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Long-Term Production and Profitability From Grazing Cattle in the Northern Mixed Grass Prairie

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Abstract

Conventional wisdom among rangeland professionals has been that for long-term sustainability of grazing livestock operations, rangeland should be kept in high good to low excellent range condition. Our objective was to analyze production parameters, costs, returns, and profit using data generated over a 34-yr period (1969–2002) from grazing a Clayey range site in the mixed-grass prairie of western South Dakota with variable stocking rates to maintain pastures in low–fair, good, and excellent range condition classes. Cattle weights were measured at turnout and at the end of the grazing season. Gross income $\cdot$ ha^{-1} was the product of gain $\cdot$ ha^{-1} and price. Prices were based on historical National Agricultural Statistics Services feeder cattle prices. Annual variable costs were estimated using a yearling cattle budget developed by South Dakota State University agricultural economists. All economic values were adjusted to a constant dollar using the Bureau of Labor Statistics' Consumer Price Index. Stocking rate, average daily gain, total gain, net profit, gross revenue, and annual costs $\cdot$ ha^{-1} varied among range condition classes. Net income for low–fair range condition (\$27.61 $\cdot$ ha^{-1}) and good range condition (\$29.43 $\cdot$ ha^{-1}) were not different, but both were greater than excellent range condition (\$23.01 $\cdot$ ha^{-1}). Over the life of the study, real profit (adjusted for inflation) steadily increased for the low–fair and good treatments, whereas it remained level for the excellent treatment. Neither drought nor wet springs impacted profit differently for the three treatments. These results support generally observed rancher behavior regarding range condition: to maintain their rangeland in lower range condition than would be recommended by rangeland professionals. Ecosystem goods and services of increasing interest to society and associated with high range condition, such as floristic diversity, hydrologic function, and some species of wildlife, come at an opportunity cost to the rancher.

Resumen

La experiencia de los profesionales en manejo de pastizales ha mantenido desde hace mucho tiempo la sostenibilidad de de los ranchos con pastoreo de ganado, en los cuales el mantener los agostaderos en condición buena o excelente ha sido una de las prioridades. El objetivo de este estudio fue analizar los parámetros de producción, costos, retornos, y rentabilidad utilizando 34 años de datos (1969–2002) de pastoreo de un sitio de pastizal con suelos arcillosos en la pradera mixta del oeste de South Dakota con una carga animal variable para mantener los potreros en condición regular-pobre, buena, y excelente. El ganado se peso al inicio y final de cada temporada de pastoreo. Los ingresos brutos $\cdot$ ha^{-1} se calcularon multiplicando la ganancia de peso $\cdot$ ha^{-1} por el precio. Los precios utilizados se tomaron de los archivos del National Agricultural Statistics Services para la alimentación de bovinos de carne. Los costos variables por año se estimaron utilizando el programa de yearling cattle budget desarrollado por economistas agrícolas de la Universidad de South Dakota. Todos los valores económicos se actualizaron los datos del Bureau of Labor Statistics' Consumer Price Index. La carga animal, la ganancia diaria promedio, ganancia total, ganancia neta, ingresos brutos, y costos anuales $\cdot$ ha^{-1}, variaron entre las diferentes condiciones de pastizal. El ingreso neto para la condición pobre-regular (\$29.43 $\cdot$ ha^{-1}) y la condición buena no fueron diferentes, pero ambos fueron superiores a la condición excelente (\$23.01 $\cdot$ ha^{-1}). Durante el transcurso del estudio, la ganancia real (ajustada por inflación) incremento en forma constante para los tratamientos de condición pobre-regular y la condición buena, mientras que se mantuvo constante para la condición excelente. La sequía o abundancia de lluvias en la primavera no afectó la ganancia en ninguno de los tratamientos. Estos resultados justifican el comportamiento general de los ganaderos para mantener los agostaderos en condición pobre en contra de las recomendaciones de los profesionales en manejo de pastizales. El interés público por l os beneficios y servicios al ecosistema que se incrementan cada mas en la sociedad y asociados con una condición de pastizal alta tales como diversidad florística, función hidrológica, y cobertura para la fauna, representan un costo de oportunidad para los ganaderos.

Key Words: livestock grazing, profit, range condition, stocking rate, variable stocking

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INTRODUCTION

A powerful mental model persists in the field of range management. It is widely held that grazing livestock on rangeland in lower range condition classes is less productive from both a biological and an economic perspective when compared to rangeland in higher range condition classes. This is based on the observation that heavy grazing of rangeland leads to changes in species composition and a decline in range condition class (Dyksterhuis 1949; Tomanek and Albertson 1953), which negatively impacts forage production (Tomanek and Albertson 1953; Goebal and Cook 1960; Frost and Smith 1991), animal production, the ability of a ranch to generate wealth (Holechek et al. 2004), and the market value of the land itself (Workman 1995). In the northern mixedgrass prairie, long-term, season-long differential stocking shifts species composition from vegetation dominated by midgrasses, to codominate mid- and shortgrasses, and ultimately shortgrass dominant vegetation (Smart et al. 2007). Historically, mid-grass-dominated plant communities have been preferred over shortgrass plant communities by federal and state conservationists and rangeland professionals because of their forage production for livestock, habitat for wildlife, diversity of flora, hydrologic function, and resilience to drought. Conventional wisdom suggests that grazing livestock over long periods of time on lower condition rangeland is not biologically or economically sustainable. In spite of this, generally observed rancher behavior is to maintain rangelands and pasturelands in condition classes lower than recommended.

Plant communities in the North American Great Plains have a long evolutionary history of grazing (Milchunas et al. 1988) such that shortgrass-dominated plant communities are stable (Smart et al. 2007). A 55-year economic analysis of light, moderate, and heavy stocking rates on shortgrass prairie near Nunn, Colorado, using the STEERISK spreadsheet program developed by Hart (1991) showed a net return to land, labor, and management of \$5.05, \$7.37, and \$9.68 $\cdot$ ha^{-1}, respectively (Hart and Ashby 1998). Predictable changes in range condition occurred as heavy grazing caused an increase in shortgrasses and a decrease in mid-grasses. If livestock grazing on rangeland in lower condition can sustain high net income for greater than 50 yr, then grazing of low condition rangeland would be considered biologically and economically sustainable. Therefore, we hypothesize that net profit from grazing livestock on rangeland in lower range condition is just as (or more) profitable and sustainable over a long period of time as grazing livestock on higher range condition rangeland in the northern mixed-grass prairie. The objective of this study was to determine the long-term production and profitability of grazing yearling steers (*Bos tarus* L.) on rangeland in three range condition classes and the actual stocking rate required to maintain those condition classes in the northern mixed-grass prairie.

METHODS

Site Description

Data were collected (Table 1) at the South Dakota State University Range and Livestock Research Station near Cottonwood, South Dakota (lat 43°94′N, long 101°85′W). The station is in the Northern Great Plains mixed-grass prairie, approximately 120 km east of Rapid City, South Dakota. Topography is gently sloping with long, rolling hills and relatively flat-topped ridges. Climate is continental and semiarid with hot summers and cold winters. Long-term average annual precipitation from 1909 to 2004 is 407 mm, 77% of which falls from April to September. Mean daily temperature for the study area is 8°C with a high of 32°C in July and a low of −14°C in January (High Plains Regional Climate Center 2004). Soils of the experimental pastures are predominantly Kyle clay (very fine, montmorillonitic, mesic Aridic Haplusterts) and Pierre clay (fine, montmorillonitic, mesic Aridic Haplusterts) developed over the Pierre shale formation (US Department of Agriculture, Soil Conservation Service 1987). Predominant ecological site classification is Clayey. Vegetation is typical of mixed-grass prairie. Dominant species include the cool-season mid-grass, western wheatgrass (*Pascopyrum smithii* [Rydb.] A. Love) and warm-season shortgrasses, blue grama (*Bouteloua gracilis* [H.B.K.] Lag. Ex Griffiths), and buffalograss (*Buchloe dactyloides* [Nutt.] Engelm.; Stubbendieck et al. 1992).

Treatments

In 1968 six pastures were rested from grazing and fence boundaries were adjusted to uniformly allocate topographic characteristics across three experimental treatments. These treatment units were pastures in low–fair, good, and excellent range condition class with two replicates per treatment. From 1969 to 2002 pastures were variably stocked with yearling steers to maintain their three original range condition classes. Stocking rates were reduced during the droughts of 1980, 1981 (which was a recovery year), 1989, and 2002.

Range and Livestock Production

Plant community composition in each replication was monitored annually to adjust stocking rate to maintain the pastures in their original range condition classes. Variable stocking rates were used in each replicate pasture to maintain 50% annual utilization. Cattle weights were measured and recorded at turnout and at the end of the grazing season. Average daily gain and gain $\cdot$ ha^{-1} were calculated.

Economic Calculations

Economic parameters determined were annual total gross income $\cdot$ ha^{-1}, annual total expenses $\cdot$ ha^{-1}, and annual net income $\cdot$ ha^{-1}. Gross income $\cdot$ ha^{-1} was calculated for each treatment by multiplying annual gain $\cdot$ ha^{-1} with the fall seasonal price of yearling cattle $\cdot$ kg^{-1} as found in Agricultural Price Reports (National Agriculture Statistics Services 2007) for each study year. As the final steer weights, and removal and marketing dates, varied little within years across treatments, a single final price was uniformly applied. Annual total expenses $\cdot$ ha^{-1} were calculated by summing monthly pasture rental rates, capitalization of initial investment, death loss, veterinary, supplemental feed, supplies, and marketing expenses. Pasture rental rates were determined by the average value of an animal unit month (AUM) of grazing for this geographical region as reported by the Economic Research Service (2007) for

Table 1. Annual precipitation (AP), spring precipitation April + May + June (SP), spring precipitation (Class), stocking rate (SR), length of grazing period (GP), average daily gain (ADG), animal production (Gain), gross income (Gross), expenses (Cost), and profit for pastures in three range condition classes from 1969 through 2002 at the Cottonwood Range Livestock Research Station located near Wall, South Dakota.

Range condition	Year	AP (mm)	SP[1] (mm)	Class	SR[2] (AUM · ha^{-1})	GP[3] (d)	ADG (kg · hd^{-1} · d^{-1})	Gain (kg · ha^{-1})	Gross ($ · ha^{-1})	Cost ($ · ha^{-1})	Profit ($ · ha^{-1})
Excellent	1969	509	227	Average	0.67	172	0.59	16.89	24.95	12.87	12.08
	1970	402	148	Average	0.88	166	0.80	30.2	45.11	19.28	25.82
	1971	669	260	Wet	1.12	175	0.64	30.7	50.77	24.33	26.44
	1972	398	205	Average	1.26	183	0.69	37.4	64.96	26.07	38.88
	1973	405	163	Average	0.84	176	0.84	30.0	45.28	15.26	30.04
	1974	361	171	Average	0.96	169	0.66	26.9	28.42	18.57	9.86
	1975	378	186	Average	1.21	93	0.79	33.6	41.08	24.63	16.45
	1976	295	161	Average	1.03	90	0.29	12.0	12.91	20.75	−7.84
	1977	515	176	Average	1.11	91	0.97	42.9	51.15	23.24	27.91
	1978	371	172	Average	1.16	91	0.68	35.8	39.47	24.13	15.31
	1979	432	210	Average	0.94	—[4]	0.82	32.5	55.28	18.03	37.22
	1980	365	112	Dry	0.67	—[4]	0.61	11.2	17.64	12.25	5.38
	1981	435	184	Average	0.54	—[4]	0.82	17.9	24.77	9.61	15.14
	1982	590	262	Wet	0.82	—[4]	0.45	14.5	20.77	15.46	5.29
	1983	381	189	Average	1.24	—[4]	0.74	36.9	50.51	26.16	24.35
	1984	417	304	Wet	0.99	—[4]	0.91	45.9	45.88	18.77	46.73
	1985	342	88	Dry	0.70	—[4]	0.76	22.9	35.68	12.63	23.05
	1986	617	293	Wet	1.11	—[4]	0.78	36.9	58.51	22.08	36.42
	1987	347	136	Average	0.77	62	0.84	28.0	48.21	13.81	34.71
	1988	371	194	Average	NA	NA	NA	NA	NA	NA	NA
	1989	323	89	Dry	0.26	60	0.76	8.4	14.20	4.00	10.20
	1990	326	137	Average	0.42	76	0.75	13.9	24.82	7.22	17.61
	1991	541	381	Wet	0.68	76	0.79	23.5	39.64	12.63	27.00
	1992	467	198	Average	0.75	63	0.79	21.8	39.22	14.66	24.58
	1993	525	235	Average	0.88	77	0.64	22.3	37.26	17.28	19.98
	1994	357	115	Dry	0.88	69	0.59	20.0	31.62	17.41	14.20
	1995	444	249	Average	0.75	92	0.95	28.9	43.15	14.96	28.20
	1996	506	191	Average	1.03	32	0.23	9.8	13.56	20.37	−6.79
	1997	664	314	Wet	0.91	120	0.90	37.6	55.69	18.39	37.30
	1998	551	170	Average	0.98	104	0.77	30.8	45.11	20.61	24.50
	1999	408	227	Average	0.96	99	0.62	21.7	38.47	20.64	17.85
	2000	366	170	Average	0.89	90	0.71	22.8	41.55	18.71	22.85
	2001	433	169	Average	1.10	112	0.78	40.0	64.32	24.44	39.87
	2002	321	86	Dry	0.61	63	1.16	33.5	60.03	11.82	48.21

Table 1. Continued.

Range condition	Year	AP (mm)	SP[1] (mm)	Class	SR[2] (AUM · ha^{-1})	GP[3] (d)	ADG (kg · hd^{-1} · d^{-1})	Gain (kg · ha^{-1})	Gross ($ · ha^{-1})	Cost ($ · ha^{-1})	Profit ($ · ha^{-1})
Good	1969	509	227	Average	0.75	172	0.59	19.0	28.28	14.96	13.31
	1970	402	148	Average	0.69	164	0.80	24.1	35.93	14.25	21.66
	1971	669	260	Wet	0.93	175	0.72	28.3	46.79	19.07	27.74
	1972	398	205	Average	0.94	183	0.70	28.2	48.93	18.04	30.89
	1973	405	163	Average	0.89	176	0.78	30.1	45.36	16.33	29.03
	1974	361	171	Average	0.89	169	0.67	26.4	27.89	16.85	11.04
	1975	378	186	Average	1.01	93	0.72	29.1	35.59	19.71	15.88
	1976	295	161	Average	0.96	90	0.29	10.9	11.76	18.92	−7.16
	1977	515	176	Average	1.01	91	1.02	40.8	48.76	20.65	28.11
	1978	371	172	Average	0.99	91	0.68	29.1	32.06	19.69	12.40
	1979	432	210	Average	1.04	NA	0.86	38.1	64.79	20.40	44.39
	1980	365	112	Dry	0.67	NA	0.56	9.0	14.10	12.25	1.88
	1981	435	184	Average	0.49	NA	0.77	14.6	20.13	8.62	11.51
	1982	590	262	Wet	0.74	NA	0.59	16.8	23.96	13.78	10.18
	1983	381	189	Average	1.11	NA	0.74	34.7	47.45	22.85	24.60
	1984	417	304	Wet	0.91	NA	0.84	41.4	59.13	17.09	42.04
	1985	342	88	Dry	0.77	NA	0.66	21.8	33.94	13.96	19.99
	1986	617	293	Wet	1.19	NA	0.75	38.1	60.28	23.97	36.31
	1987	347	136	Average	0.79	92	0.87	30.2	52.07	14.33	37.74
	1988	371	194	Average	NA	NA	NA	NA	NA	NA	NA
	1989	323	89	Dry	0.47	60	0.68	14.3	23.97	7.97	16.00
	1990	326	137	Average	0.67	NA	0.79	29.1	51.82	12.25	39.57
	1991	541	381	Wet	0.80	112	0.77	29.9	50.34	15.47	34.86
	1992	467	198	Average	1.25	92	0.79	34.6	62.13	27.17	34.98
	1993	525	235	Average	0.88	77	0.79	32.4	54.27	17.25	37.00
	1994	357	115	Dry	0.88	71	0.50	19.0	30.16	17.44	12.72
	1995	444	249	Average	1.06	92	0.81	39.4	58.86	22.69	36.17
	1996	506	191	Average	1.00	86	0.91	42.9	59.19	19.54	39.67
	1997	664	314	Wet	0.95	120	0.94	45.8	67.81	19.49	48.33
	1998	551	170	Average	0.99	104	0.93	41.1	60.23	20.64	39.61
	1999	408	227	Average	0.84	98	0.86	36.5	64.65	17.17	47.47
	2000	366	170	Average	0.85	90	0.99	38.6	70.42	17.98	52.44
	2001	433	169	Average	1.49	112	0.80	55.6	89.43	38.95	50.47
	2002	321	86	Dry	0.83	63	1.08	40.3	72.16	18.04	54.12

Table 1. Continued.

Range condition	Year	AP (mm)	SP[1] (mm)	Class	SR[2] (AUM · ha^{-1})	GP[3] (d)	ADG (kg · hd^{-1} · d^{-1})	Gain (kg · ha^{-1})	Gross ($ · ha^{-1})	Cost ($ · ha^{-1})	Profit ($ · ha^{-1})
Low–fair	1969	509	227	Average	1.41	172	0.45	29.1	43.23	34.21	9.03
	1970	402	148	Average	1.14	162	0.68	33.0	49.29	27.69	21.60
	1971	669	260	Wet	0.95	175	0.63	25.7	42.45	19.64	22.81
	1972	398	205	Average	1.17	183	0.60	30.4	52.81	24.07	28.75
	1973	405	163	Average	0.74	176	0.66	20.7	31.17	13.21	17.96
	1974	361	171	Average	0.98	169	0.63	26.1	27.59	18.92	8.67
	1975	378	186	Average	1.33	93	0.73	34.7	42.43	27.89	14.55
	1976	295	161	Average	0.82	90	0.30	9.5	10.19	15.41	−5.22
	1977	515	176	Average	0.89	91	0.81	32.0	38.19	17.54	20.67
	1978	371	172	Average	1.03	91	0.59	25.7	28.38	20.92	7.43
	1979	432	210	Average	1.24	NA	0.77	40.3	68.62	25.42	43.20
	1980	365	112	Dry	0.67	NA	0.57	10.1	15.88	12.25	3.63
	1981	435	184	Average	0.69	NA	0.73	19.0	26.31	12.77	13.56
	1982	590	262	Wet	1.38	NA	0.91	50.4	71.88	30.18	41.67
	1983	381	189	Average	1.14	NA	0.78	35.8	48.98	23.51	25.49
	1984	417	304	Wet	0.99	NA	0.74	34.7	49.52	18.77	30.75
	1985	342	88	Dry	0.98	NA	0.58	37.4	37.42	18.80	18.62
	1986	617	293	Wet	1.48	NA	0.69	44.2	70.04	31.96	38.08
	1987	347	136	Average	0.85	121	0.82	29.7	51.10	15.66	35.44
	1988	371	194	Average	NA	NA	NA	NA	NA	NA	NA
	1989	323	89	Dry	0.35	28	0.44	6.2	10.46	5.59	4.88
	1990	326	137	Average	0.90	112	0.86	33.4	59.50	17.71	41.80
	1991	541	381	Wet	1.07	112	0.74	33.4	56.38	22.29	34.09
	1992	467	198	Average	1.12	110	0.72	30.4	54.56	23.60	30.97
	1993	525	235	Average	0.88	110	0.62	32.6	54.57	17.15	37.41
	1994	357	115	Dry	0.98	106	0.63	24.4	38.72	19.88	18.85
	1995	444	249	Average	0.88	30	0.69	22.6	33.81	17.44	16.38
	1996	506	191	Average	1.17	55	0.53	27.6	38.15	24.22	13.64
	1997	664	314	Wet	1.12	120	0.89	50.9	75.42	23.80	51.62
	1998	551	170	Average	1.10	104	1.04	51.3	75.22	23.80	51.41
	1999	408	227	Average	1.20	98	0.87	51.5	91.28	27.40	63.87
	2000	366	170	Average	1.22	90	0.70	38.4	70.11	28.47	41.64
	2001	433	169	Average	1.12	112	0.80	42.6	68.47	25.32	43.14
	2002	321	86	Dry	0.63	63	1.08	32.6	58.35	12.50	45.86

[1]Average spring precipitation (April–June) during the 33-yr study period was 193 ± 67 mm. A year was classified as average if the amount received was within 1 SD of the 34-yr mean. Dry springs (1980, 1985, 1989, 1994, and 2002) were classified as having received 1 SD below the mean. Wet springs (1971, 1982, 1984, 1986, 1991, and 1997) were classified as having received 1 SD above the mean.

[2]Stocking rates were reduced during the drought of 1980, 1981 (recovery year), 1989, and 2002. In 1982, a warm-season deferment was given to pastures in low–fair condition, and a cool-season deferment was given to the others.

[3]Grazing season began mid-May and ended early November from 1969 to 1974. From 1975 to 2002 grazing was during June–August. In 1975 and 1979 pastures in low–fair condition were grazed in May to suppress western wheatgrass.

the actual length of the grazing period in each treatment each year of the study. The cost of capitalization of the livestock investment was calculated by multiplying the value of a 250-kg steer in the spring of each year as reported by the Economic Research Service (2007) by the historical interest rate as reported by the Federal Reserve (2007) for the exact number of grazing days for each year of the study. A 0.5% death loss charge, which is reasonable for this type of enterprise in this region, was calculated by multiplying the initial investment by 0.005. Annual veterinary, supplemental feed, supplies, and marketing expense were calculated from a 1982 South Dakota State University summer grazing stocker budget. To standardize the economic inputs and outputs, the impact of inflation or deflation was removed by adjusting all expenses and prices to 2002 dollars using the United States Consumer Price Index for 2002 as reported by the Bureau of Labor Statistics (2007). Annual net income $\cdot$ ha^{-1} was determined by subtracting total annual expenses $\cdot$ ha^{-1} from annual gross revenue $\cdot$ ha^{-1} for each treatment.

Statistical Analysis

For the years between 1974 and 1984, replicate data were missing. Therefore, for all variables, replications within each year were averaged, and year became the replication of treatment. Based on previously demonstrated influence of spring precipitation on vegetation production (Smart et al. 2007), data were analyzed in four separate data sets based on spring precipitation (April + May + June); the entire 34-yr data set, the average springs (n = 23), dry springs (n = 5), and wet springs (n = 6). A year was classified as an average spring if the amount of precipitation received was within 1 standard deviation (SD) of the 33-yr mean, dry spring as having received 1 SD below the mean, and wet spring as having received 1 SD above the mean. An analysis of variance and mean comparison were conducted using PROC MIXED (SAS Institute 2006) for each data set. Residuals of all variables were tested for the assumptions of normality using the NORMAL option in PROC UNIVARIATE (SAS Institute 2006) by plotting the box-plot and the normal probability plot. All variables were normally distributed. Homogeneity of variances of the variables was compared between treatments using the HOVTEST option in PROC GLM (SAS Institute 2006). The computed *P*-value for Levene's test for homogeneity of all the variables was $P > 0.05$, which indicated that variances of each variable among treatments were similar. Linear regression models for profit were developed for each treatment over time using PROC REG (SAS Institute 2006).

RESULTS

Mean annual productivity and financial performance for pastures grazed to maintain three range condition classes from 1969 to 2002 are presented in Table 1. To maintain the pastures in their initial range condition over the 34 yr of this study, the stocking rate of the low–fair pastures was higher ($P < 0.01$) than for the good or excellent treatments (Table 2). Average daily gain of steers in the good treatment was greater ($P < 0.05$) than the steers in the low–fair treatment. Total annual steer gains $\cdot$ ha^{-1} were not different for the low–fair and good treatments, but both were greater ($P < 0.01$) than the excellent treatment. Total gross income $\cdot$ ha^{-1} was not different for the low–fair and good treatments, but both were greater ($P < 0.01$) than the excellent treatment. Total annual expense $\cdot$ ha^{-1} was greatest for the low–fair treatment when compared to those in the good or excellent treatments. Net income $\cdot$ ha^{-1} was similar for the pastures in the low–fair and good treatments, and both were greater ($P < 0.01$) than the pastures in the excellent treatment.

Over the 34-yr period of the study, real profit (adjusted for inflation) steadily increased ($P < 0.01$) for the low–fair and good treatments while it remained basically level for the excellent treatment (Figs. 1–3). It is difficult to speculate as to the cause of these differences, but it is important to note that the profitability of the low condition pastures, which had the heaviest stocking rate, did not decline over time, it actually improved.

When the 34-yr data set was separated to consider only average precipitation springs (April + May + June; $n = 23$), the stocking rate of the low–fair pastures had to be maintained at a greater ($P < 0.01$) level than for the good or excellent treatment (Table 3). The average daily gain of the steers in the good treatment was greater ($P < 0.05$) than the steers in the excellent or low–fair treatment. Total annual steer gains $\cdot$ ha^{-1} was the greatest ($P < 0.05$) for good condition pastures compared to low–fair or excellent treatments. Total gross income $\cdot$ ha^{-1} was not different for the low–fair and good treatments, but both were greater ($P < 0.05$) than the excellent treatment. Total annual expense $\cdot$ ha^{-1} was greatest ($P < 0.05$) for the low–fair treatment compared to either the good or excellent treatments. Net income $\cdot$ ha^{-1} was the least ($P < 0.05$) for the excellent treatment and greatest ($P < 0.05$) for the good treatment. Net income for the low–fair treatment was not different compared to excellent or good treatments.

When only five dry springs were considered, there were no differences ($P > 0.05$) between any of the animal production or economical measures (Table 4). This was a result of low power to detect treatment differences. A power analysis revealed that none of the variables had a power greater than 36% for the main effect of treatment. When six wet springs were considered separately, the low–fair treatment resulted in an approximately 25% greater ($P < 0.05$) stocking rate than either the good or excellent treatments (Table 5). However, there were no statistical differences between the three treatments for average daily gain, total gain, gross income, or net income. Total expenses were greater ($P < 0.05$) for the low–fair treatment compared to either of the other treatments. Again, a power analysis revealed that the production and economic variables among the three range condition treatments was less than 25%, suggesting that the type II error rate was very high for the small sub-data sets for dry ($n = 5$) and wet springs ($n = 6$) compared to average springs ($n = 23$).

DISCUSSION

Stocking Rate

To maintain the plant community associated with the three original range condition classes, excellent and good range condition treatments had to be stocked at lower stocking rates

Table 2. Mean annual productivity and financial performance for pastures in three range conditions grazed to maintain that condition from 1969 to 2002.

Range condition	Stocking rate[1] ($AUM \cdot ha^{-1}$)	Avg daily gain[2] ($kg \cdot d^{-1}$)	Total gain[1] ($kg \cdot ha^{-1}$)	Gross income[1] ($\$ \cdot ha^{-1}$)	Total expenses[1] ($\$ \cdot ha^{-1}$)	Net income[1] ($\$ \cdot ha^{-1}$)
Excellent	0.88 b	0.73 cd	26.6 b	40.29 b	17.61 b	22.68 b
Good	0.90 b	0.77 d	30.6 a	47.05 a	18.11 b	28.94 a
Low–fair	1.02 a	0.70 c	31.3 a	48.20 a	21.15 a	27.05 a
SE	0.037	0.025	1.73	2.649	1.017	2.104

[1]Means within a column followed by a different letter are significantly different ($P < 0.01$).
[2]Means within a column followed by a different letter are significantly different ($P < 0.05$).

than the low–fair treatment. These results are contrary to conventional wisdom, that because of higher levels of forage production, a range site in excellent or good range condition is able to sustain higher stocking rates than if it were in low–fair condition (Dyksterhuis 1949; Stoddart et al. 1975; Valentine 1990; Holechek et al. 2004).

The choice of stocking rate is the most important decision a range manager makes (Holechek et al. 1999; Gillen and Sims 2002) and has short- and long-term, financial, and biological implications. Stocking rate is the major ecosystem driver that is under direct management control in either the Clementsian or the state and transition model of ecological succession (Holechek et al. 2004). The two models are in agreement that stocking rate plays a key role in determining the plant community of a range site, and therefore its range condition class. Financially, it determines the level of investment and cost structure and sets a framework for potential returns. It is widely held that if, over long periods of time, management chooses a stocking rate that exceeds the carrying capacity, the associated decrease in productivity could threaten the long-term sustainability of the ranch (Harlan 1958; Kothmann et al. 1970; Stoddart et al. 1975; Hart et al. 1988; Heitschmidt et al. 1990; Valentine 1990; Holechek 1994; Manley et al. 1997; Hart and Ashby 1998; Holechek et al. 2004) and may increase risk during drought (Hooper and Heady 1970; Heitschmidt et al. 1982; Holechek et al. 1999). Therefore, if a manager chooses a stocking rate that exceeds the carrying capacity, the increased investment in the livestock enterprise, and the associated increase in total costs, would prove to be unwarranted and expensive. However, economic opportunities are wasted if a stocking rate that is below the carrying capacity is chosen (Harlan 1958; Workman 1986).

The purpose of using variable stocking rates in this experiment was to determine the actual stocking rate required to maintain the plant community associated with the three original range condition classes (which represent the three treatments) throughout the entire length of the trial. The variable stocking rate approach is of importance because it allows the validity of stocking rate recommendations based on formulas to be tested over a long period of time.

Based on these results, if a rangeland professional were making stocking rate recommendations for this range site using commonly recommended formulas based on forage production, standard estimates of livestock intake, and a harvest efficiency of 25% of total forage production, and it was in good or better range condition, a decline in range condition would result. In fact, using forage production data from these pastures as reported by Smart et al. (2007), the calculated stocking rates for excellent and good range condition treatments using the methods described by Galt et al. (2000) would result in stocking rates of 69% and 22% higher, respectively, than what was used to maintain these range conditions over 34 yr. In summary, in this study, if the stocking rate had been determined by the standard formula, it may have proven to be unsustainable.

If a rangeland professional were making stocking rate recommendations for this range site and it was in low–fair range condition, use of the standard formula would underestimate the actual carrying capacity of the rangeland by approximately 13%. Economic opportunities would have been lost. Similar conclusions were reported by Hart et al. (1988), as

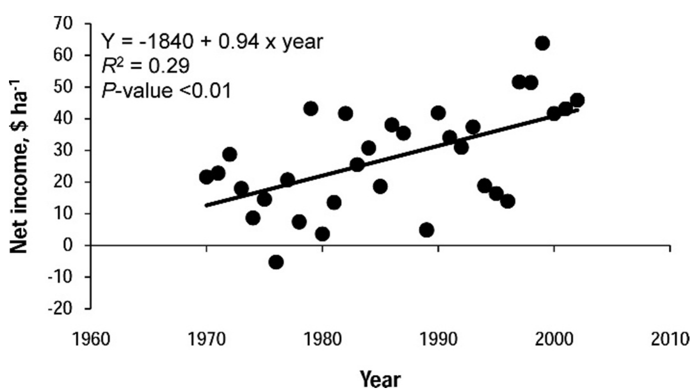

Figure 1. Net income $\cdot ha^{-1}$ from 1969 to 2002 for low–fair range condition treatment.

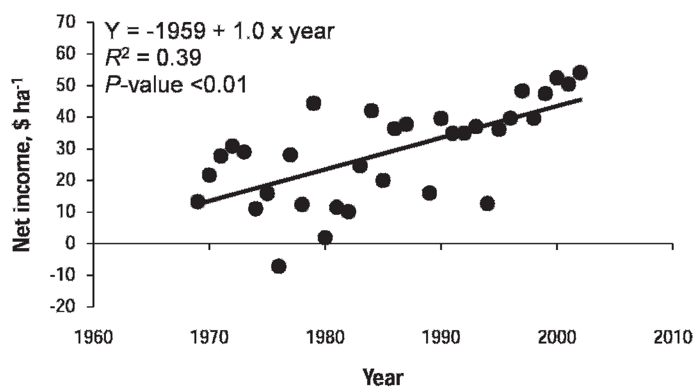

Figure 2. Net income $\cdot ha^{-1}$ from 1969 to 2002 for good range condition treatment.

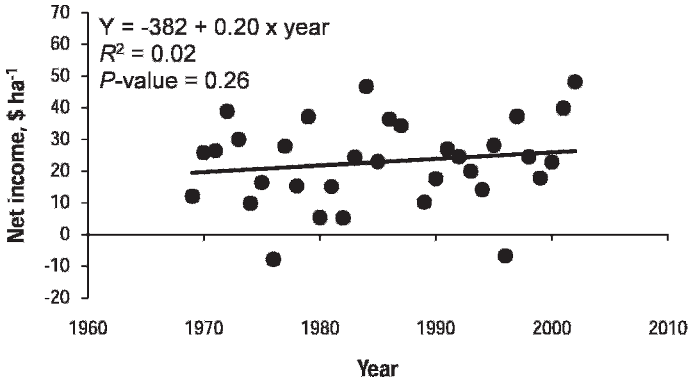

Figure 3. Net income · ha^{-1} from 1969 to 2002 for excellent range condition treatment.

they found that Soil Conservation Service stocking rate recommendations were lower than the stocking rate that provided the greatest return.

Animal Performance

It is well established from numerous grazing intensity studies that average daily gain (ADG) is negatively affected by increased stocking rate (Holechek et al. 2004). However, less known are the impacts of range condition on animal performance when stocked to maintain range condition. In spite of increased stocking rates for the lower condition pastures, our results showed relatively small biological differences in ADG attributable to range condition. Both the excellent and low–fair range condition treatments were similar in ADG. How can this be with the large differences in stocking rate observed in this study between excellent and low–fair? Because animal performance is mainly dependant on both the quantity and quality of forage available to the grazing animal, we hypothesize that that these results may have been due to two factors. First, although overall utilization was 50% in each treatment, the harvest efficiency could have been higher than the 25% as suggested by Galt et al. (2000). Second, forage quality differences in range condition class may not be large enough to impact gain. Cook et al. (1962) reported that the nutrient content in herbage from poor range was similar to that on ranges in good condition. Smith et al. (1994) found that on the rangeland of the Chihuahuan desert, excellent range condition maximized forage quantity, but from a nutrient availability perspective, good condition rangeland was superior. In a study conducted in the Nebraska Sandhills (Powell et al. 1982), digestibility of steer diets was greater for low–good condition compared to high good–excellent condition rangeland. Also, intake was greater for steers grazing low–good condition compared to high good–excellent condition pastures. Similar to the results of this study, which found small numeric differences in ADG between treatments, Powell and his coworkers (1982) also found no difference in ADG between the treatments. Because shrubs are not a major botanical component in the Northern Great Plains, ADG may have been minimally affected by range condition because shifts in species composition are predominantly between midgrasses and shortgrasses (Laurenroth et al. 1999; Smart et al. 2007).

Beef production per hectare results from the stocking rate and the ADG of the steers. As a result, the treatments that had the heaviest stocking rate (low–fair) and the highest ADG (good) had similar total gain · ha^{-1}, which were both greater ($P < 0.01$) than for excellent. It is difficult to speculate if the results from this experiment would be applicable to another class of livestock. For cow-calf enterprises, cow reproduction, lactation, maintenance, calf growth, and differences in grazing behavior and diet selection add complexity, which precludes confident prediction. However, cow-calf enterprises have less flexibility in varying stocking rates than do yearling or stocker operations.

Total Expenses

Steers grazing excellent and good condition range incurred lower ($P < 0.01$) total expenses (17.61 and 18.11 vs. \$21.15 · ha^{-1}) than those in the low–fair treatment. Because all expenses were variable, the higher stocking rate in the low–fair treatment resulted in increased costs of pasture rent, death loss, interest on invested capital, death loss, veterinary, supplemental feed, supplies, and marketing when compared to those in the other two treatments.

Profitability

The desire to maximize beef production per unit of land area has been profit driven (Shoop and McIlvain 1971; Wilson and Macleod 1991). In this study, profitability was a function of a variable stocking rate, animal performance, income, and expenses. Because the product of stocking rate and ADG resulted in similar total beef production between low–fair and good range condition, gross income and net profit were not different, even though there were substantial differences in expenses. More importantly, the excellent range condition treatment was not able to produce as much beef per unit of land area and, even with lower expenses, net income · ha^{-1} was less ($P < 0.01$) than the good and low–fair range condition

Table 3. Mean annual productivity and financial performance for pastures in three range conditions grazed to maintain that condition during average precipitation ($n = 23$) springs from 1969 to 2002.

Range condition	Stocking rate[1] (AUM · ha^{-1})	Avg daily gain[2] (kg · d^{-1})	Total gain[2] (kg · ha^{-1})	Gross income[2] (\$ · ha^{-1})	Total expenses[2] (\$ · ha^{-1})	Net income[1] (\$ · ha^{-1})
Excellent	0.93 d	0.72 c	26.9 c	39.98 c	18.70 c	21.28 b
Good	0.94 d	0.78 d	32.1 d	48.64 d	19.06 c	29.58 a
Low–fair	1.05 c	0.70 c	31.7 c	48.36 d	21.92 d	26.44 ab
SE	0.048	0.030	2.12	3.311	1.347	2.700

[1]Means within a column followed by a different letter are significantly different ($P < 0.01$).
[2]Means within a column followed by a different letter are significantly different ($P < 0.05$).

Table 4. Mean annual productivity and financial performance for pastures in three range conditions grazed to maintain that condition during dry springs ($n = 5$) from 1969 to 2002.

Range condition	Stocking rate ($AUM \cdot ha^{-1}$)	Avg daily gain ($kg \cdot d^{-1}$)	Total gain ($kg \cdot ha^{-1}$)	Gross income ($\$ \cdot ha^{-1}$)	Total expenses ($\$ \cdot ha^{-1}$)	Net income ($\$ \cdot ha^{-1}$)
Excellent	0.62	0.77	19.2	31.83	11.62	20.21
Good	0.72	0.70	20.9	34.87	13.93	20.94
Low–fair	0.72	0.66	19.5	32.17	13.80	18.37
SE	0.058	0.051	2.05	3.445	1.406	1.082

treatments. One might speculate that net income $\cdot$ ha^{-1} for the low–fair treatment, which received the heaviest stocking rate, might be more variable over time than the other treatments; it was not. In fact, net income $\cdot$ ha^{-1} for both the low–fair and good treatments steadily increased.

Although annual net income $\cdot$ ha^{-1} varied with spring precipitation for all three treatments, there were no differences ($P > 0.05$) in annual net income $\cdot$ ha^{-1} between treatments for wet or dry springs. These results, although limited, indicated that net income $\cdot$ ha^{-1} in years of spring drought was similar across treatments. Although adopting risk management alternatives for periods of drought has long been recommended as an important strategy for ranchers (Whitson et al. 1982), over the last four decades there has been an extensive and expanding mitigation of risk during periods of drought by the US government, equally available to ranchers with rangeland in all range conditions, with feed programs for livestock, cash subsidies, insurance, and tax policy adjustments (Dunn et al. 2005).

In a capitalistic economy, it is irrational for businesses to operate in ways that are detrimental to their interests. As applied to ranching, it would be logical and rational for ranchers operating in a market-driven economy to choose a range condition class for their rangeland that is both profitable for the short term as well as the long term and is sustainable. Their livelihood depends on their ability to keep their land in a condition that is appropriate from an ecological as well as financial perspective. It would follow, then, over long periods of time, that ranchers will manage for the optimum range condition for their rangeland. Results of this study do not support the general belief that ranchers should chose management strategies that lead to an improvement in range condition of their rangeland (Workman 1995; Holechek 2004). These results demonstrate no financial incentive for management to shift range condition to a higher range condition class as the adjustments required to do so carry with them a serious opportunity cost (Pearson and Whitaker 1973; Arthington et al. 2007).

Although dynamic economic and policy shifts concerning topics like carbon sequestration, consumptive and nonconsumptive uses of wildlife, wind energy, viewsheds, and recreation may create financial opportunities in the future, for practical purposes, and at a scale large enough to be considered relevant across the entire economy, the economic values of the externalities associated with these activities remain unknown (Heidenrich 2009). For ranchers in western South Dakota, livestock grazing remains the primary and, in many cases the only, goods and services from rangelands rewarded in the current economy. This was especially true for the time period of this study. Individuals and organizations that have or take the responsibility for advising ranchers and rangeland managers on land use should exercise caution, as the costs and benefits of the recommendations have serious and long-term financial impacts.

IMPLICATIONS

In our 34-yr study, rangeland managed to maintain either low–fair or good range condition was equally profitable. Profit for both steadily increased over time. Excellent condition rangeland was the least profitable to maintain and profit remained stable over time. These results are consistent with generally observed rancher behavior concerning range condition decisions. Plant communities in excellent range condition have significant proportions of midgrasses that if heavily utilized will decrease in abundance and vigor. Lighter stocking rates used to benefit these grasses results in less gross revenue and profit. For the range site evaluated in this research, rangeland in low–fair or good condition is sustainable from both an ecological as well as a financial basis. Results also document that some ecosystem goods and services, increasingly demanded by society, come at a cost to the rancher. If services generally associated with high range condition such as wildlife habitat, floristic diversity, and improved hydrologic function are publically valued, and

Table 5. Mean annual productivity and financial performance for pastures in three range conditions grazed to maintain that condition during wet springs ($n = 6$) from 1969 to 2002.

Range condition	Stocking rate[1] ($AUM \cdot ha^{-1}$)	Avg daily gain ($kg \cdot d^{-1}$)	Total gain ($kg \cdot ha^{-1}$)	Gross income ($\$ \cdot ha^{-1}$)	Total expenses ($\$ \cdot ha^{-1}$)	Net income ($\$ \cdot ha^{-1}$)
Excellent	0.94 a	0.74	31.5	48.48	18.61 a	29.86
Good	0.92 a	0.77	33.4	51.39	18.15 a	33.24
Low–fair	1.17 b	0.77	39.9	60.95	24.44 b	36.50
SE	0.088	0.066	5.23	7.554	2.269	5.620

[1]Means within a column followed by a different letter are significantly different ($P < 0.05$).

associated markets have not been established in the private sector, then funds cost-shared by federal, state, and private organizations must provide the incentive to direct ranchers' decisions (Heidenrich 2009).

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