Long-term Grazing Intensity Research in the Missouri Coteau Region of North Dakota

Bob Patton and Anne Nyren

Central Grasslands Research Extension Center, NDSU, Streeter

The objectives of the project are to determine the effects of grazing intensity on cattle performance, profitability and the sustainability of forage production. The optimum stocking rate depends on objectives, but the best compromise between profitability and sustainability falls between a moderate and a heavy stocking rate.

Summary

The question of how heavily to stock native range is complex. It primarily depends on how much forage is available, which varies each year, depending on the temperature and precipitation. If stocking rates are too low, profits will not be maximized, but if rates are too high, cattle performance will suffer and the resource will be damaged.

This study began in 1989. Five treatments are included: no grazing, and light, moderate, heavy and extreme grazing. Our goal is to stock the pastures each year so when the cattle are removed in the fall, 65, 50, 35 and 20 percent of the forage produced in an average year remains on the light, moderate, heavy and extreme treatments, respectively. Thus far, on loamy and loamy overflow ecological sites, the extreme grazing treatment produced the least forage ($P \leq 0.05$). On loamy ecological sites, the light treatment produced the most forage ($P \leq 0.05$). On loamy overflow ecological sites, the light and moderate treatments produced the most forage but were not significantly different from each other ($P \leq 0.05$).

Of the 166 plant species monitored on loamy ecological sites, 63 have responded to grazing based on frequency, density or basal cover. Of the 175 plant species monitored on loamy overflow ecological sites, 52 have responded to grazing. Average daily gain and animal body condition scores have decreased with increasing grazing intensity. This effect has been significant in most but not all years ($P \leq 0.05$). Initially, gain/ton (total weight gain of all animals/ton of available forage) increases as the stocking rate increases, but a point is reached at which gains/ton decline.

In this study, at 2.49 animal unit months (AUMs)/ton of forage, average gain/ton from 1991 to 2012 would be 76.6 pounds/ton. If cattle prices were constant, then return/ton (dollars returned to the enterprise per ton of forage) would peak at a stocking rate somewhere below maximum gain/ton, with the exact point depending on carrying costs. The stocking rate with the maximum return/ton during the last 22 years would be 1.86 AUM/ton, with an average annual return of $29.31/ton.

Introduction

At low stocking rates, individual animal performance is high, but total gains from the pasture will be low (Hart 1972). As stocking rates increase, individual performance goes down but gain/ton of forage will increase as long the individual gain of an animal added exceeds the reduced gain of the other animals in the pasture. But gain/ton will decline as more animals are competing for less forage (Hart 1972). If cattle prices were steady, then return/ton would peak at a stocking rate somewhere below maximum gain/ton, with the exact point depending on input costs. Heavy stocking can damage the resource, reducing total forage production and

shifting the species composition to species that are more resistant to grazing (Thurow 1991). The optimum stocking rate varies with objectives, but we cannot know what stocking rate is optimum for any particular objective without knowing how cattle and rangeland respond to the stocking rate.

Procedures

This ongoing study began in 1989 at the Central Grasslands Research Extension Center in Kidder County, northwest of Streeter, N.D. The site is divided into 12 pastures of approximately 30 acres each. Grazing intensities are light, moderate, heavy and extreme. The target is to leave 65, 50, 35 and 20 percent of the forage produced in an average year on the light, moderate, heavy and extreme treatments, respectively. Exclosures are used to provide a fifth, ungrazed treatment to determine how rangeland changes when it is not grazed.

Grazing begins each year in mid-May, and cattle are removed when forage utilization on half of the pastures has reached desired grazing intensity (approximately mid-October). Monitoring locations are on loamy and loamy overflow ecological sites in each pasture, as are six exclosures for the ungrazed treatment. Frequency of occurrence of all plant species is monitored each year to determine changes in the plant community. Plant density of shrubs, forbs and caespitose grasses is sampled in conjunction with the frequency sampling. Forage production and utilization is determined using the paired plot cage comparison method. Cattle performance is evaluated based on initial and final body weight, and body condition score.

Economic return is determined by subtracting the initial value of each animal, interest on the initial value for the grazing period, death loss and estimated costs per head for salt, mineral and veterinary fees from final value of the animal when taken off pasture. Initial and final values of animals are based on weight using regression equations developed from sale prices at the Napoleon Livestock Auction during the same period.

Results

Forage production. Tables 1 and 2 list the average forage production by treatment for the past 21 years. For loamy and overflow ecological sites, the extreme grazing treatment produced the least forage ($P \leq 0.05$). On the other hand, the ungrazed treatment produced significantly less forage than the light treatment on the loamy ecological site and less than the light, moderate and heavy treatments on the loamy overflow ecological site ($P \leq 0.05$). On loamy ecological sites, the light grazing resulted in the highest production ($P \leq 0.05$). On loamy overflow ecological sites, we found no difference ($P > 0.05$) in forage production on light, moderate, and heavy treatments in end of the season forage production.

Year X treatment interactions ($P \leq 0.05$) have been found only at the beginning of the grazing season for both ecological sites. On loamy overflow ecological sites, the treatment with the most forage production at the beginning of the season was light, moderate or heavy, but different treatments produced the most forage in different years ($P \leq 0.05$). On loamy ecological sites at the beginning of the grazing season, the treatment with the most forage production was ungrazed, light, or moderate in different years,

Table 1. Average above-ground biomass production by grazing treatment on loamy ecological sites from 1992 to 2012.

Treatment	Above-ground Biomass (lbs/acre)			
	Beginning of Season	Middle of Season	Peak Yield	End of Season
Ungrazed	1,271 b[1]	2,589 b	2,842 c	2,654 c
Light	1,338 a	2,896 a	3,274 a	3,145 a
Moderate	1,205 c	2,670 b	3,044 b	2,915 b
Heavy	933 d	2,250 c	2,510 d	2,414 d
Extreme	751 e	1,921 d	2,271 e	2,213 d
LSD (0.05)	59	158	194	211

[1]Means in the same column followed by the same letter are not significantly different at P=0.05.

Table 2. Average above-ground biomass production by grazing treatment on loamy overflow ecological sites from 1993 to 2012.

Treatment	Above-ground Biomass (lbs./acre)			
	Beginning of Season	Middle of Season	Peak Yield	End of Season
Ungrazed	996 c[1]	3,341 c	3,487 c	3,006 b
Light	1,170 b	4,076 a	4,369 a	4.140 a
Moderate	1,251 a	3,791 b	4,249 ab	4,108 a
Heavy	1,212 ab	3,682 b	4,053 b	3,999 a
Extreme	825 d	2,302 d	2,697 d	2,623 c
LSD (0.05)	75	259	273	290

[1]Means in the same column followed by the same letter are not significantly different at P=0.05.

with the extreme or heavy treatments always having the least forage production ($P \leq 0.05$).

Plant community dynamics. The percent of frequency and grazing response of the plant species are listed in Table 3 and 4.A total of 166 species have been found on the loamy ecological sites and 63 have shown a response to grazing based on frequency, density or basal cover. Six are favored by no grazing, 25 by moderate grazing and 32 by heavy grazing. Of the 175 species on the loamy overflow ecological sites, 52 have responded to grazing. Six are favored by no grazing, 16 by moderate grazing and 30 by heavy grazing.

On loamy sites, total forb density has become highest on the extreme treatment and lowest on the light and ungrazed treatments ($P \leq 0.05$). Total plant density has increased more on the extreme treatment than on the ungrazed or light treatments ($P \leq 0.05$). From 2004 to 2009, total grass density decreased on the ungrazed and light treatments and has not recovered on those treatments, while a steady increase has occurred in grass density on the moderate, heavy and extreme treatments ($P \leq 0.05$).

Also on loamy ecological sites, total plant basal cover decreased on all treatments, but it decreased less on the extreme than on the other treatments ($P \leq 0.05$).

On loamy overflow sites, total density of nonrhizomatous grasses has increased on the extreme grazing treatment and decreased on the ungrazed treatment ($P \leq 0.05$). Total forb density has increased with grazing intensity and has become greatest on the extreme treatment and least on the ungrazed ($P \leq 0.05$). Total plant density (including forbs, bunchgrasses and shrubs but not rhizomatous grasses) also has increased with grazing intensity ($P \leq 0.05$). Total plant basal cover has increased on the extreme and heavy treatments and decreased on the ungrazed and light treatments ($P \leq 0.05$).

In addition to the changes listed for plant species, litter has decreased on loamy ecological sites, and bare ground has increased on loamy and loamy overflow ecological sites under heavy grazing ($P \leq 0.05$).

Livestock response. Table 5 shows the average daily gain, gain per acre, gain per ton of forage and body condition scores from the different grazing intensities. Average

Table 5. Average daily gains, gains per acre, gain per ton of forage and condition scores from different stocking intensities.

Desired Grazing Intensity	2008	2009	2010	2011	2012	Average 1991-2012
Average Daily Gains (lbs./head/day)						
Light	1.75a[1]	2.05a	1.54	1.59	1.21a	1.39a
Moderate	1.58ab	1.99a	1.29	1.32	1.12a	1.27b
Heavy	1.35b	1.48b	1.09	1.30	0.98ab	1.11c
Extreme	0.95c	1.09b	1.02	1.17	0.72b	0.86d
LSD (0.05)	0.38	0.42	NS[2]	NS	0.34	0.12
Average Gain (lbs./acre)						
Light	39.73b	47.37b	41.58	51.55c	36.81	31.31d
Moderate	68.61ab	90.63a	68.95	83.22bc	62.85	56.81c
Heavy	82.15a	92.72a	84.55	121.11ab	83.17	78.79b
Extreme	76.10a	90.79a	104.70	140.29a	80.16	89.26a
LSD (0.05)	29.04	34.31	NS	54.49	NS	9.60
Average Gain (lbs./ton of forage)						
Light	27.11c	33.80b	19.01c	21.69b	17.88b	19.55d
Moderate	51.13b	62.10ab	31.24bc	32.82b	33.08ab	34.98c
Heavy	70.51ab	77.54a	52.54ab	58.61a	54.07a	58.95b
Extreme	78.22a	92.90a	64.87a	74.00a	58.94a	75.59a
LSD (0.05)	22.96	33.78	27.37	22.96	30.27	7.37
Condition Score						
Light	6.99a	5.77	5.24	5.41	5.02a	5.45a
Moderate	6.51b	5.52	5.19	5.33	4.88a	5.33ab
Heavy	6.38b	5.46	5.16	5.42	4.78ab	5.22b
Extreme	5.82c	4.97	5.05	5.25	4.57b	4.96c
LSD (0.05)	0.39	NS	NS	NS	0.24	0.17

[1]Means in the same column followed by the same letter are not significantly different at p=0.05.
[2]Means not significantly different.

score decreased with increased grazing intensity each year with few exceptions ($P \leq 0.05$). The relationships between stocking rate and average daily gain are illustrated in Figure 1. Initially, gain/ton of forage increased as the stocking rate increased, but a point is reached at which further increases in stocking rates result in reduced gain/ton (see Figure 2).

Table 6A shows the stocking rate that would have resulted in the maximum gain/ton of forage in each year. The stocking rate with the maximum gain/ton from 1991 to 2012 would be 2.49 AUM/ton ("Optimum" in Figure 2) (Values are based on regressions of gain on stocking rate. All regressions were significant at least at the P=0.0068 level). Table 6B shows what the gain/ton would have been each year if we had stocked at that rate. If we had stocked at 2.49 AUM/ton each year, gain/ton would have ranged from a gain of 34.6 pounds/ton in 2006 to 150.5 pounds/ton in 1992, with an average of 76.6 pounds/ton. Table 6C shows gain/ton if the stocking rate had been held constant at 0.70 AUM/ton, the average of the moderate treatment.

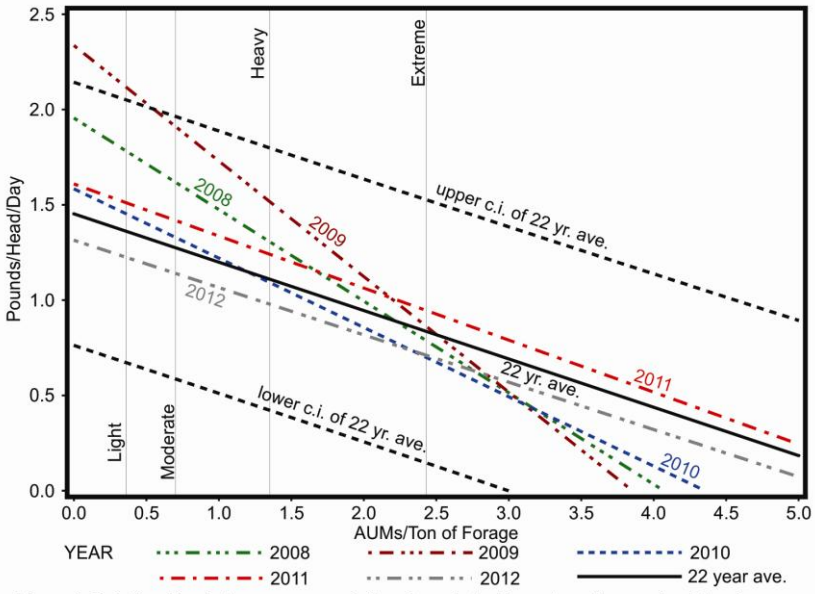

Figure 1. Relationships between average daily gain and stocking rate on the grazing intensity trial for 2008 to 2012 and the 22 year average with 95 percent confidence intervals.

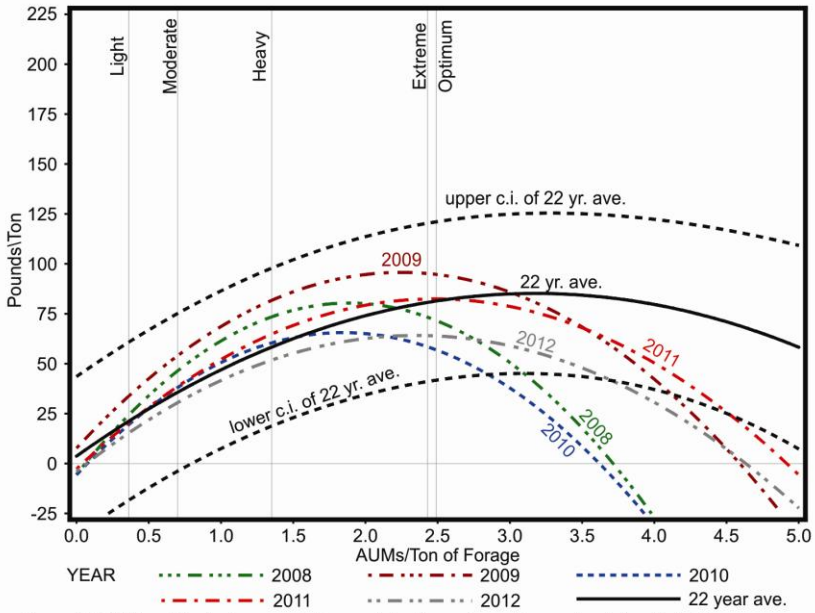

Figure 2. Relationships between gain/ton and stocking rate on the grazing intensity trial for 2008 to 2012 and the 22 year average with 95 percent confidence intervals.

Economics. Figure 3 shows the relationship between stocking rate and economic return. Costs for land, labor and management are not included because these values vary greatly from one operation to another. If cattle prices were steady, then return/ton would peak at a stocking rate somewhere below maximum gain/ton, with the exact point depending on carrying costs. However, when cattle are worth more per hundredweight in the spring than they are in the fall, the point of maximum return/ton occurs at a lower stocking rate (Hart 1987). When the cattle are worth more in the fall, the maximum return/ton occurs at a higher stocking rate.

Table 6. Comparison of gain in pounds per ton of forage from selected stocking rates.

	A		B		C	
	Stocking rate in AUMs/ton of forage that would result in the maximum gain/ton in each year.		Stocking rate in AUMs/ton of forage that if held constant would result in the maximum gain/ton during the 22-year period.		Gain/ton during the 22-year period if stocking rate were held constant at 0.70 AUMs/ton of forage, the average of the moderate treatment during this period.	
Year	AUMs/ ton of Forage	Gain/ ton	AUMs/ ton of Forage	Gain/ ton	AUMs/ ton of Forage	Gain/ ton
1991	2.61	56.5	2.49	56.4	0.70	27.5
1992	3.84	171.9	2.49	150.5	0.70	56.6
1993	2.07	102.9	2.49	98.2	0.70	54.0
1994	1.83	40.1	2.49	35.1	0.70	25.2
1995	2.52	60.3	2.49	60.3	0.70	28.8
1996	2.52	58.7	2.49	58.7	0.70	26.6
1997	2.30	95.4	2.49	94.7	0.70	46.8
1998	2.10	75.6	2.49	72.9	0.70	40.3
1999	3.46	108.3	2.49	99.5	0.70	37.2
2000	2.75	70.9	2.49	70.3	0.70	30.5
2001		*	2.49	107.4	0.70	36.7
2002		*	2.49	106.1	0.70	39.0
2003		*	2.49	76.9	0.70	28.7
2004	1.50	80.1	2.49	34.9	0.70	49.7
2005	2.43	48.3	2.49	48.3	0.70	22.8
2006	3.08	35.9	2.49	34.6	0.70	15.3
2007		*	2.49	110.0	0.70	34.8
2008	1.89	80.4	2.49	71.7	0.70	46.2
2009	2.25	95.7	2.49	94.7	0.70	53.8
2010	1.85	65.6	2.49	57.0	0.70	37.9
2011	2.48	82.5	2.49	82.4	0.70	38.4
2012	2.35	64.1	2.49	63.9	0.70	30.4
22-year avg.	**2.43**	**77.4**	**2.49**	**76.6**	**0.70**	**36.7**

* The regressions for 2001, 2002, 2003 and 2007 were not suitable to project the peak in gain/ton.

Table 7 shows the optimum return/ton for each year if stocking rates were set for the optimum for that year, a constant optimum rate and the moderate rate. The peaks of the curves in Figure 3 correspond to these optimum stocking rates. The constant stocking rate with the maximum return/ton during the last 22 years would be 1.86 AUM/ton. This is the point labeled "optimum" in Figure 3.

This year (2012), cattle prices were higher in the spring than in the fall for cattle weighing less than 875 pounds. This, coupled with the lower rate of gain on the higher stocking rates, would put the maximum return for 2012 at $15.92/ton if stocked at 1.25 AUM/ton. Although the average return/ton is higher under the optimum stocking rate, six years had negative returns, while only one year had a negative return under the moderate stocking rate. Comparing Tables 6 and 7, the stocking rate with the greatest economic return was less than the rate with the greatest gain per ton of forage in all but three years (1996, 1999 and 2004).

Discussion

Differences among treatments in biomass production indicate that grazing reduces the amount of carbohydrate reserves the plants are able to carry over to the next season. The weather for the current or previous growing season can affect forage production.

Lower production on the ungrazed treatment may be the result of litter buildup that prevents rainfall and sunlight from reaching the ground.

The rate at which average daily gain decreases with an increase in stocking rate varies greatly from year to year. These differences may be due to variation in forage quality or quantity, the effect of weather on the animals, the animals' initial weights or their potential to gain.

The objective of this study is to determine what stocking rate would result in the greatest economic return to the livestock producer in the long run. Results indicate that for the past 22 years, the optimum stocking rate would have been 1.86 AUM/ton of forage. This is equal to 1,075 pounds of forage for one animal unit, the equivalent of a 1,000-pound cow and calf, for one month. During the past 24 years, forage production on our loamy ecological sites has averaged 2,760 pounds/acre. So in a year with average production, 0.39 acre of this ecological site would be enough to supply this amount of forage for a month.

However production has varied through the years from being able to supply this amount of forage with 0.25 acre to requiring 0.91 acre. This emphasizes the importance of knowing how productive pastures are and being able to predict weather trends early in the grazing season.

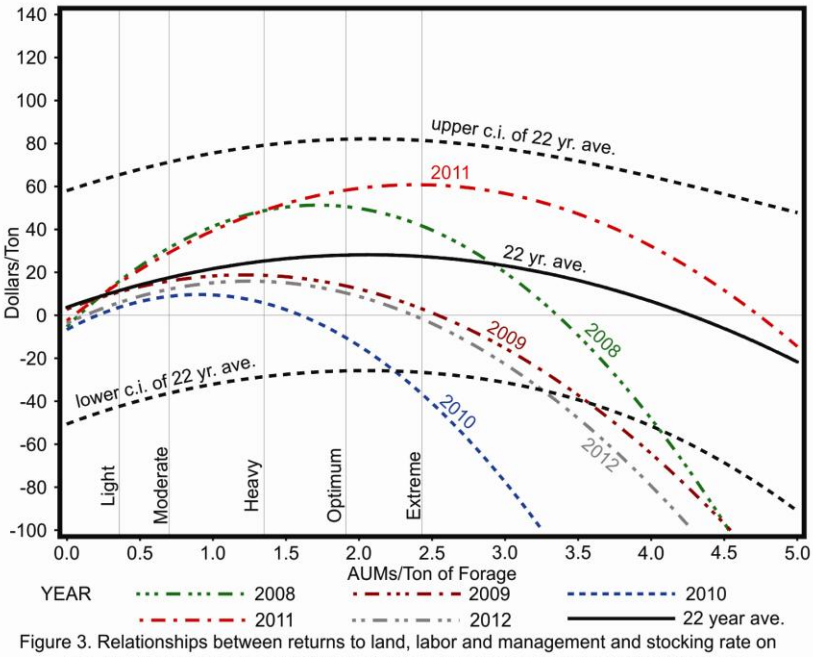

Figure 3. Relationships between returns to land, labor and management and stocking rate on the grazing intensity trial for 2008 to 2012 and the 22 year average with 95 percent confidence intervals.

Although 1.86 AUM/ton of forage would have provided the best economic return during the last 22 years, we found a number of reasons to consider a lighter stocking rate. First, the extreme and heavy pastures have been deteriorating in condition through the course of the study and may not be able to support the rates of gain we have seen in the past. Also, profits and losses are higher at higher stocking rates, depending on the difference between spring and fall livestock prices. The producer would experience more years with negative returns at the higher stocking rates.

The moderate stocking rate appears that it may be too conservative if maximizing profit is the objective. In only four out of 22 years, returns would have been higher with a stocking rate less than the moderate rate of 0.70 AUM/ton of forage. In all other years, a higher stocking rate would have resulted in higher returns. For a stocker operation in this area, the optimum stocking rate would fall in the range of 0.70 to 1.86 AUM/ton of forage.

Also, season-long grazing is used in this study; however, we recommend a rotation grazing system to take advantage of the higher forage quality found on the extreme grazing treatment and still give plants a rest, thereby avoiding the reduced production also found on the extreme grazing treatment.

Table 7. Comparison of return to land, labor and management from selected stocking rates.

	A			B			C		
	Stocking rate in AUMs/ton of forage that would result in the maximum returns/ton to land, labor and management in each year.			Stocking rate in AUMs/ton of forage that if held constant would result in the maximum returns/ton to land, labor and management during the 22-year period.			Returns/ton to land, labor and management during the 22-year period if stocking rate were held constant at 0.70 AUMs/ton of forage, the average of the moderate treatment during this period.		
	AUMs/ton of Forage	Dollars/ ton	Gain/ ton	AUMs/ton of Forage	Dollars/ton	Gain/ ton	AUMs/ton of Forage	Dollars/ ton	Gain/ ton
1991	0.42	1.81	18.3	1.86	(7.83)	52.1	0.70	1.44	27.5
1992		*		1.86	82.41	126.2	0.70	35.12	56.6
1993	1.42	59.35	91.9	1.86	53.51	101.8	0.70	44.15	54.0
1994	0.29	1.04	12.5	1.86	(13.85)	40.1	0.70	0.05	25.2
1995	0.86	0.53	34.3	1.86	(6.28)	56.2	0.70	0.34	28.8
1996	2.57	32.88	58.7	1.86	30.28	54.6	0.70	14.72	26.6
1997	1.13	15.53	69.3	1.86	7.03	91.8	0.70	12.66	46.8
1998	0.63	0.31	36.7	1.86	(10.87)	74.6	0.70	0.28	40.3
1999	3.53	55.20	108.3	1.86	42.45	84.5	0.70	18.34	37.2
2000	2.06	16.15	66.4	1.86	15.98	63.4	0.70	8.18	30.5
2001		*		1.86	42.35	85.8	0.70	18.42	36.7
2002	0.00	12.93	32.0	1.86	(18.14)	74.7	0.70	(3.61)	39.0
2003		*		1.86	81.23	58.5	0.70	34.77	28.7
2004	1.98	83.72	69.5	1.86	83.37	74.1	0.70	42.80	49.7
2005	1.47	11.28	40.5	1.86	10.42	45.5	0.70	7.95	22.8
2006		*		1.86	69.20	30.5	0.70	27.88	15.3
2007		*		1.86	57.94	85.9	0.70	23.63	34.8
2008	1.72	51.30	79.7	1.86	50.91	80.4	0.70	31.30	46.2
2009	1.22	18.82	77.3	1.86	14.35	93.2	0.70	15.89	53.8
2010	0.90	9.67	47.0	1.86	(8.59)	65.5	0.70	8.80	37.9
2011	2.39	60.81	82.3	1.86	57.73	77.2	0.70	29.04	38.4
2012	1.25	15.92	49.1	1.86	11.16	61.2	0.70	12.09	30.4
22-year avg.	**1.40**	**26.31**	**57.3**	**1.86**	**29.31**	**71.7**	**0.70**	**17.47**	**36.7**

* The regressions for 1992, 2001, 2003, 2006 and 2007 were not suitable to project the peak in returns to land, labor and management.

We plan to continue this research for a number of years because changes in forage production and plant species composition still are apparent in response to grazing intensity and weather. These factors, in turn, will affect animal response to the grazing treatments.

Literature Cited

Hart, R.H. 1972. Forage yield, stocking rate, and beef gains on pasture. Herbage Abstr. 42:345-353.

Hart, R.H. 1987. Economic analysis of stocking rates and grazing systems. p. 163-172. In: Proc. Beef Cow Symposium X. Coop. Ext. Serv. and Animal Sci. Dept., Univ. of Wyoming, South Dakota State Univ., Colorado State Univ., and Univ. of Nebraska.

Thurow, T.L. 1991. Hydrology and Erosion. In: Heitschmidt, R.K. and Stuth, J.W. (Eds.). Grazing Management: an ecological perspective. Portland, Ore.: Timber Press. 259 pp.

Table 3. Frequency of plant species in 25- by 25-centimeter frames on loamy overflow ecological sites in 1988 and 2012 and their response to long-term grazing.

Scientific Name - Common Name	Treatment										Grazing Response[1]
	Ungrazed		Light		Moderate		Heavy		Extreme		
	1988	2012	1988	2012	1988	2012	1988	2012	1988	2012	
Poa pratensis L. - Kentucky bluegrass	63.33	98.67	62.00	98.67	73.33	98.00	58.67	98.00	72.67	94.00	increase
Symphoricarpos occidentalis Hook. - buckbrush	53.33	59.33	55.33	45.33	49.33	44.00	61.33	48.00	65.33	13.33	decrease
Bromus inermis Leyss. - smooth brome	33.33	94.67	25.33	76.67	31.33	54.00	19.33	52.00	32.00	46.00	decrease
Oligoneuron rigidum (L.) Small var. *humile* (Porter) Nesom - stiff goldenrod	32.00	26.67	40.67	41.33	28.00	68.67	9.33	88.67	12.67	49.33	increase-decrease
Symphyotrichum ericoides (L.) Nesom var. *ericoides* - heath aster	35.33	42.67	23.33	36.67	32.00	46.67	34.67	49.33	40.00	39.33	increase
Artemisia ludoviciana Nutt. - cudweed sagewort	34.00	34.67	22.67	16.67	22.00	34.67	23.33	44.67	39.33	27.33	increase
Carex obtusata Lilj. - obtuse sedge	21.33	28.67	16.00	26.67	23.33	33.33	26.00	38.67	11.33	52.67	increase
Helianthus pauciflorus Nutt. ssp. *pauciflorus* - stiff sunflower	38.67	38.67	30.00	28.00	47.33	20.00	64.67	18.00	49.33	1.33	decrease
Achillea millefolium L. - western yarrow	6.67	8.67	8.00	12.67	2.67	46.67	3.33	53.33	2.67	92.00	increase
Taraxacum officinale F.H. Wigg. - common dandelion	0.00	11.33	0.00	29.33	0.00	68.67	0.00	69.33	0.00	92.67	increase
Carex inops Bailey ssp. *heliophila* (Mackenzie) Crins - sun sedge	46.67	17.33	30.67	14.00	34.00	24.00	30.67	24.67	63.33	81.33	increase
Elymus repens (L.) Gould - quackgrass	20.67	18.67	18.67	35.33	10.00	38.67	10.67	34.67	14.00	44.67	
Ambrosia psilostachya DC. - western ragweed	10.00	16.67	16.00	40.00	21.33	62.00	11.33	54.67	1.33	2.00	increase-decrease
Oxalis stricta L. - yellow wood sorrel	0.00	0.67	0.00	8.67	0.00	6.67	0.00	20.67	0.00	47.33	increase
Andropogon gerardii Vitman - big bluestem	10.00	2.00	41.33	5.33	38.00	34.00	17.33	21.33	5.33	3.33	
Galium boreale L. - northern bedstraw	8.00	22.00	6.00	12.00	10.67	18.00	5.33	8.00	16.00	12.00	
Pascopyrum smithii (Rydb.) A. Löve - western wheatgrass	14.67	2.67	4.67	5.33	4.67	19.33	1.33	35.33	11.33	42.67	increase
Solidago canadensis L. - Canada goldenrod	6.00	10.00	18.67	13.33	3.33	28.67	12.00	8.00	2.67	1.33	increase-decrease
Cerastium arvense L. - prairie chickweed	0.00	0.00	0.00	1.33	0.00	8.67	0.00	9.33	0.00	54.00	increase
Glycyrrhiza lepidota Pursh - wild licorice	12.00	24.00	12.67	34.00	4.67	2.00	8.67	4.67	0.00	0.00	increase-decrease
Viola pedatifida G. Don - larkspur violet	0.67	5.33	0.67	10.67	1.33	17.33	1.33	28.00	0.00	34.00	increase
Cirsium flodmanii (Rydb.) Arthur - Flodman's thistle	4.67	16.67	1.33	15.33	8.67	11.33	8.67	9.33	3.33	12.67	

Rosa arkansana Porter - prairie rose	8.67	22.67	7.33	12.67	10.00	10.67	13.33	2.67	26.00	2.67	decrease
Grindelia squarrosa (Pursh) Dun. - curly-cup gumweed	0.00	0.00	0.00	1.33	0.00	21.33	0.67	33.33	4.67	55.33	increase
Elymus caninus (L.) L. - slender wheatgrass	12.00	8.00	10.00	18.67	10.67	14.67	21.33	23.33	12.67	32.67	increase
Nassella viridula (Trin.) Barkworth - green needlegrass	3.33	0.67	13.33	2.67	3.33	8.67	8.67	8.00	9.33	28.00	increase
Solidago missouriensis Nutt. - Missouri goldenrod	1.33	7.33	0.00	2.67	3.33	9.33	2.00	5.33	4.00	19.33	increase
Agrostis hyemalis (Walt.) B.S.P. - ticklegrass	0.00	0.67	0.00	4.67	0.00	18.67	0.00	19.33	0.00	53.33	increase
Androsace occidentalis Pursh - western rock jasmine	0.00	0.00	0.00	2.00	0.00	2.67	0.00	3.33	0.00	16.67	increase
Medicago lupulina L. - black medic	0.00	10.67	0.00	5.33	0.00	10.00	0.00	26.67	0.00	43.33	invader
Astragalus agrestis Dougl. ex G. Don - field milkvetch	0.67	1.33	0.67	0.67	0.00	4.67	2.00	5.33	2.00	34.67	increase
Solidago mollis Bartl. - soft goldenrod	2.67	4.00	2.00	14.00	6.00	2.00	0.67	3.33	0.67	2.00	increase-decrease
Carex lanuginosa Michx. - wooly sedge	0.00	13.33	0.67	22.00	1.33	2.00	0.00	2.67	0.00	2.00	increase-decrease
Euphorbia serpyllifolia Pers. - thyme-leaved spurge	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.67	0.00	16.00	increase
Conyza canadensis (L.) Cronq. - horse-weed	0.00	0.00	0.00	0.00	0.67	0.00	0.67	0.00	0.00	0.00	increase
Spartina pectinata Link - prairie cordgrass	0.00	4.67	0.00	13.33	0.00	0.67	0.00	0.00	1.33	0.00	increase-decrease
Anemone cylindrica A. Gray - candle anemone	0.00	2.67	0.00	6.67	0.00	10.67	0.00	8.00	0.00	6.67	increase-decrease
Muhlenbergia racemosa (Michx.) B.S.P. - marsh muhly	0.67	2.00	0.67	4.00	2.00	0.67	4.67	2.67	0.00	0.00	increase-decrease
Carex praegracilis W. Boott. - clustered field sedge	0.00	1.33	0.00	18.67	0.00	3.33	0.00	1.33	0.00	2.67	increase-decrease
Artemisia frigida Willd. - fringed sagewort	6.00	0.00	0.00	0.00	0.67	0.00	0.67	0.00	0.00	2.67	increase
Trifolium repens L. - white clover	0.00	0.00	0.00	0.00	0.00	1.33	0.00	0.00	0.00	48.00	invader
Juncus balticus Willd. - Baltic rush	0.00	0.00	2.00	15.33	0.00	0.00	0.00	0.00	0.00	0.00	increase-decrease
Erigeron philadelphicus L. - Philadelphia fleabane	0.00	0.00	0.00	1.33	0.00	2.67	0.00	0.67	0.00	0.00	increase
Penstemon gracilis Nutt. - slender beardtongue	0.00	0.00	0.00	0.67	0.00	0.67	0.00	0.00	0.00	14.67	increase
Campanula rotundifolia L. - harebell	0.00	0.00	0.00	0.00	0.67	0.00	0.67	0.00	0.00	0.00	increase-decrease
Sisyrinchium montanum Greene. - blue-eyed grass	0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	increase-decrease
Polygonum ramosissimum Michx. - bushy knotweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.67	invader

Agrimonia striata Michx. - striate agrimony	0.00	0.00	0.00	2.67	0.00	2.67	0.00	0.00	0.00	0.00	increase-decrease
Erysimum inconspicuum (S. Wats.) MacM. - smallflower wallflower	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	increase
Packera plattensis (Nutt.) W.A. Weber & A. Löve - prairie ragwort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	increase-decrease
Draba nemorosa L. - yellow whitlowort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	increase
Lithospermum incisum Lehm. - yellow puccoon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.67	invader
Poa palustris L. - fowl bluegrass	0.00	0.67	0.00	5.33	0.00	0.00	0.00	0.00	0.00	0.00	increase-decrease
Sonchus arvensis L. - field sow thistle	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	decrease
Lepidium densiflorum Schrad. - peppergrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	invader
Liatris ligulistylis (A. Nels.) K. Schum. - round-headed blazing star	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	decrease

[1]"Decrease" indicates that the species seems to be favored by rest. "Increase-decrease" indicates that the species seems to be favored by moderate grazing. These are species that increase as grazing pressure increases from ungrazed to moderately grazed, but decrease as grazing pressure increases from moderate to extreme. "Increase" indicates that the species seems to be favored by heavy grazing, and "Invader" indicates species that only appear on the site after heavy grazing. No entry indicates that the species has not responded to grazing but averaged at more than 10 percent frequency during the period of the study.

Table 4. Frequency of plant species in 25- by 25-centimeterm frames on loamy ecological sites in 1988 and 2012 and their response to long-term grazing.

Scientific Name - Common Name	Treatment										Grazing Response[1]
	Ungrazed		Light		Moderate		Heavy		Extreme		
	1988	2012	1988	2012	1988	2012	1988	2012	1988	2012	
Poa pratensis L. - Kentucky bluegrass	86.00	100.00	84.67	99.33	92.67	99.33	75.33	96.67	82.00	96.67	decrease
Pascopyrum smithii (Rydb.) A. Löve - western wheatgrass	58.67	69.33	30.00	56.00	64.67	82.00	42.67	69.33	57.67	80.67	increase
Carex inops Bailey ssp. *heliophila* (Mackenzie) Crins - sun sedge	50.67	30.00	72.00	38.67	76.67	48.67	77.33	75.33	75.67	50.67	increase
Symphyotrichum ericoides (L.) Nesom var. *ericoides* - heath aster	29.33	60.00	45.33	62.67	38.67	57.33	39.33	49.33	35.00	44.67	increase-decrease
Artemisia ludoviciana Nutt. - cudweed sagewort	5.33	29.33	31.33	58.00	24.00	38.67	29.33	54.00	12.33	18.67	increase-decrease
Nassella viridula (Trin.) Barkworth - green needlegrass	36.67	12.00	34.67	10.00	48.67	60.00	30.00	67.33	41.00	55.33	increase
Carex obtusata Lilj. - obtuse sedge	16.00	44.67	16.67	67.33	15.33	41.33	8.67	52.67	6.67	19.33	
Achillea millefolium L. - western yarrow	4.00	41.33	1.33	18.00	7.33	48.00	3.33	42.00	3.67	84.67	increase
Taraxacum officinale F.H. Wigg. - common dandelion	0.67	44.67	0.00	11.33	0.00	48.00	0.00	52.00	0.00	94.00	increase
Bouteloua gracilis (H.B.K.) Lag. ex Griffiths - blue grama	49.33	1.33	24.67	4.00	42.00	28.00	45.33	56.67	30.33	45.33	increase
Oligoneuron rigidum (L.) Small var. *humile* (Porter) Nesom - stiff goldenrod	0.67	54.67	0.00	42.67	0.67	92.67	0.00	74.00	1.00	41.33	
Artemisia frigida Willd. - fringed sagewort	8.67	4.00	2.67	1.33	4.67	14.00	6.67	40.67	3.33	21.33	increase
Vicia americana Muhl. ex Willd. - American vetch	0.00	8.00	0.67	2.00	2.67	8.00	1.33	9.33	1.67	24.00	increase
Grindelia squarrosa (Pursh) Dun. - curly-cup gumweed	0.67	6.67	0.67	2.67	0.00	21.33	0.00	43.33	1.00	49.33	increase
Cerastium arvense L. - prairie chickweed	0.00	7.33	0.00	1.33	0.00	30.67	0.00	32.67	0.00	62.67	increase
Ambrosia psilostachya DC. - western ragweed	3.33	59.33	2.00	60.67	3.33	74.00	0.67	31.33	0.00	0.67	increase-decrease
Hesperostipa curtiseta (Hitchc.) Barkworth - western porcupine grass	8.67	2.67	16.00	7.33	4.00	10.00	8.00	20.67	8.33	14.67	increase-decrease
Dichanthelium wilcoxianum (Vassey) Freckmann - Wilcox dichanthelium	0.00	3.33	2.00	9.33	3.33	45.33	2.67	54.67	2.00	35.33	increase-decrease
Astragalus agrestis Dougl. ex G. Don - field milkvetch	2.67	4.67	1.33	6.67	2.00	20.00	3.33	16.67	7.33	40.00	increase
Cirsium flodmanii (Rydb.) Arthur - Flodman's thistle	0.00	22.00	6.67	24.67	6.67	22.00	4.00	20.00	1.33	8.67	increase-decrease
Elymus repens (L.) Gould - quackgrass	0.67	20.67	2.00	42.67	1.33	55.33	0.00	27.33	2.00	24.00	increase-decrease
Androsace occidentalis Pursh - western rock jasmine	0.00	0.67	0.00	0.67	0.00	2.00	0.00	2.00	0.00	4.00	increase

Koeleria macrantha (Ledeb.) J.A. Schultes - Junegrass	8.67	1.33	0.00	2.67	4.00	16.67	0.00	34.67	3.33	18.00	increase
Ratibida columnifera (Nutt.) Woot. & Standl. - prairie cone-flower	3.33	2.00	1.33	7.33	2.00	18.67	2.00	25.33	2.00	9.33	increase-decrease
Hesperostipa comata (Trin. & Rupr.) Barkworth - needle-and-thread	14.67	0.67	17.33	0.00	14.67	8.00	29.33	18.00	28.67	2.00	
Carex eleocharis Bailey. - needle-leaved sedge	0.00	0.00	0.00	0.00	0.00	2.00	0.00	2.00	0.00	0.67	increase
Solidago missouriensis Nutt. - Missouri goldenrod	2.00	10.00	0.00	8.67	0.67	9.33	2.67	20.00	1.00	18.67	
Lotus purshianus (Benth.) Clem. & Clem. - deer vetch	0.00	18.67	0.00	4.00	2.00	16.67	0.00	2.67	0.00	5.33	decrease
Psoralea argophylla Pursh - silver-leaf scurf-pea	3.33	4.67	14.00	5.33	1.33	5.33	10.00	12.67	2.67	1.33	increase-decrease
Solidago mollis Bartl. - soft goldenrod	0.67	4.67	0.00	18.67	2.67	14.00	4.00	17.33	6.00	6.00	increase-decrease
Helianthus pauciflorus Nutt. ssp. *pauciflorus* - stiff sunflower	0.00	32.67	10.67	10.67	0.00	14.00	6.67	8.67	4.67	0.00	decrease
Oxalis stricta L. - yellow wood sorrel	0.00	4.00	0.00	0.67	0.00	0.67	0.00	2.00	0.00	2.67	increase
Comandra umbellata (L.) Nutt. - comandra	0.00	1.33	8.00	14.00	7.33	18.00	0.67	12.00	0.00	0.00	increase-decrease
Euphorbia serpyllifolia Pers. - thyme-leaved spurge	0.00	0.67	0.00	0.00	0.00	4.67	0.00	8.00	0.00	6.67	increase
Rosa arkansana Porter - prairie rose	0.00	2.00	12.67	19.33	0.67	2.00	6.67	4.00	2.00	0.67	increase-decrease
Hedeoma hispidum Pursh - rough false pennyroyal	0.00	0.00	0.00	0.00	0.00	0.67	0.00	2.00	0.00	4.00	increase
Plantago patagonica Jacq. - wooly plantain	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.33	0.00	0.00	increase
Artemisia absinthium L. - wormwood	0.00	23.33	0.00	4.00	0.00	2.00	0.00	10.00	0.00	2.67	decrease
Bromus inermis Leyss. - smooth brome	0.00	4.67	1.33	28.67	1.33	10.00	0.00	1.33	0.00	0.00	increase-decrease
Potentilla pensylvanica L. - Pennsylvania cinquefoil	0.00	0.00	0.00	0.00	0.00	2.67	0.00	6.00	0.00	6.67	increase
Penstemon gracilis Nutt. - slender beardtongue	0.00	0.67	0.00	0.00	0.00	10.00	0.00	8.00	0.00	10.67	increase
Geum triflorum Pursh - prairie smoke	0.00	0.67	0.00	4.67	0.00	11.33	0.00	16.67	0.00	9.33	increase
Sphaeralcea coccinea (Pursh) Rydb. - scarlet globe mallow	14.67	0.67	3.33	0.00	7.33	1.33	4.00	0.67	10.33	2.67	increase
Medicago lupulina L. - black medic	0.00	4.67	0.00	0.67	0.00	2.00	0.00	3.33	0.00	51.33	invader
Tragopogon dubius Scop. - goat's beard	0.67	2.00	0.00	3.33	0.67	1.33	0.67	2.00	0.00	2.67	decrease
Agrostis hyemalis (Walt.) B.S.P. - ticklegrass	0.00	1.33	0.00	0.67	0.00	6.67	0.00	4.00	0.00	20.67	invader
Artemisia dracunculus L. - green sagewort	0.00	0.00	0.67	1.33	0.00	3.33	0.67	6.00	0.00	0.67	increase-decrease
Carex filifolia Nutt. - thread-leaved sedge	0.00	0.00	0.00	0.00	0.00	0.00	2.00	8.67	1.33	0.00	increase-decrease

Draba nemorosa L. - yellow whitlowort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	increase
Anemone cylindrica A. Gray - candle anemone	0.00	1.33	0.00	2.00	0.00	10.67	0.00	12.00	0.00	8.00	increase-decrease
Bouteloua dactyloides (Nutt.) J.T. Columbus - buffalograss	0.67	0.00	0.00	0.00	0.00	1.33	0.00	7.33	0.00	11.33	increase
Antennaria neglecta Greene - field pussy-toes	0.00	0.67	0.00	2.00	0.00	3.33	0.00	2.00	0.00	13.33	increase
Lithospermum incisum Lehm. - yellow puccoon	0.00	0.00	0.00	0.00	2.00	2.00	0.00	12.00	0.00	0.00	increase-decrease
Sisyrinchium montanum Greene. - blue-eyed grass	0.00	0.67	0.00	0.67	0.00	2.00	0.00	4.00	0.00	0.00	increase-decrease
Calamagrostis montanensis (Scribn.) Scribn. - plains reedgrass	0.00	0.00	0.00	0.00	0.00	1.33	0.00	0.67	0.00	1.33	increase-decrease
Asclepias ovalifolia Dcne. - ovalleaf milkweed	0.00	2.67	0.67	4.67	0.00	0.00	0.00	0.00	0.00	0.00	increase-decrease
Erysimum asperum (Nutt.) DC. - western wallflower	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	increase-decrease
Arabis hirsuta (L.) Scop. var. *pycnocarpa* (Hopkins) Rollins - rock cress	0.00	0.67	0.00	0.67	0.00	2.00	0.00	0.00	0.00	0.67	increase-decrease
Lepidium densiflorum Schrad. - peppergrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	increase
Juncus interior Wieg. - inland rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.33	invader
Trifolium repens L. - white clover	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	22.00	invader
Chrysopsis villosa (Pursh) Nutt. - golden aster	0.00	0.00	1.33	0.67	0.00	0.00	2.00	8.00	0.00	1.33	increase-decrease
Potentilla norvegica L. - Norwegian cinquefoil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	increase
Erysimum inconspicuum (S. Wats.) MacM. - smallflower wall-flower	0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	increase-decrease
Polygonum ramosissimum Michx. - bushy knotweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.00	invader
Orthocarpus luteus Nutt. - owl clover	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	increase-decrease
Psoralea esculenta Pursh - breadroot scurf-pea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	decrease

[1]"Decrease" indicates that the species is favored by rest. "Increase-decrease" indicates that the species is favored by moderate grazing. These are species that increase as grazing pressure increases from ungrazed to moderately grazed, but decrease as grazing pressure increases from moderate to extreme. "Increase" indicates that the species is favored by heavy grazing, and "Invader" indicates species that only appear on the site after heavy grazing. No entry indicates that the species has not responded to grazing but averaged at more than 10 percent frequency during the period of the study.

(blank)