Seasonal and Yearlong Grazing in the Northern Chihuahuan Desert: Impacts on Forage and Cow–Calf Production

Bulletin-793

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SUMMARY

A three-pasture seasonal suitability grazing system was studied from 1967 to 2002 on the Chihuahuan Desert Rangeland Research Center (CDRRC) in southern New Mexico to determine if seasonal grazing of cattle, rather than continuous, yearlong grazing could improve desert rangelands. One herd of cows was rotated through three pastures each year. Another herd of cows grazed continuously yearlong in a fourth pasture. Stocking rate was adjusted in spring and fall according to perennial grass availability. The vegetation of the pastures varied from grassland dominated by black grama (*Bouteloua eriopoda* [Torr.] Torr.) and mesa dropseed (*Sporobolous fleuosus* [Thurb. Ex Vasey] Rydb.) to dense mesquite (*Prosopis glandulosa* Torr.). Total annual production of the common perennial grasses averaged 150 lb./acre across the pastures, ranging from 3 lb./acre in the driest year (2002) to nearly 420 lb./acre in the wettest year (1986). Annual plants produced an average of 71 lb./acre during the study. Annual plant production was greater than 490 lb./acre at the start of the study but declined to zero production in drought years. In response to available forage, stocking rate varied from 0.7 to over 4 animal-days/acre during the study. Average perennial grass utilization ranged from 16% to 26% with an average near 21% on both grazing systems. Grazing use of the grasses varied among years depending on the abundance of other forage choices such as annual grasses, annual forbs, and perennial forbs. In drought years, utilization sometimes exceeded 50% on some perennial grass species. Calf weaning weights at an average of 7 months of age averaged 477 lb. on the seasonal pastures and 494 lb. on the yearlong pasture. Weaning percentages for both herds averaged near 85% for the entire study. Both herds of cattle were removed from the pastures from late 1994 to early 1997 because of drought conditions. Plant production and cover are reported for those years when the pastures were not stocked. No long-term differences were detected for calf production or changes in vegetative composition between the two grazing management systems. Reasons for no differences may be attributed to several factors. The first reason is the long-term nature of the study. Plant data were collected for 36 years and animal production data for 33 years. These long-term averages tended to mask any short-term differences caused by rainfall abundance, drought, and herd performance. A second reason was that the low stocking rates used in the study caused grazing to have minimal impact on vegetation changes. A third reason was that each pasture had two or more vegetation types, which offered the cattle a choice of forage plants in different seasons. The wide variety of forage plants allowed the cows to select better quality forage and therefore better maintain their body condition. The last major reason for the similarity in performance between the grazing systems was that the cows in the herds were all originally from the same herd and had similar genetic qualities.

Amount of rain, frequency of rain events, and the season in which it fell appeared to be most critical in determining plant composition changes across the pastures. The livestock grazing that oc-

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Figure1. This is an example of northern Chihuahuan Desert grassland dominated by black grama with few other plant species present. This photograph was taken in the winter-spring pasture in 1986 during an above average precipitation year. Tonuco Mountain is in the upper right-hand corner.

Figure 2. This is a scene of the Jornada Trail and adjacent grasslands in the yearlong pasture in July 1971. Mesquite borders the trail. This drought started in 1970. Note the shortness of the grass clumps and low basal cover.

curs in the future on these desert rangelands depends upon a diminishing amount of forage. The number of forage plants is declining because of increasing populations of mesquite, broom snakeweed (*Gutierrezia sarothrae* [Pursh] Skinners) and other invasive plants. The response of forage plants to precipitation events differs among forage species, making it difficult to predict future forage availability and appropriate stocking rates. Under these conditions, any livestock grazing will need to be flexible by adjusting stocking rates and season of grazing.

INTRODUCTION

Many of the grazing lands of southern New Mexico are in some deteriorated stage because of overgrazing and drought (Valentine 1970). Grasses once dominated most of these lands, according to reports written in the 1800s by explorers and settlers (Gibbens et al. 2005). Black grama (*Bouteloua eriopoda* [Torr.] Torr.) was recognized as the most important forage grass on the uplands (fig. 1; Gardner 1951, Nelson 1934). Black grama has moderate palatability and only becomes important forage when other grasses and forbs are dry. Droughts in the 1930s and the 1950s caused serious reduction of black grama stands (Paulsen and Ares 1962). Black grama was also seriously affected by drought in the early 1970s (fig. 2) and again by drought that started in the 1990s. Forage productivity and soil stability depend largely upon the maintenance or restoration of a relatively high cover of this species where it is actually or potentially dominant. Herbel and Gibbens (1996) reported that black grama recovered very little from the drought of the 1950s on deeper sandy soils on the USDA Jornada Experimental Range, which is located just east of the Chihuahuan Desert Rangeland Research Center. The greatest recovery from drought was on shallow soils. Two characteristics of black grama make restoration a difficult, slow process: (1) very low production of viable seed; and (2) dependence upon vegetative reproduction by stolons and rooting buds that are susceptible to damage by grazing, trampling, and drought (Valentine 1970).

Other perennial grasses vary in abundance according to the severity of range deterioration. Dropseeds (*Sporobolus* spp.) and threeawns (*Aristida* spp.) are often considered to be secondary forage and provide less soil protection (Paulsen and Ares 1962). However, they contribute significantly to cattle diets in certain seasons (Rosiere et al. 1975, Mofareh et al. 1997). These two genera reproduce primarily by seed and have more potential for becoming reestablished than black grama. However, deteriorated rangelands may never recover their former productivity because of overgrazing and drought, especially on deep soils (Herbel et al. 1974). Seeding of grass and forb species is a possibility on many ranges, but is not practical on arid rangelands found in southern New Mexico because of cost and possible erosion hazard from disturbing the soil for seedbed preparation (Holechek et al. 1998). On many of these rangelands, mesquite

Figure 3. The mesquite canopy cover exceeded 23% in the summer pasture in 2000. Note there are only a few forbs and snakeweeds present. Many areas across the pastures had canopy covers and densities greater than what is shown in this photo. The flagging tied to a mesquite in lower left hand corner helped locate the beginning of a permanent vegetation transect.

(*Prosopis glandulosa* Torr.) has encroached and its population is expanding (fig. 3; Gibbens et al. 1992). On rangelands not dominated by mesquite that are in poor-to-fair range condition, it is recommended that either stocking be reduced or some type of grazing system be developed that will optimize either the maintenance or establishment of new perennial forage plants (Beck 1980).

The purpose of this study was to evaluate a seasonal suitability grazing system and compare it with continuous, yearlong grazing (Valentine 1967; Beck 1978) as a possible means of increasing perennial grass production, particularly black grama, while maintaining cattle productivity. During this study, an extended drought that started in 1994 provided the opportunity to observe the impact of drought on desert rangelands with and without cattle grazing.

METHODS

General Study Area

The study pastures were located at the Chihuahuan Desert Rangeland Research Center (CDRRC), 24 miles north of Las Cruces, New Mexico The terrain of the pastures is nearly level, with slopes less than 2%. Average elevation of the pastures is near 4,350 ft. above sea level.

Precipitation was measured with seven gauges (fig. 4) located in or adjacent to the study pastures from 1967 to 1978. In 1978, an additional five gauges were interspersed among the original seven gauges to more accurately measure the amount of precipitation falling on the pastures. Long-term average annual precipitation for the area is 9.3 in. (1931-2002). Because of several years of above-average rainfall from the late 1970s to the early 1990s, average long-term annual rainfall increased from 8.5 in. to 9.3 in. by 1992 (fig. 5). The summer growing season precipitation, May through September, changed from 5.6 in. to 5.8 in. (62% of the annual total) in the same period. Another small peak of precipitation occurs from December through January with some precipitation falling as snow. Fall and winter precipitation is generally not as dependable as that which falls in late summer. The spring season is usually dry and windy. Average daily maximum temperatures vary from a high of 97º F in June to 55º F in January. Diurnal

Figures 4a (top) and 4b (bottom)

Figure 4. This rain gauge, 15-South, is in a 1-acre exclosure in the yearlong pasture. The top photograph (fig. 4a) was taken in July 1993. Mesa dropseed is the dominant grass in the picture and was very common across all pastures before the beginning of the drought in the fall of 1993. The bottom photograph (fig. 4b) was taken in early July 2004. Note the loss of dropseed cover, the presence of the large mesquite plants growing along the fence, and the mesquite growing at the base of the rain gauge, compared with the top photo.

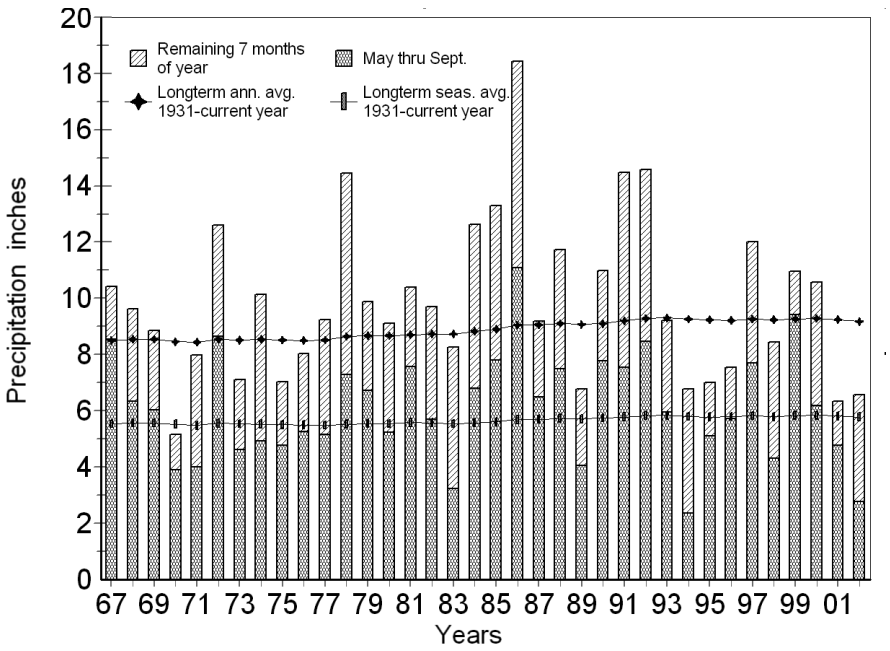

Figure 5. Summer (May through September) and annual (January through December, total bar height) precipitation for 1967 to 2002. Seven (1967-1978) or twelve (1979-2002) rain gauges were used to collect precipitation data. Long-term averages for both seasonal and annual precipitation were calculated from 1931 to each year of the study, and therefore show the changes in the averages over time (running average).

temperature fluctuations of 35º F or more between morning lows and afternoon highs occur frequently throughout the year except in the summer rainy season, when daily fluctuations of 15º F to 20º F are more common.

The vegetation on the pastures is open, mixed grassland with shrubs dominant in parts of the pastures. Most of the area is in different seral stages. The most common perennial grasses are black grama, dropseeds, and threeawns. In most years, threeawns are the first grasses to start growth in the spring and early summer, followed by dropseeds, with black grama starting growth in warmer temperatures.

Because it is difficult to distinguish dropseed species in their vegetative stages of growth, the three species of dropseeds growing on the pastures were combined into one dropseed category. Mesa dropseed (*Sporobolus flexuosus* [Thurb. Ex Vassey] Rydb) was the most common, spike dropseed (*S. contractus* A. S. Hithchc.) was the second most common, and some sand dropseed (*S. cryptandrus* [Torrey] Gray) was also present. The species of threeawns growing on the pastures were also difficult to distinguish from each other and were lumped into one category. The most common species were purple threeawn (*Aristida purpurea* Nutt.), Wooton's threeawn (*A. pansa* Woot. & Standl.) and Havard threeawn (*A. havardii* Vasey).

The most common shrub is mesquite. Broom snakeweed (*Gutierrezia sarothrae* [Pursh] Skinners) is also common in some areas. Many other plant species including forbs such as leatherweed croton (*Croton potsii* [Klotzsch] Muell.-Arg.), spectaclepod (*Dimorphocarpa wislizenii* [Engelm.] Rollins), and paperflower (*Psilostrophe tagetina* [Nutt.] Rydb.) can occur in abundance in years of average to above average rainfall. Soils on the pastures are mainly Petroargids and vary from loamy fine sands to sandy fine loams and generally have depths of 20 in. or less to a caliche layer (Teaschner 2001).

Study Pastures

Four pastures were established in 1967 (fig. 6). Three of the pastures were used in the seasonal suitability system (Valentine 1967). Each of the three pastures was grazed about the same time each year. The winter-spring pasture (1,240 acres) was grazed from early January to late June and was dominated by black grama with some mesa dropseed present. Through the study it generally remained in good to excellent condition (fig. 7). A second pasture (1,234 acres) was usually grazed from late June to mid September. This summer

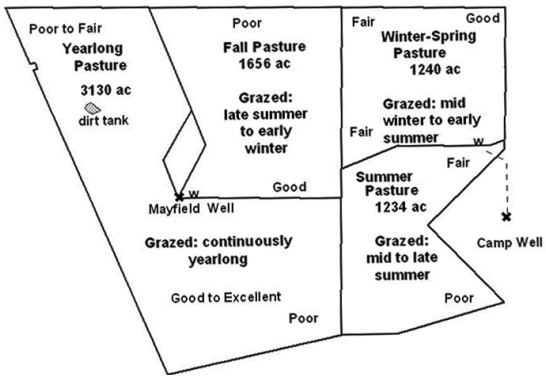

Figure 6. A diagram of the yearlong and seasonal suitability pastures. Each of the pastures had more than one range condition at the beginning of the study, which is indicated by the words: *poor*, *fair*, *good*, and *excellent*. Permanent drinking water sources are indicated by a "w". Each water source supplied water for two adjacent pastures. The dirt tank was not a permanent water source and held water for only short periods after large rain events. Each of the seasonal pastures was grazed about the same time each year; actual starting and ending times varied among years depending upon forage conditions.

Figure 7. This is a high condition black grama grassland in the winter-spring pasture in July 2000. A relatively high ground cover was maintained even under drought conditions. The larger plants in the photograph are yucca (*Yucca elata* Engelm.) and longleaf ephedra (*Ephedra trifurca* Torrey). This grassland is similar to the grasslands described by land survey crews in the mid-to-late 1800s across the Jornada Basin.

pasture had no grass-dominated areas and was mainly in poor range condition during the study (fig. 3). The fall pasture was generally grazed from mid September to late December, with grazing continuing into early January in some years. This fall pasture was in fair range condition. Mesa dropseed (fig. 8) was the most common perennial grass with some black grama also present. Mesquite and snakeweed dominated parts of the pasture. The fourth pasture (3,130 acres) was grazed continuously yearlong and had both grass- and shrub-dominated areas (fig. 9). It contained all the range condition classes in similar proportions to the three seasonal suitability pastures. The size of the areas of the condition classes changed little in the course of the study, though aboveground biomass production fluctuated dramatically from year to year.

The seasonal suitability system was designed to be flexible and the above mentioned turn-on and turn-off dates were averages, with actual dates varying as much as a month depending upon the phenological stage of perennial grasses and amount of forbs available. Examples of this were the dates the summer pasture was grazed in the early 1980s: 1982, July 15 to Sept.15; 1983, June 22 to Sept.16; 1984, July 5 to Aug.30; and 1985, July 9 to Sept. 1. The system was also kept flexible. When annual grasses and forbs produced abundant growth due to local rain-showers in the pastures not being grazed, the cattle were sometimes moved into these pastures for a few days to utilize the green forage, and then were moved back to the original pasture to complete the grazing season. Because of low stock density and the short time the herds were on the seasonal suitability pastures, stocking rate is expressed in animal days per acre. Calves were not included when calculating the stocking rate. There was one permanent water source in each pasture (fig. 6). In the north-central part of the yearlong pasture, there was a small dirt tank in a playa that would hold run-off for a few days to sometimes weeks after large rain events. This was not a dependable water source, and no management plans were made concerning it. There were no other dirt tanks in any of the pastures. For the first few years of the study, water was pumped by windmills (fig. 10) into storage tanks and then gravity fed through pipelines to drinking tanks (fig. 11). Often during the summers there was inadequate wind to pump enough water for the cattle, and water was hauled by truck to the drinking tanks in the pastures. In the latter part of the study, new pipelines were installed, and submersible pumps were put in the wells to alleviate the necessity of hauling water.

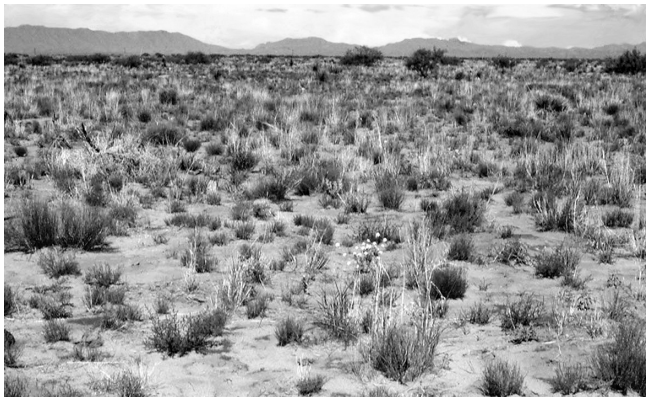

Figure 8. This grassland at the south end of the fall pasture has little ground cover and is in low condition. This photo was taken in September 1978. Mesa dropseed is the primary grass, with many new, small snakeweed plants in the foreground. Large shrubs in the background are mesquite.

Figure 10. Mayfield Well supplied water for cow herds in the yearlong pasture and the fall pasture until the early 1980s when the well casing collapsed. Water was then supplied by a pipeline from Selden Well. Snakeweed and mesquite are the most common plants growing in the sacrifice area.

Figure 9. Hereford cattle were used to graze the study pastures from 1967 to 1970. This is an example of the mixed vegetation growing in yearlong pasture. Mesquite and snakeweed are the common woody plants, and threeawns are the common grasses in the photo.

Figure 11. Cattle are resting in the "sacrifice area" near the water (drinking) tank between the summer pasture and winter-spring pasture. Water is supplied by a pipeline from Camp Well. This photo exemplifies how a large variety of plants, primarily forbs, grow in the sacrifice area around water sites during the summer rainy season.

Cow herds

The seasonal suitability and continuous yearlong pastures were stocked with purebred Hereford cows from 1967 to 1971 (fig. 9), and with purebred Brangus cows (fig. 12) from 1972 to 1992. Breeding season during the study was for three months in the summer starting in either May or June. Calves were born in the spring and weaned in the fall at 6 to 8 months of age. On the yearlong pasture in September 1992, the established Brangus herd was removed and replaced with a herd of pregnant heifers comprised of purebred Barzona, Beefmaster, and Brangus. The weaning weights used for 1992 and reported in this bulletin were from the Brangus herd that was removed. Weaning weights on the yearlong pasture for 1993 and 1994 were for calves from the mixed herd introduced in 1992. The breed of the cow herd on the seasonal pastures did not change. No cattle grazed on any of the pastures in 1995 and 1996 because of poor forage conditions. When the pastures were restocked in 1997, Brangus cows were primarily used. Other cows, including Brahmans and crossbreds, were added to each herd when additional grazing animals were needed during the remainder of the study.

Stocking rates were adjusted according to forage conditions in the spring when the calves were branded and in the fall when the calves were weaned. When adjustments were made to one herd, similar adjustments were made to the other

Figure 12. The cows frequently grazed in the low areas or depressions that characterize the landscape across the study pastures. During extended dry periods, these depressions often grew the only green forage available in the pastures. Many of the depressions also had dense stands of mesquite compared with the more open savannah on the surrounding uplands. This photograph was taken in the summer pasture in 1986.

herd in order to maintain similar stocking rates for both systems. Stocking rates were maintained at a low level in an attempt not to exceed 30% use on black grama and 45% use on mesa dropseed during drier years. In droughty years these utilization levels were sometimes exceeded. This level of stocking was used with the expectation of maintaining and improving forage stands (Valentine 1967). Herd size was often reduced in the spring if the forage production the previous summer growing season was average or less and the fall and winter seasons were dry, producing few forbs. Under these conditions, the grasses in May often appeared dead, or with only one or two live leaves. When these dry conditions occurred at the beginning of the growing season future forage production in the coming summer months was uncertain and often some animals were removed from each herd.

In the fall at the end of the growing season, it was possible to predict whether there was enough forage to support the cattle until the next summer. If there was an abundance of forage, cows were added to the herds, and if forage production was low, cows were culled from each herd. Reasons for culling specific cows included no pregnancy for two consecutive years, health conditions, and temperament. Since the animals for most years of the study were purebreds, cows often remained in the herd until they were 12 to 13 years of age. Replacement heifers were used to increase the herd size as well as replace culled cows. During the study, cows of all age groups were proportionately represented in each herd. Because of drought in 1994, calves were weaned in August, and both cow herds were removed from the pastures in September. Calves were also weaned early in August in 2001 and 2002 because of poor forage conditions, but the cows were not removed.

Weaning percentages of calves were determined from the number of calves weaned related to the number of cows exposed to the bulls the previous breeding season. If cows were added or removed from a herd following the breeding season, they were not counted in the calculation of the weaning percentage. Because the male calves in some years were not castrated, all weaning weights of heifer and bull calves were put on a steer-equivalent basis. Bull calf weaning weights were multiplied by 0.95, and heifer calf weaning weights were multiplied by 1.05. Weaning weights were also expressed as weight of calf produced per cow in the herd that year. These values took into account both the weaning weight and the calving percentage for each cow herd each year.

Plant Sampling

Each pasture was delineated into 0.5-mile concentric zones away from the water source. The concentric zones were divided into blocks, each being approximately 0.5 mile x 0.5 mile. Within each block, four permanent transects (200 ft. long) were established. Ninety-two transects and 128 transects were located in the yearlong and seasonal suitability pastures, respectively. Herbage production was measured at the end of each summer growing season. Current year's production of summer annual grasses and forbs was measured by clipping 20-ft. x 2-in. belts at each end of the transect. Annuals were not separated by species. Perennial grasses (black grama, dropseeds, and threeawns) were clipped on five equally separated 20-ft. x 2-in. belts (a total of 100 ft.) along each transect. For any plants on transects that were eaten, an estimate was made of the amount removed, and this amount was clipped from nearby plants of the same species and added to the sample. Because of clipping effects, the belt transects were offset by a minimum of 12 in. to either side each year from previous year's sampling. Clipped samples were oven dried for 72 hr at 150° F before weighing.

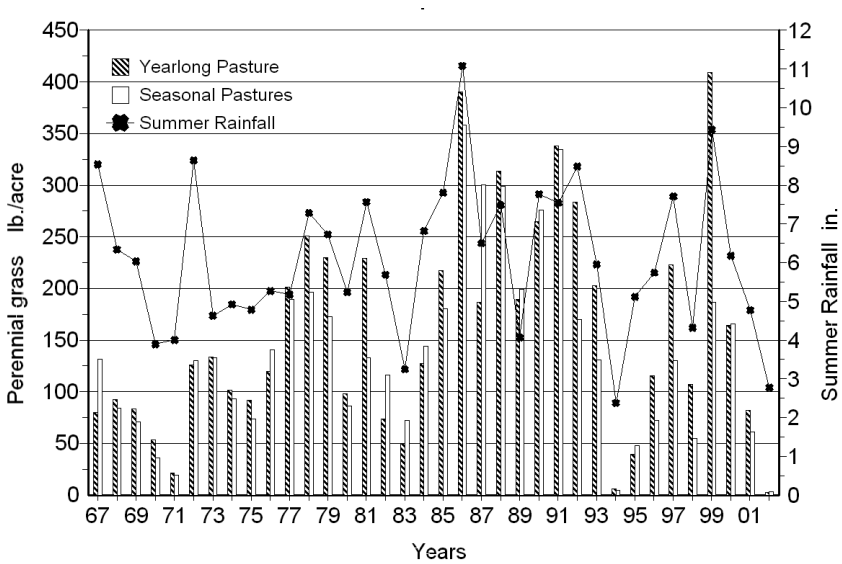

Figure 13. Total perennial grass production on the yearlong pasture and seasonal pastures from 1967 to 2002.

Percent utilization was determined on the three common perennial grasses in late spring on growth produced the previous summer. Grazed and ungrazed heights of 25 grass plants were measured along each transect. Only black grama, dropseed and threeawn plants were measured. Percent utilization was determined from height-weight charts that were developed from plants growing on the pastures. Utilization was not measured on the grasses for the years 2001 and 2002 because of little or no grass growth across the pastures and because of the difficulty in distinguishing production from prior years.

To determine changes in basal cover of perennial grasses, permanent frames (12 in. x 78 in.) were established at 47 of the transect sites in 1981 across the four pastures. Basal area of individual perennial grasses rooted in the frames was estimated. Basal cover data from 1981 to 2002 are presented to show changes during grazing as well as effects of drought after the cattle were removed and then when the pastures were restocked.

Statistical Analysis

The grazing treatments were not replicated because of the large size of the pastures. Attributes for plant and cattle production were summarized by years and expressed as means and standard errors. Correlation coefficients were determined for plant production, grass utilization, weaning percentages, weaning weights, weaning weights per cow, and calf production per acre as dependent variables with annual (January through December) and summer growing season (May through September) precipitation as independent variables.

Overall means for production and utilization of perennial grass species, production of annual plant species, calf weaning percentages, and calf production measured on the seasonal suitability and yearlong grazing systems were compared using an analysis of variance (Kachigan 1982). Since pastures were not physically replicated, yearly means for each attribute were used as replication in the analyses. Conclusions about the plant species or cattle herds being similar or different between the grazing systems should be treate with caution when applied to other rangelands.

RESULTS AND DISCUSSION

Rainfall and Plant Production

Summer growing season precipitation varied from over 11.1 in. in 1986 to less than 2.4 in. in 1994 (fig. 5). Annual precipitation varied from nearly 5.2 in. in 1970 to about 18.4 in. in 1986. Perennial grass production generally increased in the pastures until the early 1990s (fig. 13), and then dropped to a low of 5 lb./acre in 1994. Perennial grass growth in southern New Mexico is limited mainly by when warm season precipitation occurs rather than by air temperature. The perennial grasses that grow in southern New Mexico are warm season (C4) spe-

Table 1. Correlation coefficients (r) for summer, May through September, and annual, January to December precipitation with plant and livestock attributes measured from 1968-2002. Correlation values for calf production do not include the years 1995 and 1996, when pastures were destocked.

	Seasonal Pastures		Yearlong Pasture	
Compared Attributes	**Summer Precip.**	**Annual Precip.**	**Summer Precip.**	**Annual Precip.**
Plant Production				
Black grama	0.66*	0.60*	0.62*	0.46*
Dropseeds	0.64*	0.69*	0.75*	0.79*
Three awns	0.50*	0.43*	0.64*	0.52*
Total perennial grass	0.70*	0.71*	0.80*	0.76*
Annual grasses and forbs	0.23	0.04*	0.13	0.01
Animal Production				
% Weaned	0.05	-0.08	0.04	0.20
Weaning and weight	0.65*	0.71*	0.59*	0.58*
Calf weight weaned/cow	0.48*	0.45*	0.23	0.47*
Calf weight produced/acre	0.48*	0.53*	0.37*	0.40*

* Significant at 5% level for plants, 35 df, if r value >0.325; for animals, 33 df, if r value >0.334

cies and respond very little to precipitation in the cooler seasons. However, low nighttime temperatures starting in September cause plants to start senescing and limit perennial grass growth during the fall. In most years the majority of the perennial grass growth occurs from July through September when about 50% of the annual rainfall occurs. This is the most consistent rainfall period. However, in some years the summer rains start earlier, in either May or June. Nelson (1934), studying the effects of precipitation and grazing on black grama on the Jornada Experimental Range, reported that production varied widely among years. He noted that rains in May and June improved the chances for a large perennial grass crop that year. In this study 62% of the annual precipitation is accounted for by including May and June rains as part of the summer rainfall total. Year-to-year variation in perennial plant production tended to follow summer rainfall patterns. Correlation values varied from r = 0.70 on the seasonal pastures to r = 0.80 on the yearlong pasture (table 1). Paulsen and Ares (1962), studying grasslands on the Jornada Experimental Range from the 1930s through the drought of the 1950s reported that grass production was closely related to summer precipitation. They also found that the amount of precipitation in the previous summer growing season had little influence on the current year's grass production.

Total perennial grass production was similar (P> 0.10) between grazing systems except for the period 1992 to 1999, when perennial grass production increased more on the yearlong pasture compared to the seasonal suitability pastures (table 2; fig. 13). Rainfall data from individual gauges (data not presented in this bulletin) on the pastures showed that from 1992 to 1999 (except for 1994 and 1995) there was one month or more each summer growing season where 1 in. or more rain fell in the yearlong pasture than in the seasonal pastures. This additional rainfall would have allowed more growth of established plants and may have increased the germination and establishment of dropseed and threeawn plants and allowed more reproduction of black grama plants from stolons and sets. Total grass production averaged about 100 lb./acre more on the yearlong pasture as compared to the seasonal pastures except in the dry years 1994 and 1995. By 1999, perennial grass production was over 400 lb./acre on the yearlong pasture and less than 200 lb./acre on seasonal pastures. Production was again similar between the two grazing systems from 2000 to 2002 (fig. 13).

Individual production of the three primary perennial grasses varied greatly during the study. Black grama average production was similar (P>0.10) between the seasonal pastures (50 lb./acre) and yearlong pasture (42 lb./acre; table 2). Black grama production was greatest on the winter-spring pasture of the four study pastures (fig. 14). Average production varied from less than 20 lb./acre in droughty years to more than 300 lb./acre in 1991, an above average precipitation year. This pasture had the largest percentage of grassland dominated

Table 2. Mean and standard error (x±SE) for production (lb./acre) of major grasses, on seasonal and yearlong pastures. Plant production numbers are an average of 1967 to 2002, n=36.

	Seasonal Pastures		Yearlong Pasture		
Plant Species	x ±SE	Range	x ±SE	Range	x Diff.*
	lb./acre		lb./acre		
Black grama	42 ± 3.8	1-104	50 ± 5.6	2-186	NS
Dropseeds	87 ± 10.7	2-252	88 ± 12.4	0-338	NS
Three awns	15 ± 2.2	1-49	24 ± 3.2	1-77	S
Total perennial grass	142 ± 15.1	4-361	161 ± 18.6	2-483	NS
Annual plants	71 ± 13.3	0-340	69 ± 16.6	0-492	NS

* S = means are significantly different, P<0.10; NS = means are not different, P>0.10.

by black grama (figs. 1, 6, and 7). Black grama was not a dominant on any area in the other two seasonal pastures. In the yearlong pasture it was dominant on part of the grassland and in some years the black grama on that grassland would equal or exceed that produced on the grassland in the summer-winter pasture. However, because the yearlong pasture is nearly three times larger than the summer-winter pasture, average black grama production per acre is always lower on the yearlong pasture (fig. 14). Black grama production was better correlated with summer rainfall than with total annual rainfall on both grazing systems (table 1). Paulsen and Ares (1962) reported similar findings when comparing black grama production with seasonal and annual rainfall. They also reported that timing of the rainfall events is important and is responsible for the variation in production measured among years.

Dropseeds are opportunistic species that respond quickly to favorable environmental conditions (Young 1980). Some researchers have considered them secondary grasses in regard to grazing value and soil protection (Paulsen and Ares 1962), but they are important in helping recover ranges suffering from either drought or overgrazing. Total annual dropseed production varied from near zero in dry years (1971, 1994, 1998, 2001, and 2002) to more than 338 lb./acre on the fall and yearlong pastures (fig. 15; table 2). Even though production varied widely among years, overall annual production was similar between the two grazing systems averaging 87 and 88 lb./acre on the seasonal and yearlong pastures, respectively. Annual production was somewhat more correlated with annual precipitation than with summer precipitation (table 1). Paulsen and Ares (1962) point out that the temperature requirements for dropseeds to initiate growth are less exacting than for black grama, and if moisture is available in the spring the dropseed plants will begin vigorous growth. Dropseed production declined in 1992 even though summer and annual precipitation totals were above average. Low production continued after 1992 through the remainder of the study. The reasons for the continued low production are not clear. In April and May 1992 total rainfall was near 5 in., which is about 9 times the average for these two months. Following this period of rainfall was a very hot and dry period lasting nearly 8 weeks in June and July. We speculate that much of the seed in the soil germinated in April and May and these small plants died during the ensuing dry period. During the following dry period many of the older established plants died back, resulting in few inflorescences and seed produced in the normal August-September period (Young 1980). The drought period that started in late summer 1993 exacerbated the situation of established plants dying and little seed being produced. When growing conditions did become favorable there was little dropseed seed in the soil to germinate, establish and increase production.

Threeawn production was generally lower than the production for either black grama or dropseed, averaging 15 lb./acre and 24 lb./acre on the seasonal and yearlong pastures, respectively (table 2). High production (>60 lb./acre) occurred in the mid 1980s and again in the late 1990s (fig. 16) in years of above-average summer rainfall (fig. 5). Threeawns had a lower correlation coefficient (r = 0.50) with summer precipitation than either black grama (r = 0.66) or dropseeds (r = 0.64). Even though the threeawns generally initiate growth in mid-to-late spring, production was more correlated with summer precipitation than with total annual precipitation (table 1). Threeawns generally started growth during March and April and were mature by late June. This period was often dry, but rain events

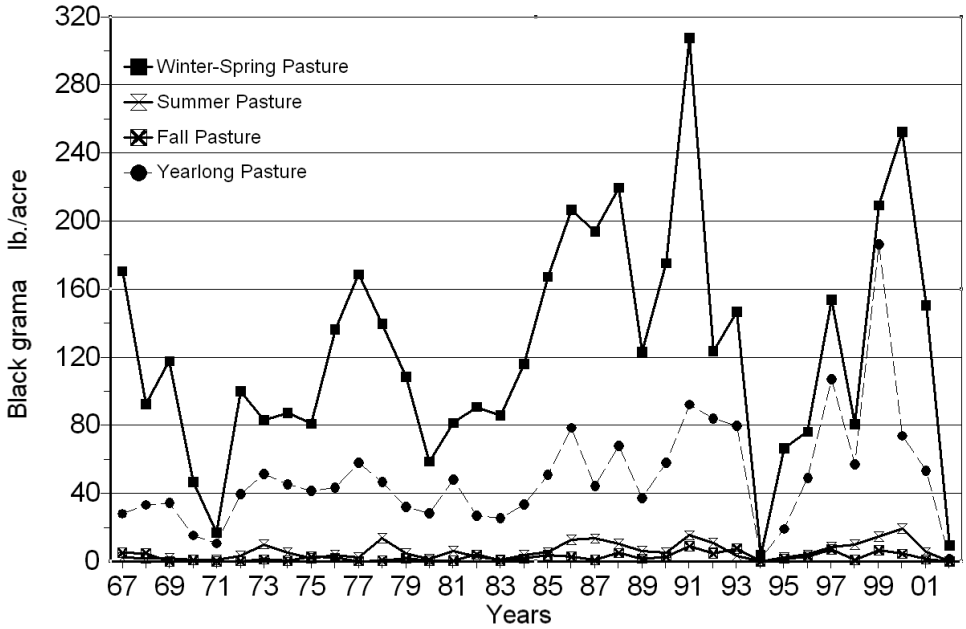

Figure 14. Average black grama production by year on the yearlong pasture and the three seasonal pastures from 1967 to 2002.

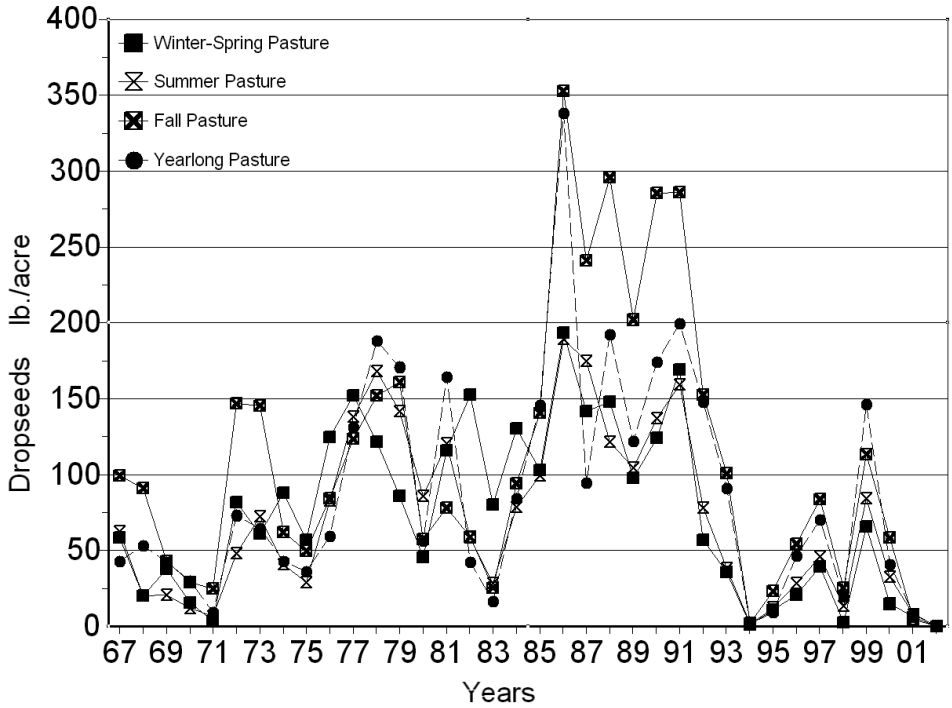

Fig. 15. Average aboveground production for dropseeds by year on the yearlong pasture and the three seasonal pastures from 1967 to 2002.

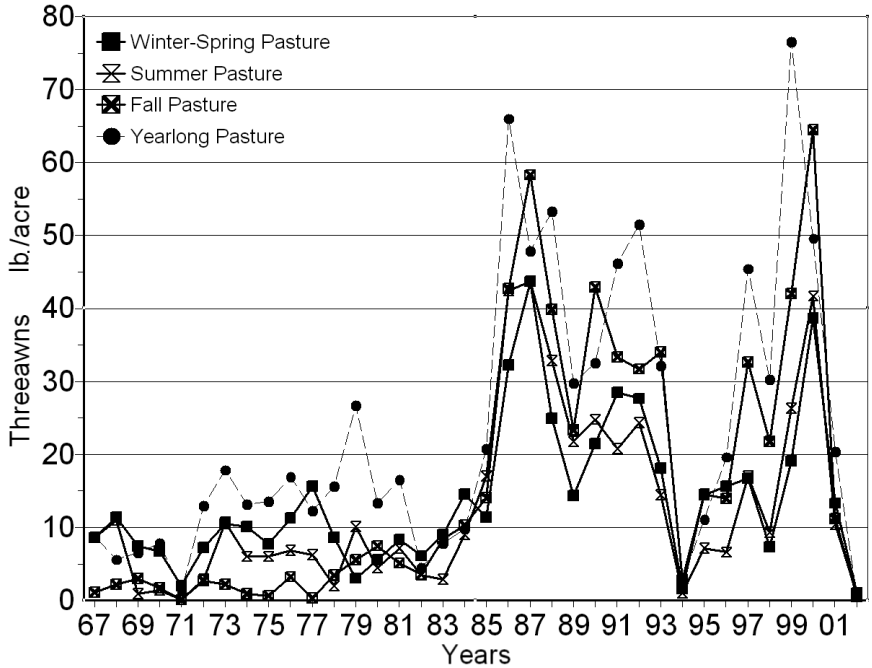

Figure 16. Average production for threeawns by year on the yearlong pasture and the three seasonal pastures from 1967 to 2002.

large enough to initiate and sustain growth sometimes occurred, causing wide variation in threeawn production from year to year. They grew very little if any in the hottest summer months but sometimes grew in September when there was adequate soil moisture.

Many annual grasses and forbs grew during the summer rainy season, but year-to-year abundance of these annuals was not predictable as they depend on amount of precipitation and frequency of events (table 2; fig. 17). In some years winter-spring annual forbs grow in the pastures, but they generally have low palatability and provide little to the total diets (Mofarreh et al. 1997). The presence of cool season annuals varies widely from year-to-year. Their presence and abundance is dependent upon fall and early-winter precipitation to initiate germination, and they also have specific temperature requirements that are neither well known nor understood.

Plant production of summer annuals was very high at the beginning of the study in 1968, and again in 1974, but generally declined on all pastures for the remainder of the study (fig. 17). In 1994 and 2002, no production of annual plants was recorded and averaged below 10 lb./acre in 1977 and 1985. This is in contrast to 1968 when annual plant growth was 490 lb./acre on the yearlong pasture (fig. 17).

The reasons for the high annual plant production in 1968 and 1974 are not clear. Both years had very low precipitation during the preceding dormant months followed by average to above-average summer rains. During the early years of the study, large populations of Russian thistle (*Salasola tragus L.*) grew on the pastures and may have accounted for part of the high annual production for those years. Annual plant production was poorly correlated (table 1) with precipitation because of the year-to-year variation in when germination occurred. If the rains fell either early or late in the growing season, this affected which annual species germinated and how much they grew.

Grazing Use and Livestock Production

Long-term average grazing use of black grama, dropseeds, and threeawns was similar ($P \geq 0.10$) between the two grazing systems (table 3). According to Mofareh et al. (1997) these three perennial grasses compose more than 80% of the forage available on these pastures. Their availability and abundance varied among locations, seasons, and years across the pastures. Stocking rate was adjusted according to the availability and abundance of these three species, with the assumption that no other forage would be available for the next few months. In many years these species produced the only forage

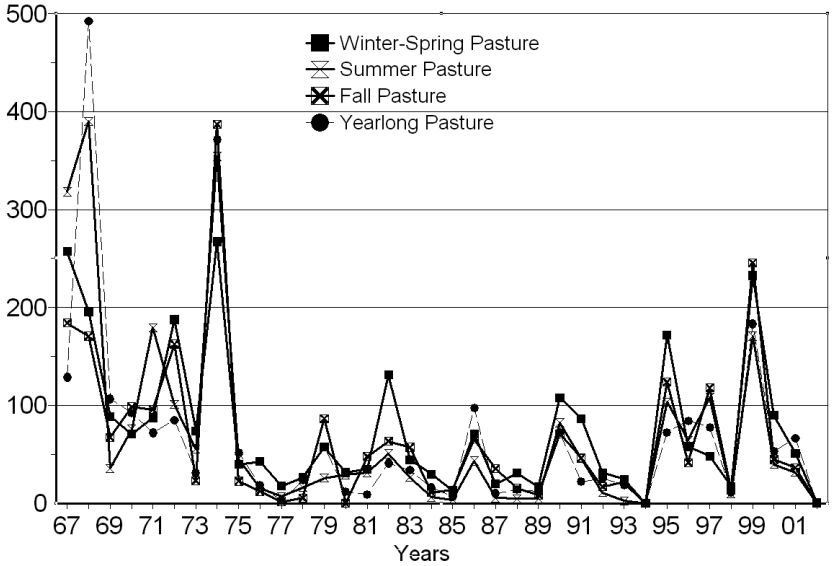

Figure 17. Average production for annual plants by year on the yearlong pasture and the seasonal pastures from 1967 to 2002.

available until the next summer rainy season (Valentine 1967). In some years adequate rainfall to initiate plant growth did not occur until August, and in other years growth was initiated in May with late summer being dry. The amount of forage produced during the summer depended on how quickly the grasses responded to any rain.

Although livestock numbers were adjusted twice a year, average utilization of the perennial grasses varied considerably from year to year (fig. 18). In dry years with limited forage, such as 1994, utilization averaged more than 37%. In high rainfall years such as 1978, with large amounts of forage available, utilization was near 10% on the pastures. In years of higher rainfall, the cows were not limited to perennial grasses but ate a large variety of plants (Mofareh et al. 1997). In other years (e.g. 1972, 1975, 1982) low use of perennial grasses resulted from reduced stocking because of drought conditions either in that specific year or in prior years.

Overall average grazing use of perennial grasses was higher ($P \leq 0.10$) on the winter-spring pasture than on the other two pastures because there were fewer forage choices in that season (table 3). The amount of grazing use on the three perennial grasses varied among seasons and reflects how the cows' preferences for the species changed in different seasons. For example, threeawns were eaten more ($P \leq 0.10$) in the winter-spring pasture than in the other two pastures, because often they were the only grasses with any green leaf material. The spring season is often very dry, and generally there are few if any other plants besides threeawns growing at that time. Dropseeds were important forage plants during the growing season but were not important in cattle diets in the dormant season (Mofareh et al. 1997). Dropseed plants respond quickly to rain events during the growing season and had the highest correlation coefficients with rainfall of the three perennial grasses (table 1). Dropseed use was highest ($P \leq 0.10$) in the winter-spring pasture because these grasses often started growth in May or June if adequate rains occurred, and provided another source of green forage. Black grama was grazed year-round but was utilized more ($P \leq 0.10$) in the fall pasture when other plants began to senese and become dormant.

Calf crop percentages ranged from 27% to 100% during the study (table 4). The lowest calf crop occurred in 1970 (27%) in the yearlong pasture (fig. 19). Because purebred cows were generally used to make up the grazing herds, only one bull was used with each herd. In 1970, a bull with low fertility was put with the cows in the yearlong pasture. As a result of this low calf crop, bulls in subsequent years were tested for semen quality before being put in the pastures with the cow herds. The next lowest calf crops (40% and 45%) for the two herds occurred in 1972 (fig. 19). These low calf crops resulted from below-average precipitation in the summer of 1971, when little forage was produced in the breeding season and thus conception was low.

Table 3. Mean and standard error (x±SE) for percent utilization of three dominant perennial grasses averaged across the years 1968 to 2000.

	Black Grama (%)		Dropseeds (%)		Threeawns(%)		Avg. (%)
Pastures	x ±SE	Range	x ±SE	Range	x ±SE	Range	x ±SE
Winter - Spring	18 ± 1.0[b]	11-30	23 ± 2.0[a]	6-48	36 ± 2.5[a]	4-59	26 ± 1.4[a]
Summer	18 ± 1.6[b]	2-38	17 ± 1.4[b]	6-37	14 ± 1.9[b]	1-46	16 ± 1.3[c]
Fall	26 ± 2.2[a]	4-53	18 ± 1.4[b]	4-39	18 ± 2.1[b]	2-42	21 ± 1.3[b]
Grazing System							
Seasonal*	19 ± 1.0[a]	8-30	20 ± 1.5[a]	7-41	23 ± 2.0[a]	4-47a	21 ± 1.2[a]
Yearlong	19 ± 0.9[a]	2-30	21 ± 1.5[a]	9-46	25 ± 2.0[a]	6-54a	22 ± 1.8[a]

[a, b, c] Within a species, mean utilization differed (P≤ 0.10) between pastures or between grazing systems when values are followed by different letters.
*Average utilization figures for "seasonal" are proportionally-based on the acerages of the winter-spring, summer and fall pastures.

Table 4. Average (x±SE) cattle production on seasonal suitability and yearlong pastures from 1968 to 2002. The years 1995 and 1996 were not included because no cattle grazed on the pastures in those years. Calf gain/acre is also separated into two time periods: pre-drought, 1968-1994, and after pastures were restocked, 1997-2002.

	Seasonal Pastures		Yearlong Pasture		
Calf Production	x ±SE	Range	x ±SE	Range	Mean Diff.*
Weaned %	86 ± 1.9	40-100	85 ± 2.9	27-100	NS
Weaning weight lb.	477 ± 13.0	311-632	494 ± 13.9	265-627	NS
Calf wt. gain/cow lb.	414 ± 15.9	194-601	426 ± 20.2	92-653	NS
Calf gain/acre lb.	2.4 ± 0.2	0.6-4.8	3.0 ± 0.2	1.0-5.4	S
1968-1994**	2.2 ± .0.2	1.5-3.0	2.9 ± 0.2	0.9-4.6	NS
1997-2002	1.5 ± 0.4	0.7-2.9	3.7 ± 0.7	1.1-5.4	S

* S = means are significantly different, P<0.10; NS = means are not different, P>0.10.
** Calves were weaned in August 1994.

Average weaning percentages were similar (P> 0.10) on the two grazing systems, 86% on the seasonal pastures and 85% on the yearlong pasture (table 4). These weaning percentages are lower than those often reported in other management and research studies, where weaning percentages frequently exceed 90%. One reason for the lower calf crop percentages was the small number of cows used to calculate weaning percentages. In some years, the numbers were as low as 12 cows, and in other years they exceeded 25 cows in each herd. Thus, depending on the number of cows in a herd, with the death of one calf the weaning percentages would drop 4% to 8%. Reasons for death losses of calves included: the cow dying, rustling, predation, poisoning by plants, or the calf being shot or hit by a vehicle. Sometimes cows aborted or did not conceive in the previous breeding season because of poisonous plants.

Calves were generally weaned in mid-fall at an average of 7 months of age. High calf weaning weights occurred in years with abundant summer rains when more forage was available for consumption (fig. 20). Some of the low weaning weights occurred in years of drought conditions (1970, 1982) or when calves were weaned as early as in August in 1994, 2001, and 2002. Low weaning weights also occurred when calves were born late in the spring (e.g. 1970 and 1971). These calves were born to cows that had conceived late in the breeding season because of poor forage conditions, or in some cases to first-calf heifers that had low body condition after partuation and did not come into estrus until late in the breeding season. The low calf weight produced per cow in 1983 was the result of low weaning percentages (fig. 19), and relatively low perennial grass production (fig.16).

Overall average weaning weights of calves (on a steer equivalent basis) were similar (P> 0.10), averaging 477 lb. for the seasonal suitability herd and 494 lb. for the yearlong herd (table 4). Weaning weights were similar between the two herds for most years (fig. 20). These weights are not adjusted for age of calves; therefore, early weaning and late birth dates have negative effects on actual weaning weights. The lowest weaning weights occurred in years of early weaning, which generally coincided with seasons of low perennial grass production. Correlation coefficients between weaning weights and precipitation ranged from r = 0.59 to 0.68

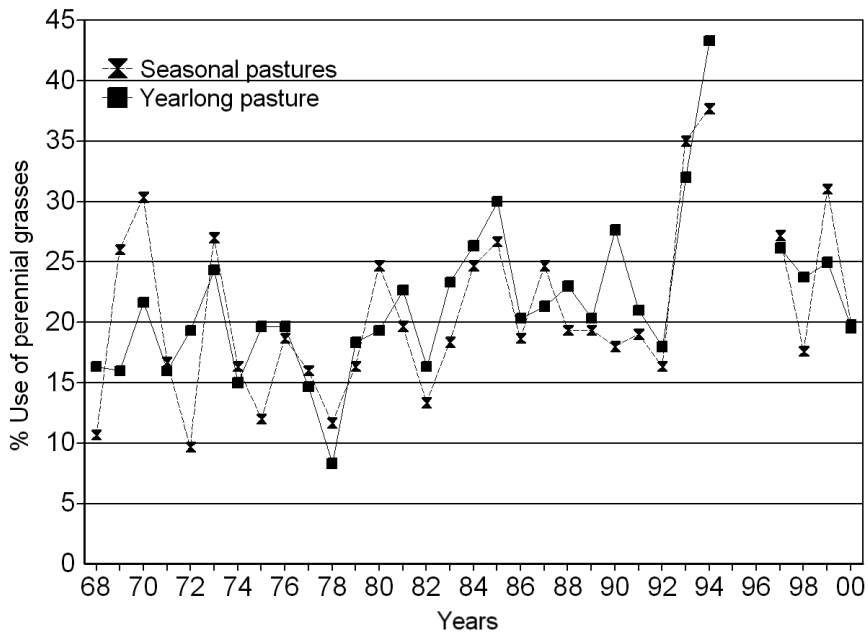

Figure 18. Average grazing use of three perennial grasses (black grama, dropseeds, and threeawns) on the seasonal and yearlong pastures from 1968 to 2000. No cattle grazed on the pastures in 1995 and 1996.

(Table 1), and correlation coefficients between weaning weights and total plant production ranged from r = 0.67 to 0.71 (Table 5). Weaning weights reflect current growing condition as well as previous summer forage conditions during the breeding season. If forage conditions are good during the previous summer breeding season, the cows are more likely to breed early in the season, which means calves will be born earlier the following spring. After the calf is born, the availability of palatable and digestible forage to the cow affects the amount of milk the cow produces, which partially determines the growth rate for the calf. Also, calves born early in the spring will have the opportunity to eat more grasses and forb as they get older before weaning, so the quantity and quality of forage is important to them.

The relatively low stocking rates generally ensured adequate forage for the cows in most years, and any additional forage was not reflected by greater calf production. Stocking rates were only moderately correlated with perennial grass production. Correlation coefficients were low for black grama, r = 0.20 and 0.23 on the seasonal suitability and yearlong pastures, respectively, but somewhat higher for dropseeds, r = 0.42 and 0.60 for the two systems, respectively (table 5). These low to moderate correlation coefficients indicate the difficulty in predicting the amount of forage that will be available for grazing and therefore making the necessary stocking adjustments. Dropseeds were more common across the pastures prior to the drought in the 1990s and in many parts of the pastures were the primary forage plant. They tended to be more palatable and were eaten more in the summer than either black grama or the threeawns. The other factor that influenced the stocking and therefore the utilization of the perennial grasses was the presence or absence of annual plants. Summer annual plant production varied widely (fig. 17) and was poorly correlated with annual and seasonal precipitation for both systems, ranging from r = 0.01 to r = 0.23 (table 1). These plants did provide forage in some seasons and years (Rosiere, et al. 1975; Mofarreh, et al. 1997).

Calf-weight weaned per cow evaluates weaning weight by combining calf weaning weight and percentage of calves weaned (fig. 19). This reflects the previous year's forage conditions as well as the current year's forage conditions. The amount of calf-weight weaned per cow increased nearly 50% from near 300 lb./cow in the early 1970s (drought conditions) to more than 450 lb./cow in the latter years of the study (fig. 19). This resulted from high weaning percentages and above-average rainfall from the mid 1980s to early 1990s. Good forage crops resulted in larger calves and more calves conceived and weaned. Neither system showed any

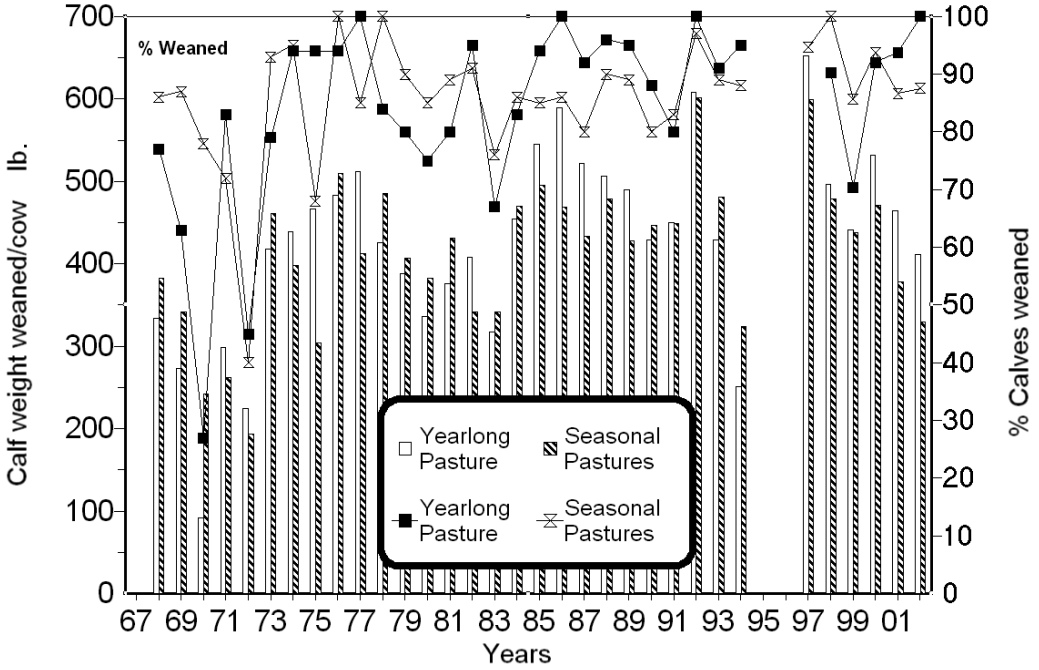

Figure 19. Average calf weight produced per cow in each cow herd and percent of calves weaned on the yearlong pasture and seasonal suitability pastures from 1967 to 2002.

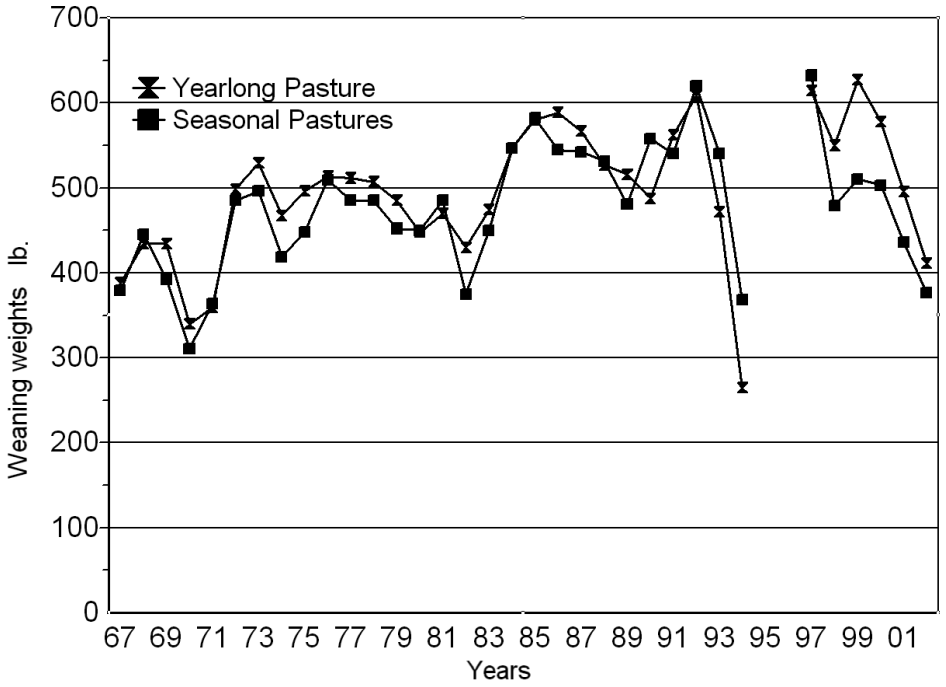

Figure 20. Average weaning weights for calves from 1967 to 2002 on the yearlong and seasonal pastures.

Table 5. Correlation coefficients of perennial grass production with calf production and stocking rate of cows on the seasonal suitability pastures and the yearlong pasture.

	Seasonal Pastures			Yearlong Pasture		
Herd Characteristics	Black grama	Drop-seed	Total grasses	Black grama	Drop-seed	Total grasses
% Weaned	0.15	0.02	0.07	0.15	0.17	0.21
Weaning weight	0.66*	0.57	0.67*	0.75*	0.52*	0.71*
Calf wt. weaned/cow	0.55*	0.39*	0.50*	0.52*	0.42*	0.55*
Calf wt. produced/acre	0.46*	0.64*	0.65*	0.67*	0.50*	0.68*
Stocking rate	0.20	0.60*	0.51*	0.23	0.42*	0.42*

* Significant at 5% level for plants, 35 df, if r value >0.325; for animals, 33 df, if r value >0.334

advantage in the amount of calf-weight weaned per cow (table 4). High calf weaning weights per cow were recorded in 1997 when the pastures were restocked (fig. 19). The primary reasons for these high weights were above-average rainfall for that growing season and that only high quality producing cows had been retained in the breeding herds after the drought. Also, the cows had been bred on good quality pastures off the CDRRC and were supplemented with protein (cotton-seed cake) that resulted in early conception and calves being born early in 1997. Because of these conditions cows were in good physical condition and milk production was high, which allowed for more total calf production.

Calf-weight produced per acre reflects the weaning weight, number of calves weaned and stocking rate of the pastures. The calf-weight produced per acre averaged 2.4 lb./acre on the seasonal pastures which was lower ($P< 0.10$) than the 3.0 lb./acre produced on the yearlong pasture (table 4). The calf-weights produced per acre were similar between the two grazing systems through 1994 (fig. 21). However, when cows were restocked after 1997, no attempt was made to keep the two herds similar, and cows were often added or removed on the seasonal suitability system in response to needs and research studies being conducted on other CDRRC pastures. It was the higher stocking rate, and more calves produced after 1997 on the yearlong pasture, that caused a significant difference in calf production per acre between the two systems (table 4). For example, in 1998 there was a large difference in calf production per acre between the grazing systems (fig. 21): 5.4 lb./acre on the yearlong pasture versus 0.23 lb./acre on the seasonal pastures. On the seasonal pastures during the year, there were only two cows with calves, even though another 12 cows used for a snakeweed grazing trial were on the pastures part of the year. At the same time in 1998, there were 31 cows with 28 calves grazing on the yearlong pasture. The yearlong pasture was stocked higher because of more forage availablity (fig. 16) and the necessity to maintain a larger herd for a companion grazing study (Holechek et al. 2003). This higher stocking rate resulted in more calf production per acre that year, but by 2002, with the continuation of drought conditions, the two systems were similar again in calf production (fig. 21).

Reasons for Production Similarities

The overall means for the calf production per cow and weaning percentages were similar ($P>0.10$) between the two systems (table 4). The reasons for this are three-fold. First, the cows used in the two herds were genetically related for the first 25 years of the study. Winder and Beck (1990) reported that average genetic merit and average change in genetic merit were similar in the Brangus herds grazing in the two systems. Regardless of genetic background, the cows were selected because of their ability to be productive in this environment. In some years cows were moved between herds and, although they did not count in weaning percentages that year, they were counted in subsequent years. The second reason for genetic similarity between the cow herds occurred from the practice of placing replacement heifers into either herd without regard to the herd in which they were born. After 1992, the cow herds were different because of the introduction of other breeds into the herd grazing the yearlong pasture. Some Brangus cows remained on the yearlong pasture and were related to the Brangus cows in the seasonal pasture herd.

The third reason for the similarities in animal production had to do with diversity of forage and relatively low stocking rate in the pastures. Even though the pastures in the seasonal suitability sys-

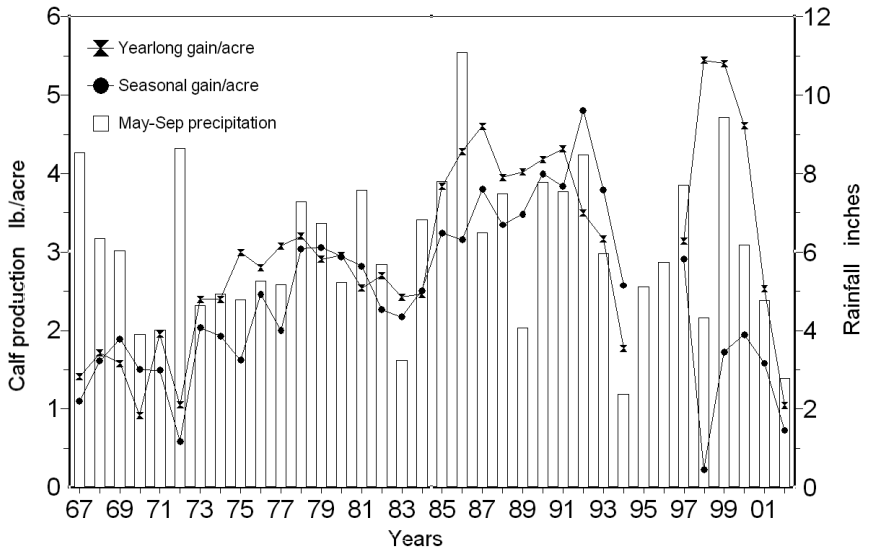

Figure 21. Average calf weight produced per acre on the yearlong pasture and the seasonal pastures compared with summer (May through September) rainfall from 1967 to 2002.

tem were relatively small, each had three to five vegetation types. Because of the variety of plants growing in each pasture, the animals were never without some green forage except during drought years. The variety of plants growing in the pastures responded differently to rain showers. The timing of when the cattle were moved from one seasonal pasture to another depended on forage availability in the pasture they were moving into as well as the one in which they were currently grazing. Cattle were never in a situation where they were short of forage. However, there were times when the forage was dry and probably had low digestibility, particularly during droughts. Rosiere et al. (1975) found during the drought of the early 1970s on the study pastures that *in vitro* organic matter digestibility varied from 39% to 64% over a 2-year period. In later studies during years of average to above-average rainfall, Heithold (1980) and Hinojosa (1983) reported that *in vitro* organic matter digestibility did not exceed 60% in the summer growing season. Heithold (1980) reported digestibilities below 25% in the winter months of 1979, when all plants were dormant. He found that diets eaten in the summer on the seasonal pastures averaged 0.8% to 2.3% lower ($P < 0.05$) in crude protein than diets eaten on the yearlong pasture and that digestibility of diets averaged 7% to 10% less ($P < 0.05$). Hinojosa (1983) reported no differences ($P > 0.05$) between the two grazing systems for crude protein and *in vitro* organic matter digestibility. The different digestibilities of forage components reported for these two studies may be explained by the rainfall patterns across the pastures between seasons and years that caused different forage plants to grow and be available to the grazing animals.

In the yearlong pasture the cows grazed the different vegetation types in different seasons. Generally they used the black grama grasslands in the dormant season. Black grama in years of average or above average precipitation retained greenness at its base during dormancy. In early spring the cows generally grazed in the mesquite-dune area of the pastures, where the first green forbs of the season were growing. Later in the spring, if there had been some rain, the cattle would graze in areas where threeawns were common. In late spring and summer, the cattle grazed on dropseeds and other grasses (including annual grasses), as well as perennial forbs such as leatherweed croton and pale scarlet globemallow (*Sphaeralcea angustifolia* [Cav.] D. Don). The fall season was generally the period when the greatest abundance and variety of plants were available. As summer plants senesced, grazing preferences switched to forbs and grass leaves that were still green, including black grama.

Drought Effects – Future of Pasture Vegetation

Low stocking rates were an advantage in the study because the cows did not need to be removed from the pastures during the droughts of 1970 to 1971

and 1983, as they were from most pastures on the CDRRC. However, the cow herds were removed from the study pastures in September 1994 because of drought conditions that started in fall 1993. In 1994, total production of the three common perennial grasses was 5 lb./acre or less (fig. 16). Production for the three perennial grasses in the first 27 years, from 1967 through 1993, averaged 162 lb./acre and 172 lb./acre on the seasonal and yearlong pastures, respectively.

Changes in perennial grass basal cover were similar across all four pastures. Season of grazing appeared to have little influence on any changes measured; rather changes were in response to years of either abundant rain or drought. Because basal cover changes were more in response to weather conditions than to livestock grazing, the basal covers shown in fig. 22 for black grama, dropseeds and threeawns are averages for all four study pastures. The amount of live basal cover for black grama dropped from an average near 1.5% in the 1981 to 0.3% in the fall of 1994 (fig. 22). Both threeawns and dropseeds also had large declines in basal cover. By 1997, basal cover of dropseeds had only slightly increased from 1994, while black grama cover nearly doubled. This reflects the adaptability of black grama to drought as described by Paulsen and Ares (1962) and Valentine (1967).

Most mature dropseed plants died in 1994 and 1995, and the few that survived had only one or two shoots alive in 1997. Dropseeds are short-lived perennials that are dependent upon abundant seed production and germination for establishment. As mentioned above, higher than average rainfall in spring 1992 may have caused much of the dropseed seed to germinate but the seedlings did not become established because of hot, dry conditions during June and July. The mature established dropseed plants started growth early because of the spring rains but were later stressed by the hot, dry weather. This resulted in less growth than was produced in the previous summer (fig. 15). With the plants under stress there would also be less seed production. Seed production would also be affected somewhat by the cattle grazing. Mofareh et al. (1997) studying the cows grazing on these pastures in different seasons found that dropseed comprised 50% to 70% of their diets in August. After 1995 there were times following light rains when seeds would germinate, but the seedlings did not become permanently established. With the loss of mature plants, the
effect of cattle grazing, and the failure of seedlings to establish, fewer seeds were produced. With less seed in the soil bank, fewer dropseed plants were able to establish when environmental conditions became favorable in the late 1990s. This resulted in less production and basal cover (figs. 15 and 22). Threeawns also had a major die-off but recovered more in some areas of the pastures than dropseeds (fig. 16). No annual grasses or forbs grew in 1994 (fig. 17). Perennial forb production was almost nonexistent during this period.

Conclusions and Future Grazing on these Pastures

Production of major plant species, weaning weights and weaning percentages were generally similar between the seasonal-suitability and yearlong grazing systems for the 36 years that data were collected. Variations in annual rainfall patterns across the study pastures resulted in total perennial grass production being greater in the yearlong pasture for 21 years and greater in the seasonal suitability pastures for 15 years (fig. 13). Any short-term studies comparing the two systems might have led to conclusions giving an advantage to one of the grazing systems over the other. For example, differences could have been found between the two systems for perennial grass production (e.g. 1977 to 1981, fig. 13), dropseed production (e.g. 1986 to 1991, fig. 15), and percent of calves weaned (e.g. 1985 to 1990, fig. 19). Even calf production per acre would have been higher for the seasonal suitability herd from 1991 to 1994 (fig. 21).

The similarity of results for the two systems can also be attributed to light stocking rates. Heavier stocking rates might have caused greater differences in plant response and animal performance between the two systems. However, heavier stocking might also have necessitated the complete removal of livestock from the pastures in dry years when little forage was available, particularly in 1971 and 1983. The severity of those dry years was not as great or long lasting as the drought that started in fall 1993, which resulted in destocking the pastures. Stocking below carrying capacity has been recognized since the early 1900s as an important management option in the arid Southwest (Sampson 1923). At the stocking levels used in this study, grazing generally had only a minor impact on any herbaceous vegetation changes. The amount of rainfall and the season

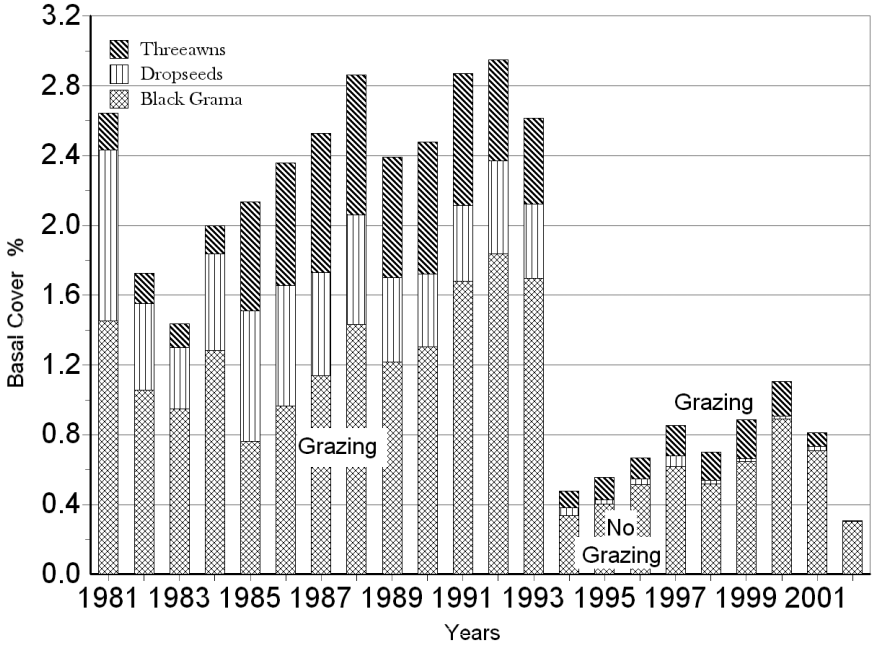

Figure 22. Average basal cover for black grama, dropseeds, and threeawn grasses across the four study pastures from 1981 to 2002. The large decline in cover from 1993 to 1994 was because of drought conditions that started in fall 1993. No grazing occurred on the pastures in 1995 and 1996.

in which it fell were more critical factors causing plant composition changes. Gibbens and Beck (1988) made similar conclusions after evaluating 64 years of quadrat data from the Jornada Experimental Range. They reported that compared to fluctuations in annual precipitation grazing had little impact on perennial grass cover.

A question that also needs to be answered is whether livestock grazing is sustainable in this part of the Chihuahuan Desert. Only a small portion of the total former desert grasslands still exists in southern New Mexico (Gibbens et al. 2005). Most of these grasslands have deteriorated, with shrubs such as mesquite, creosotebush (*Larrea tridentata* Sess.& Moc. ex DC.) Cov., tarbush (*Flourensia cernua* DC.), and broom snakeweed dominating many of the landscapes (Gibbens et al. 2005). Neilson (1986) in studying the climate of southern New Mexico, hypothesized that, with continued "global warming patterns," the black grama grasslands on the CDRRC and Jornada Experimental Range are only marginally adapted. He proposed that winter rains encourage shrub establishment, and that warm season grasses are favored if the winters are dry. Part of the increase in shrub establishment during this study may partially be attributed to the many "wet-winters" in the 1970s and 1980s (fig. 5). Teaschner (2001) reported on changes in mesquite density from 1982 to 2000 in relation to soil depth across the study pastures. Average mesquite density increased from 55 to 138 plants/acre on soils less than 20 in. deep, from 60 to 192 plants/acre on soils 20 to 40 in. deep, and from 79 to 217 plants/acre on soils greater than 40 in. deep. Even from 1993 to 2000, which included many dry years, mesquite density increased 11% or more on all soils. In 1982, some of the grasslands had no mesquite present, but by the year 2000, no area in the pastures was completely free of mesquite (fig. 4b). By 2000, average mesquite canopy cover was 5% or greater across the pastures with some areas having 25% or more mesquite canopy cover (fig. 3; Teaschner 2001).

Opportunities to improve or restore these former grasslands are limited by the low amount of precipitation. Improvement practices used in more mesic rangelands such as seeding are generally not practical in a desert environment because of low returns on investment and potential soil loss from any mechanical disturbance. Use of herbicides to control shrubs is an important alternative because herbicides are selective against woody vegetation and do not affect herbaceous plants or disturb the soil. However, herbicidal control of shrubs, particularly mesquite, has often lasted only 10 to 15 years before the area again supports pre-treatment

densities (Gibbens, et al. 1992).

Any livestock grazing that occurs on these former grasslands depends upon the perennial grasses, forbs, and annual plants that may be present. The response of these plants to precipitation events is quite different among species, and it is difficult to predict future forage availability and appropriate stocking rates. Under these conditions, livestock grazing needs to be flexible, including periodic adjustment of stocking rates and season of grazing. The practice of grazing cattle yearlong on the same pasture offers little flexibility to ranching operations in this environment. The relatively high calf production on the yearlong pasture reported in this study was a result of the many different palatable forage plants available throughout the year. Most rangelands in southwest New Mexico do not have a large variety of plants. Therefore, grazing on these rangelands should be limited to the seasons when the plants are productive and available, rather than yearlong.

During extended droughts forage plants generally grow very little and frequently die. Any livestock grazing under these conditions usually exacerbates the effects of the drought, causing even greater death loss of plants. With the loss of forage plants and the continued encroachment of unpalatable shrubs such as mesquite, livestock grazing may be severely limited on these pastures in the future.

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Because of the long-term nature of this research, the pastures in this study provided opportunities for scientists and students to research various components of the Chihuahuan Desert. The following is a partial list of journal articles, New Mexico Experiment Station publications, and New Mexico State graduate student theses and dissertations reporting research that was done, at least in part, on the pastures studied for this bulletin. Also included are a few research publications reporting on research completed prior to the start of this study.

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