browse for livestock.

Information concerning the density of shrubs on areas of conservative grazing, and 5 and 25 years of protection, is presented in tables III and IV. These data, based on the measurement of crown spread, show that the total canopy density of mesquite is affected but little by range management methods which tend to favor an increase in the perennial grass stand. Comparisons of shrub cover for the mesa type are presented in table III, and for the foothill type in table IV. These data are from 104 plots; a third of this number had been grazed conservatively for 5 years, an equal number had been protected from livestock for 5 years, and the final third had been similarly protected for 25 years.

TABLE III. *Per cent of ground covered by shrubs and half-shrubs on mesa type ranges*

Plant name	Conservatively grazed for 5 years	Protected for 5 years	Protected for 25 years
	Per cent	*Per cent*	*Per cent*
Mesquite (*Prosopis velutina*)	4.74	9.77	9.22
False mesquite (*Calliandra eriophylla*)	0.08	0.15	2.14
Burroweed (*Aplopappus tenuisectus*)	8.17	8.99	6.60
Cacti (*Opuntia* spp.)[1]	1.51	0.73	2.68
Other shrubs	3.78	1.97	2.81
Totals	18.82	21.61	23.45

[1] Principally arborescent species.

TABLE IV. *Per cent of ground covered by shrubs, half-shrubs, and cacti on foothill type ranges*

Plant name	Conservatively grazed for 5 years	Protected for 5 years	Protected for 25 years
	Per cent	*Per cent*	*Per cent*
Mesquite (*Prosopis velutina*)	6.63	8.28	6.42
False mesquite (*Calliandra eriophylla*)	4.06	4.95	5.92
Burroweed (*Aplopappus tenuisectus*)	2.81	2.10	0.38
Cacti (*Opuntia* spp.)[1]	0.54	0.09	0.88
Other shrubs	0.51	4.31	4.93
Totals	14.55	19.73	18.53

[1] Principally procumbent low-growing spp.

The import of the information concerning shrub cover based on an analysis of the data in tables III and IV is summarized as follows:

There was a moderate increase in the extent of total shrub canopy with protection from livestock. This increase is primarily due to expansion of the canopy when the shrubs are not browsed. It does not necessarily indicate that there has been an increase in the numbers of plants under protection. It does indicate the extreme longevity of most of the shrubs. It also shows that once deep rooted shrubs and trees such as mesquite become established, these plants, in a practical sense, are immune to removal by good grazing practices or total protection. There is, however, evidence that the half-shrub burroweed plants will eventually die out under long-time protection as the perennial grass cover improves.

SUMMARY

1. Composition of the perennial grass population of mesa and foothill types of semidesert grassland range varies significantly with the general intensity of grazing to which they are commonly subjected. Grasses bear the brunt of grazing in grassland types, and therefore change more quickly than their less palatable associates. Thus the grasses record the history of past grazing use and become indicators of range condition.

2. Utilization of grasses as indicators in the management of semidesert grassland ranges has its chief value in the fact that this sort of information adds precision to the more commonly recognized indicators. On the types of range studied, relative amounts of common perennial grasses, better than any other indicator, show the early changes toward range recovery or toward range deterioration.

3. When the productivity of the range has not been greatly impaired by prolonged overuse and erosion, the rate of range recovery under conservative grazing is approximately equal to the recov-

ery rate obtained under total protection from grazing by domestic livestock.

4. Tall, coarse-stemmed grasses such as Arizona cottongrass, sideoats grama, and black grama attain a high percentage of the total perennial grass cover under long periods of protection—a condition which appears to confirm the belief that these grasses are important members of the semidesert grassland climax vegetation.

5. Populations of relatively unpalatable deep rooted shrubs and trees are comparatively slow to change in response to conservative grazing or to total protection from grazing by cattle. Once these plants obtain a foothold on semidesert grassland range they become a relatively permanent part of the plant cover. Range recovery under conservative grazing and long periods of protection both show that improvement of the grass cover may take place under an established shrub or half-shrub stand without materially affecting the vigor and abundance of these slow-growing more hardy plants.

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