Report for 2003IA38B: Effects of Grazing Management on Sediment and Phosphorus Losses from Pastures

- Conference Proceedings:
    - Haan, M.M., J.R. Russell, W.J. Powers, S.K. Mickelson, S.I. Ahmed, J. Kovar, and R.C. Schultz. 2003. Effects of grazing management on sediment and phosphorus in runoff IN Proceedings of the Ninth International Symposium on Animal Agricultural and Food Processing Waste. October 12-15. Research Triangle Park, NC.
    - Haan, M.M., J.R. Russell, W. Powers, J.L. Kovar, J.L. Boehm, S. Mickelson, S.I. Ahmed, and R. Schultz. 2003. Impacts of cattle grazing management on sediment and phosphorus loads in surface waters, IN Proceedings of the Second National Conference on Grazing Lands. December 7-10. Nashville, TN.
    - Haan, M.M., J.R. Russell, W. Powers, S. Mickelson, S.I. Ahmed, J. Kovar, and R. Schultz. 2003. Effects of grazing management on pasture production and phosphorus content of forage, IN Proceedings/Reports American Forage and Grassland Council. April 25-27, Lafayette, LA, 12:286.
    - Powers, W., J. Russell, M.M. Haan, R. Schultz, E. Stauffer, G. Zaimes, J. Hunkins, J. Kovar, J. Boehm, S. Mickelson, and S. Ahmed. 2002. Grazing systems to maximize forage and minimize P, N, and sediment pollution of stream, IN Proc. Agriculture and the Environment: The Challenge of Change. Ames, IA, pp. 23-25.
    - Russell, J.R., M.M. Haan, W.J. Powers, J.L. Kovar, S. Mickelson, and R.C. Schultz. 2002. The potential for grazing management to control sediment and phosphorus pollution of pasture streams, IN Proc. of the Iowa Forage Conference. West Des Moines, IA, 9 pp.
    - Haan, M.M., J.R. Russell, W. Powers, R. Schultz, S. Mickelson, and J. Kovar. 2003. Effects of grazing management on sediment and phosphorus in pasture run-off, IN Abstracts for the annual meeting of the Midwestern section of the American Society of Animal Science. March 17-19, Des Moines, IA, p. 60.
- Other Publications:
    - Haan, M., J. Russell, W. Powers, S. Mickelson, J. Kovar, and R. Schultz. 2002. Effects of grazing management on sediment and phosphorus run-off. Proc. Amer. Forage Grassl. Council. 11:292-296.
    - Haan, M.M., J.R. Russell, W. Powers, J.L. Boehm, S. Mickelson, R. Schultz, and J.L. Kovar. 2004. Impacts of cattle grazing management on sediment and phosphorus loads in surface waters. A.S. Leaflet 1921, 2004 Iowa State University Animal Industry Report, 5 pp. Available at: http://www.iowabeefcenter.org/pdfs/BRR/R1921.pdf (Accessed 5/4/04).
    - Haan, M.M., J.R. Russell, W. Powers, S. Mickelson, S.I. Ahmed, J. Kovar, and R. Schultz. 2003. Effects of grazing management on pasture production and phosphorus content of forage (A progress report). A.S. Leaflet R1835, 2003 Beef Research Report, Iowa State University, 4 pp. Available at: http://www.iowabeefcenter.org/pdfs/BRR/R1835.pdf (Accessed 1/24/04).
    - Haan, M.M., J.R. Russell, W. Powers, S. Mickelson, S.I. Ahmed, J. Kovar, and R. Schultz. 2003. Effects of grazing management on sediment and phosphorus losses in run-off (A progress report). A.S. Leaflet R1836, 2003 Beef Research Report, Iowa State University, 5 pp. Available at: http://www.iowabeefcenter.org/pdfs/BRR/R1836.pdf (Accessed 1/24/04).
    - Haan, M.M., J. Russell, W. Powers, S. Mickelson, S.I. Ahmed, J. Kovar, and R. Schultz. 2002. Effects of grazing management on sediment and phosphorus run-off. A.S. Leaflet R1783, 2002

Beef Research Report, Iowa State University, Ames, IA.

Report Follows

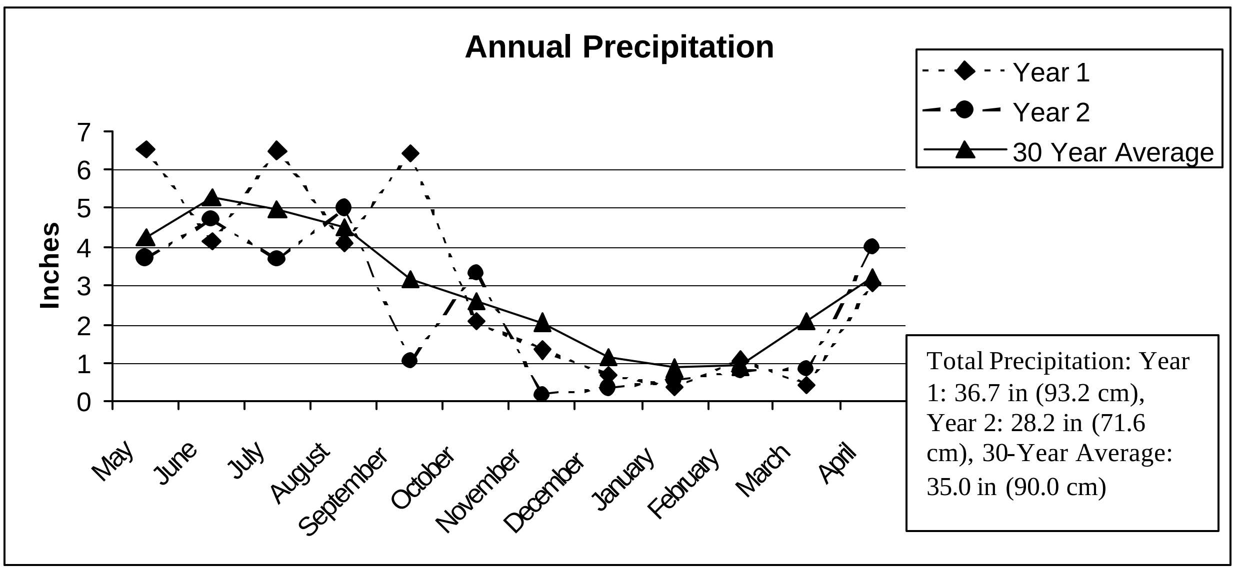
Effects of Grazing Management on Sediment and Phosphorus Losses from Pastures

James R. Russell, Wendy Powers, Richard C. Schultz,
Tom Isenhart, Steve Mickelson, and John Kovar

Materials and Methods

Site Description. The research 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*). Average annual rainfall for the area is 35 in. (90 cm) (Figure 1).

Figure 1. Annual Precipitation.



Three blocks of approximately 6.8 ac (2.75 ha) were subdivided into five 1-ac (0.4-ha) paddocks, with an 18-ft (6-m) wide lane at the top of the hill for cattle movement and a 30-ft (10-m) 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 (0 to 5 cm) and 2.5 to 5 in (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 P. Soils in all paddocks contained an optimum level (81–120 ppm K) or greater of K; therefore, no additional K was applied. In both years, urea was applied at a rate of 180 lb/ac (200 kg/ha) before the start of grazing in the spring and 100 lb/ac (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. Prior to the initiation of the study, the research area was managed for hay harvest and moderate grazing of beef cattle.

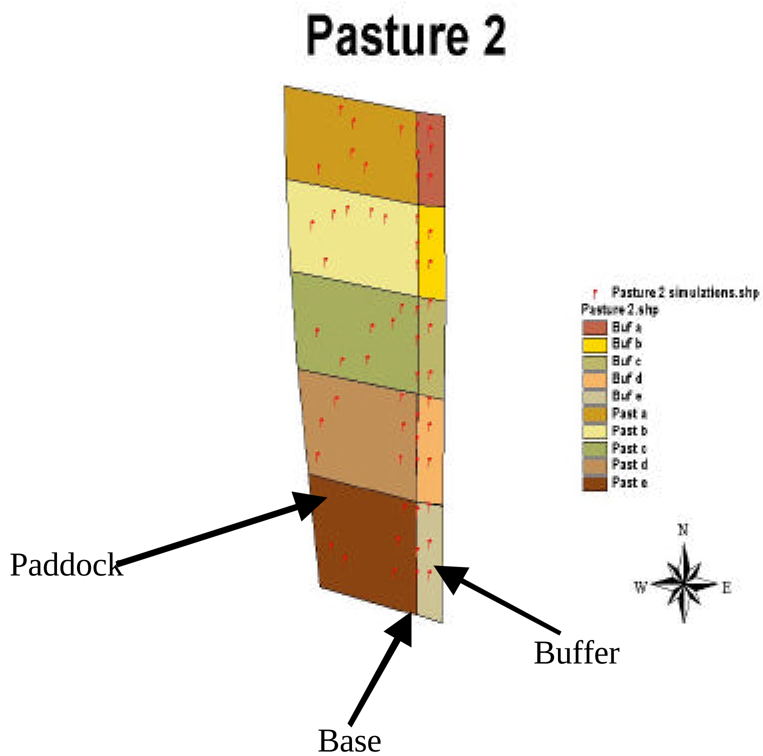
Grazing Management. Grazing treatments were randomly assigned to each of the 5 paddocks in each plot. Treatments included: an ungrazed control (U), summer hay harvest with winter stockpiled grazing to a residual sward height of 2 in (5 cm; HS), continuous stocking to a residual sward height of 2 in (5 cm; 2C), rotational stocking to a residual sward height of 2 in (5 cm; 2R), and rotational stocking to a residual sward height of 4 in (10 cm; 4R). Grazing was initiated on May 29, 2001, and May 7, 2002, with 3 mature Angus cows (body weight 1430±185 lb (647±84 kg) in 2001 and 1350±207 lb (613±94 kg) in 2002) 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 (5 cm). 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 (5 or 10 cm). Paddocks were allowed rest periods of 35 days to allow plant regrowth. Forage sward heights were measured with a raising plate meter (8.8 lb/yd^2; 4.8 kg/m^2) twice weekly during the grazing seasons. During the 2001 grazing season, mean total grazing days were 199, 153, and 117 cow-days/ac (491, 360, and 274 cow-days/ha), and, during 2002 grazing season, mean total grazing days were 162, 128, and 104 cow-days/ac (400, 316, and 257 cow-days/ha) for the 2C, 2R, and 4R stocking systems, respectively.

First-cutting hay was harvested from the HS treatment in June of 2001 and 2002, yielding 2375 and 3326 lb/ac (2660 and 3624 kg/ha) 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 (5 cm), allowing grazing for 19 and 24 cow-days/ac (47 and 59 cow-days/ha) in 2001 and 2002, respectively.

Rainfall Simulations. To determine sediment and P loss in water runoff, rainfall simulations were conducted 4 times per year for 2 years (2001 and 2002). 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°). 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 30 ft (10 m) within the buffer strip (Figure 2). Rainfall simulation locations were identified with the geographical positioning system (GPS) so that the same locations could be used during each sampling period. Rainfall simulators were 5.4 ft^2 (0.5 m^2) and assembled so that the uphill side of the simulator was 3.3 ft (1 m) high (Bowyer-Bower, and Burt, 1989). Each rainfall simulation ran for 1.5 hours at a precipitation rate of 1.6 gal/10 min (6 L/10 min) corresponding to a rainfall rate of 2.8 in/hr (7.1 cm/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 (2 m; Russell et al., 2001), 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 (0–5 cm and 5–12 cm), for determination of Bray-1 P and soil moisture. Penetration resistance was measured at 1.4-in (3.5-cm) intervals to a depth of 14 in (35 cm) using a Bush Recording Penetrometer; readings from the 0 to 5 in (0 to 10 cm) depth, 5 to 8 (10 to 20 cm) depth, and 8 to 14 (20 to 35 cm) depth were averaged for statistical analysis. Sward height was measured using a rising plate meter (8.8 lb/yd^2; 4.8 kg/m^2), and a forage sample was clipped from a 2.7-ft^2 (0.25-m^2) area adjacent to the rainfall simulation site to determine the mass of forage dry matter.

Figure 2. Block 2 Layout.



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 (APHA, 1995). Total P was determined by digestion followed by the Ascorbic Acid Method (Hach, 2002). 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 P and moisture. Phosphorus levels were determined using the Bray-1 P procedure (Frank et al., 1998). 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 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 from paddock between stocking treatments in either year**.** Mean total P concentrations in the runoff were greater in paddocks with the 2C and 2R 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 total soluble P concentrations were greater (P<0.05) in the late spring than the other sampling periods.

Table 1. Annual sediment, total P and total soluble P in runoff from paddocks grazed by different systems.

	Sediment, lb/ac (kg/ha)		**Total P, lb/ac (kg /ha)**		**Total soluble P, lb/ac (kg /ha)**	
	Year 1[b]	Year 2	Year 1	Year 2	Year 1	Year 2
U[a]	10.2 (11.4)	4.3 (4.8)[c]	0.005 (0.06)[c]	0.03 (0.03)[c]	0.04 (0.04)[c]	0.02 (0.02)[c]
HS	30.8 (34.5)	15.9 (17.8)[c]	0.20 (0.23)[c,d]	0.09 (0.10)[c]	0.17 (0.19)[d]	0.04 (0.04)[c,d]
2C	54.7 (61.2)	105.5 (118.2)[d]	0.37 (0.41)[d]	0.36 (0.40)[d]	0.26 (0.29)[e]	0.12 (0.13)[c,d]
2R	55.3 (61.9)	27.2 (30.5)[c]	0.37 (0.41)[d]	0.19 (0.21)[c]	0.31 (0.35)[e]	0.15 (0.17)[d]
4R	41.3 (46.2)	15.9 (17.8)[c]	0.23 (0.26)[c,d]	0.08 (0.09)[c]	0.18 (0.20)[d,e]	0.04 (0.04)[c,d]

[a] U = Ungrazed, HS = Summer Hay Harvest/Winter Stockpile Grazing, 2C = 2 inch Continuous Grazing, 2R = 2 inch Rotational Grazing, 4R = 4 inch Rotational Grazing.

[b] Different superscripts within the same column denote a difference, (P<0.05).

In year 2, mean sediment and total P concentrations in runoff did not differ between sampling periods. However, total soluble P concentration in runoff was less in the early spring than it was in other sampling periods.

Losses of total P were greater (P<0.05) from paddocks with the 2C and 2R treatments than U paddocks in year 1, while the HS and 4R treatments were intermediate and not significantly different from any of the other treatments. Total P losses were greater (P<0.05) from 2C treatment than from all other treatments in year 2. Losses of total soluble P were lower (P<0.05) from U paddocks than from other treatments in year 1. In year 2, the 2R treatment had greater (P<0.05) total soluble P losses than U, with the HS, 2C, and 4R intermediate to, and not significantly different from, either the U or 2R treatments. In years 1 and 2, 89% and 76% of the total P in the runoff was in the form of total soluble P. While these differences seem to be related to forage height and cover, the paddocks grazed to 2 in (5cm) by continuous or rotational stocking had greater cow days per acre which likely contributed greater fecal P excretion per acre.

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 total soluble P concentrations or total and total 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 (13.1 vs. 6.5 lb/ac; 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 2 in (5 cm) was greater in year 1 than in year 2 ($P<0.05$), 23.3% and 20.5%, respectively. Soil moisture contents were 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 2C, 2R, 4R, and HS, respectively). In both years, soil moisture followed the same trends with soil moisture highest in the late spring, lowest in the mid-summer, intermediate in the autumn, and high in early spring ($P<0.05$). Soil moisture contents were 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 5 in (0 to 10 cm) depth for the four sampling periods in year 1 was lowest for the U treatment (45.1 lb-force; 20.5 kg-force), intermediate for the HS (51.7 lb-force; 23.5 kg-force) treatment, and greatest in the summer grazing treatments (55.0, 57.4, 57.6 lb-force for the 2C, 2R, and 4R, respectively; $P<0.05$; 25.0, 26.1, and 26.2 kg-force for the 2C, 2R, and 4R, respectively), but did not differ between summer grazing treatments.

In year 2, mean penetration resistance in the 0 to 10 cm depth for the U paddocks was lower ($P<0.05$; 54.6 lb-force; 24.8 kg-force) than all other treatments. However, there were no differences in penetration resistance between paddocks with different forage utilization systems (67.3, 74.6, 73.7, and 75.9 lb-force for the HS, 2C, 2R, and 4R treatments, respectively; 30.6, 33.9, 33.5, and 34.3 kg-force for the HS, 2C, 2R, and 4R treatments, respectively). Mean penetration resistance in the 5 to 8 in (10 to 20 cm) depth was unaffected by treatment in either year, averaging 59.4 and 76.3 lb-force (27.2 and 34.7 kg-force) across all treatments for year 1 and 2, respectively. Similarly, mean penetration resistance in the 8 to 14 in (20 to 35 cm) depth was unaffected by treatment in either year, averaging 62.9 and 86.9 lb-force (28.6 and 39.5 kg-force) for year 1 and 2, respectively.

Surface roughness did not differ by treatment or time in either year. Soil Bray-1 P concentrations in the upper 2 in (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.

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 2C 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, 2C, 2R, and 4R treatments, respectively.

Erosion of sediment was not different between treatments in year 1 (Table 1). In year 2, the 2C 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: ($Y=794.1-17.81\ X + .096\ X^2$, $r^2=0.3362$) where Y is the sediment loss in lb/ac/simulation and X is the percentage of ground covered with plant material [($Y'=889.2 - 19.95\ X + 0.108\ X^2$,), where Y' is the sediment loss in kg/ha/simulation and X is the percentage of ground covered with plant material].

Buffer Effects. Mean sediment concentrations in the runoff were not affected by simulation location (paddock, base, buffer) or month in either year. However, mean total P and total soluble P concentrations in runoff were greater ($P<0.05$) in the paddocks than at the base of the paddock or 30 ft (10 m) in the buffer in both years. Over the two years, mean concentrations of total and total soluble P from paddocks were 49.5% and 47.4% greater, respectively, ($P<0.05$) than the mean values within the buffers. This result may indicate 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. However, there were no significant grazing treatment by location interactions for losses of sediment, total P, or total soluble P; these differences seem to be factors other than grazing.

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, runoff was 17.1, 11.7, and 8.6% of applied and in year 2, runoff was 12.8, 12.8, and 7.5% of applied from the paddock, base of the paddock, and 30 ft (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 (Table 2). In year 2, sediment loss was greatest from the paddock, lowest from 30 ft (10m) within the buffer, and intermediate at the base of the buffer.

As a result of differences in rainfall infiltration and the total P concentration of runoff, total P 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 total 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 Total Soluble P losses within the paddocks, at the base of the paddock, and 30 ft (10 m) within the buffer.

	Sediment, lb/ac (kg/ha)		**Total P, lb/ac (kg /ha)**		**Total soluble P, lb/ac (kg /ha)**	
	Year 1[b]	Year 2	Year 1	Year 2	Year 1	Year 2
Paddock[a]	39.3 (44.0)	34.3 (38.4)[a]	0.25 (0.28)[a]	0.14 (0.16)[a]	0.21 (0.24)[a]	0.07 (0.08)
Base	24.6 (27.6)	18.9 (21.2)[a,b]	0.07 (0.08)[b]	0.07 (0.08)[b]	0.07 (0.08)[b]	0.03 (0.03)
Buffer	18.2 (20.4)	9.3 (10.4)[b]	0.04 (0.04)[b]	0.04 (0.04)[b]	0.01 (0.01)[b]	0.02 (0.02)

[a] Paddock = Average across all paddocks, Base = At the paddock-buffer interface, within the buffer, Buffer = Within the buffer, 30 ft (10 m) down slope from the paddocks

[b] Different superscripts within the same column denote a difference, ($P<0.05$).

Across treatments, mean forage sward heights in paddocks, at the paddock base, and 30 ft (10 m) in the buffer strip were 3.7, 6.8, and 7.1 in (9.4, 17.3, and 18.1 cm) in year 1 and 4.8, 9.0, 9.7 in (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 30 ft (10 m) 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.