Grazing Values and Management of Black Grama and Tobosa Grasslands and Associated Shrub Ranges of the Southwest

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INTRODUCTION

Optimum production of livestock on black grama [1] and tobosa grasslands and associated shrub ranges of the Southwest depends on proper management of the forage resource. In this region, periods of low precipitation are frequent and fluctuations in seasonal and annual amounts are extreme. Under these circumstances, range livestock operators are faced with perplexing problems of how to maintain stability and continuity of their enterprises. Too often ranchers and land managers are handicapped by not having long-term records of forage production to give them a better idea of range potential.

The black grama, tobosa, and associated shrub types occupy nearly half of the semidesert grass-shrub ranges of the Southwest. These ranges are a part of the arid deserts of North America within the Lower Sonoran life zone described by Merriam (1898).[2] According to Wooton (1908) they suffer more quickly and more permanently from abuse than ranges where the physical environment is less severe.

Semidesert grass-shrub ranges occupy 60 million acres of land in Arizona, New Mexico, and west Texas. More than a million cattle graze this area, making it important to the general economy of the Southwest. For example, Walrath (1951) states that farmers and ranchers in New Mexico receive more cash income from the marketing of cattle than from the sale of any other agricultural product, and Pingrey (1948) reports that 94 percent of the land is grazed by livestock. In Arizona, income from the livestock industry averaged $85 million between 1948 and 1953. Rangelands of the semidesert grass-shrub type comprise the most valuable grazing lands of southern Arizona (Upson et al., 1937).

Studies of management practices and effects of weather on black grama and tobosa grasslands and associated shrub ranges have been underway in southern New Mexico since 1912. The Jornada Experimental Range was established that year as a 193,394-acre tract 23 miles northeast of Las Cruces. Because its vegetation, soils, and climate are sufficiently comparable to that of more than 26 million acres of black grama, tobosa, and associated shrub ranges in the Southwest (fig. 1), research results can be applied directly to much of this area. Many of the principles of management also are adaptable to other semidesert grass-shrub ranges in Arizona and Texas.

The experimental work on the Jornada has been a combination of empirical studies on large range pastures and detailed studies of climate, soils, and important forage plants and range types (Campbell, 1940). These studies had two main objectives: (1) to gain an understanding of the forage resource, and (2) to determine the methods of management best suited to the region. Historical records of the vegetation, climate, and stocking go back more than 40 years. Addi-

[1] Common and scientific names of species mentioned in this bulletin are listed on page 53.

[2] Names followed by dates refer to Literature Cited, page 54.

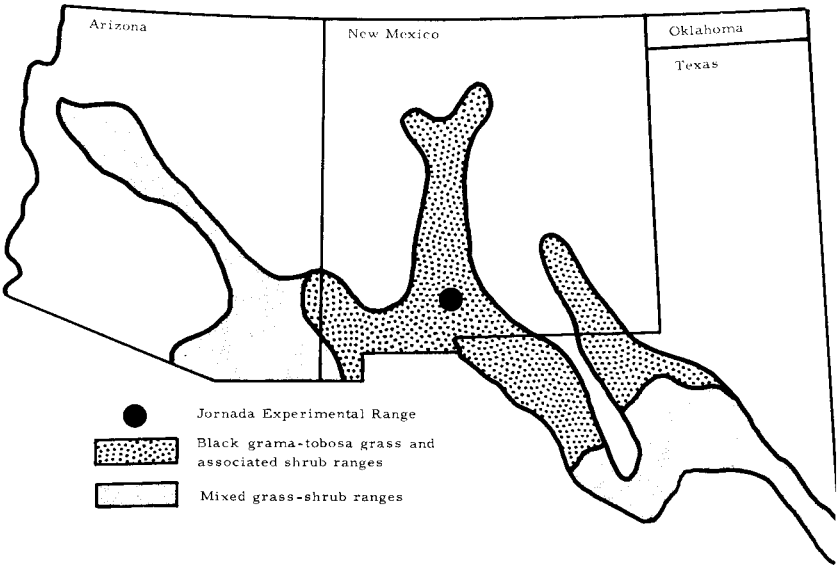

FIGURE 1.—The two major components of the semidesert grass-shrub vegetation of the Southwest: (1) black grama and tobosa grasslands and associated shrub ranges, and (2) mixed grass-shrub ranges.

tional data from studies on the Jornada, which are not cited elsewhere in the bulletin, are available in the literature.[3]

THE JORNADA EXPERIMENTAL RANGE

Physical Geography

The experimental range is in a desert basin bounded by the San Andres Mountains on the east and by several isolated mountain masses on the west. It is level or gently undulating with no permanent streams or surface drainage outlets. Elevation of the basin varies from 3,900 to 4,500 feet. The summit of the San Andres Mountains is more than 8,000 feet.

The Jornada basin consists of unconsolidated Pleistocene detritus. This alluvial fill from the nearby mountains is 300 feet thick in places, and the aggradation process is still active. Coarser sediments are found near the foothills, and the finer soil particles in the lowest areas.

The soils show almost no humus and little change in texture between surface soil and subsoil. The lime content is high in all of the soil types, and this grades into a solid, calcareous substratum at variable depths in the coarser soils.

Most differences in plant cover are related to soil texture and structure, because these soil characteristics largely influence moisture-holding capacity, aeration, and plant root development. On soils where these characteristics vary, there is a difference in the size and form of plants of the same species as well as a difference in vegetation type.

[3] Ares, 1942 and 1943; Ares and Martin, 1944; Campbell and Bomberger, 1934; Halloran and Ares, 1944; Jardine and Hurtt, 1917; Little, 1937; Little and Keller, 1937.

Climate

Climate of the basin is typical of arid regions; there is an abundance of sunshine, a wide range between day and night temperatures throughout the year, low relative humidity, and low, extremely variable precipitation.

Precipitation

Because of the close dependency of the range forage on the amount and timing of moisture for plant growth, management of the black grama and tobosa grassland and associated shrub ranges is closely related to the precipitation. Most winter moisture comes as low-intensity rainfall and occasionally as snow from general storms, but summer rainfall comes from convectional thunderstorms. Localized thunderstorms are frequently of such high intensity that much of the rainfall becomes surface runoff and is lost to the vegetation.

Rainfall from July 1 to September 30 averages 52 percent of the amount received each year and represents a distinct peak in the yearly precipitation pattern (table 1). At the headquarters of the experimental range, rainfall from 1916 to 1953 averaged 9.02 inches. In most years August was the month when rainfall was highest, followed by July and September. Rainfall averaged 1.61 inches in August compared with only 0.24 inch in April, the month of lowest rainfall. Late fall and late spring are commonly dry.

The average annual precipitation measured by 21 rain gages on the Jornada varied from a minimum of 6.92 inches near the center of the experimental range to 10.76 inches close to the mountains (fig. 2). Rainfall for the whole area averaged 4.64 inches during the July–September growing season.

The amount of summer rainfall is extremely variable. For example, summer rainfall was within 15 percent of the average in only 13 years between 1916 and 1953, and it was more than 35 percent above or below average in 12 years.

The amount and pattern of precipitation recorded at the Jornada headquarters is similar to that recorded at nearby weather stations located in basins adjacent to the mountains. From 1853 until 1890 precipitation was recorded at Army posts along the Rio Grande in the vicinity of Las Cruces, N. Mex., and after 1890 at nearby State College. Cumulative deviations from the mean precipitation recorded at these stations and at the Jornada headquarters show five periods in which precipitation alternated generally above and below average (fig. 3).

The dry period that began in grazing year 1907[4] lasted for 19 years, or until 1926 when the most recent period of above-average precipitation began. Precipitation was 11 percent below average from 1916 to 1926 and 13 percent above average during the 1927–43 period. The present downward trend of precipitation began in 1944 at State

[4] In this publication the interval referred to as a grazing year begins July 1 and ends June 30 of the following calendar year. A grazing year is designated by the year in which the closing date, June 30, falls. This interval coincides approximately with the growth of the principal forage plants.

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TABLE 1.—*Precipitation at the Jornada Experimental Range headquarters, grazing years 1916–53* [1]

Grazing year	Growing season				Dormant season, Oct.–June	Total, July 1–June 30	15 months, July 1–June 30–Sept. 30
	July	Aug.	Sept.	Total July–Sept.			
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
1916	1.40	1.91	1.55	4.86	3.26	8.12	15.63
1917	.90	.96	.72	2.58	4.22	6.80	10.70
1918	.57	1.52	.25	2.34	1.28	3.62	9.14
1919	1.53	2.88	0	4.41	6.06	10.47	8.03
1920	3.13	2.52	2.55	8.20	5.85	14.05	18.67
1921	1.50	3.28	.89	5.67	4.05	9.72	19.72
1922	1.50	1.26	.73	3.49	1.31	4.80	13.21
1923	.25	1.80	1.13	3.18	6.00	9.18	7.98
1924	.68	1.53	1.74	3.95	3.50	7.45	13.13
1925	3.34	.32	.21	3.87	2.23	6.10	11.32
1926	1.68	1.19	.89	3.76	6.72	10.48	9.86
1927	4.95	.38	3.20	8.53	5.11	13.64	19.01
1928	1.49	2.32	2.52	6.33	2.76	9.09	19.97
1929	1.27	2.62	.03	3.92	6.55	10.47	13.01
1930	1.95	2.73	1.50	6.18	2.93	9.11	16.65
1931	1.46	1.54	.03	3.03	6.94	9.97	12.14
1932	1.05	1.61	2.00	4.66	4.72	9.38	14.63
1933	.99	4.51	2.50	8.00	5.96	13.96	17.38
1934	1.48	2.06	1.02	4.56	2.73	7.29	18.52
1935	.87	.80	.07	1.74	3.87	5.61	9.03
1936	.92	3.94	1.93	6.79	3.83	10.62	12.40
1937	1.62	1.16	2.89	5.67	4.69	10.36	16.29
1938	.44	.89	3.14	4.47	3.54	8.01	14.83
1939	5.80	.06	3.16	9.02	3.57	12.59	17.03
1940	1.08	.96	2.12	4.16	6.55	10.71	16.75
1941	1.49	.73	2.34	4.56	6.16	10.72	15.27
1942	1.91	2.11	4.49	8.51	5.74	14.25	19.23
1943	.77	2.38	1.27	4.42	3.69	8.11	18.67
1944	2.34	.56	1.17	4.07	4.27	8.34	12.18
1945	2.30	1.12	1.30	4.72	3.86	8.58	13.06
1946	1.13	.94	.10	2.17	3.51	5.68	10.75
1947	2.08	2.53	2.48	7.09	3.67	10.76	12.77
1948	.87	2.83	.05	3.75	4.05	7.80	14.51
1949	.51	.16	.44	1.11	5.79	6.90	8.91
1950	2.78	.30	3.44	6.52	2.54	9.06	13.42
1951	2.70	1.00	1.64	5.34	3.27	8.61	14.40
1952	.34	.85	.18	1.37	5.38	6.75	9.98
1953	1.86	1.01	.26	3.13	2.56	5.69	9.88
Average	1.66	1.61	1.47	4.74	4.28	9.02	13.90

[1] A grazing year begins July 1 and ends June 30 of the following calendar year; it is designated by the year in which the closing date falls.

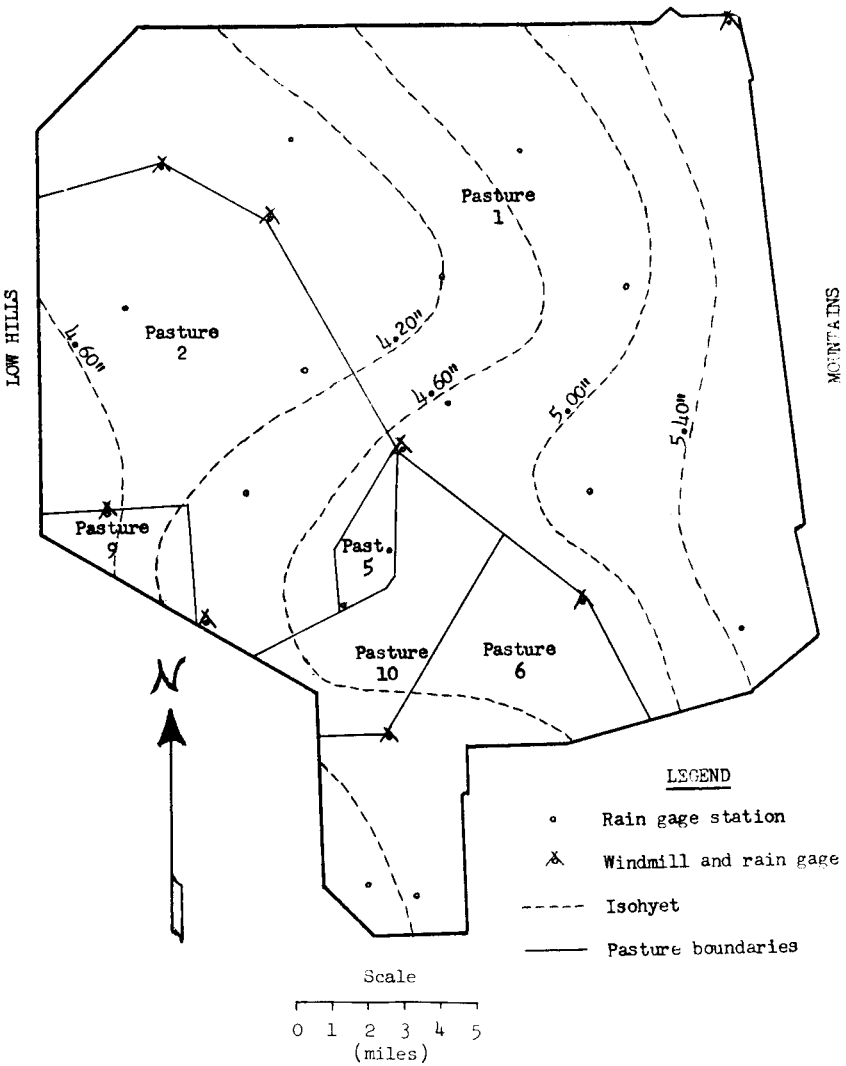

FIGURE 2.—The July–September isohyets within six pastures, Jornada Experimental Range.

College and in 1943 at headquarters on the Jornada, but drought conditions did not become acute for several years. Between 1943 and 1953 the average precipitation at headquarters was 7.84 inches or 87 percent of the annual average.

Precipitation in some years was distinctly different from the general trend. The low precipitation in grazing years 1934 and 1935 and in the three favorable years 1919 to 1921, inclusive, are good examples of variations within a generally moist or dry period.

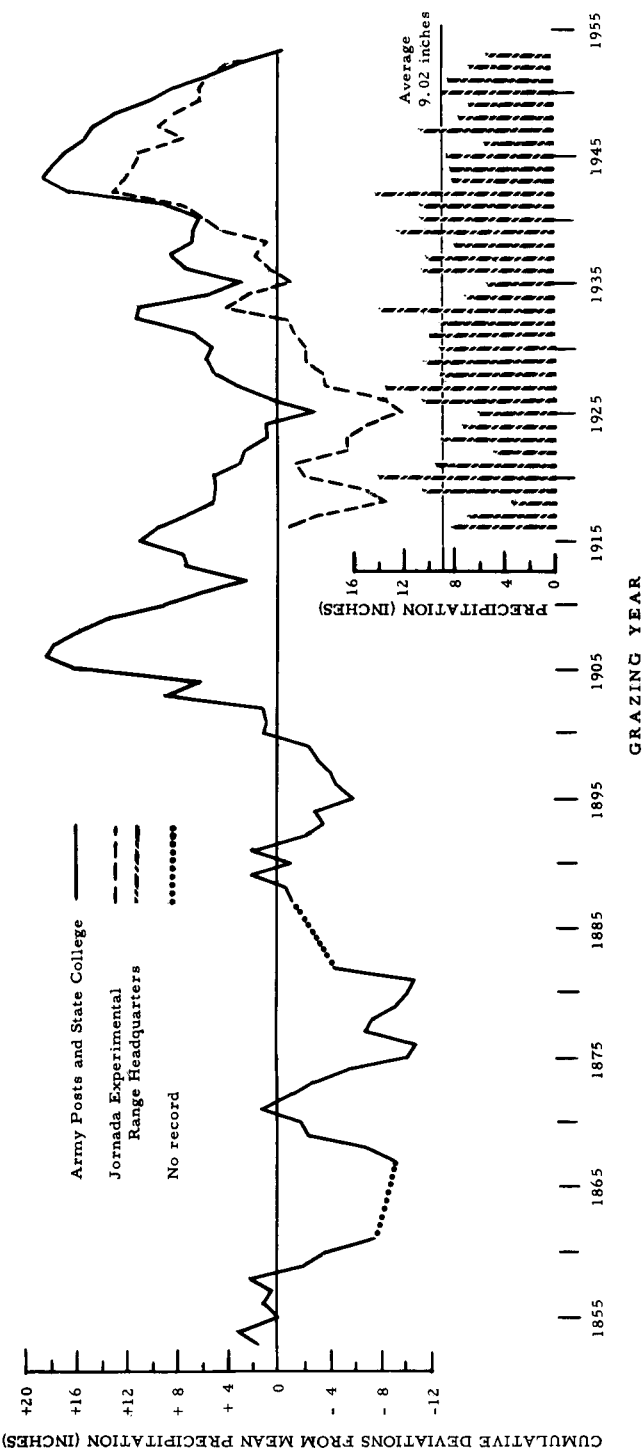

FIGURE 3.—Cumulative deviations from mean precipitation at weather stations along the Rio Grande and at State College, 1853–1953, and at the Jornada Experimental Range headquarters, 1916–53. Also shown is the annual precipitation at the Jornada headquarters, 1916–53.

Temperature, Wind, and Evaporation

Soil moisture is sufficient for growth of the forage plants for a relatively short period, but adequate temperatures for plant growth prevail much longer. The average frost-free period lasts approximately 200 days. The average maximum temperature at the Jornada headquarters is 76° F. Maximum temperatures are highest in June, averaging 97°; in January, the coldest month, the average is 56°.

Wind velocities are highest in April and May and lowest in December. They average 2 miles an hour, but velocities up to 40 miles an hour are frequent.

High temperatures and low humidities cause large water losses by evaporation, especially during late spring and early summer. On the Jornada, evaporation from a free water surface averaged 92.6 inches between July 1 and June 30, or 10 times the average precipitation; in June evaporation exceeded 13.5 inches.

The several components of the climate become collectively favorable for forage growth generally through July, August, and September (fig. 4). This growing season is usually 90 to 100 days, depending mostly on the summer rains. In some years it may begin in June or even May and extend into October. Because more than half of the total rainfall is concentrated in the summer, growth and production of forage are possible under a relatively low rainfall regime. Summer temperatures are sufficiently high to stimulate rapid growth, and wind and evaporation are considerably lower than their pregrowing-season maximums. During the period of forage growth, climatic factors on the experimental range averaged as follows: rainfall, 1.58 inches a month; temperature, maximum—91.3° F., minimum—60.6°; wind, 1.8 miles an hour; evaporation, 10.2 inches a month.

Major Vegetation

Plant geographers and ecologists have characterized the grasslands of southern Arizona and New Mexico and west Texas as similar in many respects to those of the Great Plains (Shantz and Zon, 1924; Weaver and Clements, 1938). McArdle and Costello (1936) described them as a discontinuous arid belt occupying the broad, flat valleys, low hills, and mesas, and interspersed with scattered woody shrubs and dwarf trees. The authors consider this vegetation as a semidesert grass-shrub complex and subscribe to the hypothesis that the shrub-dominated areas probably represent grazing disclimax. It is believed that essentially the same native flora that is now present existed before settlement although the relative abundance of the species components has been altered.

Vegetation on the Jornada Experimental Range may be classified as grass and shrub. Each class is represented by distinctive types dominated by certain major species. The major grass types are black grama and tobosa; the shrub types are mesquite sandhills, creosotebush, and tarbush. The boundary between shrub types is often less marked than between grass types.

Black Grama Type

Black grama is the most important range type on extensive areas in the Southwest (Nelson, 1934) (fig. 5). Griffiths et al. (1915) mentioned that it was frequently cut for hay in southern New Mexico.

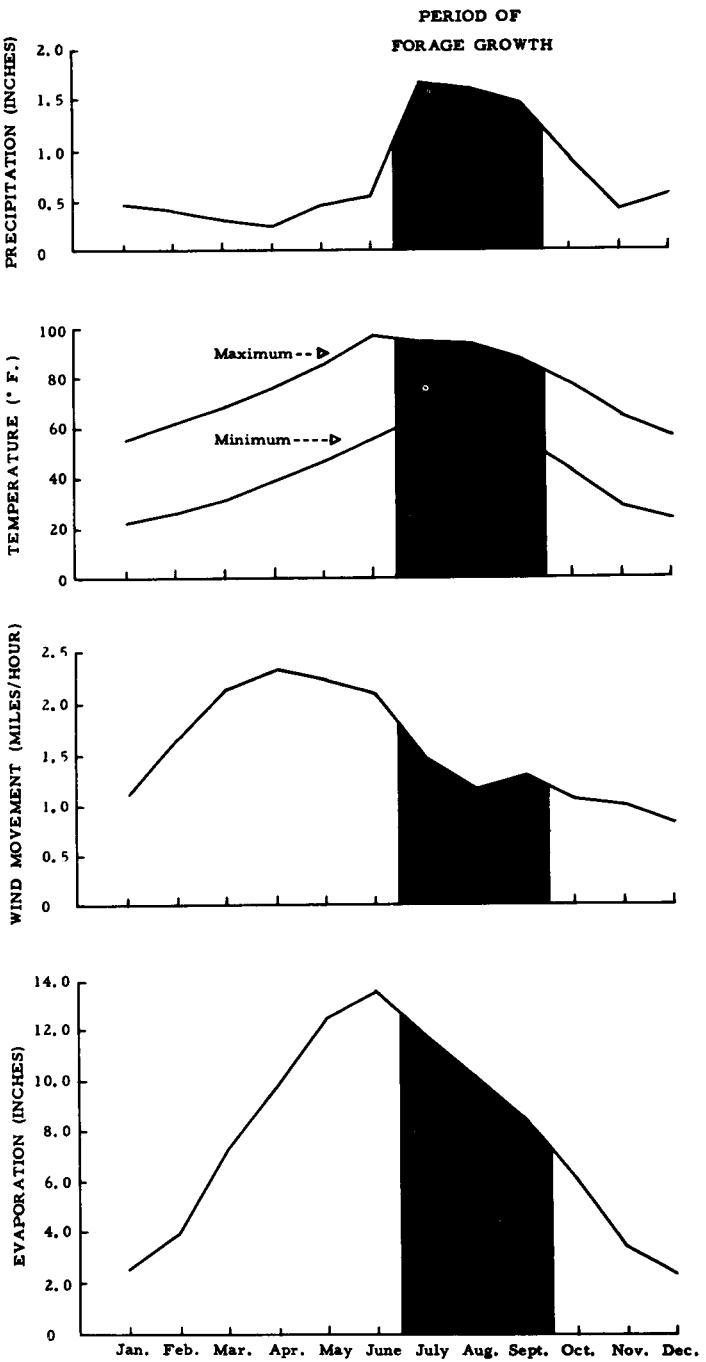

FIGURE 4.—Average monthly climate, Jornada headquarters weather station.

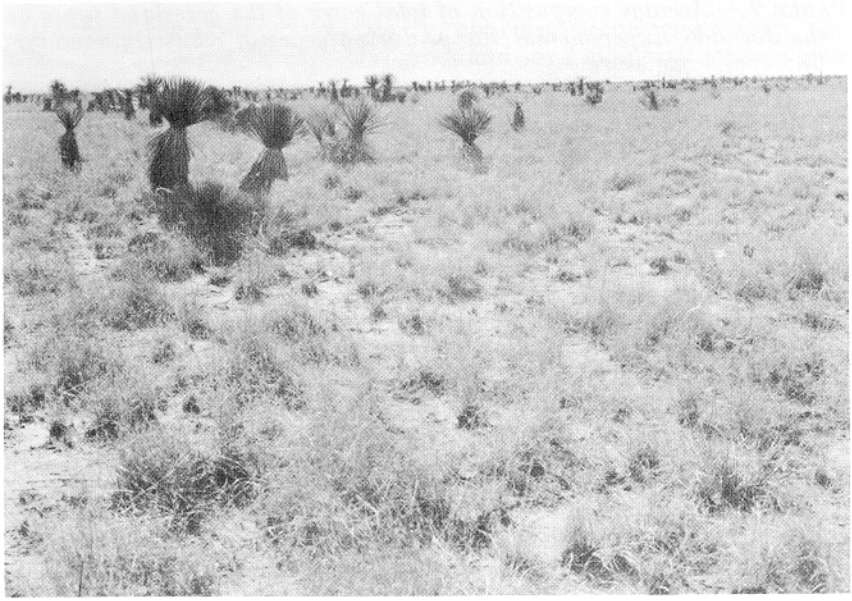

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FIGURE 5.—Black grama range. A highly valued grass type in the Southwest.

Black grama is the dominant species and furnishes the bulk of the forage in the type on the Jornada (table 2). In the best stands black grama makes up about 75 percent of the plant cover. Associated perennial grasses include red, purple, and Wooton three-awns, and sand and mesa dropseeds. Collectively, these may constitute 12 to 45 percent of the plant cover. In addition, a number of forb species may be present. Most important forbs are Wislizenus spectacle-pod, woolly paperflower, bladderpod, globemallow, leatherweed croton, and several annuals. Associated shrubs and half-shrubs in the black grama type include soaptree yucca, broom snakeweed, ephedra, and scattered mesquite. Where the type has deteriorated from excessive grazing or drought, associated grasses and forbs are usually more abundant and are pioneers in the revegetation.

The type reaches its best development on the older, more stable soils. At a representative site the soil is a fairly deep, loamy sand. The surface is a shallow layer of grayish, incoherent sand that grades into a reddish, slightly compact, loamy sand. Below 1 to 2 feet a weak carbonate cementing begins and grades into a caliche sutstratum.

On areas where surface soils are sandier and less compact, dropseeds and three-awns are more abundant and more forbs are found. Often the surface is a loose, reddish sand that has been shifted by the wind into low hummocks and ridges. A caliche layer is present at variable depths, depending upon the amount of wind erosion and deposition.

Tobosa Type

Tobosa is a productive grass type on the experimental range and characteristically occupies the lower, swale sites, which are often

TABLE 2.—*Average composition of total cover of the grassland types on the Jornada Experimental Range during years of relatively abundant and sparse moisture*

Class of forage and species	Black grama type		Tobosa type	
	High moisture	Low moisture	High moisture	Low moisture
Grasses:	*Percent*	*Percent*	*Percent*	*Percent*
Black grama	75. 0	44. 0	(1)	(1)
Dropseed and three-awns	12. 0	15. 0	(1)	(1)
Tobosa	(1)	(1)	80. 0	62. 0
Burrograss	(1)	(1)	10. 0	12. 0
Other perennial grasses	1. 5	4. 0	4. 5	11. 0
Annual grasses	. 5	9. 0	. 5	4. 0
Total	89. 0	72. 0	95. 0	89. 0
Forbs	4. 0	20. 0	2. 0	5. 0
Shrubs	7. 0	8. 0	3. 0	6. 0

[1] Rare in the type.

flooded by runoff water from the surrounding foothills (fig. 6). Successionally, the tobosa type represents the climax on adobe soils (Campbell, 1931).

Tobosa is the predominant species and furnishes most of the forage. In favorable years on the Jornada, it made up 80 percent of the composition (table 2). Other plants of minor importance include burrograss, ear muhly, alkali muhly, alkali sacaton, indian rushpea, globemallow,

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FIGURE 6.—Dense stands of tobosa occupy swales with heavy clay soils.

bitterweed hymenoxys, desertholly, ephedra, broom snakeweed, tarbush, and soaptree yucca. Gypgrass and several annual grasses grow on outcrops of gypsum.

The type is found in swales on soils that have developed from basin fill material. These soils are tight and relatively impervious. They show little change in texture or structure to a depth of 4 or 5 feet, or sometimes to as much as 15 feet. They are predominantly chocolate or dark red but in places become grayish or buff colored. Sand or gravel beds are occasionally present at 4 or 5 feet. Here, there is often some cementation with lime carbonate, but the caliche layer found in soils of the black grama type is not present.

On sites less subject to flooding, which contain a higher proportion of coarser surface soil particles, tobosa is the most important grass, but a combination of several grass species may make up a greater percentage of the composition. Together burrograss, alkali sacaton, ear muhly, and alkali muhly sometimes make up 60 percent or more of the plant cover.

Mesquite Sandhills Type

The mesquite sandhills type is referred to by Campbell (1929) as a moving dune complex. The scrubby, multiple-stemmed mesquite catches blowing sand and builds it into mounds around the plants (fig. 7). Simultaneously, the area between the mounds is scoured of loose soil and vegetation remnants. The sparse herbaceous cover that may become established is usually transitory because of soil instability and rapid depletion of soil moisture by the numerous mesquite roots.

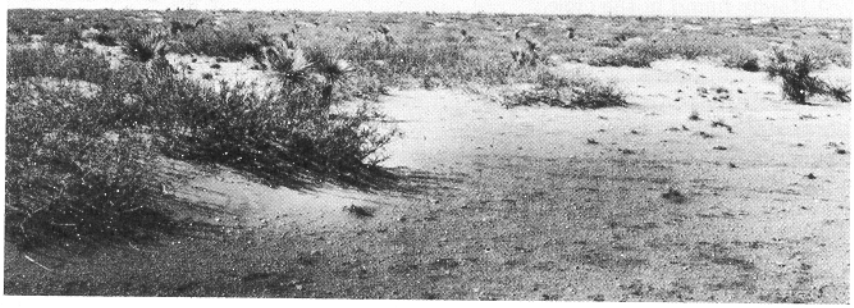

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FIGURE 7.—Mesquite sandhills type. Some forage species grow in the shelter of the mesquite plants, but forage productivity is generally low.

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Mesquite is the dominant species, making up about 30 to 55 percent of the total plant cover (table 3). Forbs are fairly abundant but grasses are scarce. The principal associated species are broom snakeweed, fourwing saltbush, sand sagebrush, black grama, dropseeds, three-awns, spectacle-pod, bladderpod, globemallow, desert baileya, and broom dalea.

Forage production is generally low. Of the total forage resource on the Jornada, mesquite sandhills contributes only about 15 percent even though it occupies at least 42 percent of the surface area.

TABLE 3.—*Average composition of the total cover on the shrub types of the Jornada Experimental Range during years of relatively abundant and sparse moisture*

Class of forage and species	Mesquite sandhills type		Creosotebush type		Tarbush type	
	High moisture	Low moisture	High moisture	Low moisture	High moisture	Low moisture
Grasses:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Black grama	10. 0	2. 0	31. 0	13. 0	1. 0	1. 0
Dropseeds and three-awns	14. 0	4. 0	2. 0	. 5	. 5	. 5
Tobosa			2. 0	1. 0	21. 0	10. 0
Burrograss			1. 0	1. 0	26. 0	19. 0
Other perennial grasses	3. 5	2. 0	22. 0	18. 5	18. 5	13. 5
Annual grasses	. 5	1. 0	(1)	(1)	(1)	(1)
Total	28. 0	9. 0	58. 0	34. 0	67. 0	44. 0
Forbs	8. 0	16. 0	2. 0	3. 0	1. 0	2. 0
Shrubs:						
Mesquite	30. 0	55. 0	3. 0	5. 0	1. 0	1. 5
Creosotebush			27. 5	45. 0	1. 5	2. 0
Tarbush			4. 0	6. 0	25. 0	45. 0
Broom snakeweed	22. 0	6. 0	2. 0	2. 0	1. 5	1. 0
Fourwing saltbush	3. 0	4. 0	(1)	(1)	(1)	(1)
Sand sagebrush	3. 0	3. 0	(1)	(1)	(1)	(1)
Other shrubs	6. 0	7. 0	3. 5	5. 0	3. 0	4. 5
Total	64. 0	75. 0	40. 0	63. 0	32. 0	54. 0

[1] Rarely found in the type.

The soil of the mesquite sandhills type is similar in origin to the soil of the black grama type. Excessive wind erosion has shifted the surface material into uneven, low dunes. A hard caliche substratum is present at variable depths. In places the scoured caliche layer is exposed, while in the dunes sand deposition may be 6 to 10 feet deep.

Creosotebush Type

The creosotebush type occupies low rolling ridges of the foothills and alluvial fans (fig. 8). It grows on well-drained areas of deep sand; relatively deep, heavy soil; shallow stony soils underlain by caliche, and in arroyo beds (Gardner, 1951). In his studies of creosotebush in the Rio Grande Valley, Gardner points out that creosote-

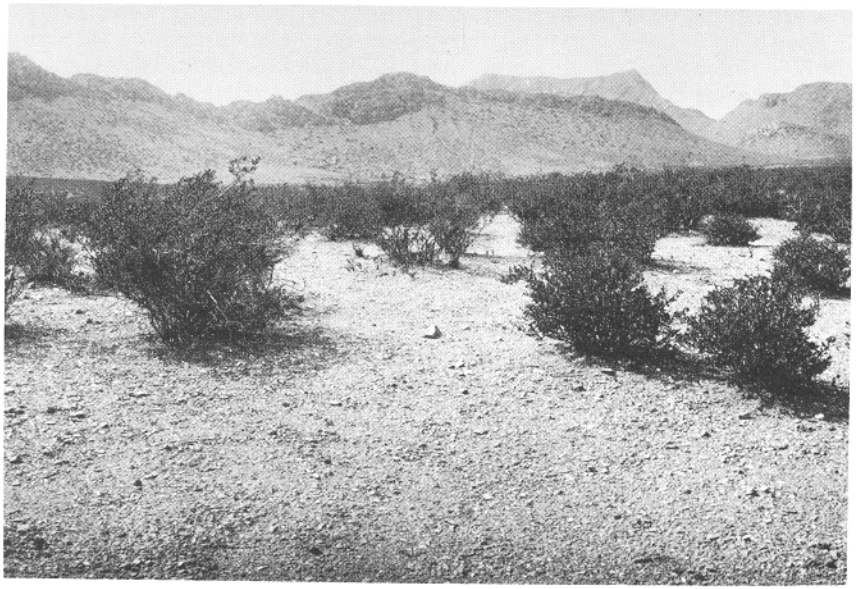

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FIGURE 8.—Creosotebush type illustrating the characteristic erosion pavement and sparseness of herbaceous vegetation.

bush is the least exacting of the shrubs in requirements for growth, and that it is invading grassland and other shrub types, except where these occur on areas of blow sand.

Creosotebush makes up about 28 to 45 percent of the cover in this type on the experimental range (table 3). Common associates include black grama (the major grass species), tobosa, alkali sacaton, fluffgrass, burrograss, bush muhly, bladderpod, lambsquarters goosefoot, Wislizenus spectacle-pod, mesquite, mariola parthenium, soaptree yucca, tarbush, and broom snakeweed.

Creosotebush is unpalatable to cattle, and the only forage in the type is furnished by some of the associated plants. Black grama and bush muhly produce most of the forage.

Tarbush Type

On clay loam soils that have some gravel near the surface, tarbush is the principal shrub. These sites receive some flood water, and the type contains herbaceous species similar to those found in the tobosa type. Tobosa and burrograss are the most important forage plants and contribute appreciably to the forage value of the tarbush type (fig. 9).

CHARACTERISTICS OF THE MAJOR FORAGE SPECIES

The principal forage plants of the black grama and tobosa grasslands and associated shrub ranges are black grama, tobosa, dropseeds, three-awns, and burrograss. These perennial grasses produce about

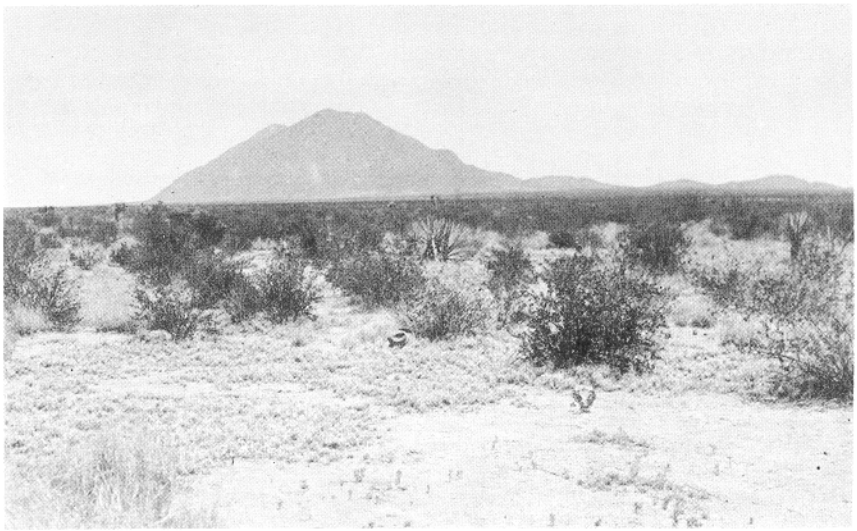

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FIGURE 9.—In the tarbush type, tobosa and burrograss are the major herbaceous components among the tarbush plants.

85 percent of the total forage in all types except the mesquite sandhills where they contribute much less.

Approximately 90 percent of the growth of these plants is made during the summer growing season, July through September (Nelson, 1934). Occassionally, growth begins in June or even May, depending on the advent of the summer rains. On the other hand, growth may not begin until mid-August. Ordinarily, growth continues into October before it is stopped by frost.

A variety of forbs produce some forage in the spring if late fall and early spring moisture is plentiful. Most perennial grasses are relatively quiescent at this time, although some may freshen up if temperatures are also favorable. On the Jornada Experimental Range, forage produced in late fall and early spring has averaged 7 percent of the total forage crop.

Shrubs produce some forage on the Jornada. This is especially true in the mesquite sandhills type where fourwing saltbush and sand sagebush furnish about 60 percent of its total; grasses furnish 30 percent and forbs 10 percent. Mesquite beans and leaves supply a small amount of forage during a short period in the summer and early fall.

Black Grama

Black grama is a mainstay of the forage resource. It is palatable to cattle throughout the year in contrast to most other grasses that lose much of their palatability after the summer growing season.

Characteristically, black grama grows in open stands of individual tufts (Canfield, 1939). Nelson (1934) describes it as a branching, strong-rooted, long-lived perennial that makes its main growth during the summer growing season. It cannot persist on shifting sand and soon succumbs when covered.

The inflorescence of black grama consists of three to eight spikes in racemes along a main flower stalk axis (fig. 10). Seed is produced in spikelets arranged in two rows along one side of the rachis. Many spikes do not mature seed, and even when well matured the seed often has poor viability (Nelson, 1934).

Black grama spreads almost entirely by stolons and tillering (Nelson, 1934). Rooting at the nodes of prostrate stems followed by separation from the parent plant and the development of new stems from the perimeter of the root crown are especially prominent in favorable years.

When not grazed, black grama forms large clumps. During drought these may die out in the center and break up into several smaller tufts. With more abundant rainfall, these smaller tufts may again grow together into a single large tuft. Under grazing, the individual plants are smaller and generally more evenly distributed over the soil surface (Nelson, 1934).

The stems of black grama may reach 36 inches in length if growing conditions are favorable for 1 year or more. Stems commonly do not die back to the crown each year but remain green through the winter and spring period. Canfield (1934) noted that black grama and other perennial grasses on the Jornada have solid stems in contrast to most other grasses. Leaves of black grama are chiefly stem leaves; the stems, especially near the base, are covered with short, white hairs; hence, its local names of woolyfoot or hairyfoot grama (Canfield, 1939).

Black grama roots penetrate sandy soil to 4 feet or more. In the interstices between individual tufts, the numerous shallow, lateral roots are effective soil binders.

In his studies of black grama, Canfield (1939) noted that the period of growth varied from 64 to 176 days, but in most years it approxi-

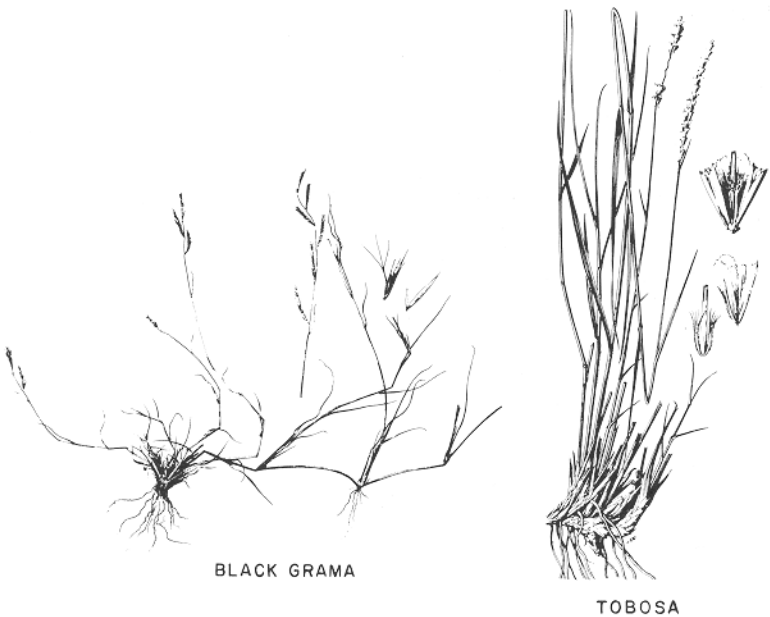

FIGURE 10.—Characteristics of the two main forage grasses on the Jornada Experimental Range, black grama and tobosa.

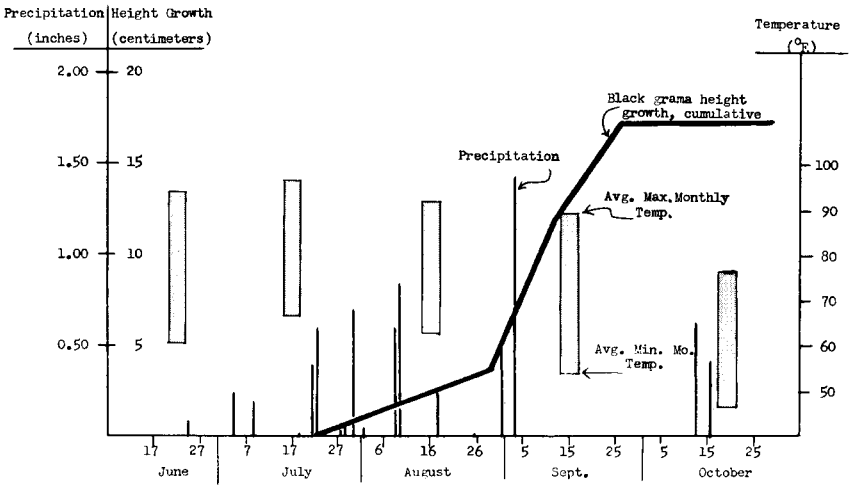

FIGURE 11.—Height growth of black grama as related to precipitation and temperature. Jornada Experimental Range, 1925.

mated 98 days. In grazing years 1935, 1949, and 1952 when rainfall was extremely low, there was no measurable growth.

Most height growth is completed within a relatively short time in the summer, often within 30 days. Flower stalks ordinarily head out and mature within 5 to 7 weeks after growth starts. Hence, in most years flowering begins early in August, the caryopses are set by late September, and seed dissemination begins in October (Nelson, 1934).

Nelson(1934) reported close association between height growth of black grama and precipitation. Although temperatures were favorable for plant growth, rains of 0.25 and 0.20 inch 4 days apart in early July 1925 did not induce measurable growth (fig. 11). Beginning July 22, height growth started when precipitation totaled 1 inch in 2 days. Measurements of stem heights showed slow elongation until late August, after which most of the height growth was completed within a month. Because cooler temperatures prevailed when the next rains fell no new stems were produced and there was very little additional growth of the leaves. Visible growth often temporarily ceases during the usual 3-month growing season unless rainfall is adequate and well timed throughout that period.

McGinnies and Arnold (1939) determined the water requirements of black grama for the production of plant dry matter. They found that during the summer growing season the mean water requirement of this species per pound of dry matter produced was in the ratio of 476:1. Their studies support the concept advanced by Maximov (1929) that while many desert plants are not economical in the use of water, they have the ability to grow rapidly when moisture is available and yet remain alive when moisture conditions are unfavorable.

Tobosa

Tobosa is strikingly different from black grama in site preference, growth habit, method of reproduction, and forage value. On favorable sites it forms a dense, coarse sod. On drier sites, it grows in scattered stands of large, individual tufts. Tobosa is intolerant of

shifting sand or submersion for longer than a few days; however, it tolerates occasional flooding. Its period of most active growth is similar to that of black grama.

Culms of tobosa may attain a height of 2 feet. When actively growing, they are green and succulent, but with maturity they become harsh, woody, and relatively unpalatable. Leaves are smooth, mainly basal, and up to 6 inches long. Tobosa has coarse rhizomes by which it spreads vegetatively. Seed viability under laboratory conditions is generally high, although few seedlings are found in the field (Campbell, 1931). Roots are dense and coarsely fibrous through the upper 3 feet of soil and have been found almost 6 feet deep.

Dropseeds

Dropseeds, principally mesa and sand dropseeds, are usually secondary grasses insofar as forage and soil protective values are concerned. They reproduce from seed, and seedlings of these species may be especially numerous following a dry period. They are important in stabilizing loose, sandy soils, especially where black grama has been depleted by drought or overgrazing. Because their root systems are not so extensive as black grama's, they are crowded out by that species. Most of their growth is made during the summer rainy period. Their temperature requirements for growth are less exacting than those for black grama, and if moisture is available they frequently begin vigorous growth in the spring. Dropseeds are less palatable than black grama and lose much of their forage value when dry.

Three-Awns

Three-awns are usually secondary species in the black grama type. They are similar to dropseeds in that they reproduce from seeds and frequently begin growth in the spring. After they have cured, they are much less palatable than black grama.

Burrograss

Burrograss grows during the summer rainy season, but it begins growth earlier than most associated grasses. Herein lies its main forage value (Jardine and Forsling, 1922). It spreads by stolons and by seeding into denuded or drought-depleted areas. Seeds are produced profusely in favorable years and have long awns that facilitate their dissemination by wind, water, and animals. The seeds have high viability, and seedlings are frequently abundant. Campbell (1931) reports that the formation of sets is correlated with years of favorable rainfall. Moreover, set production is more prolific from young burrograss tufts than from older, well-established plants.

CHANGES IN BASAL AREA OF PERENNIAL GRASSES

Records of the major forage species have been maintained since 1916 to determine their response to cattle grazing and to the extremely variable precipitation. To study changes of the primary forage grasses, basal area at 1 inch above the ground was charted on meter-square quadrats. Initially, the area of individual plants was charted

from a decimeter grid, but during most of the period a pantograph was used in charting.

Quadrats were located both on grazed and ungrazed range. The longest continuous records were from 1916 to 1953. Sequentially, during this time, groups of years were generally dry, then moist, and finally dry. Consequently, records of most grasses show a period of large reduction of basal area, a period of recovery within which was a shorter cycle of smaller reduction and recovery, and then again a period of large reduction.

Black grama was present on 71 quadrats that were charted annually. Of 34 quadrats having the most complete and longest charting history, 4 were protected from cattle grazing, and 30 were open to cattle use. Most of the grazed quadrats were located at half-mile intervals along lines radiating from permanent stock water. A few were at mile intervals and some were located without particular reference to water. The protected quadrats were located in cattle exclosures.

Precipitation records were obtained from one or more standard rain gages near each quadrat. Where more than one gage was available records were averaged for the particular quadrat.

Changes in basal area of black grama on the quadrats were more closely correlated with precipitation during a 15-month period from July 1 of one year to September 30 of the next year than with precipitation during the current growing season or with annual precipitation. If precipitation is well timed and relatively abundant during this 15-month period, there is an increase in general plant vigor and a buildup of stored food reserves in one growing season. Usually this is followed by an increase in basal area by tillering and in production of foliage the second growing season. When precipitation is unfavorable, plants decrease in vigor and basal area.

The effect of various intensities of grazing was studied by grouping the quadrats according to the following average intensities of grazing on black grama for the 1916–53 period: Heavily grazed, where more than 55 percent of the herbage weight of the plant was removed annually; intermediately grazed, where 40 to 55 percent was removed; and conservatively grazed, where less than 40 percent was removed. During extremely dry periods some quadrats classified as intermediately grazed were occasionally grazed heavily; these same quadrats were sometimes conservatively grazed when forage was abundant. Twelve quadrats were heavily grazed, 8 intermediately grazed, 10 conservatively grazed, and 4 protected from grazing.

Basal area of black grama was recorded on quadrats within each intensity of grazing (fig. 12). Initial basal area was intermediate between maximums and minimums obtained later. The prolonged dry period between 1916 and 1926 reduced basal area to roughly the same level regardless of the intensity of grazing or initial basal area. The average annual change amounted to a loss of 16 to 47 square centimeters. Three years of favorable precipitation from 1919 to 1921 resulted in increased basal areas in 1921 and 1922. The 15-month precipitation through September 1922 was 13.21 inches (table 1, p. 4). However, basal area was reduced markedly under all conditions in 1923 when the 15-month precipitation was only 7.98 inches. In 1923, the protected quadrats declined most. The other groups lost in proportion to their 1922 basal area.

During the period of favorable moisture, 1927–34, black grama increased under all intensities of grazing and on the protected areas.

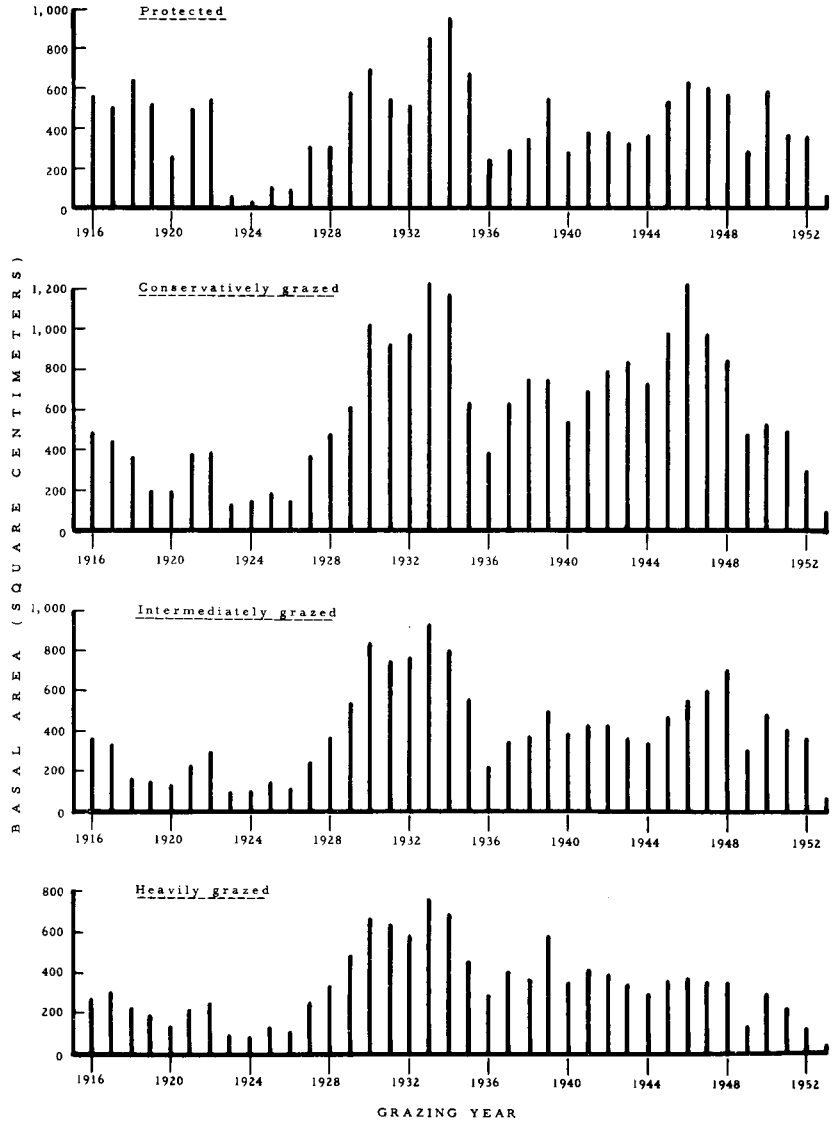

FIGURE 12.—Basal area of black grama on meter-square quadrats protected from grazing and at three intensities of grazing. Jornada Experimental Range, 1916–53.

The 15-month precipitation was more than 5 inches above average in 1927, and basal area increased nearly threefold on the conservatively grazed and protected quadrats and more than doubled on the intermediately and heavily grazed quadrats. By 1930 under conservative use, intermediate use, and protection from grazing, basal area had increased to seven times more than it was in 1926 and, on heavily grazed quadrats, to six times. In 1930 on all grazed quadrats black grama made its greatest increase. This was due to the cumulative effects of several years of precipitation that was well above average in 3 out of 4 years and only slightly below average in the other.

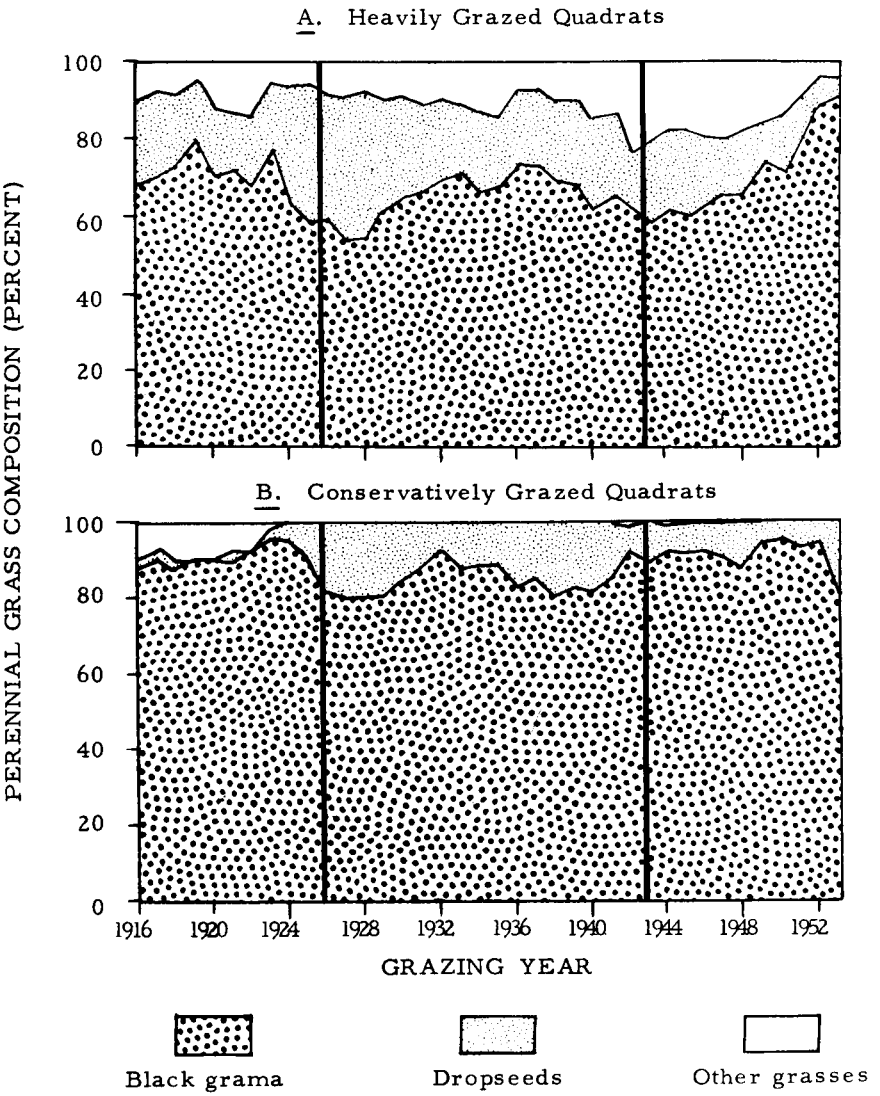

FIGURE 13.—Changes in perennial grass composition on meter-square quadrats: *A*, Conservatively grazed and *B*, heavily grazed. Jornada Experimental Range, 1916–53.

The very low rainfall from October 1934 to September 1935 resulted in an immediate and marked decline in black grama under all conditions. This indicates there is little carryover effect from previous years of abundant rainfall in preventing a reduction in basal area. For example, conservatively grazed quadrats declined 46 percent in 1935 and 40 percent the year following. Precipitation was better in 1936 but black grama did not recover until 1937 when basal areas increased 68, 62, and 42 percent on the conservatively, intermediately, and heavily grazed quadrats, respectively, and 20 percent on those protected from grazing. Black grama did not again reach the high

basal area that it had before 1935 on any but the conservatively grazed range.

Beginning in 1943 precipitation was below average 9 out of the 11 years. However, during the first few years it was well timed and sufficient for plant growth. As a result, black grama tended to increase on all but the heavily grazed quadrats until the mid-1940's when rainfall was distinctly limited. Black grama basal area then generally declined on all quadrats until in 1953 it was much the same as it had been in 1924.

The percentage composition of black grama on the quadrats increased during protracted dry periods as other less drought-enduring species succumbed. But in subsequent moist years the associates recovered rapidly and made up a relatively greater percentage of the species composition until they were replaced by black grama. From the earliest charting, black grama composition on the heavily grazed quadrats was lower than on the others. The stock wells of the experimental area were drilled several years before the Jornada record began, and it is possible that by 1915 heavy, yearlong grazing had altered the composition. By 1952, average composition on heavily grazed quadrats was more nearly comparable to that under conservative grazing (fig. 13).

By 1956, 20 quadrats had lost all vestiges of black grama—it had been missing from these quadrats for 1 to 7 years. This species had disappeared from all protected quadrats, 67 percent of the heavily grazed, 62 percent of the intermediately grazed, and 30 percent of the conservatively grazed. In contrast, at the close of the 1916–26 dry period, it remained on all 34 quadrats, although the basal area was less than 100 square centimeters on 18. Also in 1956 there were no perennial grasses on 9 of the 20 quadrats.

During drought, black grama stems die first. Ordinarily they remain green yearlong to the second or third node from the tip. If drought is particularly acute or extended, the entire root crown of the plant may die and the plant is then lost.

The interval for plant recovery following a period of deficient rainfall is significant. With moisture favorable for growth beginning in 1927, a good stand was produced in 3 to 4 years. Figure 14 illustrates a similar situation on an area that had only an occasional living stem of black grama in October 1954; 2 years later, following localized, favorable rainfall, much of the soil surface was again covered by vigorous tufts among the blackened remnants of drought-killed stems. Also following 1949, a year of extremely low rainfall between 2 years of more abundant rainfall, there was some plant recovery in 1950. However, when severe losses occur over extensive areas, recovery is necessarily much slower even with favorable moisture.

Three relationships, which are pertinent to the management of black grama grasslands, are apparent from the analyses of the quadrat records:

1. First, there was evidence of a basal area cyclic trend that is related to precipitation. Following establishment of the quadrats there was a general decline to a low point in the midtwenties. With favorable moisture conditions, associated grasses increased first, then black grama increased to its maximum cover of the entire period of charting, only to again decline in subsequent drought periods. Within each of the longer periods there were 1 or 2 years when precipi-

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FIGURE 14.—*A*, Drought-killed stems of black grama; *B*, recovery of the stand in the same area after 2 years.

tation was markedly different from the general trend. These resulted in basal area changes that were less drastic.

2. Basal area was reduced to an approximately similar point under each of the intensities of grazing and protection from grazing during extended drought.

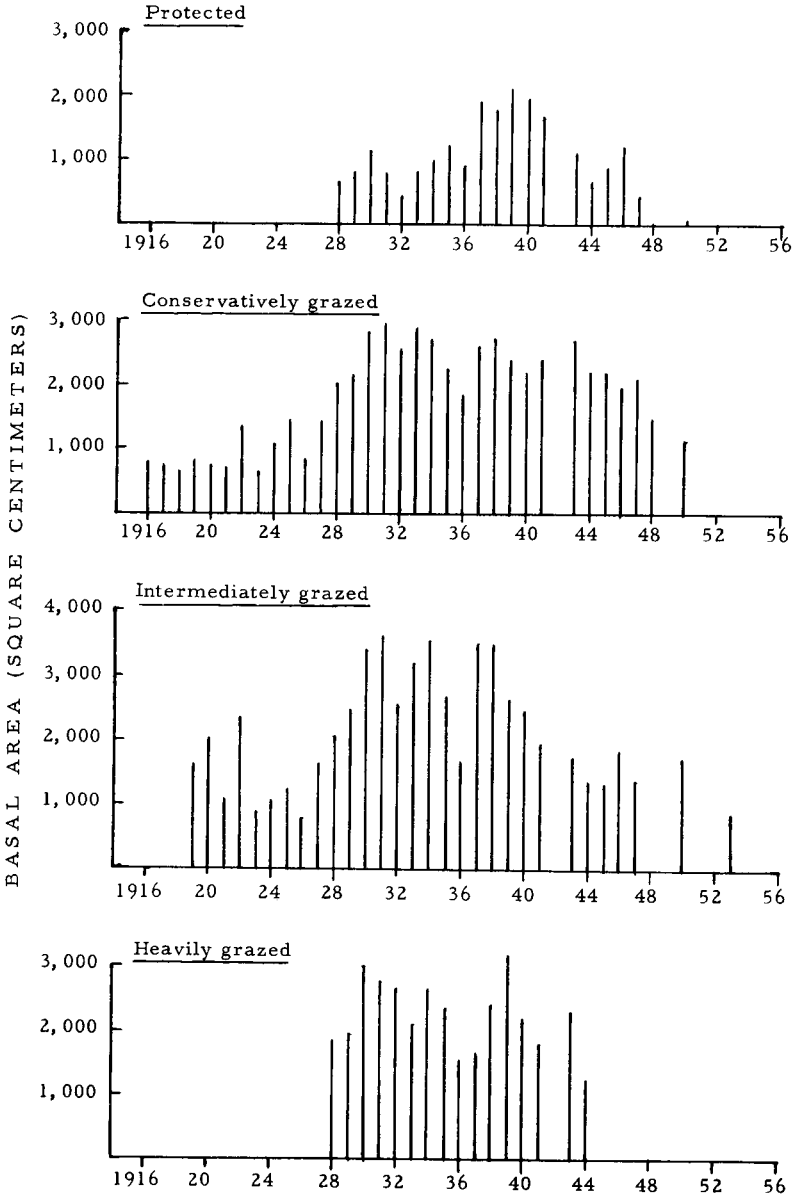

FIGURE 15.—Basal area of tobosa on quadrats protected from grazing and at three intensities of grazing. Jornada Experimental Range, 1916–53.

3. Greatest increase in basal area following drought was under conservative grazing. It was greater than on the protected plots even though the protected plots had had greater basal area when first charted.

Tobosa was charted for varying periods on five quadrats that were conservatively grazed; three intermediately grazed, seven heavily grazed, and two protected from grazing (fig. 15). These meager records show how tobosa stood up under different types of use.

As with black grama, change in basal area of tobosa was most closely associated with precipitation received between July 1 of one year and September 30 of the next.

Basal area of tobosa was generally highest under intermediate grazing. It was higher on intermediately grazed quadrats than on those conservatively grazed in 18 years between 1919 and 1943. On intermediately grazed quadrats it was exceeded by that on heavily grazed quadrats in only 3 of 16 years when records were obtained.

Basal area of tobosa was lowest on the protected quadrats. Observations in protected areas suggest that tobosa plants tend to stagnate when the old growth is not removed. Average area of tobosa tufts for the four groups of quadrats was as follows:

Grazing use:	*Basal area, 1928–43* *cm.²*
Protected	1, 191
Conservative	2, 461
Intermediate	2, 718
Heavy	2, 294

Tobosa on the conservatively and intermediately grazed quadrats reached a low point in 1924 and 1926. Greatest increases occurred by 1930 and slight increases continued through 1931.

Basal area on all grazed quadrats reached another low point in 1936 because of the 2 preceding dry years. Tobosa then responded rapidly to the more favorable moisture beginning in 1937. It responded somewhat more slowly on the heavily grazed quadrats than it did on the other grazed quadrats.

From the limited quadrat information, variations in the basal area of tobosa caused by fluctuations in weather are somewhat similar to those of black grama. Because of its habitat on sites that receive some surface runoff and its characteristically vigorous vegetative growth, however, it is less sensitive than black grama to these fluctuations. Intermediate grazing is desirable to maintain a vigorous tobosa stand. Observations indicate that stands break up and yields decline under too heavy grazing.

Dropseeds were present on 56 grazed and 9 protected quadrats where they occurred as secondary species. On seven out of nine protected quadrats, dropseeds disappeared at least once in the charting period, and they are regarded as transient species.

On conservatively grazed areas, dropseeds were far less abundant on the quadrats than black grama; however, under heavy grazing their basal areas were about equal (fig. 16). Dropseeds, being less palatable to livestock, have an advantage over black grama on heavily grazed range and may form a greater percentage of the stand.

According to Campbell (1931), burrograss characterizes the first successional stage having real forage value on heavy clay soils. This species often grows in various sized patches intermingled with tobosa, but tobosa usually replaces it on adobe soils. On clay loam soils it continues as a major component of the composition with tobosa, alkali muhly, ear muhly, and alkali sacaton. For example, on one quadrat, burrograss accounted for 11 to 85 percent of the total basal area between 1916 and 1952. Burrograss averaged 34 percent, tobosa 43 percent, and dropseeds 23 percent on this quadrat. During the dry periods burrograss accounted for a higher proportion of the quadrat basal area than during years of more abundant moisture.

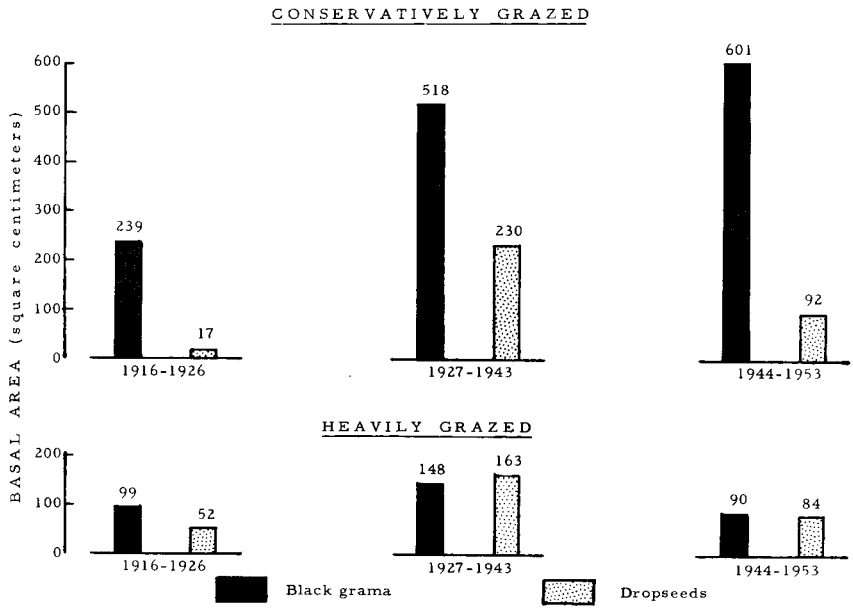

FIGURE 16.—The relation between basal area of black grama and dropseeds under two intensities of grazing. Jornada Experimental Range, 1916–53.

Low rainfall caused losses of burrograss. Where found with tobosa, the initial recovery of the vegetation following drought was made by burrograss, but tobosa regained dominance in 4 years (Campbell, 1931).

HERBAGE PRODUCTION

Black Grama Type

Annual herbage production in pounds of air-dry plant material per acre is shown in table 4 for the black grama type in five pastures of the Jornada Experimental Range. Weight of the perennial grasses was measured in the fall each year on belt transects 50 feet long and 4 inches wide. On the average, 192 transects were clipped each year from 1939 to 1953.

Herbage production varied greatly from year to year. In one pasture herbage production of all perennial grasses dropped from 962 pounds per acre in grazing year 1948 to 284 pounds per acre in 1949, a difference of 678 pounds of air-dry herbage per acre. The maximum production of black grama on any pasture in the 1939–53 period was 711 pounds of air-dry herbage, and the minimum in the same pasture was 97 pounds only 2 years later. During the 1939–53 period, black grama yielded 65 to 94 percent of the total production of perennial grasses on the five pastures, exclusive of tobosa sites that were not sampled by clipped transects.

Herbage production is more closely related to rainfall received between July and September than to other combinations tested (fig. 17). However, timing of the rainfall is important; it may also cause variation in herbage production. In 1942, for example, precipitation was 9 inches, but herbage production averaged only 321 pounds per

TABLE 4.—*Average air-dry herbage production per acre of black grama and all perennial grasses on 5 pastures of the Jornada Experimental Range, 1939–53*

Grazing year	Pastures										Average of all pastures	
	1		2		5		9		10			
	Black grama	All perennial grasses	Black grama	All perennial grasses	Black grama	All perennial grasses	Black grama	All perennial grasses	Black grama	All perennial grasses	Black grama	All perennial grasses
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1939	305	476	431	692	379	482	477	580	407	532	400	552
1940	380	490	258	354	180	247	331	406	473	525	324	404
1941	134	252	494	511	186	204	533	559	432	444	356	394
1942	126	231	224	271	277	307	348	389	322	405	259	321
1943	103	157	273	363	247	268	352	456	357	431	266	335
1944	176	244	450	542	448	469	538	657	542	658	431	514
1945	140	275	430	584	409	572	679	795	647	803	461	606
1946	50	93	308	402	320	390	418	498	498	589	319	394
1947	120	219	558	813	230	406	597	822	450	622	391	576
1948	134	311	468	778	704	962	446	615	441	715	439	676
1949	51	56	341	410	284	284	333	383	243	260	250	279
1950	154	239	484	602	365	399	512	679	503	540	404	492
1951	172	227	532	608	711	755	540	594	596	630	510	563
1952	49	65	202	283	120	139	203	255	237	239	162	196
1953	56	74	120	132	97	97	139	139	146	151	112	119
15-year average	143	227	372	490	330	399	430	522	420	503	339	428

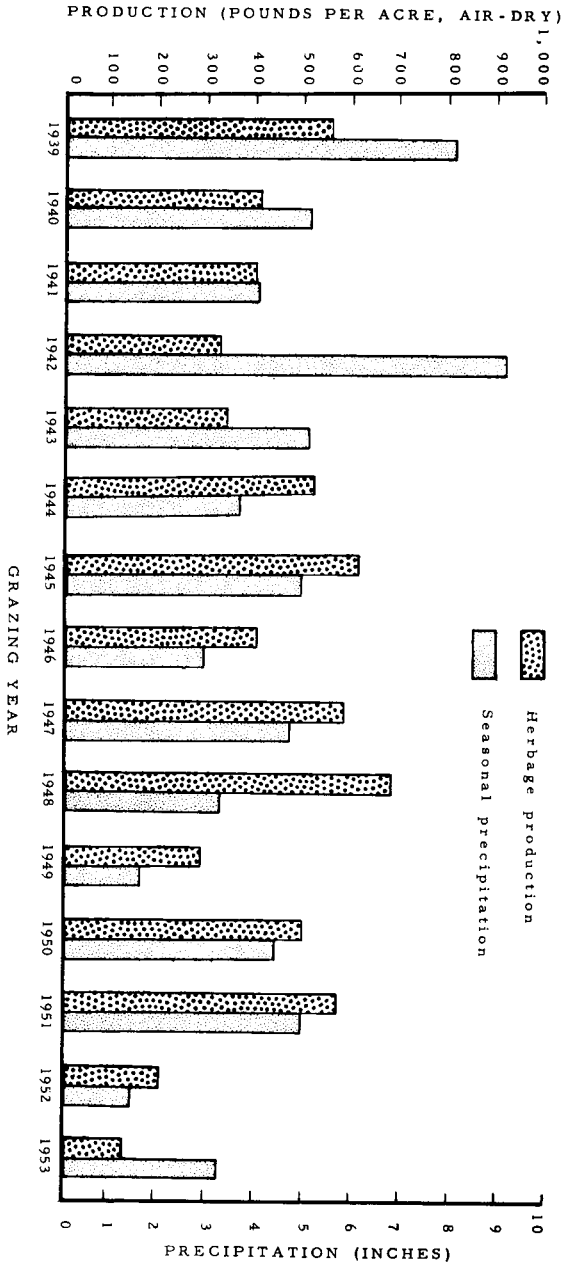

FIGURE 17.—Perennial grass herbage production in pounds per acre, air-dry, and July–September rainfall, Jornada Experimental Range, 1939–53.

acre, air-dry. More than 5 inches of precipitation was recorded in September, too late in the fall for the grasses to make maximum use of the ample moisture. Furthermore, most precipitation that summer came as widely spaced, intense showers that were not fully effective for plant growth.

On the other hand, grass production in grazing year 1948 exceeded the production of all other years, although seasonal rainfall was only 73 percent of average. Rainfall was effective for growth that year; nearly 3 inches fell at headquarters in August. Furthermore, the stand of forage was in vigorous condition from the previous year's ample rainfall.

Herbage production was also above average in 1950, a year in which seasonal rainfall was slightly below average. It is noteworthy that this response was obtained following a year when seasonal rainfall was only 1.57 inches.

Herbage production reached 132 percent of average by 1951 as rainfall continued to be favorable. Two extremely dry years followed in which July-to-September rainfall averaged 2.25 inches, and production by 1953 was only 33 percent of the 15-year average for black grama and 28 percent of average for all perennial grasses.

Tobosa Type

Tobosa and associated perennial grasses furnish approximately one-third of the total forage produced on the Jornada Experimental Range. These species are most palatable when actively growing. Grazing of these grasses, therefore, takes place mainly in the summer. This permits grazing deferment of the black grama type until the dormant season.

Canfield (1939) has shown that if tobosa is frequently but not too closely harvested during the growing period, it will produce a maximum amount of high-quality forage. His studies showed that tobosa under weekly clipping to a 4-inch stubble averaged 1,922 pounds per acre. He also found that clipping to 4 inches produced 110 percent more total herbage during the study period than clipping to 2 inches. Canfield concluded that frequent clipping stimulates rhizome development, but that this stimulus is dissipated if the plants are clipped too closely.

Tobosa herbage production is often thought to be less erratic than that of black grama. However, the production of new forage varies widely, as shown by Canfield's data. In one instance, yield decreased from 11.99 grams per square decimeter in one year to 0.45 gram the next, or to approximately $\frac{1}{27}$, and in another it increased 25 times in a single year.

Tobosa on the Jornada Experimental Range was mowed for hay in 1937 and 1938 and fed with a ration of cottonseed cake to cattle during the winter. The total yield in these 2 years ranged from 1,000 to 1,500 pounds per acre (Ares, 1939a). Cattle readily ate the tobosa hay, which was cut when the plants were green and succulent, and the animals remained in good condition through the winter.

NUTRITIONAL VALUE OF FORAGE

The nutritional value of the primary forage plants has been determined by Watkins (1943). During the growing season, percentage of crude protein in black grama, mesa dropseed, and tobosa averaged 8.20, 9.96, and 7.52, respectively. Watkins found that from November to June crude protein of dry herbage in these species averaged 4.88, 4.80, and 4.03 percent, respectively. The National Research Council (1958) suggests that the diet for wintering mature pregnant cows and pregnant heifers should contain 7.5 percent total protein,

and for wintering 400-pound weaner calves 10.3 percent total protein is needed in the diet. For cows nursing calves, 8.3 percent total protein is suggested. Thus, the dried grass is well below the minimum protein requirements. When there is little precipitation during the winter-spring months, the grasses make better forage because leaching of nutrients is at a minimum (Watkins, 1943).

Watkins (1943) also reported that the minimum phosphorus requirement of cattle is met by black grama, mesa dropseed, and tobosa only during a short period at the peak of the growing season. In addition, calcium levels in these grasses are usually below the cattle needs in the winter and spring periods. Both calcium and phosphorus deficiencies in the grasses are increased if winter rainfall is abundant, but the deficit is then often compensated by a spring weed crop (Knox et al., 1941).

In the mesquite sandhills type, protein, calcium, and phosphorus in fourwing saltbush and sand sagebrush were found to be generally high, as shown in the following tabulation from Watkins (1943):

	Crude protein (percent)	*Calcium (percent)*	*Phosphorus (percent)*
Fourwing saltbush:			
February	11. 24	0. 917	0. 086
May	13. 40	1. 375	. 155
August	14. 60	1. 562	. 174
November	11. 99	1. 091	. 157
Sand sagebrush:			
February	9. 45	. 448	. 108
May	10. 27	. 678	. 224
August	12. 93	. 778	. 340
November	11. 10	. 838	. 212

SHRUB INVASION

The encroachment of nearly worthless shrubs into the grassland is detrimental to the condition and production of the ranges. Many investigators have reported on rates and causes of shrub invasion in several areas.[5] In specific reference to southern New Mexico, Parker and Martin (1952) state that mesquite sandhills have existed for several hundred years, but now mesquites are spreading into adjacent grassland.

Rodents and livestock scatter mesquite seeds (Glendening and Paulsen, 1955; Reynolds and Glendening, 1949). Census data reported by Norris (1950) indicate rodent numbers were approximately 3⅓ times greater on mesquite sandhills than on black grama areas. As rodent populations increase, they extend their activities beyond the shrub type and into the fringe of the adjacent grassland. In these areas rodent grazing of the perennial grass herbage may be appreciable. For example, control of these animals on a ranch adjoining the Jornada Experimental Range resulted in an increase of 300 pounds of grass forage per acre (Knox et al., 1951).

Norris (1950) concluded that rodents and rabbits exert enough influence in the mesquite sandhills type to practically prevent vegetation improvement. In addition to use of the perennial grass forage, certain of these animals—for example, the Merriam kangaroo rat (*Dipodomys merriami merriami* Mearns)—collect considerable quantities of mesquite seeds and store them in shallow caches. Many seeds

[5] Allred, 1949; Brown, 1950; Darrow, 1944; Glendening, 1952; Young et al., 1948.

not retrieved by the rodents germinate in the caches. These planted seeds increase the infestation in the grass stand.

Dissemination of mesquite seed, as well as conditions for seedling establishment, has been favored by introduction of livestock on semiarid rangelands. At maturity mesquite pods supply highly palatable, nutritious feed that is readily eaten by cattle. Since the seeds are hard-coated, many are not digested but are eliminated, often at considerable distances from where they were eaten.

The rapidity with which mesquite is becoming established in grassland that has been conservatively grazed is indicated by repeat measurements of vegetation on a permanent belt transect 1,500 feet long and 1 foot wide, which extends from mesquite sandhills into adjacent grassland on the Jornada Experimental Range (table 5). In 15 years mesquite increased 125 percent in numbers of plants and 74 percent in number of feet occupied by the crowns of the plants. In the same period, black grama decreased 23 percent in basal area and dropseeds decreased nearly 52 percent. On a similar area adjacent to the Jornada, Norris (1953) reported mesquite numbers in black grama grassland increased 165 percent in 12 years.

TABLE 5.—*Changes in vegetation on a 1,500-foot transect, Jornada Experimental Range, 1936–51*

Vegetation	1936		1951		Change in number of plants	Change in distance occupied
	Plants	Distance occupied	Plants	Distance occupied		
	Number	*Feet*	*Number*	*Feet*	*Percent*	*Percent*
Mesquite	16	98	36	171	+125.0	+74.5
Snakeweed	81	60	55	56	−32.1	−6.7
Black grama	----	696	----	533	----	−23.4
Dropseeds	----	85	----	41	----	−51.8
Soapweed	9	7	14	13	+55.6	+85.7

As the mesquite stand thickens, grassland is converted to the shrub type. Conversion from grass to mesquite is taking place most rapidly in the transition zone between the mesquite-sandhills type and adjacent black grama grassland (fig. 18). Mesquite plants in this transition zone increased from 2 to 11 plants in 15 years. On the first 500 feet of the transect, within the mesquite sandhills, mesquite increased from 11 to 19 plants; and in the last 500-foot segment, which was in the grassland, it increased from 3 to 6 plants.

Gardner (1951) has reported that creosotebush and tarbush are also invading grassland ranges in the Rio Grande Valley. No information is available on this from studies on the Jornada Experimental Range. However, studies and observations have shown that both species quickly reinvade areas where the conversion of the types to grassland has been attempted.

Three separate areas in the creosotebush type on the Jornada were entirely cleared of all shrubby vegetation in 1936. The original crown intercept of creosotebush was 147 feet on 490 feet of transect line. Twelve years after clearing, it had reestablished to 11 percent

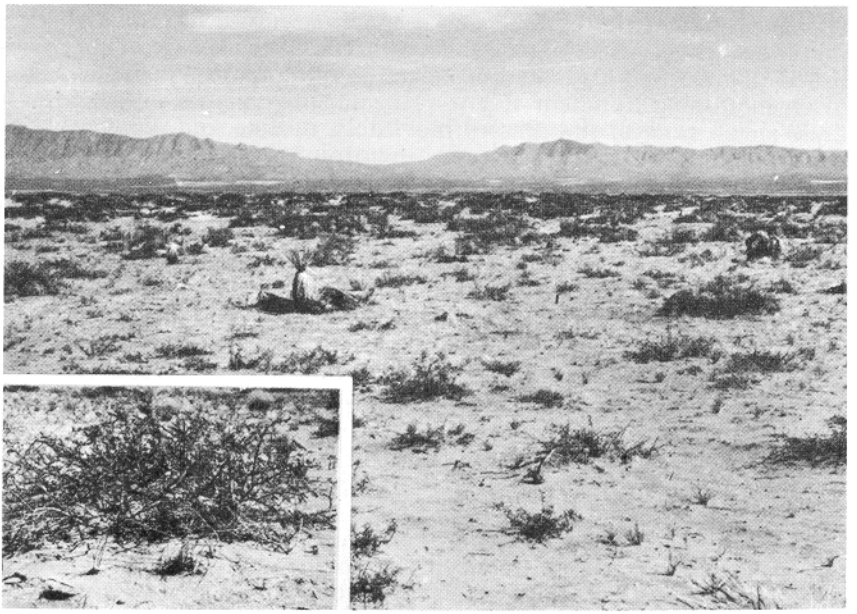

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FIGURE 18.—Invasion of young mesquite plants in the transition zone between mesquite sandhills and adjacent grassland. The accumulation of loose sand at the base of the plants, as shown in the inset, accompanies deterioration of the grass cover.

of its pretreatment crown intercept. On areas protected from jack rabbits and cottontails, reinvasion was even more rapid; in 12 years creosotebush reached 22 percent of its original crown intercept.

On two uncleared check plots, creosotebush declined an average of 28 feet in crown intercept between 1936 and 1947 along the 490 feet of transect line. Originally, creosotebush crown intercept averaged 211 feet, or 43 percent of the total length of transect. On a third check plot the crown intercept of creosotebush in 1936 totaled but 77 feet of the 490-foot transect. In 12 years it had increased to 117 feet, an increase of 52 percent.

Occupancy of 40 to 50 percent of the surface area probably approaches the maximum crown cover for creosotebush. After the early invasion stages are completed, it increases rapidly to that upper limit. Gardner (1951) states that the invasion or thickening up process may be recognized by a decrease of grass cover among the shrubs, increased soil erosion, increase of creosotebush seedlings among the larger plants, increase in size of the creosotebush area by encroachment on the surrounding grassland, and eventually the absence of grasses and the appearance of an erosion pavement (fig. 8).

Mesquite was also present on the two check plots on which creosotebush crown intercept declined between 1936 and 1947. In the remeasurement it had increased an average of 10.9 feet but was still only 25 percent of the crown intercept of creosotebush. Perennial grasses were mainly black grama, bush muhly, and fluffgrass, and their basal intercept decreased 99 percent in the interval between the two measurements.

Irrespective of the various causal agents involved, there has been a material increase in low-value shrubs. New seedlings are being established in grassland areas and are focal points for subsequent invasion. With increasing numbers of low-value shrubby plants on semidesert grass-shrub ranges, the grasses inevitably decline and are unable to regain dominance of the site even when rainfall is not limiting.

It is difficult to assess the changes in grass cover due solely to the invasion of shrubs, since climate and other environmental factors all affect vegetation changes. Doubtless, adverse climate in the past reduced the grass cover periodically, and local denuded areas were present where invading shrubs could have become established if seeds were available. In the present environmental complex where the grass vegetation is annually grazed and an ideal method of seed dispersal is provided, the shrubby species are favored. Eventually, these can completely dominate the vegetation cover.

GRAZING CAPACITY

The term grazing capacity usually implies a constant level of stocking that a range will support year after year without damage to the forage resource. This concept cannot be applied to black grama and tobosa grasslands and associated shrub ranges, because their production of forage varies greatly from year to year. Stocking must be adjusted yearly to meet this variable forage supply. During severe droughts, herbage growth may be so limited that there is virtually no forage production and, therefore, little or no possibility of grazing livestock. In contrast, the ranges will support large numbers of cattle during periods of good growth. Long-term changes in grazing capacity also are taking place as a result of the spread and thickening of shrubs.

On the Jornada Experimental Range, annual and long-term changes in grazing capacity have been determined from records of forage production, stocking, and related utilization on six pastures.

The Experimental Pastures

The six range pastures totaled 140,255 acres and were located on the relatively level part of the experimental range. Four have remained more or less intact since 1916, and two were formed by fence adjustments about 1928. Pasture boundaries and permanent water developments of the six pastures have existed since 1928 (fig. 2, p. 5). On approximately two-thirds of the experimental range, the permanent water is available within a 3-mile radius. Much of the remainder of the area has large surface tanks that usually contain water for part of each year.

In grazing year 1929 the acreage of each vegetation type in each pasture was determined by an intensive range survey (table 6). Three pastures contained primarily shrubs and comparatively less of the grass types. These were designated as shrub or brush pastures 1, 2, and 6. The other three pastures, numbered 5, 9, and 10, were predominately grass types.

Pasture 1, the largest of the pastures, had 81.6 percent of its total area covered by shrub types. Nearly half of the area was mesquite sandhills. The grass types, although occupying only 18.4 percent of

the pasture, covered 15,451 acres; whereas, there were only 11,726 acres in the grass types of the three grass pastures. Moreover, the tobosa and black grama types were about equally represented in pasture 1. Five permanent water developments and numerous small earthen tanks, which are often filled for short periods in the summer and early fall, provided water and aided in distributing the cattle over the large area.

Grazing in pasture 1 was slightly heavier from July to October than in other periods, but for practical considerations this pasture may be classified as a yearlong unit. Grazing was frequently too heavy within ½ to ¾ mile from permanent water, although in the later years of the experiment better distribution of the livestock was obtained by closing off the permanent water and utilizing water temporarily impounded in small tanks scattered over the pasture.

TABLE 6.—*Acreages of pastures and vegetation types of six pastures on the Jornada Experimental Range, as determined by a range survey completed in grazing year 1929*

Pasture	Black grama		Tobosa		Mesquite sandhills		Creosotebush and tarbush [1]		Total
Brush:	*Acres*	*Percent*	*Acres*	*Percent*	*Acres*	*Percent*	*Acres*	*Percent*	*Acres*
1	8, 175	9. 7	7, 276	8. 7	38, 938	46. 4	29, 572	35. 2	83, 961
2	9, 302	31. 5	959	3. 3	19, 251	65. 2	0	0	29, 512
6	1, 859	12. 7	3, 970	27. 1	254	1. 7	8, 575	58. 5	14, 658
Grass:									
5	1, 461	82. 1	132	7. 4	187	10. 5	0	0	1, 780
9	3, 028	95. 5	0	0	144	4. 5	0	0	3, 172
10	5, 992	83. 6	1, 113	15. 5	25	. 3	42	. 6	7, 172
Total	29, 817		13, 450		58, 799		38, 189		140, 255

[1] Creosotebush and tarbush have been grouped because the types are often intermingled.

Pasture 2, with 29,512 acres, was the second largest unit. Mesquite sandhills covered 65 percent of the pasture, and most of the rest of the area was black grama grassland. Five permanent wells around the perimeter of the pasture gave some control of livestock distribution.

Pasture 2 had more favorable management treatment than pasture 1, inasmuch as grazing was usually semideferred during the growing season. This amounted to 50.4 percent more animal units per month on the average from November to June than from July to October.

The third brush pasture, pasture 6, was largely occupied by creosotebush and tarbush. The grass types occupied 40 percent of the pasture, and tobosa was the more prominent grass type. Two wells and several surface tanks provided stock water. Cattle grazing was concentrated in the summer growing season.

The three grass pastures each contained minor amounts of the shrub types; the grass types covered 89.5, 95.5, and 99.1 percent of the area in pastures 5, 9, and 10, respectively. Black grama was the major type in each, although a substantial amount of tobosa type was present in pasture 10. Pasture 10 contained 7,172 acres, and had a well at each end plus one surface tank. Pasture 9 was 3,172 acres in area and also had two wells on opposite boundaries. In

pasture 5, there was one well for 1,780 acres. Pastures 9 and 10 were commonly grazed after forage growth was completed in the fall, but pasture 5 was usually grazed yearlong. Because of the small size of pasture 5 and its proximity to headquarters, it was often used as a holding trap for cattle that were to be shipped or doctored. At times it was used as a horse pasture.

Forage Appraisal

An appraisal of forage production was made each fall as a basis for determining annual stocking. Initially this appraisal consisted of a combination of ocular estimates and height measurements of forage plants. Later, an inventory of annual height growth and numbers of seedstalks for black grama plants was used as a basis for pasture stocking. Beginning in 1939 these measurements were supplemented by approximately four clipped transects per section in the black grama type.

The forage available for livestock grazing was computed as 30 percent of the air-dry weight of the clipped herbage. Although removal of not more than 40 percent of the black grama herbage is recommended, 30 percent of the herbage was used as the forage available for livestock to allow for sampling errors, uneven distribution of the cattle, wind erosion, and rodent damage.

Twenty pounds of air-dry forage was assumed to be the daily requirement of a cow and calf, and by expanding this for the number of acres of such forage, a stocking base was established for each coming winter-spring season. Fall and spring weeds occasionally provided additional forage, but these were not included in determining stocking.

Utilization Appraisal

The degree of forage utilization by domestic livestock is closely associated with the restoration and maintenance of the important forage plants. It is a measurement of the agreement between stocking rate and forage production of the range area.

The utilization appraisal, which was made each year before the summer's growth began, recognized and made adjustments for differences in plant composition, species palatability, size of the pastures, and livestock watering facilities. Campbell (1943) found that utilization of black grama on the Jornada Experimental Range decreased with distance from water at a rate of 10 percent a mile up to 3.5 miles. In comparing three levels of pasture utilization, he reported that black grama was utilized very lightly at 2 miles from water and was too closely grazed only in the first ¼ mile from water when the pasture as a whole was lightly grazed. In contrast, at the heaviest level, black grama was utilized too closely out to 2 miles from water. The effect of distance from salt grounds on utilization of black grama was not great, although improved salting increased utilization up to 15 percent at 3 miles or more from water. Campbell (1943) also found utilization increased with thinness of the stand of black grama and with proximity to roads and trails.

Over the years, methods of estimating utilization on the experimental range have varied and have become increasingly intensive. From 1916 to 1927 utilization of forage for each pasture was estimated

and summarized in percentage of what was, at that time, considered proper grazing of the key species. After 1927 pasture utilization was made essentially on a reconnaissance basis. Each pasture was classified by range types in which estimates of utilization were made of the main species. These were summarized into type-utilization figures and converted into percentage of proper use for the type. Average utilization of all forage was determined by combining all types, weighted by their respective forage acres.

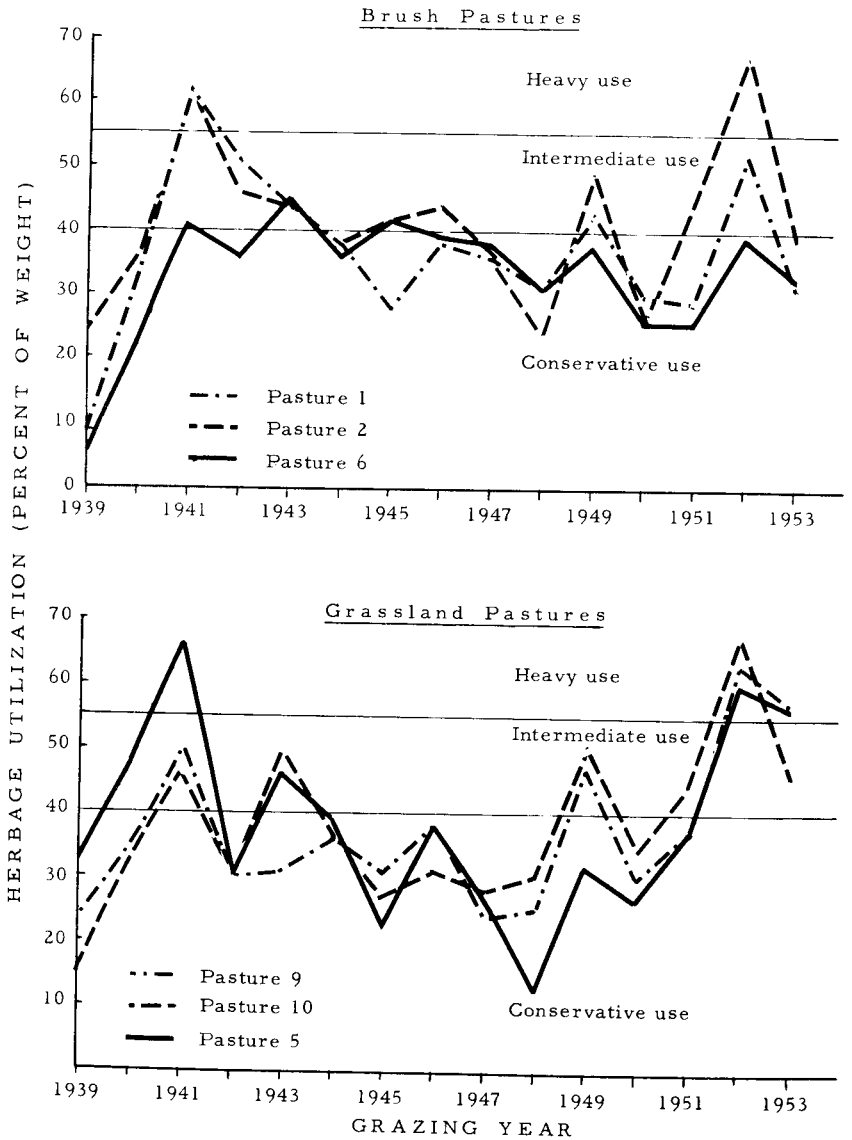

FIGURE 19.—Forage utilization on brush pastures 1, 2, and 6, and on grassland pastures 5, 9, and 10. Jornada Experimental Range, 1939–53.

From 1939 to 1953 a modification of the height-weight method described by Parker and Glendening (1942) was used. Stubble height was measured on transects near the forage production transects and the meter-square quadrats. These measurements, combined with ocular estimates of utilization by the reconnaissance method in the brush and tobosa grass types, gave estimates of utilization in each pasture. Utilization averages ranged from 37 percent in pasture 1 to 42 percent in pasture 2 for the 15-year period (fig. 19). In pasture 6 utilization averaged 33 percent, which, on the basis of the quadrat studies, was somewhat too light to maintain the greatest basal area of tobosa. However, it probably favored the small segments of black grama type.

The general appearance of black grama range under conservative and heavy use is distinct (fig. 20). When conservatively used, the average stubble height of black grama exceeds 3 inches, and at least 10 to 20 percent of the flower stalks remain ungrazed. On tobosa, utilization of 40 to 55 percent of the herbage removes approximately 80 to 85 percent of the height growth.

Stocking

Livestock records from the Jornada include stocking by classes of livestock, seasons of grazing by pastures, calf crops, death losses, animal weights, and sale prices.

Mostly cows, both dry and with calves, were grazed in pastures 1 and 2. Yearling animals, either from the natural herd increase or from additional stock purchased when forage conditions warranted, were grazed in pastures 6, 9, and 10. In pastures 6 and 10 the percentage of cows and yearlings was approximately equal. Bulls made up 2 to 5 percent of the stocking in all six pastures. Fifty-seven percent of the animal units in pasture 5 were horses, a far larger percentage than in any of the other pastures. Cows and yearlings each averaged 19 percent of the pasture stocking.

To compensate for different classes of livestock, pasture stocking records are expressed in terms of animal units. The equivalent values in terms of animal units of the various classes of livestock grazed on the experimental range are as follows:

	Animal unit
Cow and calf	1.00
Dry cow	.87
Yearling	.57
Bull	1.25
Horse	1.25

Stocking in animal units for the six pastures is presented in table 7. In grazing year 1916 stocking was initially too heavy in view of information subsequently accumulated, although at the time it was assumed to be about right. Numbers were soon adjusted to the forage supply as drought conditions became increasingly severe. Throughout this drought there was heavy supplemental feeding of cottonseed cake or chopped soapweed (Jardine and Forsling, 1922).

Because of limited forage growth, the experimental area was practically ungrazed between February 1925 and May 1926. The range was gradually restocked in grazing year 1927 as the drought diminished. In the meantime, a more conservative concept of proper

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FIGURE 20.—Black grama range: *A*, Conservatively grazed; *B*, heavily grazed. Jornada Experimental Range.

range use developed, and stocking never reached the high numbers of the initial period. On the four original pastures (1, 2, 5, and 10), stocking averaged 1,513 animal units from 1916 to 1926, inclusive, and 865 animal units in the grazing years 1927 to 1943 when growing conditions were more favorable. Fencing changes about 1928 added two additional pastures, 6 and 9.

During the second dry period, which began in 1944, stocking in the six pastures was reduced and in 1953 was only 40 percent of the 1928–53 average. After 1943, the average of the six pastures was 639

TABLE 7.—*Animal units grazed on the pastures of the Jornada Experimental Range, 1916–53*

Year	Pasture					
	1	2	5	6	9	10
	Number	*Number*	*Number*	*Number*	*Number*	*Number*
1916	1, 477	973	127			323
1917	1, 483	515	82			170
1918	753	649	163			229
1919	929	340	124			116
1920	1, 070	541	130			104
1921	993	880	122			151
1922	751	237	52			49
1923	656	286	48			46
1924	793	367	50			71
1925	485	161	38			43
1926	27	30	9			2
1927	331	43	18	193		41
1928	380	142	49	117	9	94
1929	631	329	40	94	44	84
1930	821	231	37	56	34	126
1931	437	322	12	20	41	70
1932	530	298	24	133	101	113
1933	583	337	33	173	64	173
1934	779	334	27	140	38	156
1935	304	154	7	141	41	86
1936	508	218	14	123	19	83
1937	653	232	12	192	54	96
1938	524	181	35	68	70	110
1939	242	242	28	25	67	112
1940	476	171	27	73	42	107
1941	561	190	23	61	64	85
1942	510	178	14	59	48	123
1943	485	152	18	57	51	115
1944	398	150	20	58	57	99
1945	334	235	17	112	53	84
1946	434	158	18	90	66	104
1947	317	148	25	96	30	108
1948	258	170	22	44	37	118
1949	217	142	28	70	68	104
1950	279	79	14	68	33	66
1951	290	127	20	69	54	87
1952	121	69	17	61	24	69
1953	155	51	9	90	16	30
Average	552	265	41	92	47	104
	[1] (432)	(194)	(23)	(88)	(47)	(100)

[1] Figures in parentheses are averages for period 1928–53.

animal units, but stocking was not reduced appreciably until lack of forage necessitated cutting the herd to 361 animal units in grazing year 1952. Additional reductions were necessary in 1953 in brush and grass pastures.

Surface-Acre Requirement

Grazing capacity for the six pastures was estimated from actual stocking records and annual estimates of utilization (fig. 21). Pasture area divided by actual stocking of the pasture in animal units yearlong, as adjusted to 40 percent utilization, gave the surface-acre requirement per animal unit. As previously pointed out, utilization for pastures 1, 2, 5, 9, and 10 averaged approximately 40 percent after adjustment for differences in vegetation, pasture size and physical improvements. Only the period 1916–51 was included because of the severity of the drought in 1952 and 1953. The only available forage of consequence in these years was the unused dry herbage produced in previous years. Furthermore, the determination of grazing capacity was complicated by the heavy feeding program needed to maintain the cattle remaining on the range during the drought.

Brush Range

Grazing capacity on all the brush pastures decreased greatly over the period of record, as is indicated by the increased surface acres needed to carry an animal unit. The trend of grazing capacity, however, differed between the brush pastures.

Pasture 6, with almost 60 percent of its surface area in tarbush and creosotebush types, averaged 90 surface acres per animal unit for the first 11 years. From grazing years 1946 to 1951, grazing capacity averaged 171 surface acres.

In the first 5-year period the average surface-acre requirement in pasture 1 was 79 acres per animal unit. Between 1947 and 1951 the average requirement was 268 acres. The annual observations indicated a steady decline in grazing capacity and no immediate tendency towards stabilization. Grazing capacity in pastures 1 and 2 was almost nil in grazing year 1952.

Initially, pasture 2 contained some of the best grassland of the experimental range. Before grazing year 1935, grazing capacity averaged 69 acres per animal unit, or an equivalent of about nine cows with calves per section yearlong. By 1951 the capacity was approximately 2 animal units per section, and in the next 2 years it declined to less than 1 animal unit per section yearlong. Pasture 2 which had 65 percent of its area occupied by mesquite sandhills, was in the early stages of mesquite invasion in 1928. The combined effects of drought and mesquite encroachment resulted in a progressive decrease in grazing capacity.

Grassland Range

The three grassland pastures showed far less change in grazing capacity than the brush pastures. The surface-acre requirement per animal unit in pasture 5 averaged 28 acres between 1916 and 1926, 89 acres between 1927 and 1943, and 66 acres between 1944 and 1951.

The surface-acre requirement per animal unit in pasture 9 averaged 24 acres per animal unit from 1928 to 1934. Then followed 3 years, which included the severe 1935 drought, when the requirement increased to an average of 57 acres. From 1936 to 1952 an average of 51 surface acres per animal unit was needed. Pasture 9 received better grazing treatment than any of the other pastures: it was not

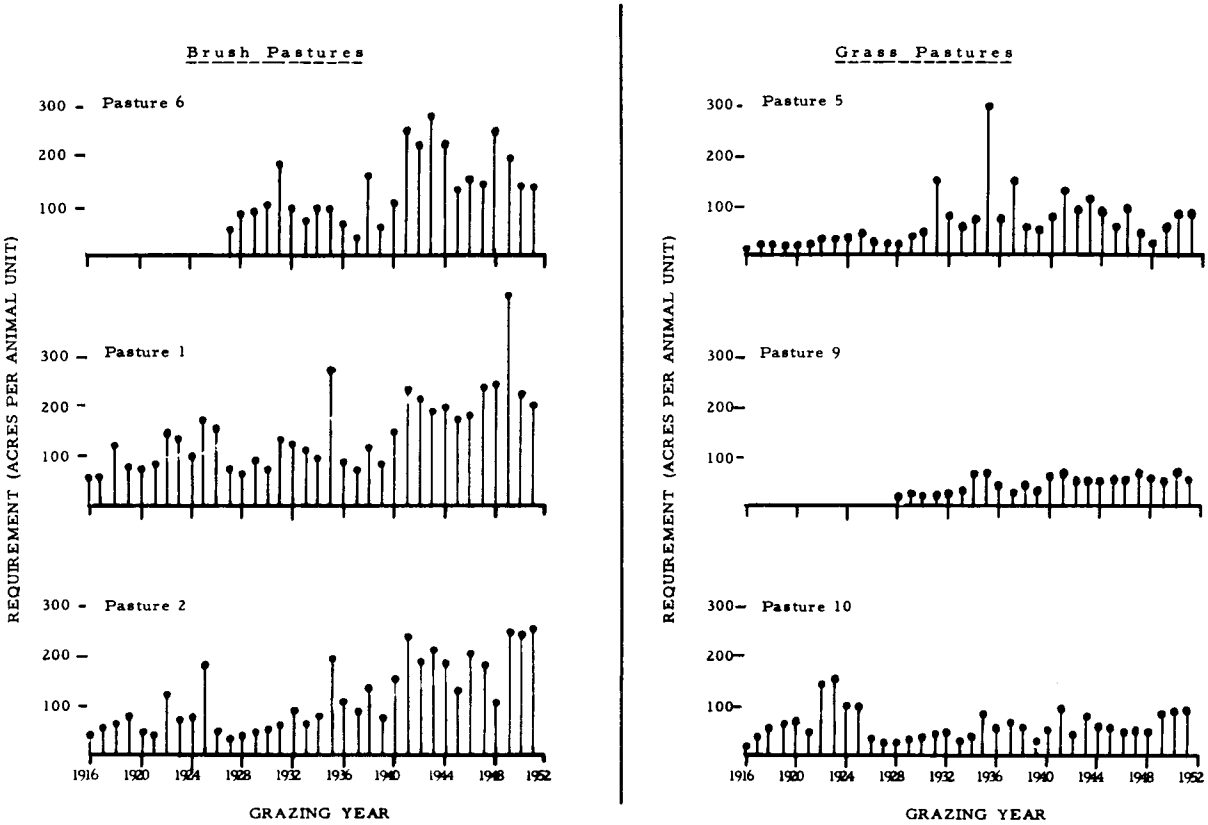

FIGURE 21.—Annual surface-acre requirement per animal unit on six experimental pastures. Jornada Experimental Range, 1916–51.

heavily stocked, grazing was reasonably uniform over the entire pasture, and nearly 90 percent of the use took place when the grass was dormant. Notwithstanding, grazing capacity averaged 244 surface acres per animal unit in 1952 and 1953.

In pasture 10, the average surface-acre requirement was 77, 49, and 68 acres for the grazing years 1916–26, 1927–43, and 1944–51, respectively. For the span of years 1916–51, the requirement averaged 61.5 surface acres per animal unit.

Brush vs. Grassland Pastures

The average grazing capacity from 1916 to 1951 was 59 surface acres per animal unit on the grass pastures and 134 surface acres on the brush pastures. This amounted to 10.9 and 4.8 animal units per section for the grass and brush pastures, respectively. The average grazing capacity was 2.3 times as great on the grass pastures as on the brush pastures for the entire period of record, and 3.2 times as great in the final 8 years, 1944–51.

Brush pasture 2 and grass pasture 10 are examples of how changes in grazing capacity differed between areas dominated by brush and those primarily in grass. Both were grazed mostly after forage growth was completed in the fall, and thus both received management that favored the grass stand. The grazing capacity of both pastures was about equal during the 1916–26 dry period. Moreover, both declined at an equal rate during this interval. In the period of generally favorable precipitation which followed, the capacity in pasture 2 began to decline at an accelerated rate, but in pasture 10 it did not. In the 1944–51 period, one of increasing drought intensity, grazing capacity in pasture 2 decreased more rapidly than in pasture 10. In 1951 the capacity of the grassland pasture was 2.8 times as great as pasture 2. Futhermore, the average capacity in pasture 10 was higher in the second dry period up to 1952 than in the initial period, despite lower amounts of precipitation in the later years. This is attributed to improved management, which is discussed later.

The decrease in grazing capacity in the brush pastures was the result of the continuous encroachment of brush into the isolated islands and main segments of the grass types. This was particularly prominent with mesquite; however, in the tarbush and creosotebush areas, forage depletion was similar.

Numerous mesquite seedlings in the grass stands are a potential source of brush invasion in each of the grass pastures. Once these seedlings become established, they are well adapted and eventually will dominate the site unless control measures are used. If the process is allowed to continue to the mesquite sandhills stage (fig. 7, p. 11), the site will become almost, if not entirely, beyond economic rehabilitation by any known method for low-producing range (Knox et al., 1951).

Brush also invades tobosa sites and may cause declines in grazing capacity. Tarbush and creosotebush are the principal invaders, although mesquite will also invade such areas. Tarbush suffered mortality in the drought, and its invasion into tobosa sites was retarded in some areas. Besides, grass associates with tarbush often remain abundant until the brush thickens considerably (fig. 9, p. 14).

Climatic variations in this region are so frequent and of such degree that they may forestall complete recovery of the vegetation

under all but the most judicious grazing use. The quadrat records, however, attest that the grass stands, although seriously depleted by drought, will normally recover when precipitation becomes more favorable. When the recovery of grasses is handicapped by shrub competition, production declines until only vestigial plants remain. Gardner (1950) has shown that, once the grass cover has been completely eliminated, recovery is a long, slow process even when the area is protected from grazing.

MANAGEMENT AND OPERATION

Methods of management to make the best use of black grama and tobosa grasslands and associated shrub ranges must be fitted to the hazardous environmental conditions. This requires herd composition that is adaptable to rapid fluctuations in numbers, wide distribution of animals to avoid overgrazing and undergrazing on parts of the range, and animal husbandry and marketing practices to obtain the highest net income. Even with these techniques, severe droughts may make it necessary to remove all livestock from the range for 1 year or more. Also, following drought, special management provisions should be made to promote rapid forage recovery.

Livestock husbandry is an integral part of any range management or operational plan. A systematic program to minimize death losses and improve the quality and production of a herd can easily mean the difference between success or failure of the ranch operation. Since the Jornada Experimental Range was established to represent a practical range operation upon which the cooperator who owned the cattle was dependent as a source of income, livestock husbandry received attention as well as phases more directly related to the vegetation.

Grade improvement of the herd was an important aim of management. Cows with characteristics of good Hereford range cattle were selected. They were seldom held longer than 8 years, and their replacements were selected from the natural herd increase or by purchase of high-grade stock. Replacement heifers were not bred until they reached the age of 20 months. Unproductive animals, as well as poor-grade and off-color animals, were sold in the annual culling.

Bulls were purebred Herefords, either registered or subject to registration. Youth and vigor of the herd bulls were insured by fixing 5 years as the maximum period of service. During the fall and early winter, the bulls were segregated from the rest of the herd and fed supplements to keep them in top condition. An average of one bull for each 20 cows was maintained.

These range management and herd improvement practices resulted in steady improvement in the grade of livestock, lowered the death losses, and increased the calf crop. The calf crop increased from an average of 65 percent in the early period to 85 percent between grazing years 1939 and 1951. Losses of adult livestock from all causes averaged only 1.74 percent annually. They ranged from a high of 4.7 percent in grazing year 1935 to a low of 0.1 percent in 1948. The maximum loss occurred when 84 percent of the herd was composed of breeding cows.

Seasonal Grazing of Forage

Ranches that have a combination of range types, such as on the Jornada Experimental Range, will benefit by grazing the principal

forage species at certain times of the year. Although black grama is palatable to cattle at any time, grazing may be detrimental during its active growth. Stolons, which are produced at this time, are often grazed or dislodged before they become rooted. This seriously restricts the spread of black grama.

On the other hand, tobosa and burrograss are most palatable and nutritious during the summer growing season. They become much less so after growth is completed and the plants cure. Tobosa can withstand moderate grazing during the growing season (Campbell, 1931).

Because of the differences in palatability and response of the major forage species, most of the cattle on the Jornada were turned onto the tobosa and tarbush ranges in the summer after forage growth began. The animals usually remained there until fall, when they were moved to black grama range or mesquite sandhills and creosotebush types where black grama was present.

Benefits from this kind of management were illustrated on two adjacent and once comparable black grama ranges. One area was grazed principally from October to July, and the other was grazed yearlong at approximately the same intensity. After 20 years, plant composition on the range grazed October to July was 72 percent black grama, 20 percent other grasses, and only 8 percent snakeweed. The other area's composition was 69 percent snakeweed, 9 percent black grama, and the remainder mostly other grasses.

Advantages of deferring grazing during the growing season on ranges having a high percentage of black grama are also illustrated by the average surface-acre requirement and the percentage of animal units grazed from November to July on the three grass pastures for the period 1928–51:

Pasture	*Percent of grazing during November to July*	*Surface-acre requirement*
9	88. 2	45. 0
10	71. 7	56. 0
5	57. 5	84. 3

As shown, the surface-acre requirement varied inversely with the percentage of animal units grazed during the winter-spring period.

Many ranches of the region do not have a favorable balance of black grama and tobosa ranges. On some ranches tobosa range is inadequate and animals necessarily must be grazed on the black grama and associated shrub types in the summer and early fall. A systematic plan of periodic summer deferment of the black grama type during the growing period is best on these ranges. On ranges grazed yearlong, only a small percentage of the forage should be removed during the relatively short summer growing season, for damage to black grama can be minimized with carefully controlled, conservative grazing.

When tobosa is succulent and actively growing, cattle will stay on tobosa range quite well. However, if frequent rains are not received during the summer, tobosa becomes less palatable. Cattle will then seek other forage until the tobosa freshens up following the next rain. They will frequently leave the tobosa for the surrounding black grama range. Therefore, when tobosa is abundant, fencing, salting, and inexpensive water developments promote better use of this type of forage. Results of tests with electric fence show that

this is a cheap and effective means of restricting cattle to tobosa areas (Ares, 1939b). It is best to fence large areas of tobosa into permanent pastures separate from types where black grama is the principal forage species.

Livestock Distribution

Measures for obtaining distribution of the livestock should be given much consideration in any management plan. Certain of these have been previously suggested as means for implementing seasonal use of the black grama and tobosa areas.

Topography is comparatively level on black grama-tobosa ranges and does not influence livestock distribution to the same extent that it does on foothill and mountain ranges. Nevertheless, areas around water developments are often severely overgrazed, while forage is practically untouched only a short distance away. Low land values limit the number of permanent type water developments, and distance from water definitely restricts utilization of range forage in this region.

Construction of low-cost earthen dams that temporarily impound runoff water in remote areas of the Jornada Experimental Range where cattle ordinarily would not graze helped distribute the animals. Not every tank was filled each year, but enough tanks were built so that some usually caught water. Stock waters at windmills, watering rims, or large surface tanks were closed to cattle when the small structures were filled, thereby relieving the area around the more permanent watering places. Ares (1936a) has shown that these inexpensive developments were effective in keeping cattle from grazing adjacent black grama range as well as increasing utilization of the tobosa forage. Placing salt at the temporary water developments in the large tobosa areas was also helpful. This did not prove detrimental to the vegetation for the short time water was available. Ares (1936b) reported that with judicious use of salt on one area, tobosa was utilized 50 percent; three-awns 70 percent; and burrograss and dropseeds 20 percent. Previously, utilization of these grasses averaged 30, 50, and 10 percent, respectively.

Placing salt 1 to 4 miles from permanent water proved successful in improving livestock distribution on black grama areas of the Jornada (Ares, 1936b). Overutilization of areas near water was substantially reduced, and much better use was made of the forage even near the most remote salt ground. These studies showed that it was desirable to maintain several salt grounds rather than to have only a few.

The use of meal-salt supplement has been another efficient practice for improving cattle distribution (Ares 1953a). This has also been satisfactory for supplying mineral and protein supplements to the cattle. In contrast to other concentrates, which must be hand fed, the meal-salt mixture can be fed free-choice because salt content limits the amount of concentrate taken. The ratio of the mixture varies, depending upon whether the objective of feeding is to provide a maintenance ration or to put on substantial weight gains.

For range feeding of yearlings, a ratio of 80 percent cottonseed meal and 20 percent granulated rock salt was used on the Jornada. The mixture was available to the animals at several points located away from permanent water in one instance, and in another, both at and away from water. Feeding the mixture away from water practi-

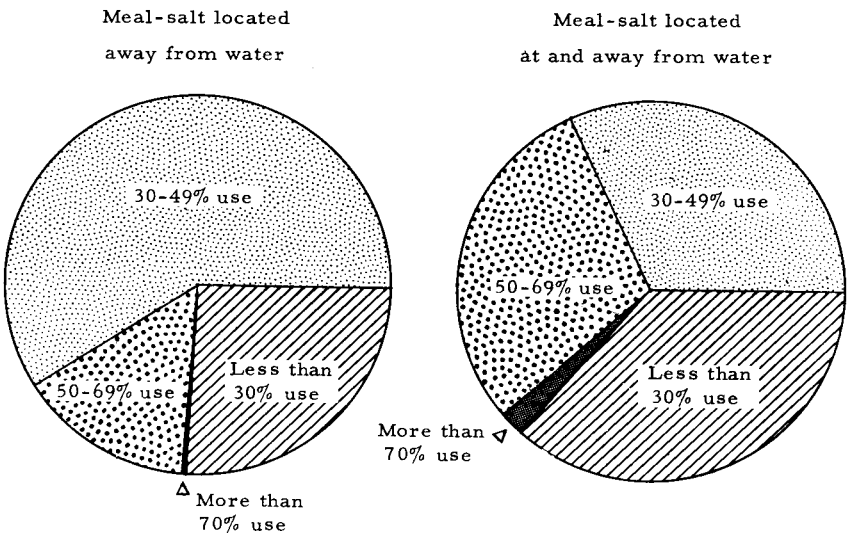

FIGURE 22.—Relative areas receiving different degrees of forage utilization as a result of two systems of feeding meal-salt supplement to yearling animals. Jornada Experimental Range, 1950–51. Adapted from Ares (1953a).

cally eliminated the area in which utilization exceeded 70 percent, reduced by one-half the zone of 50 to 69 percent forage utilization, and almost doubled the zone of 30 to 49 percent use (fig. 22).

No losses from salt poison resulted from feeding the meal-salt supplement, although some of the feeding stations were located as far as 3 miles from water. Yearling steers gained an average of 0.17 pound per head more per day when the supplement was offered both at and away from water than when it was available only at sites away from water. However, Ares (1953a) concluded that the dual purpose of this type of range feeding—to obtain most efficient use of the range forage and yet maintain condition and growth of the yearling animals—was best realized by the out-station feeding.

Flexible Herd Management

The composition of the cattle herd should be such that it can be adjusted to meet large fluctuations in forage and yet retain the quality of the breeding herd. Although the range is suitable for a breeding-herd type of operation, it has proved advantageous to diversify the operation by including significant numbers of yearling animals as part of the herd.

During the years 1916–26 large fluctuations in forage production required drastic adjustments in the size and composition of the herd. Beginning in grazing year 1935 the ratio of breeding cows to the total herd was reduced (fig. 23), while that of yearlings was increased. Between grazing years 1940 and 1951, when the system of flexible herd management was in operation, yearlings constituted 30 percent of the total herd; breeding cows, 61 percent; and bulls and horses, the remaining 9 percent. Normally, 10 to 15 percent of the breeding cows were culled each year and replaced by yearling heifers raised on the range. This allowed the herd to be built up from the best of the natural increase and thus preserve quality and grade that have been achieved

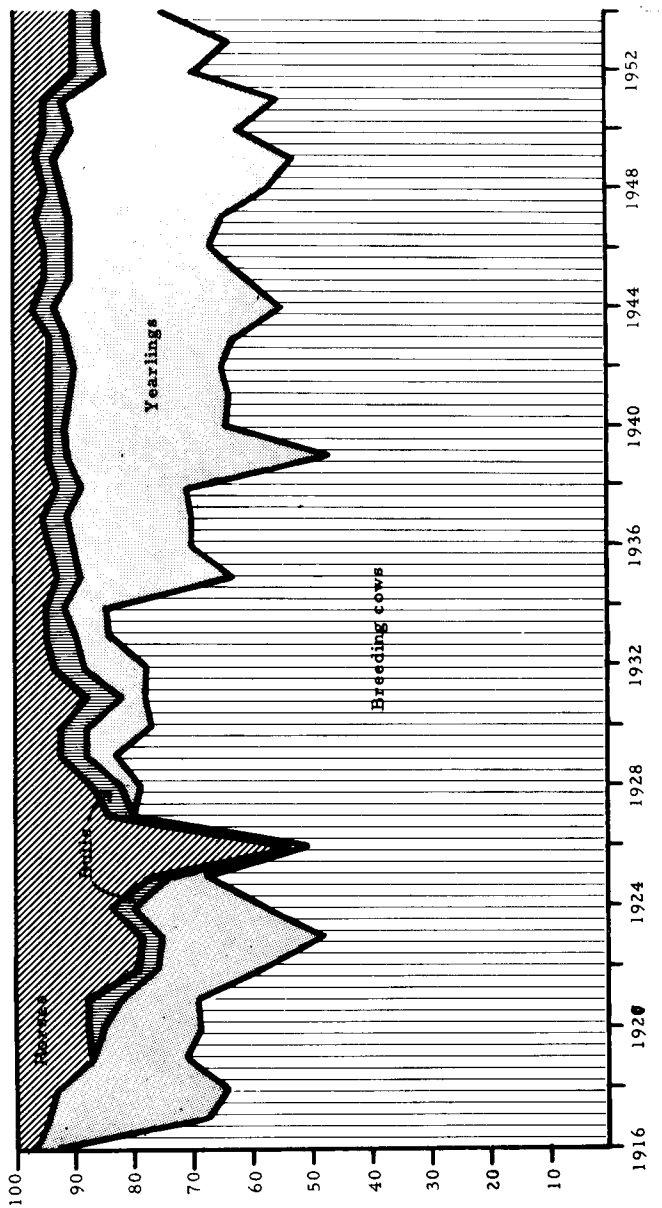

FIGURE 23.—Experimental herd composition on the Jornada Experimental Range, 1916–53. From 1916 to 1925, animals classified as yearlings included many 2- to 3-year-old steers.

by years of selective breeding. Flexibility in herd composition permitted the ranch operation to continue through all but the most extreme dry weather.

Flexible herd management, as applied on the Jornada, began with an annual appraisal of forage production. In years of low forage production, adjustments in the size and composition of the herd were planned for the winter-spring season to bring the herd within the capacity indicated by the appraisal. Adjustments were made in this way: First, weaner calves were sold; second, holdover yearlings were marketed; and third, a heavier than normal culling was made in the cow herd and, when necessary, even some of the replacement heifers were sold. Maintaining the cow herd at approximately 60 percent made it possible to reduce stocking by more than 40 percent without too much sacrifice of the breeding-cow herd.

In the years of above-average forage growth, additional stock were added to the herd that was carried through the winter-spring period. For example, when forage conditions warranted, all the natural increase from the breeding herd was held over until spring and additional weaner calves were purchased for winter pasturing. Depending upon the market and forage conditions, these yearling animals were sold in the spring or following fall when forage production was again appraised and the herd adjusted to meet the new situation.

Breeding animals on many ranches throughout the region have been replaced with heifers and yearling steers. This more flexible cow-yearling type of operation has permitted herd adjustments in years of poor growth without seriously affecting the breeding herd (Ares, 1952; Reynolds, 1954). Also, more pounds of beef can be produced with this type of operation than with the breeding-herd type (Stubblefield, 1956).

Income and Operating Costs

Yearlings and calves have been the main source of income from the Jornada operation. Table 8 gives a breakdown of sales data for two periods: grazing years 1927–34 and 1940–51. The first period was before adoption of flexible herd management on the experimental range. During the second period, the system of flexible herd management was in effect. The interim period 1935–39 was the one during which the breeding herd was being reduced. After 1951, drought necessitated a sharp reduction in the number of animal units.

The herd that grazed on the experimental range from 1927 to 1934 averaged 80 percent cows and 6 percent yearlings. Calves made up 47 percent of the total number of animals sold in this period, yearlings 32 percent, and cows 20 percent. Calf sales contributed 36 percent to the total pounds of beef sold and 40 percent to the total value of sales.

From 1940 to 1951, when the system of flexible herd management was in effect, cows averaged 61 percent and yearlings 30 percent of the total herd. Yearlings constituted 62 percent of the total number of animals sold in this period, calves 17 percent, and cows 19 percent. Yearlings exceeded all other classes of animals in total pounds of beef marketed and total value of sales.

During the period 1927–34 an average of 1,110 animal units grazed on the range, and 377 pounds of beef per animal unit were sold. The beef sold was valued at $23.21 per animal unit grazed. Under the

TABLE 8.—*Average annual sales of beef from the Jornada Experimental Range for grazing years 1927–34 and 1940–51*

Grazing year and animal class	Animals sold	Weight per animal	Total weight of beef sold		Total value	
1927–34:	*Number*	*Pounds*	*Pounds*	*Percent*	*Dollars*	*Percent*
Cows	176	676	118, 976	28. 4	6, 112. 97	23. 8
Calves	419	364	152, 516	36. 5	10, 258. 86	39. 8
Yearlings	285	453	129, 105	30. 8	8, 941. 29	34. 7
Bulls	13	1, 353	17, 589	4. 3	445. 92	1. 7
Total	893		418, 186	100. 0	25, 759. 04	100. 0
1940–51:						
Cows	142	836	118, 947	30. 8	9, 991. 55	19. 8
Calves	127	303	38, 633	10. 0	4, 481. 43	8. 9
Yearlings	465	467	217, 433	56. 4	34, 789. 28	69. 2
Bulls	10	1, 091	10, 910	2. 8	1, 058. 27	2. 1
Total	744		385, 923	100. 0	50, 320. 53	100. 0

flexible system of management, an average of 780 animal units grazed the range from 1940 to 1951, inclusive, and produced an average of 495 pounds of beef valued at $64.51 per animal unit grazed.

Beef produced in the period 1940–51 sold for higher prices than in the period 1927–34, which accounted for some of the differences in returns. However, a comparison of value for the two periods in terms of 1940–51 sale prices illustrates the advantage of flexible herd management. As shown in the following tabulation, the gross return during the second period would have exceeded that received in the first, although an average of 330 fewer animal units were grazed:

Class of animal:	*Average sale price per pound (cents)*	*Average annual gross return*	
		1927–34 (dollars)	*1940–51 (dollars)*
Cows	8. 4	9, 993. 98	9, 991. 55
Calves	11. 6	17, 691. 86	4, 481. 43
Yearlings	16. 0	20, 656. 80	34, 789. 28
Bulls	9. 7	1, 706. 13	1, 058. 27
Total		50, 048. 77	50, 320. 53

So expressed, the annual gross return per animal unit grazed would have averaged $45.09 for the 1927–34 period and $64.51 from 1940 through 1951—an advantage of $19.42 per animal unit in favor of the second period.

Ares (1952) has pointed out that flexibility in herd composition resulted in more uniform annual cattle sales on the Jornada Experimental Range. Fluctuations were extreme from 1924 through 1939 (fig. 24); annual sales of beef varied from nothing to more than 1 million pounds. From 1939 through 1951, sales were less erratic but still showed considerable variability. Apparently a rancher in this region must contend with annual fluctuations in sales even though he uses the best known techniques of management in conjunction with conservative grazing. Each year he must balance herd numbers with

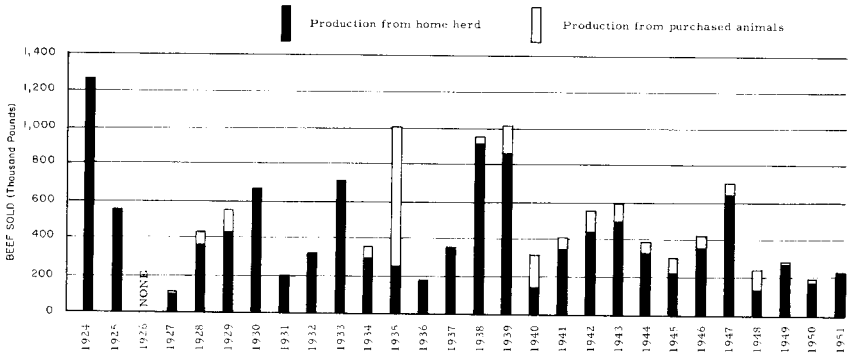

FIGURE 24.—Total pounds of beef marketed from the Jornada Experimental Range, 1924–51.

the size of the forage crop. Frequently, animal adjustments on Southwestern ranges are made too late to avoid weight losses and to prevent injury to the forage resource (Lantow and Flory, 1940).

A summary of costs and returns from the Jornada ranch operation follows:

	1916–26	*1928–37*	*1941–47*
Breeding cows—average number	1, 572	868	654
Calf crop—percent	65. 0	71. 7	88. 0
Losses—do	2. 0	1. 8	1. 4
Operating cost per cow—dollars	11. 47	8. 61	24. 42
Net income per cow—do	3. 04	7. 00	35. 61
Average animal units—number	2, 340	1, 272	1, 006
Net income per animal unit—dollars	2. 04	4. 78	23. 15

Schoeller (1927) reported that the operating cost per cow averaged $11.47 between grazing years 1916 and 1926. Net income in these early years averaged $3.04 per cow, with a 65-percent calf crop and a death loss of less than 2 percent. Between 1928 and 1937, the operating cost was $8.61 and the net income per cow averaged $7.00, an increase of $3.96 over the previous period (Ares and Valentine, 1943).

Finally, during the period of flexible herd management, 1941–47, average net income per cow was $35.61 (Ares, 1953b). Most of the sales during that period were of yearling animals. These data show that net income per animal unit was $21.11 greater than in the first period and $18.37 greater than in the second. Although operating costs doubled those of the second period, they were offset by the unusually favorable selling prices that prevailed during World War II.

Application

The range management practices that were useful on the Jornada Experimental Range can, with some variations, be applied on most semidesert grass-shrub ranges. Chronological application of these practices are as follows:

1. An annual plan of management is prepared. The techniques will depend upon the individual circumstances and the proportion of forage types on the particular ranch.

2. The herd should be sized up well before the end of the summer growing season; prospects for the range forage crop are usually evident by this time. Knowledge of the animals to be shipped, including cull cows, cut-back steers, overaged bulls, and calves, is needed to determine what adjustments in numbers can best be made.

3. The forage supply should be determined at the end of the growing season and should serve as the base for operation. The yield of forage is measured or, with experience, estimated within each pasture or range unit before shipping in the fall. Winter and spring annuals may be produced in some years and these will provide a welcome green supplement to the cured grasses and browse. But winter and spring growth is undependable and is best considered only as a bonus.

In developing the annual plan of management, the safe rule is to stock on the basis of forage available each fall, making adequate allowance for forage that may be lost after the inventory. Allowances must also be made for unequal distribution due to size, shape, and terrain of the pasture and number and placement of livestock waters. Although 40 percent utilization by weight of the major forage grasses is usually not detrimental to their maintenance, 30 percent utilization is recommended to allow for unforeseen reductions in the forage and for irregular distribution.

4. Final adjustments in the herd are made on the foregoing basis, and marketing is planned. A cow-yearling ratio of approximately 2:1 permits adjustments in the number of animals of up to 40 percent without selling any of the breeding cows. If forage growth is below normal, the herd should be reduced accordingly by selling the more easily salable yearling animals first. Unless numbers are reduced sufficiently when the forage supply is short, only a bare maintenance ration will be provided for all animals, whereas a lesser number may not only maintain themselves in condition but produce a larger weight increment (Neale, 1937). If surplus forage is available, more weaner calves can be retained through the winter as yearlings. The herd can also be increased by outside purchases if conditions warrant.

5. The management plan for the winter-spring period is in effect until new forage is produced the following summer. This may extend to the latter part of July or even August before sufficient rain to start forage growth is received. Supplemental feed and salt are located in the pastures where they will improve distribution of cattle. This usually means placing these supplements on the outlying areas to obtain the optimum use of the forage.

Yearlings carried through the winter-spring season are usually marketed between April 1 and May 15. If they are held until the following fall, the management plan must recognize the need for additional forage.

6. In late June, a survey is made of all the pastures to determine the degree of grazing use actually sustained on the pasture.

Collection of such data for several years builds up records that may be used for appraisal purposes and to develop future plans. Longtime records let the manager know how the forage plants respond to fluctuating weather conditions and how management can be adjusted to fit the environment that prevails in the Southwest.

Managers of semidesert grass-shrub ranges must be reconciled to the inevitable occurrence of frequent and often times extreme drought periods. In severe drought there may be little or no current forage growth, and many perennial forage plants may be killed. Restoration

of the vegetation is slow. Three years or longer is often required for the range to recover. To minimize the impact of drought on the weakened vegetation, livestock grazing should be carefully managed throughout the drought and post-drought period.

On many well-managed ranges, the better forage plants are being replaced by inferior plants such as mesquite. This replacement is often so gradual as to be almost imperceptible. Once a seed source is present, mesquite has increased on areas that have been consistently grazed very conservatively (table 5, p. 30). Stockmen faced with this invasion threat should include an active program of brush removal as part of their management.

The most effective and economical method of mesquite eradication to date is hand-grubbing of small plants. Success has been erratic with hormone-type herbicides applied as foliage sprays. In well-developed mesquite sandhills where sand has become mounded around the plants, foliage applications have not been effective. Mechanical control methods such as bulldozing or cabling, which are usually effective on large shrubs, are not feasible on mesquite sandhill sites because they cause excessive soil disturbance and leave much bare soil. Revegetation of the bare areas by natural means is haphazard, and seeding with native or introduced species has been generally unsuccessful.

Grubbing should be done first on the more valuable grassland sites where the invasion is in the initial stages. In young relatively sparse stands where the plants are small, the job can be done with a single blow of a mattock, striking well below the bud line or root crown of the plants. In 1958 on the Jornada, the cost of hand-grubbing was 39 cents an acre on areas that averaged 55 small plants an acre (Herbel et al., 1958). In a study 10 years earlier where the infestation was much heavier (161 plants an acre), the cost was $3.81 an acre, a price often too high to be economical on such range. Control of creosotebush and tarbush requires more study before recommendations can be made for these two species.

SUMMARY AND CONCLUSIONS

Ecology of the range plants, grazing capacity of the forage resource, and techniques of management most suited to black grama and tobosa grasslands and associated shrub ranges of the Southwest have been interpreted from records of vegetation, climate, and livestock on the Jornada Experimental Range. The experimental range is located 23 miles northeast of Las Cruces, N. Mex. Research, which has application to more than 60 million acres, has been underway on this area since 1916.

1. Annual rainfall at the Jornada Experimental Range headquarters from 1916 to 1953 averaged 9.02 inches; more than 50 percent of this amount was received in July, August, and September. Precipitation records showed no significant longtime trend in amount, but alternate periods of generally higher or lower rainfall were apparent at intervals of approximately 20 years. Rainfall alternately averaged about 10 percent above or below the overall mean in these intervals; however, individual years were often much more divergent.

2. Vegetation types on the experimental area include black grama, tobosa, mesquite sandhills, creosotebush, and tarbush. Perennial grasses furnish the bulk of the forage in all types except the mesquite

sandhills, where grasses are sparse and palatable browse plants yield more forage. Most forage growth is made from July through September. Growth characteristics and maintenance of black grama and tobosa are given primary consideration in the management of the experimental area. Black grama grows in open stands on the more coarse-textured, sandy soils. It is palatable throughout the year and can advantageously be reserved for use during the dormant or winter season. Tobosa grows on the fine-textured soils that usually receive some flood water. It is highly palatable when actively growing and can withstand moderate grazing at that time.

3. The basal area of grasses on meter-square quadrats charted yearly from 1916 to 1953 was found to fluctuate with precipitation received in a 15-month period, which includes the previous grazing year (July 1–June 30), plus the current growing season (July, August, and September). The basal area of black grama was more closely related to this 15-month precipitation under conservative grazing than under other intensities of grazing use and nonuse. Conservative grazing removes up to 40 percent of the herbage; intermediate use removes between 40 and 55 percent of the herbage; and heavy grazing, more than 55 percent. Basal area of black grama during extended dry periods was reduced to about the same minimum irrespective of the degree of grazing; however, recovery was greatest on quadrats conservatively grazed. Heavier grazing than was experienced on the quadrats very likely would result in greater decimation of the stand. Where tobosa was dominant, its basal area was highest on intermediately grazed quadrats. During periods of above- and below-average precipitation, the basal area of tobosa varied in a manner similar to that of black grama; however, it is less sensitive than black grama to changes in precipitation.

4. Herbage production of perennial grasses varied widely from year to year in response to fluctuations in precipitation during the growing season. In dry years production was reduced to approximately 100 pounds an acre, air-dry. In favorable years herbage production in the black grama type averaged 500 pounds to the acre. Production of tobosa averaged much higher than black grama; it yielded 1,000 to 1,900 pounds of herbage an acre.

5. Shrubs became more numerous on many areas in the black grama and tobosa types during the period of record. As this happened, the grasses and grazing capacity were materially reduced. Mesquite was the primary invader of the black grama type, and creosotebush and tarbush encroached into tobosa grasslands. Creosotebush invades other grass and shrub types except on areas of unstable, sandy soils. Grass associates of the tarbush type were often abundant until the brush thickened considerably. Under the conditions observed, continual invasion of grasslands by shrubby species is inevitable unless control measures are used.

Creosotebush and tarbush have quickly reinvaded areas where conversion to grassland has been attempted.

6. On three experimental pastures, which were predominantly covered by shrub types, grazing capacity averaged 4.8 animal units per section in contrast to 10.9 animal units on 3 pastures that were mostly grass. The brush pastures showed a consistent decline in grazing capacity over the years, but the grass pastures exhibited no such trend. Grazing capacity fluctuated widely in all pastures as a result of annual variations in the forage crop.

7. For best use and maintenance, tobosa range should be grazed during the growing season and black grama areas should be reserved for fall-winter-spring use when the grasses are dormant.

8. Other features of management included constant improvement of the herd through careful culling, selection of good-quality cows, the use of bulls either registered or eligible for registration, the use of numerous inexpensive water developments in the tobosa areas, salting away from water on black grama range and fencing to obtain better distribution of the cattle. A mixture of cottonseed meal and salt fed to the stock away from water improved the grazing use in the outer reaches of the winter-spring pastures and also supplemented forage deficiencies in protein and phosphorus.

9. Because of the wide fluctuations in forage production, it was advantageous to maintain the number of breeding cows at approximately 60 percent of the entire herd. This permits stocking reductions of as much as 40 percent through selling all yearlings and heifer replacements in years of poor forage growth. When abundant forage is produced, the herd can be increased by retaining weaner calves and forage purchasing additional yearlings.

10. The cow-yearling herd arrangement increased beef production per animal unit grazed, and it also increased the value of the beef produced because of the higher percentages of animals sold as yearlings. During the period 1927–34 when the herd was managed as a cow-calf operation, 377 pounds of beef were sold per animal unit grazed; average annual value was $23.21. When the cow-yearling herd was maintained from 1940 to 1951, 495 pounds of beef per animal unit were sold, valued at $64.51. Comparable value of the beef sold during the 1927–34 period averaged $45.09 per animal unit grazed.

11. Despite application of the best known techniques of range management, ranchers and land administrators of semidesert grass-shrub range areas often face periods of low forage production when stocking must be reduced. In severe drought periods a large part of the stand of perennial forage plants will be killed and livestock must be removed for one year or more to permit general range recovery.

COMMON AND BOTANICAL NAMES OF SPECIES MENTIONED

Grasses

Common Name	*Botanical Name*
Burrograss	*Scleropogon brevifolius* Phil.
Dropseed, mesa	*Sporobolus flexuosus* (Thurb.) Rydb.
Dropseed, sand	*S. cryptandrus* (Torr.) A. Gray
Fluffgrass	*Tridens pulchellus* (H.B.K.) Hitchc.
Grama, black	*Bouteloua eriopoda* Torr.
Gypgrass	*Sporobolus nealleyi* Vasey
Muhly, alkali	*Muhlenbergia asperifolia* (Nees & Mey.) Parodi
Muhly, bush	*M. porteri* Scribn.
Muhly, ear	*M. arenacea* (Buckl.) Hitchc.
Sacaton, alkali	*Sporobolus airoides* Torr.
Three-awn, purple	*Aristida purpurea* Nutt.
Three-awn, red	*A. longiseta* Steud.
Three-awn, Wooton	*A. pansa* Woot. & Standl.
Tobosa	*Hilaria mutica* (Buckl.) Benth.

Forbs

Baileya, desert	*Baileya multiradiata* Harv. & A. Gray
Bladderpod	*Lesquerella fendleri* (A. Gray) S. Wats.
Croton, leatherweed	*Croton corymbulosus* Engelm.
Dalea, broom	*Dalea scoparia* A. Gray
Desertholly	*Perezia nana* A. Gray
Globemallow	*Sphaeralcea* spp.
Goosefoot, lambsquarters	*Chenopodium album* L.
Hymenoxys, bitterweed	*Hymenoxys odorata* DC.
Paperflower, woolly	*Psilostrophe tagetinae* (Nutt.) Greene
Rushpea, indian	*Hoffmannseggia densiflora* Benth.
Spectacle-pod, Wislizenus	*Dithyrea wislizenii* Engelm.

Shrubs and Half-Shrubs

Saltbush, fourwing	*Atriplex canescens* (Pursh) Nutt.
Creosotebush	*Larrea tridentata* (DC.) Coville
Ephedra	*Ephedra* spp.
Mesquite	*Prosopis juliflora* vars. *glandulosa* (Torr.) Cockerell and *torreyana* L. Benson
Parthenium, mariola	*Parthenium incanum* H.B.K.
Sagebrush, sand	*Artemisia filifolia* Torr.
Snakeweed, broom	*Gutierrezia sarothrae* (Pursh) Britt. & Rusby
Tarbush	*Flourensia cernua* DC.
Yucca, soaptree	*Yucca elata* Engelm.

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