FINAL REPORT

IOWA WATER QUALITY/WATERSHED PROTECTION PROJECT

Project title:

Use of Grazing Management to Limit Sediment and Phosphorus Pollution of Pasture Streams from Streambank Erosion and Manure Deposition

DNR Agreement number: 04-7143-10

Dates covered: July 1, 2004 to December 31, 2007

Project personnel:

Participant	Affiliation
Dr. James R. Russell	Dept. of Animal Science, Iowa State University
Dr. Daniel G. Morrical	Dept. of Animal Science, Iowa State University
Dr. John L. Kovar	USDA-ARS National Soil Tilth Laboratory
Dr. Daryl Strohbehn	Dept. of Animal Science, Iowa State University
Dr. John D. Lawrence	Dept. of Economics, Iowa State University
Dr. Wendy Powers	Dept. of Animal Science, Michigan State University
Mr. Mathew. M. Haan	Dept. of Animal Science, Iowa State University
Ms. Shelly Nellesen	Dept. of Agronomy, Iowa State University

Executive Summary

Sediment and phosphorus are major non-point source pollutants affecting Iowa's surface waters. It has been demonstrated that managed grazing of pastures can reduce the amounts of these pollutants transported in surface runoff from upland areas of pastures. However, because much of the sediment and phosphorus arriving in surface waters likely originates from stream banks and riparian areas, improved management practices to reduce sediment and phosphorus from these areas need to be demonstrated. A three-year grazing study, initiated in the spring of 2005, was conducted at the Rhodes Research farm in central Iowa to demonstrate the effects of continuous stocking of cattle having unrestricted stream access (CSU), continuous stocking of cattle with stream access restricted to a reinforced crossing with the remainder of the riparian area fenced to prevent cattle access (CSR), and rotational stocking with grazing of the riparian paddock limited to a maximum of 4 days or a minimum forage sward height of 4 inches (RS). Over the three years of the demonstration, stream bank erosion and channel morphology were measured, as were the occurrence of bare and fecal-covered ground and forage sward height and mass in the riparian and upland portions of the pasture. Cattle distribution patterns were also monitored monthly during the grazing seasons to determine the proportion of time cattle were in the stream and riparian areas of pastures. Stream bank erosion susceptibility scores were greater in CSU pastures during the 2006 and 2007 grazing seasons than in CSR or RS pastures. Even though stream banks in CSU pastures were more susceptible to erosion than were stream banks in CSR and RS pastures, no difference in net stream bank erosion was observed between grazing management practices in any year. Annual net stream bank erosion averaged -2.13 (erosion), 0.03 (deposition), and 2.57 (erosion) inches across all treatments in 2005, 2006, and 2007, respectively, resulting in 92, 7.8, and 20 pounds of phosphorus loss per year, respectively. No differences were observed between grazing management practices in the proportion of bare ground on stream banks except in September and October of 2007, when CSU pastures had a greater proportion of bare ground on the banks than did CSR pastures. Forage mass along stream banks and within 110 feet of streams did not differ between CSR and RS pastures during most months, while CSU pastures had or tended to have a lower forage masses than did CSR pastures in several months. Over three grazing seasons, cattle were in or within 110 feet of the stream an average of 6 and 16% of the time, respectively, in CSU pastures, based on visual observations. Based on GPS collars, cattle were in or within 110 feet of the stream an average of 1.2 and 10.6%, respectively, in CSU pastures. Based on visual observation and GPS collars, the proportion of time cattle in CSR and RS pastures were present in and within 110 feet of the stream were less than CSU pastures. The presence of off-stream water decreased the proportion of time cattle spent in the stream during the 2006 grazing season, but not in 2005 or 2007. At greater ambient temperatures, (°C; $Y=8.9 - 1.27X + 0.063X^2$, R^2=.87) the proportion of time cattle were within 110 feet of the stream increased. Observed cattle distribution patterns were highly related (R^2=.99) with defecation distribution patterns.

Conclusions

- **When cattle were allowed unrestricted access to a pasture stream they averaged 1.3% of the time within the stream (1% of pasture area) and an additional 8.8% within the riparian area (6.1% of pasture area).**

- **Restricting access to pasture streams to stabilized crossings or use of rotational grazing with limited grazing of riparian paddocks will reduce the proportion of time grazing cattle are in or near pasture streams**

- **Providing off-stream water sources at sites that are a minimum of 730 feet from a pasture stream may reduce the proportion of time cattle are in or near streams if no natural sources of off-stream water are present.**

- **By altering cattle distribution, restricting access of grazing cattle to stabilized crossings or rotational grazing will reduce the potential for sediment and phosphorus loading of pasture streams as implied by greater forage masses and sward heights and lower proportions of bare and manure-covered ground on and/or near pasture stream banks compared to continuous stocking of grazing cattle with unrestricted access to pasture streams.**

- **Because net erosion and soil erosion-deposition activity did not differ between grazing treatments and there were no month by treatment interactions for erosion susceptibility score or stream channel morphology, the effects of natural variation in stream bank erosion were greater than any effects of grazing over 3 years.**

Introduction:

Because of its association with eutrophication of rivers and lakes, phosphorus loading of surface water sources is a major non-point source pollution problem in Iowa. As much of the phosphorus in soil is adsorbed to soil particles, soil erosion promotes phosphorus pollution of surface water sources. It is recognized that overgrazing along pasture streams may result in soil erosion, but little research has evaluated the effects of grazing management on sediment and phosphorus loading of pasture streams in the Midwest. In a previous study at the Rhodes Research Farm, rotational grazing to a residual height of 4 inches reduced sediment and phosphorus losses from upland pastures by as much as 90 and 80% compared to continuous grazing to a sward height of 2 inches, primarily by reducing the proportions of bare soil. Therefore, grazing management seems to be a practice that should be considered to limit sediment and phosphorus loading of pasture streams.

While upland sediment and phosphorus flow likely contribute to non-point source pollution of surface water sources, sediment and phosphorus flows from congregating locations within riparian areas, stream bank erosion, and direct deposition of feces and urine may have greater effects on stream water quality because of their proximity to streams. Altering grazing animal behavior by maintaining adequate forage outside the riparian area through control of grazing intensity, duration, and timing, providing controlled access to riparian areas, providing alternative water sites, improving ramps and fording areas to and across streams and/or providing shade away from streams have been proposed as methods to reduce sediment and phosphorus loading of pasture streams from stream bank erosion and direct deposition of animal wastes. The goal of this project was to evaluate and demonstrate the effectiveness of restricting grazing to stabilized crossings or rotational stocking as management practices to reduce non-point source pollution of pasture streams.

Objectives:

1) **To quantify losses of sediment and phosphorus (P) from stream banks in pastures grazed under different stocking systems at a single location to control animal management and minimize differences in factors such as stream flow and structure, soil chemical and physical structure and riparian and upland pasture vegetation.**
2) **To measure the spatial and temporal distribution patterns of location, defecation, and urination of beef cattle managed in different stocking systems in pastures with upland and riparian zones.**
3) **To demonstrate site-specific models of grazing management practices that optimize the quality of stream water and the profitability of beef cow-calf production in pastures in Iowa.**

Materials & Methods:

Grazing Management
Six 30-acre cool-season grass pastures, each bisected by a 462-foot segment of Willow Creek in Marshall County, Iowa, were grouped into 2 blocks and assigned one of three grazing management treatments. Treatments included: continuous stocking with unrestricted stream access (CSU), continuous stocking with stream access restricted to a 16-foot wide crushed rock crossing (CSR), and 5-paddock rotational stocking with one paddock in the riparian zone (RS). Riparian paddocks in the RS treatment were stocked until forage sward height decreased to a minimum of 4 inches or for a maximum of 4 days. Grazing was not allowed in approximately 2.25 acres that were fenced as riparian buffers on either side of the crossing in the CSR treatment. Each pasture was stocked with 15 fall-calving Angus cows from mid-May through mid-October in 2005, 2006, and 2007 (initial mean BW = 1428, 1271, and 1369 lbs., respectively).

Stream Bank Erosion Susceptibility Score, Stream Channel Morphology, and Stream Bank Surface Roughness
Pre-, mid-, and post-grazing in each year, stream banks were visually scored and stream channel morphology and stream bank roughness were measured. Stream banks within each pasture were visually evaluated and assigned a score for slope (1(flat) to 3(steep)), vegetative cover (1 (heavy) to 4 (bare)), and stability (1 (stable) to 5 (very unstable)). An overall erosion susceptibility score was calculated as the product of these values weighted for their percentage of stream length. Stream bank erosion susceptibility score ranged from 1 to 60 with a greater value indicating greater potential for erosion to occur.

Digital photographs were taken of the channel cross-sections at 10 transects placed at equal distances in the stream across each pasture. Photographs were analyzed by image analysis to measure stream morphology characteristics (channel area, stream width, and width between the tops of the banks).

Surface roughness was measured using a 41-pin meter with a length of 2 m from the stream's edge on banks on each side of the stream at each of the 10 transects. Surface roughness was calculated as the average standard deviation in pin length.

Stream Bank Erosion
Stream bank erosion was measured using 5/8 x 30 inch fiberglass pins inserted perpendicularly into the bank to a depth of 28 inches at intervals of 36 inches from the stream surface to the top of both banks at the 10 equidistant transects in each pasture. Lengths of exposed pins were measured monthly in May through November of all years. Net erosion and erosion/deposition activity (the absolute value of the change in exposed erosion pin length) were calculated as the change in pin length within each transect and averaged by pasture.

To refine our estimates of stream bank erosion and deposition, we used ground-based LiDAR (Light Detection and Ranging) technology to capture a 3D image of stream banks in each of the six pastures. Scanning was conducted (Leica HDS300 laser scanner, 6 mm accuracy at 50 m) pre- and post-grazing in 2006 and 2007 at one site per pasture. One pasture (Pasture 5) has two LiDAR sites, because it includes a very active stream cut bank with two transects of erosion pins. These scan data are useful for gathering information comparing the accuracy of LiDAR to erosion pin measurements for monitoring erosion of stream banks.

Stream Stage and Microclimate
Stream stage was monitored throughout the three grazing seasons to determine the effect of precipitation events on the height of the water column in Willow Creek. Pressure transducers (GE Druck Inc, New Fairfield, CT) were installed in farthest upstream and downstream points of the stream reach within the project area. The transducers measured water stage (height) in the creek every 15 minutes. Daily high and low stages are recorded on Campbell CR-10 and CR-510 data loggers. Data were downloaded weekly. Rainfall was measured with rain gauges in the uplands on both sides of the stream. Ambient temperature, black globe temperature, wind speed and direction, and relative humidity were recorded at 10 minute intervals using a HOBO weather station equipped with data loggers.

Bare and Fecal-covered Ground and Forage Mass, Sward Height, and Nutrient Concentration
Forage sward height, mass and nutrient composition and the proportion of bare and fecal-covered ground were determined monthly from open and congregation areas within 4 zones in the pasture. Zones were defined as on the stream bank (bank), from the stream bank to 110 feet from the stream bank (110), 110 feet to 220 feet from the stream bank (220), and greater than 220 feet from the stream bank (upland). Congregation areas were defined as areas providing cattle access to the stream, water tanks or mineral supplementation sites, and under the drip-line of trees. Open areas were any areas that were not classified as a congregation area. Area of congregation areas was determined with tape measures in August of each year.

The proportions of bare and manure-covered ground and sward heights were measured and forage samples were hand-clipped from a 0.25-m^2 square at 6 sites in open and congregation areas on the banks and in the 110 and 220 foot zones in each pasture unless limited by the number of congregation areas. In the upland zone, proportions of bare and fecal-covered ground and sward height were measured in 48 open and 24 congregation areas and forage samples were hand-clipped from 24 open and congregation areas. The proportions of bare or fecal-covered ground were determined by a line-transect method over 50 feet. Forage sward height was measured with a rising plate meter (8.8 lb/yd^2). Forage samples were analyzed for *in vitro* dry matter disappearance (IVDMD), crude protein (CP), and phosphorus (P). Mean proportions of bare and fecal-covered ground and the forage mass, sward height and nutrient concentrations within each zone of each pasture were calculated as weighted averages, based on the ratio of open and congregation area. To evaluate the possibility of nutrient accumulation or loss near the stream, forage composition data from the stream banks and the 110 foot zone were analyzed across treatments. In analysis of the nutritional value of the grazed forage, data from the stream banks and the 110 foot zone in the CSR pastures were excluded.

Data were analyzed using the MIXED procedure of SAS. Proportions of congregation areas within pasture zones were analyzed by zone with a model which included treatment, year and treatment × year. The proportions of bare and fecal covered ground, and forage mass, sward height and nutrient composition were analyzed by year and month with a model which included treatment. Block was a random variable for all analysis. Values reported in text and figures are LSmeans, effects were considered to differ at $P<.10$ and tended to differ at $P<.20$.

Cattle Distribution, Alternative Water, Defecation Patterns, Microclimate

Cattle distribution patterns were monitored by visual observation and with GPS collars. During visual observations, cattle distribution patterns were monitored from 0600 to 1800 hours on two consecutive days during seven observation periods in 2005 and five observation periods in 2006 and 2007. Observations were conducted in May, June, July, August, and September without access to alternative watering sites for cattle in the continuously stocked pastures in both years. A second observation period occurred in May and July of 2005 after cows were allowed 1 week to adjust to the presence of off-stream water sites in continuously stocked pastures. Off-stream water sources were located at a minimum distance of 730 feet from the stream in the upland portion of the pastures on both sides of the stream. Cow herd location, number of cattle in the herd, and observed defecations and urinations were recorded at 10 minute intervals during observations.

To record cattle distribution, a GPS collar (AgTraX^{tm} - BlueSky Telemetry, Aberfeldy, Scotland) was placed on one cow per pasture for approximately 2 weeks in each month from May through September. Collars were programmed to record cattle position data at 10 minute intervals for 24 hours per day during the 2 week period. In 2005, GPS collar data sets were not complete due to technical difficulties, and, therefore, only 2006 and 2007 GPS collar data were analyzed. Cattle location was determined using position data from GPS collars and ArcGIS 9.1 software. For time periods in which GPS collars were unable to record cattle position, the position was assumed to be the same as the previous reading. In 2006 and 2007, the effects of off-stream water on cattle distribution was evaluated by providing access of off-stream water to cows during the second week in which GPS collars were attached to the cows in May, July, and September.

Using GPS data, cattle location was defined as within stream (stream), 0 to 110 ft (110) from the stream, 110 to 220 ft (220) from the stream, and greater than 220 ft (upland) from the stream. The 110 zone was approximately the same width as the riparian paddock in the RS pastures and the grazing exclusion area in the CSR pastures. The 220 zone included the remainder of the riparian area. The stream, 110, 220, and upland zones were 1.1, 6.1, 6.1, and 86.8% of the total pasture area, respectively.

Data were analyzed using the GLM procedure of SAS. Values reported are LSmeans. Means are considered different at $P<0.05$ with a tendency for a difference at $P<0.10$.

Fecal and Phosphorus Excretion by Cattle

In June and August of all years, 2 cows per pasture were dosed with chromium-mordanted fiber and fecal samples were collected over the following five days. Fecal samples were analyzed for chromium concentration and total daily fecal excretion was calculated from the passage kinetics of Cr. Fecal samples were also analyzed for phosphorus concentration and daily excretion of phosphorus was calculated as the product of the fecal excretion and phosphorus concentration..

Results & Discussion:

Objective 1: Stream Bank Erosion Monitoring and Analysis

Rainfall and Stream Stage

Total annual precipitation during 2005, 2006, and 2007 was 36.1, 32.1, and 40.2 inches (Data from NOAA-COOP weather station in Colo, IA; 2007 does not include December precipitation), 30 year average precipitation for the area is 32.2 inches. Rainfall during the 2005 (Fig. 1), 2006 (Fig. 2), and 2007 (Fig. 3) grazing seasons were 25.0, 18.9, and 27.0 inches, respectively. Mean, 30-year average rainfall during this time period (May 15 through October 15) is 28.7 inches. Lower rainfall during the 2006 grazing season resulted in fewer and smaller spikes in stream flow during 2006 (Fig. 5) than in the 2005 (Fig. 4) grazing season. Rainfall during 2007 was more evenly distributed than during the previous years, with the exception of a dry period during July. This precipitation pattern resulted in a relatively flat hydrograph (Fig. 6).

Figure 1. Rainfall during 2005 grazing season.

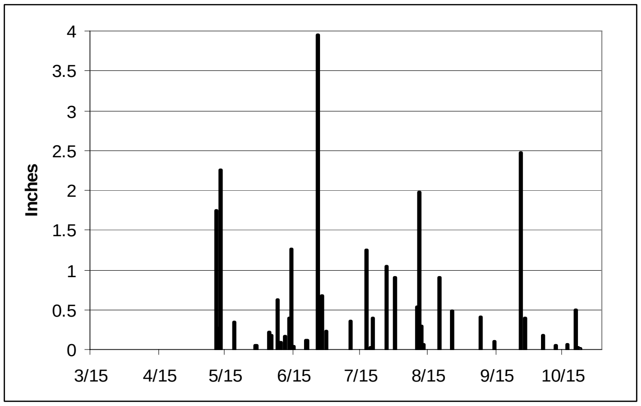


Figure 2. Rainfall during 2006 grazing season.

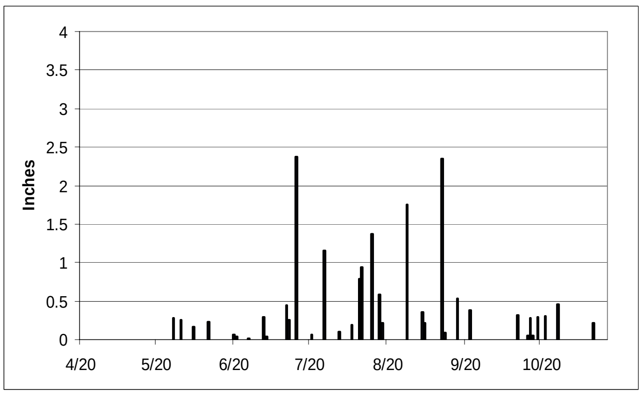


Figure 3. Rainfall during the 2007 Grazing Season.

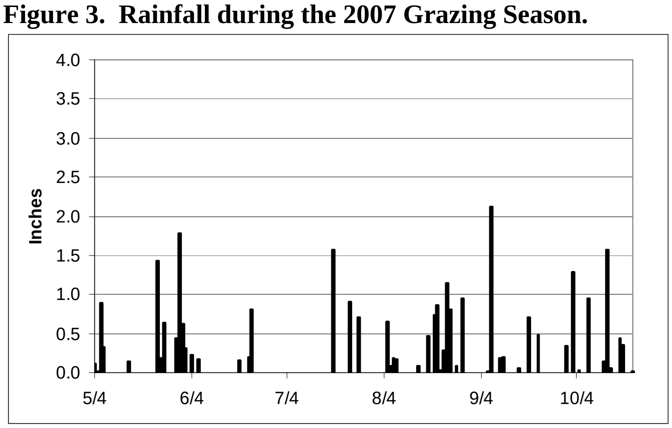


Figure 4. 2005 Willow Creek stream stage.

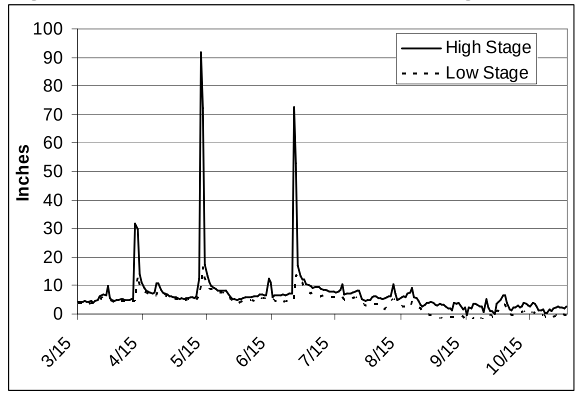


Figure 5. 2006 Willow Creek stream stage.

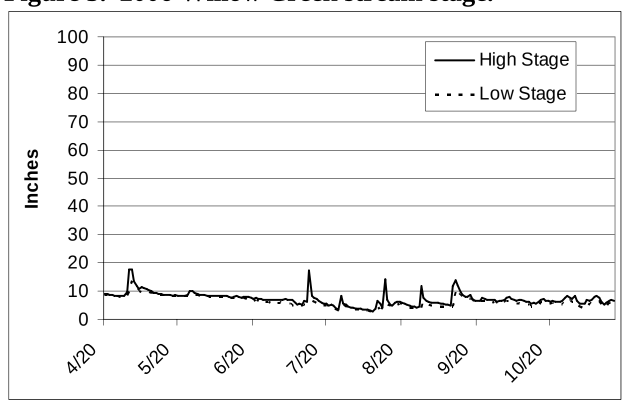
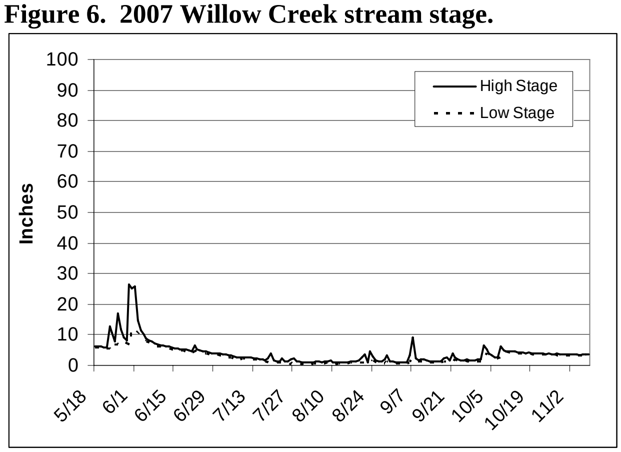


Figure 6. 2007 Willow Creek stream stage.



Stream Bank Erosion Susceptibility Score

Stream bank slope score did not differ between grazing management treatment or sampling period (pre-, mid-, or post-grazing) in any year (Table 1). Stream bank vegetative cover score was greater ($P<.05$) in CSU pastures than in either CSR or RS pastures in 2006 and 2007 (Table 2). A greater vegetative cover score indicates a greater amount of bare ground along the stream banks caused either from removal by grazing cattle or sloughing of soil from erosion. Stream bank stability score was greater ($P<.05$) in CSU pastures than in either CSR or RS pastures during all study years (Table 3). A greater stability score indicates a greater instability of the stream banks. Given that CSU pastures had greater stability scores pre-grazing in 2005, differences in stability score at later periods may not be a result of grazing management, but may reflect natural variability in the stream banks. Stream bank erosion susceptibility score tended to be greater ($P=.06$) in 2005 and was greater ($P<.05$) in 2006 and 2007 in CSU pastures than in either CSR or RS pastures (Table 4). The greater erosion susceptibility score indicates that stream banks in CSU pastures have a greater potential for erosion to occur than do stream banks in CSR or RS pastures. However, similar to the stability score, the lack of treatment by period interactions implies that the greater erosion susceptibility of CSU pastures than CSR and RS pastures may have been more due to natural characteristics of the pastures than to grazing treatments.

Table 1. Stream bank slope score[1] as affected by grazing management over three grazing seasons.

	2005			2006			2007		
	Pre[2]	Mid	Post	Pre	Mid	Post	Pre	Mid	Post
CSU[3]	2.47	2.40	2.13	2.43	2.41	2.48	2.47	2.42	2.20
CSR	2.59	2.58	2.47	2.72	2.71	2.67	2.64	2.68	2.58
RS	2.49	2.40	2.39	2.50	2.54	2.64	2.41	2.55	2.41
	trt	NS		trt	NS		trt	NS	
	prd	NS		prd	NS		prd	NS	
	trt×prd	NS		trt×prd	NS		trt×prd	NS	

[1]Slope score (1 = Flat, 3 = Steep).
[2]Pre = pre-grazing (early May), Mid = mid-grazing (late July), Post = post-grazing (mid October).
[3]CSU = Continuous stocking with unrestricted stream access, CSR= Continuous stocking with restricted stream access, RS = Rotational stocking.

Table 2. Stream bank vegetative cover score[1] as affected by grazing management over three grazing seasons.

	2005			2006			2007		
	Pre[2]	Mid	Post	Pre	Mid	Post	Pre	Mid	Post
CSU[3]	2.80	2.84	2.86	3.03	2.73	2.58	3.22	2.94	2.83
CSR	2.43	2.15	2.08	2.26	1.72	1.64	2.49	1.88	1.71
RS	2.15	2.36	2.28	2.32	1.88	1.86	2.62	1.83	1.96
	trt	NS		trt	.05		trt	.05	
	prd	NS		prd	NS		prd	NS	
	trt×prd	NS		trt×prd	NS		trt×prd	NS	

[1]Vegetative cover score (1 = Heavy, 4 = Bare).
[2]Pre = pre-grazing (early May), Mid = mid-grazing (late July), Post = post-grazing (mid October).
[3]CSU = Continuous stocking with unrestricted stream access, CSR= Continuous stocking with restricted stream access, RS = Rotational stocking.

Table 3. Stream bank stability score[1] as affected by grazing management over three grazing seasons.

	2005			2006			2007		
	Pre[2]	Mid	Post	Pre	Mid	Post	Pre	Mid	Post
CSU[3]	3.50	3.96	4.22	3.83	4.03	3.79	4.20	4.22	3.69
CSR	3.10	2.96	2.96	3.00	2.32	2.54	3.58	2.69	2.37
RS	2.70	2.66	3.36	3.22	2.81	2.98	3.85	2.76	2.70
	trt	.05		trt	.05		trt	.05	
	prd	NS		prd	NS		prd	.06	
	trt×prd	NS		trt×prd	NS		trt×prd	NS	

[1]Stability score (1 = Stable, 5 = Unstable).
[2]Pre = pre-grazing (early May), Mid = mid-grazing (late July), Post = post-grazing (mid October).
[3]CSU = Continuous stocking with unrestricted stream access, CSR= Continuous stocking with restricted stream access, RS = Rotational stocking.

Table 4. Stream bank erosion susceptibility score[1] as affected by grazing management over three grazing seasons.

	2005			2006			2007		
	Pre[2]	Mid	Post	Pre	Mid	Post	Pre	Mid	Post
CSU[3]	29.67	28.42	26.05	31.34	27.49	26.19	37.94	31.16	23.70
CSR	21.42	19.08	17.14	21.53	13.49	14.00	25.22	16.22	12.42
RS	18.68	17.31	20.52	22.26	17.04	17.43	25.93	15.91	14.38
	trt	.06		trt	.05		trt	.05	
	prd	NS		prd	NS		prd	.05	
	trt×prd	NS		trt×prd	NS		trt×prd	NS	

[1]Bank erosion susceptibility score (1 to 60 = Slope score × Veg. cover score × Stability score). A higher number indicates greater potential for erosion to occur.
[2]Pre = pre-grazing (early May), Mid = mid-grazing (late July), Post = post-grazing (mid October).
[3]CSU = Continuous stocking with unrestricted stream access, CSR= Continuous stocking with restricted stream access, RS = Rotational stocking.

Stream Bank Surface Roughness

Stream bank surface roughness was not affected by grazing management in any year (Table 5).

Table 5. Stream bank surface roughness[1] as affected by grazing management over three grazing seasons.

	2005			2006			2007		
	Pre[2]	Mid	Post	Pre	Mid	Post	Pre	Mid	Post
CSU[3]	2.02	1.83	1.72	1.42	1.91	1.63	1.97	1.88	1.55
CSR	1.70	1.82	1.86	1.55	1.66	1.74	1.91	1.91	1.81
RS	1.93	1.88	1.92	1.74	1.95	2.05	2.13	2.00	1.75
	trt	NS		trt	NS		trt	NS	
	prd	NS		prd	.11		prd	.17	
	trt×prd	NS		trt×prd	NS		trt×prd	NS	

[1]Surface roughness was determined as the average standard deviation of pins on a 41-pin min meter.
[2]Pre = pre-grazing (early May), Mid = mid-grazing (late July), Post = post-grazing (mid October).
[3]CSU = Continuous stocking with unrestricted stream access, CSR= Continuous stocking with restricted stream access, RS = Rotational stocking.

Stream Morphology

There was considerable variation in the stream channel cross sectional areas between pastures over the 3 years of the study (Fig. 7). Stream channel cross sectional areas decreased at a rate of 2.02 in^2 per day. There were no effects of grazing management on the rate of change of stream channel cross sectional area over the three years of the study.

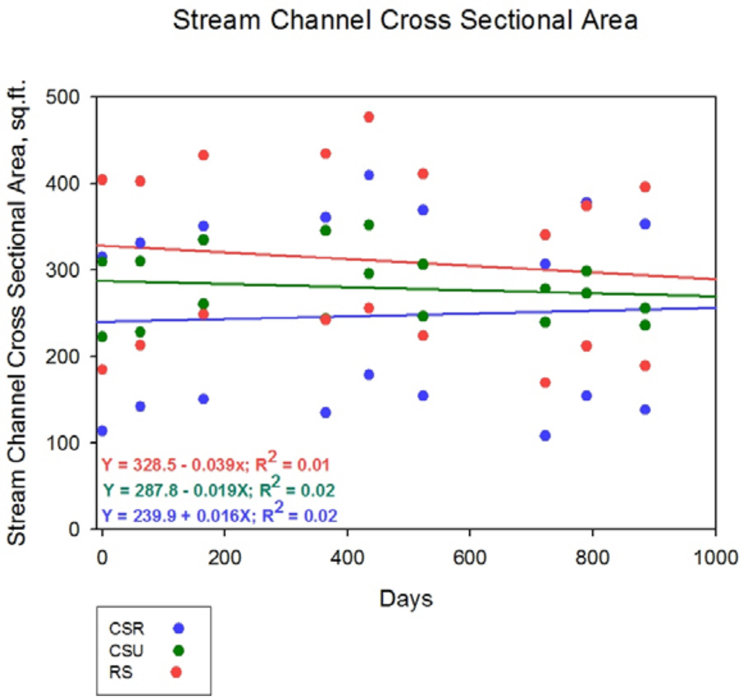


Figure 7. Effect of grazing management on stream channel cross sectional area.

Stream Bank Erosion

There were 2.1, 1.1, and 3.2 inches of net stream bank erosion from CSU, CSR, and RS pastures, respectively, during 2005 (Table 6). In 2006, there were 0.2 inches of net stream bank erosion from CSU pastures and 0.2, and 0.1 inches of net stream bank deposition in CSR and RS pastures, respectively (Table 7). In 2007, net erosion was 2.5, 3.7, and 1.5 inches in CSU, CSR, and RS pastures, respectively (Table 8). During 2007, July was the only month in which there was a significant difference in net erosion between grazing treatments, with slightly greater erosion in CSU pastures than pastures with other treatments. Across all grazing treatments in 2007, the majority (nearly 90%) of net erosion occurred between November 2006 and May 2007. Over the entire study period (May, 2005 through December, 2007), the rate of net soil erosion from stream banks averaged -0.004 inches of soil per day and did not differ between treatments. Net erosion did not differ between grazing management treatments in any year.

Table 6. Effect of grazing management on net erosion during 2005.

			Net Erosion (in)[1]				
	June[2]	July	August	September	October	November	Annual
CSU[3]	-0.39	-1.81	0.04	-0.98[e]	-0.87	0.24	*-2.05*
CSR	-0.91	-0.31	-0.20	-0.20[f]	0.08	0.39	*-1.10*
RS	-1.22	-1.50	-0.31	-0.12[f]	0.28	0.24	*-3.19*

[1]Negative values represent soil erosion; positive values represent deposition.
[2]June value indicates change from previous November; all other values are from the previous month.
[3]CSU = Continuous stocking with unrestricted stream access, CSR= Continuous stocking with restricted stream access, RS = Rotational stocking.
[ab]Within a column, means with different superscripts differ (P<0.05).

Table 7. Effect of grazing management on net erosion during 2006.

	Net Erosion (in)[1]						
	June[2]	July	August	September	October	November	Annual
CSU[3]	-0.12	-0.12	-0.004	-0.28	0.04[e]	0.28	*-0.20*
CSR	0.24	-0.16	-0.08	-0.04	0.16[f]	0.04	*0.16*
RS	0.08	-0.04	-0.02	0.04	-0.04[e]	0.12	*0.14*

[1]Negative values represent soil erosion; positive values represent deposition.
[2]June value indicates change from previous November; all other values are from the previous month.
[3]CSU = Continuous stocking with unrestricted stream access, CSR= Continuous stocking with restricted stream access, RS = Rotational stocking.
[ab]Within a column, means with different superscripts differ (P<0.05).

Table 8. Effect of grazing management on net erosion during 2007.

	Net Erosion (in)[1]							
	May[2]	June	July	August	September	October	December	Annual
CSU[3]	-2.1	-0.2	-0.4[a]	0.1	-0.1	0.0	0.2	-2.5
CSR	-3.4	-0.1	-0.3[b]	0.2	-0.1	0.0	0.0	-3.7
RS	-1.3	-0.1	-0.1[b]	0.0	-0.1	0.2	0.0	-1.5

[1]Negative values represent soil erosion; positive values represent deposition.
[2]May value indicates change from previous November; all other values are from the previous month.
[3]CSU = Continuous stocking with unrestricted stream access, CSR= Continuous stocking with restricted stream access, RS = Rotational stocking.
[ab]Within a column, means with different superscripts differ (P<0.05).

Erosion-deposition activities were 5.8, 3.2, and 4.7 inches for CSU, CSR, and RS pastures, respectively, in 2005 (Table 9). Erosion-deposition activities were 4.5, 3.2, and 3.3 inches for CSU, CSR, and RS pastures, respectively, in 2006 (Table 10). In 2007, erosion-deposition activities were 8.7, 7.1, and 6.7 inches for CSU, CSR, and RS pastures, respectively (Table 11). As with net erosion, July was the only month in 2007 in which there was a significant effect of grazing management on erosion-deposition activity with CSU being greater (P<0.05) than CSR, which was greater (P<0.05) than RS. In no year was there a significant difference between grazing management treatments on erosion-deposition activity of stream banks.

Table 9. Effect of grazing management on stream bank erosion/ deposition activity during 2005.

	Erosion/Deposition Activity (in)[1]						
	June[2]	July	August	September	October	November	Annual
CSU[3]	0.98	1.93	0.47	1.14[e]	0.98[e]	0.28[f]	*5.79*
CSR	0.91	0.87	0.31	0.31[f]	0.31[f]	0.43[e]	*3.15*
RS	1.38	1.89	0.35	0.24[f]	0.55[f]	0.28[f]	*4.65*

[1]Determined from the absolute values of changes in erosion pin lengths.
[2]May value indicates change from previous November; all other values are from the previous month.
[3]CSU = Continuous stocking with unrestricted stream access, CSR= Continuous stocking with restricted stream access, RS = Rotational stocking.
[abc]Within a column, means with different superscripts differ (P<0.05).

Table 10. Effect of grazing management on stream bank erosion/ deposition activity during 2006.

	Erosion/Deposition Activity (in)[1]						
	June[2]	July	August	September	October	November	Annual
CSU[3]	1.02	0.67	0.71	0.75	0.79	0.51	*4.45*
CSR	0.71	0.39	0.59	0.51	0.55	0.43	*3.19*
RS	0.71	0.47	0.51	0.59	0.55	0.47	*8.31*

[1]Determined from the absolute values of changes in erosion pin lengths.
[2]May value indicates change from previous November; all other values are from the previous month.
[3]CSU = Continuous stocking with unrestricted stream access, CSR= Continuous stocking with restricted stream access, RS = Rotational stocking.
[abc]Within a column, means with different superscripts differ ($P<0.05$).

Table 11. Effect of grazing management on stream bank erosion/ deposition activity during 2007.

	Erosion/Deposition Activity (in)[1]							
	May[2]	June	July	August	September	October	December	Annual
CSU[3]	4.3	1.0	0.8[a]	0.9	0.3	0.7	0.6	8.7
CSR	4.8	0.7	0.6[b]	0.6	0.2	0.1	0.1	7.1
RS	3.3	0.8	0.5[c]	0.9	0.4	0.6	0.1	6.7

[1]Determined from the absolute values of changes in erosion pin lengths.
[2]May value indicates change from previous November; all other values are from the previous month.
[3]CSU = Continuous stocking with unrestricted stream access, CSR= Continuous stocking with restricted stream access, RS = Rotational stocking.
[abc]Within a column, means with different superscripts differ ($P<0.05$).

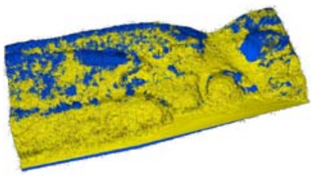
LiDAR Scans of Streambanks

The LiDAR scan data suggest that deposition was the dominant activity in each of the sites during the 2006 grazing season (Table 12). During the winter of 2006 to 2007, significant deposition occurred in the pasture 4 (CSR) site, while significant erosion of the cut bank in Pasture 5 (CSU) occurred. During the 2007 grazing season, bank erosion occurred in four of the seven sites, with more than 37 m^3 of soil lost from the cut bank in Pasture 5 (CSU). Because of the slope of this cut bank, the significant loss of bank material was a naturally occurring event, and cannot be attributed to cattle activity. In the 3D model of the 2006 scanned areas (Fig. 8), yellow surfaces, which represent areas of deposition, are most evident. Soil deposition ranged from 1 m^3/m of stream to 0.01 m^3/m of stream, both values being in the CSU grazing treatment pasture. Erosion pin data suggested that no trend existed; however, differences between the two methods are to be expected. LiDAR scan data were collected at only one active area of each pasture, whereas erosion pins were placed in both active and inactive sites. More data are needed to compare the two methods of erosion monitoring.

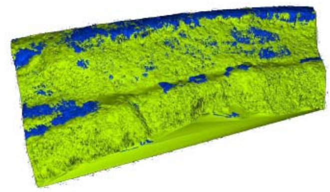
Table 12. Stream bank soil erosion or deposition estimated with LiDAR scan data during the 2006 grazing season, 2006-2007 winter, and 2007 grazing season. The location labeled Pasture 5a is an active stream cut bank.

Pasture	Trt.	Soil Loss (-) or Gain (m^3)		
		April ’06 – Nov. ‘06	Nov. ’06 – April ‘07	April ’06 – Nov. ‘06
1	CSR	3.78	2.27	-1.03
2	CSU	2.75	1.43	0.51
3	RS	5.64	-0.49	-2.41
4	CSR	8.32	33.51	1.79
5	CSU	19.36	1.17	-1.43
5a	CSU	0.23	-12.97	-37.32
6	RS	3.58	-2.88	0.48

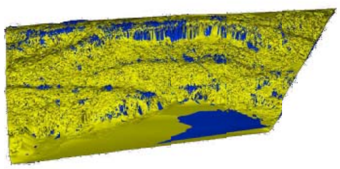
LIDAR models of stream bank erosion/deposition



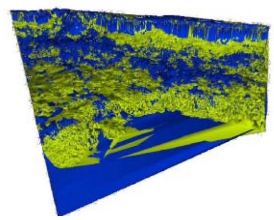
Pasture 1. RS Treatment.
Deposition of .26 m^3/m stream



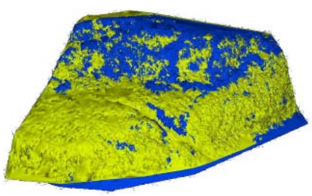
Pasture 2. CSU Treatment.
Deposition of .26 m^3/m stream



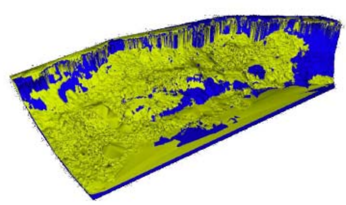
Pasture 3. CSR Treatment.
Deposition of .47 m^3/m stream



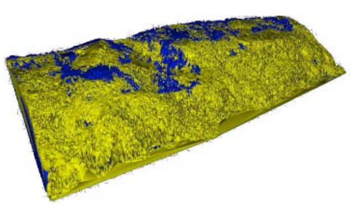
Pasture 4. RS Treatment.
Deposition of .61 m^3/m stream



Pasture 5. CSU Treatment.
Deposition of 1 m^3/m stream



Pasture 5a Cut Bank. CSU Treatment.
Deposition of .01 m^3/m stream



Pasture 6. CSR Treatment.
Deposition of .29 m^3/m stream

Figure 8. LiDAR point cloud meshes of April 2006 and November 2006 scans. Blue surfaces indicate areas where erosion or no change occurred from April 2006 to November 2006. Yellow surfaces indicate depositional areas.

Estimated Phosphorus Losses

Potential P losses from the stream banks in each of the six pastures were estimated by multiplying the area of the stream bank within a given transect, the mean net erosion within the transect, the bulk density of the soil, and total P concentration of the stream bank soil (Table 13). During the three years of the study, P losses tended to be lower in the rotational stocking treatment. More interesting, potential P losses significantly decreased after the 2005 grazing season. This is probably related to the intense rainfall events of 2005 (Fig. 1).

Table 13. Estimated losses of total soil phosphorus (TP) from stream banks during each of the three years of the project. Values are means of two treatment replications.

	Estimated P Losses (lb)[1]		
	2005	2006	2007
CSU[2]	139	11	19
CSR	108	3	32
RS	29	9	8

[1]Determined from monthly estimates of stream bank erosion, bulk density of the soil, and total P content of the soil.

[2]CSU = Continuous stocking with unrestricted stream access, CSR= Continuous stocking with restricted stream access, RS = Rotational stocking.

Congregation Area

The percentage of congregation area along stream banks was greater ($P<.10$) in CSU (60.7%) pastures than in pastures managed by CSR (31.1%) or RS (30.8%). The relatively larger congregation areas in CSU pastures than in other pastures was not a result of grazing management but were a pre-existing characteristic of the pastures. The percentage of congregation area within the 110 foot zone tended to be greater ($P<.20$) in pastures managed by CSR (16.8%) or CSU (13.1%) than in RS (5.0%) pastures. Congregation areas within the 220 foot zone (7.3, 4.0, and 6.5% for CSU, CSR, and RS pastures, respectively) and upland zone (4.7, 10.6, and 5.5% for CSU, CSR, and RS pastures, respectively) did not differ between grazing management treatments. There were no year or year × treatment interactions for the proportion of congregation area within any pasture zones.

Bare and Fecal-covered Ground

The proportions of bare ground (Fig. 9) and fecal-covered ground (Fig. 10) in pastures managed by either continuous or rotational stocking were greater ($P<.10$) in congregation than in open areas of pastures in most months over three grazing seasons. There were no grazing management treatment by pasture zone interactions for bare or fecal-covered ground in any month. These results imply that while grazing management might affect the proportion of area that the cattle congregate in, the effects of that congregation are similar across treatments and zones.

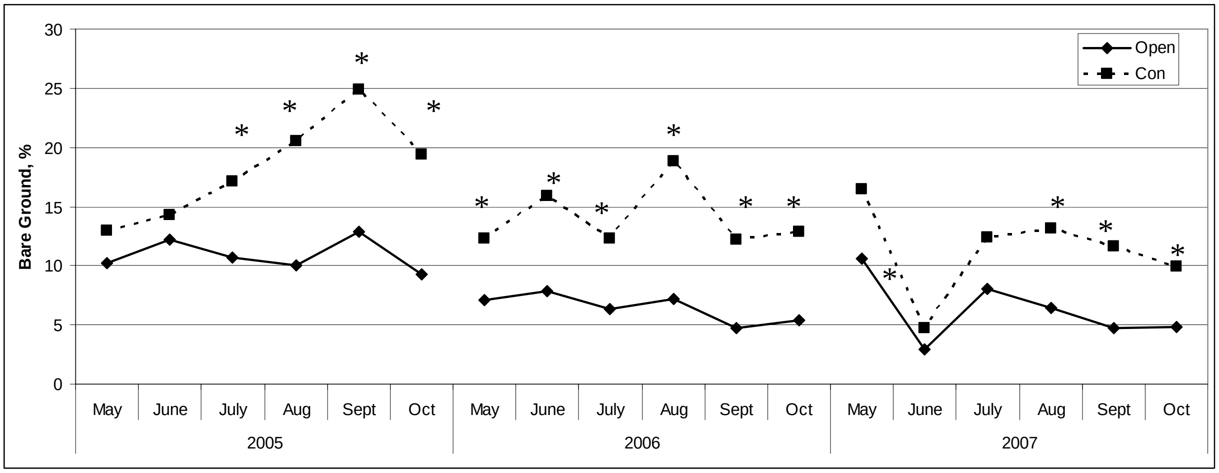


Figure 9. Proportion of bare ground in open and congregation areas of pastures managed by continuous or rotational stocking over three grazing seasons. * = values differ (P<.10).

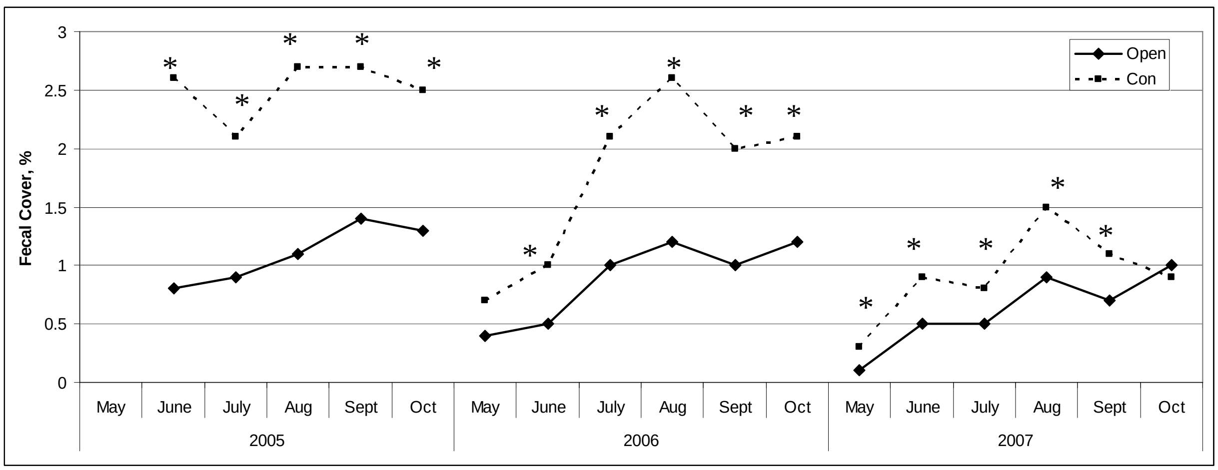


Figure 10. Proportion of fecal-covered ground in open and congregation areas of pastures managed by continuous or rotational stocking over three grazing seasons. * = values differ (P<.10).

The proportion of bare ground on stream banks did not differ (P>.10) or tend to differ (P>.20) between grazing management treatments in any month except September and October 2007 when CSU pastures had a greater (P<0.10) proportion of bare ground than did CSR pastures (Fig. 11). The lack of significance between treatments resulted from a large degree in variability in bare ground on banks within pastures. The proportion of bare ground within 110 feet of the stream was greater (P<0.10) in the CSU pastures than in CSR or RS pastures during July and August of 2005, August, September, and October of 2006, and August of 2007 (Fig. 12). There was no difference in the proportion of bare ground on or within 110 feet of the stream banks in pastures managed by CSR and RS in any month.

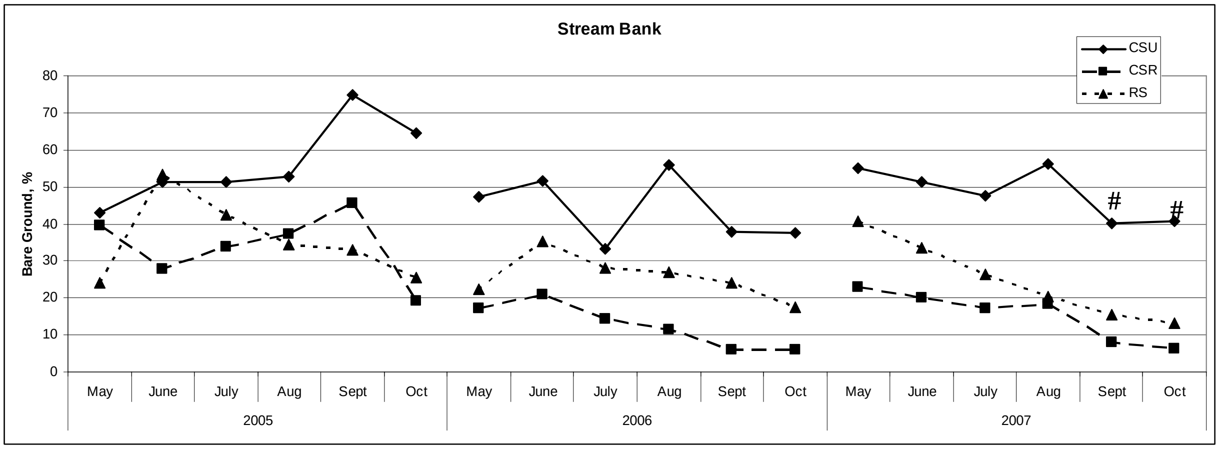


Figure 11. Proportion of bare ground on stream banks in pastures managed by continuous stocking with unrestricted stream access (CSU), continuous stocking with restricted stream access (CSR), and rotational stocking (RS). * = CSU differs from RS, # = CSU differs from CSR, @ = CSR differs from RS (P<.10).

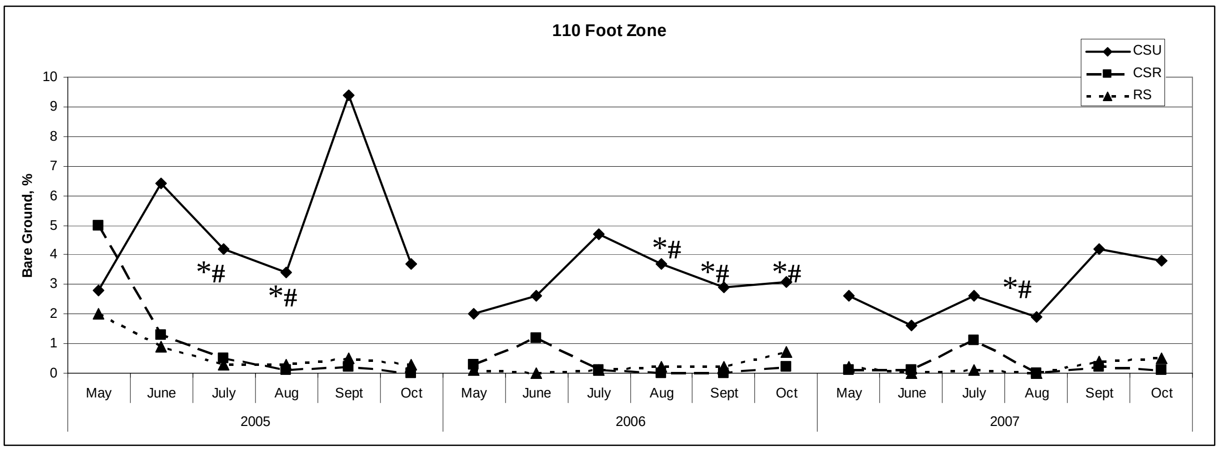


Figure 12. Proportion of bare ground within 110 feet of streams in pasture managed by continuous stocking with unrestricted stream access (CSU), continuous stocking with restricted stream access (CSR), and rotational stocking (RS). * = CSU differs from RS, # = CSU differs from CSR, @ = CSR differs from RS (P<.10).

Fecal cover was greater (P<.10) on stream banks in CSU pastures than CSR or RS pastures in July, August, and October of 2005, July and August of 2006, and June and July of 2007 (Fig. 13). In October, 2005, there was greater fecal cover on stream banks of RS pastures than CSR pastures. In June, July, and September of 2005, July of 2006, and August of 2007, there was greater (P<.10) fecal cover within 110 feet of the stream in RS than in CSR pastures (Fig. 14).

The proportion of bare ground in pasture areas available for grazing did not differ between grazing management practices in any month (Fig. 15). Similarly, the proportions of fecal-covered ground in grazed pasture areas did not differ (P>.10) between grazing treatments in most months (Fig 16).

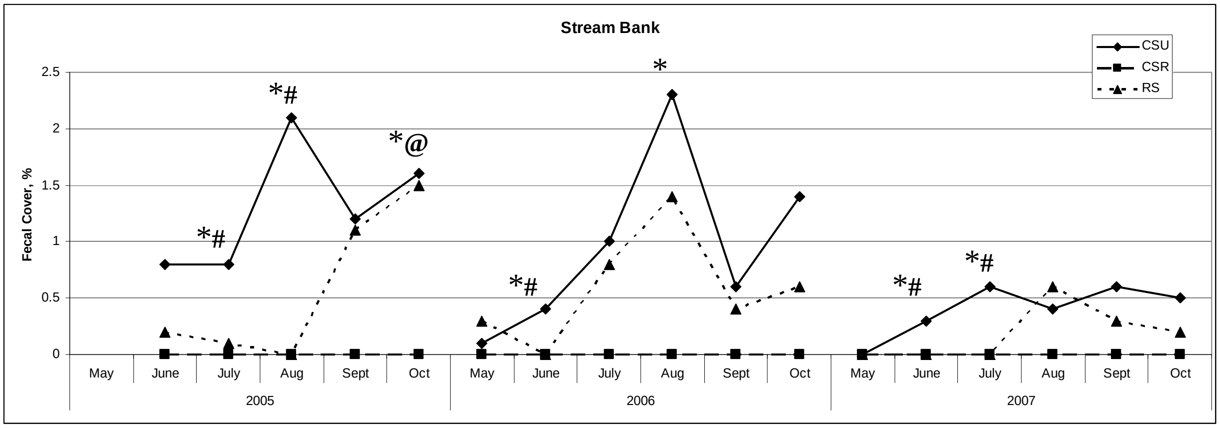


Figure 13. Proportion of fecal-covered ground on stream banks in pastures managed by continuous stocking with unrestricted stream access (CSU), continuous stocking with restricted stream access (CSR), and rotational stocking (RS). * = CSU differs from RS, # = CSU differs from CSR, @ = CSR differs from RS (P<.10).

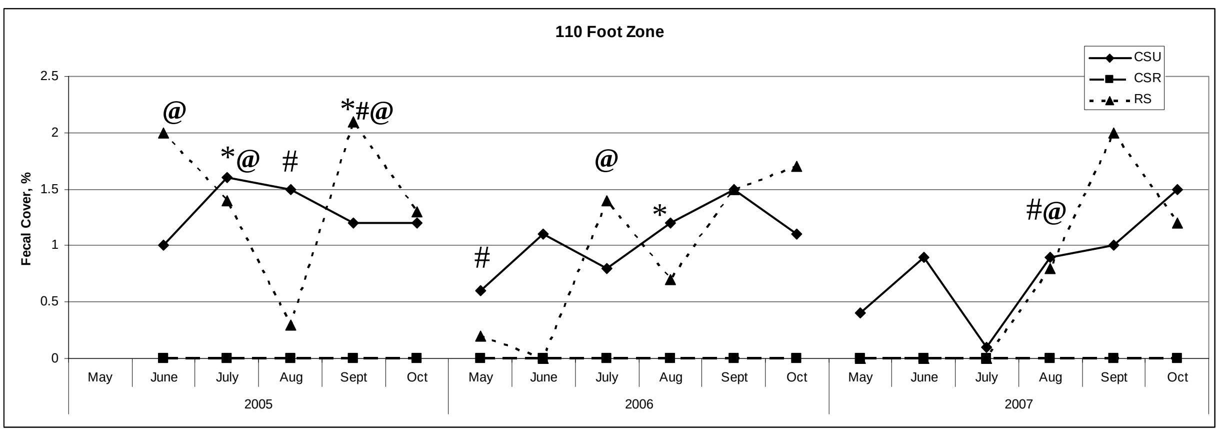


Figure 14. Proportion of fecal-covered ground within 110 feet of streams in pasture managed by continuous stocking with unrestricted stream access (CSU), continuous stocking with restricted stream access (CSR), and rotational stocking (RS). * = CSU differs from RS, # = CSU differs from CSR, @ = CSR differs from RS (P<.10).

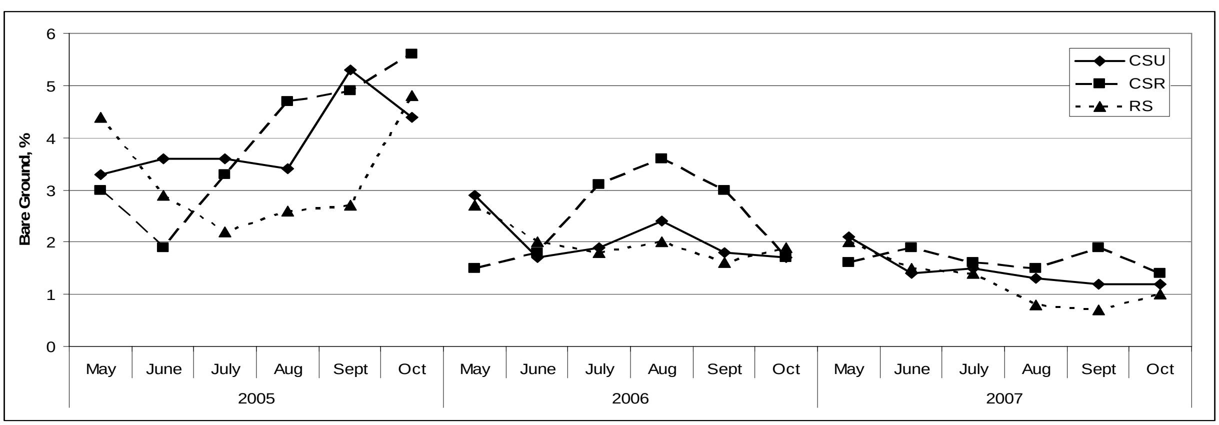


Figure 15. Proportion of bare ground, in areas available for grazing, in pasture managed by continuous stocking with unrestricted stream access (CSU), continuous stocking with restricted stream access (CSR), and rotational stocking (RS). * = CSU differs from RS, # = CSU differs from CSR, @ = CSR differs from RS (P<.10).

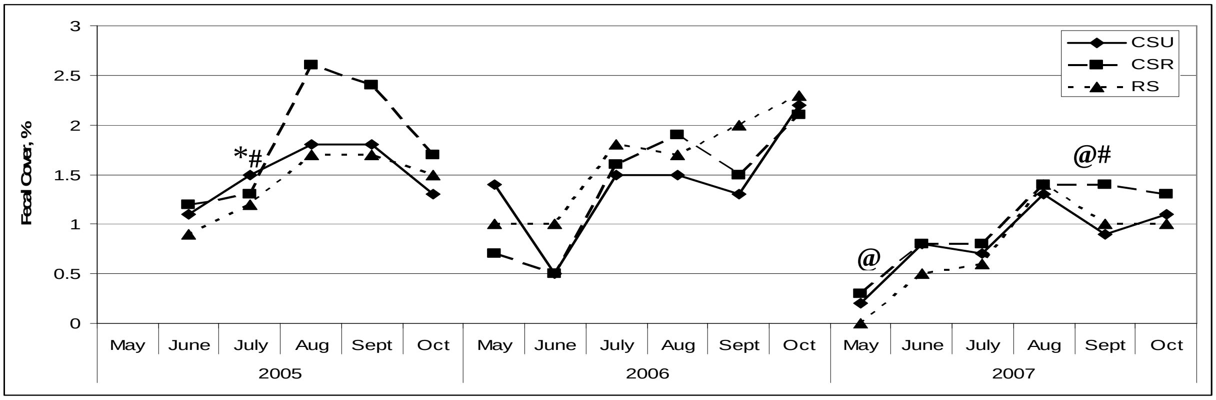


Figure 16. Proportion of fecal-covered ground, in areas available for grazing, in pasture managed by continuous stocking with unrestricted stream access (CSU), continuous stocking with restricted stream access (CSR), and rotational stocking (RS). * = CSU differs from RS, # = CSU differs from CSR, @ = CSR differs from RS (P<.10).

Forage Mass and Sward Height

Forage mass was greater (P<.10) in open than congregation areas of pastures in all months except May and July of 2005 and June of 2007 (Fig. 17). Similarly, forage sward height was less (P<.10) in congregation areas than in open areas of pastures (Data not shown).

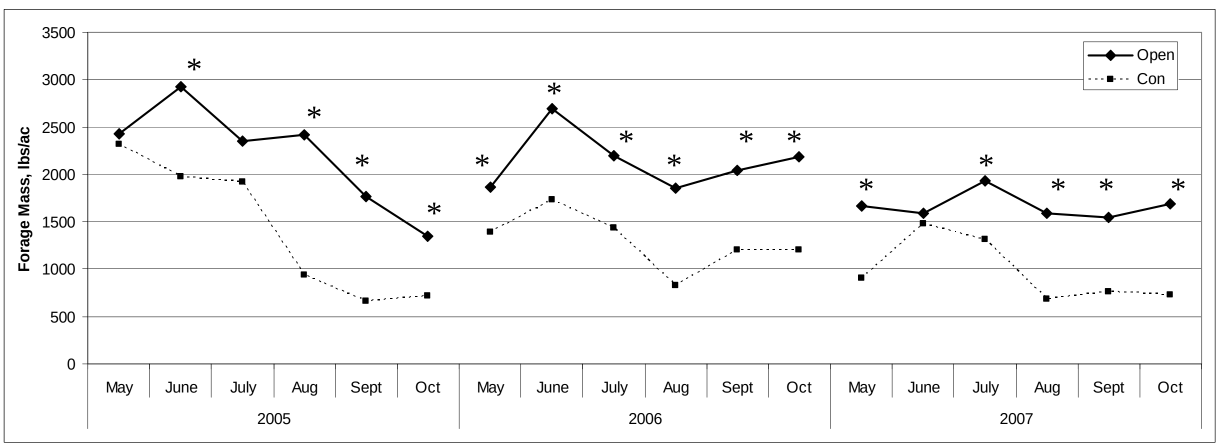


Figure 17. Forage mass (lbs/ac) in open and congregation areas of pastures managed by continuous or rotational stocking over three grazing seasons. * = values differ (P<.10).

Forage mass on stream banks was greater (P<.10) in CSR pastures at the end of the 2005 grazing season, but did not differ between grazing management treatments during the 2006 grazing season. Forage mass was greater (P<.10) or tended to be greater (P<.20) in CSR pastures than in CSU pastures during 2007 (Fig. 18). However, forage mass on or within 110 feet of the stream banks in CSR and RS pastures did not differ in any month. However, in every month except May, June, and July of 2005 and May of 2006, CSU pastures had a lower (P<.10) forage mass within 110 feet of the stream banks than CSR or RS pastures (Fig. 19). Forage sward height was inversely related to forage mass (Data not shown).

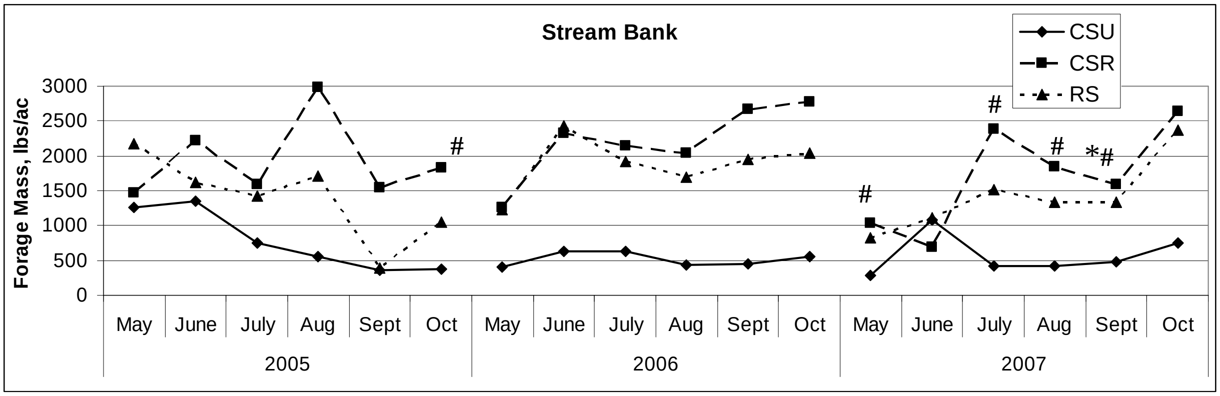


Figure 18. Forage mass (lbs/ac) on stream banks in pasture managed by continuous stocking with unrestricted stream access (CSU), continuous stocking with restricted stream access (CSR), and rotational stocking (RS). * = CSU differs from RS, # = CSU differs from CSR, @ = CSR differs from RS (P<.10).

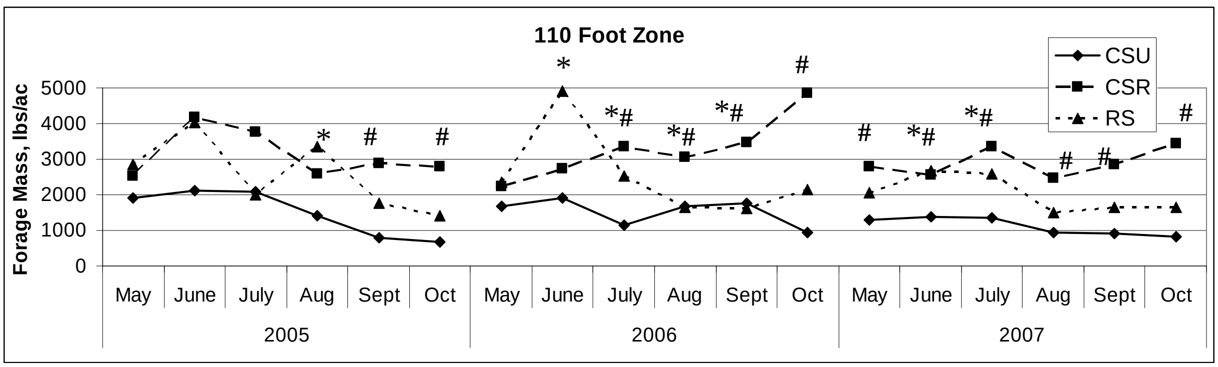


Figure 19. Forage mass (lbs/ac) within 110 feet of streams in pasture managed by continuous stocking with unrestricted stream access (CSU), continuous stocking with restricted stream access (CSR), and rotational stocking (RS). * = CSU differs from RS, # = CSU differs from CSR, @ = CSR differs from RS (P<.10).

Forage masses in pasture areas available for grazing did not differ between treatments during the 2005 or 2006 grazing seasons. However, the areas available for grazing in the RS pastures had greater forage mass than either the CSU or CSR pastures in June and October 2007 (Fig. 20).

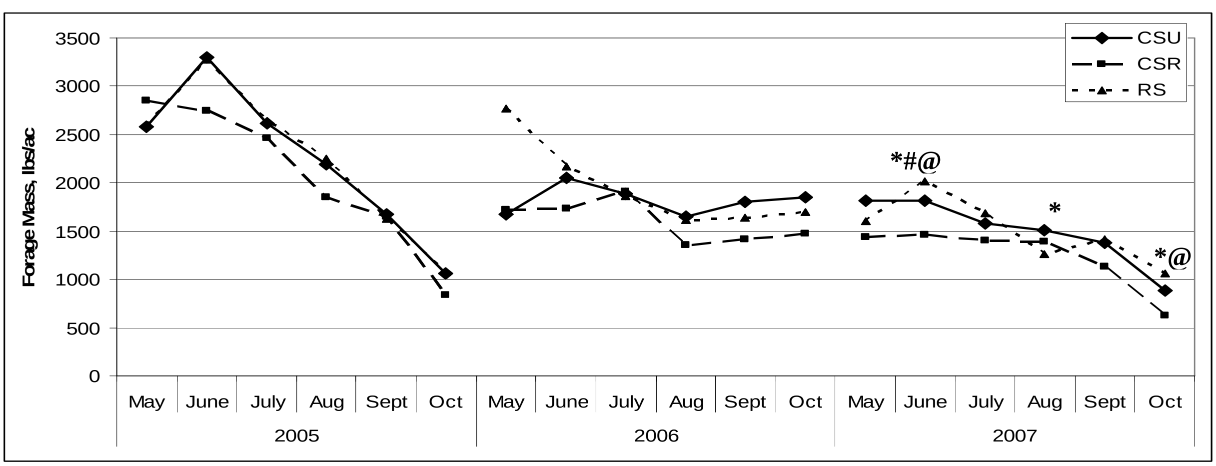


Figure 20. Forage mass, in areas available for grazing, in pasture managed by continuous stocking with unrestricted stream access (CSU), continuous stocking with restricted stream access (CSR), and rotational stocking (RS). * = CSU differs from RS, # = CSU differs from CSR, @ = CSR differs from RS (P<.10).

Forage Nutrient Concentration
In Vitro dry matter disappearance (Fig. 21) and concentrations of crude protein (Crude Protein = Nitrogen × 6.25) and phosphorus in forage in pasture areas available for grazing did not differ between grazing treatments in any month. Crude protein concentrations of available forage were below requirements for a 1200 pound beef cow at peak lactation in June and July of both years, but were at or above required concentrations for the remainder of the grazing seasons (Fig. 22). Phosphorus concentrations of available forage were below requirements for a 1200 pound beef cow at peak lactation in July of 2006, but were at or above required concentrations for the remainder of the grazing seasons (Fig. 23). As cattle are able to select forage of better quality than the average of the forage that is hand-clipped, the quality of the forage in these pastures may not have a negative impact on animal performance. Nutrient concentrations were never below maintenance requirements for a non-lactating beef cow.

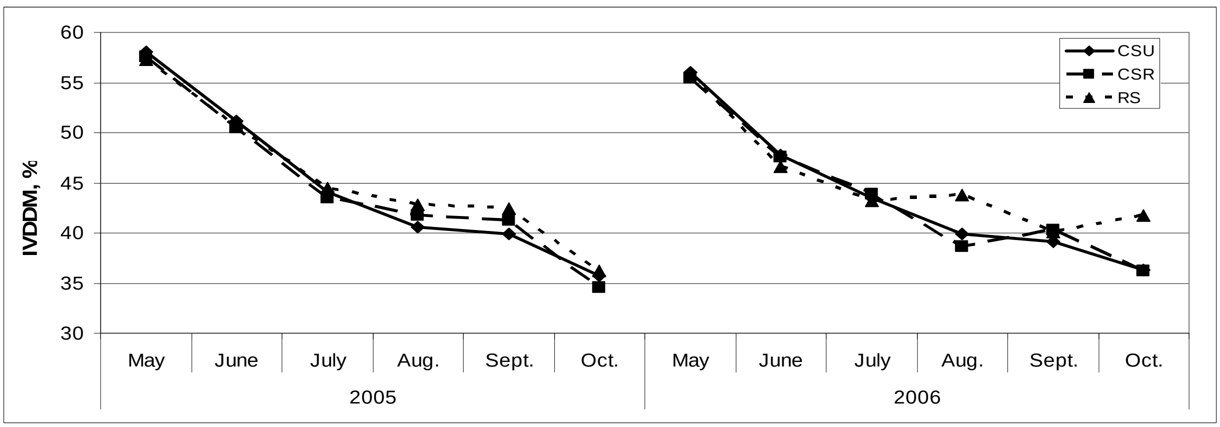


Figure 21. *In Vitro* dry matter digestibility of forage, in areas available for grazing, in pasture managed by continuous stocking with unrestricted stream access (CSU), continuous stocking with restricted stream access (CSR), and rotational stocking (RS). * = CSU differs from RS, # = CSU differs from CSR, @ = CSR differs from RS (P<.10).

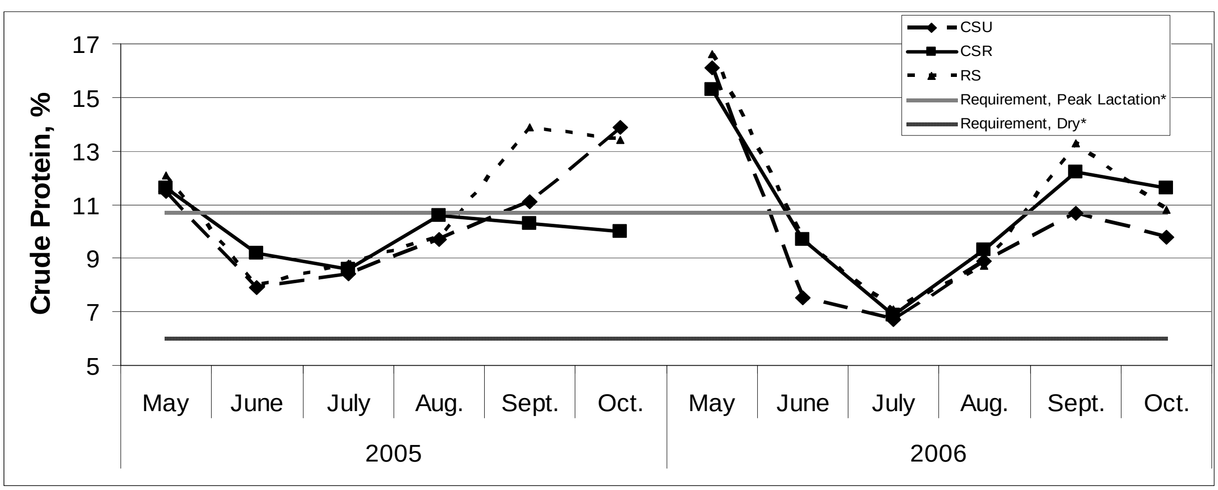


Figure 22. Crude protein concentration of forage, in areas available for grazing, in pasture managed by continuous stocking with unrestricted stream access (CSU), continuous stocking with restricted stream access (CSR), and rotational stocking (RS). * = CSU differs from RS, # = CSU differs from CSR, @ = CSR differs from RS (P<.10). Required dietary crude protein concentration for a 1200 lb beef cow producing 20 lbs. milk per day at peak lactation and when dry (NRC 1996).

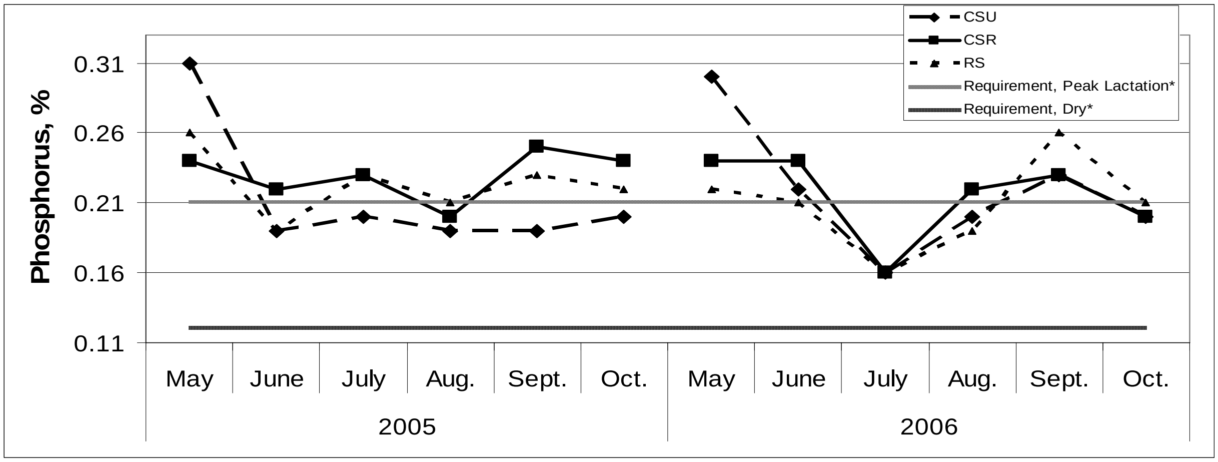


Figure 23. Phosphorus concentration of forage, in areas available for grazing, in pasture managed by continuous stocking with unrestricted stream access (CSU), continuous stocking with restricted stream access (CSR), and rotational stocking (RS). * = CSU differs from RS, # = CSU differs from CSR, @ = CSR differs from RS (P<.10). Required phosphorus concentration for a 1200 lb beef cow producing 20 lbs. milk per day at peak lactation and when dry (NRC 1996).

Near Stream Forage Nutrient Accumulation

Nitrogen concentration of forage along the stream banks did not differ between grazing management treatments in any month (Table 14). During 2005, the nitrogen concentration of forage within 110 feet of the stream were greater (P<.05) or tended to be greater (P<.20) in RS pastures than in CSR pastures in May, July, and August. This difference was not observed in 2006. Phosphorus concentration of forage along stream banks was greater (P<.05) in RS pastures than in CSU pastures in August 2005, but no differences were observed in any other month in 2005 or 2006 (Table 15). Phosphorus concentrations of forage within 110 feet of the stream did not differ between grazing management treatments in any month in either year.

Table 14. Nitrogen concentration (%) in forage on the stream banks and within 110 feet of a pasture stream in pastures managed by continuous or rotational stocking.

	2005						2006					
	May	June	July	August	September	October	May	June	July	August	September	October
						Stream Bank[1]						
CSU[2]	1.85	1.32	1.59	1.84	1.85	1.68	2.40	1.29	1.01	1.08	1.56	1.42
CSR	1.48	1.46	1.36	1.57	1.28	1.46	2.56	1.40	1.10	1.21	1.49	1.17
RS	2.01	1.35	1.68	1.69	1.98	1.57	2.31	2.11	1.20	1.77	1.35	1.13
	NS	NS	NS	NS	NS	NS	NS	0.06	NS	NS	NS	NS
						110 Zone						
CSU	2.04	1.56	1.53[ab]	1.95	2.06	2.32	2.71	1.33	1.15	1.79	2.16	1.92
CSR	2.17	1.61	1.36[b]	1.62	1.57	1.41	2.49	1.56	1.17	1.17	1.66	1.91
RS	2.51	1.47	2.31[a]	1.82	2.27	2.32	2.61	1.64	1.30	1.60	2.36	2.16
	0.15	NS	0.05	0.06	NS	NS	NS	NS	NS	NS	NS	NS

[ab]Values with different superscripts within a column differ (P<0.05).
[1]Stream bank = On stream banks, 110 Zone = from the edge of the stream bank to 110 feet from the stream.
[2]CSU = continuous stocking with unrestricted stream access, RS = rotational stocking, CSR = continuous stocking with restricted stream access.

Table 15. Phosphorus concentration (%) in forage on the stream banks and within 110 feet of a pasture stream in pastures managed by continuous or rotational stocking.

	2005						2006					
	May	June	July	August	September	October	May	June	July	August	September	October
						Stream Bank[1]						
CSU[2]	0.27	0.25	0.24	0.27[ab]	0.26	0.25	0.28	0.23	0.21	0.20	0.32	0.21
CSR	0.27	0.28	0.23	0.23[b]	0.19	0.26	0.21	0.23	0.18	0.21	0.26	0.23
RS	0.28	0.25	0.22	0.30[a]	0.33	0.24	0.28	0.25	0.17	0.22	0.24	0.20
	NS	0.09	NS	.05	NS	NS	NS	NS	NS	NS	NS	NS
						110 Zone						
CSU	0.29	0.25	0.25	0.25	0.24	0.30	0.31	0.24	0.22	0.22	0.27	0.24
CSR	0.32	0.26	0.25	0.25	0.36	0.24	0.26	0.26	0.18	0.23	0.28	0.23
RS	0.33	0.24	0.34	0.26	0.24	0.26	0.30	0.28	0.26	0.23	0.32	0.28
	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[ab]Values with different superscripts within a column differ (P<0.05).
[1]Stream bank = On stream banks, 110 Zone = from the edge of the stream bank to 110 feet from the stream.
[2]CSU = continuous stocking with unrestricted stream access, RS = rotational stocking, CSR = continuous stocking with restricted stream access.

Even though there was a wide range in forage masses along stream banks between grazing treatments forage mass did not differ between grazing management treatments in any month of either year (Table 16). Forage masses within 110 feet of the stream were lower (P<.05) or tended to be lower (P<.20) in CSU pastures than in CSR pastures in August through October during 2005 and June through October 2006, as a result of the 110-foot zone CSR pastures not being grazed.

Table 16. Forage mass (lbs/ac) in forage on the stream banks and within 110 feet of a pasture stream in pastures managed by continuous or rotational stocking.

	2005						2006					
	May	June	July	August	September	October	May	June	July	August	September	October
						Stream Bank[1]						
CSU[2]	1262	1356	746	565	354	372	410	634	625	434	451	563
CSR	1473	2228	1588	2986	1551	1833	1260	2331	2154	2048	2684	2776
RS	2176	1625	1425	1719	395	1046	1229	2436	1930	1704	1955	2043
	NS	NS	NS	NS	NS	.10	NS	NS	.19	NS	NS	NS
						110 Zone						
CSU	1910	2127	2107	1420[b]	797[b]	670[b]	1681	1918[c]	1140[c]	1672	1778	936[b]
CSR	2539	4190	3788	2590[ab]	2898[a]	2802[a]	2228	2734[b]	3375[a]	3077	3475	4871[a]
RS	2853	4038	2003	3355[a]	1782[ab]	1410[ab]	2356	4934[a]	2523[b]	1653	1632	2156[ab]
	NS	NS	NS	.05	.05	.05	NS	.05	.05	.08	.08	.05

[abc]Values with different superscripts within a column differ (P<0.05).
[1]Stream bank = On stream banks, 110 Zone = from the edge of the stream bank to 110 feet from the stream.
[2]CSU = continuous stocking with unrestricted stream access, RS = rotational stocking, CSR = continuous stocking with restricted stream access.

As a result of no differences in forage mass or nitrogen concentration of forage between grazing treatments, there was no difference in total nitrogen contained within forage along stream banks in any month (Table 17). Largely as a result of differences in forage mass, total nitrogen contained in the forage mass within 110 feet of the stream was greater (P<.05) or tended to be greater (P<.20) in CSR than in CSU pastures during May, August, September, and October 2005 and every month in 2006 except August. As a result of no differences in forage mass or phosphorus concentration of forage between grazing treatments there were no treatment differences in total phosphorus contained within forage along stream banks in any month (Table 18). Largely as a result of differences in forage mass, total phosphorus contained in the forage mass within 110 feet of the stream was greater (P<.05) or tended to be greater (P<.20) in CSR than in CSU pastures during June, August, September, and October 2005 and every month in 2006 except July.

As a result of accumulating forage mass and its associated nutrients within the CSR pasture, as compared to CSU pastures, there is a potential for these nutrients to be lost to surface waters following a killing frost in the fall.

Table 17. Nitrogen mass (lbs/ac) in forage on the stream banks and within 110 feet of a pasture stream in pastures managed by continuous or rotational stocking.

	2005						2006					
	May	June	July	August	September	October	May	June	July	August	September	October
						Stream Bank[1]						
CSU[2]	23.5	17.1	10.7	11.0	7.8	5.2	9.8	24.8	19.4	8.3	13.5	7.6
CSR	21.2	32.5	20.4	45.8	20.5	28.5	32.6	32.8	22.8	23.6	39.1	32.7
RS	45.7	24.4	22.3	29.1	6.5	16.0	27.4	49.5	21.8	34.8	24.8	26.4
	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
						110 Zone						
CSU	38.7	31.5	32.4	26.8[b]	15.7[c]	14.5[b]	45.0	25.9	13.3	30.2	38.0	17.6
CSR	54.7	67.1	51.6	42.2[ab]	46.0[a]	39.3[a]	55.7	43.0	39.6	35.8	56.5	94.0
RS	71.3	60.0	43.5	60.8[a]	39.0[b]	32.3[a]	61.1	83.4	33.0	27.3	39.1	45.0
	0.16	NS	NS	0.05	0.05	0.05	0.12	0.16	0.08	NS	0.18	0.08

[ab]Values with different superscripts within a column differ (P<0.05).
[1]Stream bank = On stream banks, 110 Zone = from the edge of the stream bank to 110 feet from the stream.
[2]CSU = continuous stocking with unrestricted stream access, RS = rotational stocking, CSR = continuous stocking with restricted stream access.

Table 18. Phosphorus mass (lbs/ac) in forage on the stream banks and within 110 feet of a pasture stream in pastures managed by continuous or rotational stocking.

	2005						2006					
	May	June	July	August	September	October	May	June	July	August	September	October
						Stream Bank[1]						
CSU[2]	3.5	3.3	2.2	1.6	1.0	1.2	1.2	4.8	4.1	0.9	2.6	1.2
CSR	4.1	6.2	3.7	7.2	3.6	4.9	2.7	5.3	3.8	4.2	6.9	6.3
RS	6.6	3.9	3.2	5.3	1.4	2.6	3.4	5.4	3.2	3.7	4.6	4.6
	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
						110 Zone						
CSU	5.7	5.2	5.0	3.6	2.0	1.9	5.2	4.6[b]	2.5	3.7	4.9	2.2
CSR	7.9	10.6	9.5	6.3	10.9	6.6	5.7	7.0[ab]	6.1	7.1	9.8	11.0
RS	9.4	9.8	6.7	8.6	4.4	3.7	7.1	13.7[a]	6.7	4.0	5.4	6.2
	NS	0.19	NS	0.10	0.08	0.07	0.15	0.05	NS	0.18	0.16	0.08

[ab]Values with different superscripts within a column differ (P<0.05).
[1]Stream bank = On stream banks, 110 Zone = from the edge of the stream bank to 110 feet from the stream.
[2]CSU = continuous stocking with unrestricted stream access, RS = rotational stocking, CSR = continuous stocking with restricted stream access.

Objective 2: Spatial and Temporal Distribution and Activity of Cattle

Grazing Management Effects on Cattle Distribution

In June, July, and August of 2005 through 2007, cattle in CSU pastures spent a greater (P<.05) proportion of time within the stream than did cattle in RS or CSR pastures (Table 19). Over the grazing seasons, cattle in the CSU, RS, and CSR pastures spent 6.1, 3.5, and 0.8% of the time in the stream from 0600 to 1800 hours. In every month except September, cattle managed by continuous stocking with unrestricted stream access spent a greater proportion of time within 110 feet of the stream. Time spent in or within 110 feet of the stream did not differ between cows provided restricted access to the stream or those grazing by rotational stocking.

Table 19. Proportion of time cattle spent within different pasture zones from May through September (Visual observation pooled across 2005, 2006, and 2007 data).

	May				June				July			
	Stream[1]	110	220	Upland	Stream	110	220	Upland	Stream	110	220	Upland
CSU[2]	1.6[a]	18.4[a]	4.8[b]	75.3	9.5[a]	14.1[a]	5.5	70.7[b]	10.5[a]	12.8[a]	4.0	72.7
RS	0.0[b]	1.0[b]	17.3[a]	81.8	0.0[b]	0.2[b]	8.6	91.2[a]	0.0[b]	0.0[b]	12.1	87.9
CSR	0.9[ab]	1.3[b]	7.3[ab]	90.5	1.1[b]	0.7[b]	7.9	90.5[a]	1.5[b]	0.3[b]	11.2	87.1
Trt	.05	.05	.05	.06	.05	.05	NS	.05	.05	.05	NS	NS
	August				September				Grazing Season			
	Stream	110	220	Upland	Stream	110	220	Upland	Stream	110	220	Upland
CSU	6.5[a]	11.9[a]	6.0	75.6[b]	2.6	21.3	6.7	69.4	6.1	15.7	5.4	72.7
RS	0.0[b]	0.0[b]	3.1	96.9[a]	1.5	16.4	11.4	70.8	0.3	3.5	10.5	85.7
CSR	1.2[b]	0.8[b]	7.6	90.4[a]	1.5	0.8	10.9	86.8	1.2	0.8	9.0	89.1
Trt	.05	.05	NS	.05	NS	NS	NS	NS	.05	.05	NS	NS

[ab]Values with different superscripts within a column differ (P<0.05).
[1]Stream = Within the stream, 110 = from the edge of the stream to 110 feet from the stream, 220 = from 110 feet to 220 feet away from the stream, Upland = greater than 220 feet from the stream.
[2]CSU = continuous stocking with unrestricted stream access, RS = rotational stocking, CSR = continuous stocking with restricted stream access.

In May, June, and August of 2006 and 2007, cattle managed by continuous stocking with unrestricted stream access spent a greater (P<.05) proportion of their time within the stream than did cattle managed by either rotational stocking or continuous stocking with restricted stream access (Table 20). As opposed to visual observations, cows in the CSU, RS, and CSR pastures only spent 1.3, 0.1, and 0.4% of the entire day in the stream over the grazing season. In May, June, and July, cattle managed by continuous stocking with unrestricted stream access also spent a greater (P<.05) proportion of their time within 110 feet of the stream than did cattle managed by either of the other grazing management treatments. Although cattle managed by continuous stocking with unrestricted stream access spent more time in or near the stream than cows in other treatments, in no month did cows with unrestricted stream access spend more than 2.4% of their time in the stream or more than 13.5% of their time within 110 feet of the stream. The proportion of time cows grazing by continuous stocking with restricted stream access or rotational stocking measured with GPS collars spent in or within 110 feet of a stream, did not differ.

Over the three grazing seasons cattle averaged 155 days on pasture. In the RS pastures, cattle spent an average of 9.5 days per year, or 6.1% of total grazing days, within the riparian paddock. The average time cattle were in the riparian paddock (Stream + 110 zone) is a better estimate of the amount of time cattle spent in or near the stream than is either visual observation or GPS collar data because cattle were not necessarily within the riparian zone during visual observations and GPS collar sampling.

Table 20. Proportion of time cattle spent within different pasture zones from May through September (GPS Collar pooled across 2006 and 2007 data).

	May				June				July			
	Stream[1]	110	220	Upland	Stream	110	220	Upland	Stream	110	220	Upland
CSU[2]	0.5[a]	13.5[a]	4.4	81.7[a]	2.1[a]	10.7[a]	4.5	82.7	2.4	11.0[a]	3.7	83.0
RS	0.0[b]	0.6[b]	6.9	87.7[ab]	0.0[b]	0.5[b]	7.5	92.0	0.0	0.5[b]	9.8	89.8
CSR	0.1[b]	1.2[b]	11.8	91.9[b]	0.1[b]	1.7[b]	6.5	91.8	0.6	2.1[b]	5.2	92.1
Trt	.05	.05	.08	.05	.05	.05	NS	.06	NS	.05	NS	NS
	August				September				Grazing Season			
	Stream	110	220	Upland	Stream	110	220	Upland	Stream	110	220	Upland
CSU	0.6[a]	7.5	5.2	86.7	0.2	10.1	10.0	79.7	1.3	8.8	5.6	83.0
RS	0.0[b]	0.1	0.5	99.4	0.2	6.1	13.7	80.1	0.1	3.1	7.7	90.3
CSR	0.0[b]	1.1	6.7	92.3	0.1	1.8	8.0	90.1	0.4	1.5	7.6	91.6
Trt	.05	NS	.09	.09	NS	NS	NS	NS	.05	.05	NS	NS

[ab]Values with different superscripts within a column differ (P<0.05).
[1]Stream = Within the stream, 110 = from the edge of the stream to 110 feet from the stream, 220 = from 110 feet to 220 feet away from the stream, Upland = greater than 220 feet from the stream.
[2]CSU = continuous stocking with unrestricted stream access, RS = rotational stocking, CSR = continuous stocking with restricted stream access.

Based on both visual observation and GPS collar data, cattle in CSU pastures spent a greater (P<.05) proportion of time in and within 110 feet of the stream than did cattle in CSR or RS pastures. Cattle in CSU pastures spent an average of 6.1% of the time within the stream and an additional 15.7% of the time within 110 feet of the stream over the 3 grazing seasons, based on visual observation data. Cattle in RS pastures spent 0.3 and 3.5% of the time in and within 110 feet of the stream, respectively, while cattle in CSR pastures spent 1.2 and 0.8% of the time in or within 110 feet of the stream, respectively, based on visual observation. The proportions of time cattle spent in or within 110 feet of the stream estimated by GPS collars were 1.2 and 10.6% in CSU pastures. The difference between visual observation and GPS collar data is likely caused by the visual observations being conducted during daylight hours only, while GPS collar data is collected 24 hours per day. With warmer temperatures during daylight hours, cattle are more likely to congregate near the stream in an attempt to regulate body temperature.

Defecation Patterns

Distribution of observed defecations by cattle within pasture zones was highly correlated (R = 0.998, slope = 0.996) with cattle distribution patterns during the 2005, 2006, and 2007 grazing seasons (Fig. 24). This result indicates that if GPS collars are used to monitor cattle distribution, as apposed to visual observation, it can be assumed that cattle will defecate in pasture areas in proportion to the amount of time which they spend in each area.

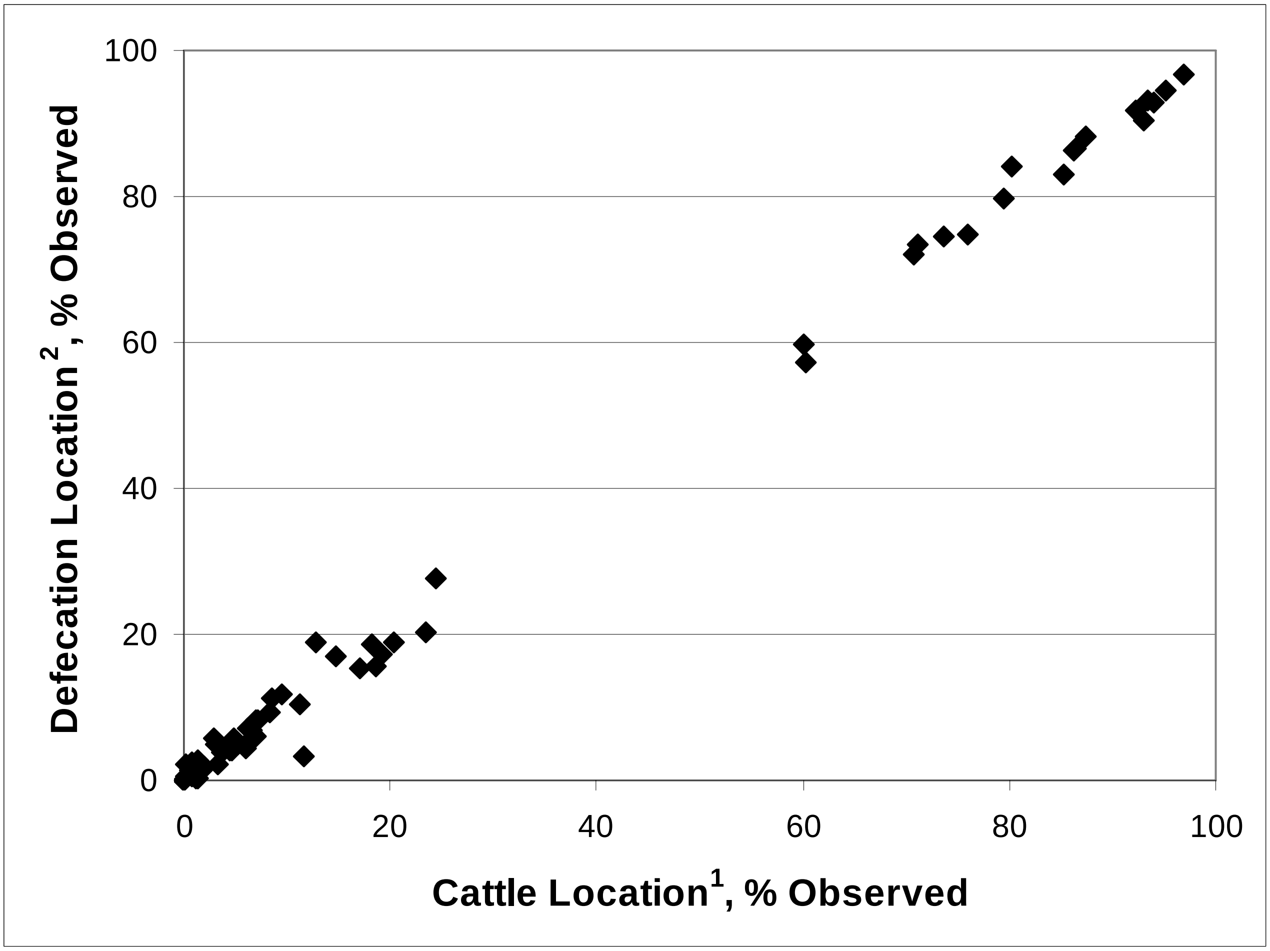


Figure 24. Relationship between cattle distribution and the distribution of observed defecations.

[1]Proportion of time cattle were observed within 4 pasture zones (stream, 110, 220, and upland) in pastures managed by continuous or rotational stocking during the 2005, 2006, and 2007 grazing seasons.

[2]Proportion of observed defecations by cattle within 4 pasture zones (stream, 110, 220, and upland) in pastures managed by continuous or rotational stocking during the 2005, 2006, and 2007 grazing seasons.

Alternative Water Effects on Cattle Distribution

Pooled data from 2006 and 2007 failed to show that the presence of off-stream water would decrease the proportion of time cattle spent with or near a pasture stream (Table 21). These results contrast from 2006 data which demonstrated that the presence of an alternative water source would significantly decrease (P<.05) the proportion of time cattle in CSU pastures spent within the stream (Table 22). The difference in response between the years may have been caused by the presence of small ponds and gullies, resulting from greater precipitation in 2007, in the pastures that may have acted as natural sources of off-stream water in 2007.

Table 21. Effect of an alternative water source on the proportion of time cattle spend in different pasture zones (GPS Collar Data pooled across 2006 and 2007)

	May				July				September			
	Stream[1]	110	220	Upland	Stream	110	220	Upland	Stream	110	220	Upland
	Continuous Stocking Unrestricted Stream Access											
No Alternative Water	0.6	12.1	4.5	82.8	3.2	12.8	3.8	80.2	0.2	9.7	8.8	81.4
Alternative Water	1.8	8.2	1.5	88.4	0.6	7.7	6.4	85.3	0.1	7.9	13.2	78.9
	Continuous Stocking Restricted Stream Access											
No Alternative Water	0.1	1.0	5.1	93.8	0.4	2.2	5.6	91.8	0.0	2.3	7.5	90.2
Alternative Water	0.0	0.9	4.0	95.0	0.0	0.9	4.7	94.4	0.0	1.7	15.0	83.3
Water	NS	NS	.05	.05	NS	NS	NS	NS	NS	NS	NS	NS
Trt x Water	.07	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1]Stream = Within the stream, 110 = from the edge of the stream to 110 feet from the stream, 220 = from 110 feet to 220 feet away from the stream, Upland = greater than 220 feet from the stream.

In 2006, in both CSU and CSR pastures, cattle spent less (P<.05) time in the 110-foot zone when alternative water sources were available in the uplands. Neither the presence of alternative water nor water availability by grazing treatment interactions altered cattle distribution patterns in either the 220 or upland zones. Cattle spent the greatest (P<.05) amount of time in the stream and 110 foot zone in July when an alternative water source was not available (Table 23).

Table 22. Effect of grazing management and the availability of alternative water on cattle distribution patterns managed by CSU and CSR treatments during the 2006 grazing season.

	Stream	110	220	Upland
		CSR		
No Alternative Water, % of GPS readings	0.4[d]	3.6[cd]	7.9	88.2
Alternative Water, % of GPS readings	0.1[d]	1.1[d]	10.2	88.6
		CSU		
No Alternative Water, % of GPS readings	3.2[b]	16.5[b]	6.3	74.0
Alternative Water, % of GPS readings	1.6[c]	10.3[bc]	5.8	82.4
water[a]	< 0.05	< 0.05	NS	NS
water × trt	< 0.05	NS	NS	NS

[a]water = presence or absence of an alternative water source, water × trt = alternative water by grazing management treatment interaction, NS = no significant differences, P<0.05.
[bcd]Values with different superscripts within a column differ (P<0.05). Values reported are LSmeans.

Table 23. Effect of grazing management and the availability of alternative water on cattle distribution patterns managed by CSU and CSR treatments during the 2006 grazing season.

	Stream	110	220	Upland
		May		
No Alternative Water, % of GPS readings	0.4[d]	6.8[c]	5.9	86.8
Alternative Water, % of GPS readings	1.7[c]	7.0[c]	2.8	88.5
		July		
No Alternative Water, % of GPS readings	4.9[b]	17.5[b]	6.9	70.8
Alternative Water, % of GPS readings	0.7[cd]	3.6[d]	4.1	91.5
		September		
No Alternative Water, % of GPS readings	0.1[e]	5.9[c]	8.4	85.6
Alternative Water, % of GPS readings	0.1[e]	6.4[c]	17.1	76.5
water × mth[a]	<.05	<.05	NS	NS

[a]water × mth = alternative water by month effect, NS = no significant differences, P<.05.
[bcde]Values with different superscripts within a column differ (P<.05). Values reported are LSmeans.

Microclimate Effects in Cattle Distribution

As black globe temperature increased, the proportion of time cattle spent in the shade increased in CSU and CSR pastures in 2006 and 2007 (R^2=0.87, Fig. 25). Based on 2006 and 2007 GPS collar data, at ambient temperatures above 27°C (approximately 80°F), the proportion of time cattle in CSU pastures spent within 110 feet of the stream increased, both when off-stream water was unavailable (R^2=0.87; $Y = 8.9 – 1.27X + 0.063X^2$; Fig. 26) or available (R^2=0.84; $Y = 5.5 – 1.27X + 0.63X^2$; Fig. 27)., this response was not observed for cattle in CSR pastures when off-stream water was unavailable (R^2=0.20; $Y = 1.57 – 0.37X + 0.018X^2$; Fig. 28) or available (R^2= 0.20; $Y = 062 + 0.40X + 0.001X^2$; Fig. 29).

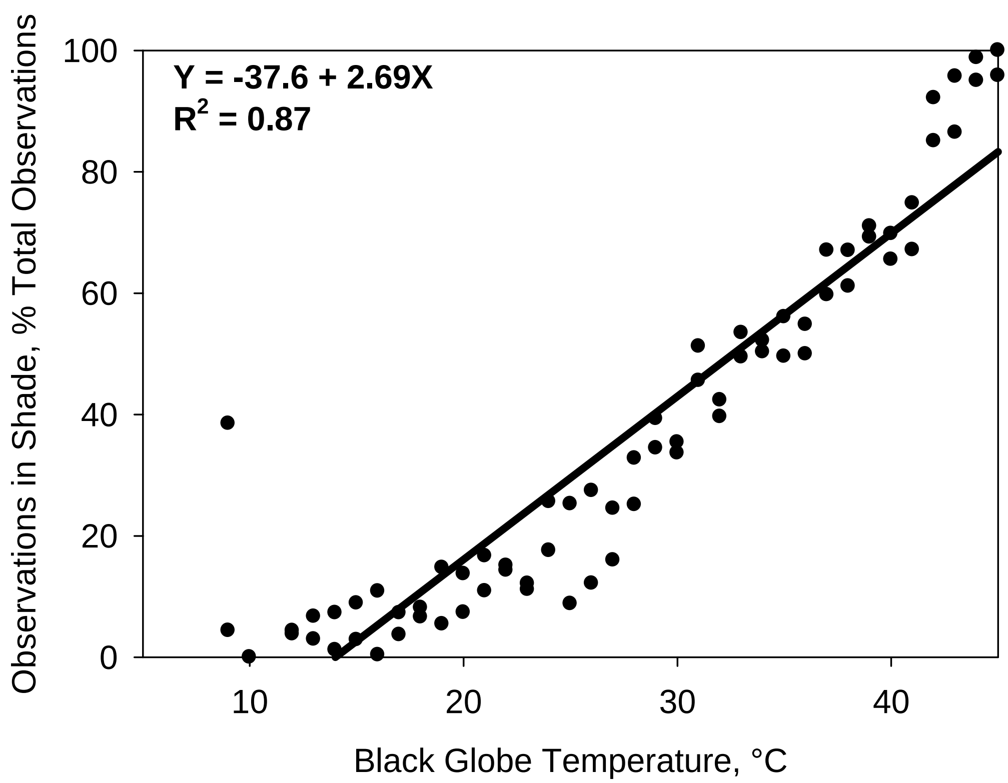


Figure 25. Effect of black globe temperature on the proportion of time cattle spend in the shade. Based on pooled visual observation data from CSU and CSR pastures in 2006 and 2007.

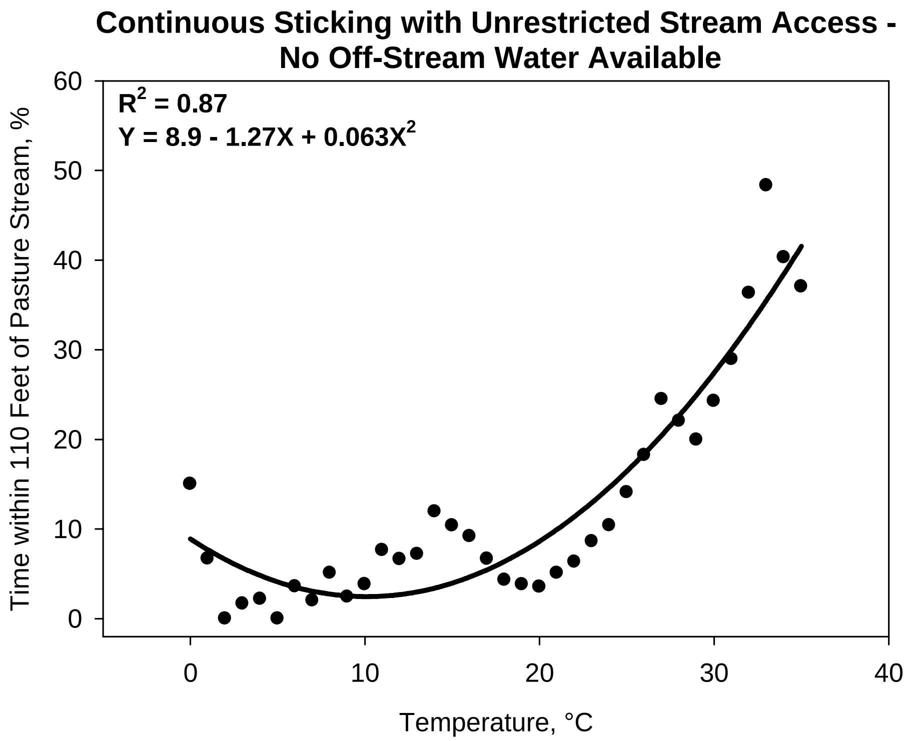


Figure 26. Effect of temperature on cattle distribution in CSU pastures when no off-stream water source was available.

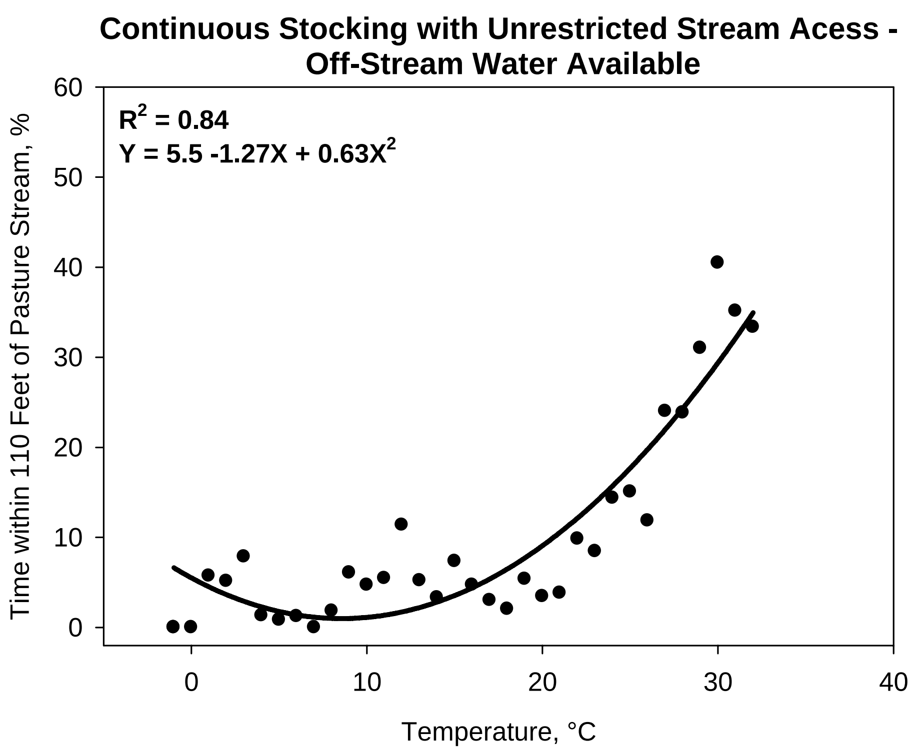


Figure 27. Effect of temperature on cattle distribution in CSU pastures when an off-stream water source was available.

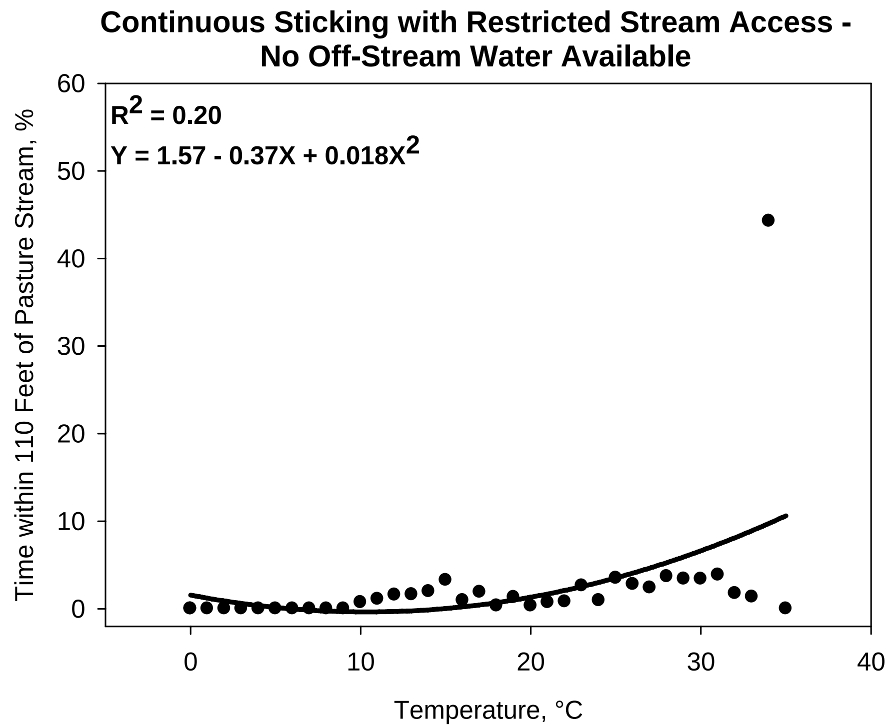


Figure 28. Effect of temperature on cattle distribution in CSR pastures when no off-stream water source was available.

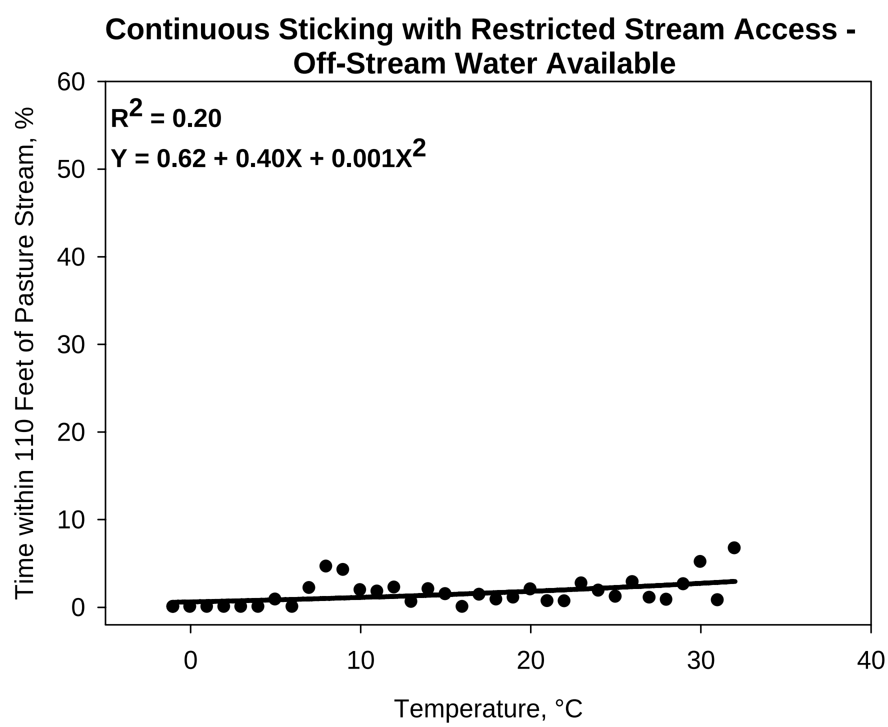


Figure 29. Effect of temperature on cattle distribution in CSR pastures when an off-stream water source was available.

Fecal Contamination of Streams

On a daily basis, cattle on the demonstration pastures excreted approximately 18 pounds of fecal material (on a dry matter basis) and 50 g of phosphorus in these feces. The distribution of cattle defecations is similar to cattle distribution patterns (Fig. 24), meaning that the amount of feces deposited in a given area is directly proportional to the amount of time cattle spend in that area. By decreasing the proportion of time cattle are in or within 110 feet of the stream, the amount of feces and fecal phosphorus, in addition to other nutrients and pathogens, deposited in or near pasture streams can be decreased (Table 24). By adding on off-stream water source to the CSU pastures the amount of fecal material and phosphorus deposited in the stream was decreased by 38% and the amounts deposited within 110 feet of the stream was decreased by 32%. The use of CSR and RS decreased the amount of feces and fecal phosphorus deposited within the riparian area (Stream + 110 Zone) by 84 and 53%, respectively, compared to CSU pastures.

Table 24. Grazing management and off-stream water effects on fecal and fecal phosphorus excretion in or within 110 feet of a pasture stream.

		Fecal Excretion[1], lbs/cow/day			Phosphorus Excretion[1], g/cow/day		
	Off-Stream Water	Total	In Stream	Within 110 Feet of Stream	Total	In Stream	Within 110 Feet of Stream
CSU[2]	Absent	17.9	0.24	2.06	50.6	0.67	5.83
CSR[2]	Absent	17.9	0.03	0.33	50.6	0.09	0.93
CSU[2]	Present	17.9	0.15	1.40	50.6	0.42	4.01
CSR[2]	Present	17.9	0.00	0.21	50.6	0.00	0.59
RS[3]	--	17.9	--	1.09	50.6	--	3.1

[1]Pregnant fall-calving cows receiving no phosphorus supplementation. Average of 2005 and 2006 excretion data over 3 grazing treatments.

[2]CSU = continuous stocking with unrestricted stream access, CSR = continuous stocking with restricted stream access. Calculated as the proportion of time cattle were within each zone based on 2006 and 2007 GPS collar data.

[3]RS = rotational stocking. Calculated as the percent of days in riparian paddock over the three grazing seasons (6.1% of grazing time within riparian paddock).

Objective 3: Demonstration of Site-Specific Models to Optimize Pasture Stream Water Quality

Publication

Animal Industry Reports

- Russell, J., J. Kovar, D. Morrical, D. Strohbehn, W. Powers, and J. Lawrence. 2006. Effects of Grazing Management on Pasture Characteristics Affecting Sediment and Phosphorus Pollution of Pasture Streams (Progress Report). Iowa State University Dept. of Animal Science, Animal Industry Report. A.S. Leaflet R2122. On-line: http://www.ans.iastate.edu/report/air/, verified 1/11/2008.
- Haan, M.M., J. R. Russell, D. Morrical, and D. Strohbehn. 2007. Effect of Grazing Management on Cattle Distribution Patterns in Relation to Pasture Streams. Iowa State University Dept. of Animal Science, Animal Industry Reports. A.S. Leaflet R2205. On-line: http://www.ans.iastate.edu/report/air/, verified 1/11/2008.
- Haan, M.M., J. R. Russell, D. Morrical, and D. Strohbehn. 2007. Effects of Grazing Management on Forage Sward Height, Mass, and Nutrient Concentrations and the Proportions of Fecal Cover and Bare Soil in Pastures. Iowa State University Dept. of Animal Science, Animal Industry Reports. A.S. Leaflet R2206. On-line: http://www.ans.iastate.edu/report/air/, verified 1/11/2008.
- Haan, M.M., J. R. Russell, J. Kovar, S. Nellesen, D. Morrical, and D. Strohbehn. 2007. Effects of Grazing Management on Selected Stream Bank Characteristics and Stream Bank Erosion. Iowa State University Dept. of Animal Science, Animal Industry Reports. A.S. Leaflet R2207. On-line: http://www.ans.iastate.edu/report/air/, verified 1/11/2008.
- Haan, M.M., J.R. Russell, D. Morrical, and D. Strohbehn. 2008. Effect of Grazing Management on Cattle Distribution Patterns in Relation to Pasture Streams. Iowa State University Dept. of Animal Science, Animal Industry Reports. A.S. Leaflet R2268. On-line: http://www.ans.iastate.edu/report/air/, verified 1/30/2008.
- Haan, M.M., J.R. Russell, D. Morrical, and D. Strohbehn. 2008. Effects of Grazing Management on the Physical and Nutritional Characteristics of Pastures. Iowa State University Dept. of Animal Science, Animal Industry Reports. A.S. Leaflet R2323. On-line: http://www.ans.iastate.edu/report/air/, verified 1/30/2008.
- Haan, M.M., J.R. Russell, J. Kovar, D. Morrical, and D. Strohbehn. 2008. Effects of Grazing Management on Selected Stream Bank Characteristics and Stream Bank Erosion. Iowa State University Dept. of Animal Science, Animal Industry Reports. A.S. Leaflet R2325. On-line: http://www.ans.iastate.edu/report/air/, verified 1/30/2008.
- Haan, M.M., D. Assman, J.R. Russell. 2008. Phosphorus, Crude Protein, and Digestible Dry Matter Concentrations of Forage Selected by Grazing Beef Cattle. Iowa State University Dept. of Animal Science, Animal Industry Reports. A.S. Leaflet R2271. On-line: http://www.ans.iastate.edu/report/air/, verified 1/30/2008.

Proceedings and Abstracts

- Haan, M., J. Russell, J. Davis, D. Morrical, D. Strohbehn, and W. Powers. 2006. Effect of Grazing Management on Cattle Distribution Patterns and Implications on Water Quality. Proceedings 3rd National Conference on Grazing Lands.
- Haan, M., J. Russell, J. Davis, D. Morrical, D. Strohbehn, and W. Powers. 2006. Grazing management effects on the distribution of forage, bare ground, and fecal cover in pastures. Proceedings 3rd National Conference on Grazing Lands (Abstract).
- Haan, M., J. Russell, J. Davis, D. Morrical, D. Strohbehn, and W. Powers. 2006. Grazing management effects on stream morphology, stream bank condition, and stream bank erosion. Proceedings 3rd National Conference on Grazing Lands (Abstract).
- Moeller, S.L., J.L. Kovar, J.R. Russell, and M.M. Haan. 2006. Grazing Management Effects on Potential Sediment and Phosphorus Loss from Stream banks. Proceedings ASA - CSSA – SSSA International Annual Meetings (Abstract).
- Haan, M., J. Russell, J. Davis, D.Morrical, D. Strohbehn, and W. Powers. 2006. Effects of grazing management on cattle distribution patterns. Journal of Animal Science 84 (Supp. 1): 389 (Abstract).
- Haan, M., J. Russell, D. Morrical, D. Strohbehn, W. Powers, J. Lawrence, and J. Kovar. 2006. Effects of grazing management on pasture characteristics affecting sediment and nutrient loads in surface waters. Journal of Animal Science 84 (Supp. 1): 319-320 (Abstract).
- Russell, J. and M. Haan. 2007. Grazing and Nutritional Management of Beef Cows to Limit Non-Point Source Pollution of Streams in Midwestern Pastures. Journal of Animal Science 85(Suppl. 2): (Abstract).
- Haan, M., J. Russell, D. Bear, and D. Morrical. 2008. Grazing management and microclimatic effects on cattle distribution patterns in riparian pastures. Journal of Animal Science 86(Suppl.): (Abstract).
- Haan, M., J. Russell, and D. Morrical. 2008. Grazing management effects on physical and nutritional characteristics of pastures. Journal of Animal Science 86(Suppl.): (Abstract).
- M. Haan, J. Russell, and J. Kovar. 2008. Grazing management effects on selected stream bank characteristics and erosion. Journal of Animal Science 86(Suppl.): (Abstract).
- Haan, M., J. Russell, D. Bear, and D. Morrical. 2008. Impacts of grazing management on cattle distribution and non-point source pollution from pastures in the central United States. Proceedings of the International Conference on Grazing Lands (Abstract).

Presentations

Conference Presentations

- November 16, 2005. GIS Day Conference. Mat Haan and Jim Russell presented (Poster) "*Impact of Management on Spatial and Temporal Cattle Distribution within a Pasture*." Ames, IA.
- November 16, 2005. GIS Day Conference. J.H. Davis, M.J. Darr, H. Xin, J.D. Harmon, and J.R. Russell presented (Poster): "*Sampling Methodologies for GPS Tracking of Beef Cattle*." Ames, IA.

- October 2005. ASA - CSSA – SSSA International Annual Meetings. Shelly Moeller and John Kovar presented (Poster): "*Potential Phosphorus Losses from Streambanks in Grazing Lands.*" Salt Lake City, UT.
- January 2006. Kansas Graziers Association Winter Grazing Conference. Mat Haan and Jim Russell presented (Oral): "*Managing Pastures to Minimize Water Quality Impacts*." Assaria, KS.
- March 2006. 2006 Agriculture and the Environment Conference. Dan Morrical presented (Oral): "*Grazing Management Effects of Sediment and Phosphorus Loading of Pasture Streams by Stream Bank Erosion and Manure Deposition.*" Ames, IA.
- April 2006. Heartland Regional Water Quality Coordination Initiative Conference. Mat Haan presented (Oral): "*Phosphorus Management in Pasture Systems*." Nebraska City, NE.
- June 2006. Annual Meeting of the NCERA-87 Cow-Calf Nutrition and Management Committee. Jim Russell and Mat Haan. Presented (Oral): "*Effects of grazing management on cattle distribution, forage quality/ quantity, and stream bank erosion*." Columbia, MO.
- July 2006. USDA Grazing Behavior Workshop. Mat Haan and Jim Russell. Presented (Oral): "*Effect of grazing management on cattle distribution patterns.*" State College, PA.
- July 2006. American Society of Animal Science – American Society of Dairy Science Annual Joint Meeting. Mat Haan presented (Poster): "*Effects of grazing management on pasture characteristics affecting sediment and nutrient loads in surface waters*." Minneapolis, MN.
- July 2006. American Society of Animal Science – American Society of Dairy Science Annual Joint Meeting. Mat Haan presented (Oral): *"Effect of grazing management on cattle distribution patterns."* Minneapolis, MN.
- November, 2006. Iowa Forage and Grassland Conference. Dan Morrical and Mat Haan presented (Poster): "*Effects of grazing management on pasture characteristics affecting sediment and nutrient loads in surface waters*." Des Moines, IA.
- November, 2006. Iowa Forage and Grassland Conference. Dan Morrical and Mat Haan presented (Poster): "*Effect of Grazing Management on Cattle Distribution Patterns in Relation to a Pasture Stream.*" Des Moines, IA.
- November 2006. GIS Day Conference. Mat Haan presented (Poster): "*Effect of Grazing Management on Cattle Distribution Patterns in Relation to a Pasture Stream.*" Ames, IA.
- November 2006. ASA - CSSA – SSSA International Annual Meetings. John Kovar presented (Poster): *"Grazing Management Effects on Potential Sediment and Phosphorus Loss from Stream banks."* Indianapolis, IN.
- December, 2006. 3rd National Conference on Grazing Lands. Mat Haan presented (Oral): "*Effect of grazing management on cattle distribution patterns and implications on water quality.*" St. Louis, MO.
- December, 2006. 3rd National Conference on Grazing Lands. Mat Haan presented (Poster): "*Grazing management effects on the distribution of forage, bare ground, and fecal cover in pastures.*" St. Louis, MO.
- December, 2006. 3rd National Conference on Grazing Lands. Mat Haan presented (Poster): *"Grazing management effects on stream morphology, stream bank condition, and stream bank erosion."* St. Louis, MO.

- January, 2007. Iowa Watersheds Annual Meeting. Mat Haan and Jim Russell presented (Poster): *"Use of Grazing Management to Limit Sediment and Phosphorus Pollution of Pasture Streams from Stream bank Erosion and Manure Deposition."* Des Moines, IA.
- March 2007. Midwest Sectional Meetings of the American Society of Animal Science and the American Dairy Science Association. Jim Russell and Mat Haan presented (Oral): *"Grazing and Nutritional Management of Beef Cows to Limit Non-Point Source Pollution of Streams in Midwestern Pastures."* Des Moines, IA.
- April 2007. Iowa Feed and Nutrition Seminar. Mat Haan presented (Oral) *"The Use of Grazing Management to Control Non-Point Source Pollution of Pasture Streams."* Ames, IA.
- June 2007. American Forage and Grasslands Conference Annual Meeting. Mat Haan presented (Oral): *"Grazing Management and Microclimatic Effects on Cattle Distribution Patterns in Riparian Pastures."* State Collage, PA.
- June 2007. American Forage and Grasslands Conference Annual Meeting. Mat Haan presented (Oral): *"Grazing Management Effects on Forage Mass and Composition and Ground Cover within Riparian Pastures."* State Collage, PA.
- June 2007. American Forage and Grasslands Conference Annual Meeting. Mat Haan presented (Poster): *"Beef Cattle Grazing Management Effects on Pasture Stream Bank Erosion."* State Collage, PA.
- June 2007. Annual Meeting of the National Workgroup on Minimizing Agricultural Phosphorus Losses (SERA-17) John Kovar presented (Poster): *"Potential Sediment and Phosphorus Losses from Stream Banks in Grazed Riparian Pastures."* Fayetteville, AR.
- September 13, 2007. Rathbun Land and Water Alliance Annual Meeting. J. Russell, M. Haan, D. Bear, et al. presented (Poster): *"Pasture Management Effects on Non-point Source Pollution in the Rathbun Watershed."* Chariton, IA.
- September 18, 2007. Iowa Water Center Team Building Symposium. J.L. Kovar, S.L. Nellesen, J.R. Russell, and M.M. Haan presented (Poster): *"Potential Sediment and Phosphorus Losses from Stream Banks in Grazed Riparian Pastures."* Iowa City, IA.
- November 20, 2007. Iowa Forage and Grasslands Conference. Mat Haan, Jim Russell, and Doug Bear presented (Oral): "*Grazing Management of Beef Cows to Limit Non-point Source Pollution of Streams in Midwestern Pastures*". Des Moines, IA.

Field Days

- August 3, 2004. Location: Rhodes Research farm. Topic: Discussion of research objectives and design and the installation of stream crossings. Eighteen members of the Grassland Alliance attended.
- August 3, 2004. Location: Rhodes Research Farm. Topic: Discussion of stream crossing construction and the use of governmental programs to assist in the funding of such improvements. Fifteen extension personnel and producers attended.
- September 15, 2005. Location: Rhodes Research Farm. Topic: Discussion of stream crossing construction and maintenance, cattle behavior with different grazing systems, and grazing management. Seventy-five producers and extension personnel were in attendance. As a result of this Field Day, an interview was given to the River Valley Cooperative for an article posted on their Web page.

- October, 2006. Location: Rhodes Research Farm. Topic: Riparian grazing management. Iowa State University Area Extension Livestock Specialist In-Service Training.
- May 16, 2007. Location: McNay Research and Demonstration Farm. Topic: Grazing and nutritional management of beef cows to limit non-point source pollution of streams in Midwestern Pastures. Approximately 50 veterinarians and extension personnel were in attendance.
- June 27, 2007. Location: Rhodes Research Farm. Topic: The effects of grazing management on cattle distribution and stream bank erosion. Approximately 80 producers and extension personnel were in attendance.
- August 28, 2007. Location: McNay Research Farm. Topic: Grazing management of beef cows to limit non-point source pollution of streams in Midwestern pastures. Approximately 60 participants were in attendance.

Other Presentations

- A project web page was constructed in October 2004 by Rachel Martin and Daryl Strohbehn and is located at:

www.iowabeefcenter.org/content/stream bankcrossing.htm
The web page has been continuously updated as new information becomes available.

- Jim Russell gave an interview to writer from the Iowa Cattlemens' Association for an article describing project in the Iowa Cattlemens' Magazine in the spring of 2005.