Report for 2002IA7B: Effects of grazing management on sediment and phosphorus losses in pastures

There are no reported publications resulting from this project.

Report Follows:

Problem and Research Objectives

The amounts of sediment and phosphorus in water runoff from agricultural lands are of concern because of the potential for siltation and eutrophication brought on by high phosphorus concentrations of surface waters. Currently, there is limited information about the total sediment and phosphorus loads in runoff coming from pastureland in the Midwest. Because vegetation limits soil disruption caused by the impact of raindrops and forage roots hold soil particles, forages harvested at an appropriate height through suitable grazing management should maintain water infiltration and minimize sediment and phosphorus losses in water runoff from pastures. The objectives of this experiment were to quantify the amounts of sediment and phosphorus in the runoff from pasturelands managed by different systems, develop tools to monitor and control sediment and phosphorus loss from pastures, and develop best management practices for producers to control sediment and phosphorus losses while optimizing productivity of pastures.

Methodology

Pasture Management. Three blocks of approximately 2.75 hectares were located on hills with slopes up to 15° in a smooth bromegrass (*Bromus inermis*) pasture at the Iowa State University Rhodes Research and Demonstration Farm near Rhodes, Iowa. Each block was subdivided into five 0.4-hectare paddocks, with a 6-meter wide lane at the top for cattle movement and a 10-meter wide buffer area at the bottom. Prior to the initiation of grazing in 2001, soil samples were collected to depths of 0 to 5 cm and 5 to 10 cm to determine soil P and K levels. Diammonium phosphate was applied in the spring of 2001 so that all pastures were at least at an optimum level (11 - 15 ppm P) of phosphorus. Soils in all paddocks contained an optimum level (81 - 120 ppm K) or greater of potassium; therefore, no additional potassium was applied. In both years urea was applied at a rate of 200 kg/ha before the start of grazing in the spring and 115 kg/ha at the initiation of the forage stockpiling period, in August, to all pastures. Sandbags were placed around the perimeter of the pastures and between each paddock to prevent contamination from runoff by natural rainfall events from outside the experimental area and between neighboring paddocks.

Grazing treatments were randomly assigned to each of the 5 paddocks in each plot. Treatments included an ungrazed control (U), summer hay harvest with winter stockpiled grazing to a residual sward height of 5 cm (HS), continuous stocking to a residual sward height of 5 cm (5C), rotational stocking to a residual sward height of 5 cm (5R), and rotational stocking to a residual sward height of 10 cm (10R). Grazing was initiated on May 29, 2001, and May 7, 2002, with 3 mature Angus cows in each grazed paddock.

In the continuous stocking system, cattle were removed from the paddocks after the sward height decreased to 5 cm. Paddocks were allowed a rest period of 7 to 10 days to limit regrowth, thereby simulating continuous stocking. In the rotational stocking systems, cattle were removed from the paddocks after the sward height decreased to 5 or 10 cm. Paddocks were allowed rest periods of 35 days to allow plant regrowth in rotational stocking. Forage sward heights were measured with a raising plate meter (4.8 kg/m^2) twice weekly during the grazing seasons. During the 2001 grazing season, mean total grazing days were 491, 360, and 274 cow-days/ha, and during 2002 grazing season, mean total grazing days were 400, 316, and 257 cow-days/ha for the 5C, 5R, and 10R stocking systems, respectively.

First-cutting hay was harvested from the HS treatment in June of 2001 and 2002, yielding 1079 and 1471 kg of forage dry matter per acre, respectively. Regrowth from these paddocks was clipped in early August of each year to initiate forage stockpiling, but the yield of clipped forage was inadequate to bale. Each paddock in the HS system was stocked in mid-November of each year and grazed to a residual sward height of 5 cm, allowing grazing for 47 and 59 cow-days/ha in 2001 and 2002, respectively.

Rainfall Simulations. To determine sediment and phosphorus loss in water runoff, rainfall simulations were conducted 4 times per year for 2 years. Year 1 simulations were conducted in the late spring, mid-summer, and autumn of 2001, and early spring of 2002. Year 2 simulations were conducted in late spring, mid-summer, and autumn of 2002 and early spring 2003. Six simulation sites were selected within each paddock—3 within a low slope range (1° to 7°) and three in a high slope range (7° to 15°). Six simulation sites were selected within the buffer zone below each paddock. Three of these sites were at the base of the paddock and 3 were 10 meters within the buffer strip. Rainfall simulation locations were identified with GPS so that the same locations could be used during each sampling period. Rainfall simulators were 0.5 x 1.0 meter and assembled so that the uphill side of the simulator was 1 meter high. Each rainfall simulation ran for 1.5 hours at a precipitation rate of 7.1 cm/hour. The water source used was rural water that had been filtered through an additional 0.45 µm filter, to remove particulate matter. During simulations, the amount of rainfall and runoff was measured at 10-minute intervals, and a sample of runoff was collected and added to a composite sample that was used to determine total sediment, total phosphorus, and soluble phosphorus. Surface roughness was measured with a 41-pin meter with a length of 2 meters; ground cover was determined by the percentage of pins on the pin meter striking plant material. During simulations, soil samples were taken adjacent to each site at depths of 0–5 cm and 5–12 cm for determination of Bray-1 phosphorus and soil moisture. Penetration resistance was measured at 3.5-cm intervals to a depth of 35 cm using a Bush Recording Penetrometer; readings from the 0 to 10 cm depth, 10 to 20 cm depth, and 20 to 35 cm depth were averaged for statistical analysis. Sward height was measured using a rising plate meter (4.8 kg/m^2), and a forage sample was clipped from a 0.25-m^2 area adjacent to the rainfall simulation site to determine the mass of forage dry matter.

Principal Findings and Significance

Grazing Effects in Paddocks. The proportion of rainfall lost as runoff was less ($P<0.05$) in the U paddocks than in all other treatments during both years 1 and 2. In year 1, the proportion of rainfall lost as runoff was greater ($P<0.05$) in the late spring (36%) than in mid-summer (11.8%), autumn (13.1%), or early spring (7.1%) across all treatments. Similarly, in year 2, the proportion of rainfall lost as runoff in late spring (19.4 %) was greater ($P<0.05$) than the mid-summer (7.5%), autumn (11.8%), and early spring (12.6%) periods.

There were no differences in mean concentrations of sediment in runoff between stocking treatments in either year. Mean total P concentrations in the runoff were greater in paddocks with the 5C and 5R treatments than other treatments in both years ($P<0.05$). Mean sediment and total P concentrations did not differ between months in year 1, but soluble P concentrations were greater ($P<0.05$) in the late spring than the other sampling periods. In year 2, mean sediment and total P concentrations in runoff did not differ between sampling periods. However, soluble P concentration in runoff was less in the early spring than it was in other sampling periods.

Erosion of sediment was not different between treatments in year 1. In year 2, the 5C paddocks contributed greater amounts of erosion ($P<0.05$) than the other treatments. The greatest amount of erosion occurred in the late spring period across all treatments in both years ($P<0.05$). Of the pasture physical characteristics measured sediment loss was most highly correlated with percent surface cover ($Y=889.2 - 19.95\,x + 0.108\,x^2$, $r^2=0.3362$), where Y is the sediment loss in kg/ha/simulation and x is the percentage of ground covered with plant material.

Losses of total P were greater ($P<0.05$) from paddocks with the 5C and 5R treatments than U paddocks in year 1, while the HS and 10R treatments were intermediate and not significantly different from any of the other treatments (Table 1). Total P losses were greater ($P<0.05$) from 5C treatment then from all other treatments in year 2. Losses of soluble P were lower ($P<0.05$) from U paddocks than from other treatments in year 1. In year 2 the 5R treatment had greater ($P<0.05$) soluble P losses than U, with the HS, 5C, and 10R intermediate to, and not significantly different from, either the U or 5R treatments. In years 1 and 2, 89% and 76% of the total P in the runoff was in the form of soluble P.

Table 1. Annual sediment, total P and soluble P in runoff.

	Sediment, (kg/ha)		**Total P, (kg P/ha)**		**Soluble P, (kg P/ha)**	
	Year 1[b]	Year 2	Year 1	Year 2	Year 1	Year 2
U[a]	11.4	4.8[c]	0.06[c]	0.03[c]	0.04[c]	0.02[c]
HS	34.5	17.8[c]	0.23[c,d]	0.10[c]	0.19[d]	0.04[c,d]
5C	61.2	118.2[d]	0.41[d]	0.40[d]	0.29[e]	0.13[c,d]
5R	61.9	30.5[c]	0.41[d]	0.21[c]	0.35[e]	0.17[d]
10R	46.2	17.8[c]	0.26[c,d]	0.09[c]	0.20[d,e]	0.04[c,d]

[a] U = Ungrazed, HS = Summer Hay Harvest/Winter Stockpile Grazing, 5C = 5cm Continuous Grazing, 5R = 5cm Rotational Grazing, 10R = 10cm Rotational Grazing.
[b] Different letter within the same column denotes a difference, ($P<0.05$).

High slope areas had a greater percentage of rainfall lost as runoff than low slope areas in both years (21.2 vs. 14.6% in year 1 and 16.0 vs. 9.8% in year 2) across all treatments and months ($P<0.05$). There was no effect of slope on sediment or total P and soluble P concentrations or total and soluble P losses in runoff for either year. Sediment loss from high slope areas was greater ($P<0.05$) than from low slope areas in year 1 (14.7 vs. 7.3 kg/ha) across all treatments. There was no significant effect of slope on sediment loss in year 2.

In both years, sward heights of the grazed paddocks were greatest in the early summer period ($P<0.05$). By later sampling periods, the paddocks had been sufficiently grazed to reach their prescribed forage sward height.

Soil moisture in the upper 5 cm was greater in year 1 than in year 2 ($P<0.05$), 23.3% and 20.5%, respectively. Soil moisture was greater in the U paddocks (24.6% and 22.1% for year 1 and 2, respectively) than in all other paddocks ($P<0.05$) in both years, with no difference in soil moisture between the other treatments (23.1%, 23.8%, 23.0%, and 21.8% in year 1 and 19.6%, 20.8%, 20.9%, and 20.0% in year 2 for 5C, 5R, 10R, and HS, respectively). In both years soil moisture followed the same trend with soil moisture high in the late spring, lowest in the mid-summer, intermediate in the autumn, and high in early spring ($P<0.05$). Soil moisture was 27.5%, 16.2%, 22.9%, and 26.6% in year 1 and 24.2%, 13.6%, 21.9%, and 23.8% in year 2 for late spring, mid-summer, autumn, and early spring, respectively.

Mean penetration resistance in the 0 to 10 cm depth for the four sampling periods in year 1 was lowest for the U treatment (20.5 kg-force), intermediate for the HS (23.5 kg-force) treatment, and greatest in the summer grazing treatments (25.0, 26.1, and 26.2 kg-force for the 5C, 5R, and 10R, respectively; $P<0.05$) but did not differ between summer grazing treatments. In year 2, mean penetration resistance in the 0 to 10 cm depth the U paddocks were lower ($P<0.05$) (24.8 kg-force) than all other treatments. However, there were no differences in penetration resistance between paddocks with different forage utilization systems (30.6, 33.9, 33.5, and 34.3 kg-force for the HS, 5C, 5R and 10R treatments, respectively). Mean penetration resistance in the 10 to 20 cm depth was unaffected by treatment in either year, averaging 27.2 and 34.7 kg-force across all treatments for year 1 and 2, respectively. Similarly, mean penetration resistance in the 20 to 35 cm depth was unaffected by treatment in either year averaging 28.6 and 39.5 kg-force for year 1 and 2, respectively.

Averaged across months, surface cover in ungrazed paddocks was greater ($P<0.05$) than paddocks in which forage was harvested either as hay or grazed. In both years, surface cover in the 5C paddocks was lower than paddocks with other treatments ($P<0.05$). Mean surface covers were 99.0%, 93.5%, 82.8%, 89.9%, and 93.3% in year 1 and 99.1%, 95.5%, 89.1%, 91.4%, and 94.1% in year 2 for the U, HS, 5C, 5R, and 10R treatments, respectively.

Surface roughness did not differ by treatment or time in either year. Soil Bray-1 P concentrations in the upper 5 cm were 20 to 25 ppm at the initiation of the experiment and did not differ between treatment or sampling period in either year. However, total P losses during rainfall simulations were greater from simulation sites that had greater soil Bray-1 P concentrations.

Buffer Effects. Mean sediment concentrations in the runoff were not affected by simulation location or month in either year. However, mean total P and soluble P concentrations in run-off were greater ($P<0.05$) in the paddocks than at the base of the paddock or 10-meter in the buffer in both years. Over the two years, mean concentrations of total and soluble P from paddocks were 49.5% and 47.4% greater, respectively, ($P<0.05$) than the mean values within the buffers. This result indicates that grazing will increase the amount of P that is available for transport within a pasture, but it rapidly becomes immobile again in ungrazed buffer areas.

In year 1, the proportion of rainfall lost as runoff was greater ($P<0.05$) in the paddocks than at the paddock base and at 10 meters within the buffer. In year 2, the proportion of rainfall lost as runoff was greater ($P<0.05$) in the paddocks and at the paddock base than at 10 meters within the buffer. In year 1, percent runoff was 17.1%, 11.7%, and 8.6% and in year 2 percent runoff was 12.8%, 12.8%, and 7.5% from the paddock, base of the paddock, and 10 m within the buffer, respectively. These differences can partially be attributed to the differences in soil slope, soil texture, and forage composition that exist between locations.

In year 1, there was no difference in sediment loss between the paddock and the two locations within the buffer. In year 2, sediment loss was greatest from the paddock, lowest from 10m within the buffer, and intermediate at the base of the buffer (Table 2). As a result of differences in rainfall infiltration and the total phosphorus concentration of runoff, total phosphorus flows from the paddocks were 3.5 and 7.0 times greater ($P<0.05$) than those from the paddock base and in the buffer in year 1 and 2.0 and 4.0 times greater ($P<0.05$) than those from the paddock base and in the buffer in year 2. Amounts of soluble P in the runoff were 3.0 and 24 times greater in the buffer and at the base of the paddock than in the paddock in year 1.

Table 2. Sediment, Total P, and Soluble P losses within the paddocks, at the base of the paddock, and 10m within the buffer.

	Sediment, (kg/ha)		Total P, (kg P/ha)		Soluble P, (kg P/ha)	
	Year 1[b]	Year 2	Year 1	Year 2	Year 1	Year 2
Paddock[a]	44.0	38.4[a]	0.28[a]	0.16[a]	0.24[a]	0.08
Base	27.6	21.2[a,b]	0.08[b]	0.08[b]	0.08[b]	0.03
Buffer	20.4	10.4[b]	0.04[b]	0.04[b]	0.01[b]	0.02

[a] Paddock = Average across all paddocks, Base = At the paddock-buffer interface, within the buffer, Buffer = Within the buffer, 10m down slope from the paddocks
[b] Different letter within the same column denotes a difference, ($P<0.05$).

Across treatments, mean forage sward heights in paddocks, at the paddock base, and 10 meters in the buffer strip were 9.4, 17.3, and 18.1 cm in year 1 and 12.2, 22.9, and 24.6 cm in year 2 ($P<0.05$).

Penetration resistance in the upper 10 cm of soil was greater in the paddocks than at either the paddock base or 10 meters in the buffer strip ($P<0.05$) for all sampling periods except late spring of year 1. In both years at all locations and depths, penetration resistance was low during the late spring, increased to a maximum in mid-summer, decreased to an intermediate level by autumn, and had returned to late spring levels by early spring. These differences not only represent treatment effects but are also influenced by soil moisture and texture differences between location and sampling periods.

Major Findings. Of the physical measurements, the proportion of ground cover was most highly related to sediment loss. Results imply that sediment and phosphorus losses in pasture runoff may be reduced by managing rotational stocking to maintain adequate sward height and/or using vegetative buffer strips along pasture streams. Such management practices are particularly important in pastures on soils with high Bray-1 P concentrations.

Time line of research and outreach activities for the March 2002 to February 2003 time period

- April 2002 - Early spring rainfall simulations
- April/May 2002 - Processed runoff samples from April rainfall simulations
- May 2002 - Grazing initiated on pastures, Hay cut
- June 2002 - Late spring rainfall simulations, Processed runoff samples from June rainfall simulations
- July 2002 - Presented preliminary research results at the Rhodes Research and Demonstration Farm Field Day, Presented first years data at the American Forage and Grassland Conference meetings (Title "Effects of grazing management on sediment and phosphorus runoff"), Mid-summer rainfall simulations
- July/August 2002 - Processed runoff samples from July rainfall simulations
- October 2002 - Summer grazing period terminated, Fall rainfall simulations
- October/November 2002 - Processed runoff samples from October rainfall simulations
- November 2002 - Stockpile forage grazing period
- January 2003 - Results from 2001 and 2002 summarized for *2003 ISU Beef Research Report*, titles: "Effects of Grazing Management on Pasture Production and Phosphorous Content of Forage (A Progress Report)" and "Effects of Grazing Management on Sediment and Phosphorous Losses in Runoff (A Progress Report)." Copies available online at http://www.iowabeefcenter.org.