Cattle, vegetation, and economic responses to grazing systems and grazing pressure

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Abstract

Manipulating stocking rate and duration of grazing is fundamental to range management. It has been claimed that rotation grazing systems will increase stocking capacity of range while maintaining or improving animal gains, range condition, and forage production. To test these claims, we compared continuous, 4-pasture rotationally deferred, and 8-paddock short-duration rotation grazing on mixed-grass range near Cheyenne, Wyo. from 1982 through 1987. Grazing pressures ranged from 19 to 81 steer-days per tonne of forage dry matter produced. Steers were weighed biweekly; forage production, utilization, and botanical composition were estimated by clipping; and basal cover was estimated by inclined point frame. Basal cover of litter and bare ground responded to stocking rate or grazing systems, but basal cover of vegetation was affected only by years. Steer average daily gain decreased as grazing pressure increased ($r^2 = 0.66$); systems had no significant effect. The most profitable stocking rate at 1986–87 costs and prices was approximately 60 to 80% above SCS recommendations, but the increase in return was small and range conditions and forage production probably could not be maintained at this rate.

Key Words: continuous grazing, rotationally deferred grazing, short-duration rotation grazing, Savory Grazing Method, range condition

Short-duration rotation grazing is a form of rotational grazing, in which the time grazing animals spend in each pasture and the time each pasture is rested vary with growth rate of the forage and the amount of forage in the pasture (Kothmann 1984). When grass is growing fast, animals spend fewer days in each pasture and rest intervals are shorter. Animals should be moved to another pasture before they graze new regrowth and before gains are seriously reduced by a shortage of forage. It has been claimed that short-duration rotation grazing, under the name of the Savory Grazing Method, will permit a doubling of the recommended stocking rate without a decrease in animal gain/ha, and at the same time will improve range condition and forage production (Savory 1983).

Pioneer research in the United States in the use of short-duration rotation grazing began in the South and Southwest (Pieper 1980, Dahl 1986, Heitschmidt 1986). Short-duration rotation research in the northern United States started more recently (Kirby et al. 1986, Lewis et al. 1982, Marlow and Whitman 1983, Malechek and Dwyer 1983, Reece 1986).

This paper describes and summarizes the results of the first 6 years, 1982–1987, of a planned 12-year grazing system and stocking rate study. This project was designed to quantify yearling steer performance and vegetation response to 3 grazing systems at a range of stocking rates, and to determine the optimum or most profitable stocking rate for all systems.

Study Area and Methods

Study Area

Experiments were initiated in 1982 on the High Plains Grasslands Research Station, approximately 7 km northwest of Cheyenne, Wyoming. Climate of the area is semiarid with a wide temperature range seasonally as well as daily. Average growing season is 127 days. Wind is predominantly from the west and down slope from the Laramie Range (Stevenson et al. 1984). Average (1871–1986) annual precipitation at Cheyenne is 338 mm, with maximum precipitation in May and early June and approximately 70% of the precipitation falling between 1 April and 30 September (NOAA 1987).

The area consists of rolling hills of mixed grass prairie at elevation of 1,910 to 1,950 m. Prevalent soils are Ascalon and Altvan loams (mixed, mesic, Aridic Argiustolls), Cascajo gravelly loam (a mixed, mesic, Aridic Calciorthid), and Larim Variant gravelly loam (a mixed, mesic, Ustollic Haplargid).

Dominant cool-season grasses are western wheatgrass [*Agropyron smithii* Rydb.] and needleandthread [*Stipa comata* Trin. and Rupr.]. Blue grama [*Bouteloua gracilis* (H.B.K.) Griffiths] is the dominant warm-season grass. Blue grama is an increaser and western wheatgrass and needleandthread are decreasers at this location. These grasses provide the majority of livestock forage (Samuel and Howard 1982).

The area has been grazed very lightly by various forms of livestock and wildlife in the past. A survey of plant composition in the summers of 1981, 1982, and 1983 indicated that the range sites of the area were in high good condition.

Grazing Management and Cattle Gains

The grazing systems compared in this study were:

(1) Season-long or continuous with no pasture subdivisions (C).

(2) Rotationally deferred with a different quarter of the area deferred each year until 1 September; then all 4 pastures were grazed the rest of the season (R).

(3) Short duration rotation with each of the 8 pasture subdivisions or paddocks grazed in rotation (S).

All systems were stocked with yearling steers at 2 stocking rates: moderate (M, 4 steers/12 ha) and heavy (H, 4 steers/9 ha) in 1982 through 1984. The moderate stocking rate (SR) was approximately the SCS recommended rate for the condition of the sites, 1.2 steer-months/ha; the heavy SR was approximately 33% higher (SCS 1986). In 1985 through 1987, each moderate or heavy pasture was stocked with 5 steers. Grazing seasons are given in Table 1. Steers were of Hereford-Angus-Simmental or Hereford-Angus-Charolais breeding. Initial weights were 298, 292, 245, 249, 295, and 219 kg in 1982 through 1987, respectively.

Each system by stocking rate combination had 2 replicates. The experimental design, therefore, was a randomized block design with 2 blocks. The blocking factor was topography (Fig. 1). The first block was on a steeper, predominately north slope (0–15%) while the second block was on a more nearly level (0–6%) southern exposure.

A lightly stocked continuous treatment was begun on an 81-ha pasture in 1982, but cattle weights from this treatment were not included in this analysis until 1983. The light stocking rate was approximately 1 steer/5 ha, about 35% below the SCS-recommended stocking rate. This unreplicated treatment was stocked such that forage supply would not limit steer gains.

In 1982 and 1983 the steers on short-duration rotation grazed

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Table 1. Grazing seasons, precipitation, forage production, and stocking rate, 1982–1985.

Grazing season	Precip., % of normal*	Forage prod., kg/ha	Steers/pasture Light	Steers/pasture Mod.	Steers/pasture Heavy	Steer-days/ha Light	Steer-days/ha Mod.	Steer-days/ha Heavy
24 June–19 Oct 1982	107	1180	—	4	4	—	28.5	51.4
16 June–27 Oct 1983	151	1670	16	4	4	25.5	43.7	58.3
12 June– 2 Oct 1984	131	1140	18	4	4	24.2	36.8	49.2
29 May –16 Oct 1985	94	1040	14	5	5	23.5	57.6	76.8
10 June– 8 Oct 1986	113	1140	15	5	5	21.5	50.0	66.7
3 June– 8 Oct 1987	138	870	14	5	5	21.3	52.9	70.6

*In 12 months (September–August) before forage clipping; based on 1871-1986 averages.

each paddock for 3 days at the beginning of the grazing season; length of grazing period was increased gradually to 7 days by the end of the season. In 1984 through 1987 each grazing period on each paddock was determined by growth rate and forage supply; grazing periods ranged from 2 to 11 days.

All steers were weighed on the first day of the grazing period and bi-weekly thereafter until the last day. The steers were shrunk for 15 to 16 hours (no water or feed) prior to weighing.

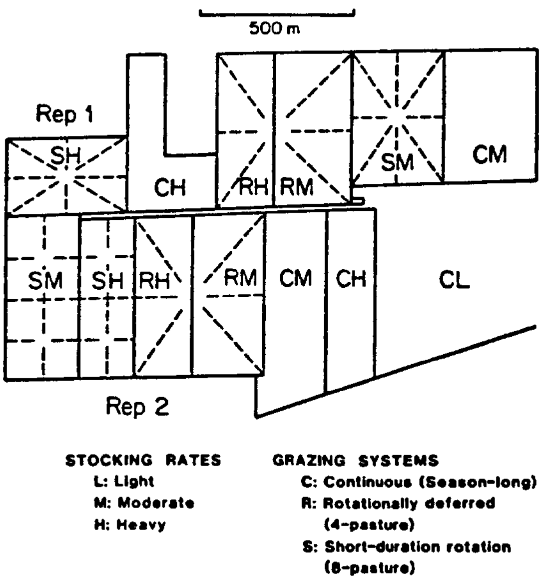

Fig. 1. *Map of grazing systems and stocking rates study, showing replications, treatments, and pasture design.*

Herbage Production, Botanical Composition, and Basal Cover

Peak standing crop of herbage in each pasture was estimated by total harvest of herbage from two 0.18-m² quadrats within each of four 1.5-m² permanent exclosures in 1982 and 1983. In 1984 through 1987, total forage on both quadrats was estimated by capacitance meter; then 1 quadrat was clipped and the data used to develop a regression equation to estimated standing crop on the unclipped quadrats. Correlation between standing crop and capacitance meter readings was acceptable: $r^2 = 0.63$ to 0.82, $n = 12$ to 24. Exclosures were stratified on loamy or gravelly loamy sites depending on the relative abundance of each site in a pasture. The exclosures were clipped in late summer when standing crop was near maximum. Herbage was hand clipped to ground level in each quadrat. The samples were oven dried at 60° C for 24 hours and then weighed to the nearest 0.001 g. From 1982 through 1985, the samples from each quadrat were divided into (1) western wheatgrass, (2) blue grama, (3) other graminoids which included mostly cool-season perennial grasses, sedges [*Carex* spp.], and annual grasses, and (4) forbs. Scarlet globemallow [*Sphaeralcea coccinea* (Pursh) Rydb.] was the major forb and fringed sagewort [*Artemisia frigida* Willd.] the major half-shrub. Most dead material was removed in the field by hand; remaining dead material in blue grama samples was removed in the laboratory after drying.

Utilization or herbage disappearance was estimated using the difference between peak standing crop inside the permanent exclosures and standing crop remaining near the exclosures after grazing was completed. In 1982 and 1983, two 0.18-m² quadrats were clipped outside each exclosure. In 1982 utilization was estimated only in the continuous and rotationally deferred pastures of 1 replication before a heavy snowfall stopped field work for the year. In 1984 through 1987, capacitance meter readings were taken in 5 quadrats outside each exclosure, and 1 of the 5 was clipped to calculate the regression of yield on meter reading. Utilization was equal to the difference expressed in percent of standing crop production in the exclosure.

Basal cover was estimated on 2 transects (1 on a slope and 1 on a nearly flat area) in each of the heavy use pastures. For comparison, 4 transects were established in the continuous light pasture: 2 on the north side of the ridge to correspond to block 1, and 2 on the south side to correspond to block 2. Data were collected in July of each year. A 50-m tape was stretched along the transect and basal cover was measured with a point frequency (Mueller-Dombois and Ellenberg 1974) frame with 10 pins approaching the ground at a 60-degree angle. The point frame was put down at each meter mark. Categories recorded were: bare ground, litter, and all plants by species.

Data Analysis

Vegetation data were analyzed using standard analysis of variance procedures, and means were separated with Tukey's HSD procedure. Response of ADG to grazing pressure (steer-days per tonne of forage dry matter produced) was evaluated by regression and optimum stocking rate estimated according to the model of Hart (1978). Differences between regressions were tested by methods outlined by Steel and Torrie (1980).

Results and Discussion

Vegetation

There were no significant differences in total herbage production, as measured by peak standing crop, among grazing systems or stocking rates in any year. Differences in production among years (Table 1) were largely a result of differences in amount and timing of precipitation (Hart and Samuel 1985).

No significant difference in utilization between moderate and heavy stocking rates was detected in 1982 or 1983 but the heavier rate tended to have greater utilization (Table 2). In 1984 through 1987 utilization was significantly greater on heavy than on moderate stocking rate. Utilization did not differ significantly among systems within stocking rates in any year.

No differences in botanical composition of peak standing crop were detected among grazing systems, stocking rates, or years. Average composition by dry weight was 52% blue grama, 16% western wheatgrass, 18% other graminoids, and 14% forbs and half-shrubs.

Table 2. Response of forage utilization to stocking rate, 1982–1985.

Year	Moderate	Heavy
	——% utilization——	
1982[1]	35	44
1983	44 a	48 a
1984	22 b	33 a
1985	24 b	37 a
1986	47 b	54 a
1987	45 b	52 a

[1]Only 1 replication of the continuous and rotationally deferred pastures, and none of the short-duration rotation, were clipped before a heavy snowfall halted field operations for the year.
a,b Utilization figures in the same year, followed by the same letter, are not significantly different, 5% level.

Litter cover increased from 1983 to 1987 on all treatments (Fig. 2), but litter increased more under CL and by 1987 was higher than on all systems under heavy stocking. The amount of bare ground was the same on all treatments at the start of the study in 1982. Since then, bare ground has decreased on CL. By 1987 there was significantly less bare ground on CL than on CH, but the amount of bare ground on RH and SH was not significantly different from that on CL or CH.

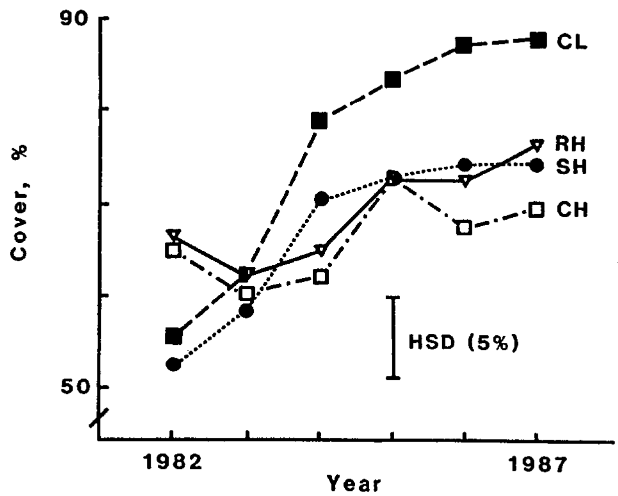

Fig. 2. *Response of litter cover to grazing systems and stocking rates, 1982–1987 (CL = continuous grazing, light stocking; CH = continuous grazing, heavy stocking; RH = rotationally deferred grazing, heavy stocking; SH = short-duration rotation grazing, heavy stocking).*

Total cover of all vegetation and of blue grama decreased in 1983 and again in 1984 from a maximum in 1982, then remained unchanged from 1984 through 1987 (Fig. 3). The similar response of total vegetation and blue grama is expected because blue grama is the major species in the study area. Cover of total cool-season graminoids decreased in 1983 but has not changed significantly since. Cover changes of other species and species groups from year to year were minor and inconsistent.

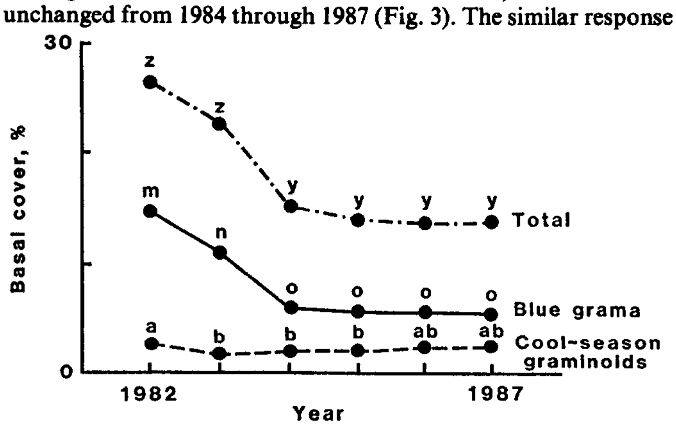

Fig. 3. *Annual changes in basal cover of all vegetation, blue grama, and cool-season graminoids (points on the same line labeled with the same letter are not significantly different, 5% level).*

Grazing systems and stocking rates did not significantly affect basal cover of blue grama, western wheatgrass, total cool-season graminoids, lichens, forbs and half-shrubs, or total vegetation. Dahl (1986) reported that differences in species composition occurred only because of yearly weather changes after 7 years of short-duration rotation grazing in west Texas. Reece (1986) suggested that changes in species composition caused by grazing management may not be seen for several years, and reported changes in cover of prairie sandreed [*Calamovilfa longifolia* (Hook.). Scribn.] only after 6 years of grazing in western Nebraska. Smoliak (1974) reported that blue grama basal cover increased but western wheatgrass basal cover decreased during 19 years of heavy sheep grazing.

Animal Gains

Differences in steer performance among systems at the same stocking rates occurred in 1982 and 1983 (Fig. 4). In 1982, steer average daily gain on SH was less than on RH.

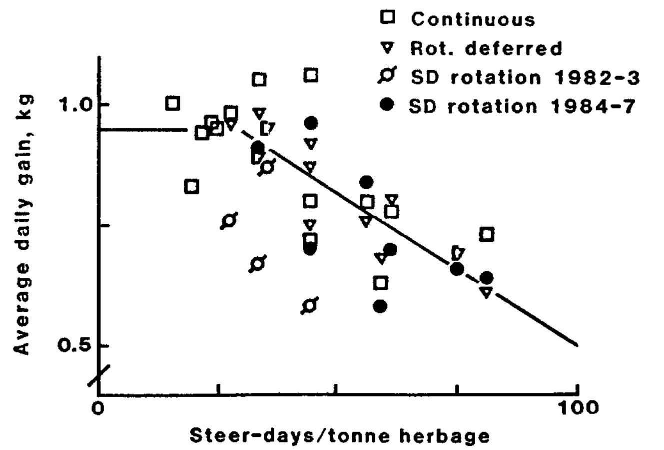

Fig. 4. *Response of average daily gain (ADG, kg) of steers to grazing pressure (GP, steer-days/tonne) under 3 grazing systems. 1982–1987. For GP less than 29.0, ADG = 0.95; for GP more than 29.0, ADG = 1.13 – 0.00625 GP; r^2 = 0.66 (data from SD rotation 1982–83 not used in calculating regression).*

In 1983, steers on SM gained less than steers on CM or RM. In 1982 no difference in steer gain occurred among systems at moderate stocking rates. In 1983 no difference occurred among the systems at heavy rates.

With a change in the rotation plan of the short-duration rotation systems in 1984 through 1987, all differences among systems at the same stocking rates disappeared (Fig. 4). The lower performance of the short-duration rotation steers in 1982 and 1983 was caused by rotation according to a fixed schedule, resulting in overgrazing of some paddocks and undergrazing of others, rather than according to forage supply and plant growth rate (Savory 1983). The length of grazing in short-duration systems must be short to minimize forced grazing which could limit intake and/or increase consumption of lower quality forage (Denny and Barnes 1977, Allison et al. 1978, Gammon and Roberts 1978, Heitschmidt 1986).

Average daily gain (ADG) of steers remained high and constant at low stocking rates, then declined at high stocking rates. Because forage production varied among years (Table 1), stocking rate was expressed as grazing pressure (GP) or steer days per tonne (1,000 kg or 1 metric tonne) of forage dry matter produced (Fig. 3). Gains remained constant at 0.95 kg per day until grazing pressure exceeded 29.0 steer days per tonne of forage; then gains declined according to the equation:

$$\text{ADG (kg)} = 1.13 - 0.00625 \text{ (Steer-days/tonne)} \quad (1)$$

($r^2 = 0.66$). In calculating the stocking rate response, gains under short-duration rotation grazing in 1982 and 1983 were omitted because rotation was by calendar rather than by forage supply and growth, and steer gains were depressed.

Curves describing response of ADG to grazing pressure (GP, steer-days/tonne) below the critical GP did not differ significantly among systems. Equations were:

Continuous	$ADG = 1.13 - 0.00598\ GP\ r^2 = 0.54$
Rotationally deferred	$ADG = 1.15 - 0.00656\ GP\ r^2 = 0.81$
Short-duration rotation	$ADG = 1.08 - 0.00586\ GP\ r^2 = 0.48$

If H = stocking rate in steer days/ha or/tonne, then average daily gain or

$$ADG = a - bH \quad (2)$$

in which b = the rate at which ADG decreases with increasing GP and a = theoretical ADG at infinitely low GP. Gain per ha per year, G, equals stocking rate times ADG or

$$G = aH - bH^2 \quad (3)$$

Maximum gain/ha, 59.5 kg, occurred at 105.5 steer-days/ha.

Other studies being conducted in the Northern Great Plains area seem to indicate similar gains per animal on short-duration rotation systems and on continuous or season-long grazing (Lewis et al. 1982, Kirby et al. 1986, and Marlow and Whitman 1983), although stocking rates were higher on short-duration rotation. When all stocking rates are below the critical stocking rate, stocking rates can be increased, gains per animal can be maintained, and gains per unit area increased. That is why it is essential to compare grazing systems at the same stocking rate, or to provide a range of stocking rate so the gain/stocking rate response can be fully defined.

Return to the Land, Labor, and Management

Gross return per ha per year, R_G, equals selling price, P, times gain per ha or

$$R_G = P(aH - bH^2). \quad (4)$$

If C = carrying cost per animal per day (including salt, implants, vaccinations, other supplement and veterinary costs, transportation, death loss, interest, and decline in value of the initial weight of the animal), then R or return per ha per year to land, labor and management is calculated by

$$R = PaH - PbH^2 - CH = (Pa - C)H - (Pb)H^2 \quad (5)$$

Maximum return per ha occurs when R no longer increases with an increase in H (stocking rate), or when

$$dR/dH = (Pa - C) - (2Pb)H = 0, \quad (6)$$

which is equivalent to

$$H = (Pa - C)/(2Pb) \quad (7)$$

In Equation 2, a = 1.13. The value of b in Equation 2, originally calculated on a per tonne basis, must be corrected for the expected forage production of the range. If we assume forage production of 1,170 kg/ha (the average during 1982 – 1987) then b = 0.00625 (1000/1170) = 0.00534.

Average selling price of feeder steers in October 1985 was \$1.37/kg (all cattle prices obtained from Cattle-Fax, Denver, Colo.). Carrying costs include the loss in value of the original weight of the steer; if a 250-kg steer was bought in the spring for \$1.59/kg, this amounts to \$55. Interest costs for 150 days at 12.25% (rate quoted by several Cheyenne banks) equals \$20.01. Salt, implants, vaccination, trucking, other veterinary and supplement cost, and death loss might amount to \$30 per steer (Jose et al. 1985). Total carrying costs or C for 150 days come to \$105.01 per steer or \$0.70 per steer per day. Plugging these values into Equation 7, we arrive at an optimum stocking rate of 57.7 steer-days/ha, equivalent to 2.60 ha/steer. Predicted ADG (from Equation 2) equals 0.82 kg and gain/ha (Equation 3) equals 47.2 kg. Using Equation 5, maximum net return to land, labor, and management (curve R1, Fig. 5) is calculated at \$24.34 per ha.

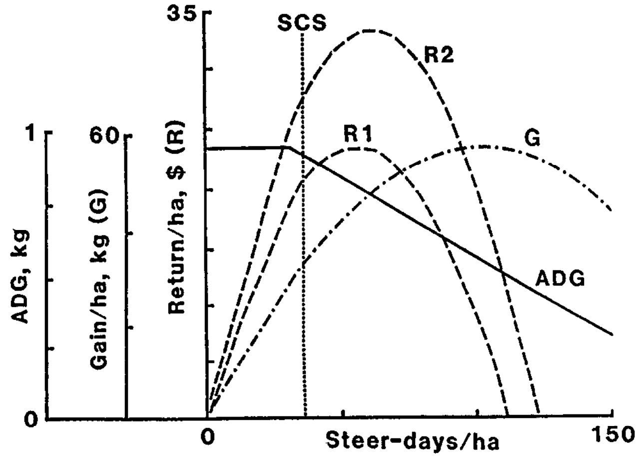

Fig. 5. *Response of average daily gain (ADG), gain/ha (G) and net return/ha to land, labor and management (R1 and R2) to stocking rate of steers [1,170 kg/ha forage dry matter produced, steers weighing 250 kg initially, 150-day grazing season; steers bought for \$1.59/kg and sold for \$1.37/kg, carrying costs \$0.70/steer/day (R1) or bought for \$1.71 and sold for \$1.59, carrying costs \$0.71 (R2); SCS = SCS-recommended stocking rate].*

The stocking rate recommended by the Soil Conservation Service, calculated from range sites and conditions of the study area and recommended stocking rates in the appropriate SCS Technicians Guide (SCS 1986), is 36.0 steer-days/ha. Net profit at 1986 prices and the SCS-recommended rate = \$20.90 per ha (Fig. 5). Increasing to the optimum stocking rate (a 60% increase) produced a 16% increase in net profit. Prices and costs in 1987 were more favorable than in 1986; feeder steers were bought for an average of \$1.71 and sold for \$1.59. The higher initial cost increased interest to \$21.52 for 150 days and carrying costs to \$0.71 per day. Optimum stocking rate increased to 63.7 steer-days/ha (77% above SCS recommendations) or 2.35 ha/steer, and return increased to \$34.47/ha vs. \$27.95/ha at the SCS-recommended stocking rate, (curve R2, Fig. 5) an increase of 23%. Optimum stocking rates at 1986 and 1987 prices were 55% and 60%, respectively, of the stocking rate that produced maximum gain/ha.

Stocking rates recommended by SCS might be increased profitably, at least in the short term; but this is possible with all systems, not just with short-duration systems. When stocking rate is increased, potential short-term increases in livestock gain must be weighed against potential long-term decreases in range condition and productivity (Torell and Hart 1988). No evidence of changes in forage production or range condition because of stocking rate or system has been seen in 6 years of this study. However, changes in litter and bare ground have occurred which may precede future changes in production and range condition. Longer-term data can be found in studies by Klipple and Costello (1960) on buffalograss-blue grama range for 15 years; Sims et al. (1976) on blue grama-prairie sandreed range for 9 years; and Launchbaugh (1967) on buffalograss-blue grama-western wheatgrass range for 10 years. Forage production at the end of each study, expressed as a percent of forage production at the beginning, declined with increasing stocking rate in all 3 cases (Fig. 5). Range condition remained the same or increased under light and moderate stocking and remained the same or declined under heavy stocking.

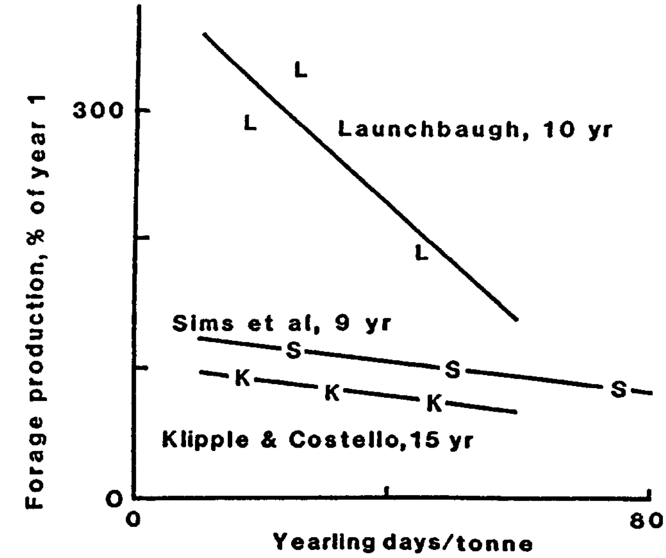

Fig. 6. *Changes in range forage production after indicated number of years at indicated stocking rates (Klipple and Costello 1960, Launchbaugh 1967, and Sims et al. 1976).*

Conclusions

The 3 grazing systems did not affect steer gains differentially when compared at the same stocking rates under proper management. In 1982 and 1983 the steers on the short-duration rotation were improperly managed. With improved rotation management based on forage supply and growth rate in 1984 through 1987, the steers on the short-duration rotation systems gained at the same rate as those on the other systems at the same grazing pressure. About 66% of the variation of ADG was accounted for by grazing pressure differences.

Soil Conservation Service stocking rate recommendations for the study area fell below the stocking rate which produced the greatest return/ha. At the level of forage production, costs, and prices encountered in this study and its analysis, a rancher could operate any grazing system at stocking rates well above SCS recommendations and increase short-term profitability. However, past research has shown that increasing stocking rates to such high levels may result in range deterioration, and the small increase in returns may not compensate for the risk of such deterioration.

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