VALIDATING THE WISCONSIN P INDEX WITH MEASURED RUNOFF P LOSSES FROM AGRICULTURAL FIELDS

Laura Ward Good and Larry G. Bundy
University of Wisconsin-Madison, Madison, Wisconsin

Abstract

Phosphorus (P) indices have been developed by most states in the USA for use as planning tools to assess the risk of P loss and identify appropriate management alternatives to control these losses where needed. Little information is available on the relationship between P index values and actual P runoff losses in the field. We compared annual P losses in runoff measured at 21 field or sub-watershed locations with Wisconsin P index values calculated for the same areas. The research sites included soils, cropping systems, and management practices representative of cropland acreage in the state. Results showed that measured annual edge-of-field P loads from the monitored areas were well correlated (r^2 = 0.79) with edge-of-field P loss risk values calculated for the same areas using the Wisconsin P index. Average soil test P values for the monitored areas were not related to the measured P losses. A comparison of matrix and model P index structures showed that the semi-quantitative model P index more accurately reflected measured P losses than the matrix-type P index. The close relationship found between measured P losses and Wisconsin P index values confirms the reliability of the index as a nutrient management planning tool.

Introduction

Phosphorus (P) loss in runoff from cropland is a water quality concern because this P often promotes algae and other vegetative growth in lakes and streams (Carpenter, et al., 1998; Correll, 1998). When this vegetation decomposes, dissolved oxygen levels in the natural waters are depleted. This can cause death or damage to fish and other aquatic organisms as well as odors and a general degradation of the aesthetic and recreational value of the environment. National policy and general guidelines on nutrient management issued by USDA-NRCS (1999) recognized the need for enhanced P-based nutrient management in agriculture to control nonpoint source losses of P. Three risk assessment tools were proposed in the NRCS national policy: agronomic soil test P interpretation categories; soil test P threshold values resulting in a critical runoff P concentration; or a comprehensive P loss risk assessment tool (P-index). The soil test P category option is appealing because soil test information is widely available for many agricultural fields and this parameter can be readily obtained at low cost. However, soil test P is not a reliable predictor of P loss risk because it does not consider the transport component required for P losses in runoff.

Development of P indices has occurred in essentially every state in the USA, because these products are the most promising approaches to predicting the risk of P losses from agricultural fields and developing appropriate management practices to control or reduce these losses (Maguire et al., 2005; Sharpley et al., 2003). The P indices developed are intended primarily to assess risk of P loss from fields and, therefore, for use as planning tools for agronomic P management. The P indices developed typically use state-specific or regional data as the research basis to construct these tools. The overall structures of most of the indices developed consist of a matrix approach or a semi-quantitative modeling approach. Initially, Lemunyon and Gilbert (1993) proposed a matrix P index structure that involved assigning a numerical value to each major source or transport factor likely to influence P loss. Index values for individual fields were categorized using a general P loss risk ranking (low to very high), and nutrient management recommendations appropriate for the level of P loss risk were made. Subsequent P indices continued with the matrix structure proposed by Lemunyon and Gilbert (1993), but included additional factors affecting P loss potential, grouped P loss factors into separate P transport and P source categories, and employed a multiplicative approach to calculating the P index value.

The P-indices currently in use in Delaware (Leytem et al., 2003), Pennsylvania (Weld et al., 2002), and Maryland (Coale et al., 2002) are examples of the matrix or row and column P index structure described above. These indices provide a numerical or categorical rating of P loss potential on a field scale, but do not attempt to provide a quantitative estimate of annual P loss in runoff. Several states in the North Central Region of the USA have developed P indices using semi-quantitative modeling approaches that attempt to estimate annual P losses on a field by field basis. In the Eastern USA, North Carolina has developed a P index using a generally similar modeling approach (NC PLAT Committee, 2005). These indices are sensitive to the need to utilize input data that is available or easily obtainable by users and are much less data intensive than more complex research P loss models. The P indices developed in Iowa (Mallarino et al., 2002), Minnesota (Minnesota Phosphorus Site Risk Index, 2005), and Wisconsin (http://wpindex.soils.wisc.edu/) are examples of P indices using a semi-quantitative modeling approach.

Validation of P indices as tools for predicting the risk of P runoff from agricultural landscapes requires measurement of actual annual P runoff losses from field-scale areas where P index values for the same fields can be obtained. Several reports have compiled information on the relative proportion of agricultural fields in a designated region that would be assigned to various interpretive categories for the P index being evaluated (Coale et al., 2002; Leytem et al., 2003). While these studies provide valuable information on the magnitude of management changes needed to bring most fields into an acceptable interpretive category, no information on the relationship between P index values and actual P losses is obtained, and the need for field validation is recognized by the authors (Coale et al., 2002; Leytem et al., 2003).

Veith et al. (2005) recently compared measured P runoff losses from a south-central Pennsylvania watershed with losses from this watershed predicted by the Soil and Water Assessment Tool (SWAT). In addition, field-level P loss predictions from SWAT for 22 fields within the monitored watershed were compared with values from the Pennsylvania P index for the same fields. Results showed that watershed P loss measurements for dissolved and total P were of the same magnitude as SWAT P loss predictions. The P index and SWAT categorized P loss risk similarly for 73% of the 22 fields evaluated, and P loss assessments by the two methods were well correlated. The authors concluded that the P index can be reliably used to assess where P losses occur in a watershed and where management practices are needed to control losses and ultimately provide for improved water quality.

Since little information is currently available confirming the relationship between P index values and measured annual P runoff losses from individual fields, we compared annual P losses in runoff measured multiple field locations with Wisconsin P index values calculated for the same areas. We also evaluated the performance of the Pennsylvania P index (a matrix or row and column P index) relative to the Wisconsin P index which uses a semi-quantitative modeling approach.

Materials and Methods

In this work, annual (12 month) measurements of P runoff losses were obtained from 21 crop years at a field or sub-watershed scale, and these measurements were compared with the Wisconsin P index values for the same areas. The 21 sites represented 18 fields on 7 farms in 4 major topographic areas of the state (Table 1). Soil textures included silty clay loam, silt loam, and loam, slopes ranged from 4 to 13%, crops included alfalfa, alfalfa/brome, corn grain, and corn silage, and manure was applied (4 incorporated, 7 surface) in the monitoring year in 11 of the 21 sites. Eight of the runoff monitoring stations utilized passive interception devices with drainage areas of 0.04 to 2.5 acres. The remaining 13 sites were equipped with H-flumes and USGS automated gauging stations with drainage areas of 9 to 40 acres. Runoff volumes and analyses of runoff for sediment, total P and dissolved P were compiled for each site.

Results and Discussion

Data in Figure 1 show that measured annual edge-of-field P loads from the monitored areas were well correlated ($r^2 = 0.79$) with the Wisconsin P index edge-of-field values calculated for the same areas. This finding indicates that the Wisconsin P index is a reliable predictor of actual P runoff losses from cropland. As expected, no relationship was found between annual runoff P loads and field average soil test P values, since soil test P alone indicates only the level of P source and does not reflect the transport component involved in runoff P losses (Figure 2).

Figure 3 shows the relationship between index values calculated using the Pennsylvania P index and measured annual P runoff loads from the same 21 locations as used in Figures 1 and 2. Comparison of Figures 1 and 3 indicate that the Wisconsin P index values are much more closely related to measured P losses than the P-index values calculated with the Pennsylvania P index. Since the P indices used in Wisconsin and Pennsylvania were developed from local information available in each state, part of the difference in performance may be due to state-specific influences that are reflected in the P index calculations. Specifically, the Pennsylvania P index may not reflect measured P losses under Wisconsin conditions because this index was developed using information specific to factors affecting P losses in Pennsylvania. Alternatively, the site-specific quantitative consideration of factors affecting P runoff losses that can be obtained with the modeling approach used in the Wisconsin P index may have better capability to predict runoff P losses.

Conclusions

Measured annual edge-of-field P loads from 21 field sites were well correlated ($r^2 = 0.79$) with edge-of-field values calculated for the same areas using the Wisconsin P index. Average soil test

P values for the monitored areas were not related to the measured P losses, indicating that soil test P alone is not a reliable predictor of the risk of P loss in runoff. A comparison of matrix and model P-index structures showed that the semi-quantitative model P index values more accurately reflected measured P losses than the matrix-type P index. The close relationship found between measured P losses and Wisconsin P index values confirms the reliability of the index as a nutrient management planning tool.

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	Subwatershed		Field characteristics and management									Monitoring results			
								P applied					Runoff P		
	Acres	Monitoring system	Crop	Tillage	Soil texture (as mapped)	Slope	Soil test P (ppm)	Winter (lb/a)	Surface (non-winter) (lb/a)	Inj./inc (lb/a)	Other feature	Sediment (T/a/yr)	Total (lb/a/yr)	Dissolved (lb/a/yr)	Particulate (lb/a/yr)
1	0.4	passive	corn silage	fall chisel	loam	10%	53			40		5.6	18.0	0.90	17.1
2	0.08	passive	corn	fall chisel	silty clay loam	4%	18			32		0.7	0.5	0.03	0.5
3	0.2	passive	corn	no-till	silt loam	7%	81					0.2	0.6	0.28	0.3
4	2.5	passive	alfalfa	none	silt loam	13%	52					1.8	3.4	0.3	3.1
5	0.09	passive	corn	no-till	silt loam	8%	57					0.03	0.2	0.05	0.2
6	16.7	automated	alfalfa/brome	none	silt loam	5%	41					0.8	0.5	0.1	0.3
7	16.7	automated	1st yr. corn	spring chisel	silt loam	5%	39					10.6	7.9	0.6	7.4
8	13.0	automated	1st yr corn	spring chisel	silt loam	6%	88	6	15			0.1	2.6	0.7	1.9
9	13.0	automated	2nd yr corn	fall chisel	silt loam	6%	88			68		0.4	1.6	0.8	0.8
10	9.3	automated	1st yr corn	spring chisel	silt loam	6%	130					0.7	2.0	0.2	1.8
11	9.3	automated	2nd yr corn	fall chisel	silt loam	6%	116			65		0.3	1.6	0.9	0.6
12	29.7	automated	alfalfa/brome	none	silt loam	5%	116					0.1	0.8	0.5	0.2
13	16.9	automated	corn	no-till	silt loam	6%	74	9	6			0.2	3.2	2.5	0.8
14	17.2	automated	corn	no-till	silt loam	6%	74	9	8			0.4	2.8	1.7	1.1
15	39.5	automated	soybeans	no-till	silt loam	6%	67		10			0.04	0.7	0.5	0.2
16	20.5	automated	alfalfa	none	silt loam	4%	39		17		tiled	0.08	1.4	1.1	0.3
17	22.1	automated	alfalfa	none	silt loam	4%	14		18		tiled	0.03	0.2	0.1	0.1
18	13.2	automated	alfalfa	none	silt loam	4%	53		11		tiled	0.06	0.7	0.4	0.3
19	0.04	passive	corn	fall chisel	silt loam	7%	38					3.3	3.6	0.1	4
20	0.04	passive	corn silage	fall chisel	silt loam	9%	51					26.8	20.6	0.1	28.5
21	0.04	passive	corn silage	fall chisel	silt loam	9%	74			18		11.9	14.9	0.2	15

Table 1. Site characteristics and measured annual P losses for 21 site-years used in Wisconsin P index validation study.

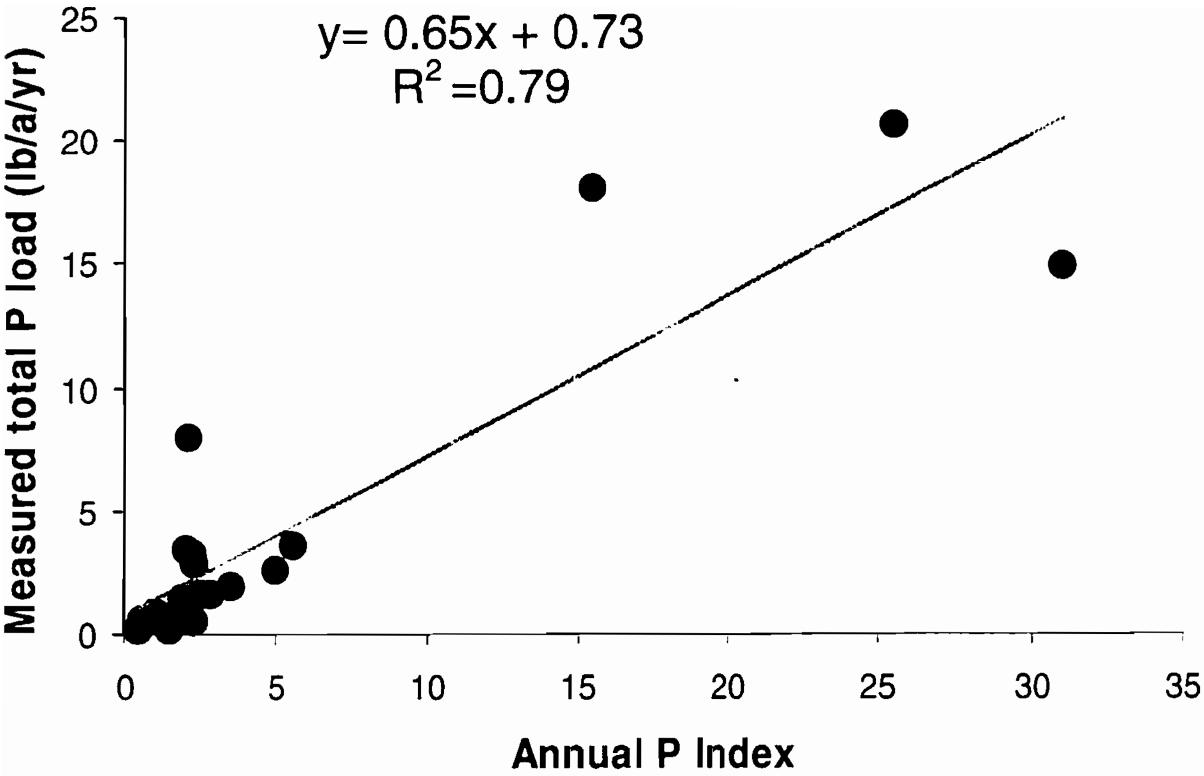

Figure 1. Relationship between measured annual runoff P loads and Wisconsin P index values for 21 field locations in Wisconsin.

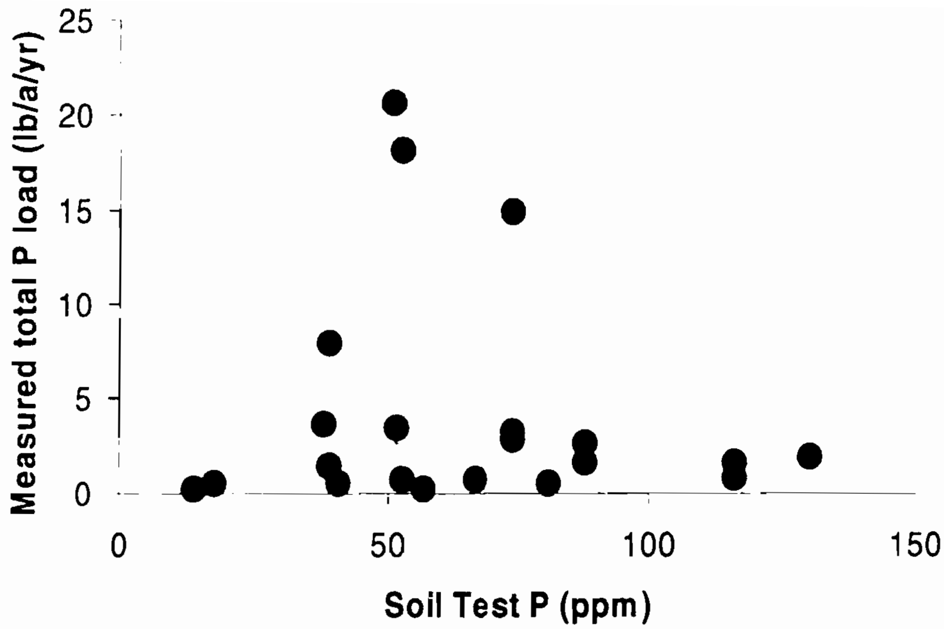

Figure 2. Relationship between measured annual runoff P loads and Bray P-1 soil test values for 21 field locations in Wisconsin.

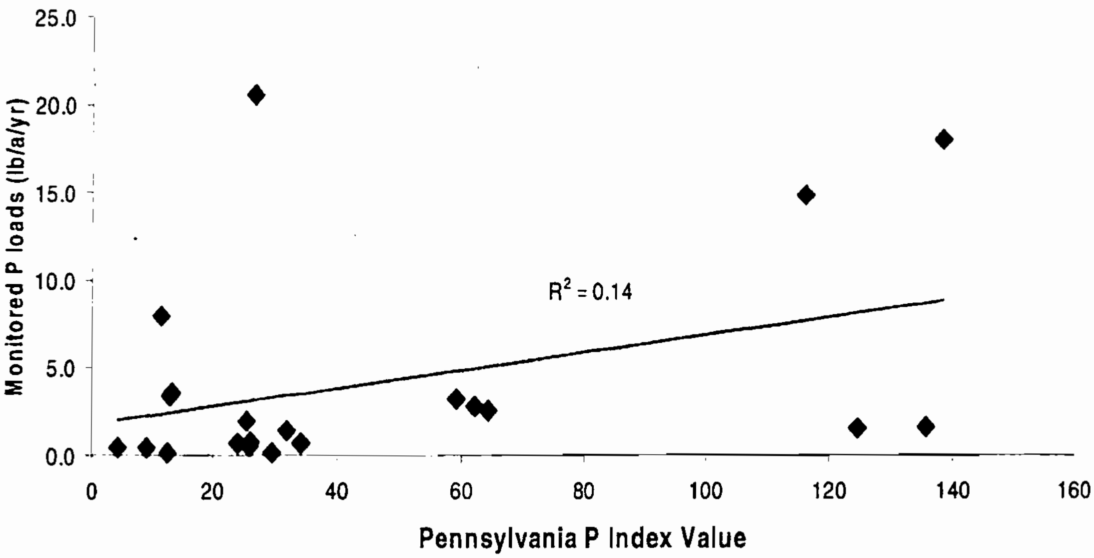

Figure 3. Relationship between measured annual runoff P loads and P index values calculated using the Pennsylvania P index for 21 field locations in Wisconsin.

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Program Chair:

Brad Joern
Purdue University
West Lafayette, IN
(765) 494-9767

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772 – 22nd Avenue South
Brookings, SD 57006
(605) 692-6280
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