

Effects of Grazing Management on Sediment and Phosphorus Runoff (A Progress Report)

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Summary

In spring 2001, grazing was initiated on pastures at the ISU Rhodes Research Farm to determine the effects of grazing treatment on nutrient and sediment loss from pastureland. Treatments included an ungrazed control, summer hay harvest with winter stockpiled grazing, continuous stocking to a residual height of 2 inches, rotational stocking to a residual height of 2 inches, and rotational stocking to a residual height of 4 inches. At two times (June and August) during the summer, rainfall simulations were conducted at 6 sites within each paddock and 6 sites in a buffer zone beneath each paddock. Rainfall simulators dripped at a rate of 6 liters/10 minutes over a .5-m² area (2.8 inches/hours) for a period of 1.5 hours. Amounts of rainfall and runoff were recorded at 10-minute intervals during the sampling period. Runoff was collected and analyzed for total sediment, total phosphorus, and dissolved phosphorus. Simultaneous to each rainfall simulation, measurement was taken of ground cover, penetration resistance, surface roughness, slope, the contents of phosphorus and moisture of the soil, and the sward height and mass of forage. Slope and forage treatment in paddocks did not significantly affect the concentration and amount of sediment in runoff. However, the concentrations and amounts of total phosphorus in runoff from paddocks that were grazed were greater than paddocks that were ungrazed or harvested for hay during summer. The concentrations and amounts of total phosphorus in runoff were lower in paddocks that were rotationally stocked to a height of 4 inches than in those that were rotationally stocked to 2 inches. The amounts of sediment and total phosphorus in runoff from paddocks that were grazed were greater than their respective buffers.

Introduction

The amount of sediment and phosphorus in water runoff from agricultural lands is 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 about the total sediment and phosphorus loads in runoff 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 runoff from pastures. The objectives of this experiment are 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.

Materials and Methods

Grazing Treatments

Three plots of approximately 6.8 acres were identified on hills with slopes up to 15 degrees in a smooth bromegrass pasture at the ISU Rhodes Research and Demonstration Farm near Rhodes, Iowa. Each plot was subdivided into five 1-acre paddocks, with a 6-meter wide lane at the top for cattle movement and a 10-meter wide buffer area at the bottom. The paddocks were fenced in the spring of 2001, and initial soil samples were collected to depths of 0–2.5 inches and 2.5–5 inches to determine soil phosphorus and potassium levels. Phosphorus was applied in the spring of 2001 so that all pastures were at a minimum of an optimum level (11–15 ppm P₂O₅), and urea was applied at a rate of 180 pounds/acre to all pastures. Soils in all paddocks contained an optimum level (81–120 ppm K₂O) or greater, therefore no additional potassium was applied. Sandbags were placed around the perimeter of the pastures and between each paddock to prevent cross-contamination from runoff by natural rainfall events between neighboring paddocks.

Grazing treatments were randomly assigned to each of the 5 paddocks in each plot. Treatments included: an ungrazed control, summer hay harvest and winter stockpiled grazing, continuous stocking to a residual sward height of

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2 inches, rotational stocking to a residual sward height of 2 inches, and rotational stocking to a residual sward height of 4 inches. Grazing was initiated on May 29, 2001, 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 7–10 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 simulate plant regrowth in rotational stocking. Forage sward heights were measured twice weekly during the grazing season to determine when cattle should be removed. Mean total grazing days for the grazing season were 199, 153, and 117 cow-days/acre for the 2-inch continuous stocking, 2-inch rotational stocking, and 4-inch rotational stocking systems, respectively. First-cutting hay was harvested from the hay/stockpile treatment on June 8, 2001. Regrowth from these paddocks was clipped on August 13 to initiate forage stockpiling, but the yield of clipped forage was inadequate to bale. Each paddock in the hay/stockpile system was stocked with 2 cows on November 12 and grazed to a residual sward height of 2 inches on November 21.

Rainfall Simulations

To determine sediment and phosphorus loss in water runoff, rainfall simulations were conducted in June, August, and October 2001. Six simulation sites were selected within each paddock; 3 within a low slope range (1 to 7 degrees) and three in a high slope range (7 to 15 degrees). 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. The same sites were used for each set of rainfall simulations. Rainfall simulators were 0.5 x 1 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 6 liters /10 minutes (2.8 inches/hour). 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. Before conducting rainfall simulations, a digital photo of each simulation site was taken to determine ground cover by image analysis. Surface roughness was measured with a 40-pin meter with a length of 2 meters. During simulations, soil samples were taken adjacent to each site at depths of 0–2 inches and 2–6 inches, to be analyzed for phosphorus and moisture. Penetration resistance was measured at 3.5-cm intervals to a depth of 28-cm using a Bush Recording Penetrometer. Sward height was measured using a rising plate meter (4.8 kg/m²), and a forage sample was clipped from a 0.25-meter squared area to determine dry matter mass. At present, only the June and August data from the rainfall simulations have been analyzed.

The effects of forage treatments and slopes within the paddocks on the concentrations and flows of sediment and total phosphorus were analyzed by a split-split-split plot, with the main plot of treatment tested with the block by treatment interaction as the error term and the subplot of slope and the interaction of slope and treatment tested with the position by block by treatment by slope interaction as the error term. The effects of forage treatments and buffers on the concentrations and flows of sediment and total phosphorus were analyzed by a split-split plot, with the main effects of treatment and buffer and the interaction of treatment and buffer tested with the position by block by treatment by buffer interaction as the error term.

Results and Discussion

Grazing Effects in Paddocks

As expected, the forage sward height differed between treatments and months (Figure 1). In June, the grazed paddocks had a shorter sward height than did the ungrazed paddocks, but there was no significant difference in sward height between the grazing treatments (Month X Treatment, $P < .05$). The lack of a difference in sward height in June likely resulted from the cattle being placed in the paddocks on May 29 with, therefore, inadequate time to achieve desired sward height before the sampling period. In August, the sward height of ungrazed paddocks were greater than grazed paddocks, and the sward height of paddocks that were rotationally grazed to 4 inches or harvested for hay were greater than those that were grazed to 2 inches either by continuous or rotational stocking.

Rainfall infiltration rates of soils on sites in August were greater ($P < .01$) than the same sites in June. This effect was most likely related to lower soil moisture concentrations in August than June. The mean infiltration rate of paddocks that were ungrazed was greater than grazed paddocks ($P < .01$) or paddocks harvested as hay ($P < .05$). Although the infiltration rate of paddocks harvested as hay were lower than grazed paddocks in June, infiltration rate of paddocks harvested as hay were greater than grazed paddocks in August (Month X Treatment, $P < .01$). Stocking rate or residual sward height did not affect the soil infiltration rates of grazed paddocks. However, sites with slopes of 7–15 degrees had 7% lower infiltration rates than sites with lesser slopes. Mean concentrations or flows of sediment did not differ between forage management treatments or slopes of paddocks. Mean total phosphorus concentrations in runoff from ungrazed paddocks were 42% lower ($P < .01$) than grazed paddocks in both months (Figure 2). Similarly, mean total phosphorus concentration in runoff from grazed paddocks were greater ($P < .05$) than paddocks used for hay harvest. There was no significant difference in mean total phosphorus concentrations between the continuously grazed paddock and the rotationally grazed paddocks, but the mean total phosphorus concentration in runoff from paddocks rotationally stocked to 4 inches were 48% lower ($P < .05$) than paddocks rotationally stocked to 2 inches. This effect

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was more prevalent in August than in June (treatment by month, $P < .01$) because of the greater time allowed for the treatments to have effects. Slope did not have a significant effect on phosphorus concentration in the runoff.

Mean flows of total phosphorus in runoff from paddocks were 2.5 times greater ($P < .01$) in June than in August. Mean total phosphorus flows from ungrazed paddocks were 81% lower ($P < .01$) than paddocks in which the forage was harvested by grazing or hay harvest. Similarly, total phosphorus flows from paddocks harvested as hay was 31% lower ($P < .10$) than grazed paddocks. However, mean total phosphorus flows from paddocks grazed by rotational stocking to a residual height of 4 inches were only 3% greater than paddocks harvested for hay and were 38% lower ($P < .05$) than paddocks grazed to a residual sward height of 2 inches either by continuous or rotational stocking.

Buffer Effects

There was a significant difference in sward height for the grazed and hayed treatments depending on location of the simulator (in the paddock, at the base of the paddock, or 10-meters from the base of the paddock). Mean sward height in paddocks, at the paddock base, and 10-meters in the buffer strip was, respectively, 11.7, 23.0, and 24.5 cm ($P < .01$). While mean sward height varied according to treatment within the paddocks, there were no differences in sward height at the paddock base or in the buffer (Treatment X Location, $P < .01$; Figure 3).

Mean rainfall infiltration rates of soils in paddocks were 93.3 and 92.9 percent of those at the paddock base or in the buffer ($P < .10$). However, this effect seemed to vary with treatment (Treatment X Location, $P < .10$). Mean infiltration rates of soils in paddocks that were ungrazed, harvested for hay, grazed by continuous stocking for 2 inches, or grazed by rotational stocking to 2 or 4 inches were 112, 86, 82, 92, and 93% of those in their respective buffers.

Mean sediment concentration in the runoff was not affected by treatment, location, or month. Although sediment concentration did not vary, the mean amounts of sediment flow from sites in the paddocks were 1.9 and 2.3 times greater ($P < .05$) than from sites at the paddock base and buffer, respectively (Figure 4).

Mean total phosphorus concentrations of runoff from paddocks were 2.7 and 2.6 times greater ($P < .01$), respectively, than those from the paddock base or buffer.

This effect was greater in paddocks that were grazed to a residual height of 2 inches by continuous or rotational stocking than in paddocks that were ungrazed, harvested for hay, or grazed by rotational stocking to a residual height of 4 inches (Treatment X Location, $P < .10$). As a result of differences in rainfall infiltration and the total phosphorus concentration of runoff, mean total phosphorus flows from paddocks were 3.8 and 4.9 times greater ($P < .01$), respectively, than those from the paddock base or in the buffer. There was no difference between the amount of total phosphorus flow at the base of the paddock and at 30 feet within the buffer. The extent of the difference in total phosphorus flows between measurements within the paddock, at the paddock base, and in the buffer varied with treatment (Treatment X Location, $P < .01$). Total phosphorus flow from sites in the paddocks that were ungrazed, harvested for hay, grazed by continuous stocking to 2 inches, grazed by rotational stocking to 2 inches, and grazed by rotational stocking to 4 inches were 1.2, 6.5, 40.3, 5.3, and 2.1 times greater than the measurements in their respective buffers.

Implications

Because this experiment has just been initiated, no conclusions can be made. However, data show that rainfall infiltration rate and, thus sediment and phosphorus flow, are highly affected by the ambient soil moisture concentration and sward height. Thus, if these two variables continue to exhibit effects in future data analysis, they will need to be considered in the development of grazing management systems that minimize nutrient flow from pastures.

Acknowledgments

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Figure 1. Effects of forage management on sward height of pastures.

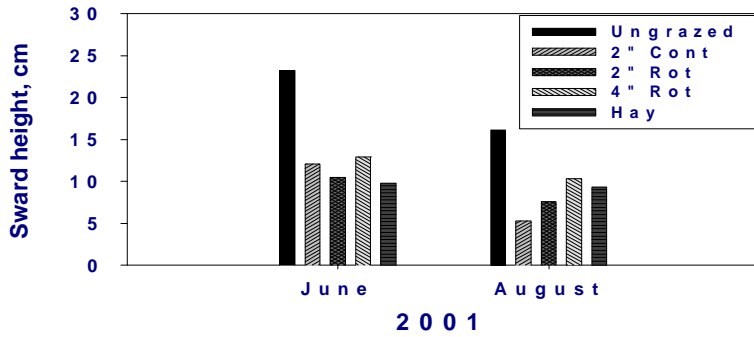
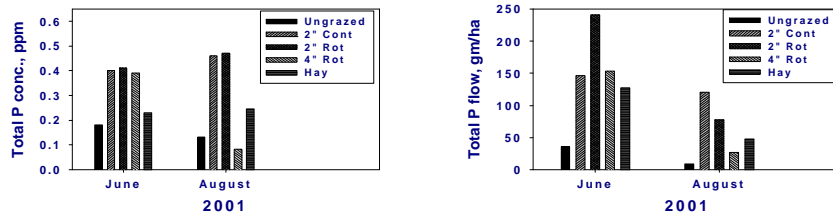


Figure 2. Effects of forage management on total phosphorus concentration and flow in runoff from pastures.



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Figure 3. Effects of forage management on sward height in and at the base of paddocks and 30 feet within buffers, in June and August 2001.

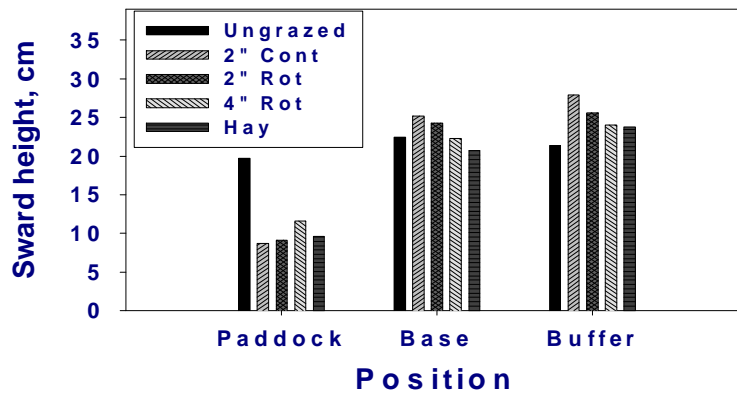


Figure 4. Effects of forage management on the sediment and phosphorus flows in and at the base of paddocks and 30 feet within buffers in June and August 2001.

