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ORIGINAL RESEARCH

Drought and grazing influence on Northern Chihuahuan desert rangelands, New Mexico

[1]Tshireletso, K., [2]Beck R. F. and [2]McNeely, R.

[1]Department of Animal Sciences, Botswana College of Agriculture, Private Bag 0027, Gaborone Botswana.
[2]2Department of Animal and Range Sciences, New Mexico State University, Las Cruces, New Mexico 88003, USA.

TK, collected data & analysis, prepared the manuscript, BRF, Conceived idea, analysis, prepared manuscript, MR, collected data, animal operation

ABSTRACT

A short term cattle grazing trial was started in June 1992 in the Chihuahuan Desert in Southern New Mexico to study the influence of drought and grazing on plant responses. Paddocks were grazed in June and September each year except in 1996, 1999 and 2000 because of drought. Summer growing season precipitation was below average 6 of the 9 years of the study. Only 29 mm fell from July through September in 2000, the driest summer. Most herbaceous perennial plants died during the study. Perennial grass basal cover declined from a high near 1.6% in 1992 to 0.4% in 2000. Densities of perennial grasses and forbs decreased from near 50 plants m^{-2} in 1992 to fewer than 15 plants m^{-2} by 2000. Annual forbs and grasses germinated and grew in response to specific rainfall events regardless of drought conditions. No significant ($P > 0.10$) year grazing treatment interaction was found for basal cover and density of plants. However, both attributes were significant ($P < 0.10$) across years. Correlations between grazing treatments and precipitation for plant total cover were significant ($P < 0.10$) and ranged between 0.75 and 0.87. Loss of plant density and basal cover occurred on both grazed and non-grazed areas during the study, indicating that drought was primarily responsible for any plant changes while grazing effects at the intensities studied were minimal.

Keywords: Chihuahuan Desert rangelands, plant basal cover, precipitation, grazing treatments.

Corresponding author E-mail:ktshirel@bca.bw; Tel: 3650153

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INTRODUCTION

The sustainability of rangelands in the Chihuahuan Desert in southern New Mexico for livestock grazing is of considerable interest and concern to ranchers, environmental groups, and government management agencies. This is because sustainability of natural resources on these rangelands has been questioned because of the vegetative changes that have occurred (Archer, 1994). Many of these lands once supported dense grass stands dominated by black grama (*Bouteloua eriopoda* [Torr.] Torr.) (Herbel*et al.,* 1972) but currently supports little perennial grass and are generally dominated by different shrub species, including mesquite (*Prosopis glandulosa* Torrey), creosotebush (*Larrea tridentate* (Sess. & Moc. ex DC.) Cov. and suffrutescent plants such as broom snakeweed (*Gutierrezia sarothrae* [Pursh] Britt & Rusby).There is a believe that if livestock grazing is stopped then rangelands will improve and succeed back to former pristine conditions (Pieper, 1994). In contrast, Other primary external influence is the amount of precipitation in the growing season (Navarro *et al.,* 2002; Holechek (1991) reported that livestock grazing is sustainable in pastures receiving about 30% use of key forage species. This author also observed that range improvement may be faster on moderately grazed areas compared to non-grazed areas. Evaluating factors that influence grazing on rangelands using small-grazing paddocks is a research-worthy topic. Using small paddocks allows for intensive plant sampling and better measure of plant changes

Determining plant changes in large pastures with the same precision as in small pastures requires more labour, and it is difficult to obtain the desired amount of grazing-use on sample plots because of uneven distribution of the grazing animals across the large pastures. However changes in desert plant communities result from disturbances such as competition, fire and grazing.

Khumalo and Holechek, 2005; Holecheket *al.,* 2006). Although drought is unpredictable, it does occur periodically in the Southwest. In rangelands, drought occurs due to below normal rainfall and when plant water demands are not met (Thurow and Taylor, 1999). Total annual or seasonal precipitation may be near or above average but plant demands for water may not be met. Much of the precipitation in southern New Mexico is received during infrequent, brief, intense summer thundershowers. Consequently, low plant cover and the high intensity of storms causes much of the precipitation to run-off. However, when rains are gentle and the water infiltrates the soil, the sandy soils hold relatively little moisture as it loses much moisture through evaporation. The effects of drought and grazing on plant communities are usually difficult to separate as demonstrated in the following studies. In a study on the USDA Jornada Experimental Range, Campbell (1936) reported that up to 77% of the black grama cover was lost on conservatively grazed areas during the drought of 1934 when only 16 mm of rain fell during the growing season. During the drought of the 1950's basal area of black grama was reduced in equal amounts across grazed pastures irrespective of grazing intensity (Herbel *et al.,* 1972). Gibbens and Beck (1988) evaluated 64 years of quadrat data and noted that grazing had little influence on basal cover while drought had large influence. In another study, Holechek and Khumalo (2006) comparing grazed and exclosure paddocks observed that climatic conditions impacted vegetation composition more than livestock grazing. Understanding drought effects on plant communities in association with grazing continues to be of interest to federal land managers and ranchers in desert regions. Therefore, the objectiveof the study was to determine the combined effects of drought and grazing on plant responses.

MATERIALS AND METHODS

Description of the study area

This study was conducted on the Chihuahuan Desert Rangeland Research Center (CDRRC), located 38 km north of Las Cruces, New Mexico. Elevation of the study area is 1325 m above sea level. Average long-term (1931 to 2000) annual precipitation was 235 mm. The primary summer growing period for plants occurs from July through September when 54% (126 mm) of the annual precipitation falls. Spring months, February through June, are the driest with a long term average rainfall of 44 mm or 19% of total. Strong winds are common in the spring. October to November are fall months while December to January are winter months.

The daily maximum average temperature is 36^{o}C in June and 13^{o}C in January. Freezing temperatures are common during the winter months. The vegetation of the study area is semi desert grassland in poor to fair range condition. Black grama, mesa dropseed (*Sporobolus flexuosus* (Thurb) Rydb), fluff grass (*Dasyochloa pulchella* (Kunth) Steudel) and three awns (*Aristida spp.*) are the most common perennial grasses. Many annual and perennial forb species also occur in the study area. Broom snakeweed is very common in the area, and some mesquite plants are present. The soils in the study area are mainly light loamy sands and sandy loams with depths generally of 50 cm or less to a calcium carbonate (caliche) layer.

Experimental design and grazing treatments

Two 2.5 ha pastures (replications) were established in 1992. These pastures were built to study the effects of grazing intensity and season of grazing on plant responses (Nsinamwa *et al.,* 1999). Each pasture was divided into five 0.5 ha paddocks. The 5 treatments were (1) no-grazing or control, (2) moderate grazing (35% utilization of perennial grasses) before the rainy season in June, (3) heavy grazing (50% utilization of perennial grasses) before the rainy season in June, (4) moderate grazing (35% utilization of perennial grasses) after the rainy season in September, and (5) heavy grazing (50% utilization of perennial grasses) after the rainy season in September. Perennial grass utilization was determined by comparing biomass of all perennial grasses before grazing with the biomass remaining after the grazing trial. In order to monitor grazing during the trials the stubble heights of grazed mesa dropseed plants were compared with non-grazed plants. This helped in making the decision as to when to stop grazing the paddocks. Mesa dropseed was considered a key species because of its abundance and productivity. Grazing trials started in 1992, with 3 to 6 mature cows being used for each trial. For the first days of each grazing trial the cows were allowed to graze both the moderate and heavy use paddocks at the same time. When mesa dropseed had received an estimated use of 35% across both the moderate and heavy paddocks, a fence was then put between the paddocks restricting the cows to graze on the paddock designated to receive heavy use. This paddock was then grazed till the mesa dropseed had received approximately 50% use. This was repeated each year in the paddocks used for the June and September grazing trials. Grazing trials lasted 3 to 6 days.

Vegetation measurements

Within each paddock 5 belt transects (0.5 x 10 m) were permanently established for measuring plant attributes. A 0.5 x 1 m quadrat was located at the 1, 3, 5, 7, and 9 m marks on the belt transect each time plant data were collected. The basal cover for all grass, forb, and shrub species in each quadrat was determined by measuring basal dimensions for each plant growing in the quadrat. Densities for all plant species were also determined from these quadrat data. During drought conditions when no grazing took place, the paddocks were only sampled once in either June or September. Densities for all plant species and utilization of the perennial grasses were determined with the before-and-after grazing technique (Bonham, 1989).

The basal area of these plants was estimated before clipping. After obtaining dry weights of each individual plant, the grams of dry weight *per* square centimeter of basal area were calculated for each perennial grass species. These numbers were then multiplied by the average basal area of each plant species *per* square meter determined in the before and after sampling. The product of this multiplication gave estimates of above ground biomass before and after grazing. The differences in weight of all perennial grasses before grazing and after grazing were considered to be utilization (Bonham, 1989). This utilization or loss of forage included both forage eaten by the cows and the plants scuffed-out of the ground when the cows walked across the paddocks. Plant attributes were measured every year from 1992 through 2000. Because of the lack of "after-grazing" data for 1996, 1999 and 2000 because of drought, only the plant data for "before-grazing" are reported in this paper.

Data analysis

Basal cover and density for each plant category were analyzed for pre-planned comparisons using a mixed analysis of variance (ANOVA) procedure that incorporated repeated measures within each season (Cody and Smith, 1997). Grazing treatments, years, and their interaction were the main effects. Significant differences among means were determined using least square means with probabilities of less than 10%. To better understand the relations between grazing treatments, an importance value was calculated by adding the relative percent density and the relative percent basal cover for each plant category in each grazing treatment. Correlation values were determined between grazing treatments using the importance values for the plant categories Correlation and regression analyses were used to compare total plant basal cover for each plant category in each grazing treatment with precipitation across years. Precipitation totals used for these analyses were for the 12 months prior to the grazing trials

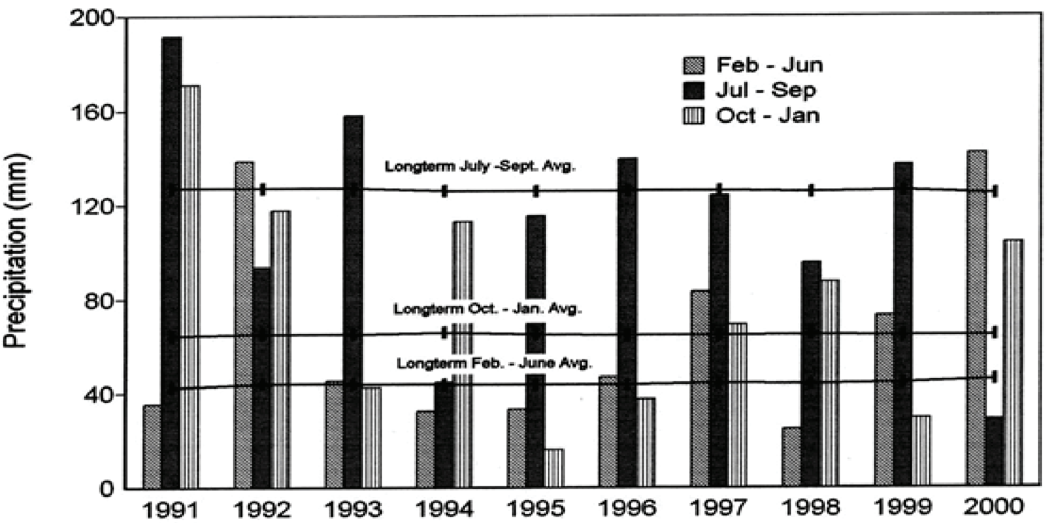

Figure 1. Precipitation for spring, summer, and fall-winter from 1991 to 2000 are averages of 2 rain gauges within 1 km of study paddocks. Long-term floating averages are for 1931 to 2000 for each respective season

RESULTS

Precipitation during the study period

Average annual and summer precipitation from 1992 to 2000 was 244 and 104 mm, respectively, for the study area (Figure 1). The annual average was slightly above the long-term average of 235 mm and the seasonal average was 16 % below the long-term average of 126 mm for the area. In 1991, the year prior to the start of the study, a total of 391 mm of precipitation was recorded. In May 1992, a month prior to the first grazing trial, 88 mm of rain fell, which is 10 times the average for May. A total of 372 mm of precipitation was recorded for 1992. Starting in the fall of 1993 rainfall was below average through 1995 except for the fall-winter season in 1994 (Figure 1). Below average summer growing season precipitation was recorded in 1992, 1994, 1995, 1997, 1998, and 2000. The year 2000 had the lowest summer precipitation (29 mm), and the second lowest recorded summer precipitation was in 1994 (45 mm), which also had the lowest annual total of 172 mm (73% of average). The long-term average fall-winter precipitation was 65 mm and from 1992 to 2000 the years 1993, 1995, 1996, 1999 were below average. The spring season, February through June is the driest (44 mm) and windiest. It is common for no precipitation for 1 or 2 months each spring.

Forage utilization and biomass production

In the June grazed paddocks, the average use of available biomass of perennial grasses on the moderate and heavy grazed paddocks were 27 and 53%, respectively, for the years in which grazing occurred. Biomass was however high, 38 and 50% in the September grazed paddocks for the moderate and heavy grazing treatment respectively. Above ground production of perennial grass averaged 667 kg ha^{-1} in June 1992 and 479 kg ha^{-1} in September 1992 (Table 1).

Table 1. Average perennial grass production on paddocks before grazing trials. June production figures include those from previous summer, while September production is only what grew in the current growing season. SE[1] = standard error

	Months			
Year	June (kg/ha)	SE1	September (kg/ha)	SE1
1992	667	110	479	80
1993	462	62	409	60
1994	279	41	73	17
1995	12	3	92	14
1996	23	3	55	9
1997	76	12	187	28
1998	135	46	38	5
1999	27	8	24	6
2000	80	15	144	30
Average	186	37	167	35

Plant production measured in June 1992 was exceptionally high because of the above average rainfall in the previous May (88 mm vs. 8 mm for long-term average). For most years during the study, plant biomass measured in June was plant material from growth of the previous summer growing season, while production measured in September was plant growth produced during the current summer growing season. In 1995 production averaged 12 kg ha^{-1} in the June paddocks and 92 kg ha^{-1} in the September paddocks. Because of the low production in 1995, there was little forage present in June 1996 and grazing trials were canceled. There was very little growth that summer so trials were also canceled for September 1996. Because of this precedence, in future years if grazing was canceled in June, no trials were held in September even if some plant growth occurred during the summer months.

Plant density and cover responses

Analyses of density and cover data indicated no significant ($P > 0.10$) interaction between year and grazing treatments. All plant categories were different ($P \leq 0.10$) among years for both basal cover and density data Correlation values Correlation values were significant ($P < 0.10$) and ranged from r = 0.72 (perennial forbs in moderate vs. heavy grazing treatments) to r = 0.99 (perennial grasses in moderate vs. heavy grazing treatments). These high correlation between grazing treatments are shown in Table 2. These high correlation values between non grazed and grazed paddocks for perennial grasses and forbs indicate that the plant responses were similar across years whether the plants were subject to grazing or not. Because of the generally high correlation values between grazing treatments, data for each plant category were averaged across grazing treatments and analyzed for year differences (Figures 2, 3, and 4).

Basal cover of perennial grasses was generally similar between the June and September paddocks (Figure 2) as it decreased during the period 1992 until 1996 (Figure 2). In Figure 5, mesa dropseed is the primary forage grass showing. In 1992, there was an average of 15 and 11 plants m^{-2} in the June and September paddocks, respectively. By 2000, densities were 2 plants m^{-2} in the June paddocks and 1 plant m^{-2} in the September paddocks. In a 3-week period in late July and early August 1995, there was a series of 7 rain events for a total of 38 mm and again in September there was an additional 45 mm.

Table 2. Correlations between grazing treatments comparing importance values (relative basal cover and relative density of respective plant categories added together) for June and September grazed paddocks.

	Perennial Grasses	Perennial Forbs	Half Shrubs
June			
Non grazed vs. Moderate	0.92*	0.73*	0.92*
Non grazed vs. Heavy	0.95*	0.92*	0.92*
Moderate vs. Heavy	0.89*	0.77*	0.92*
September			
Non grazed vs. Moderate	0.89*	0.87*	0.86*
Non grazed vs. Heavy	0.84*	0.79*	0.96*
Moderate vs. Heavy	0.99*	0.72*	0.89*

*Significant at the $P < 0.10$ within a row

It was observed that dropseed seedlings comprised 25 of the 27 perennial grass plants m^2 found growing on the September paddocks. In contrast, the following 6 months were extremely dry, and only 3 plants m^2 were still alive the next September.

Perennial grasses and forbs were positively correlated (P < 0.10) with precipitation, while annual grasses and annual forbs had either negative or low correlation values (Table 3). Eighteen species of perennial forbs were found growing in the study pastures. Perennial forb density varied from a high of 24 plants m^{-2} in 1995 to a low of 6 plants m^{-2} in 2000 in the June paddocks (Figure 3). Densities on the September paddocks were intermediate. Perennial forb density appeared less affected by drought conditions compared to other plant categories in this study (Figure 3). Coefficient of determination (r^2) values indicate the amount of variation in perennial forb basal cover that can be explained by rainfall ranged from 0.22 to 0.37 in the June grazed paddocks, and from 0.20 to 0.58 in September paddocks (Table 3). Density of perennial forbs was lowest in 1994 in the September paddocks and lowest again in 1996 for June paddocks (Figure 3). Perennial forb densities were generally constant from 1997 through 2000. These years did not experience high rainfall. Annual grasses were not present for most of the June grazing trials (Figure 3). However, there was some germination and establishment of annual grasses in 2000 due to 129 mm of rainfall in June of that year.

Nineteen species of annual forbs grew in the study paddocks and had higher populations in the June grazed paddocks than annual grasses. In several years during the study, these forbs were senescing before the June grazing trials. The density of annual forbs was similar ($P \geq$ 0.10) across the paddocks in June, however there was a significant difference ($P \leq$ 0.10) among grazed paddocks for September. The non-grazed paddock had an average density of 7.5 plants m^{-2} from 1992 to 2000, which was significantly ($P \leq$ 0.10) lower than the 11.7 and 12.7 plants m^{-2} for the moderate and heavy grazed paddocks, respectively (Figure 3).

Annual grass and annual forb cover estimates were either poorly or negatively correlated with the total precipitation which fell the previous 12 months (Table 3). Density of annuals was much lower at the beginning of the trial, but, generally increased during the latter part of the study (Figure 3). On the other hand, annual forbs responded well in 1995 and 1996 (drought years) compared to 1997 (average summer rainfall) for the September season.

Generally, no distinct patterns were observed with annuals from year to year. Few mesquite occurred on the study paddocks and only 2 mesquite seedlings were found during the study, and both died. The other important woody plants were 5 species of suffrutescent- or half-shrubs. Three were uncommon and 2, plains zinnia and snakeweed made up more than 99% of the half-shrub populations. Plains zinnia was common in the study area and made up 30 % of the half-shrub populations in the wetter years. High densities were noted during June 1995 and 1999, and during September 1999 (Figure 4). In 1995 many seedlings germinated in the spring and were present in the June sampling (Figure 6), but died during the summer because of low summer rainfall (Figure 1). Again, in 1999 many snakeweed seeds germinated in the spring, and because of the above average rainfall in the spring and summer they grew and survived well as indicated by the September densities and basal cover

Little rain fell in fall of 1999 and spring of 2000 until June when 130 mm fell. Because of the fall-spring dryness no germination occurred and many snakeweed plants died (Figure 4). There was more loss of snakeweed during the summer rainy season when only 28 mm fell (Figure 1) and significant ($P \leq$ 0.10) declines in both density and basal cover occurred

DISCUSSION

In the Chihuahuan Desert rangelands, major changes in vegetation are due to fluctuations in annual precipitation (Navarro *et al.*, 2002; Khumalo and Holechek, 2005) and this is reflected in Figure 1. In the current study, 1994 and 1995 summer seasonal precipitation was lower than long-term average (Figure 1). The effects of this continued

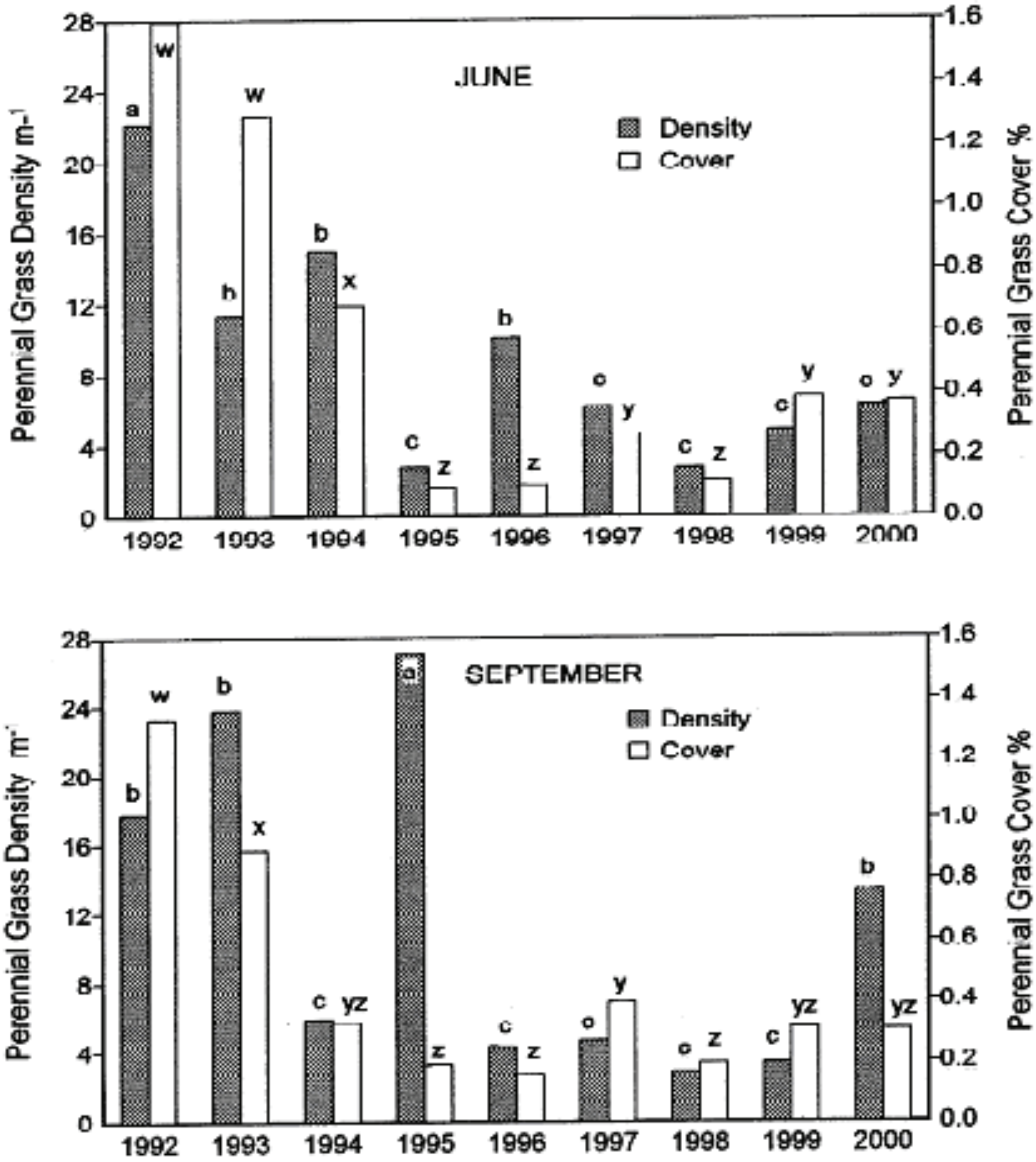

Figure 2. Density and basal cover for perennial grasses prior to grazing trials in June and September from 1992 through 2000. Bars with different letters (density - a, b, c) and (cover - w, x, y, z) are different, P ≤ 0.10.

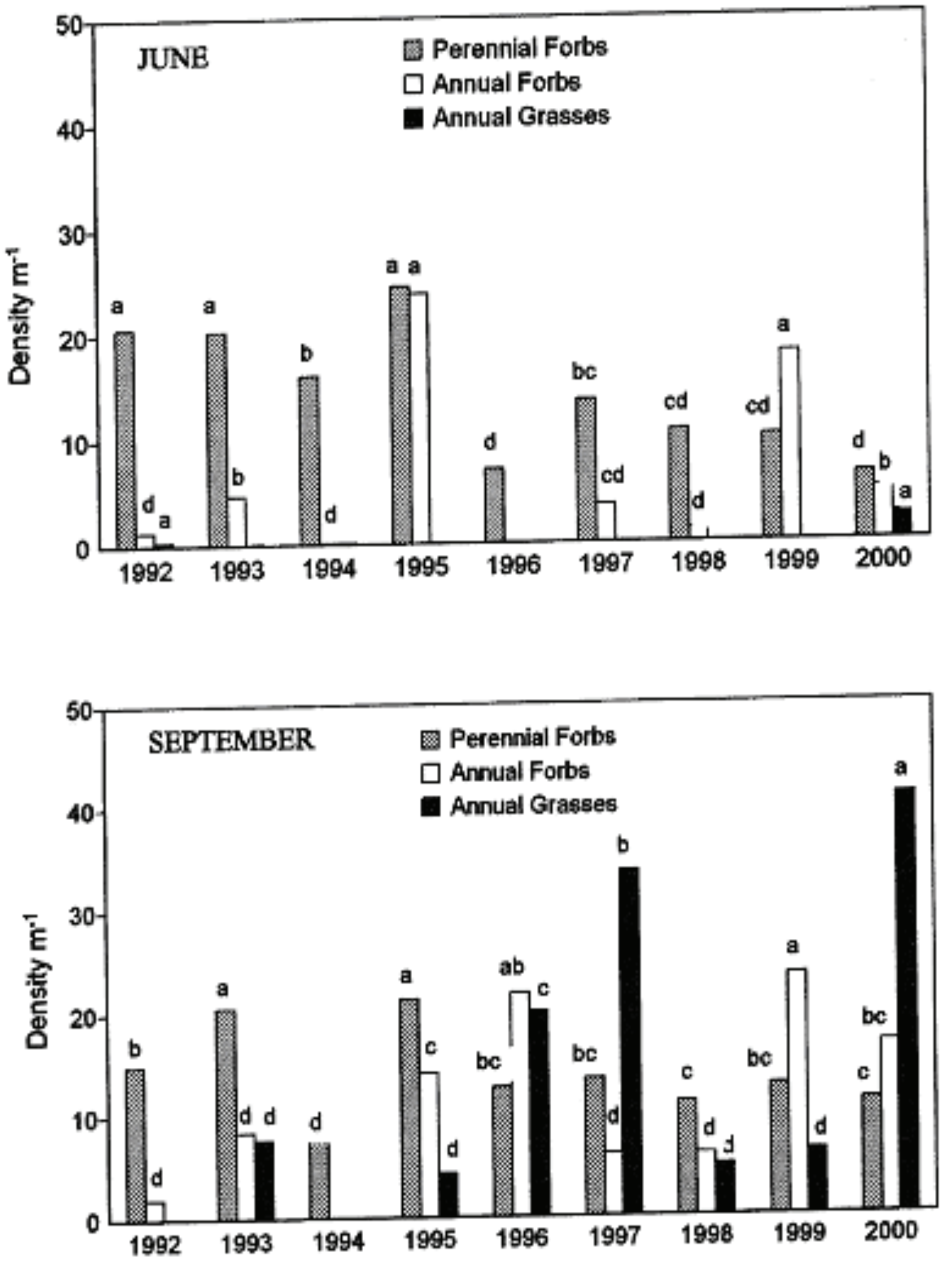

Figure 3. Density of perennial forbs, annual forbs, and annual grasses on paddocks grazed in either June or September from 1992 to 2000. Bars with different letters for each vegetation class are different (P ≤ 0.10).

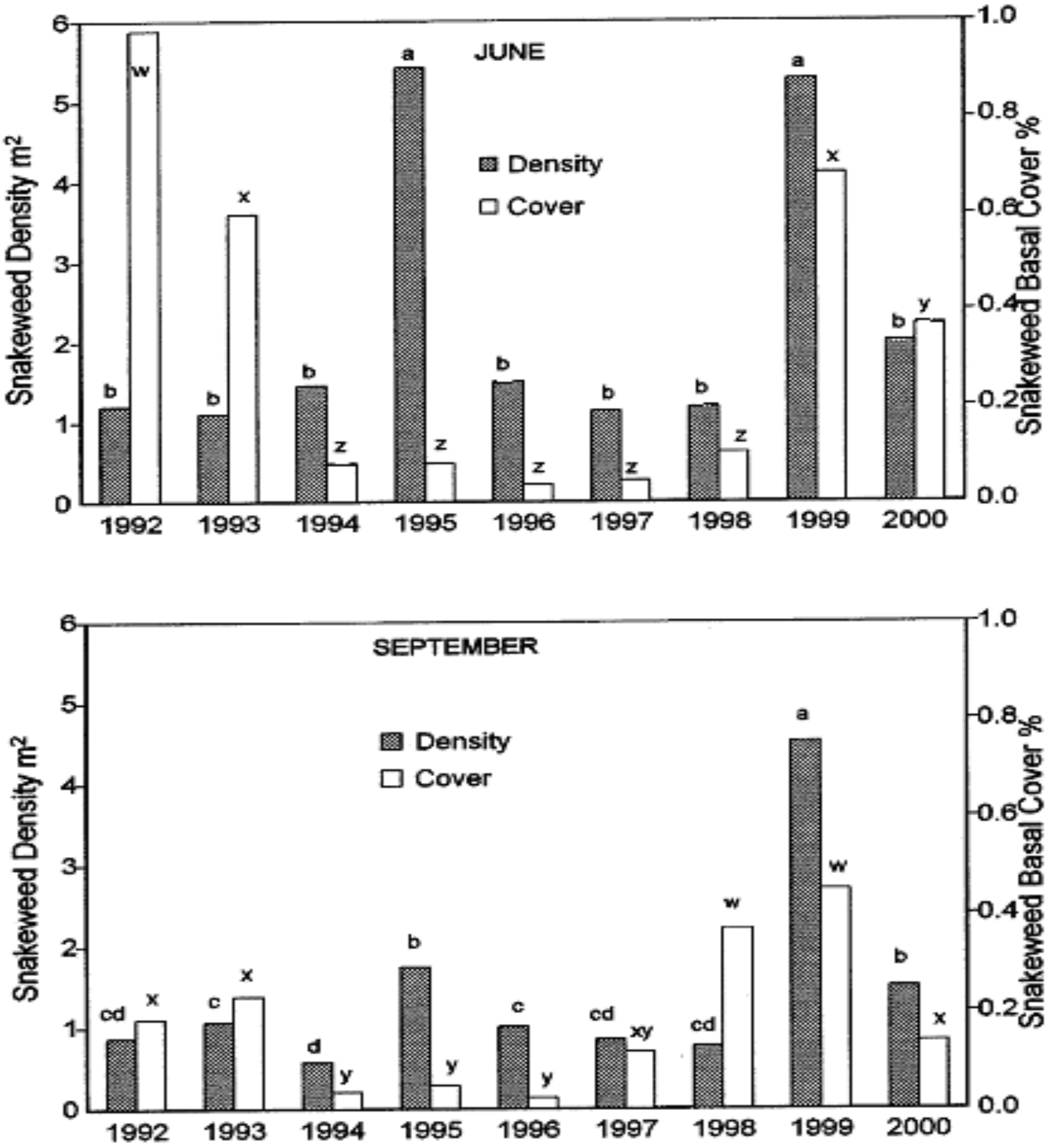

Figure 4. Snakeweed (Gutierreziasarothrae) density and cover on paddocks grazed in June and September from 1992 to 2000. Bars with different letters (density - a, b, c, d) and (cover - w, x, y, z) are different (P ≤ 0.10).

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Figure 5: Cattle grazing in June 1992 on the moderate use paddock. The grasses are primarily mesa dropseed. Some broom snakeweed and yucca are visible in the foreground and mesquite can be seen in the background

Figure 6*:* June study paddocks in summer of 1999 after 6 years of drought. Note the absence of grasses and the plants in the foreground are broom snakeweed and a few small forbs. The white stakes mark the beginning and end of transects

Table 3. Correlations (r) and coefficient of determinations (r^2) for basal cover of plants (%) with total precipitation for the 12 months prior to sampling either June or September grazed paddocks from 1992 to 2000. *Significant at $P < 0.10$ within a row

	Correlation value, r			Coefficient of determination, r^2		
Category	No-Grazing	Moderate	Heavy	No-Grazing	Moderate	Heavy
June						
Basal Cover (%)						
Perennial grasses	0.77*	0.8*	0.91*	0.59	0.64	0.51
Annual grasses	0.48	0.44	0.9	0.23	0.19	0.81
Annual forbs	-0.43	-0.22	0.47	0.18	0.05	0.22
Perennial forbs	0.61	0.52	0.47	0.37	0.27	0.22
Snakeweed	0.78*	0.74*	0.88*	0.6	0.55	0.77
Total Cover (%)	0.81*	0.8*	0.83*	0.65	0.64	0.69
September						
Basal Cover (%)						
Perennial grasses	0.71*	0.81*	0.77*	0.5	0.65	0.59
Annual grasses	-0.28	-0.06	-0.18	0.08	0.06	0.09
Annual forbs	0.06	0.1	0.08	0.01	0.01	0.01
Perennial forbs	0.76*	0.66*	0.44	0.58	0.44	0.2
Snakeweed	0.26	0.28	0.42	0.07	0.08	0.18
Total Cover (%)	0.75*	0.85*	0.87*	0.56	0.73	0.75

dry weather could be seen in 1996, even though the growing season precipitation for that year was above average. The increase in basal cover could be attributed to relatively high rainfall events from January through June of 1997. Though plant growth was restricted due to low temperatures in the colder months, precipitation is important in keeping buds alive. This resulted in quick plant growth as shown in the September grazed paddocks once the rains started. Mesadropseed is an important mid-seral perennial grass, in the northern Chihuahuan Desert and in years of high rainfall it can produce several hundred kilograms of biomass *per* hectare. It is relatively short-lived (Herbel *et al.,* 1972) and depends on seed germination for establishment. It does not survive well in dry periods and as a result of the drought conditions there were considerable losses.

Much of the perennial forb populations comprised of leatherweed (*Croton pottsii* (Klotzsch) Muell.-Arg) which has low to moderate palatability (Mofareh *et al.,* 1997). This species usually produces new plants from rhizomes after the rains start in the summer growing season. The perennial forbs growing in this area are tolerant to a wide range of environmental conditions, including extended dry periods. Like leatherweed, most of the other perennial forbs have low palatability and thus are less utilized by cattle.

In this part of the Chihuahuan Desert, in most years, little plant growth occurs before the summer rains in July. During the rainy season in July and August of most years, germination of annual grasses occurs following some rain showers. The amount that germinates and establishes would vary between years, but appears to have little relation to grazing treatment. Their abundance in the ecosystem relies on the amount of seed (Dwyer and Edmundo, 1978) in the soil and the timing and amount of precipitation (Gibbens and Beck, 1988). Annual forbs would germinate more readily than annual grasses in cooler temperatures and use any available winter and spring precipitation (Guo and Brown, 1997). Cool-season annuals, an important vegetation component in the Chihuahuan Desert as in most North American deserts, often do not show clear annual seasonal patterns (Inouye *et al.,* 1980; Henderson *et al.,* 1988). In the current study, a possible explanation for high annual forb density for the moderate and heavy grazing treatment may be the trampling-in of the seeds during the grazing trials the previous fall. This put the seeds into a more favorable environment and reduced their chances of being eaten by seed predators (ants, birds, rodents, etc.). Summer annual forbs such as pigweed (*Amaranthuspalmeri*Wats.),purslane (*Portulacaolereca* L.), Russian thistle (*Salsola tragus* L.) and many others only germinate at relatively high temperatures while winter annuals such as tansy mustard (*Descurainiapinnata*(Walt.) Britt.), bladderpod (*Lesquerellafendleri* (gray) Wats.), deer's tongue (*Namahispidum* Gray), etc. germinate at relatively cool temperatures. Rainfall events are localized summer convectional storms of high intensity, but low frequency. These storms are also coupled with high temperatures that result in increased evaporation. Adequate rainfall to induce germination of annuals may be followed by a dry period where soil moisture is inadequate for many of the annual species to complete their life cycles. Desert annual plant species spend much of their life cycle as seeds. Suggested theoretical models predict that annual plants growing in uncertain environments may or may not have evolved innate dormancy to offset the possibility of population extinction due to complete germination followed by complete mortality under severe weather conditions (Freas and Kemp, 1983). Desert annual plants success depends on their seeds germinating during periods when the environment is suitable to complete the life cycle (Coffin and Lauenroth, 1989; Freas and Kemp, 1983). Thus, if a species germinates too quickly in response to a rain shower it may risk extinction. The observed patterns for annuals in this study may be attributed to the explanations described above. Annuals' populations reflect the amount and timing of precipitation, which falls during the appropriate growing season. By including the total rainfall for the 12 months preceding the grazing trials into the correlation calculations, the relationship between rainfall and annual plant basal cover was almost nonexistent or in some cases negative. This further explains synergy of germination and current precipitation in annual's life cycle. This response might be attributed to less competition by perennial species whose plant cover may have been reduced due to drought. With less perennial plant cover, more water was presumably available for annuals to germinate and grow. Therefore, their response probably depended more on the amount and frequency of rainfall events rather than the total rainfall.

Both plains zinnia and snakeweed are unpalatable to cattle. Broom snakeweed was common, but it is susceptible to drought and insect populations that result in cyclic populations (Pieper and McDaniel, 1990). The changes in density and basal cover observed for snakeweed in this study can be attributed to rainfall patterns. Some loss of small plants occurred with trampling by cattle. Even at low populations, snakeweed has the potential to be a strong competitor with warm season grasses (Pieper and McDaniel, 1990). The results of the present study corroborated reports by Wood *et al.* (1997) who observed that most snakeweed seedlings germinate in the spring following above average precipitation the preceding fall and winter.

CONCLUSIONS

Grazing did not influence either plant density or plant basal cover regardless of grazing intensity. Most of the changes of plants observed during the study were due to drought. Therefore, if drought continues for more than 1 year, even the non-grazed areas are detrimentally affected, with reduced plant density, loss of basal cover and biomass production. This means that even with intensive grazing systems such as short-duration grazing, it may become necessary to de-stock the affected rangelands.

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Conflict of interest

None

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