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# MANURE MATTERS

Volume 8, Number 1

## Phosphorus Risk Assessment Index Evaluation Using Runoff Measurements

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### Introduction

Manure and composted manure are valuable and renewable resources that can be effectively utilized for crop production and soil improvement. However, runoff from cropland areas receiving manure or compost may contribute to increased phosphorus (P) in streams and lakes. The main factors controlling P movement in surface runoff are transport (runoff and erosion) and source factors such as manure or fertilizer application method and rate, and soil P test level. Elevated soil P levels may result from application of manure at rates in excess of crop nutrient requirements. Research conducted by the authors indicated a significant accumulation of plant available P in the top 6 inches of soil following N-based beef cattle manure or compost application, but no accumulation occurred with P-based applications. Elevated soil test P levels have been shown to increase soluble P concentrations in runoff.

In many agricultural watersheds, total annual P transport occurs mainly from a few relatively large storms. In a study on a small upland agricultural watershed in Pennsylvania, it was found that the areas of runoff production, and consequently the

areas controlling most P transport, are often a limited and identifiable portion of the landscape.

Natural Resource Conservation Service (NRCS) scientists developed an index to assess risk to surface water pollution by P. The index included both transport and source factors. The factors of erosion, runoff, soil test P level, P fertilizer application rate, P fertilizer application method, organic P source application rate, and organic P source application method were assigned weighted values of 1.5, 0.5, 1.0, 0.75, 0.5, 1.0, and 1.0, respectively. Each factor included several risk levels classified as none, low, medium, high, and very high, to which weight values of 0, 1, 2, 4, and 8 were assigned, respectively. By multiplying the weight value of each factor by its level weight a score is determined, i.e., for a soil with medium erosion, the erosion score is  $1.5 \times 2 = 3$ . By adding the scores for all factors, a site vulnerability index can be calculated. A low index value ( $< 8$ ) indicates low P loss vulnerability while a very high value ( $> 32$ ) indicates substantial vulnerability to P loss.

The factors that influence P loss from a

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field need to be tested so that the usefulness of the P risk assessment index can be evaluated. The weight values for the variables used in the P index should also be examined. The objectives of our study were to examine the effects of source and transport factors on P loss from three sites that had received beef cattle manure, composted manure, or inorganic fertilizer, and to evaluate the P index with measurements obtained from three rainfall simulation studies.

### **Procedure**

Data from three field rainfall simulation experiments were used in this study. Two experiments, one with sorghum residue and the other with winter wheat residue, were conducted on a Sharpsburg silty clay loam soil located near Lincoln, NE. Experimental treatments in the sorghum residue study included the application of composted and noncomposted beef cattle feedlot manure to meet N or P requirements of the succeeding corn crop, chemical fertilizer, and an untreated check under no-till and disked conditions. On the plots containing wheat residue, treatments included the application of composted and noncomposted beef cattle feedlot manure (N-based), chemical fertilizer, and an untreated check under no-till and disked conditions. On the no-till plots, the manure, compost, and fertilizer were left undisturbed on the soil surface. A single disking operation to a depth of approximately 2.5 inches was performed up and down the slope on the tilled treatments to incorporate the manure, compost, and fertilizer. Average slope gradients were 7 and 6% on the sorghum and wheat residue plots, respectively.

The third experiment was conducted on a Monona soil that contained corn residue located near Treynor, IA. Within the study area, which had an average slope of 12%, narrow (~ 30 inches) switchgrass hedges, separated by 16 corn rows (38 inch row spacing), had been established perpendicular to the slope. Experimental treatments included the application of beef cattle feedlot

manure, inorganic fertilizer, and untreated checks in no-till and disked systems, with or without a switchgrass hedge. Manure and fertilizer were left undisturbed on the soil surface of the no-till plots or were incorporated to a soil depth of 3 inches by disking on the tilled plots (plots were located within two hedges).

In all three experiments, a portable rainfall simulator was used. Each 12 by 36 ft plot was established using sheet metal borders. Runoff measurements were made soon after manure, compost, and fertilizer were applied. This represented an optimum situation for P loss in runoff. An initial 1-hr rainfall was applied at an intensity of 2.5 inches per hour over the entire plot area at existing soil-water conditions. A second 1-hr application (wet run) at the same intensity was conducted approximately 24-hr later. Runoff was collected during both runs and sampled for total P, particulate (sediment-bound) P, bioavailable P, and soluble P. Bioavailable P is the fraction of the P in runoff that is available to algae. P index values were determined for each plot of each experiment based on the inputs and runoff potential of that plot. The P index that was developed by NRCS is shown in Table 1.

### **Results**

Stepwise regression was used to indicate importance of each variable in the P index as they related to P loss in runoff. Total and particulate P losses were significantly related to measured erosion while tillage, runoff amount, and the P source were the most important factors affecting the transport of soluble and bioavailable P (Table 2). Erosion accounted for 78 and 88% of the variability in total and particulate P losses, respectively. Runoff amount, soil test P, and tillage factors minimally affected total and particulate P losses (Table 2). In this study, P application rates of manure, compost, and chemical P fertilizer did not significantly influence loss of particulate and

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bioavailable P even though the rates of applied manure or compost P were several times greater than the recommended chemical P fertilizer rate. This indicates that a greater portion of the fertilizer P was carried in runoff as compared to manure or compost P.

Total and particulate P losses were highly related to measured erosion in the three experiments. On the other hand, bioavailable and soluble P losses were unaffected by the erosion amount. Controlling erosion seems to be a major factor in reducing total and particulate P losses from fields receiving manure, compost, and chemical P fertilizer. Soil test P accounted for 1% of the variability in the total and soluble P losses. It should be emphasized that the P levels in the top 2-in of soil in these experiments ranged from 31 to 83 ppm. Even though these values are considered excessive for crop production in Nebraska, they are smaller than those reported by others who showed a significant linear relationship between soil P level and soluble P loss in runoff. The proportion of variability in soluble P loss explained by the soil test P might have increased if the soil test P levels were higher.

Controlling bioavailable and soluble P losses would require a significant reduction in runoff and incorporation of the applied P source within the soil. Strategies that can be used to reduce runoff include increased residue on the soil surface, greater infiltration by increasing soil organic matter and improved soil structure. Narrow grass hedges or buffer strips can also reduce loss of soluble P.

The P index may be modified to correspond with the management and environmental conditions to which it is applied. For example, while erosion is an important factor on cropland areas, runoff and soil test P may be more important factors on pasture or grassland sites. Thus, erosion would have a high weight on cropland and a low weight on grasslands.

Total and particulate P losses in runoff were

significantly related to the P index values when measured erosion was used to determine the erosion weight factor (Fig. 1). Soluble P loss was unrelated to the index value (Fig. 1). Perhaps another index needs to be developed for soluble or bioavailable P loss in which runoff amount, P source, and tillage factors would have greater weights.

Site vulnerability needs to be considered when management systems are implemented. As site vulnerability increases from low to very high, conservation practices and a long-term P management system needs to be implemented to reduce or eliminate P loss in runoff. Our field experiments were conducted to represent the worst-case scenario for runoff P losses as rainfall occurred just after manure, compost, and fertilizer applications. We also assumed that the sediments were carried directly into concentrated flow. Some of the sediment may settle before reaching a stream, and hence reduce the sediment-bound P loss on a watershed scale.

## Conclusions

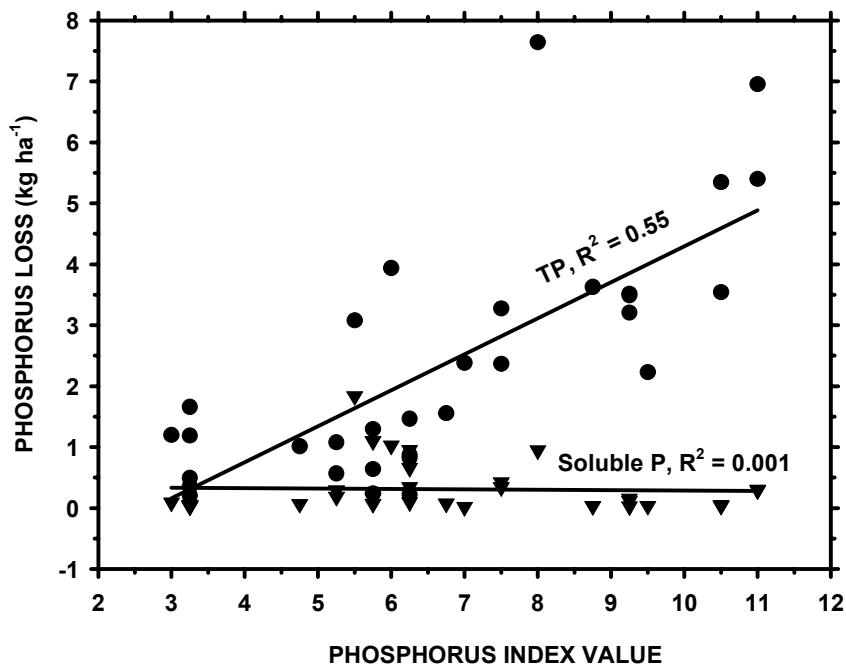
Erosion was the primary factor influencing total and particulate P losses in runoff from fields receiving manure, compost, chemical P fertilizer, and no treatment under no-till and disked conditions. Runoff amount, P source, and tillage were the main factors influencing loss of soluble and bioavailable P in fields that had recently received organic and inorganic P. In the long-term, organic or inorganic P application should increase soil P level and may make this factor more important in the loss of soluble and bioavailable P. Control of runoff and erosion is important in areas that are subject to P loss in runoff. Conservation practices, which reduce runoff and erosion, should be employed in vulnerable areas receiving animal manure and chemical P fertilizer. The P risk assessment index was significantly correlated with total and particulate P loss but not with the loss of bioavailable or

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soluble P, indicating the usefulness of the index in assessing site vulnerability to runoff P loss. The P risk assessment index may be modified for varying situations under which it is applied. For cropland conditions, erosion is a dominant factor, while on pasture or grassland areas, runoff amount or soil test P might be the important factors influencing runoff loss of P. The P index can serve as a useful tool for identifying sites where transport of P to surface water can be a potential concern if erosion and runoff are accurately predicted.

**Fig. 1. P index value (modified) as influenced by loss of total P and soluble P.**



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Table 1. Phosphorus risk assessment index and site vulnerability ratings based on the index developed by Lemunyon and Gilbert of NRCS.

Site characteristics	Unit	None (0)	Low (1)	Medium (2)	High (4)	Very High
Erosion (1.5)	ton/ac	Not applicable	< 5	5-10	10-15	> 15
Runoff (0.5)	-	Negligible	very low or low	Medium	high	very high
Soil test (1.0)	ppm	Not applicable	very low or low	Medium	high	very high
P fertilizer rate (0.75)	lb P <sub>2</sub> O <sub>5</sub> /ac	None	1-30	31-90	91-150	> 150
P fertilizer method (0.5)	-	None applied	placed with planter	Incorporated	incorporated > 3 months	surface-
P organic rate (1)	lb P <sub>2</sub> O <sub>5</sub> /ac	None	1-30	31-60	60-91	> 90
P organic method (1)	-	None applied	Injected deeper	Incorporated	incorporated > 3 months	surface-
<b>9</b>						
Total of weighted rating value						
( 3 site characteristic X weight)						
< 8						
8 – 14				Low		
15 – 32				Medium		
> 32				High		
				Very High		

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Table 2. Stepwise regression indicating the effects of selected factors on quantities of total, particulate, bioavailable, and soluble P losses in runoff from rainfall simulation experiments conducted in Nebraska and Iowa.

Variable	Total P	Particulate P	Bioavailable P	Soluble P
		-----Partial R <sup>2</sup> -----		
Erosion	0.78	0.88	_ <sup>‡</sup>	0.06
Runoff	0.10	0.04	0.07	0.12
B & K P (0-2 in) <sup>†</sup>	0.01	-	-	0.01
Applied P rate	0.01	-	-	0.01
Tillage	0.01		0.14	0.20
P source <sup>¶</sup>	-	-	0.13	0.06
<b>Total</b>	<b>0.91</b>	<b>0.92</b>	<b>0.34</b>	<b>0.46</b>

<sup>†</sup> B & K is Bray and Kurtz No. 1 soil test P.

<sup>‡</sup>Slashes indicate that the variable had a probability level > 0.50.

<sup>¶</sup>Discrete variables of tillage systems (0 for no-till and 1 for tillage) and P source (0 for no treatment, 1 for fertilizer and 2 for organic P sources) were converted to numeric.

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