Effects of Grazing Management on Pasture Characteristics Affecting Sediment and Phosphorus Pollution of Pasture Streams (Progress Report)

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Summary and Implications

To evaluate the effects of grazing management on pasture properties related to soil erosion and P pollution of streams, six 30-acre cool season grass pastures bisected by a stream were grazed by 15 fall-calving Angus cows by continuous stocking with full access to the stream, continuous stocking with stream access limited to a 16 x 80 foot stabilized crossing, or rotational stocking. The riparian paddocks of rotationally stocked pastures were never grazed to a sward height lower than 4 inches or longer than 4 days. Congregation areas in pastures had greater proportions of the ground that were bare or covered with manure and lower forage sward heights and masses than open areas. Stream banks had greater proportions of ground that was bare and lower forage sward height and masses than in the riparian zone from 110 to 220 feet from the bank and in the uplands. Pastures with continuous stocking and full stream access had greater proportions of bare soil and lower forage sward heights and masses on and adjacent to the stream bank compared to upland zones in the same pastures or on and adjacent to the stream bank in the ungrazed riparian buffers. This damage was particularly evident in October which would leave the banks susceptible to erosion during the winter. There was no difference in manure distribution across the different zones in pastures with full stream access. Pastures with continuous stocking and limited stream access had less bare soil, greater forage sward heights and masses on and adjacent to the banks than pastures with full stream access. There was no manure cover on or adjacent to the banks of riparian buffers in pastures with limited stream access, but manure cover was concentrated in the zone from 110 to 220 feet from the stream. The proportions of bare soil on and adjacent to stream banks in rotationally grazed pastures did not differ from ungrazed buffers and the forage sward heights and masses in these zones were intermediate between pastures with full and limited access in October. However, similar to pastures with continuous grazing and full access, manure coverage did not differ across zones of rotationally grazed pastures.

The preliminary results of this project imply that limiting access to streams to stabilized crossings or use of rotational grazing may decrease the potential for sediment and phosphorus loading from stream bank erosion.

Introduction

Because of its association with eutrophication of surface water sources, phosphorus loading of surface water sources is a major nonpoint source pollution problem in Iowa. As much of the phosphorus in soil is adsorbed to soil particles, soil erosion promotes phosphorus pollution of surface water sources. It is recognized that overgrazing along pasture streams may result in soil erosion that will contribute to phosphorus loading of pasture streams. However, little research has evaluated the effects of grazing management on sediment and phosphorus loading of pasture streams in the Midwest. In a previous study at the Rhodes Research Farm, rotational grazing to a residual height of 4 inches has reduced sediment and phosphorus losses from upland pastures by as much as 90 and 80% compared to continuous grazing to a sward height of 2 inches, primarily by reducing the proportions of bare soil. Therefore, grazing management seems to be a practice that should be considered to limit sediment and phosphorus loading of pasture streams.

While upland sediment and phosphorus flow likely contribute to nonpoint source pollution of surface water sources, sediment and phosphorus flows from congregating locations within riparian areas, stream bank erosion, and direct deposition of feces and urine may have greater effects on stream water quality because of their proximity to the streams. Altering grazing animal behavior by maintaining adequate forage outside the riparian area through control of grazing duration and timing, providing controlled access to riparian areas, providing alternative water sites, improving ramps and fording areas to and across streams and/or providing shade away from streams have been proposed as methods to reduce sediment and phosphorus loading of pasture streams from stream bank erosion and direct deposition of animal wastes.

The objectives of this project were to measure the effects of the spatial and temporal distribution patterns of beef cattle in different grazing management systems on forage cover, sward height and mass and manure cover across the upland and riparian zones of pastures.

Materials and Methods

During the summer of 2004, six 30-acre pastures equally divided by a 642-foot reach of Willow Creek were fenced at the Rhodes Research Farm. Vegetation in the upland areas of the pastures was primarily composed of smooth bromegrass while that in the riparian zones was largely reed canarygrass.

Two of the pastures had no cross fencing and, therefore, cattle were allowed to graze continuously with full access to the stream. One 16 x 80 foot crossing built from geofabric, polyethylene webbing and crushed rock was constructed across the stream in two of the pastures. The remaining lengths of the stream in these pastures were fenced in 2.25-acre riparian buffers. Cattle were allowed to graze these pastures continuously with access to the stream limited to the stabilized crossings. The remaining two pastures were divided into four 6.94-acre upland paddocks and one 2.25-acre riparian paddock parallel to the stream to allow rotational grazing. Water was piped to tanks approximately midway across the pastures on each side of the stream in each pasture.

On May 10, 2005, fifteen fall-calving Angus cows (mean weight, 1428 lb) in mid-gestation were allotted to each pasture. Cattle were allowed to graze continuously with full or limited access to the stream or to rotationally graze with access to the stream only when cattle were in the riparian paddock. In rotationally grazed pastures, cattle were moved from upland paddocks after 50% of the forage was removed in each rotation. Grazing of the riparian paddock was controlled so that the forage was never grazed to less than 4 inches or for longer than 4 days in each rotation. Grazing was terminated in all pastures on October 12, 2005.

Cows in rotationally grazed pastures had access to alternate water sites in each paddock. To evaluate the effects of alternate water sites on the distribution of cattle in continuously grazed pastures, cattle were allowed access to the alternate water sites in these pastures for two weeks in May, July, and September.

To evaluate the effects of grazing management on the distribution of bare soil, manure deposition, and forage sward height and mass, sampling sites were selected from two to three sites in animal congregation and open areas in zones on the banks, 0 to 110 feet from the bank and 110 to 220 feet from the bank and from 12 sites in animal congregation and open areas in upland zones greater than 220 feet from the bank on each side of the stream in each month. Congregation areas were defined as areas providing cattle access to the stream, alternate water or mineral supplementation sites and under the dripline of trees and were measured with a tape measure in September, 2005. Open areas consisted of the remainder of the pastures. Because of the large amount of open area in the upland zones of the pastures, bare soil, manure deposition, and forage sward height were measured in an additional 12 sites in this zone on each side of the stream.

The proportion of soil that was bare or covered with manure was measured at each sampling site by counting the percentage of beads on a 50-foot line that was over bare soil or manure. Forage sward height was measured at each sampling site using a falling plate meter (8.8 lb/yd^2). Forage mass was determined by hand-clipping forage from a .25-m^2 square at each sampling location. Forage samples from congregation and open areas in each pasture were composited within zone, weighed, and dried at 65^{o}C for 48 hours. For analysis of treatment effects within pasture zones, the proportions of bare soil and manure, forage sward heights, and forage masses were calculated as means weighted for the proportion of congregation and open areas in each zone of each pasture. Areas on stabilized ramps and stream crossings were not considered in the calculations.

To evaluate the main effects of congregation or open areas and their interactions with grazing treatment and zones, bare soil, manure, sward height and forage mass data were analyzed within month with the GLM procedure by a split-plot analysis with treatment and zone in the main plot and congregation area as the split plot. To evaluate the treatment effects within pasture zones on these variables, weighted means for these data were analyzed within month using two-way analysis of variance for the main effects of treatment and zone and the treatment by zone interaction. All data are reported as least squares means.

Results and Discussion

As expected, the proportion of ground surface that was bare was greater ($P < 0.05$) in congregation areas than in open areas of pastures in July through October (Table 1). There were no zone by congregation area nor treatment by congregation area interactions in May through September. This result implies that the proportions of bare ground in congregation areas did not differ regardless of treatment or zone. While there was no difference in the proportion of bare soil in open areas in pastures with different treatments in October, the proportions of bare soil in congregation areas were 30.1, 10.6, and 17.9% in pastures with continuous grazing and full stream access, continuous grazing and limited stream access, and rotational grazing (treatment x congregation area, $P < 0.05$). Results imply that while the percentage of bare soil is greater in congregation areas than open areas in all treatments, this difference is even greater in pastures where the cattle have full stream access.

Similar to the proportion of bare soil, the proportion of ground surface covered with manure was greater ($P < 0.05$) in congregation than open areas of pastures from August through October and tended to be greater in congregation than open areas of pastures in June ($P = 0.07$) and July ($P = 0.09$) as well. There were no zone by congregation area nor treatment by congregation area interactions in May through September. This result implies that the proportions of manure cover in congregation areas did not differ regardless of treatment or zone. However, while there was no difference in the proportions of manure in open areas of pastures in October, the proportions of manure cover were 0.84, 3.97, 2.74, and 2.39% of ground surface in congregation areas on the bank, 0 to 110 feet from the bank, 110 to 220 feet from the bank, and in the uplands (zone x congregation area, $P < 0.05$) which implies that cows defecated more frequently in congregation areas in zones outside the bank.

At the initiation of grazing in May, the sward height of forage in congregation areas was greater ($P < 0.05$) than open areas of pastures. This difference may have been caused by the high proportion of reed canarygrass under the trees or possibly by a greater concentration of phosphorus in the soil resulting from the concentration of feces under the trees from previous years of grazing. In June through October, the forage sward height was lower ($P < 0.05$) in congregation than open areas of pastures. There were no zone by congregation area nor treatment by congregation area interactions for sward height in May through August. However, while there were no differences in the sward height of congregation and open areas in the zone from 0 to 110 feet from the bank in September and October, sward heights in open areas were 5.1, 10.0, and 8.2 cm greater than congregation areas in September and 4.6, 4.8, and 3.4 cm greater than congregation areas in October on the bank, 110 to 220 feet from the bank, and in the uplands (zone x congregation area, $P < 0.05$). In October, the lack of difference in sward height between congregation and open areas in the zone from 0 to 110 feet from the stream bank resulted from heavy grazing to an average sward height of 3.0 cm in both congregation and open areas in this zone in pastures that were continuously grazed with full access to the stream, limited grazing to an average sward height of 6.9 cm in both congregation and open areas in this zone in pastures that were rotationally grazed, and no grazing with an average sward height of 13.2 cm in either congregation or open areas in this zone in pastures in which access to this zone was prevented (treatment x zone x congregation areas, $P = 0.07$).

Forage masses in congregation areas were less ($P < 0.05$) than open areas of pastures in June and in August through October. While there tended to be no difference in the forage masses of congregation and open areas in the zone from 0 to 110 feet from the stream bank, forage masses in congregation areas were considerably lower than those in open areas on the bank, 110 to 220 feet from the stream bank, and in the uplands in July (zone x congregation area, $P = 0.10$), August (zone x congregation area, $P = 0.10$), and September (zone x congregation area, $P = 0.15$).

When data from congregation and open areas were weighted for their proportions in the different pasture zones, the proportion of ground that was bare was greater ($P < 0.05$) on the stream bank than in the zone from 0 to 110 feet from the stream bank, 110 to 220 feet from the stream bank, and in the uplands in each month (Figure 1). Grazing management treatments did not affect the proportion of ground that was bare from May through September. However, at the termination of grazing in October, the mean proportion of ground that was bare was greater ($P < 0.05$) in pastures with continuous grazing and full access to the stream than pastures with continuous grazing and limited access or rotational grazing. While the proportion of ground that was bare on the bank and from 0 to 110 feet from the bank was considerably greater in pastures with continuous grazing and full access to the stream than pastures with the other treatments in October, the proportion of ground that was bare from 110 to 220 feet in pastures with continuous grazing and limited stream access was 2.63% units greater than pastures with continuous grazing and full stream access or rotational grazing. This effect in pastures with limited access may have been caused by cattle concentrating immediately outside the riparian buffer area.

The proportion of ground surface covered with manure was greater ($P < 0.05$) in the zone from 110 to 220 feet from the bank than other pasture zones in June, September, and October and in the uplands than other pasture zones in July and August (Figure 2). Mean proportions of ground surface covered with manure in pastures with continuous grazing and full access to the stream and with rotational grazing were greater ($P< 0.05$) than pastures with continuous grazing and limited stream access in June. However, in August, the proportions of ground surface covered manure in pastures with continuous grazing and full stream access were greater ($P < 0.05$) than pastures with either continuous grazing and limited stream access or rotational grazing. While no manure covered the ground surface on the bank or in the zone from 0 to 110 feet from the stream bank in the riparian buffer in pastures with continuous grazing and limited access to the stream and little manure covered the ground surface on the bank of pastures with rotational grazing, there was little difference in the proportion of ground covered with manure at distances greater than 110 feet from the stream bank in June and August (treatment x zone, $P < 0.05$). In September and October, the proportion of ground surface covered with manure did not differ in any zone between pastures with continuous grazing and full access to the stream and pastures with rotational grazing. However, in pastures with continuous grazing and limited stream access, manure cover was greatest in the zone from 110 to 220 feet from the stream bank and was absent on the bank and from 0 to 110 feet from the stream bank in the riparian buffer (treatment x zone, $P < 0.05$). Because manure cover on the ramps to the stabilized stream crossings was not considered in the calculation of manure cover on the banks of pastures with limited stream access, values on the bank for this treatment were lower than actual. As the proportions of ground covered by manure concentrated on the ramps were 5.5, 9.0, 4.3, and 5.0% in July, August, September, and October, actual proportions for the entire bank in these pastures would be 0.14, 0.22, 0.11, and 0.12% rather than 0 for these months.

Forage sward heights were greater (P < 0.05) in the zones greater than 110 feet from the stream bank than the zone from 0 to 110 feet from the stream bank that was greater than on the bank in May and June (Figure 3). In July through September, forage sward heights were greater (P < 0.05) in the zones from 0 to 110 feet from the stream bank, 110 to 220 feet from the stream bank, and in the uplands than on the bank. However, at the end of grazing in October, mean forage sward heights on the bank and from 0 to 110 feet from the stream bank were greater (P < 0.05) than the zones greater than 110 feet from the stream bank. In both June and October, the mean forage sward heights were 38 and 59% greater (P < 0.05) in pastures grazed continuously with limited access to the stream than pastures grazed continuously with full access to the stream. The sward height of forage in pastures grazed by rotational grazing in June and October were 23 and 18% greater than pastures grazed continuously with full access to the stream.

The differences between zones and treatments in October resulted from the interaction of treatment and zones (treatment x zone, P < 0.05). In pastures with continuous grazing and full stream access, forage sward heights on the bank (2.8 cm) and 0 to 110 feet from the stream bank (3.6 cm) were lower than those from 110 to 220 feet from the stream bank (8.0 cm) or in the uplands (5.0 cm). In contrast, in pastures with continuous grazing and limited stream access, forage sward heights on the bank (10.7 cm) and 0 to 110 feet from the stream bank (12.3 cm) were greater than those from 110 to 220 feet from the stream bank (4.4 cm) and in the uplands (3.4 cm). Forage sward heights of pastures grazed by rotational stocking were 5.0 cm on the bank, 7.8 cm from 0 to 110 feet from the stream bank, 5.1 cm from 110 to 220 feet from the stream bank, and 4.9 cm in the uplands, differing little across zones.

Mean forage masses in the zones from 0 to 110 feet from the stream bank, 110 to 220 feet from the stream bank, and in the uplands were greater (P < 0.05) than the forage mass on the bank in May through September (Figure 4). However, there were no effects of treatment nor interactions of treatments and zones on forage mass during these months. In October, mean forage mass in the zone from 0 to 110 feet from the stream bank (1622 lb/acre) was greater (P < 0.05) than 110 to 220 feet from the stream bank (1211 lb/acre) which were greater than on the bank (1080 lb/acre) or in the uplands (976 lb/acre). Similar to sward height, this effect resulted from a treatment by zone interaction (treatment x zone, P < 0.05). Forage masses in pastures grazed continuously with full access to the stream were lower on the bank (371 lb/acre) and from 0 to 110 feet from the stream bank (668 lb/acre) than those from 110 to 220 feet from the stream bank (1448 lb/acre) or in the uplands (1067 lb/acre). In contrast, forage masses in pastures grazed continuously with limited stream access were greater from 0 to 110 feet from the stream bank (2795 lb/acre) and on the bank (1829 lb/acre) than those from 110 to 220 feet from the stream bank (1013 lb/acre) or in the uplands (822 lb/acre). Similarly, forage masses in pastures with rotational grazing were greater from 0 to 110 feet from the stream (1406 lb/acre) than on the bank (1043 lb/acre), from 110 to 220 feet from the stream (1172 lb/acre) or in the uplands (1041 lb/acre). Thus, the forage masses on the banks or 0 to 110 feet from the stream bank of pastures with continuous grazing and limited stream access were 392 and 318% greater than pastures with continuous grazing and full stream access at the termination of grazing in October. Similarly, forage masses on the banks or 0 to 110 feet from the stream banks of pastures with rotational grazing were 110 and 181% greater than pastures with continuous grazing and full stream access. The greater forage masses on the stream banks and in the pasture zone adjacent to the stream bank implies that either preventing access to these areas along the stream or controlling access with rotational grazing is likely to reduce the potential from erosion into pasture streams during the winter.

Because of features such as cut banks and oxbows, stream banks have more bare soil and less forage that make them susceptible to erosion than upland zones. Congregation areas including areas under trees or near stream access, alternate water, and mineral supplementation sites have more bare soil and manure surface cover and less forage height and mass than open areas which make them susceptible to erosion and phosphorus loss particularly in sensitive areas such as on stream banks or hillsides. Continuous grazing with full stream access increases the risk of sediment and phosphorus loading of pasture streams because of greater proportions of bare soil and lower forage sward heights and masses on and adjacent to the stream bank compared to upland zones in the same pastures or on and adjacent to the stream bank in the ungrazed riparian buffers. This damage was particularly evident in October which would leave the banks susceptible to erosion during the winter. The presence of manure on the stream bank in pastures with full stream access increases the risk of phosphorus pollution, however, manure wasn't concentrated on the bank as there was no difference in its distribution across the different zones in pastures with full stream access. Preventing grazing in the riparian buffers resulted in less bare soil, greater forage sward heights and masses, and no manure cover on the banks and in the riparian buffers which should limit sediment and phosphorus loading of the pasture streams. Bare soil and manure cover was concentrated immediately outside the riparian buffer, but this was 110 to 220 feet from the stream. The proportions of bare soil on and adjacent to stream banks in rotationally grazed pastures did not differ from ungrazed buffers and the forage sward heights and masses in these zones were intermediate between pastures with full and limited access in October. However, similar to pastures with continuous grazing with full access, manure coverage did not differ across zones of rotationally grazed pastures. These results imply that rotational grazing will reduce erosion risk, but not reduce P loading from direct manure deposition.

The results of this project imply that limiting stream access to stabilized crossings or use of rotational grazing may decrease the potential for sediment and phosphorus loading from stream bank erosion. However, it should be emphasized that these are preliminary results from the first year of a multi-year study and the actual effects of these alterations in pasture characteristics on stream bank erosion may not be observed until subsequent years.

Table 1. Least squares means of the proportions of bare soil and manure surface cover of the ground and sward height and forage mass in congregation and open areas of pastures.[a]

	Month					
Area	May	June	July	August	September	October
			Bare soil, % of surface			
Congregation	12.5	19.3	17.0*[b]	20.3*	24.9*	19.5*
Open	11.2	12.2	10.7	9.9	12.9	9.3
			Manure, % of surface			
Congregation	-	2.3	2.1	2.7*	2.7*	2.5*
Open	-	0.8	0.9	1.1	1.4	1.3
			Sward height, cm			
Congregation	23.1*	10.9*	10.4*	6.2*	3.5*	3.3*
Open	18.1	22.1	17.6	14.4	9.6	6.5
			Forage mass, lb/acre			
Congregation	2383	1748*	1771	946*	658*	658*
Open	2430	2923	2351	2414	1743	1343

[a]Least squares means of measurements or samples collected from stream bank and distances of 0 to 110, 110 to 220 and greater than 220 feet from the stream bank from pastures grazed by continuous stocking with full or limited stream access or rotational stocking.
[b]$P < 0.05$.

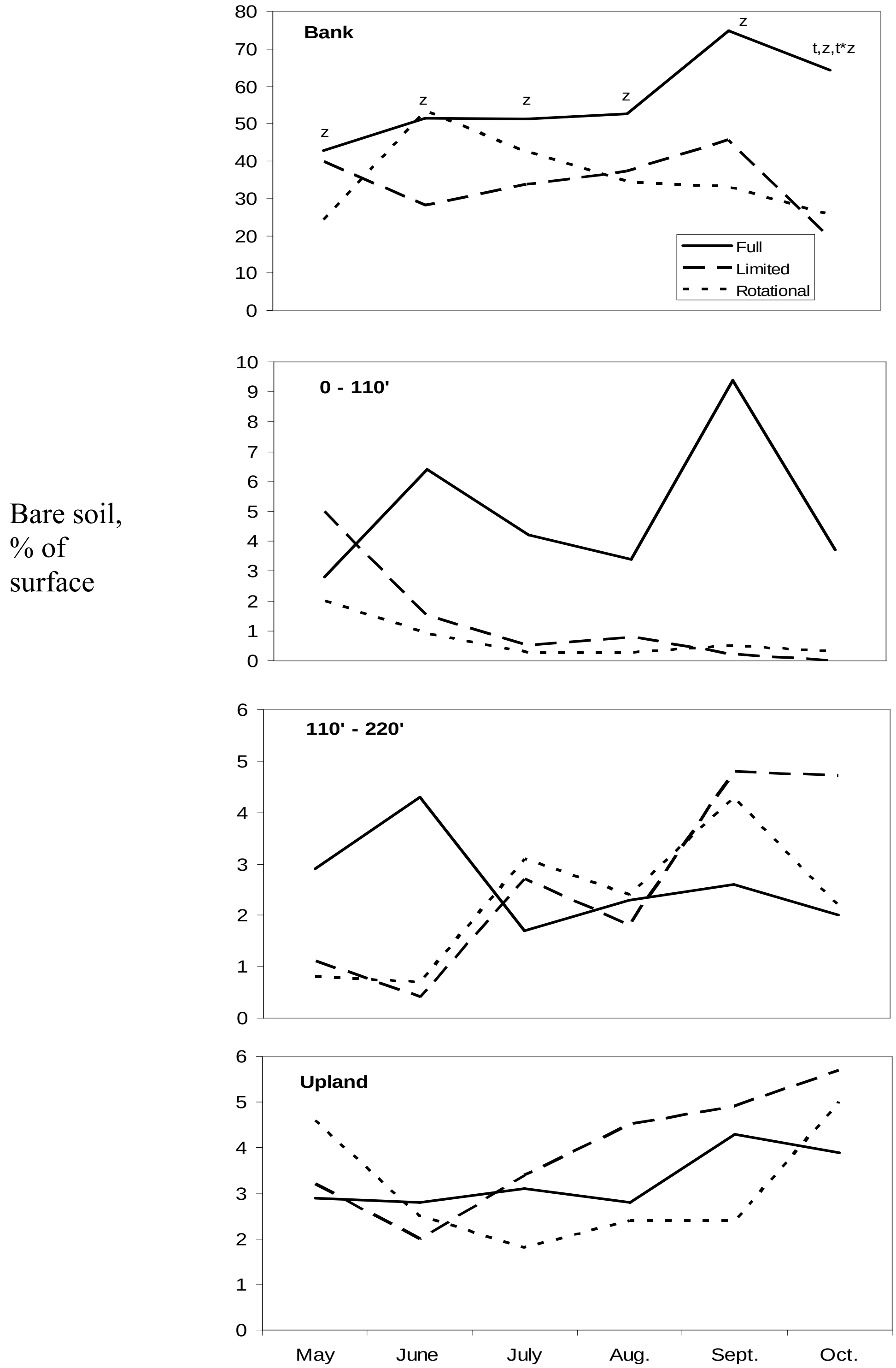

Figure 1. Least squares means of the proportion of soil surface that was bare, weighted for congregation and open areas, in different zones of pastures with continuous grazing and full or limited stream access or rotational grazing. (t, z and t*z designate significant treatment effects, zone effects, and treatment by zone interactions, $P < 0.05$).

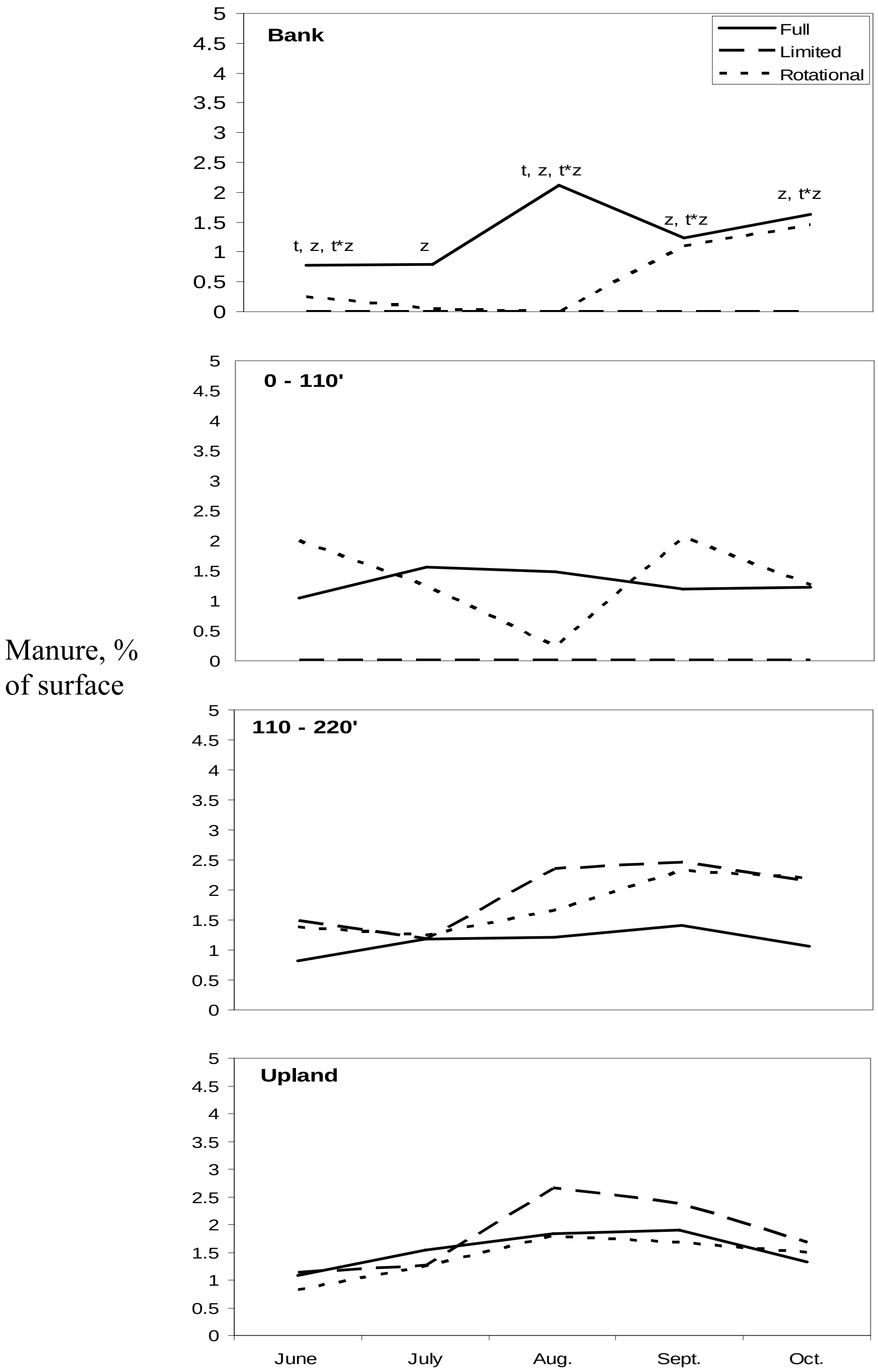

Figure 2. Least squares means of the proportion of soil surface covered with manure, weighted for congregation and open areas, in different zones of pastures with continuous grazing and full or limited stream access or rotational grazing. (t, z and t*z designate significant treatment effects, zone effects, and treatment by zone interactions, $P < 0.05$).

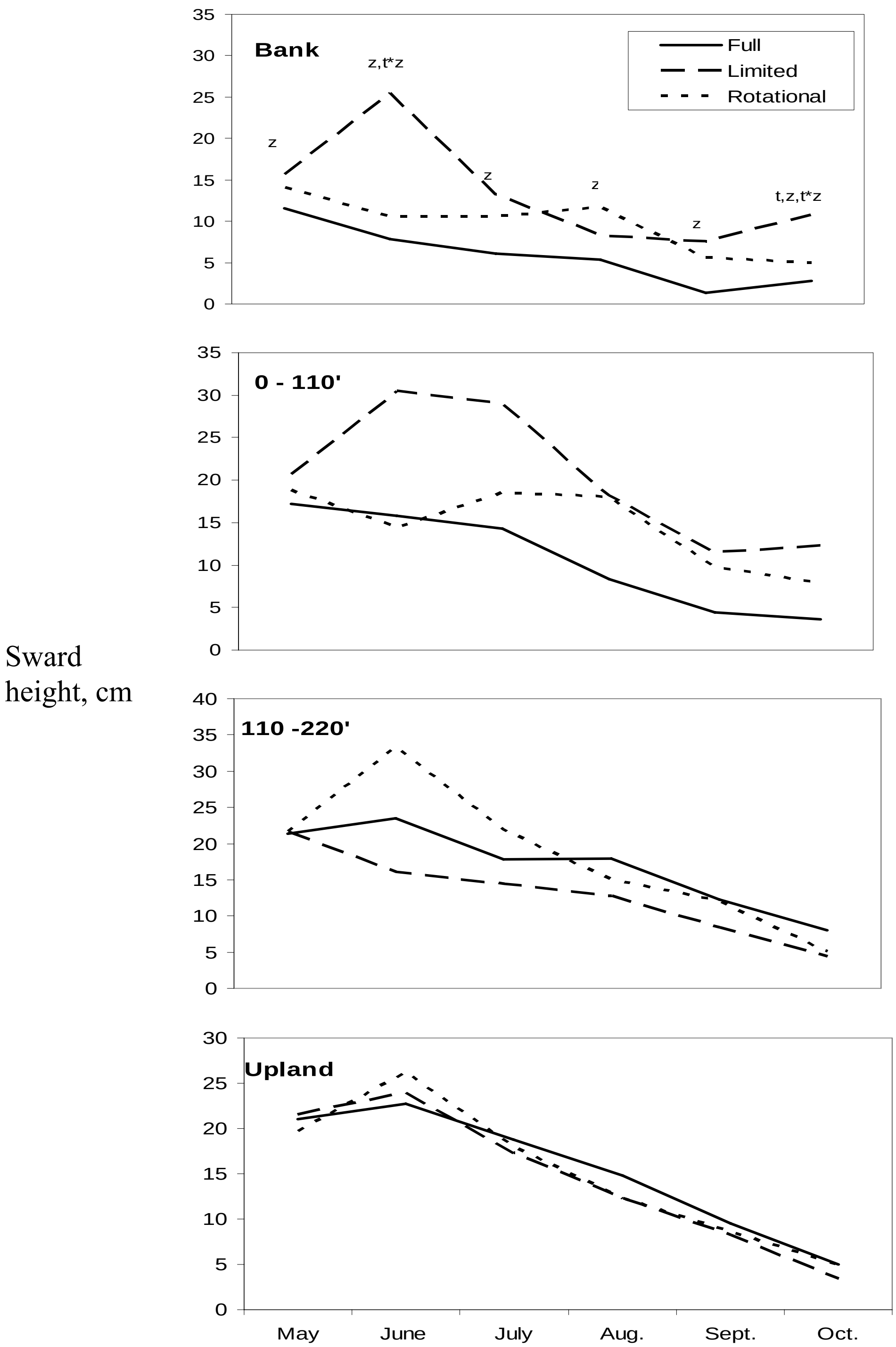

Figure 3. Least squares means of the forage sward height, weighted for congregation and open areas, in different zones of pastures with continuous grazing and full or limited stream access or rotational grazing. (t, z and t*z designate significant treatment effects, zone effects, and treatment by zone interactions, P < 0.05).

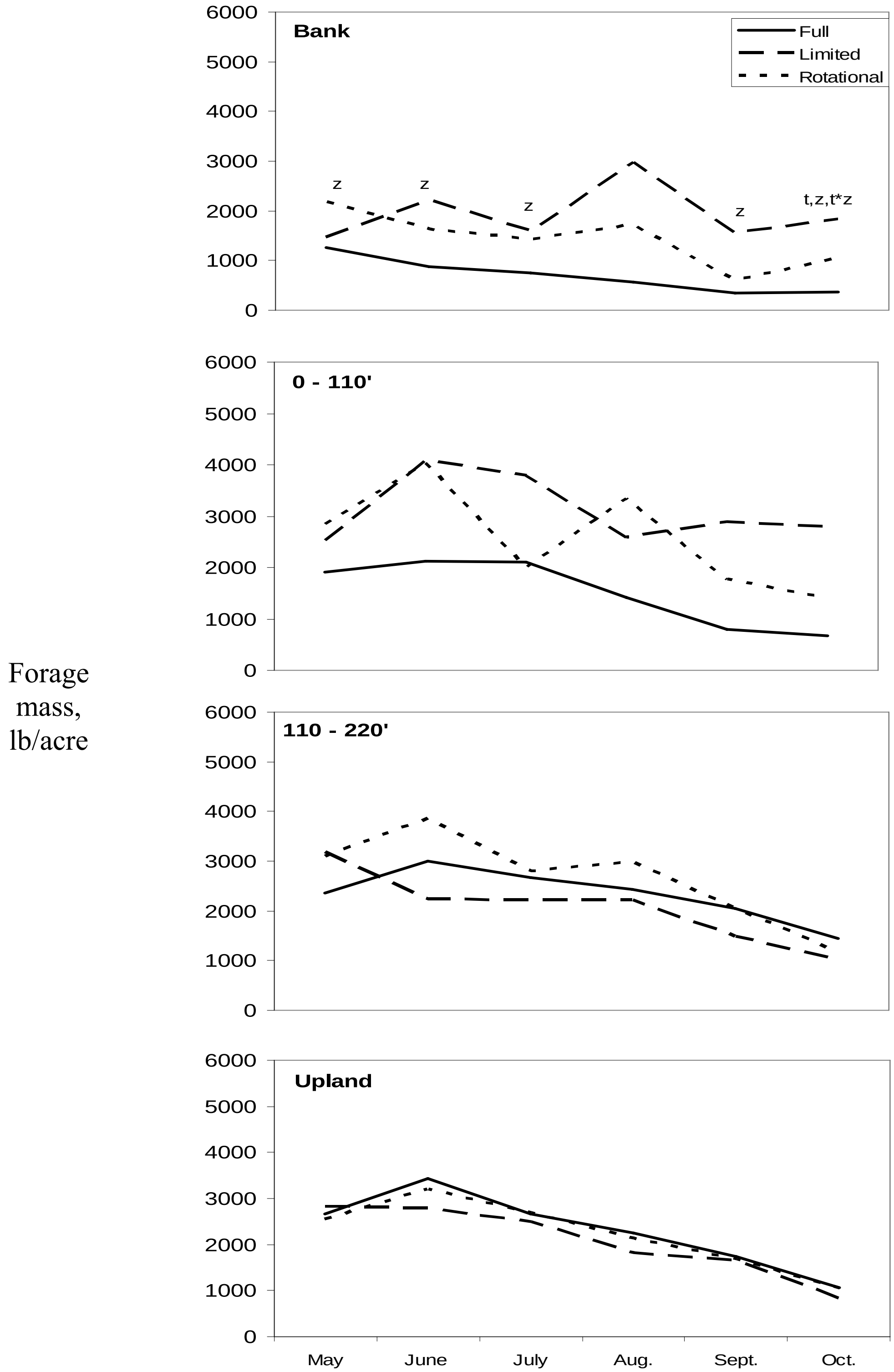

Figure 4. Least squares means of the forage mass, weighted for congregation and open areas, in different zones of pastures with continuous grazing and full or limited stream access or rotational grazing. (t, z and t*z designate significant treatment effects, zone effects, and treatment by zone interactions, P < 0.05).

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