1-2003

Developing and Using the Iowa P-Index

John E. Sawyer
Iowa State University, jsawyer@iastate.edu

Developing and Using the Iowa P-Index

Abstract
Movement of phosphorus (P) from farm fields to surface waters can elevate P above critical levels for aquatic plant growth and thus enhance nutrient enrichment and seasonal deficient oxygen, a process called eutrophication. Phosphorus commonly controls vegetative production in freshwater bodies, and hence the potential for eutrophication. The sourcing of P from production fields (including P from soil, manure, and fertilizer) is one area identified as being an important contributor of total P entering surface waters, and hence significantly contributing to water quality concerns. In recent years considerable effort has focused on developing methods to assess risk of P loss from production fields to surface water systems.

Disciplines
Agricultural Science | Agriculture | Agronomy and Crop Sciences

Presented at the 2003 Wisconsin Fertilizer, Aglime and Pest Management Conference, January 21-23, 2003, Madison, WI.

DEVELOPING AND USING THE IOWA P-INDEX

John E. Sawyer[1]

Introduction

Movement of phosphorus (P) from farm fields to surface waters can elevate P above critical levels for aquatic plant growth and thus enhance nutrient enrichment and seasonal deficient oxygen, a process called eutrophication. Phosphorus commonly controls vegetative production in freshwater bodies, and hence the potential for eutrophication. The sourcing of P from production fields (including P from soil, manure, and fertilizer) is one area identified as being an important contributor of total P entering surface waters, and hence significantly contributing to water quality concerns. In recent years considerable effort has focused on developing methods to assess risk of P loss from production fields to surface water systems.

Background for Development of a P-Index

In April 1999, the Iowa Natural Resources Conservation Service (NRCS) issued an Interim Conservation Practice Standard, Nutrient Management Code (590). This standard is the guidance used by NRCS staff and the private sector when providing technical assistance to producers requesting assistance on nutrient management. Under some situations the technical guidance in this standard may be required if the producer is voluntarily participating in cost share programs that address water quality concerns. The NRCS in each state was required to revise their state Nutrient Management standard (590) in accordance with guidance provided by national policy and in the national 590 standard. For P, the national standard provided states with three options. In other words, there was a choice of three methods states could use to assess the risk of P loss from farm fields, and thus determine the potential management changes needed to modify P application. These were to be field specific assessments of the potential for P transport from the field. These options were 1) soil test, 2) soil P threshold level, 3) P-Index rating. The state NRCS had until April 2001 to implement one of these methods in the Iowa 590 standard.

The Iowa Approach

The Iowa NRCS, through work and discussion of the State Technical Committee, decided from the three suggested assessment methods to develop a P-Index for use in the Iowa Nutrient Management 590 standard. Other Midwestern states have also considered this approach. A P-Index was developed in Iowa by a team of NRCS employees, Iowa State University Extension specialists, and Iowa State University and United States Department of Agriculture (USDA) soil scientists. In October 2000, the USDA State Technical Committee approved this P-index. The NRCS Iowa Technical Note 25, Iowa Phosphorus Index, was finalized January 2001. The index was incorporated into the NRCS Nutrient Management Code 590 standard in March 2001. Since then NRCS staff have been trained on use of the P-Index and it is being utilized across Iowa.

Why a P-Index

The P-Index is an integrated approach to estimating the risk of P loss from farm fields and movement to surface waters. Instead of looking at just one factor, such as a soil test, it

[1] Soil Fertility Extension Specialist and Associate Professor, Dept. of Agronomy, Iowa State Univ., 2104 Agronomy Hall, Ames, IA 50011-1010

integrates the many field specific factors that influence P loss and potential movement to surface waters: erosion, sediment delivery, relative field location in the watershed, buffer strips, soil conservation practices, soil test P, precipitation, runoff, tile flow, and P application method (fertilizer or manure), timing, and rate.

The P-Index has several advantages over other risk assessment methods: 1) estimates erosion and sediment losses because total P is an important aspect of P supply to aquatic vegetation in surface waters; 2) accounts for beyond field edge effects on P reaching surface waters; 3) includes P applications; and 4) adjusts for P management strategies and soil conservation practices. The P-Index also could include some characteristics of other risk assessment methods, for example an environmental P threshold. The P-Index is more complex and difficult to determine than soil test or threshold methods, but because of the integrated approach the P-Index is useful for understanding the important factor or factors contributing a high P loss risk.

The Iowa P-Index

As stated in the NRCS Technical Note 25, "The purpose of Iowa phosphorus (P) index is to assess the risk of P delivery to surface waters. The index is a tool to help conservation planners, landowners/land users and others to evaluate the current risk from P reaching surface water from a specific site, and to determine factors which dominate the risk due to P transport to surface waters. It will also assist landowners/land users in making management decisions to reduce the risk." More specifically the P-Index should assist in the following ways (again taken from NRCS Technical Note 25): "Use of the P index provides a means of identifying fields that have a low to moderate potential for P delivered to surface water, as well as fields that have very high risk of P loss and, therefore, require conservation practices and/or limits to manure or fertilizer P. The P index provides a relative rating as to the risk of P moving from individual fields, which can be used to prioritize fields for nutrient and soil management practices. Because of the integrated system, the P index is useful for understanding the processes causing a high P delivery to surface water, and can help identify management practices to lower that risk. Ultimately, use of the P-index should reduce risks of P delivered to surface water, improve or maintain water quality, and provide producers options for improved P management." Clearly the goal of the P-Index is to assist with understanding of P loss from production fields and to help guide management to lower that risk.

The intent of this paper is not to provide a detailed accounting of the Iowa P-Index or the calculation methods. Instead only an overview will be presented here. Those interested in learning more about the Iowa P-Index, or wanting specific background information supporting the P-Index, can go to the following web site and access the indicated publications.

http://www.ia.nrcs.usda.gov/Technical/Phosphorus/phosphorusstandard.htm

- NRCS Technical Note 25 (the Iowa P-Index)
- Background and Basic Concepts (provides detailed information and support material)
- Phosphorus Index Fact Sheet (one-page information about the Iowa P-Index)
- Iowa Phosphorus Calculator (electronic index calculation, requires Microsoft Excel)

Also, a paper was recently published in the Nov.-Dec. 2002 issue (Vol. 57, Issue 6) of the Journal of Soil and Water Conservation (Phosphorus indexing for cropland: overview and basic concepts of the Iowa phosphorus index; A.P. Mallarino, B.M. Stewart, J.L. Baker, J.D. Downing, and J.E.

Sawyer) that provides more detail regarding specific components of the Iowa P-Index. It is hoped that an electronic version of that publication will also be available on the web site.

Brief Overview of the Iowa P-Index Components and Interpretation

The Iowa P-index is comprised of three components, which summed together gives the overall P-Index rating. Within each component are several factors, which multiplied together results in the component rating.

1. Erosion Component – potential P delivered to surface water with sediment.
    a. Gross erosion: includes sheet and rill erosion (RUSLE prediction), ephemeral erosion, and gully erosion.
    b. Sediment trap: accounts for sediment captured in-field by conservation practices.
    c. Sediment delivery ratio (SDR): estimates sediment delivery from fields to nearest surface water system (intermittent or perennial stream).
    d. Buffer: vegetative buffers that meet NRCS standards for filter strips.
    e. Enrichment: accounts for the increase in the proportion of fine soil particles in eroded sediment.
    f. Soil Test P (STP) erosion: represents the amount of particulate P in delivered sediment that likely will be released to the water and available to aquatic plants over a long period of time. It is estimated as 70% of the total P concentration of the sediment, and is based on an average amount of total P (soil with low STP) in the surface 6-inch layer of soil and the increase in total P due to application of fertilizers or manure estimated from a recent measurement of STP (STP by Bray P-1, Mehlich-3, or Olsen).
2. Runoff Component – potential P delivered to surface water in runoff.
    a. Runoff: estimated by the NRCS Runoff Curve Number (RCN) to convert precipitation to a fraction of water that runs off a field (assumed that only 50% of total rainfall would produce runoff).
    b. Precipitation: the 30-year average annual precipitation for each county in Iowa (converted to million lb of water per acre).
    c. STP Runoff: total dissolved P concentration in runoff estimated from STP (6-inch depth) by the Bray P-1, Mehlich-3, or Olsen.
    d. P Application: estimate of the additional impact of recent P applications from fertilizer, manure, or other organic sources on change in STP (P rate since the last soil sampling and before growing a crop). Method and time of P application modify the impact of P application on dissolved P with runoff. All P sources are treated the same.
3. Subsurface Drainage Component – potential P delivered to surface water with subsurface drainage.
    a. Precipitation: the 30-year average annual precipitation for each county in Iowa.
    b. Flow: the presence or absence of flow through tiles or coarse-textured subsurface/substrata and assumed 10% of precipitation will flow through tiles or coarse textured subsoils/substrata.
    c. STP drainage: two classes – a value of 0.1 if STP<100 ppm Bray P-1 or Mehlich-3 (<60 ppm Olsen) or a value of 0.2 if STP ≥100 ppm (≥60 ppm Olsen).

The result of the P-Index provides a numerical value related to estimated P delivery to surface waters (examples are given in Figures 1-4). The risk assessment is then rated according to the following interpretation classes provided in Technical Note 25:

VERY LOW– 0-1. A field in which movement of P off site will be VERY LOW. If soil conservation and P management practices are maintained at current levels, impacts on surface water resources from P losses from the field will be small.
LOW – 1-2. A field in which movement of P off site will be LOW. Although the P delivery to surface water bodies is greater than from a field with a very low rating, current soil conservation and P management practices keep water quality impairment low.
MEDIUM – 2-5. A field in which movement of P off-site will be MEDIUM. Impacts on surface water resources will be higher than for the field with a low rating, and the P delivery potential may produce some water quality impairment. Careful consideration should be given to further soil conservation and P management practices that do not increase P delivery to surface water.
HIGH – 5-15. A field in which movement of P offsite will be HIGH. Water quality impairment will be large. Remedial action is required to reduce P movement to surface water bodies. New soil and water conservation and/or P management practices are necessary to reduce offsite P movement and water quality degradation.
VERY HIGH – >15. A field in which movement of P offsite will be VERY HIGH. Impacts on surface water resources are extreme. Remedial action is required to reduce P delivery to surface water. All necessary soil and water conservation practices plus a P management plan, which may require discontinuing P applications, must be put in place to reduce water quality impairment.

The Iowa P-Index does not contain specific recommendations on P use, P management, or soil conservation practices. Those are provided in other Iowa NRCS practice standards, such as the Nutrient Management 590 standard.

The P-Index was designed for use on a field basis. For NRCS, this is interpreted to be Conservation Management Units (CMU). These can be a whole field, a portion of a field, a grouping of fields, or other land units of the same land use and having similar treatment needs and management plans.

Certain components or factors of the Iowa P-Index are being found to have a major influence on P loss risk, and hence calculated index values. These include soil erosion, STP, distance to a surface water system, and conservation practices that trap sediment within fields. When development of the Iowa P-Index began many assumed that P application or STP would be the main factors for assessing risk of P loss. However, when consideration of total soil P was incorporated into the index (through eroded sediment), then erosion, total soil P (reflected through STP), and erosion/runoff control became large influences. These components have forced a renewed focus on soil management. Figures 1-4 show the influence of erosion level, distance to a surface water system, and soil test P on P-Index calculations for example fields located in Northeast Iowa.

Iowa P-Index Use

Currently in Iowa, implementation is related to areas with voluntary producer involvement in nutrient management planning and cost share practices (like EQIP or special watershed projects). As indicated by NRCS, several field situations trigger use of the P-Index when nutrient management planning is being conducted. These situations are: 1) when animal manure or other organic by-products are applied; 2) in areas of Iowa with an identified or designated P-related water quality impairment (waters identified in the Iowa Department of Natural Resources (DNR) Iowa 303 (d) list as impacted by P); 3) in fields with a very high STP, as interpreted for agronomic crops in the Iowa State University publication PM 1688 (General Guide for Crop Nutrient and Limestone Recommendations in Iowa); and 4) when soil loss is > T.

Once the field is rated then management alternatives are provided in the NRCS Nutrient Management 590 standard. For example, when manure or organic by-products are being applied as a plant nutrient source, the following guidance is provided: "If a field is rated very low risk, low risk, or medium risk by the Iowa P-Index, the application of manure or by-products may be made based on the nitrogen needs of the crop … If a field is rated in the medium risk category, planned conservation and phosphorus management practices should not increase the rating of the field above the medium risk category. If a field is rated high risk or very high risk by the Iowa P-Index; manure or organic by-products may be applied to meet the needs of the planned crop rotation for phosphorus removal if conservation practices and/or phosphorus management practices are adopted to reduce the risk of phosphorus movement; nitrogen application limits … should not be exceeded." If a field is in an area with an identified or designated P-related water quality impairment or has current STP levels in the very high range, the following guidance is provided: "fertilizer may be applied to meet the needs of the planned crop rotation for phosphorus removal if conservation practices and/or phosphorus management practices are adopted to reduce the risk of phosphorus movement; nitrogen application limits … should not be exceeded."

These management examples clearly show the integrated relationship within the P-Index between P use, soil erosion, and runoff. They also highlight the varied approaches that can be taken to reduce the risk of P loss, and not just reliance on adjustment in P application.

Questions

Since assessing the risk of P loss from production fields is a relatively new concept, it would be expected that questions or issues would arise with implementation of a tool like the P-Index. With increased use, awareness, and evaluation have come several questions regarding the Iowa P-Index.

- Unexpected emphasis on soil erosion/runoff and associated soil conservation practices instead of P application practices such as rate/method/timing/source. This places a large importance on predicting soil erosion (RUSLE, ephemeral, and gully erosion), soil movement off-field, and movement into surface water systems. And, this puts an increased burden on NRCS staff to provide specific information related to soil erosion and runoff for calculating the P-Index, especially if the index is run on sub-field areas.
- Low incidence of fields with a high or very high P risk assessment. The index, with the heavy weighting on sediment loss (total P) and movement to surface water systems appears to require high erosional situations or a combination of high erosion, high STP, and short distances to surface water systems before the risk moves above the medium class.
- Implementation of the P-Index to sub-field areas. This relates to the concept of "hot spots" or "critical P source areas." Some research indicates that a large percentage of P leaving a field comes from small sub-field areas. This has prompted Iowa NRCS to instruct field staff using the P-Index for whole-field risk assessment to use the worst-case scenario in fields when calculating the P-Index unless producers wish to break out field areas and treat them differently. A question is whether the index was designed adequately to predict P loss and delivery to water systems from sub-field areas. This also raises the need for appropriate procedures to identify different field zones for P management, both agronomic and environmental.

- Concerns that the P-Index allows STP to build to unreasonable levels, even though the index does not indicate a high risk. This poses questions related to potential for P movement through soils to tile systems and the potential heightened level of "background" P leakage from watersheds to surface water systems that may occur over many years (especially in light of the low EPA proposed total-P criteria for surface waters).
- Limited recognition within the index for catastrophic P loss events. The Iowa P-index assumes average precipitation and a long-term relationship to P loss. Also, the rate of P application is factored through the increase in STP and STP relationship to runoff P rather than directly through rate impacts on potential P loss. However, in the Iowa P-Index method and timing does modify the impact of P application on dissolved P in runoff.

The Future

At this time the Iowa P-index appears well received as it makes sense in relation to knowledge regarding soil management and erosion, P management, and P loss. Since the index does not focus on a STP threshold, it gives producers multiple management options if fields have identified high or very high risk for P loss. Research continues to evaluate various aspects of P loss and to validate components and factors used in the Iowa P-Index. At some point in time it is reasonable to assume that the index will be adjusted for new information.

Of current interest is the fact that in the spring of 2002 the Iowa legislature passed Senate File 2293 (livestock regulations). In SF 2293 the Iowa DNR is directed to develop a P-Index by rule that is based on the NRCS Technical Guide for Iowa. Iowa DNR is to cooperate with the NRCS State Technical Committee to refine and calibrate the P-Index. The P-Index will be used to determine application rates. This legislative action was taken despite the clear precaution for use of the Iowa P-Index stated in NRCS Technical Note 25: "The P index is not intended to be an evaluation scale for determining whether land users are complying with water quality or nutrient management standards established by local, state, or federal agencies. Use of this P index as a regulatory tool would be beyond the concept and philosophy of the working group that developed it." The P rules developed by DNR are to become effective after July 1, 2003, and are to be applied on a staggered system. These rules have not been finalized at this time. The expectation is that DNR will use directly the current Iowa P-Index, but will develop specific rules for P-Index implementation and concurrently for risk interpretation and management options for risk rating categories. With the current structure of the Iowa P-Index, DNR must recognize the soil conservation aspects related to P management. It could be beneficial to producers in Iowa to have only one P-Index, however, it could also be confusing if risk interpretation and suggested management practices are not consistent.

Index Component		Fayette County A - 5
Gross Erosion	5	RUSLE erosion: 5 ton
Sediment Trap/SDR	0.64	PP: 350 feet
Buffer Factor	1	Buffer: None
Enrichment Factor	1.1	Tillage without Buffer
STP Erosion Factor	1.03	Bray 1-P: 79 ppm
Erosion	3.63	
Runoff Factor	0.22	RCN: 79
Precipitation Factor	7.6	Fayette County
STP Runoff Factor	0.45	Bray 1-P: 79 ppm
P Application Factor	0.03	83 lb P_2O_5/acre; Inc. One Week
Runoff	0.80	
Flow Factor	0.1	Tile/Coarse Subsurface: Yes
Precipitation Factor	7.6	Fayette County
STP Drainage Factor	0.1	Bray 1-P: 79 ppm
Subsurface	0.08	
P-Index	4.50	[0-1 VL; 1-2 L; 2-5 M; 5-15 H; >15 VH]

Figure 1. Example Iowa P-Index calculation from Northeast Iowa: 5 ton gross erosion, 350 feet to surface water system, 83 lb P_2O_5/acre applied since last soil test and incorporated within one week, and 79 ppm STP.

Index Component		Fayette County B - 5
Gross Erosion	5	RUSLE erosion: 5 ton
Sediment Trap/SDR	0.50	PP: 1000 feet
Buffer Factor	1	Buffer: None
Enrichment Factor	1.1	Tillage without Buffer
STP Erosion Factor	0.78	Bray 1-P: 20 ppm
Erosion	2.15	
Runoff Factor	0.22	RCN: 79
Precipitation Factor	7.6	Fayette County
STP Runoff Factor	0.15	Bray 1-P: 20 ppm
P Application Factor	0.03	83 lb P_2O_5/acre; Inc. One Week
Runoff	0.30	
Flow Factor	0.1	Tile/Coarse Subsurface: Yes
Precipitation Factor	7.6	Fayette County
STP Drainage Factor	0.1	Bray 1-P: 20 ppm
Subsurface	0.08	
P-Index	2.52	[0-1 VL; 1-2 L; 2-5 M; 5-15 H; >15 VH]

Figure 2. Example Iowa P-Index calculation from Northeast Iowa: 5 ton gross erosion, 1000 feet to surface water system, 83 lb P_2O_5/acre applied since last soil test and incorporated within one week, and 20 ppm STP.

Index Component		Fayette County A - 12
Gross Erosion	12	RUSLE erosion: 12 ton
Sediment Trap/SDR	0.64	PP: 350 feet
Buffer Factor	1	Buffer: None
Enrichment Factor	1.1	Tillage without Buffer
STP Erosion Factor	1.03	Bray 1-P: 79 ppm
Erosion	8.70	
Runoff Factor	0.22	RCN: 79
Precipitation Factor	7.6	Fayette County
STP Runoff Factor	0.45	Bray 1-P: 79 ppm
P Application Factor	0.03	83 lb P_2O_5/acre; Inc. One Week
Runoff	0.80	
Flow Factor	0.1	Tile/Coarse Subsurface: Yes
Precipitation Factor	7.6	Fayette County
STP Drainage Factor	0.1	Bray 1-P: 79 ppm
Subsurface	0.08	
P-Index	9.58	[0-1 VL; 1-2 L; 2-5 M; 5-15 H; >15 VH]

Figure 3. Example Iowa P-Index calculation from Northeast Iowa: 12 ton gross erosion, 350 feet to surface water system, 83 lb P_2O_5/acre applied since last soil test and incorporated within one week, and 79 ppm STP.

Index Component		Fayette County B - 12
Gross Erosion	12	RUSLE erosion: 12 ton
Sediment Trap/SDR	0.50	PP: 1000 feet
Buffer Factor	1	Buffer: None
Enrichment Factor	1.1	Tillage without Buffer
STP Erosion Factor	0.78	Bray 1-P: 20 ppm
Erosion	5.15	
Runoff Factor	0.22	RCN: 79
Precipitation Factor	7.6	Fayette County
STP Runoff Factor	0.15	Bray 1-P: 20 ppm
P Application Factor	0.03	83 lb P_2O_5/acre; Inc. One Week
Runoff	0.30	
Flow Factor	0.1	Tile/Coarse Subsurface: Yes
Precipitation Factor	7.6	Fayette County
STP Drainage Factor	0.1	Bray 1-P: 20 ppm
Subsurface	0.08	
P-Index	5.52	[0-1 VL; 1-2 L; 2-5 M; 5-15 H; >15 VH]

Figure 4. Example Iowa P-Index calculation from Northeast Iowa: 12 ton gross erosion, 1000 feet to surface water system, 83 lb P_2O_5/acre applied since last soil test and incorporated within one week, and 20 ppm STP.