Impacts of Cattle Grazing Management on Sediment and Phosphorus Loads in Surface Waters

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Summary and Implications

In 2001 (yr 1), 2002 (yr 2), and 2003 (yr 3), three blocks of five 1-ac paddocks were grazed by beef cows on hills at the Iowa State University Rhodes Research and Demonstration Farm to determine the effects of grazing management on phosphorus (P) and sediment runoff from pastureland. Grazing management treatments included an ungrazed control (UG), summer hay harvest with winter stockpiled grazing (HS), grazing by continuous stocking to a residual sward height of 2 in. (2C), rotational stocking to a residual sward height of 2 in. (2R), and rotational stocking to a residual sward height of 4 in (4R). At four times (late spring, mid-summer, early autumn, and early the subsequent spring) in each year, rainfall simulations were conducted at 6 sites within each paddock. Rainfall simulators dripped at a rate of 2.8 in./hr over a 5.4-ft^2 area for a period of 1.5 hours. Runoff was collected and analyzed for total sediment, total P, and total soluble P. Simultaneous to each rainfall simulation, ground cover, penetration resistance, surface roughness, slope, the contents of P and moisture of the soil, sward height and forage mass were measured. Sediment flow was not affected by forage management practice. There was no difference between UG, HS, 4R in the amount of total P or soluble P lost in runoff, but greater amounts of total and soluble P were lost from 2C and 2R than from the other management practices (P<0.05). A greater amount of sediment was lost from the pastures during the late spring period than during other parts of the year (P<0.05). Losses of sediment, total P, and soluble P from pastures can be controlled by suitable grazing management practices.

Introduction

The amounts of sediment and P in water runoff from agricultural lands are of concern because of the potential for siltation and eutrophication of surface waters. Inappropriate grazing management can accelerate erosion and sediment transport to surface waters. Phosphorus is the primary nutrient of concern for causing eutrophication in fresh water lakes and streams. Many factors contribute to the amount of sediment and P that can potentially be dislodged from a pasture and contribute to diminished water quality. These factors include the amount of ground cover, treading damage by livestock, slope, antecedent soil moisture, and soil P content. Studies have found that there is no single physical characteristic of a pasture, for example ground cover and sward height, that is a good predictor of the chemical constituents of runoff water. Once sediment and P have been dislodged from the landscape, vegetative buffers are effective tools for reducing the amounts that arrive in surface waters. It has been shown that approximately 75% of the total P and ortho-P load in runoff were removed with a 6.1 m vegetative filter strip when artificial rainfall was applied to an area treated with cattle manure. It is the belief of the authors that the amounts of sediment and P that are actually lost from pastureland can be reduced through forages harvested at an appropriate height through suitable management practices. The objectives of the current study were to quantify the amounts of sediment, total P, and total soluble P in the runoff produced by simulated rainfall during different times of the year in pastures with different forage management systems.

Materials and Methods

Site Description

The study was conducted at the Iowa State University Rhodes Research and Demonstration Farm (42°00' N, 93°25' W). Pastures were located on hills with slopes up to 15° and were primarily composed of smooth bromegrass (*Bromus inermis*). While the thirty-year average annual precipitation for the area is 35 in., precipitation was 36.7, 28.2, and 37.8 in. in yr 1, 2, and 3, respectively.

Three blocks of approximately 6.8 ac were subdivided into five 1-ac paddocks, with an 18-ft wide lane at the top of the hill for cattle movement and a 30-ft wide buffer area at the bottom of the hill. Prior to the initiation of grazing in 2001, soil samples were collected to depths of 0 to 2.5 in. and 2.5 to 5 in. to determine soil P and K levels. Diammonium phosphate was applied in the spring of 2001 so that all pastures were at an optimum level (11 - 15 ppm P) of P or greater. Soils in all paddocks contained an optimum level (81 - 120 ppm K) or greater of K; therefore, no additional K was applied. In all years, urea was applied at a rate of 180 lb/ac before the start of grazing in the spring and 100 lb/ac 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 during natural rainfall events from outside the experimental area and between neighboring paddocks. Prior to the initiation of the study, the research area was managed for hay harvest and moderate grazing of beef cattle.

Grazing Management

Grazing treatments were randomly assigned to each of the 5 paddocks in each plot. Treatments included: an ungrazed control (UG), summer hay harvest with winter stockpiled grazing to a residual sward height of 2 in. (HS), continuous stocking to a residual sward height of 2 in. (2C), rotational stocking to a residual sward height of 2 in. (2R), and rotational stocking to a residual sward height of 4 in. (4R). Grazing was initiated on May 29, 2001, May 7, 2002, and May 7, 2003 with 3 mature Angus cows (body weights 1430±185 lbs. in 2001, 1350±207 lbs. in 2002, and 1374±117 lbs. in 2003) in each grazed paddock. Cattle received no supplemental P while stocked on pastures.

In the continuous stocking system, cattle were removed from the paddocks after the sward height decreased to 2 in. Paddocks were allowed a rest period of 7 to 10 days to limit regrowth, and thereby, simulate continuous stocking. In the rotational stocking systems, cattle were removed from the paddocks after the sward height decreased to 2 or 4 in. Paddocks were allowed rest periods of 35-days to allow plant regrowth. Forage sward heights were measured with a rising plate meter (8.8 lb/yd^2) twice weekly during the grazing seasons. During the 2001 grazing season, mean total grazing days were 199, 153, and 117 cow-days/ac for the 2C, 2R, and 4R stocking systems, respectively. During the 2002 grazing season, mean total grazing days were 162, 128, and 104 cow-days/ac for the respective treatments and during the 2003 grazing season, mean total grazing days were 160, 128, and 109 cow-days/ac for the respective treatments.

First-cutting hay was harvested from the HS treatment in June of 2001, 2002 and 2003, yielding 2375, 3236, and 2966 lb/ac forage dry matter, 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 harvest. Paddocks in the HS system were stocked in mid-November of each year, with animals that had been used during the summer grazing period, and grazed to a residual sward height of 2 in., allowing grazing for 19, 24, and 34 cow-days/ac in 2001, 2002, and 2003, respectively.

Rainfall Simulations

To determine sediment and P loss in water runoff, rainfall simulations were conducted 4 times per year for 3 years (2001, 2002, and 2003). Simulations were conducted in the late spring, mid-summer, and autumn of each year and early spring of the following year. 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°). Rainfall simulation locations were identified with the geographical positioning system (GPS), allowing the same locations to be used during each sampling period. Rainfall simulators were 5.4-ft^2 and assembled so that the uphill side of the simulator was 3.3 ft high. Each rainfall simulation ran for 1.5 hours at a precipitation rate of 2.8 in./hr. 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 P, and total soluble P. Surface roughness was measured by digital photography of a 41-pin meter with a length of 6.5 ft, and 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 - 2 in. and 2 - 6 in., for determination of Bray-1 P and soil moisture. Penetration resistance was measured at 1.4-in. intervals to a depth of 14-in. using a Bush Recording Penetrometer. Sward height was measured using a rising plate meter (8.8 lb/yd^2), and a forage sample was clipped from a 2.7 ft^2 area adjacent to the rainfall simulation sites to determine the mass of forage dry matter.

Laboratory Analysis

Water samples were analyzed for sediment, total P, and total soluble P. Sediment was determined by filtering the water sample through a 0.45 μm filter. Total P was determined by digestion followed by the Ascorbic Acid Method. Total soluble P was determined by filtering through a 0.45 μm filter followed by digestion and the Ascorbic Acid Method.

Soil samples were analyzed for plant available P and moisture. Phosphorus levels were determined using the Bray-1 P procedure. Soil moisture was determined by drying samples at 105° C for 24-hours. Surface roughness was calculated as the standard deviation in pin height determined by image analysis.

Results and Discussion

Grazing Management Effects in Paddocks

Water runoff, as a percent of total rainfall, was greatest from the 2C and 2R treatments ($P<0.05$, Table 1). Runoff losses from these paddocks were 15% greater than were losses from UG. This greater percentage of runoff increases the volume of water to potentially transport sediment and nutrients and decreases the amount of moisture retained in the soil to support future plant growth. The percentage of runoff lost from the 4R treatment was not significantly greater than the loss from the UG treatment.

Even though the amount of sediment flow in runoff was numerically greatest from the 2C treatment, there was no significantly different between forage management treatments. There was also no difference in total P flow between the UG, HS, and 4R treatments. The greatest amount of total P flow came from the 2C treatment, and the 2R was intermediate to and not significantly different from the HS, 4R, or 2C treatments. By switching from a continuously grazed paddock to a rotationally managed paddock, while maintaining a 2-inch residual forage sward height, resulted in a 26% reduction in total P loss. By switching to a rotationally managed pasture and maintaining a residual forage sward height at 4 inches, compared to a 2-inch continuous management system, resulted in a 65% reduction in total P loss.

There was no difference in soluble P flow between the UG, HS, and 4R treatments, but there were greater soluble P losses from the 2R and 2C treatments. Switching from a rotational grazing system with a 2-inch residual forage sward weight to one with a 4-inch residual forage sward height resulted in a 64% reduction in soluble P flow.

Of the pasture physical characteristics measured (ground cover, forage mass, soil penetration resistance, forage height, and surface roughness), percent ground cover was most closely related to sediment loss (r^2=0.17). The relationship between sediment loss and percent ground cover was:

$Y\ 244.41 - 3.8013X + 0.0138X^2$; when Y = sediment loss (kg/ha) and X = percent ground cover.

Seasonal Effects in Paddocks

The greatest amount of water runoff, as a percentage of rainfall, occurred in the late spring (25.9%), the lowest amount occurred during the summer (5.5%), with fall (14.5%) and early spring (13.7%) being intermediate ($P<0.05$; Table 2). The late spring period is the time when there is the greatest amount of precipitation and greatest antecedent soil moisture (data not shown), with the soil being saturated and unable to absorb additional rainfall. The greater runoff during this period makes pastures particularly sensitive to the loss of sediment and nutrients. During the summer, soil moisture is low because of low precipitation resulting in greater capacity to absorb additional rainfall.

Sediment and total P losses from pastures were greater during the late spring than during any of the other time periods ($P<0.05$). Forty-seven percent of sediment loss and 50% of the total P loss occurred during the late spring period.

Soluble P loss was greater during the late spring, intermediate during the summer, and lowest during the fall and early spring periods ($P<0.05$). Soluble P flow was second highest during the summer even though the total amount of runoff was lowest during this time period. This discrepancy is a result of greater concentrations of soluble P in the runoff during this time period. Soluble P concentrations were 0.23, 0.33, 0.13, and 0.08 mg PO_4-P/L during the late spring, summer, fall, and early spring periods, respectively.

Conclusion

Losses of sediment, total P, and soluble P from pastures can be controlled by suitable grazing management practices. Both total and soluble P losses from pastures can be controlled by using rotational grazing practices that leave sufficient forage residue; 4 inches residual forage height, in the pasture. Additionally, certain periods of the year, late spring, are more prone to losses of sediment and P than are other periods of the year.

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Table 1. Effect of forage management system on runoff, and sediment, total P, and soluble P flows from pastures.

	Treatment					
	U*	HS	4R	2R	2C	SEM
Runoff, % Rainfall**	6.4[b]	16.4[a,c]	12.7[b,c]	20.7[a]	21.9[a]	2.7
Sediment Flow, lbs/ac	1.88	5.72	7.95	11.25	22.15	6.70
Total P Flow, lbs/ac	0.010[c]	0.033[b,c]	0.034[b,c]	0.071[a,b]	0.096[a]	0.014
Soluble P Flow, lbs/ac	0.005[a]	0.021[a]	0.019[a]	0.053[b]	0.046[b]	0.005

* U = Ungrazed, HS = Hay/ Winter Stockpile Grazing, 4R = 4 inch Rotational Grazing, 2R = 2 inch Rotational Grazing, 2C = 2 inch Continuous Grazing.

** Values are LS means of treatment effects. Different superscripts within a row indicate denote a difference, ($P<0.05$).

Table 2. Effect of season on runoff, and sediment, total P, and soluble P flows from pastures.

	Season				
	Late Spring	Summer	Fall	Early Spring	SEM
Runoff, % Rainfall*	25.9[a]	5.9[b]	14.5[c]	13.7[c]	1.6
Sediment Flow, lbs/ac	18.31[a]	4.38[b]	6.34[b]	10.09[b]	3.75
Total P Flow, lbs/ac	0.096[a]	0.039[b]	0.029[b]	0.029[b]	0.008
Soluble P Flow, lbs/ac	0.066[a]	0.030[b]	0.012[c]	0.006[c]	0.004

*Values are LS means of seasonal effects. Different superscripts within a row indicate denote a difference, ($P<0.05$).