Verification of the Wisconsin Phosphorus Index through in-Field Runoff Monitoring

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Summary

Wisconsin's Phosphorus (P) Index is a surface-water-delivery P loss risk index for agricultural fields. It uses a quasi-modeling or "pathway" approach to estimate the annual per acre runoff P losses from a specific field. The P Index equations are primarily based on relationships between runoff P concentrations and soil type, soil test P, and manure management observed in small-plot research. It is being verified through on-going, year-round in-field sub-watershed monitoring projects in agricultural fields throughout the state. These fields vary by crop, soil type, topography, P additions in manure and fertilizer, and tillage practices. With twenty-one site-years of runoff monitoring, there was a strong relationship (r^2 = 0.79) between Wisconsin P Index edge-of-field P loss risk estimates and measured crop year runoff P loads. In contrast, the relationship between the risk assessment provided by a representative matrix-type and measured P loads was not strong (r^2 = 0.14), although the field information required to run both indices is virtually the same. Soil test P was not good indicator of runoff P risk for these sites, as there was no relationship between soil test P and monitored runoff P across all sites. For Wisconsin cropland, this pathway-type P Index appears to be a much better indicator of P loss risk than either soil test P or a matrix-type P Index.

Agricultural Phosphorus Loss Risk Indices

In their national policy guidelines on nutrient management, the USDA-Natural Resources Conservation Service (NRCS, 1999), identified three strategies for managing P applications to cropland to reduce the risk of resulting surface water contamination. Two of the strategies – limiting applications to agronomic recommendations and limiting applications above specified soil test P threshold levels – rely on soil test phosphorus as the sole indicator for guiding management decisions. The third NRCS strategy is the use of a comprehensive P loss risk assessment, or P Index. Phosphorus indices have been or are currently being developed on a state-by-state basis throughout the United States. In general, there are two types of approaches being followed in developing P Indices – one is a risk-rating approach recommended by the NRCS that considers both the availability of phosphorus in the field (source factor) and the likelihood that phosphorus will be carried to surface water in runoff or subsurface drainage (transport factor) (NRCS, 1994). In this kind of "risk matrix", numerical values are assigned to risk level ratings for relevant field and crop management variables, and these risk values are summed to arrive at the source and transport factors. The Wisconsin P index takes a different approach to assessing risk by calculating a gross estimate of the phosphorus that would be delivered annually in runoff from a field to the closest water body. Separate estimates are made for dissolved P, particulate P, and acute (single-event) losses from unincorporated manure and fertilizer P applications. Equations for the Wisconsin Phosphorus Index are shown below. These equations were developed using Wisconsin-based small plot and simulated rainfall runoff research.

Wisconsin P Index Component Equations

P Index = Annual edge-of-field P loss risk x Field-to-water P delivery ratio

Annual edge-of-field P loss risk = Particulate P + Soluble P + Acute losses from unincorporated P applications

Annual particulate P loss risk = Sediment delivery (RUSLE2) x Sediment P concentration

Annual soluble P Index = Rainfall and snowmelt runoff volume x Runoff Dissolved P Concentration

Acute losses from P applications = P application rate x Proportion surface-applied P removed in severe runoff event

More information on these equations and the research base for each can be found at http://wpindex.soils.wisc.edu/.

P Index Information Requirements

The information required for nutrient management planners to calculate the Wisconsin P Index is virtually the same as that required for a representative risk-matrix-type index (Weld, 2003). This is:

- Routine soil test reports
- Fertilizer P rate, method, and timing of application.
- Manure type, P rate, method, and timing of application
- Soil series or mapping unit, field slope, slope length, crop and tillage method (needed to calculate soil loss and identify runoff potential)
- Distance to water from the edge-of-field and some knowledge of the flow path (presence of off-field filter for the risk- matrix index, average slope for Wisconsin's)

Run-off Monitoring

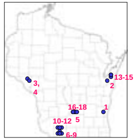

Figure 1. Location of cropland runoff monitoring sites in Wisconsin, 2003 and 2004.

Currently, 18 fields in Wisconsin have had at least one crop-year of continuous year-round runoff monitoring (Figure 1 and Table 1). These fields are on both private and research farms.

The in-field monitoring systems are of two types:

•Automated samplers on H flumes installed by United States Geological Survey (USGS) staff

•Passive samplers with flow splitters

Both types are designed to operate during the freezing and thawing conditions of snowmelt events.

Runoff Monitoring Researchers: Dave Owens, Todd Stuntebeck, and Matt Komiskey, USGS; Carlos Bonilla, John M. Norman, and Christine Molling, UW Dept. of Soil Science; John Panuska, Paul Miller, and K.G. Karthikeyan, UW Dept. of Biological Systems Engineering; Randy Mentz, Chris Baxter, and Tom Hunt, UW-Platteville Pioneer Farm

Automated samplers

Passive samplers

As shown in Table 1, the monitored fields vary by crop, tillage, soil P, soil type, topography, and P applications – all of which are taken into account in the Wisconsin P Index. Annual monitored sediment and phosphorus losses also varied widely. Sediment loss ranged from 0.07 Mg ha^{-1} yr^{-1} to 60 Mg ha^{-1} yr^{-1}. Total phosphorus yields were from 0.2 kg ha^{-1} yr^{-1} to 23.3 kg ha^{-1} yr^{-1}. Most of the results shown in Table 1 are from crop year 2004, which was characterized by unusually heavy spring and summer rainfall throughout most of Wisconsin.

Table 1. Field characteristics of runoff monitoring sites and annual sediment and phosphorus yields[1]

Field Number	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^{-1})	Surface (non-winter) (lb a^{-1})	Inj./Inc (lb a^{-1})	Other feature	Sediment (T a^{-1} yr^{-1})	Total (lb a^{-1} yr^{-1})	Dissolved (lb a^{-1} yr^{-1})	Particulate (lb a^{-1} yr^{-1})
1	0.4	passive	corn silage	fall chisel	loam	10%	53			40		9.1	20.1	1.39	18.7
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	0.9	0.4	0.5
4	2.5	passive	alfalfa	none	silt loam	13%	52					1.8	0.39	0.03	0.4
5	0.09	passive	corn	no-till	silt loam	8%	57					0.03	0.2	0.1	0.1
6	16.7	automated	alfalfa/brome	none	silt loam	5%	41					0.8	0.5	0.1	0.3
6	16.7	automated	1st yr. corn	spring chisel	silt loam	5%	39					5.8	7.9	0.3	6.2
7	13.0	automated	1st yr corn	spring chisel	silt loam	6%	88	6	15			0.1	2.6	0.7	1.9
7	13.0	automated	2nd yr corn	fall chisel	silt loam	6%	88			68		0.4	1.6	0.8	0.8
8	9.3	automated	1st yr corn	spring chisel	silt loam	6%	130					0.7	2.0	0.2	1.8
8	9.3	automated	2nd yr corn	fall chisel	silt loam	6%	116			65		0.3	1.6	0.9	0.6
9	29.7	automated	alfalfa/brome	none	silt loam	5%	116					0.1	0.8	0.5	0.2
10	16.9	automated	corn	no-till	silt loam	6%	74	9	6			0.2	3.2	2.5	0.8
11	17.2	automated	corn	no-till	silt loam	6%	74	9	8			0.4	2.8	1.7	1.1
12	39.5	automated	soybeans	no-till	silt loam	6%	67		10			0.04	0.7	0.5	0.2
13	20.5	automated	alfalfa	none	silt loam	4%	39		17		tiled	0.08	1.4	1.1	0.3
14	22.1	automated	alfalfa	none	silt loam	4%	14		18		tiled	0.03	0.2	0.1	0.1
15	13.2	automated	alfalfa	none	silt loam	4%	53		11		tiled	0.06	0.7	0.4	0.3
16	0.04	passive	corn	fall chisel	silt loam	7%	38					3.3	3.6	0.1	4
17	0.04	passive	corn silage	fall chisel	silt loam	9%	51					26.8	20.6	0.1	20.5
18	0.04	passive	corn silage	fall chisel	silt loam	9%	74			18		11.9	14.9	0.2	15

[1] Units shown in this table are non-SI units used for nutrient management and conservation planning.

Measured Phosphorus Losses Compared to Risk Index Values

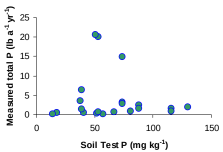

Figure 2. Soil test P (Bray-Kurtz P1) and P yields.

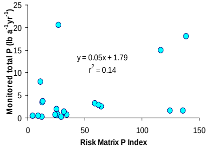

Figure 3. Risk-matrix P Index and P yields.

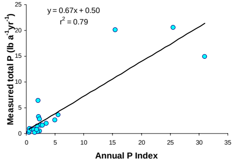

Figure 4. Wisconsin P Index annual value and P yields.

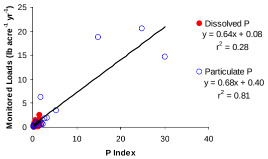

Figure 5. Wisconsin P Index annual values by soluble P and P components and dissolved and particulate P yields

Across all monitored fields, soil test P was not related to P losses (Fig. 2). We calculated the annual P Index values related to edge-of-field runoff risk for each of the monitored fields for the monitored year using the Wisconsin P Index and a representative matrix-type P Index (Weld et al., 2003)[1] and compared them to the measured P losses. The risk-matrix type P Index was weakly related to P losses (Fig. 3), while there was a strong relationship between the pathway approach P Index and P yields (Fig. 4). Plotting the soluble and particulate P components of the P Index for each field[2] against measured dissolved and particulate P in runoff (Fig. 5) revealed that the particulate P component accounts for the strength of the relationship between the Index and P losses.

[1]This P Index was not developed for Wisconsin soils. We adapted it for the purpose of comparing it to the crop year field runoff results from Wisconsin soils by using the actual measured runoff volume to determine the runoff potential rating. We also used RUSLE2 crop year rather than rotational soil loss estimates.

[2] Acute (single-event) P loss estimates from surface P applications were partitioned between dissolved and particulate forms for this analysis .

References:

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