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ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Forage Production and Stocking Rates on Southern Arizona Ranges Can be Improved[1]

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Most semidesert cattle ranges in southern Arizona can grow more grass and beef than they do. Early plot studies in the Southwest showed that mesquite control increased grass production (Parker and Martin 1952),[3] and indicated that maximum benefits could be expected only with good grazing management. These findings have not been verified experimentally on a practical scale. This paper discusses increases in forage production and carrying capacity within 5 years after changing the grazing management on two range units recently cleared of mesquite and two mesquite-infested units on the Santa Rita Experimental Range.

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[3] *Names and dates in parentheses refer to Literature Cited, p. 11.*

DESCRIPTION OF THE STUDY RANGES

Four units of the Santa Rita Experimental Range near Tucson, Arizona, are being used in this study. They contain from 659 to 996 acres each, and lie at elevations of from 3,700 to 4,800 feet (fig. 1). The soils on the flatter slopes, primarily coarse sandy loams of the Whitehouse and Tumacacori series, grade into shallow stony phases of Coronado coarse sandy loam on the steeper slopes. Subsoils of the Tumacacori series are loose and open, while those of the Whitehouse and Coronado series are clay loam.

Average annual precipitation varies from about 14.5 inches at the lowest elevation to 19 inches at the highest elevation. The precipitation falls in two distinct rainy seasons: about 56 percent of the total annual precipitation falls during the summer growing season, early July till late September, and 33 percent falls from December through April; the remaining 11 percent falls in the relatively dry periods separating these precipitation periods. Usually all available soil moisture is

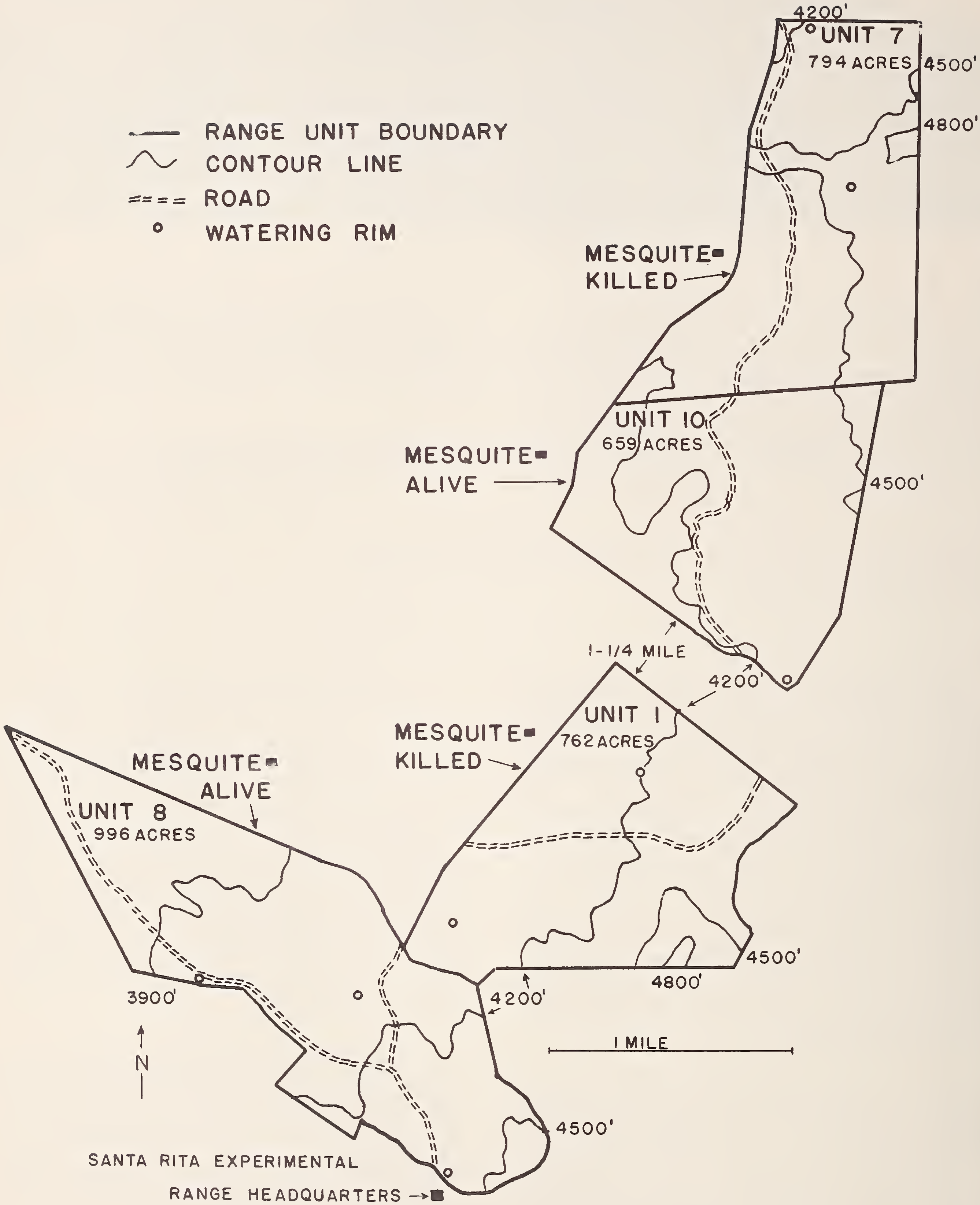

Figure 1.--Range units used in the study.

removed by evaporation and transpiration during the dry periods preceding each rainy season. Summer rainfall, which produces about 90 percent of the perennial grass herbage (Culley 1943), varied greatly during the study period:

	Precipitation	
	Mesquite-killed	Mesquite-alive
	(Inches)	
Lowest year	4.60	5.58
Highest year	15.41	19.32
Average year	10.14	11.64
Longtime average	9.62	10.02

Maximum daytime temperatures in summer are usually in the high eighties or low nineties, although the temperature may rise above 100° F. on 1 or 2 days during the summer. Winter minimums generally are in the upper thirties although freezing temperatures, seldom lower than 20° F., have been recorded at the range headquarters, 4,300 feet, an average of 27 nights each winter.

Vegetation cover.--Vegetation on the range units in 1957 consisted of a relatively good stand of native perennial grasses overtopped on two of the units by an invasion stand of velvet mesquite (*Prosopis juliflora* var. *velutina* (Woot.) Sarg.). Invading mesquite had been killed on the other two units. Perennial grass basal intercept averaged 0.82 and 1.09 percent on the mesquite-killed and mesquite-alive units, respectively, and perennial grass herbage production averaged 218 and 299 pounds per acre air-dry.

Grama grasses, principally sprucetop (*Bouteloua chondrosioides* (H.B.K.) Benth.), side-oats (*B. curtipendula* (Michx.) Torr.), black (*B. eriopoda* Torr.), and slender (*B. filiformis* (Fourn.) Griffiths), comprised from one-half to three-fourths of the perennial grass stand. Arizona cottontop (*Trichachne californica* (Benth.) Chase) and *Aristida hamulosa* Henr. made up most of the remainder. Predominant annual grasses were sixweeks three-awn (*Aristida adscensionis* L.) and needle grama (*B. aristidoides* (H.B.K.) Griseb.).

Total shrub crown intercept averaged 9.58 and 12.16 percent, of which mesquite comprised 2 percent on the mesquite-killed units and 31 percent on the mesquite-alive units. Other common shrubs were velvetpod mimosa (*Mimosa dysocarpa* Benth.), false mesquite (*Calliandra eriophylla* Benth.), catclaw acacia (*Acacia greggii* A. Gray), and Engelmann pricklypear (*Opuntia engelmannii* Salm-Dyck).

The mesquite stands before treatment averaged from about 80 to 180 plants per acre on the four range units. Although some small areas with very dense stands (up to 775 trees per acre on 0.5-acre plot) had essentially no perennial grass understory, most of the area on the range units still had fair to good stands of perennial grasses. Mesquite control was essentially complete by 1957. Vegetation characteristics of study ranges in 1957 are summarized as follows:

	Mesquite-killed	Mesquite-alive
Perennial grass basal intercept (Percent)	0.82	1.09
Perennial grass herbage production (Lbs/A)	218	299
Annual grass herbage production (Lbs/A)	179	38
Shrub crown intercept (Percent)	9.58	12.16
Mesquite crown intercept (Percent)	0.19	3.76
Mesquite density (Trees/A)	9	128

Grazing history.--The four range units had been grazed yearlong by cattle since 1915. From 1915 to 1925 the stocking rate averaged from 32 to 34 head per section. Declining productivity soon showed, however, that such rates of stocking were too high, and numbers were reduced more or less progressively until around 1940. During the 16-year period 1941-56 immediately before the change in grazing management, the stocking rate averaged 16, 13, 14, and 15 head per section on units 1, 7, 8, and 10, respectively. Utilization of perennial grasses during this period averaged 60, 58, 59, and 47 percent on the four units.

Recent rainfall history.--Summer rainfall during the period 1946-53 was generally deficient: 1947, 1948, 1952, and 1953 were markedly below the longtime mean, and there were moderate summer rainfall shortages in some of the range units in 1949 and 1951. Precipitation for the summers of 1952 and 1953 was 65 percent of the longtime average in units 1 and 8, and 57 percent of the mean in units 7 and 10. This 8-year period of generally low rainfall, climaxed by two successive summers of severe drought, had reduced the perennial grass stand to a rather low state of productivity by the time the mesquite-control program began in 1954 (fig. 2a).

METHODS

Mesquite control.--Mesquites were killed in range units 1 and 7 by spraying diesel oil on the stem bases as described by Reynolds and Tschirley (1957). Oiling was started in 1954 and completed in 1957. New plants and the few small plants that were missed in the original treatment were sprayed during the summer of 1960. Spraying the original stand cost about 5 cents per tree, half for oil (1-1/2 pints per tree average) and half for labor. The 1960 spraying also cost about 5 cents per tree, 80 percent for labor and 20 percent for oil (3/4 pint per tree average).

The basal oiling treatment killed most trees within a few weeks. The few trees that survived were usually located in sandy washes where stream-deposited sand buried the sprouting bud zone too deep for the oil to reach.

Grazing management.--Two significant changes in grazing management were made beginning with the 1957-58 grazing year: the use objective for perennial grasses was lowered to 40 percent, and alternate-year summer deferment (July 1 to September 30) was started. Two range units, one mesquite-killed and one mesquite-alive, were summer-deferred in 1958, the other pair in 1959.

The number of cattle needed each year to obtain the utilization objective is determined in October after the summer growth is complete but before normal marketing time, around November 1. The number is computed from multiple regression equations derived from past records of the summer yields of annual and perennial grasses, actual stocking, and utilization of perennial grasses. The form of this equation, which gives a direct stocking estimate for 40 percent use, is

$$S = b_1 A + b_2 P + a$$

where

- S = estimated stocking for 40 percent utilization
- A = air-dry annual grass per acre (pounds)
- P = air-dry perennial grass per acre (pounds)
- b_1, b_2, and a = constants derived from the regression computations

Figure 2.--Grass stand before and after mesquite control, unit 7; mesquite killed, 1955 and 1956.

A. September 1953, after many years of close grazing, and two consecutive dry summers, 1952 and 1953.

B. October 1961; utilization reduced to 40 percent, 1957; grazing deferred in summers of 1959 and 1961; above-average rainfall, summer 1961.

This equation differs from those reported by Reid, et al. (1963) in two important respects. First, the independent variables are the yields of annual and perennial grass (pounds per acre) rather than the reciprocals of these values. Second, the dependent variable is the estimated number of animals needed to obtain 40 percent use on perennial grasses, rather than the reciprocal of "actual percent use." Each range unit has its own equation, which is recomputed each year to include data from the year immediately past.

Vegetation measurements.--Several kinds of vegetation data are being obtained yearly on or immediately adjacent to 20 randomly located permanent 100-foot line transects in each range unit.

1. Herbage yields of annual and perennial grasses are expressed as pounds per acre air-dry. Since 1954, estimates have been obtained by a double-sampling method similar to that described by Wilm et al. (1944).

2. Line intercept measurements of perennial grasses (basal intercept) and shrubs (crown intercept) began in 1953 in units 1 and 8, 1954 in unit 7, and 1955 in unit 10. Intercept is measured by Canfield's (1942) method.

3. Utilization of perennial grasses is measured by the ungrazed-plant-count method of Roach (1950). Prior to establishment of permanent transects, utilization was measured each year on 10 paced transects per range unit.

4. Numbers and crown diameters of living mesquites on plots 100 by 200 feet overlying each of the line transects were recorded in 1957. Most of the mesquites in units 1 and 7 had been killed at the time this count was made.

It should be noted that the mesquite-control program began in 1954, the permanent transects were established from 1953 to 1956, and the grazing treatment change was made in 1957. Consequently, data taken before 1957 show the response of vegetation to current rainfall, unmeasured influences, and to mesquite control. Responses measured after 1957 include the influence of better grazing management.

RESULTS AND DISCUSSION

The grass cover improved substantially on all four range units during the study period. Grass production, especially of annual grasses, increased most conspicuously on the mesquite-killed units (fig. 2). Mesquite-alive units produced almost no annual grass in dry summers, and only moderate amounts in summers of average or above-average rainfall.

Changes in Perennial Grass Herbage Production

Perennial grass production varied greatly during the 1954-61 study period (fig. 3):

	Herbage Production	
	Mesquite-killed	Mesquite-alive
	(pounds per acre)	
Lowest year	133	142
Highest year	660	638
8-year average	331	347

Highest production in 1958 was from 4.5 to 5 times as much in 1956, the year of lowest production. Yields in these 2 years, 1956 and 1958, were near the all-time extremes for the study area. Summer rainfall, grazing management, and mesquite density appear to be the major factors that affected perennial grass production during this period.

Although the individual influences of these variables on perennial grass production cannot be completely isolated at this time, some indication of their separate effects can be obtained by (1) correlating total perennial grass production per acre with total summer rainfall to estimate the direct effect of rainfall, (2) determining production per acre per inch of summer rainfall by years to evaluate trends in production with time, and (3) comparing total production per acre and production per acre per inch of summer rainfall on mesquite-alive units with those on mesquite-killed units.

Correlation with summer rainfall.--Low grass production was associated with low

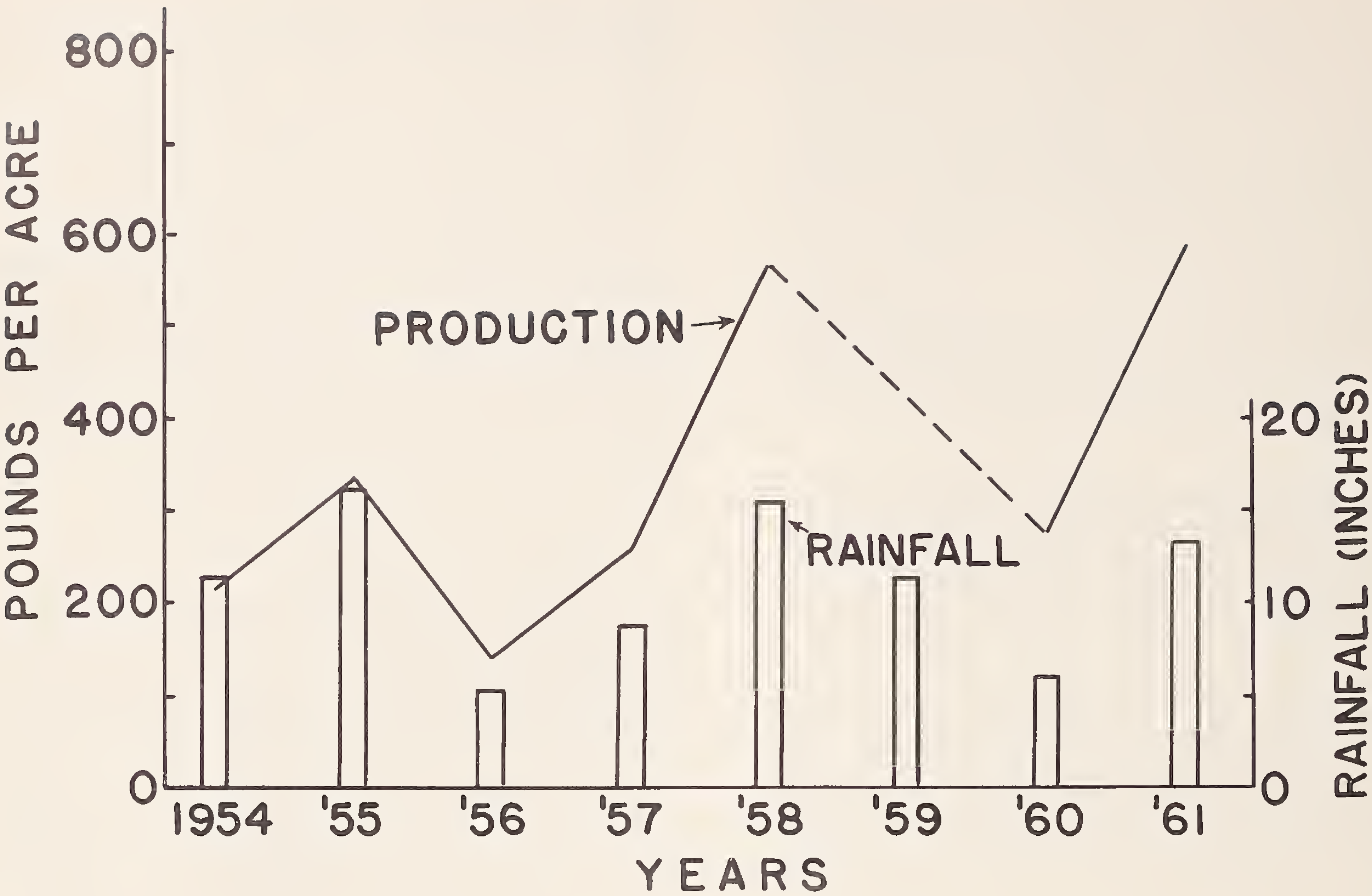

Figure 3.--Perennial grass herbage production and June-September rainfall--average for four range units.

summer rainfall, and high grass production with high summer rainfall, as would be expected (fig. 3). The correlation between total summer rainfall and perennial grass production accounts for only 39 percent (r = 0.622) of the variation in production, but is highly significant. Other rainfall variables such as the size and spacing of individual storms undoubtedly influence rainfall effectiveness, but no adequate evaluation of these variables is available.

Trends with time.--The trend in summer rainfall during this period was slightly downward, but not significantly so. Perennial grass production, on the other hand, exhibited a generally upward trend on both the mesquite-killed and mesquite-alive units (fig. 3). This upward trend in production, without a comparable increase in summer rainfall, implies improved productivity independent of rainfall. The extent of this improvement can be seen by expressing production in terms of pounds per acre per inch of summer rainfall.

Perennial grass production on the mesquite-killed and the mesquite-alive range units increased an average of 4.63 and 3.71 pounds per acre per inch of summer rainfall, respectively, for each year during the study period (fig. 4). Average production per acre per inch of rainfall on the four units increased from 19 pounds in 1954 to 45 pounds in 1961.

Several factors contributed to this increase in productivity, but the specific causes cannot be pinpointed. The rising trend in productivity was initiated by above-average summer rainfall in 1954 and 1955 following the 1947-53 period of generally unfavorable rainfall. Improvement subsequent to 1957 has been attributed to improved management: a reduction in utilization objective to 40 percent (actual use averaged 35 percent), coupled with alternate-summer deferment, which started in the 1957-58 grazing year. Productivity of adjacent range units, managed differently, did not improve during this period. Range unit 9, which lies between units 1 and 10, has been managed

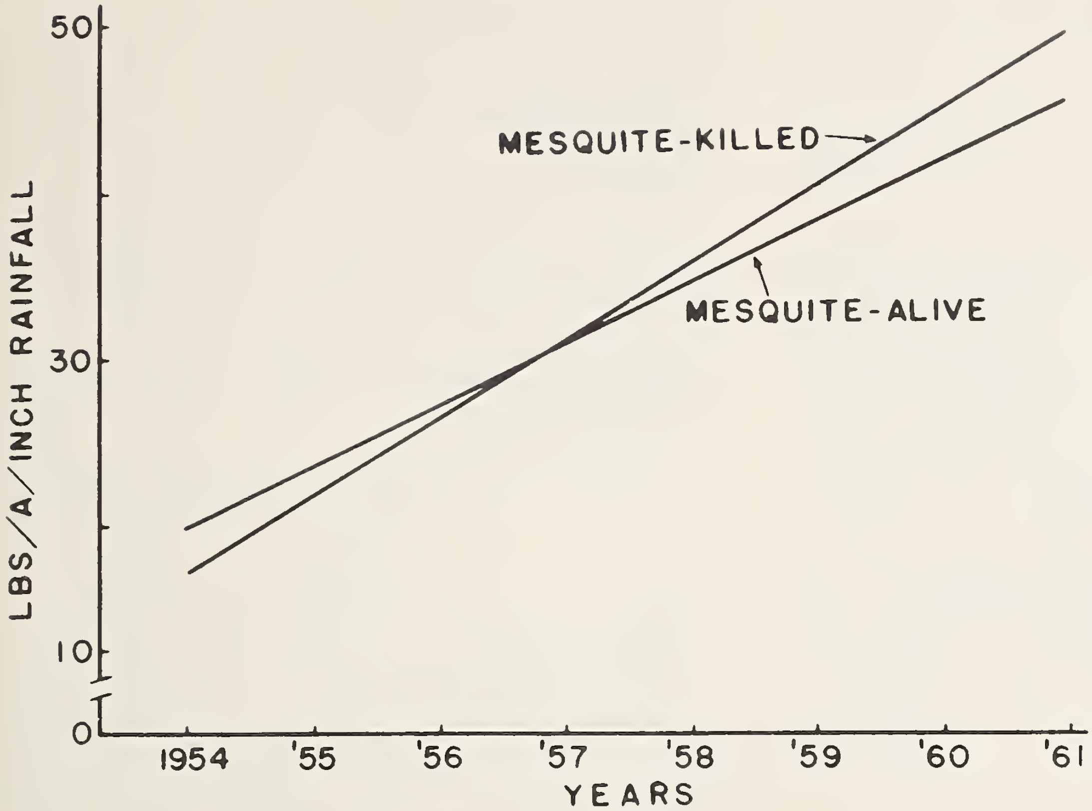

Figure 4.--Change in perennial grass production per inch of June-September rainfall on mesquite-killed and mesquite-alive range units.

in the same way as the four study units except that since 1958 this unit has been grazed yearlong and has carried extra cattle in alternate summers. Productivity in unit 9 increased from 1954 to 1957, but has decreased since 1958. Also, on three larger adjacent units, where grazing has been yearlong and utilization has averaged somewhat higher (about 45 percent), there has been a slight but not significant downward trend in productivity.

Total summer rainfall and the improving trend with time together account for 76 percent of the variation in perennial grass productivity during the 1954-61 period, with rainfall being slightly more influential. The multiple correlation coefficient for this relation is $R = 0.87$.

Influence of mesquite control.--Between 1957 and 1961, perennial grass herbage production on the mesquite-killed range units increased relative to production on the mesquite-alive units. Production on the mesquite-killed range units increased over twice as much (443 pounds per acre) as did that on the mesquite-alive range units (220 pounds per acre). This difference between the two pairs of range units is significant at $p = 0.01$.

	Perennial grass production	
	Mesquite-killed	Mesquite-alive
	(Pounds per acre)	
1957	217	299
1961	660	519
Increase	443	220

This improvement due to resquite control, while substantial and important, was slower and much less dramatic than had been reported previously from studies in which moderate to dense stands of mesquite were removed from small plots with very sparse stands of perennial grasses (Parker and Martin 1952). The smaller response in this study was not unexpected, and was probably due to a lower potential for improvement because of the relatively light stand of mesquite and the relatively good stand of perennial grass present at the start of the study.

The somewhat divergent trends in production per inch of rainfall (fig. 4) also show the influence of mesquite control, although with the limited amount of data available, these trends are not significantly different.

Changes In Perennial Grass Basal Intercept

The period 1957-59 has been established as a base for studying the trends in perennial grass cover in this study. On this basis, by 1961 perennial grass basal intercept had increased significantly more ($p = 0.01$) on the mesquite-killed units, 61.6 percent average increase, than on the mesquite-alive units, 19.4 percent average increase.

	Basal intercept	
	Mesquite-killed	Mesquite-alive
	(Percent)	
1957-59 average	1.38	1.75
1961	2.23	2.09
Change	+61.6	+19.4

Since the basal area of perennial grass plants is relatively insensitive to year-to-year changes in rainfall, this trend indicates long-term cumulative effects of weather and management (in contrast, production of herbage is highly sensitive to year-to-year changes in rainfall and is therefore more indicative of the short-term effects of weather and management).

Changes In Annual Grass Production

Annual grass production varied more widely from year to year than did perennial grass production.

	Annual grass production	
	Mesquite-killed	Mesquite-alive
	(Pounds per acre)	
Lowest year	53	22
Highest year	424	163
8-year average	227	74

In the year of highest production annual grasses yielded from 7.5 to 8 times as much herbage as in the year of lowest production. These differences apparently were responses mostly to variations in summer rainfall and in mesquite density.

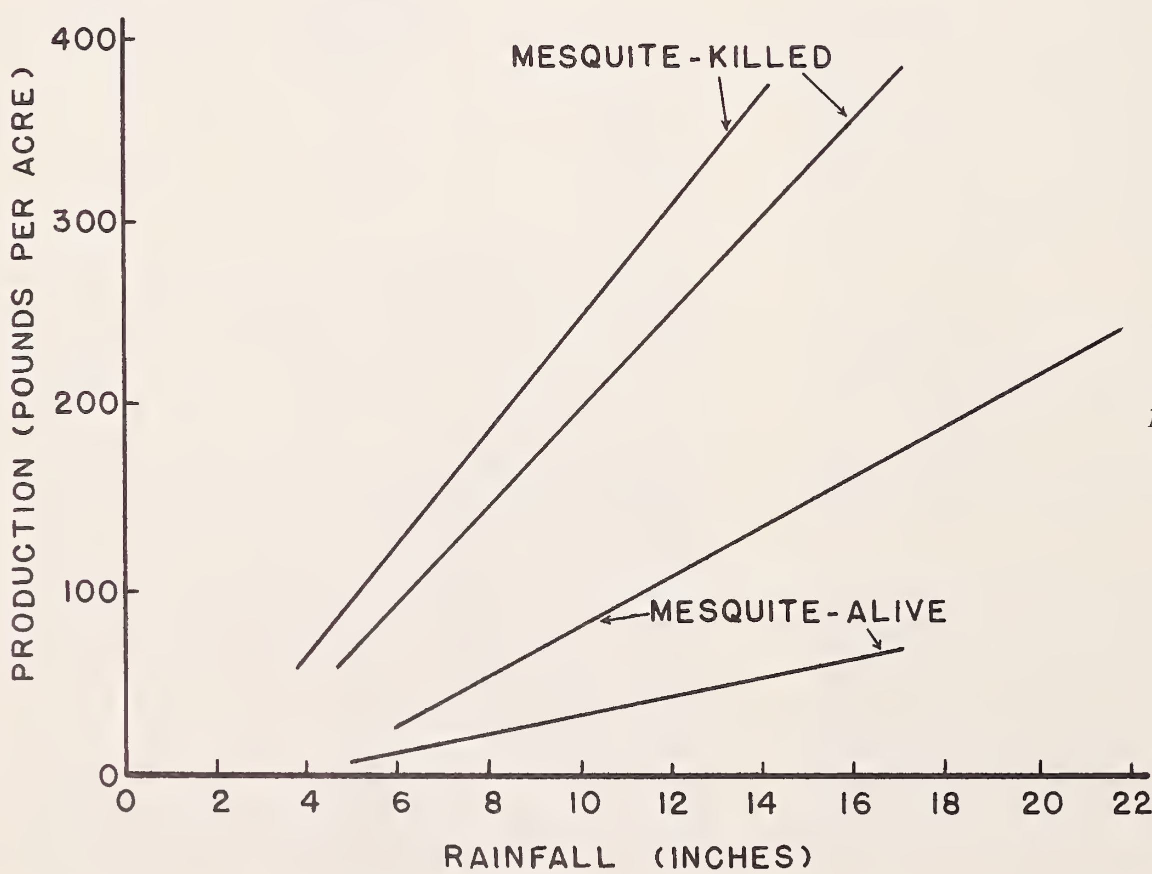

Figure 5.--Relation between annual grass production and June-September rainfall on the four range units.

Influence of rainfall.--Because the annual grasses complete their life cycle from seed to seed within 6 to 12 weeks during the summer rainy season, they are obviously dependent on summer rain for their growth. Correlation coefficients of 0.73 and 0.76 between June-September rainfall and annual grass production on the mesquite-alive and mesquite-killed range units indicate that a little over half of the variation in annual grass production during the 1954-61 period is explained by variations in total summer rainfall. A large part of the remaining variation is probably due to variation in. size and spacing of individual storms.

Range-unit regressions of annual grass production and rainfall for the 8-year period show the separate effects of rainfall and mesquite density. Each additional inch of June-September rainfall produced on the average 27 and 31 pounds per acre of annual grass herbage on the two mesquite-killed units, but only 5 and 14 pounds per acre on the mesquite-alive units (fig. 5).

Influence of mesquite density.--As noted above, annual grasses produced more herbage on the mesquite-killed than on the mesquite-alive units; the two mesquite-killed units averaged 227 pounds per acre from 1954 to 1961, while the two mesquite-alive units averaged only 74 pounds per acre.

Relating the rates of change in annual grass production per acre per inch of summer rainfall to mesquite crown intercept for the four range units indicates that annual grass production per inch of summer rainfall decreased markedly, but nonlinearly, as mesquite intercept increased (fig. 6). Thus, with a mesquite crown intercept of 0.25 percent, annual grass production was about 20 pounds per acre per inch of summer rainfall; production dropped to 10 pounds per acre per inch with 2 percent crown intercept, and 5 pounds per acre per inch with 7 percent crown intercept.

Changes In Stocking Rates

Because the stocking rates are based on yearly production of grass herbage, the pattern of change in stocking rates should resemble the pattern of change in grass produc-

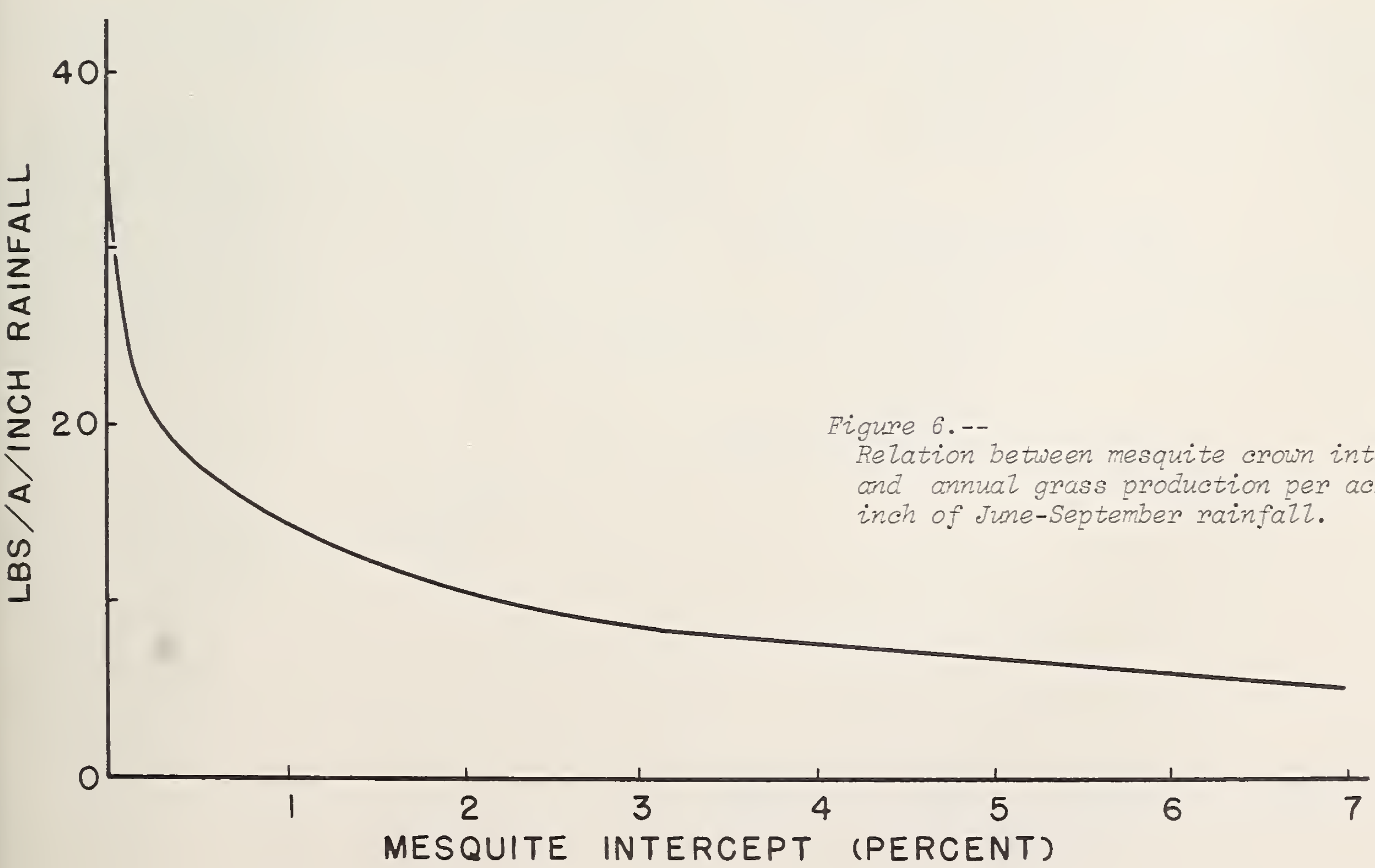

*Figure 6.--
Relation between mesquite crown intercept and annual grass production per acre per inch of June-September rainfall.*

tion. Also, if the type of management has improved grass productivity, stocking rates during the study period should show improvement over those of prior years.

Direct comparison of stocking rates between the study period and prior years is not valid because utilization averaged much higher during the earlier period. When stocking rates are adjusted to a utilization of 40 percent of the available grass forage, direct comparison is valid.

During the 1954-61 period, the stocking rate for 40 percent use increased an average of 2.5 head per section per year on the mesquite-killed units--from 10.2 head per section in 1954 to 27.4 head per section in 1961 (fig. 7). The rate of increase on the mesquite-alive units was 1.1 head per section per year--from 13.0 head per section in 1954 to 21.0 head per section in 1961. These trends resemble in direction and magnitude those for perennial grass production discussed previously. Thus, the increase in grass production, due both to better management and mesquite control, has made it possible to increase the stocking rates appreciably.

SUMMARY AND CONCLUSIONS

Herbage production of annual and perennial grasses, basal intercept of perennial grasses, and stocking rates have been measured since 1954 on four range units of the Santa Rita Experimental Range, primarily to determine the reaction to mesquite control. Mesquites were killed on two of the units between 1954 and 1957 by spraying diesel oil on the lower trunk of each tree.

The changes in vegetation measured during the 8-year period were caused by three main factors: year-to-year variation in precipitation, management practices, and mesquite control.

The native annual and perennial grasses on these range units are primarily summer growers, and thus depend for their growth primarily on summer rainfall. The correlation between June-September rainfall and perennial grass herbage production is significant, but explains only about 39 percent of the year-to-year variation in production. Annual grass production, on the other hand, is more closely correlated with rainfall: over half of

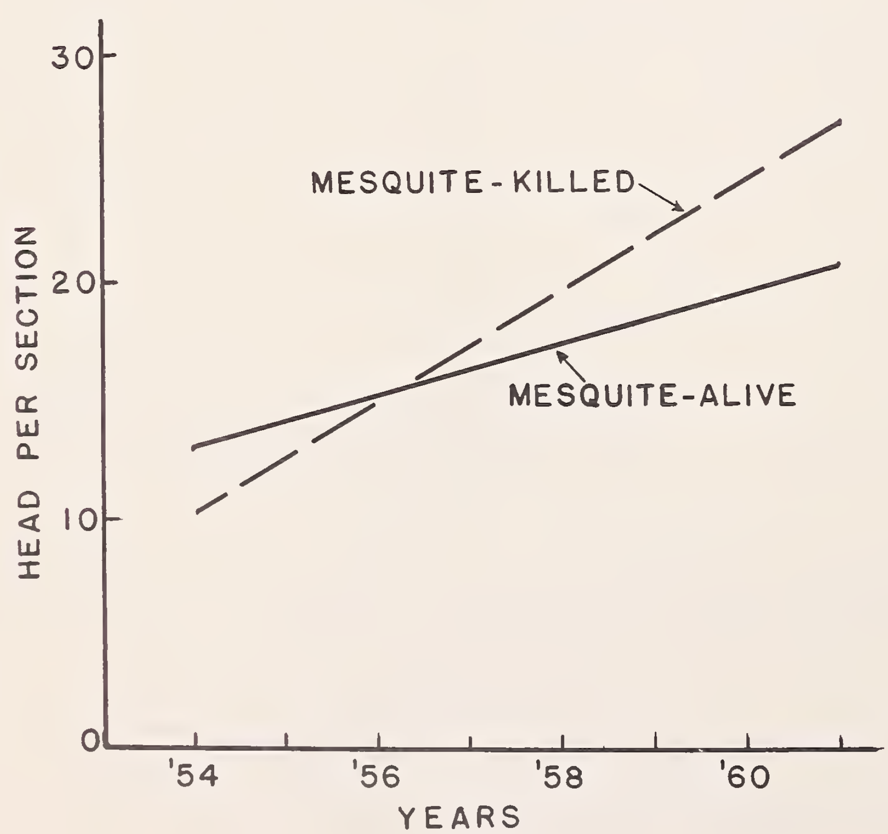

Figure 7.--Changes in stocking rates for 40 percent use, 1954-61.

the year-to-year variation in production is explained by variations in June-September rainfall.

Moderate utilization of the perennial grasses combined with alternate-summer deferment of grazing resulted in marked range improvement. On the average, production of perennial grasses increased by more than 4 pounds per acre per inch of summer rainfall per year, from about 19 pounds per acre per inch of summer rainfall in 1954 to about 45 pounds in 1961.

Perennial grass production on the mesquite-killed range units increased relative to the two untreated units between 1957 and 1961. The increase amounted to a net gain of 443 pounds per acre on the mesquite-killed units compared to 220 pounds per acre on the mesquite-alive units.

Annual grass production was more markedly affected by mesquite density than was perennial grass production. Annual grass production decreased nonlinearly from 20 pounds per acre per inch of summer rainfall with 0.25 percent mesquite crown intercept to 5 pounds with 7 percent crown intercept.

Calculations of stocking rates that would have given 40 percent use of perennial grasses for each unit and year show that the stocking rates on the two mesquite-killed units have increased an average of 169 percent between 1954 and 1961, compared to an increase of 62 percent on the two mesquite-alive units.

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