Effects of Grazing Management on Sediment and Phosphorus Losses in Run-off (A Progress Report)

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Summary

In 2001 and 2002, pastures at the ISU Rhodes Research and Demonstration Farm were grazed to determine the effects of stocking treatment on nutrient and sediment loss from pastureland. Treatments included an ungrazed control (UG), summer hay harvest with winter stockpiled grazing (HS), continuous stocking to a residual height of 2 inches (2C), rotational stocking to a residual height of 2 inches (2R), and rotational stocking to a residual height of 4 inches (4R). At three times in 2001 (late spring, mid-summer, and fall) and four times in 2002 (early spring, late spring, mid-summer, and fall), rainfall simulations were conducted at 6 sites within each paddock and 6 sites in a buffer zone down slope from each paddock. Run-off was collected and analyzed for total sediment, total phosphorus, and dissolved phosphorus. Simultaneous to each rainfall simulation, ground cover, penetration resistance, surface roughness, slope, contents of phosphorus and moisture of the soil, and the sward height and mass of forage were measured. In years 1 (late spring 2001 through early spring 2002) and 2 (late spring 2002 through fall 2002), mean concentrations of sediment in runoff did not differ between ungrazed or grazed paddocks. Mean concentrations of total P in the run-off were greater ($P < .05$) in paddocks grazed to 2 inches by continuous or rotational stocking than in paddocks that were ungrazed, grazed to 4 inches by rotational stocking or harvested as hay and grazed as stockpiled forage. In year 1, mean losses of sediment, total P, and soluble P were greater ($P < .1$) from paddocks grazed to 2 inches by continuous or rotational stocking than other treatments. In year 2, mean losses of sediment and total P in paddocks grazed to 2 inches by continuous stocking and mean losses of soluble P from paddocks grazed to 2 inches by rotational stocking were greater ($P < .05$) than the other treatments.

Introduction

The amounts of sediment and phosphorus in water run-off from agricultural lands are of concern because of the potential for siltation and eutrophication of Iowa's waterways. Because of these problems, it is likely that the U.S. Environmental Protection Agency will implement regulations to control the total maximum daily loads of nutrients in watersheds in the near future. Currently, there is limited information regarding the total sediment and phosphorus loads in run-off coming from pastureland in the Midwest. Because forage leaves limit 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 loss in water run-off from pastures. The objectives of this experiment were to quantify the amounts of sediment and phosphorus in the run-off 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.

Materials and Methods

Grazing Treatments

Three blocks of approximately 6.8 acres were identified on hills with slopes up to 15° in a smooth bromegrass (*Bromus inermis*) pasture at the ISU Rhodes Research and Demonstration Farm. Each block was subdivided into five 1-acre paddocks with an 18-foot wide lane at the top for cattle movement and a 30-foot wide buffer area at the bottom (Figure 1). 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 fertility. Phosphorus was applied in the spring of 2001 so that all pastures were at a minimum of an optimum level (11 - 15 ppm P). Soils in all paddocks contained optimum (81 - 120 ppm) or greater levels of K; therefore, no additional potassium was applied. Each year, urea was applied at a rate of 180 pounds/acre before the start of grazing in the spring and 100 pounds/acre at the initiation of the forage stockpiling in August to all pastures. Sandbags were placed around the perimeter of the pastures and between each paddock to prevent cross-contamination from run-off by natural rainfall events between neighboring paddocks.

Grazing treatments were randomly assigned to the 5 paddocks in each block. Treatments included: an ungrazed control (UG), summer hay harvest with winter stockpiled grazing (HS), continuous stocking to a residual sward height of 2 inches (2C), rotational stocking to a residual sward height of 2 inches (2R), and rotational stocking to a residual sward height of 4 inches (4R). Grazing was initiated on May 29, 2001, and May 7, 2002 with 3 mature cows in each grazed paddock.

In the continuous stocking system, cattle were removed from the paddocks after sward height decreased to 2 inches. Paddocks were allowed a rest period of 7 to10 days to limit regrowth and, thereby, simulate continuous stocking. In the rotational stocking systems, cattle were removed from the paddocks after sward height decreased to 2 or 4 inches. Paddocks were allowed rest periods of 35 days to permit plant regrowth as in rotational stocking. Forage sward heights were measured twice weekly during the grazing seasons to determine when cattle were removed from the pasture. Stocking rates were 199, 153, and 117 in 2001 and 162, 128, and 104 in 2002 cow-days/acre for the 2C, 2R, and 4R treatments, respectively.

First-cutting hay was harvested from paddocks with the hay/stockpile (HS) treatment in June of 2001 and 2002 yielding 2,720 and 3,700 pounds 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. Paddocks in the HS system were stocked with three cows in mid-November of each year and grazed to a residual sward height of 2 inches, allowing 19 and 24 cow-days/acre in 2001 and 2002, respectively.

Rainfall Simulations

To determine sediment and phosphorus loss in water run-off, rainfall simulations were conducted 4 times per year; in the late spring, mid-summer, and fall of 2001, and early spring, late spring, mid-summer, and fall of 2002. A year begins with the late spring sampling period, after cattle have been turned out on pasture, and continues until early spring of the following calendar year, before cattle are turned out on pasture. Six simulation sites were selected within each paddock; 3 within a low slope range (1° to 7°) and three within a high slope range (7° to 15°). Six simulation sites were selected within the buffer zone down slope of each paddock. Three of these sites were at the base of the paddock and 3 were 30-feet within the buffer strip. Rainfall simulations were conducted at the same location in each of the sampling periods. Rainfall simulators were 1.6 x 3.3 feet and assembled so that the uphill side of the simulator was 3.3 feet high. Each rainfall simulation ran for 1.5 hours at a precipitation rate of 1.6 gallons /10 minutes (2.8 inches/hour). During simulations, amounts of rainfall and run-off were measured at 10-minute intervals. Run-off was sampled, composited and analyzed for total sediment, total phosphorus, and soluble phosphorus.

Before each series of rainfall simulations, surface roughness was measured, as the standard deviation in height of pins in a 40-pin meter with a length of 6.5 feet and ground cover was determined as the inverse of the percentage of pins on the pin meter striking bare ground. Simultaneous to each simulation, soil samples were collected adjacent to each site at depths of 0 to 2 inches and 2 to 6 inches so they could be analyzed for phosphorus and moisture. Penetration resistance was measured at 1.4-inch intervals to a depth of 14-inches using a Bush Recording Penetrometer; readings from the 0 to 4 inch range, 4 to 8 inch range, and 8 to 14 inch range were averaged for statistical analysis. Sward height was measured using a rising plate meter (8.8 lb/yd^2), and a forage sample was clipped from a 0.30-yd^2 area to determine dry matter mass.

Results and Discussion

Grazing Effects in Paddocks

The proportion of rainfall lost as run-off was less ($P < .05$) in the UG paddocks than in all other treatments during both years 1 and 2 (Figures 2 and 3). In year 1, the proportion of run-off was greater ($p<.05$) in the late spring sampling period (36%) than those in mid-summer (11.8%), fall (14.8%) or early spring (7.1%) across all treatments. Similarly, in year 2, the proportion of run-off in late spring (19.4 %) was greater ($p<.05$) than the mid-summer (7.5%) and fall periods(11.8%).

In year 1 and 2, there were no differences in mean concentrations of sediment in run-off between stocking treatments**.** Mean total P concentrations in the run-off were greater ($P < .05$) in paddocks with the 2C and 2R treatments than other treatments in both years ($P < .05$). Mean sediment and total P concentrations did not differ between months in year one, but soluble P concentrations were greater ($P < .05$) in the late spring than the later sampling periods during the same year. In year 2, mean sediment concentrations in run-off were greater ($P < .05$) in late spring than the later sampling periods. However, mean total P and soluble P concentrations in run-off were not affected by sampling period.

Mean losses of sediment (Figures 4 and 5), total P (Figures 6 and 7), and soluble P (Figures 8 and 9) were greater ($P < .1$) in paddocks with the 2C and 2R treatments than other treatments. But, in year 2, paddocks with the 2C treatment had greater ($P < .05$) losses of sediment and total P than the other treatments whereas paddocks with the 2R treatment had the greater ($p<.05$) soluble P losses than the other treatments. Mean sediment losses in late spring were greater ($P < .05$) than other periods across all treatments in both years. In years 1 and 2, 89 and 76% of the total P in the run-off was in the form of soluble P.

High slope areas had a greater percentage of run-off 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 ($P < .05$). There was no effect of slope on either sediment or P concentrations or P loss in run-off for either year. Sediment loss from high slope areas was greater ($P < .05$) than from low slope areas in year 1 (13.1 vs. 6.5 lbs./acre) across all treatments and months. There was no significant effect of slope on sediment loss in year 2.

In both years, sward heights of the grazed paddocks were greater ($P < .05$) in the late spring than in the mid-summer and fall sampling periods when paddocks had been sufficiently grazed to reach their prescribed forage sward heights (Table 1).

Surface cover of ungrazed paddocks was greater ($P < .05$) than paddocks in which forage was harvested either as hay or grazed. In both years, surface cover in the 2C paddocks was lower than paddocks with other treatments ($P < .05$). Year 1 averaged 99.0%, 93.5%, 82.8%, 89.9%, and 93.3% cover and year 2 averaged 99.2%, 95.2%, 88.0%, 90.2%, and 94.4% cover for the UG, HS, 2C, 2R, and 4R treatments, respectively.

Penetration resistance in the 0 to 4 inch range for year 1 was lowest for the UG treatment (45 lbs-force), intermediate for the HS (51.7 lbs-force) treatment and were greatest in the summer grazing treatments (54.9, 57.4, and 57.6 lbs-force for the 2C, 2R, and 4R, respectively; $P < .05$), but did not differ between summer grazing treatments. In year 2, penetration resistance in the UG paddock was lower ($P < .05$) (61.1 lbs-force) than all other treatments. However, there were no differences in penetration resistance between paddocks with different forage utilization systems (73.0, 79.2, 78.3, and 82.5 lbs-force for the HS, 2C, 2R and 4R treatments, respectively). Penetration resistance in the 4 to 8 inch range was unaffected by treatment in either year, averaging 59.8 and 85.6 lbs-force across all treatments for year 1 and 2, respectively. Penetration resistance in the 8 to 14 inch range was unaffected by treatment in either year averaging 63.0 and 93.1 lbs-force for year 1 and 2, respectively.

Soil P levels in the upper two inches have remained constant across treatments at 20 to 25 ppm over all periods in both years. Surface roughness did not differ by treatment or time.

Buffer Effects

Mean sediment concentrations in the run-off were not affected by simulation location or month in either year. However, mean total P and soluble P concentrations in run-off were greater ($P < .05$) in the paddocks than at the base of the paddock or 30-feet 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 ($P < .05$) 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.

As a result of differences in rainfall infiltration and the total phosphorus concentration of run-off, mean total phosphorus flows from paddocks were 3.4 and 4.1 times greater ($P < .05$) than those from the paddock base or in the buffer in year one and 2.2 and 4.8 times greater ($P < .05$) than those from the paddock base or in the buffer in year two. Amounts of soluble P in the run-off were 24% and 28% lower in the buffer and at the base of the paddock than in the paddock when averaged across both years.

In both years, the proportions of rainfall lost as run-off were greater ($P < .05$) in the paddock and at the paddock base than at 30 feet within the buffer. These differences can partially be attributed to the differences in soil slope, soil texture, and forage composition that exist between locations.

Mean forage sward height in paddocks, at the paddock base, and 30 feet in the buffer strip were 3.7, 6.8, and 7.1 inches in year 1 and 4.8, 9.0, and 9.7 inches in year 2 ($P < .05$). While mean sward heights varied according to treatment within the paddocks, there were no differences in sward heights at the paddock base or in the buffer.

Penetration resistance in the upper 4 inches of soil was greater in the paddocks than at either the paddock base or 30 feet in the buffer strip ($P < .05$) for all sampling periods except late spring of year 1. In year 1at 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 fall and had returned to late spring levels by early spring. Year 2 data has followed a similar trend so far, with no early spring sampling period data yet.

Implications

These data show that pasture management affects rainfall run-off and the flows of sediment and phosphorus within a pasture. It also appears that the use of ungrazed buffer areas can be effective in controlling sediment and P from reaching surface waters.

Acknowledgments

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Figure 1. Pasture 2 Layout.

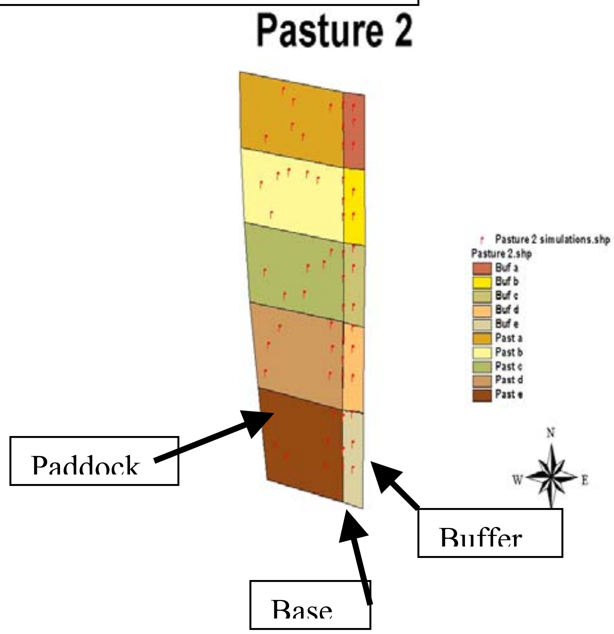
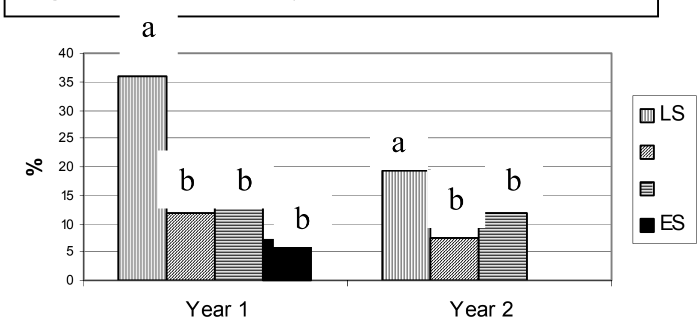


Table 1. Forage sward height by treatment and sampling period for year 1 and 2 (in.).

	Year 1				Year 2		
Treatment	**LS***	**MS**	**F**	**ES**	**LS**	**MS**	**F**
UG**	**12.8[a]**	**6.4[a]**	**4.4[a]**	**3.0**	**14.4[a]**	**9.3[a]**	**5.6[a]**
HS	**3.9[b]**	**3.7[b]**	**4.3[a]**	**2.6**	**2.1[b]**	**4.5[b]**	**4.1[b]**
2C	**4.8[b]**	**2.1[c]**	**1.5[b]**	**1.7**	**2.6[b]**	**2.7[c]**	**1.5[b]**
2R	**4.1[b]**	**2.3[c]**	**2.1[b,c]**	**2.1**	**4.6[c]**	**3.5[b,c]**	**2.6[b]**
4R	**5.1[b]**	**4.1[b]**	**3.1[a,c]**	**2.5**	**6.6[d]**	**4.6[b]**	**2.8[b]**

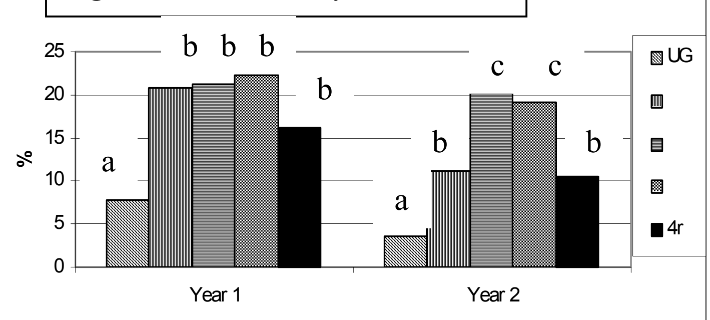
*** LS = Late Spring, MS = Mid-Summer, F = Fall, ES = Early Spring**
****UG = Ungrazed, HS = Hay/Stockpile, 2C = 2" Continuous, 2 R = 2" Rotational, 4R = 4" Rotational.**
Different letters within a column represent a difference (p<.05).

Figure 2. % Run-off, by month.

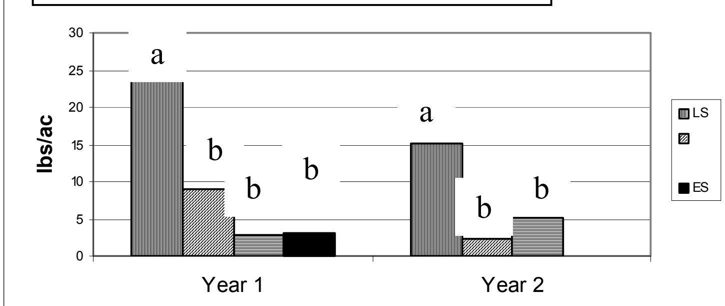


Different letters denote a difference, p<.05

Figure 3. % Run-off, by treatment.

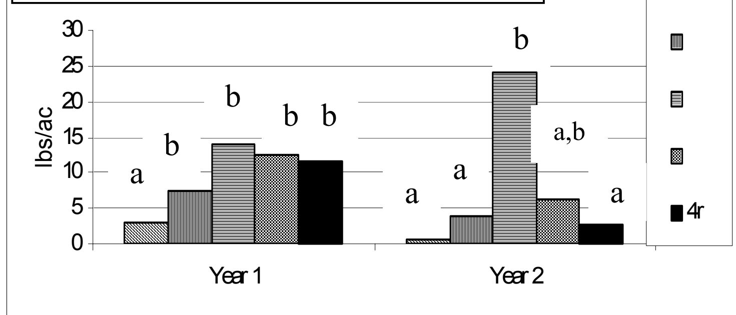


Different letters denote a difference, p<.05



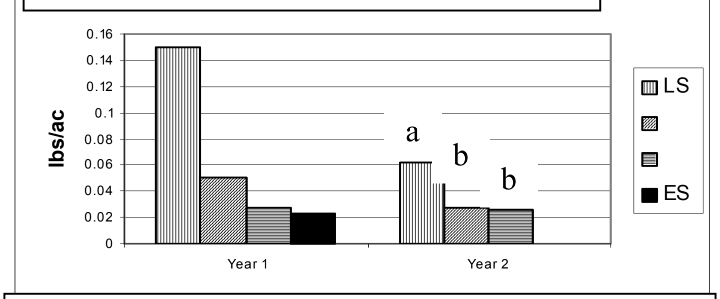
Different letters denote a difference, p<.05

Figure 5. Sediment loss by treatment.

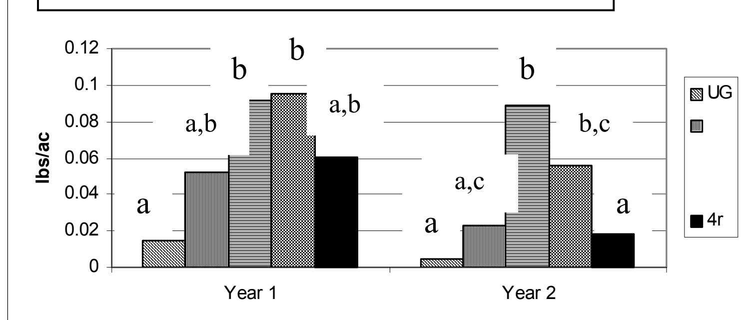


Different letters denote a difference, p<.08

Figure 6. Total P loss, by month.

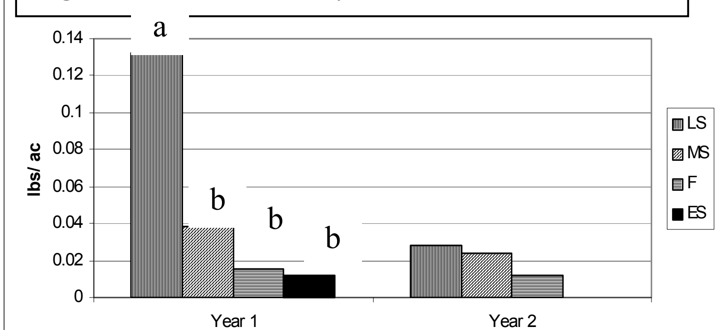


Different letters denote a difference, p<.05



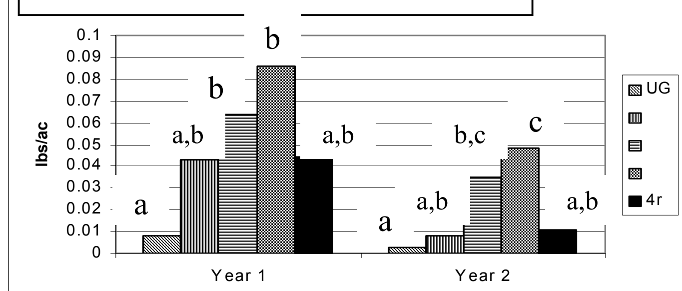
Different letters denote a difference, p<.05

Figure 8. Soluble P loss, by month.



Different letters denote a difference, p<.05

Figure 9. Soluble P loss, by treatment.



Different letters denote a difference, p<.05