Optimal stocking rate for cow-calf enterprises on native range and complementary improved pastures

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Abstract

Complementary pasture-native range systems are known to increase production per cow and per hectare of cow-calf enterprises, but the proper ratio of complementary pasture to range and the optimum stocking rate on each has not been established. From 1978–1985, crested wheatgrass [*Agropyron desertorum* (Fisch.) Schult.]-native range and meadow bromegrass (*Bromus biebersteinii* Roem. and Schult.)-alfalfa (*Medicago sativa* L.)-native range systems were grazed by cow-calf pairs and yearling heifers at a range of grazing pressures. Gains of all classes of cattle and conception rate of cows remained constant across a range of low grazing pressures, then declined linearly as grazing pressure increased. These response functions were used to calculate economically optimum pasture-to-range ratios and stocking rates at 1980–1984 average costs and prices. The optimum ratio of crested wheatgrass to range at estimated yields, costs and prices was 1:3.94 (0.66 ha of wheatgrass and 2.60 ha of range per animal unit), which returned $35.70/ha to land, labor, and management. Usual ratios of 1:8 to 1:12 were much less profitable. At optimum stocking rates, the brome-alfalfa-native range system returned only $3.38 more per hectare than the crested wheatgrass-native range system, not enough to pay additional cost of irrigation. Optimum ratios, stocking rates, and returns will vary with levels of forage production, production costs, and livestock prices.

Key Words: pasture systems, gains, reproduction, profitability, crested wheatgrass, alfalfa-bromegrass

Cow-calf herds grazing crested wheatgrass [*Agropyron desertorum* (Fisch.) Schult.] in spring and native range the remainder of the grazing season generally produce greater calf crops, weaning weights, and pounds of weaned beef per hectare (Houston and Urick 1972, Hart et al. 1983b) than herds grazing native range season-long. Similar results have been reported from cow-calf herds grazing other types of complementary pastures in conjunction with range (McIlvain and Shoop 1973, Sims 1984, Manske and Conlon 1986). Cattle gains and carrying capacity have been greater on crested wheatgrass-range systems than on range alone (Cook et al. 1983, Jefferies et al. 1967, Lodge 1970, Smoliak and Slen 1974).

Kearl (1984) and Cordingly and Kearl (1975) cited a number of studies showing increased forage production, calf crop, and calf weight gains, plus lengthened grazing season, reduced winter feed requirement, and development of special use pastures as benefits of seeding crested wheatgrass complementary pastures. They calculated that seeding 385 ha of a 5,844-ha ranch to crested wheatgrass would, within 5 years, increase net ranch income 26% and the return to capital 35%. Godfrey et al. (1979) used estimated rates of gain before and after seeding crested wheatgrass to estimate the economic returns from seeding. Spielman and Shane (1985) concluded it was profitable to seed crested wheatgrass pastures if meadow hayland and range forage resources were not limiting on the ranch in question.

These studies did not consider the functional relationships among stocking rate, livestock performance, and profitability; data on these relationships are seldom available. The grazing studies compared range and range-complementary pasture systems at a single stocking rate on each. Often the stocking rates were different for the 2 systems, and were less than those required to maximize profits. Because stocking rate has an over-riding impact on profitability of grazing systems (Quigley et al. 1984, Hart et al. 1988), comparisons of systems are valid only at the optimum stocking rate or grazing pressure (GP) on each. Determining this rate depends upon reliable estimates of biological responses.

We concluded that the superiority of complementary pasture systems over native range alone had been adequately demonstrated, but that optimum management of each system, in terms of the area and stocking rate of each component, had not been defined. Our objective was to quantify these parameters for complementary pasture systems combining dryland crested wheatgrass or irrigated bromegrass-alfalfa pastures with native range, and to

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demonstrate how these parameters could be used for economic analysis.

Materials and Methods

The study site was on the High Plains Grasslands Research Station located 7 km northwest of Cheyenne, Wyo. Climate at the Station is semiarid continental. Mean January and July temperatures in Cheyenne are -3 and 20° C, respectively, and mean (1871-1986) annual precipitation is 338 mm, with 55% falling April-July (NOAA 1987). Average frost-free season is 127 days (Stevenson et al. 1984).

Pasture Management

Four crested wheatgrass pastures, established 30-40 years before the study began in 1978, were grazed. The 2 pastures grazed in 1978-1979 were on Nucla loam (fine-loam, mixed, mesic Aridic Haplustoll) and Ascalon loam, (fine loamy, mixed, mesic Aridic Argiustoll). The 2 pastures grazed 1980-1985 were on Wheatridge loam, a fine-loamy over sandy, mixed, mesic Aridic Argiustoll. Crested wheatgrass and smooth bromegrass (*Bromus inermis* L.) provided about 90 and 10% of the forage from the pastures grazed in 1978-1979, with only traces contributed by other species. Forage from the pastures grazed 1980-1985 was 98% crested wheatgrass with traces of several native grasses and forbs.

The irrigated 'Regar' bromegrass (*Bromus biebersteinii* Roem. and Schult.)-alfalfa (*Medicago sativa* L.) pastures were established in 1976 on Wheatridge loam. Brome and alfalfa were seeded in rows 20 cm apart at 6 and 7 kg/ha, respectively. Superphosphate was applied at 20 kg/ha of P before seeding and annually thereafter. Irrigation was by flooding as needed. During the years the pastures were grazed, forage composition averaged 28% alfalfa and 72% bromegrass.

The native range pastures were on mixed-grass prairie. Botanical composition averaged approximately 50% blue grama [*Bouteloua gracilis* (H.B.K.) Lag ex Griffiths], 17% western wheatgrass (*Agropyron smithii* Rydb.), 19% other graminoids (chiefly needle-andthread (*Stipa comata* Trin. and Rupr.) and needleleaf sedge (*Carex eleocharis* Bailey), and 14% forbs and half-shrubs [chiefly scarlet globemallow, *Sphaeralcea coccinea* (Pursh.) Rydb.; Drummond milkvetch, *Astragalus drummondi* Dougl.; and fringed sagewort, *Artemesia frigida* Willd.]. Topography is rolling hills at altitudes of 1,915 to 1,975 m. Soils are predominantly Altvan, Ascalon and Ascalon Variant loams (fine-loamy, mixed, mesic Aridic Argiustolls), with smaller areas of Albinas loam (fine-loamy, mixed, mesic Pachic Argiustoll), Cascajo gravelly loam (sandy-skeletal, mixed, mesic Aridic Calciorthid), and Larim Variant gravelly loam (loamy-skeletal, mixed, mesic Ustollic Haplargid).

The bromegrass-alfalfa pasture was grazed as a single unit in 1978. In 1979 it was subdivided into 2 pastures, each further divided into 2 paddocks and managed as a 2-pasture 1-herd system. Grazing and rest periods were 5 to 10 days, depending on forage supply and growth rate. Crested wheatgrass pastures were not subdivided but pastures used in 1978 and 1979 were different from those used in 1980 through 1985. The native range area originally consisted of 2 pastures. In 1982 a portion of the larger pasture which had been fenced off and excluded from the study in 1980 was brought into the experiment to provide a third and heavier stocking rate. In 1985 this area was again excluded, and the smaller of the 2 original pastures was subdivided into 4 units to provide a total of 5 stocking rates. Pasture sizes and stocking rate are presented in Table 1.

Table 1. Pasture size, forage production (standard error in parentheses) and stocking rate (SR).

	Bromegrass-alfalfa			Crested wheatgrass			Native range		
Year	Ha/ pasture	Forage, kg/ha	SR, AUD/ha	Ha/ pasture	Forage kg/ha	SR, AUD/ha	Ha/ pasture	Forage, kg/ha	SR, AUD/ha
1978	8.1	2740	90	7.6	2420	103	191.4	—	30
		(210)		10.3	(340)	76	283.3		20
1979	3.5	4270	106	7.6	1820	82	191.4	—	30
	4.6	(430)	81	10.3	(190)	60	283.3		20
1980	3.5	2200	136	11.3	1650	49	191.4	—	27
	4.6	(310)	103	14.6	(190)	38	248.9		21
1981	3.5	2720	180	11.3	980	42	191.4	—	25
	4.6	(430)	146	14.6	(160)	35	248.9		22
1982	3.5	2570	170	11.3	1030	50	34.4	1180	44
	4.6	(380)	97	14.6	(60)	23	191.4	(270)	32
							214.5		13
1983	*			*			34.4	1450	60
							191.4	(260)	40
							202.4		11
1984	*			*			34.4	1280	47
							191.4	(600)	30
							202.4		13
1985	*			*			24.3	950	50
							24.3	(260)	42
							24.3		37
							118.6		28
							202.4		26

*In 1983-1985, all cattle grazed together on 8.1 ha bromegrass-alfalfa and 25.9 ha of crested wheatgrass during the improved pasture grazing season.

Appendix Table 1. Program for calculating response of average daily gain to grazing pressure, with constant ADG below critical grazing pressure; sample data set; and sample response curve. Coded in Compaq[1] BASIC, Version 3.

```
10 DIM X(64), Y(64)
20 PRINT "REGRESSION OF ADG ON GRAZING PRESSURE"
30 INPUT "TITLE ",Q$
40 INPUT "MEASURE OF GRAZING PRESSURE (X) ",X$
50 INPUT "UNITS OF ADG ",Y$
60 INPUT "NO. OF DATA POINTS ",N
70 PRINT "INPUT X & Y, WITH X'S IN ORDER FROM SMALLEST
   TO LARGEST"
80 FOR I=1 TO N:PRINT "X"; I:INPUT X(I):PRINT "Y"; I:INPUT
   Y(I):NEXT I
90 FOR I=1 TO N:S1=S1+X(I):S2=S2+Y(I)
100 S3=S3+X(I)^2:S4=S4+Y(I)^2:S5=S5+(X(I)*Y(I)):NEXT I
110 S7=S4-(S2^2/N):B=(N*S5-S2*S1)/(N*S3-S1^2):A=(S2-B*S1)/N
120 R=(S5-((S1*S2)/N))^2/((S3-S1^2/N))*(S4-(S2^2/N)))
130 LPRINT Q$:LPRINT :LPRINT "ADG (";Y$;") = ";B;"(";X$;") +";A
140 LPRINT "R SQUARED =";R:LPRINT
150 FOR M=2 TO (N-1)
160 S1=0:S2=0:S3=0:S4=0:S5=0:S6=0:R2=0
170 FOR I=M TO N:S1=S1+X(I):S2=S2+Y(I)
180 S3=S3+X(I)^2:S4=S4+Y(I)^2:S5=S5+X(I)*Y(I):NEXT I
190 B1=((N-M+1)*S5-S2*S1)/(N-M+1)*S3-S1^2):A1=(S2-B1*S1)/
    (N-M+1)
200 FOR I=1 TO M-1:S6=S6+Y(I):NEXT I:S6=S6/(M-1):Z1=(S6-A1)/B1
210 FOR I=1 TO N:IF X(I)>Z1 GOTO 230
220 R1=(S6-Y(I))^2:GOTO 240
230 R1=(Y(I)-(B1*X(I)+A1))^2
240 R2=R2+R1:NEXT I:R2=(S7-R2)/S7
250 IF R2<R GOTO 270
260 R=R2:A=A1:B=B1:Z=Z1:S8=S6
270 NEXT M
280 IF Z=0 GOTO 340
290 LPRINT "IF GRAZING PRESSURE IS LESS THAN";(INT(Z*100))/
    100;X$;" THEN"
300 LPRINT" ADG (";Y$;") =";S8
310 LPRINT "IF GRAZING PRESSURE IS MORE THAN";(INT(Z*100))
    /100;X$;" THEN"
320 LPRINT " ADG (";Y$;") = ";B"(";X$;") +";A
330 LPRINT "R SQUARED = ";R
340 END
```

Grazing pressure AUD/t DM	ADG, kg	Test
11	0.98	ADG (kg) = -8.409248E-03 (AUD/
28	0.97	tonne DM) + 1.192086
32	1.01	R SQUARED = .9342105
45	0.86	
62	0.69	IF GRAZING PRESSURE IS LESS
89	0.48	THAN 33.22 AUD/tonne DM THEN
101	0.26	ADG (kg) = .9866667
		IF GRAZING PRESSURE IS MORE THAN 33.22 AUD/tonne DM THEN
		ADG (kg) = -1.009543E-02 (AUD/ tonne DM) + 1.322086
		R SQUARED = .9880446

Herbage dry matter yields and utilization were estimated by clipping inside and outside exclosures. In 1978-1982, 5 exclosures were located at random on each crested wheatgrass pasture. Two 0.18-m^2 quadrats were clipped inside and 2 outside each exclosure at the end of grazing each year. In the same years, 6 exclosures were located on each brome-alfalfa pasture, 3 in each half of each pasture. Two quadrats inside and 2 outside each exclosure were clipped whenever cattle were removed from that half of the pasture; if cattle were to be rotated back to that half later, the exclosures were moved a few meters to another location.

On the native range pastures, production was not estimated until 1982. Four, 9, and 7 exclosures were placed on the small, intermediate, and large pasture in 1982–1984. In 1985, 3, 6, and 7 exclosures were placed on each 24.3-ha, the 118.6-ha, and the 202.4-ha pasture, respectively. Locations of exclosures were stratified by soil type each year. Herbage production inside the exclosures was measured in August at the approximate time of peak standing crop. Standing crop outside the exclosures was clipped after the cattle were removed from the pastures in late fall when possible, although in some years snow prevented clipping outside some or all of the exclosures on the range pastures. Two 0.18-m^2 quadrats were clipped inside and outside each exclosure in 1982–1984; in 1985 one quadrat per exclosure was clipped after herbage standing crop was estimated on both quadrats with an electronic capacitance meter (Neal et al. 1976). Correlations (r^2) between clipped yields and meter estimates were 0.90 in August and 0.74 after grazing; n=18. Estimated herbage dry matter yields are shown in Table 1.

Cattle Management

All pastures were grazed with mixed herds of Hereford cows with calves, yearling heifers, bulls in breeding season, and in 1978–1981, esophageally fistulated steers (the latter were used in a diet study reported by Samuel and Howard 1982 and Hart et al. 1983a). In some years dry cows were included in the herds on the most lightly stocked pastures. Grazing on the improved pastures began between 13 and 23 May and ended between 13 June and 6 July when cattle were moved to range pastures. Cattle were removed from the range to winter pasture between 7 and 21 November, except in 1985 when snow forced removal on 9 October. Cattle were assigned randomly to improved pastures, then randomly reassigned to range pastures. Stocking rates on all pastures are shown in Table 1. Stocking rates and grazing pressures were calculated assuming each cow-calf pair, dry cow or bull was 1 animal-unit (AU) and each yearling heifer or steer was 0.75 AU.

Cattle were wintered together on a large pasture, partly native range and partly crested wheatgrass and smooth bromegrass. They were fed good quality grass-legume hay ad lib and 0.5 to 1.0 kg of concentrate daily to maintain gains of approximately 0.5 kg/day during the third trimester of pregnancy. In all years but 1984, estrus was synchronized with Lutalase[1] or similar products. The breeding season began between 26 May and 10 June and ended between 21 July and 14 August. Cows were artificially inseminated at the first estrus after synchronization; bulls were present for the entire breeding season. All cattle were weighed every 2 weeks, after an overnight shrink without feed or water. Pregnancy was determined by palpation in late summer or early fall each year.

Experimental Design and Data Analysis

The experiment was designed and analyzed as a non-replicated sampling study. Responses of weight gain and conception rate to grazing pressure (GP, animal-unit days per tonne of herbage dry matter produced) were fitted to the model of Hart (1978) by regression; see Appendix Table 1 for the program used. Replications are superfluous in regression analysis, although they provide additional data points. Validity of the model used is supported by the SMART model of forage growth, forage intake by cattle, and cattle gains (Hart 1986).

[1]Mention of a trademark or proprietary product does not constitute its approval by USDA to the exclusion of similar products.

Expressing the independent variable as grazing pressure rather than stocking rate eliminated effects of years on forage production, but effects of year-to-year variation in nutritional quality of cattle diets (Hart et al. 1983a) were necessarily confounded with those of grazing pressure. Variation in cow weight and condition at the beginning of the breeding and grazing seasons was minimized by maintaining a high plane of nutrition during each winter. Differences in potency and enthusiasm of bulls also may have contributed to variation.

Available land limited the number of grazing pressures which could be tested each year and the number of animals which could be carried at each grazing pressure; it would have been desirable but not practical to have greater numbers of both. For example, to estimate conception rate to the nearest 4% within each experimental pasture would require 25 cows per stocking rate. If all stocking rates were tested each year, a minimum of 4 stocking rates on each type of improved pasture would be needed, for a total of 200 cows. Our average stocking rates were 123 AUD/ha on brome-alfalfa and 48 AUD/ha on crested wheatgrass, and average length of grazing season on improved pastures was 32 days. Thus this ideal experiment would have required 26 ha of brome-alfalfa and 67 ha of crested wheatgrass. Average stocking rate and grazing season on range were 30 AUD/ha and 141 days; 940 ha of range would be needed to accomodate the 200 cows. And these areas do not include the requirements of 40 to 50 replacement heifers necessary to maintain the herd. Such an ideal experiment was impractical in terms of land, cattle, and money. However, we felt that estimates of production based on less precise data from a less-than-ideal experiment were preferable to estimates based on no data at all as a basis for economic analysis.

Economic Analysis

The functions defining the response of gain and conception rate to grazing pressure were used to calculate the most profitable stocking rate on a matrix of improved pasture-native range combinations. These calculations demanded certain assumptions about returns and costs.

Returns derive from the sale of calves and dry cows. Certain fixed costs, including but not limited to interest, veterinary and supplement costs, death losses, and transportation, are incurred to maintain an animal unit.

When cows lose weight and condition, estrus may be delayed and conception rate reduced (Dunn and Kaltenbach 1980, Herd and Sprott 1986). Thus a simplified objective might be to end the grazing season with cows at the same weight as at the start of the season. If cows have lost weight, additional feed must be provided to restore that lost weight; on the other hand, if they have gained weight, less winter feed will be needed and this weight gained can be considered a return.

Finally, a cost is incurred if a cow does not conceive. In the simplest case, this is the cost of buying a replacement heifer times 1.09 (in the study reported here, 109 bred yearling heifers were needed to produce as many live calves as 100 bred cows), minus the price received when the open cow is sold.

Results and Discussion

Liveweight Gains

Gains of lactating cows, yearling heifers, and calves declined linearly with increasing grazing pressure (GP) on irrigated bromegrass-alfalfa pastures (Fig. 1, Table 2). There was no indication that any of the grazing pressures imposed were below the critical grazing pressure (i.e., the grazing pressure heavy enough to reduce gains). On dryland crested wheatgrass pastures, on the other hand, critical grazing pressure was estimated as approximately 40 animal-unit days (AUD) per tonne (1 tonne = 1,000 kg) of forage dry matter produced (Fig. 1, Table 2). Below the critical grazing pressure, cow, heifer, and calf gains remained approximately constant at 1.27, 1.16, and 0.97 kg/day, respectively. Above the critical

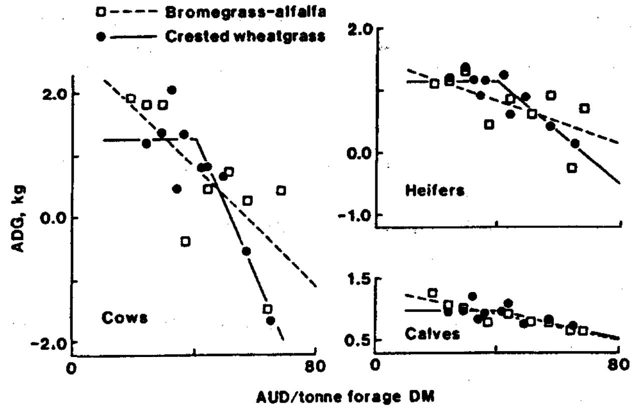

Fig. 1. *Grazing pressure and average daily gains (ADG) of lactating cows, yearling heifers and calves on irrigated bromegrass-alfalfa or dryland crested wheatgrass pastures, 1978–1982.*

grazing pressure, gains declined linearly with increasing grazing pressure as on brome-alfalfa, but the rate of decline was more rapid for all age classes. Thus gains were higher on crested wheatgrass at intermediate grazing pressure but higher on brome-alfalfa at high and low grazing pressures (in the case of calves, the difference between pasture types was extremely small).

Calf gains decreased very slowly with increasing grazing pressure, because milk provided most of their nutritional needs. Because of the nutritional demands on the cow for milk production, cow gains declined precipitously with increasing grazing pressure. Cows lost weight at the highest grazing pressures in this study, even though quality of crested wheatgrass and brome-alfalfa usually are assumed to be excellent.

On native range, critical grazing pressure and gains below critical grazing pressures of cows and heifers were much lower than on the improved pastures (Fig. 2, Table 2). Maximum gains of calves were nearly the same on range as on crested wheatgrass but lower on both than on brome-alfalfa. Again, cow gains declined sharply

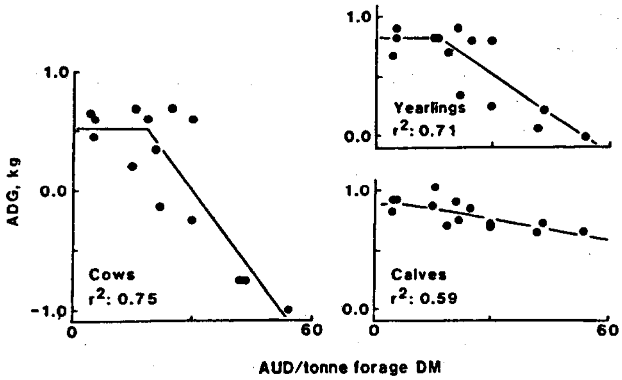

Fig. 2. *Grazing pressure and average daily gains ADG) of lactating cows, yearling heifers, and calves on native range, 1981–85.*

with increasing grazing pressure above the critical grazing pressure, and cows lost weight at the highest grazing pressures. Yearling heifers, which still had the potential for rapid growth, showed a higher rate of gain below the critical grazing pressure than did cows, and heifer gains declined more slowly with increasing grazing pressure, as they did on improved pastures.

Conception Rates

Data on conception rate do not include first-calf heifers, which

Table 2. Relationship of average daily gains (ADG) of lactating cows, yearling heifers, and calves, and conception rate (C) of cows, to grazing pressure (GP, animal-unit-days/tonne of herbage dry matter produced) on irrigated bromegrass-alfalfa, dryland crested wheatgrass, and mixed-grass native range pastures.

Pasture, parameter and sample size (n)	Critical GP, AUD/t	Estimates of performance: Units	Below critical GP	Above critical GP	r^2
Bromegrass-alfalfa (n = 9)					
Cow ADG	——	kg	——	ADG = 2.69 – 0.0477 GP	0.52*
Heifer ADG	——	kg	——	ADG = 2.50 – 0.0170 GP	0.40+
Calf ADG	——	kg	——	ADG = 1.33 – 0.0104 GP	0.84*
Conception rate	41.1	%	100	C = 129 – 0.708 GP	0.86*
Crested wheatgrass (n = 10)					
Cow ADG	40.2	kg	1.27	ADG = 5.77 – 0.112 GP	0.84**
Heifer ADG	40.1	kg	1.16	ADG = 2.85 – 0.0421 GP	0.84**
Calf ADG	42.0	kg	0.97	ADG = 1.47 – 0.0119 GP	0.44*
Conception rate, 1979	28.1	%	100	C = 117 – 0.67 GP	0.83**
Conception rate, 1980	6.6	%	100	C = 104 – 0.67 GP	0.91**
Conception rate, 1981 & '82	47.0	%	100	C = 129 – 0.67 GP	0.96**
Conception rate, 1979, '81 & '82	41.0	%	100	C = 125 – 0.67 GP	0.81**
Native range (n = 14)					
Cow ADG	18.9	kg	0.52	ADG = 1.39 – 0.0459 GP	0.75**
Heifer ADG	15.6	kg	0.81	ADG = 1.16 – 0.0222 GP	0.71**
Calf ADG	9.3	kg	0.94	ADG = 1.00 – 0.00607 GP	0.59**

+, * and ** indicate regression is significant at the 10, 5 and 1% probability level, respectively.

were bred at the University of Wyoming, Laramie, in 1978–1979 to calve in January and February rather than in March and April with the older cows. In later years heifers were bred at the High Plains Grasslands Research Station, but numbers in all years were too small to provide reliable data on conception rate.

Cow breeding data from 1978 also were excluded from calculations of the response function because of reproductive problems in newly purchased cows. Only 17 of the 32 cows purchased in 1978 calved in 1979, while 28 of the 34 cows raised at High Plains Grasslands Research Station calved.

Timing and length of breeding season had no apparent effect on conception rate. The response of conception rate to grazing pressure followed the same model as did liveweight gain. On brome-alfalfa, conception rate was 100% below the critical grazing pressure of 41.1 AUD/tonne of herbage dry matter produced, then declined linearly with further increases in grazing pressure (Fig. 3, Table 2).

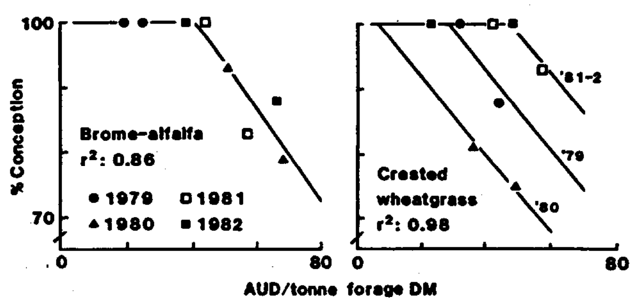

Fig. 3. *Grazing pressure and conception rates of cows on irrigated bromegrass-alfalfa or dryland crested wheatgrass spring pastures, 1979–1982.*

The response on crested wheatgrass was more complex. The rate of decline in conception rate with increasing grazing pressure seemed to be similar in all years, but the critical grazing pressure varied widely, from 6.6 AUD/tonne in 1980 to 47.0 AUD/tonne in 1981 and 1982.

Annual variation in the rate of maturity of crested wheatgrass, caused by variation in temperature and precipitation, may be responsible. In 1980 conception rates began to decline at a very low grazing pressure. June of 1980 was the driest June in 104 years of records. As a result, crested wheatgrass matured early with a resulting rapid decline in quality. Crude protein concentration of crested wheatgrass was 9.8% on 12 June 1980 vs. 12.5% on 11 June 1981 (Adams 1986). Brome-alfalfa, under irrigation, maintained higher crude protein levels in both years and showed less difference between years, 13.8% and 15.4% respectively. Because weather conditions during 1980 deviated substantially from normal, the mean response of conception rate to grazing pressure over 1979, 1981, and 1982 was used to calculate optimum stocking rate on crested wheatgrass.

Calculating the Most Profitable Stocking Rate

The most profitable stocking rate can be calculated by an expansion of the equations presented by Hart et al. (1988), but it is simpler to compute conception rate and cow and calf gains over a range of stocking rates and at the same time calculate values, costs, and net return per hectare. The information in Figure 4 was so

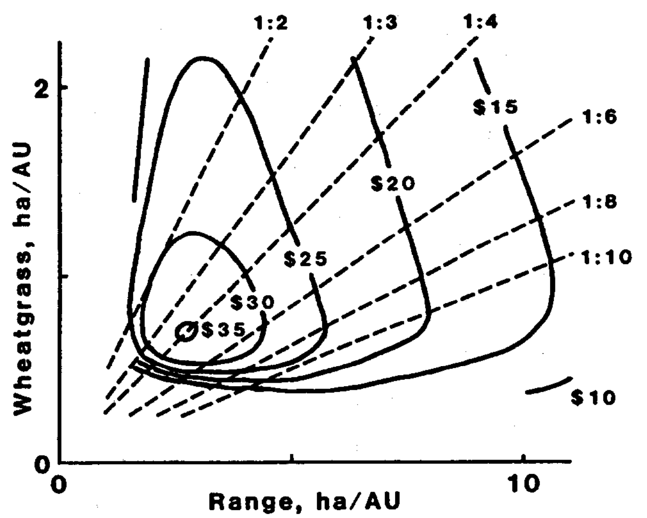

Fig. 4. *Contours of net return/ha to land, labor, and management (solid lines) from cows and calves grazing a crested wheatgrass-native range complementary pasture system; effects of ratio of wheatgrass to range (broken lines) and stocking rates.*

generated. Optimum stocking rate and ratio of crested wheatgrass to native range will depend upon range types, forage production, grazing season, production costs, and livestock prices. Level of management (Wilson et al. 1987) and marketing strategies (Ethridge et al. 1987) also influence returns. Finally, these calculations are based on short-term studies and do not consider possible long-term effects of stocking rate (Torell and Hart 1988).

A 42-day grazing season from 1 June to 12 July was assumed on the improved pasture, with forage production of 2,500 and 1,600 kg/ha of dry matter on brome-alfalfa and crested wheatgrass, respectively, during the time. Cattle would graze native range for 112 days from 13 July to 1 November. Calves would be weaned 20 September so would be on range only 70 days. Forage production on range was set at 1,200 kg/ha.

Livestock prices of \$1.50 per kg for weaned calves, \$438 for a 500-kg dry cow in September, and \$478 for a pregnant 360-kg heifer at the same date were taken from the 1980–84 averages given in Kearl (1985). Thus the total cost of replacing an open cow is \$40 times 1.09 or \$43.60. Herd and Sprott (1985) indicate 4.1 kg of shelled corn or its energy equivalent are required for 1 kg of gain by a mature cow. The average price of corn was \$0.105/kg in 1980–84 (USDA 1984); 1 kg of cow gain was valued at 4.1 times \$0.105 or \$0.43. Daily fixed costs per AU were estimated at \$0.30 from data in Jose et al. (1985) and Kearl (1984); these include interest costs of \$0.25 per day.

On improved pastures, conception rate remained at 100% until stocking rate increased beyond the point of maximum net return (Fig. 3). A conception rate of 100% did not mean a 100% weaned calf crop. We found that 95% of the cows and 84% of the heifers which tested pregnant in late summer produced live calves the following spring. Of those producing live calves, 95% of the cows and 98% of the heifers weaned those calves. Thus 90% of the pregnant cows and 82% of the pregnant heifers weaned calves the following year or, as stated in Material and Methods, 109 bred heifers are needed to produce as many calves as 100 bred cows.

Loss of weight by cows limited the stocking rates which could be sustained. At stocking rates in the permissible range of cow gains or losses, conception rate remained at 100%. Calf weaning weights, assuming a calf weight of 100 kg at the start of grazing on 1 June, varied only from 188 to 170 kg over all stocking rates and crested wheatgrass/range ratios simulated, reflecting the relative insensitivity of calf gains to stocking rate.

The optimum combination of 0.66 ha of crested wheatgrass and 2.60 ha of range per animal unit, equal to 1 ha of crested wheatgrass per 3.94 ha of range, returned \$35.70/ha to land, labor, and management (Fig. 4). This is a much higher ratio of crested wheatgrass to range than is usually used or recommended. Cordingly and Kearl (1975) based their calculations for "a typical northern plains ranch" (range type and productivity unspecified) on 1 ha of crested wheatgrass per 12.1 ha of range. Houston and Urick (1972) used 1 ha of crested wheatgrass-alfalfa per 8.6 ha of range in Montana; botanical composition was similar to our range, but average production was only 740 kg/ha. Hart et al. (1983b) used 1 ha of crested wheatgrass per 11.3 ha of the same range used in this study; average forage production was 1,020 kg/ha. Our calculations indicate production at such a wide ratio of crested wheatgrass to range would be greater than that on optimally stocked native range alone but less than that from the optimum ratio and stocking rate on a crested wheatgrass-range system. For example, maximum return at a 1:10 ratio of crested wheatgrass to range was calculated as \$23.67/ha, on 0.53 ha of crested wheatgrass and 5.3 ha of range per AU (Fig. 4). This return is 20% higher than the \$19.77/ha return calculated for optimally stocked range alone (at 4.53 ha/AU) but 33% less than the return of \$35.70/ha from the optimum stocking rate (3.26 ha/AU) and optimum ratio of crested wheatgrass to range (1:3.94).

Two factors may account for the large increase in net return formerly predicted from a ratio of crested wheatgrass to range of 1:10. First, net returns from range alone were underestimated because the range was understocked. Houston and Urick (1972) provided 10.4 ha of range per AU and Hart et al. (1983b) provided 10 ha/AU, but our calculations predict maximum return at 4.53 ha/AU. Predicted net return at a stocking rate of 10 AU/ha for a 154-day grazing season was \$14.62/ha. The combination of 0.53 ha of crested wheatgrass and 5.3 ha of range per AU (A 1:10 ratio) should return \$23.67/ha or 62% more. This is in line with previously cited estimates of increased returns which can be expected from seeding 1 ha of crested wheatgrass complementary pasture per 8 to 12 ha of range.

Secondly, other analyses may have over-estimated the cost of an open cow, considering each open cow equivalent to loss of income from 1 calf. But if open cows are detected at the end of the grazing season, they can be sold for almost enough to cover the cost of replacements. Figures cited earlier (Kearl 1985) indicated each open cow can be replaced at a net cost of \$43.60. Thus the 9% reduction in conception considered by Cordingly and Kearl (1975) would cost only \$0.87/ha at the optimum stocking rate of 4.53 ha/AU on range.

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