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Cow/Calf Production and Economic Returns from Yearlong Continuous, Deferred Rotation and Rotational Grazing Treatments

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Livestock production from grazing is an integrated measure of the quantity and quality of forage produced and consumed. Research was conducted over 6-yr to assess the effects of four yearlong grazing treatments on cow-calf production (382 cows *Bos taurus*) and economic returns under extensive rangeland conditions (4637 acres). Treatments were heavy (HC) and moderate (MC) stocked continuous (1-pasture; 1-herd), a moderate stocked 4-pasture, 3-herd deferred rotation (DR); and a very heavily stocked 16-pasture, 1-herd rotation (RG). Averaged across years, stocking rates were approximately 12, 16, 15, and 10 acres/cow-year for the HC, MC, DR, and RG treatments, respectively. From 1982 through 1987, conception rates averaged 89, 93, 95, and 89%; weaned calf crops averaged 80, 83, 86, and 80%; weaning weights averaged 579, 574, 593, and 550 lb; production/cow averaged 466, 467, 508, and 439 lb; production per acre averaged 40, 31, 35, and 45 lb; and residual returns to land, management and profit averaged $60.81, $69.57, $93.12, and $62.72/cow and $5.35, $4.46, $6.47, and $6.63/acre for the HC, MC, CR, and RG treatments, respectively. Results show that stocking rate was the major factor affecting differences among grazing treatments in cow/calf production and economic returns and that, as stocking rate was increased, production stability decreased.

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LIVESTOCK production from grazing is an integrated measure of the quantity and quality of forage (nutrients) consumed, which varies as a function of the quantity and quality of forage produced. Control of the intensity of defoliation is the basic principle of grazing management because it directly affects both ongoing and future levels of livestock production. Ongoing levels of production are affected because, as intensity of defoliation increases, livestock production generally increases up to some maximum before rapidly declining. However, future levels of livestock production are often depressed at high levels of grazing intensity because amount of residual plant tissue is less than that required to maximize post-defoliation forage production. It may be surmised, therefore, that the major challenge in grazing management is to balance these antagonistic relationships over time and space.

This is a particularly formidable challenge in arid and semi-arid grasslands that characteristically support a multitude of forage species because intensity of defoliation varies among individual plants as a result of selective grazing processes. Because the more palatable or productive plants or plant species are generally defoliated more intensively than the less palatable or productive plants, preferred species often decline in abundance. This decline results from a reduction in their ability to compete with less desirable plants for critical resources such as water and nutrients. A major objective of any grazing management strategy is to prevent a shift in species composition towards an assemblage of plants that is dominated by species of lower nutritional value.

There are basically four grazing tactics used to balance the antagonistic relationship between ongoing and future livestock production. These tactics center around the (i) temporal and (ii) spatial distribution of various (iii) kinds and (iv) numbers of livestock (Gammon, 1978; Kothmann, 1980; Wilson et al., 1984). The objective of this paper is to examine the relative impact of temporal and spatial distribution (grazing systems) and numbers of animals (stocking rate) on cow/calf production and economic returns in a southern mixed grass prairie.

MATERIALS AND METHODS

Study Area

Research was conducted at the Texas Experimental Ranch located on the eastern edge of the southern mixed-grass prairie region of North America. Climate is continental, semi-arid, and highly variable. Average (1960–1987) annual precipitation is 26.8 in. with peak rainfall occurring in May and September (Fig. 1). Average maximum daily temperatures range from 52 °F in January to 96 °F in July. Average minimum daily temperatures range from 28 °F in January to 72 °F in July. Soils range from deep, well-drained clays and clay loams on the nearly level uplands (< 1% slope), rolling uplands (1–3%), and broad valleys (< 1%) to shallow stony clay and clay loams on the steeper slopes (> 5%). Dominant range sites are clay loam, clay slopes, clayey upland, loamy bottomland, and rocky hills (Soil Conservation Service, 1984). Elevation ranges from 1338 to 1519 ft.

Vegetation is a mixture of mid- and shortgrasses under an overstory of variably light to moderate stands of honey mesquite (*Prosopis glandulosa* var. *glandulosa* Torr.). Dominant midgrasses are sideoats grama [*Bouteloua curtipendula* (Michx.) Torr.], a warm-season perennial; Texas wintergrass (*Stipa leucotricha* Trin. and Rupr.), a cool-season perennial; and Japanese brome (*Bromus japonicas* Thunb.), a cool-season annual. Dominant shortgrasses are buffalograss [*Buchloe dactyloides* (Nutt.) Engelm.] and common curlymesquite [*Hilaria berlangeri* (Steud.) Nash], both warm-season perennials. Texas broomweed [*Xanthocephalum texanum* (DC.) Shinners] is the dominant annual forb and western ragweed (*Ambrosia psilostachya* DC.) is the dominant perennial forb. For a more complete description of climate, soils, and vegetation at the ranch, see Heitschmidt et al. (1985).

Grazing Treatments and Livestock Management

Grazing treatments were: yearlong, continuous-stocked at heavy (HC) and moderate (MC) rates; 3-herd, 4-pasture deferred rotation (DR) stocked at a moderate rate; and 16-paddock, 1-herd rotation (RG) stocked at a very heavy rate. The HC, MC, and DR treatments were initiated in 1960 whereas the RG treatment was initiated in 1981. The HC and MC treatments consisted of two pastures and two herds each. Size of the HC and MC pastures averaged 568 and 637 acres, respectively. Normal herd sizes were 50 and 41 cows, respectively. The two herds within each of the yearlong continuous treatments were switched annually (October) between the two pastures within each treatment to minimize the potential effect of differences between pastures on herd performance. Pastures in the DR treatment averaged 270 acres with each of the three herds consisting of 25 cows. Herd rotation in the DR treatment sequentially provided each pasture a 16 wk rest following a 1-yr grazing period, thereby insuring each pasture was sequentially rested during three different 16-wk intervals every 4 yr (Merrill, 1954). The RG treatment consisted of a single herd of 125 cows that were rotated through 16 paddocks that ranged in size from 25 to 120 acres (1148 total acres). Grazing cycle (i.e., length of rest periods) in the RG treatment varied from 30 to 65 d depending upon vegetation growth rates and the physiological condition of the cows. During extended periods of rapid forage growth (spring), cows were rotated rapidly (30-d rest), while during winter dormancy they were rotated slowly (65-d rest).

Range site composition of pasture was similar across treatments (Heitschmidt et al., 1985). The dominant range site in all treatments was the clay-clay loam complex (i.e., clay loam, clayey upland, and clay slopes) averaging 66, 66, 81, and 73% of the total land area in the HC, MC, DR, and RG treatments, respectively.

Production year (weaning to weaning) stocking rates between 1981 and 1987 averaged about 12 and 16

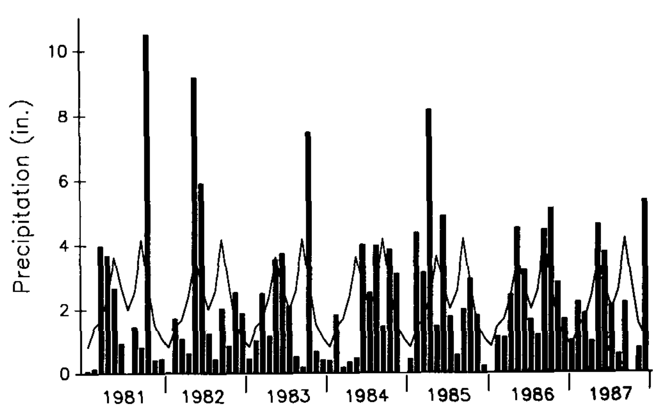

Fig. 1. Monthly precipitation (inches) from 1981 through 1987 at Texas Experimental Ranch. Continuous line depicts long-term (27-yr) monthly mean precipitation.

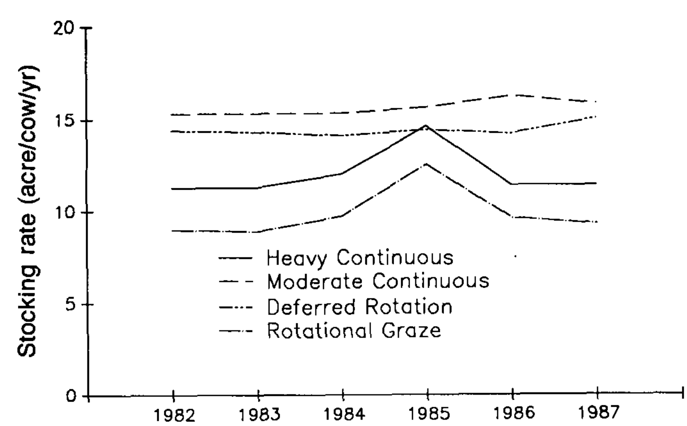

Fig. 2. Annual rates of stocking (acres/cow-year) from 1982 through 1987 for four yearlong grazing treatments.

Table 1. Mean cow and calf weights from 1982 through 1987 in four grazing treatments.

Treatment	Month									
	December†		April		June		August‡		October	
	Cow	Calf	Cow	Calf	Cow	Calf	Cow	Calf	Cow	Calf
	lb									
Heavy continuous	1089b*	--	922ab	227ab	1020a	373b	1045ab	514b	1020a	579b
Moderate continuous	1080b	--	892b	214b	991a	366b	1020b	503b	1009a	576b
Deferred rotation	1161a	--	984a	240a	1067a	390a	1093a	528a	1071a	593a
Rotational graze	1095b	--	924ab	215b	988a	350c	1021b	485c	995a	550c
Mean	1106	--	931	224	1017	370	1045	508	1024	574

* Treatment means in a column followed by same letter are not significantly different at $P < 0.05$.
† December 1981-1986. ‡ Does not include 1984 weight.

acres/cow-year in the HC and MC treatments, respectively, 15 acres/cow-year in the DR treatment, and 10 acres/cow-year in the RG treatment (Fig. 2). Minor variations among years were the result primarily of cow death losses and/or the occasional addition of experimental animals (esophageally fistulated steers) for short periods of time. Cows that died during a production year were replaced only at the end of each production year (October). In addition to minor variations among years, a major destocking in the heavily stocked treatments (HC and RG) was undertaken in June 1984 due to a prolonged drought (Fig. 1). These treatments were restocked to predrought levels at the beginning of the 1986 production year (October 1985).

Amount of winter supplement (20% crude protein range cube) fed varied among treatments and years. In accordance with previous research findings (Kothmann et al., 1970; Heitschmidt et al., 1982), cows in the two heavily stocked treatments (HC and RG) were fed every year whereas cows in the moderately stocked treatments (MC and DR) were fed only during periods of severe winter storms or during winters following summers of heavy Texas broomweed production. Averaged across years, amounts of supplement fed per cow per year were: 247 lb (range 148–410 lb) in the HC treatment, 251 lb (range 148–406 lb) in the RG treatment, 53 lb (range 0–192 lb) in the MC treatment, and 53 lb (range 0–163 lb) in the DR treatment. When fed on a regular basis, supplement was supplied three times per week.

Cattle used for performance evaluations were F-1 Hereford-Angus crossbred cows bred to fertility-tested Charolais bulls. The breeding season extended from 1 April to 30 June each year with a bull:cow ratio of approximately 1:20. Cows were weighed (unshrunk) five times per production year: December, prior to calving; April, when calves were worked; June, near the time of peak live herbage standing crop; August, during the usual summer drought period; and October, when calves were weaned. Conception rates were determined via rectal palpation in October. Calving season, during which all calf birth dates were recorded, extended from late December to early April. Calves were weighed (unshrunk) at the same time as cows from April through October.

Cows were culled at, or shortly after, weaning for: (i) health reasons (i.e., blindness, non-functional udders, and crippled), (ii) age (10–11 yr old), (iii) failure to breed, and (iv) after the second year, a bred cow failed to wean a calf. Data from replacement cows were not included in the data set until 1 yr after placement in a treatment. As a result of this restriction, the 1981 production data were not included in this study.

Data Summarization and Analyses

The data set consisted of annual herd means for: cow weights (5 weights/yr), calf weights (4 weights/yr), conception rates, and calf birth dates. All calf weights were adjusted for sex of calf by averaging the average weights of the heifers and steers. From these data, weaned calf crops, weight fluxes (absolute and relative), and production per cow and per acre were calculated. Percentage calf crop weaned was calculated by multiplying percentage cows bred by percentage calves weaned (e.g., 90% of calves weaned by 90% of cows bred = 81% calf crop). Absolute weight fluxes were calculated by subtraction (e.g., 1000 lb December weight minus 800 lb April weight = 200 lb weight flux). Relative weight fluxes were calculated by dividing absolute flux by beginning weight (e.g., 200 lb/1000 lb = 20% flux). Average daily gains of calves were adjusted for differences among years in number of days between weigh dates. Production per cow was calculated by multiplying calf weaning weight by percent calf crop (e.g., 500 lb average weaning weight with 81% calf crop = 405 lb/cow). Production per acre was calculated-by dividing production per cow by annual rate of stocking (e.g., 405 lb/cow at stocking rate of 10 acre/cow-year = 40.5 lb/acre).

Data were analyzed with general linear least squares analysis of variance and analysis of covariance models. The fixed variable models were applied as a repeated measures factorial design. Herds within treatment were the experimental units and main effects were grazing treatment and year. The error term for testing for treatment effects was herd within treatment (d.f. = 4). Year, year by treatment interaction, and covariant effects were tested using the residual mean square. Covariants used in the analyses were age of calf (calf weight analyses) and cow weights (conception rate analyses). Tukey Q values were used for mean separation where appropriate (Snedecor and Cochran, 1967). Unless otherwise stated, all tests of significance are at $P < 0.05$.

Table 2. Mean cow and calf live weights in four yearlong grazing treatments from 1982 through 1987.

Year	December† Cow	December† Calf	April Cow	April Calf	June Cow	June Calf	August Cow	August Calf	October Cow	October Calf
	lb									
1982	1104b*	--	883c	223b	987cd	377ab	1001c	515a	1003bc	591a
1983	1057d	--	883c	220b	1016b	401a	1018c	511a	972c	562a
1984	1076cd	--	876c	201c	980d	339c	--	--	1041ab	584a
1985	1118ab	--	994a	253a	1046a	378ab	1059ab	513a	1032ab	570a
1986	1137ab	--	959b	232b	1010bc	368bc	1047bc	508a	1039ab	582a
1987	1145a	--	987ab	224b	1061a	354bc	1098a	491a	1055a	555a
Mean	1106	--	931	224	1017	370	1045	508	1024	574

* Annual means in a column followed by same letter are not significantly different at $P < 0.05$. † December 1981-1986.

Economic Analyses

The four grazing strategies were analyzed for economic returns using annual values of the stocking rates, amounts of supplemental feed, and production levels reported for 1982 to 1987. For purposes of estimating operating costs and returns, each grazing strategy was analyzed as if it were a single enterprise being operated on 3000 acres of land. Prices and costs used were representative of those that prevailed from 1983 through 1986. Important items of cost were: supplemental feed $180/ton; vet, salt, misc., $8.66/cow (includes part for calf, bull, etc.); and marketing, $10/head. Costs for repairs, fuel, and labor were assumed equal across treatments. This assumption was made to expand the utility of these data across a wide range of situations. Estimated costs for a 3000 acre ranch/yr were $416.25 for fuel, $611.25 for equipment repairs, and $10 480 for labor. Annual fence repair costs were set at $5.20/mile for external line finces and $1.73/mile for internal electric fences. Total repair costs/year were $45 for the HC and MC strategies and $52.50 and $75 for the DR and RG systems, respectively. Product prices used were also representative of prices for 1983 through 1986 and included: $64.25/cwt for weaned steer calves, $60.75/cwt for heifer calves, and $36.50/cwt for 900 lb cull cows.

All four strategies were evaluated with average cow death losses of 2.6%/yr with 10.4% of cows culled each year and enough heifer calves retained each year to equal 13% of the cow herd. Bull:cow ratios for each system were 1:25 for all but the RG system which was 1:33. Cost of investment capital was assumed to be 10%/yr and investment required was $650/cow, $1250/bull and $500/replacement heifer. In addition, the HC and MC strategies were assumed to require $52 539 in fences and equipment while the DR and RG systems required $64 854 and $93 020 respectively. Standard enterprise budgeting techniques were used to produce estimates of annual net (residual) returns to land, management, and profit. A separate budget was developed for each strategy for each year, then average annual returns were determined for each treatment for the 6-yr.

Annual returns per cow and per acre were statistically analyzed using a 2-way (grazing treatment and year) analysis of variance model. Tukey Q values were used for mean separation.

RESULTS

Cow Weights

Across dates and years, cow weights averaged 1019, 998, 1075, and 1005 lb in the HC, MC, DR, and RG treatments, respectively. Cows in the DR treatment were consistently heavier than cows in other treatments on all dates (Table 1) although differences were not always statistically significant. Effect of weigh dates was similar in all treatments and followed expected weight flux patterns relative to seasonal fluctuations in herbage growth dynamics and physiological condition of the spring calving cows. Cows were heaviest in December prior to calving and lightest in April at the end of the calving season. Differences among years (Table 2) were the result, primarily, of differences in quantity or quality of forage produced as a result of varying precipitation patterns (Fig. 1). Within date analyses revealed a significant treatment × year interaction in April but not in December, June, August, or October. This interaction effect was the result of differences among years and treatments in stocking rates and amount of winter supplement fed.

Analyses of percentage change in cow weights between dates revealed one significant treatment effect (April–June) and two significant year effects (December–April and April–June) whereas analyses of actual change in weights between dates revealed no significant treatment effects and two significant year effects (December–April and April–June). The absence of significant treatment effects on cow weight change during the winter calving season and the presence of significant year effects indicated our winter supplemental feeding regimes, as varied among treatments and years, were appropriate for maintaining similar cow weight flux among treatments within years but not between years.

The biological significance of absolute and relative changes in cow weights during the breeding season (April–June) was difficult to interpret because weight flux, both relative and actual, was closely tied to beginning weight (April). For example, when absolute and relative changes in cow weights were ranked by treatment within years, there was only one instance (1982) when relative ranks based on percentage change in weights varied from relative ranks based on actual change. In this instance, weight of cows in the HC, MC, DR, and RG

Table 3. Mean cow conception rate, weaned calf crop, production/cow, and production/acre from 1982 through 1987 in four yearlong grazing treatments.

Treatment	Conception rate	Weaned calf crop	Production Per cow	Production Per acre
	%	%	lb	lb
Heavy continuous	89b*	80a	466ab	40b
Moderate continuous	93ab	83a	476ab	31d
Deferred rotation	95a	86a	508a	35c
Rotational graze	89b	80a	439b	45a
Mean	92	82	472	38

* Treatment means within a column followed by same letter are not significantly different at $P < 0.05$.

treatments increased 15.4% (133 lb), 10.1% (90 lb), 9.9% (93 lb), and 11.9% (101 lb), respectively, as compared to 6-yr averages of 10.8% (98 lb), 11.4% (99 lb), 8.7% (83 lb), 7.1% (65 lb), respectively. We believe the above-average gains in the two heavily stocked treatments in 1982 were related primarily to the combined effects of greater-than-normal forage availability, as a result of ample precipitation during May and June (Fig. 1) and above-average weight gain potentials as a result of cows being lighter than normal in April. Average cow weights in April (Table 1) over the 6-yr study were 922, 892, 984, and 924 in the HC, MC, DR, and RG treatments, respectively, as compared with 859, 889, 936, and 849, respectively, in 1982. The absence of significant treatment, year and treatment × year interaction effects during summer and fall indicated cow weight flux was similar across all treatments all years.

Calf Weights

Averaged across years, there was little difference among treatments in calf weights in April and major differences thereafter in that weights in June, August, and October were significantly greater in the DR treatment and significantly less in the RG treatment than in either the HC or MC treatments (Table 1). Averaged across treatments, calf weights varied significantly among years in April and June but not in August or October (Table 2). The year × treatment interaction effect was not significant on any date.

Average daily gains (ADG) of calves within a period also varied among treatments and years but no interactions were significant. From April to June, ADGs were significantly greater in the HC (2.35 lb/s), MC (2.42 lb/d), and DR (2.39 lb/d) treatments than in the RG (2.16 lb/d) treatment. There were no differences among treatments or years in ADGs from June to August (2.22 lb/d) or among treatments from August to October (1.20 lb/d).

These results, in combination with previous studies at the ranch, suggested there was a strong grazing treatment effect on calf weights and weight gains as a result of differences among treatments in amount of winter supplement fed and stocking rate. Previous work (Vantassell et al., 1987) at the ranch has examined the effects of various climatic variables, level of winter supplement, rate of stocking, and grazing system on calf weights. Using a series of regression analyses, weights in early spring

Table 4. Mean cow conception rate, weaned calf crop, production/cow, and production/acre in four yearlong grazing treatments from 1982 through 1987.

Treatment	Conception rate	Weaned calf crop	Production Per cow	Production Per acre
	%	%	lb	lb
1982	90bc*	84ab	497ab	41a
1983	93ab	83ab	466ab	38a
1984	84c	85ab	496ab	40ab
1985	97a	73a	415c	29c
1986	93ab	89b	515a	42a
1987	93ab	80ab	442bc	35b
Mean	92	82	472	38

* Annual means within a column followed by same letter are not significantly different at $P < 0.05$.

(April) were found to be negatively related to stocking rate and positively related to age of calf, precipitation during fall and winter, minimum temperatures during January and February, and level of winter supplement fed. Similar relationships were found for the June and October weights. Although birth dates did not vary significantly among treatments in the current study, weaning weights (October) did increase slightly in the HC (583 lb), MC (577 lb), and RG (551 lb) treatments when adjusted for age of calf at weaning, whereas they decreased slightly in the DR (588 lb) treatment.

Differences among years in precipitation patterns (Fig. 1) appeared to be the major factor affecting average weights across years (Table 2) as evidenced by the low weights in April and June of 1984 (spring drought). Examination of calf weights also indicated level of winter supplement tended to ameliorate the effects of stocking rate in that calf weights were generally greater in the HC than MC treatment although the difference was not significant.

Conception Rates

Averaged across years, conception rates in the DR treatment were significantly greater than those in the HC or RG treatments (Table 3). The MC treatment was intermediate and was not significantly different from any of the other treatments. Conception rates in the DR treatment were consistently greater than all other treatments in every year except 1987 when they were less than in the HC and MC treatments. In general, conception rates revealed a strong stocking rate effect in that they were greatest in the two moderately stocked treatments (MC and DR) and least in the heavily stocked treatments (HC and RG). Significant differences in conception rates did occur among years (Table 4), being least in 1984 (84%), a drought year, and greatest in 1985 (97%), a year with above average spring and early-summer precipitation (Fig. 1). There was no significant treatment × year interaction effect.

To assess the potential impact of cow weight on conception rates, analyses of covariance were used to analyze conception rates. Covariants were December, April, and June weights and percentage and actual weight changes from December to April and from April to June. Of the seven covariants, only actual and percent weight change during the calving season (December–April) were significant. These analyses showed that when conception rates were adjusted for weight change from December to April, conception rates in the HC, DR, and RG treatments decreased slightly (<1%), conception rate in the MC treatment increased slightly (2%), and differences between treatments were no longer significant. However, the presence of significant year and treatment × year interaction effects revealed that these covariates did not adequately account for all differences among treatments in conception rates.

Death Losses and Weaned Calf Crop

Neither cow nor calf death losses varied significantly among treatments or years. Across all years and treatments, cow death losses averaged 2.6% whereas calf death losses averaged 8.3%.

Weaned calf crop (Table 3) did not vary significantly among treatments, although it was greatest in the DR treatment and least in the RG treatment. It did, however, vary significantly among years (Table 4). The lowest calf crop weaned occurred in 1985 (73%), following the 1984 drought when conception rates averaged 84%, and the highest weaned calf crop occurred in 1986 (89%), following the 97% conception rate achieved in 1985. The treatment × year interaction effect was not significant.

Production per Cow

Production per cow was significantly greater in the DR than RG treatment (Table 3) with the HC and MC treatments intermediate and not significantly different from either the DR or RG treatments. Generally, production per cow followed a standard stocking rate response in that more pounds of calf were produced per cow in the moderately stocked (MC and DR) than in the heavily-stocked treatments (HC and RG). Averaged across treatments, production per cow varied significantly among years and ranged from 415 lb/cow in 1985 to 515 lb/cow in 1986 (Table 4). These data were directly related to variation among years in forage production and its effects on conception rates. The year × treatment interaction was not significant.

Production per Acre

Production per acre was significantly different among all treatments when averaged across years (Table 3). Production per acre also followed standard stocking rate response patterns wherein the heavily-stocked treatments (HC and RG) produced more pounds of calf per acre than the moderately-stocked treatments (MC and DR). Significant differences also occurred among years with the across treatments average being lowest in 1985 (29.5 lb/acre) and greatest in 1986 (41.6 lb/acre). These differ-

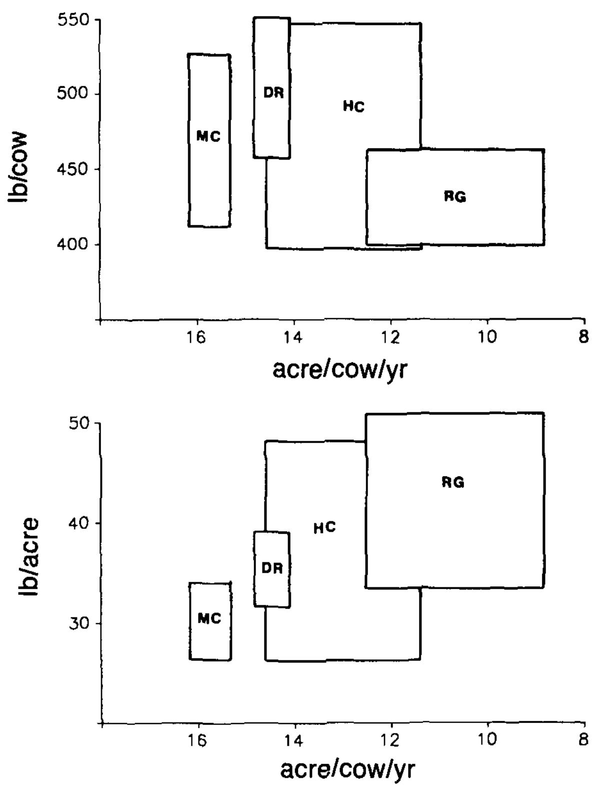

Fig. 3. Range in annual stocking rates and production per cow and per acre (lb) in the heavy continuous (HC), moderate continuous (MC), deferred rotation (DR), and rotational grazing (RG) treatments during the 6-yr study.

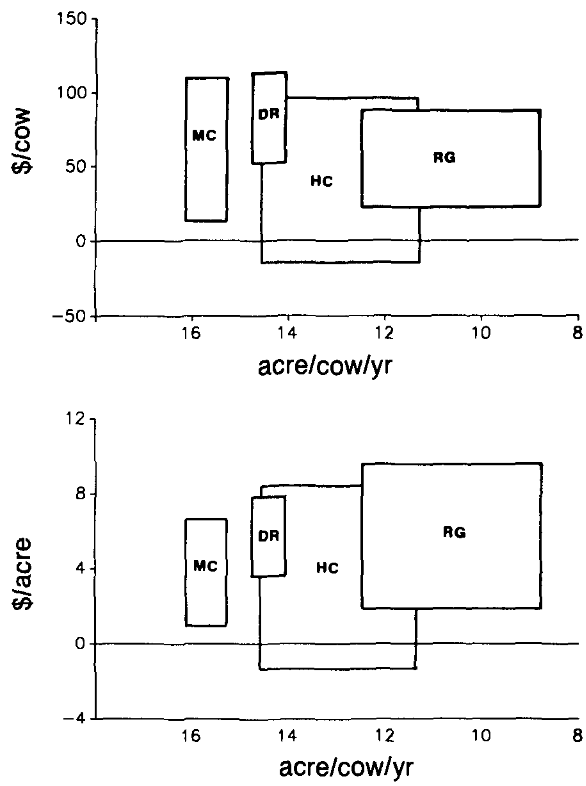

Fig. 4. Range in annual stocking rates and residual returns to land, management and profit in the heavy continuous (HC), moderate continuous (MC), deferred rotation (DR), and rotational grazing (RG) treatments during the 6-yr study.

ences were attributable primarily to the reduced stocking rates in the HC and RG treatment during 1985 (Fig. 1) and to differences in conception rates and weaning weights as affected by variation among years in forage production. The year × treatment interaction was not significant.

Economic Returns

Over the 6-yr study, average residual returns (i.e., net returns to land, management, and profit) per cow averaged \$60.81, \$69.57, \$93.12, and \$62.72/yr in the HC, MC, DR, and RG treatments, respectively. Net returns per acre averaged \$5.25, \$4.46, \$6.47, and \$6.63, respectively. Returns per cow were significantly greater in the DR than HC and RG treatments. There was no difference in returns per cow between the MC and the other three treatments. There were no differences between any treatments in the net returns per acre when averaged across years.

Net returns varied significantly among years in that returns in 1985 (\$17.46/cow and \$1.26/acre) were significantly less than all other years, which averaged \$82.37/cow and \$6.62/acre. All other contrasts among years were nonsignificant. However, as with the livestock production estimates (Fig. 3), there was considerable variation in returns among years and treatments (Fig. 4), thereby indicating that economic risk varied as a function of grazing treatment. For example, net returns ranged from \$−1.26/acre and \$−18.34/cow to \$8.43/acre and \$95.78/cow in the HC treatment while in the DR treatment the range was only from \$3.55/acre and \$50.95/cow to \$8.80/acre and \$124.07/cow. Thus, economic risk was least in the DR treatment and greatest in the HC treatment. This agrees with previous economic analyses (Whitson et al. 1982) of the HC, MC, and DR treatments from 1961 through 1978.

DISCUSSION

A major problem associated with the interpretation of production scale research findings is identification of associated factors affecting measured responses. This is particularly true in range livestock production studies because livestock production is an integrated product of a multitude of factors. The major causal factors, however, are quantity and quality of forage produced and consumed. Thus, any interpretive conclusions from the results of this study must be based first on the probable effects of the four treatments on these factors.

The major factors affecting quantity and quality of forage produced are the inherent potential productivity of an area (range site) and the kinds and numbers of plants present (range condition). Because range site composition was similar in all treatment, potential forage production was similar. Likewise, we believe actual forage production was similar across treatments because previous studies at the ranch have shown differences in forage production between fair (i.e., HC pastures) and good (i.e., MC, DR, and RG pastures) condition range are small, although differences in species composition are substantial. For example, Heitschmidt et al. (1985) reported annual forage production in the HC treatment (fair condition) averaged 2933 lb/acre on loamy bottomland sites, 2357 lb/acre on clay loam sites and 1652 lb/acre on rocky hill sites, as compared with estimates in the MC treatment (good condition) of 2777, 2625, and 2236 lb/acre, respectively. Assuming these estimates reflected the average effect of range condition (fair vs. good) on annual forage production, estimated production in the HC, MC, DR, and RG treatment pastures was about 2300, 2500, 2700, and 2600 lb/acre, respectively, after minor adjustment for differences among treatment pastures in range site composition.

As to forage quality, previous research in the RG and MC treatments (Heitschmidt et al., 1987) and the HC and MC treatments (Heitschmidt et al., 1989) has shown that average quality is greater generally in the heavily stocked HC and RG treatments than the moderately stocked MC treatment. These differences were attributed to differences among treatments in the live/dead mix of the available forage. Although there were no differences between the heavily and moderately stocked treatments in amount of green tissue (high quality), there were greater amounts of senesced tissue (low quality) in the MC than the HC and RG treatments.

Differences between treatments in quantity and quality (crude protein or organic matter digestibility) of forage consumed, were minor, according to recent diet quality studies in the RG and MC treatments (Walker et al., 1989), and in the HC and MC treatments (Pinchak et al., 1988). Results showed, however, that nutrient intake was periodically less in the RG (McKown, 1987) and HC (Pinchak et al., 1988) treatments than in the MC treatment during periods of summer drought or winter dormancy (Heitschmidt et al., 1987; 1989). As a result, occasional destocking was necessary in both heavily stocked treatments (Fig. 1), and increased levels of winter supplement were required to maintain acceptable levels of livestock production. Regardless of potential forage production (range condition) or type of grazing system, a forage reserve must be accumulated annually in most rangeland grazed yearlong to achieve a reasonable level of production stability, as has been demonstrated previously (Black et al., 1937; Sarvis, 1941; Lang et al., 1956; Launchbaugh, 1957; Reed and Peterson, 1961; Pieper et al., 1978; Gammon, 1978; Heitschmidt et al., 1982; Pitts and Bryant, 1987; Hart et al., 1988).

INTERPRETIVE SUMMARY

Livestock production from grazing is an integrated measure of the quantity and quality of forage produced and consumed. A major problem in extensively managed rangeland environments is that grazing intensity directly affects ongoing production as well as future levels of production. This study was designed to evaluate the effects of four grazing strategies on cow/calf production and economic returns. The four grazing treatments were yearlong continuous grazing (1-pasture, 1-herd) stocked at heavy (HC) and moderate (MC) rates, 4-pasture, 3-herd deferred rotation (DR) stocked at a moderate rate, and 16-pasture, 1-herd rotational grazing (RG) stocked at a very heavy rate.

The data from the study show that stocking rate was the major factor affecting livestock production and economic returns because, as stocking rate was increased, average production and residual returns per cow declined, whereas average production and residual returns per acre increased (Fig. 2 and 3). Moreover, the results show that annual production stability also tended to decrease as rate of stocking was increased except at the highest stocking rate (RG), whereby livestock production was continually depressed. Quite simply, the results show that in semiarid and arid rangelands grazed yearlong, it is not possible to continually stock at heavy rates without encountering increased financial risk because of the need to periodically destock or provide a substitute feed in the absence of sufficient amounts of forage.

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