

The Phosphorus Index: A Tool for Management of Agricultural Phosphorus in Vermont

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The Phosphorus (P) Index is a tool developed to assess the potential for phosphorus runoff from individual fields based on soil and field characteristics and on management practices. The P Index is much more comprehensive than relying only on a soil test because it considers erosion and runoff potential and manure and fertilizer P management. Use of the P Index provides a means of identifying fields that have high P runoff potential and, therefore, require conservation practices and/or limitations of manure or fertilizer P application, as well as fields that have low or moderate potential for P runoff. The P Index provides a relative rating as to the risk of P runoff from individual fields, which can be used to prioritize fields for nutrient and soil management practices. It does not attempt to estimate actual quantity of P lost in runoff.

The Phosphorus Index for Vermont (Jokela, 2000) is based on the original Phosphorus Index developed several years ago by a USDA-university working group (Lemunyon and Gilbert, 1993; NRCS, 1994; Sims, 1996). It also incorporates a number of ideas from modified P Index versions from other states (McFarland et al., 1998; Klausner et al., 1997; Gburek et al., 1998; and Coale and Layton, 1999), as well as some from our own work in Vermont (Jokela et al., 1998; Magdoff et al., 1999).

Ten site characteristics are included in the Vermont version of the P Index (Table 1); they are grouped into P Source and P Transport Potential categories. The P Index combines an estimate of phosphorus available for loss via runoff and erosion (P Source Potential) with that of transport mechanisms that could move the phosphorus from the field in runoff (P Transport Potential) (Table 2). Each site characteristic in the P Index is weighted to account for the relative importance in contributing to P runoff potential. The relative weighting is reflected in the different values for the maximum, or very high category (Table 2). (Most previous P Index versions include a separate weighting coefficient for each site characteristic that is part of the calculation. We have incorporated the weighting into the value assigned to each category.) Based on P Index, fields are given a P Index class (Low, Medium, High, Very High), each with associated interpretations and recommendations (Table 3).

Calculating Phosphorus Source Potential

Three sources of P are considered in determining the P Source Potential – soil test P (STP), fertilizer P (FP), and organic or manure P (MP) (Table 2). Soil test phosphorus is a measure of plant-available P and has been shown to be well correlated with the concentration of soluble P in runoff (Pote et al., 1996). Applied fertilizer and manure represent readily available sources of P that are susceptible to runoff; but the values for fertilizer and organic P application rate need to be adjusted depending on how the applied P is managed – timing and method, or placement. Phosphorus applied during the non-growing season period (November-April) and left on the surface has maximum availability for loss in runoff and receives full value (1.0). If improved P management

methods are used, P Source Potential values are reduced to account for the estimated reduction in availability for runoff.

When manure is incorporated in a timely, effective way, the effect of manure on P runoff is primarily a function of increased P enrichment of sediment and runoff water leaving the field, as indicated by increase in P soil test. Different soils, however, vary greatly in the P test increase that results from a given P addition. The “Reactive Aluminum” test (Al in modified Morgan’s extractant) is a good indicator of how much the addition of P (as manure or fertilizer) will increase the soil test P level. (Those testing low to moderate in Al show a much greater increase in soil test P than those testing high.) So, we have incorporated the Reactive Al test into the Index as a modifier for incorporated (i.e. non-surface-applied) manure or fertilizer. If manure is not incorporated in a timely manner, the presence of manure on the surface will tend to outweigh the effect on increased soil test P, so no adjustment for Al is made

The P Source Potential, then, is calculated as follows using values from Table 2 for each site characteristic (Al factor to be used only for non-surface-applied fertilizer or manure):

$$P \text{ Source Potential} = STP + (FP \text{ Rate} \times FP \text{ Method} \times Al) + (MP \text{ Rate} \times MP \text{ Method} \times Al)$$

Calculation of P Transport Potential

The P Transport Potential is calculated by adding values for three types of field transport – soil erosion (E), runoff (R), and flooding (F) -- after modifying the soil erosion value (E) by a factor for the width of vegetated buffer (BW) between field and adjacent drainage path or waterway (Table 2). The existence of a vegetated buffer would be expected to reduce the amount of eroded, or sediment-bound, P entering the waterway by a percentage that is a function of the width of the buffer. The values for each field transport mechanism are added because the total amount of P transported from the field would be expected to be the sum from all three methods. However, we express the field transport potential as a fraction by dividing the sum by the sum of maximum or Very High values for the two main transport mechanisms, erosion and runoff (15 + 10 = 25).

$$P \text{ Transport Potential} = ((E \times BW) + R + F) / 25 \quad (\text{Value from } 0.1 \text{ to } 1.0)$$

The P Transport Potential is considered a measure of the relative effectiveness of this site for transporting P that is potentially available from various sources. It has a value less than one unless all factors are at their maximum, in which the P Transport Potential would be 1.0.

Calculation of Phosphorus Index

The final Phosphorus Index is calculated by multiplying the P Source Potential by the P Transport Potential. Thus, the P Index is essentially an estimate, or indicator, of available P (from all sources) that is likely to be transported off the field under the conditions of this site.

$$P \text{ Index} = P \text{ Transport Potential} \times P \text{ Source Potential}$$

The P Index calculated for 19 fields on several dairy farms in the Champlain Valley are shown in Figure 1. Results are distributed among the low, medium, and high categories but none were rated very high. See Figure 2 for an example P Index calculation, including a recalculation after management practices were modified to lower the P Index.

P Index Interpretation and Management Recommendations

Depending on the P Index, a field is rated as having low, medium, high, or very high potential for P movement from the site (Table 3). Some general management practices are recommended for each category, but a more site-specific nutrient management program should be developed for each field.

Table 1. Description of Individual P Index Site Characteristics.

Site Characteristic	Description
<i>P Source Characteristics</i>	
Soil Test P	Available P in Modified Morgan's (or Morgan's) extractant, expressed as ppm.
Fertilizer P Rate	Rate of fertilizer P, expressed as lb P ₂ O ₅ /acre.
Fertilizer P Application Method/Timing	Sub-surface is 1 inch or more below surface. Incorporation means with tillage to 3-inch or greater depth within 3 days of application.
Organic P Rate	Rate of P applied as manure, compost, or other organic material, expressed as lb P ₂ O ₅ /acre.
Organic P Application Method/Timing	Same as fertilizer P.
Reactive Aluminum	Aluminum in Modified Morgan's extractant, expressed as ppm.
<i>P Transport Characteristics</i>	
Soil Erosion	Average annual erosion rate in tons/acre as estimated by NRCS Revised Universal Soil Loss Equation (RUSLE).
Soil Runoff Class	Runoff Class as determined from % slope and either Runoff Curve Number (NRCS, 1985) or saturated soil conductivity (NRCS, 1993)
Flooding Frequency	Designation as defined in NRCS soil survey database for each soil mapping unit.
Buffer width	Distance, in feet, of grass or other vegetated buffer from field edge to waterway or path of seasonal concentrated flow.

Table 2. The Phosphorus Index for Vermont: site characteristics and P runoff potential ratings. Draft 4.12 1/25/01

Site Characteristic	Phosphorus Source Potential Rating			
	Low/None (0-8)	Medium (8.1-20)	High (20-40)	Very High (>40)
Soil Test P, ppm Mod. Morgan's	Soil test P, ppm			
Fertilizer P Rate	lb P ₂ O ₅ /acre			
Fertilizer P Application Method/Timing	Inject or sub- surface band 0.2	Broadcast and incorporate 0.4	Surf-applied May-Sept. 0.7	Surf-applied Oct.-April 1.0
Reactive Aluminum, ppm	>80 ppm 0.7	41-80 0.75	21-40 0.8	<20 1.0
Manure P Rate	lb P ₂ O ₅ /acre			
Manure P Application Method/Timing	Inject or sub- surface band 0.2	Broadcast and incorporate 0.4	Surf-applied May-Sept 0.7	Surf-applied Oct-April 1.0
Reactive Aluminum, ppm	>80 ppm 0.7	41-80 0.75	21-40 0.8	<20 1.0

P Source Potential =
STP + (FP Rate x FP Method x AI) + (MP Rate x MP Method x AI)
 Note: Use AI factor only for non-surface-applied fertilizer or manure.

Site Characteristic	Phosphorus Transport Potential Rating			
	Low/None	Medium	High	Very High
Soil Erosion (E) tons/acre/yr (RUSLE)	(0-3) 1.5 x tons soil loss/acre/yr			
Soil Runoff Class (R)	Low/ V. Low 4	Medium 6	High 8	Very High 10
Flooding Frequency (F)	Rare/None 0	Occasional 3		Frequent 5
Buffer Width (BW), ft.	>100 0.7	41-100 0.8	16-40 0.9	<15 1.0

P Transport Potential = ((E x BW)+R+F)/25 (Value from 0.1 to 1.0)

P Index = P Transport Potential x P Source Potential

Table 3. Interpretation for the Phosphorus Index. (Modified from NRCS, 1994)

Phosphorus Index	Site Interpretations and Recommendations
<25	LOW potential for P movement from site. If farming practices are maintained at the current level there is a low probability of an adverse impact to surface waters from P loss. N-based nutrient management is acceptable.
25-50	MEDIUM potential for P movement from site. Chance for an adverse impact to surface water exists. N-based nutrient management is acceptable, but some remedial action should be taken to lessen probability of P loss.
50 - 100	HIGH potential for P movement from site and for an adverse impact on surface waters to occur unless remedial action is taken. Soil and water conservation as well as P management practices are necessary to reduce the risk of P movement and water quality degradation. P-based nutrient management should be followed.
> 100	VERY HIGH potential for P movement from site and for an adverse impact on surface waters. Remedial action is required to reduce the risk of P movement. Soil and water conservation practices, plus a P management plan must be put in place to reduce potential for water quality degradation. No manure or fertilizer P is to be applied.

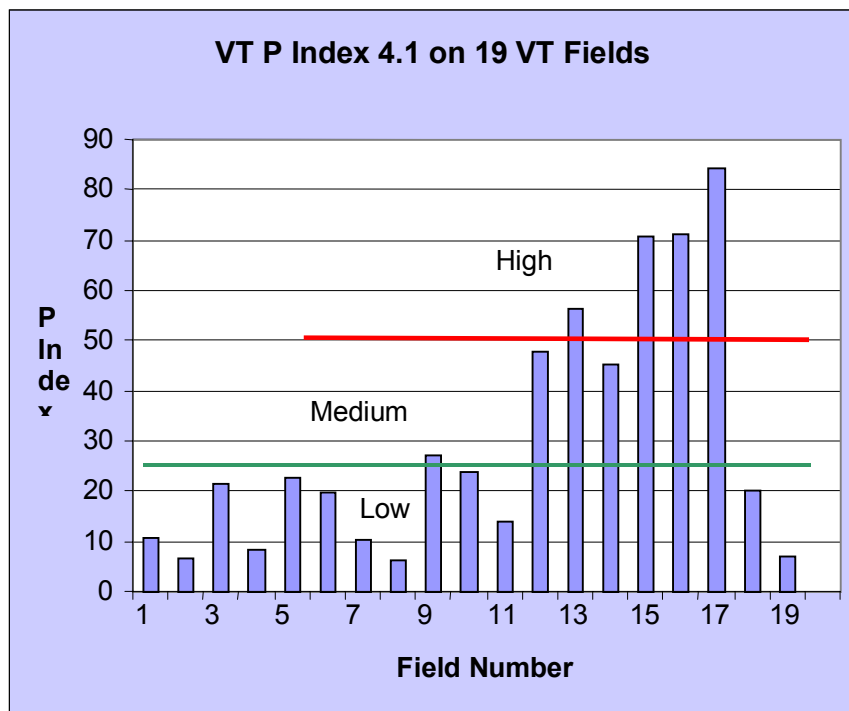


Figure 1. P Index for 19 Vermont fields.

Figure 2. Example Calculation of P Index**Field 1. Corn for silage. Vergennes clay. 5% slope.**

Modified Morgan's soil test results: Available P = 31 ppm; Reactive Al = 35.

Fertilizer P: 40 lb P₂O₅/acre, banded at planting.

Manure: 10,000 gal/acre, 12 lb P₂O₅/1000 gal. Applied in November; left on surface.

Soil erosion estimated by RUSLE = 8 ton/acre.

Runoff Class = High.

Flooding Frequency = Rare.

Vegetated field buffer <15 ft.

P Index Calculation (from Table 2) for Field 1:

P Source Potential

$$= \text{STP} + (\text{FP Rate} \times \text{FP Meth} \times \text{A Factor}) + (\text{OP Rate} \times \text{OP Meth} \times \text{AI Factor})$$

$$= \mathbf{157.4}$$

P Transport Potential

$$= [((\text{E} \times \text{BW}) + \text{R} + \text{F})/25]$$

$$= \mathbf{0.80}$$

$$\mathbf{P\ Index} = \text{P Source Potential} \times \text{P Transport Potential} = 157.4 \times 0.80 = 125.9 = \mathbf{\text{Very High}}$$

Management changes to lower P Index:

- 1) Reduce banded starter P fertilizer from 40 to 20 lb P₂O₅/acre.
- 2) Manure: Change from fall, surface to spring, incorporated application.
- 3) Soil erosion: Implement soil conservation practices to reduce erosion from 8 to 4 tons/acre.

Recalculate P Index:

P Source Potential = 82.2

P Transport Potential = 0.56

$$\mathbf{P\ Index} = 82.2 \times 0.56 = \mathbf{46.0 = \text{Medium}}$$

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