

## **STREAM BANK EROSION UNDER DIFFERENT RIPARIAN LAND-USE PRACTICES IN NORTHEAST IOWA**

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### **ABSTRACT**

Row-cropping and grazing in riparian areas have altered the natural hydrologic cycle and accelerated stream incision and bank erosion. In incised streams, bank erosion can typically contribute 50 to 90% of the streams sediment and phosphorus load. In this northeast Iowa project, stream bank erosion along riparian forest buffers was compared to bank erosion along continuous and intensive rotational pastures and pastures with the cattle excluded from the stream. Our hypothesis was that stream bank erosion would increase in the following order: riparian forest buffers, pastures with cattle excluded from the stream, intensive rotational pastures and continuous pastures. At the conclusion of the study, riparian forest buffers and pastures with the cattle excluded from the stream had the least soil and phosphorus losses from stream bank erosion followed by intensive rotational pastures which had lower losses than continuous pastures. Erosion rates of individual banks did not differ between grazing practices with full access to the stream or between buffers and pastures with cattle excluded from the stream. The differences in soil and phosphorus losses between practices were primarily the result of percentages of the total bank lengths that were severely and very severely eroding within each practice. Total severely and very severely eroding lengths varied from about 10-11% for the buffered and pastures with the cattle excluded from the stream to 27% for the intensive rotational and 38% for the continuously grazed pastures. This translated to 5-7 tons  $\text{km}^{-1} \text{yr}^{-1}$  soil losses and 3 and 2  $\text{kg km}^{-1} \text{yr}^{-1}$  phosphorus losses for the two practices where the cattle had no access to the stream to 156-235 tons  $\text{km}^{-1} \text{yr}^{-1}$  soil losses and 67-122  $\text{kg km}^{-1} \text{yr}^{-1}$  phosphorus losses for the two practices with full access to the stream.

**Keywords:** stream bank erosion, soil losses, phosphorus losses, riparian forest buffers, grazing practices.

## INTRODUCTION

Agriculture has changed the Iowa landscape more dramatically than any other state in the US with more than 90% of the native vegetation being converted to row-crop agriculture and continuously grazed cool-season grass pastures (Burkhart et al. 1994). These land-use changes along with channel straightening and drainage tile installation have led to higher annual and peak stream discharges that have increased the scouring potential and sediment transport capacity of the channels, leading to extensive incision and stream bank erosion (Menzel 1983).

Stream bank erosion can contribute 45-50% of the sediment load in streams in Iowa (Odggard 1984; Schilling and Wolter 2000), and up to 80-90% in other regions of the US (Simon et al. 1996) and other countries (Krovang et al. 1997). In Minnesota, stream bank erosion contributed only 7-10% of the total phosphorus load in the stream (Sekely et al. 2002), while in Illinois (Roseboom 1987) and in Denmark (Krovang et al. 1997) the percentages were much higher with 56% and 90%, respectively. Phosphorus has been identified as the primary nutrient limiting eutrophication of many surface waters (Daniel et al. 1998) while sediment is the number one water quality problem in the US (Simon and Darby 1999).

In Iowa many pastures are located in riparian areas and studies have shown that livestock grazing can increase stream bank erosion (Belsky et al. 1999; Zaines et al. 2004). Intensive rotational grazing is slowly replacing traditional continuous grazing in Iowa because it better utilizes pasture forages, and increases profitability (USDA-NRCS 1997a). In intensive rotational grazing the pasture is divided into numerous small paddocks that are grazed for short periods with long rest periods that allow plant regrowth that should lead to improved stream bank stability. A conservation practice that has been developed to reduce stream bank erosion along crop fields or pastures is the riparian forest buffer (USDA-NRCS 1997b). In this project stream bank erosion along riparian forests buffer reaches were compared to reaches with three different riparian grazing practices: (1) continuous, (2) intensive rotational pastures, and (3) pastures with the cattle excluded from the stream. The hypothesis was that total stream bank erosion would decrease in the following order: continuous pastures, intensive rotational pastures, pastures with the cattle excluded from the stream and riparian forest buffers.

## METHODS

Four different riparian land-use practices were located on 1-3 order (Strahler 1957) deeply incised stream reaches with banks 1.8-3.0 m (5.9-9.8 ft) tall, on private farms in northeast Iowa (Table1). The riparian forest buffers, consisted of a tree, shrub and warm season grass zone, provided the practice with the most stable vegetation community (USDA-NRCS 1997b). Reaches selected for this practice had been established for more than five years. In the intensive rotational grazing practice, the pasture was divided into more than six paddocks and each paddock was grazed one to seven days and rested for 30-45 days. Reaches with this practice were selected only if they had been established for three years or more. In the continuous grazing practice, pastures were not divided into paddocks and cattle had full access to the stream during the entire grazing period. Pastures with the cattle completely excluded from the stream had fences 3-5 m (10-17 ft) away from the stream bank. Again reaches with this practice were

Table 1. General characteristics of the land-use practice reaches. Precipitation values are ranges of National Oceanic and Atmospheric Administration weather stations nearest the replicated reaches. Soil series data are from Soil Survey Geographic (SSURGO), 2004.

Practices	Reaches (#)	Soil series	Stocking rate (cow-calf ha <sup>-1</sup> )	Precipitation (cm)			
				Year 1	Year 2	Year 3	Year 1-3
Continuous pastures	3	Dorchester, Radford, Otter-Ossian complex	1.5-2.4	62-92	52-64	106-107	233-250
Intensive rotational pastures	3	Dorchester, Dorchester-Chaeseburge-Viney and Dorchester-Chaeseburge complexes	1.2-2.1	92-134	52-59	95-108	242-300
Pastures with the cattle excluded from the stream	2	Radford, Spillville	Not applicable	91-92	52-55	104-106	249-250
Riparian forest buffers	2	Colo-Otter-Ossian complex, Spillville	Not applicable	91-92	52-55	104-106	249-250

selected only if they had been established for three years or more. All pastures consisted of cool-season grasses and were grazed from early May to early November by beef cattle.

To measure stream bank erosion rates, steel rods (erosion pins) that were 762 mm (30 in) long and 6.4 mm (0.25 in) in diameter, were inserted perpendicularly into the bank face (Lawler 1993). Only severe and very severe eroding stream banks were selected for erosion pin plots because these sites provide the majority of the sediment in the channel. Severe eroding banks are defined as bare with slumps, vegetative overhang and/or exposed tree roots, and very severe eroding banks are bare with massive slumps or washouts, severe vegetative overhang, and many exposed tree roots (USDA-NRCS 1998). Five erosion pin plots were randomly assigned in each practice reach. Each erosion pin plot had five columns, 1 m (3.3 ft) apart, and two rows at 1/3 and 2/3 the stream bank height, apart. These exposed pin lengths were measured in spring, summer and fall from August 2001 to August 2004.

In August 2002, the total length and height (at specific length intervals) were measured for all the severe and very severe stream banks in all practice reaches. Stream practice lengths were the total lengths of each given practice along the stream owned by the cooperating landowners. The measurements enabled us to estimate the areas and percentages of bank lengths that were severe and very severely eroding for each practice (USDA-NRCS 1998).

Soil samples were collected on the stream bank face adjacent to three (randomly selected) of the five erosion pin plots in each practice reach. Starting at the top (0.0 m/ft) and every 0.5 m (1.6 ft) down to the bottom of the stream bank, two 7.5 cm (3.0 in) long x 3 cm (1.2 in) diameter and two 5 cm (2.0 in) long x 3 cm (1.2 in) diameter soil cores were collected to determine bulk density and total soil phosphorus, respectively. The two samples at each depth for each parameter were consolidated into one sample. The bulk density soil samples were weighed after drying for 1 d at 105 °C (221 °F) (Blake and Hartge 1986). For total phosphorus, the soil samples were air dried for 48 hr, sieved through a 2 mm (0.08 in) screen, digested with a sodium hypobromide solution (Dick and Tabatabai 1977) and the extracted phosphorus identified colorimetrically by a modified molybdenum blue reaction (Murphy and Riley 1962).

The product of the mean stream bank erosion rate, the mean bulk density and the total eroding area of the severe and very severe eroding banks for each practice were used to estimate the total stream bank soil loss in each practice. Then by multiplying the total soil loss by the mean stream bank soil phosphorus concentration for each practice, the total phosphorus loss from stream banks was estimated. Soil and phosphorus loss per unit length of stream bank were estimated by dividing the total soil and phosphorus loss for each practice by the total length of its reaches.

Rainfall data used in the analysis were obtained from the closest NOAA weather station to each practice reach (2002-4a and b). The analysis of covariance in SAS was used to examine differences in stream bank erosion rates between practices for each year and for the sum of all three years with rainfall as the covariant (SAS Institute, 1999). The analysis of variance in SAS was used to compare differences in the percentages of severe and very severe eroding lengths and total phosphorus concentrations among practices.

## RESULTS AND DISCUSSION

In year 1 (August 2001 to August 2002) the riparian forest buffers and the pastures with the cattle excluded from the stream had net deposition rates instead of erosion rates while the two grazing systems had low bank erosion rates (Table 2). The pastures with the cattle excluded from the stream had a significant lower bank rate (deposition) compared to the continuously grazed pastures (erosion rate) ( $p=0.0997$ ). In year 2 (August 2002 to August 2003), the bank erosion rates of the continuous pastures were significantly higher than those of the riparian forest buffers ( $p=0.0815$ ). Year 3 (August 2003 to August 2004) had greater precipitation than the other two years (Table 1) which likely led to higher bank erosion rates (Table 2). In year 3, the intensive rotational pastures had significantly higher bank erosion rates than the riparian forest buffers ( $p=0.0006$ ), the pastures with the cattle excluded from the stream ( $p=0.0010$ ) and even the continuous pastures ( $p=0.0321$ ). The bank erosion rates of the continuous pastures were significantly higher than those of the riparian forest buffers ( $p=0.0317$ ) and the pastures with the cattle excluded from the stream ( $p=0.0444$ ). At the conclusion of the study, the continuous pastures had higher cumulative (years 1-3) bank erosion rates than the riparian forest buffers ( $p=0.0317$ ) and the pastures with the cattle excluded from the stream ( $p=0.0444$ ). The intensive rotational pastures also had higher bank erosion rates than the riparian forest buffers ( $p=0.0255$ ) and the pastures with the cattle excluded from the stream ( $p=0.0357$ ) over the three-year study period.

Significant differences in stream bank erosion rates were only found between the practices with no cattle access to the stream and those where the cattle had full access to the stream. Riparian forest buffers and pastures with the cattle excluded from the stream had very low similar bank erosion rates. The two pasture systems with full access to the streams (continuous and intensive rotational), over the three years of the study, also had similar erosion rates. This would suggest that even though both sets of practices had severe and very severe eroding banks, the rates of erosion of banks were less where cattle had no access to the banks.

The percentage of severe and very severe eroding bank length in the continuous pastures was significantly higher than those along the riparian forest buffers ( $p=0.0019$ ) and the pastures with the cattle excluded from the stream ( $p=0.0021$ ) and nominally higher than the intensive rotational pastures ( $p=0.1048$ ) (Table 2). Lyons et al. (2000) also found that continuous grazing had significantly higher severe and very severe eroding bank percentages than intensive rotational grazing and riparian forest buffers. The intensive rotational pastures had significantly higher percentages of severe and very severe eroding bank lengths than the riparian forest buffers ( $p=0.0437$ ) and pastures with the cattle excluded from the stream ( $p=0.0496$ ) (Table 2). The percentage of severe and very severe eroding stream bank lengths in the practice reaches had more significant differences among practices than the erosion rates. Severe and very severe eroding lengths of banks are more indicative of the actual practice impact on bank erosion because they consider the entire reach impacted by the practice. In contrast the erosion rate considers the bank retreat of individual banks. Differences between the continuous and intensive rotational practices were not as large as expected, possibly because stocking rates between the practices were not very different (Table 1). Upstream land-use differences were also not considered in these comparisons and potentially could have a significant effect on the practice reaches (Lyons et al. 2000; Zaines et al. 2004). Simonson et al. (1994) suggest that high quality

**Table 2.** Mean stream bank erosion rates, severe and very severe eroding bank lengths and soil and total phosphorus loses from stream bank erosion under different practices in northeast Iowa. The stream bank erosion rates have been adjusted for the mean rainfall that each practice reach received. Year 1: August, 2001 to August, 2002; year 2: August, 2002 to August, 2003, and year 3: August, 2003 to August, 2004. To estimate stream bank soil and phosphorus losses the average erosion rate of all three years for each practice was used. The standard errors are in parenthesis.

Practices	Erosion rate				Stream reaches length total	Severe and very severe stream bank		Bulk density	Stream bank soil loss		Stream bank phosphorus concentrations	Stream bank phosphorus loss	
	Year 1	Year 2	Year 3	Year 1-3		length	area		total	per unit length		total	per unit length
	mm					m	%		m <sup>2</sup>	g cm <sup>3</sup>		tons yr <sup>-1</sup>	tons km <sup>-1</sup> yr <sup>-1</sup>
Continuous pastures	15.1 (6.3)	18.4 (4.8)	13.7 (4.5)	51.2 (10.9)	1614	38.3 (5)	1935	1.15 (0.06)	380.3	235.6	518 (59)	197.0	122.0
Intensive rotational pastures	11.4 (7.4)	9.8 (5.3)	31.3 (3.9)	51.1 (13.0)	1473	26.7 (5)	1125	1.20 (0.06)	230.3	156.3	432 (62)	99.5	67.5
Pastures with the cattle excluded from the stream	-2.5 (7.3)	5.1 (6.5)	2.4 (4.7)	6.7 (13.7)	749	10.5 (6)	203	1.16 (0.07)	5.2	6.9	464 (76)	2.4	3.2
Riparian forest buffers	-1.0 (7.3)	3.6 (6.5)	0.1 (4.7)	4.5 (13.7)	838	10.0 (6)	244	1.10 (0.07)	3.8	4.5	479 (75)	1.8	2.2

streams should have less than 20 % of the total length of stream banks eroding. The riparian forest buffers and the pastures with the cattle excluded from the stream were below this percentage while the other pasture systems were above this percentage.

When comparing stream bank total phosphorus concentrations among practices few significant differences were found (Table 2). The primary reason for the lack of differences was that all the practice reaches had similar soils. Riparian soils represent an irregular and incohesive mixture of eroding upland soils and deposited alluvial material and would be expected to have similar characteristics.

Soil losses per unit length of stream bank were consistent with our hypothesis (Table 2). Continuous pastures had the highest soil loss rates with 235 tons  $\text{km}^{-1} \text{yr}^{-1}$ , (419 short tons  $\text{mi}^{-1} \text{yr}^{-1}$ ) followed by the intensive rotational pastures with 156 tons  $\text{km}^{-1} \text{yr}^{-1}$  (277 short tons  $\text{mi}^{-1} \text{yr}^{-1}$ ). The continuous pastures had approximately 34% higher soil losses than the intensive rotational pastures. The pastures with the cattle excluded from the stream and the riparian forest buffers had very low soil losses with 7 and 5 tons  $\text{km}^{-1} \text{yr}^{-1}$  (12 and 9 short tons  $\text{mi}^{-1} \text{yr}^{-1}$ ), respectively.

The phosphorus losses from stream banks followed a similar pattern to the soil losses (Table 2). The continuous pastures lost 122 kg  $\text{km}^{-1} \text{yr}^{-1}$  (433 lbs  $\text{mi}^{-1} \text{yr}^{-1}$ ) whereas the intensive rotational pastures lost 67 kg  $\text{km}^{-1} \text{yr}^{-1}$  (241 lbs  $\text{mi}^{-1} \text{yr}^{-1}$ ). The continuous pastures had approximately 45% higher phosphorus losses than the intensive rotational pastures. The pastures with the cattle excluded from the stream, and riparian forest buffers had the lowest phosphorus losses with both losing approximately 3 and 2 kg  $\text{km}^{-1} \text{yr}^{-1}$  (11 and 7 lbs  $\text{mi}^{-1} \text{yr}^{-1}$ ), respectively.

## CONCLUSIONS

Riparian forest buffers and pastures with the cattle excluded from the stream were the land-use practices that minimized soil and phosphorus loss from stream bank erosion compared to continuous and intensive rotational pastures. Restricting access of cattle to stream banks appears to result in more stable banks that resist erosion probably because of lack of access paths and maintenance of healthier vegetation with larger root masses along the edge of the banks. Reductions in bank erosion following removal of direct access of cattle to the stream banks have been demonstrated (Laubel et al. 2003) but this practice is not socially and economically acceptable to many farmers (Platts and Wagstaff 1984). In cases where off-stream water is provided as an alternative to fencing, stream bank erosion has also been reduced (McInnis and McIver 2001). However in Iowa, off-stream water sources would not be as effective without fencing the stream since most pastures are confined in narrow riparian areas along low order streams. In this study intensive rotational pastures had lower severe and very severe eroding length percentages (nominally) and soil and phosphorus losses compared to continuous pastures but not lower bank erosion rates. Results from this study suggest that intensive rotational grazing can improve stream bank stability and decrease soil and phosphorus losses although stocking rates, season and number of grazing days may be as important as the grazing system (Clary and Kinney 2002).

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