

# **USING THE IOWA PHOSPHORUS INDEX AND VARIABLE-RATE TECHNOLOGY FOR EFFECTIVE AGRONOMIC AND ENVIRONMENTAL PHOSPHORUS MANAGEMENT**

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The phosphorus (P) index is a tool that was developed to assess the potential for P losses from fields to surface water bodies. In 1999, the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) issued national policy and general guidelines on nutrient management to include risk assessments for P. States were required to revise these guidelines by April 2001. These guidelines apply to nutrient management where nutrients are applied to the land, including organic by-products and animal manure. All NRCS staff will use this guidance when providing financial or technical assistance to producers. Third party vendors and other non-NRCS employees will use these guidelines when providing assistance through federal conservation programs for which NRCS has technical responsibility. The national guidelines suggested the use of one of the following risk assessments: soil-test P values, threshold limits, or a P risk index. The Iowa State Technical Committee recommended the use of the P index approach based on the advice of an interdisciplinary group that involved scientists, technical personnel, and representatives from various groups. The P index tool provides a rating of the risk of P delivery from agricultural fields to surface water supplies that can be used to prioritize fields for nutrient and soil management practices. The purpose of this presentation is to provide a brief overview of how the P index and variable-rate technology can be used to do better agronomic and environmental P management within a field.

## **The Need for an Environmental P Assessment Tool**

Increasing concentration of animal production in certain areas is increasing the amount of manure being applied to the land. Often, the manure is applied at frequencies and rates that exceed the P required for optimizing crop yield or the amount of P removed in harvested crops. Animal manure can supply the nitrogen (N) and P needed by crops as well as other nutrients. Due to its relative N and P content and potential N losses, however, continued use of rates that supply the N removed in harvested grain results in P accumulation in soils. Phosphorus accumulation in excess of crop needs may increase the potential for eutrophication of surface waters. Eutrophication occurs when nutrient levels in water, especially P, are high and result in excessive algae growth, which may reduce oxygen levels in water and often creates imbalances in water ecosystems and the esthetic value of lakes or streams. The potential problem of large P loss from agricultural fields is compounded because soils of many grain crop production areas already have soil-test P levels that are at or above levels that optimize grain yield. The upper limit for amounts of manure that could be applied with minimal nutrient loss could be ultimately determined by the P level in the topsoil and the potential for soil erosion, water runoff, and/or P leaching through the soil profile that can reach surface water bodies. Thus, better estimates of the potential for P loss from agricultural soils, especially manured soils, are required.

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## **The P Index in Relation to Soil-Test Thresholds and P Application Rates**

The soil-test P level and the P application rate are the most frequently mentioned aspects in relation to estimates of P losses to surface waters and as the subject of possible regulation. Use of these two methods have serious limitations as tools to predict P losses from soils, however. The amount of P lost from a field depends only partly on the soil P concentration and the method or rate of P application. Additional major factors include soil P release characteristics and the transport mechanisms that control the amount of P that can move off a field and reach surface water supplies. Factors that influence soil erosion and water runoff, the distance between the field and streams or lakes, and any other factor affecting the transport of water or sediment from the field are very important in addition to soil-test P. Additional factors such as the depth from which the soil sample should be collected, the depth that is relevant to predict losses of P, and the method of manure or fertilizer application further complicate the interpretation of soil-test P for environmental purposes. Thus, the P index approach is more comprehensive than relying only on a soil test P threshold value. Use of the P index provides a means of identifying fields that have high P loss potential through erosion, runoff, or subsurface drainage and, therefore, provide guidelines for improved conservation and nutrient management practices involving manure or fertilizer P application.

### **Basic Concepts of the Iowa P Index and Inputs Needed**

All P indices that are being developed or implemented in the U.S. include a number of field characteristics that influence soil P levels and P transport. The Iowa P index (NRCS Iowa Technical Note No. 25) and a complementary support document (Mallarino et al., 2001) are available to the public, and details will not be discussed here. The index relates source and transport factors to roughly estimate P that can reach surface water resources and to establish five risk classes. The source factors are arranged within three major components related to three major P transport mechanisms: an Erosion Component (P loss with sediment), a Runoff Component (P dissolved in surface runoff), and a Subsurface Drainage Component (P lost with water flow through tiles and/or coarse subsoil/substrata). At an intermediate stage, the different components of the index yield lb P/acre/year lost. The outputs from the three components are summed to get an approximate overall estimate of P loss. In a second step, the resulting numbers (one per field, or one per each contrasting conservation management unit within a field) are placed into five risk classes ranging from very low to very high.

The index makes use of common tools used by NRCS field staff to estimate the impact of landscape forms, soil types, and management practices on soil and water loss from fields. Thus, the index uses existing databases for soil classification, landscape forms, and major soil physical properties; the revised universal soil loss equation (RUSLE) to estimate sediment loss through sheet, rill, and ephemeral gully erosion; sediment delivery ratio (SDR) or sediment trap efficiency of conservation practices (terraces and ponds, for example) to estimate sediment delivery off fields; runoff curve numbers (RCN) to estimate water runoff; and county historical precipitation data to estimate precipitation. This approach utilizes background information already available through NRCS field offices to simplify as much as possible the implementation of the index.

The index considers losses of both dissolved P in water and P bound to sediment (or particulate P). The dissolved P is readily available for algae growth, whereas a large proportion of the particulate P will be released to the water over a variable period of time depending on numerous factors. Aquatic research demonstrates that a major portion of the particulate P can be made available to algae through chemical, biological, and hydrological processes. Thus, the Iowa P index weighs particulate P losses heavily when erosion risk is high, and considers potentially high loss of dissolved P during short periods relative to the total potential annual loss. Accurate predictions are difficult because of the many factors that influence the release of P from particulate P (such as soil and water chemistry, water depth, water input and output patterns, and water body usage among others).

The index emphasizes long-term processes and does not differentiate between commonly used fertilizer or organic sources. Differences in water solubility of the P in some organic sources may have a large influence on the short-term impact of P applications on P loss through runoff or tiles. For example, it is possible that dissolved P loss through runoff or leaching processes immediately after applying solid manures (especially when it is mixed with bedding) and compost is lower than for other manures (such as liquid swine manure or poultry manures) because they often have a lower proportion of water soluble P. However, this may not necessarily be the case when long-term losses (one or more years) are considered, or for total P loss with sediment.

Only currently recommended soil-test P measurements for crop production are needed for the index. These include use of any of the three soil-P tests currently supported by Iowa State University (Bray-1, Mehlich-3, or Olsen) and other suggestions such as those concerning soil sampling depth and soil sampling strategies. The soil-test P value is used to estimate dissolved P losses through runoff and subsurface drainage, and to estimate total soil P loss with eroded sediment. Available research does not clearly support the need for a change to other possible soil testing procedures (including extractants, sampling depth, and sampling strategies) either because results are similar, methods are less practical, or are too expensive for producers. Many years of research have produced field calibrations useful to soil-test interpretation ranges and optimal fertilization rates for crops. Soil-test P interpretations and fertilizer recommendations are available in the Extension Publication Pm-1688 (Voss et al., 1999). The concept of soil test calibration also applies when the main objective of soil testing is to estimate the amount of total or dissolved soil P that could potentially reach surface water supplies. Data from Iowa or other states have been used to obtain estimates of total soil P and dissolved P loss on the basis of commonly used field and lab procedures.

The computer spreadsheet and printed versions of the P index were designed to require as few inputs as possible from the producer or nutrient management planner. By knowing the location of the field and major soil and crop management practices, the equations automatically include estimates for landscape forms, average county rainfall, sediment delivery ratios, runoff potential, potential water flow through subsurface drainage and other important factors that influence sediment and water transport as well P transport. The most important user inputs required include the following.

- Field location and predominant soil survey map units.
- Soil and crop management practices such as crop rotation, tillage, amount of P applied as manure or fertilizer since the last time the field was tested for soil P, method of application, time of application, etc.
- Soil erosion. This information can be supplied by the NRCS field offices when appropriate information for the field is provided (location, soil and crop management, existence of gullies, etc.).
- Distance from the center of the field to the nearest perennial or intermittent stream down the slope.
- Existence of vegetative buffers that meet NRCS standards for filter strips (and its width), level terraces, ponds, tile inlet terrace, etc.
- Existence of drainage tiles.
- A recent soil-test P value from a 6-inch soil sample using either the Bray-1, Mehlich-3, or Olsen P soil tests (preferably from samples collected since the last crop harvest).

### **Risk Interpretation Classes and P index Application**

The current NRCS recommendation concerning application of the P index states that it should be calculated and applied to a conservation management unit (CMU). The NRCS defines a CMU as a field or field portion of the same landuse, treatment needs, and management plans. Thus, in most situations the index will be calculated for an entire field by considering the predominant soil map units. However, the index can be calculated for different parts of a field if parts of fields are managed in different ways according to that definition.

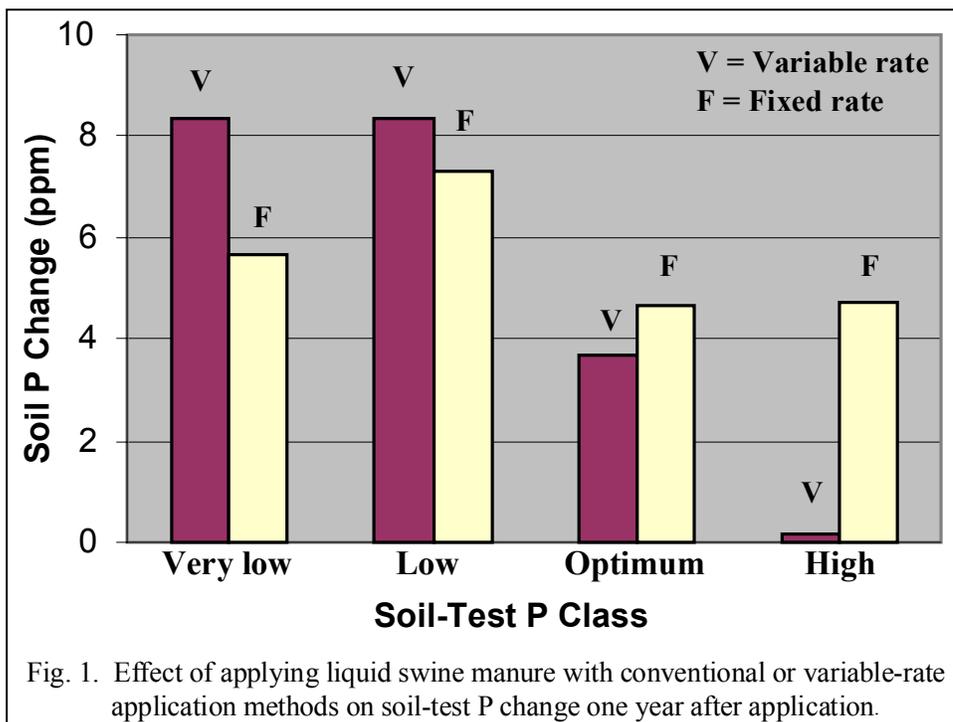
The five risk classes also are described in detail in the publications listed above. Briefly, they are the following.

- Very Low (0-1): Soil conservation and P management practices result in small impacts on surface water resources.
- Low (1-2): The P delivery to water resources is greater than from a site with a very low rating, but current practices keep water quality impairment low.
- Medium (2-5): The P delivery may produce some water quality impairment. Consideration should be given to future soil conservation and/or P management practices that do not increase the risk of larger P delivery.
- High (5-15): The P delivery produces large water quality impairment. Remedial action is required. New soil and water conservation and/or P management practices are necessary to reduce offsite P movement.
- Very High (higher than 15): Impacts on surface water resources are extreme. Remedial action is urgently required. Soil and water conservation practices plus a P management plan, which may require discontinuing P applications, must be implemented.

### **Using Variable-Rate Technology to Apply Fertilizer or Manure**

Ongoing Iowa research has been studying the value of variable-rate application of fertilizer or manure within a field (Mallarino and Wittry, 2000; Wittry et al., 2000). Details of this project, including soil sampling procedures and summary yield results, were presented in the 2000 conference and will not be discussed here. Briefly, the criterion used for deciding the variable

rates were soil-test values collected using an intensive soil sampling method. For the P studies, soil-test P are used to decide fertilizer or liquid swine manure for corn or soybean production. The results of this research are showing that although the use of variable-rate technology does not always increase yield, it is very useful for improving nutrient management because there is a better distribution of fertilizer or manure over a field and it tends to reduce within-field soil-test variability. For example, Fig. 1 shows the impact of fixed-rate and variable-rates of liquid swine manure on the change of soil-test P values of field areas testing within various P interpretation classes. A fixed manure rate along the entire length of long strips increased soil-test P in all areas. However, use of the variable-rate technology produced higher soil-test P increases in areas with low-testing soil (because the rate applied was higher) and less or no increase in areas that tested optimum or high because less or no manure was applied.



### Using Variable-Rate Fertilizer or Liquid Manure Application Based on the P Index

The concept of applying liquid manure or P fertilizer according to soil-test P can be extended and adapted to be used in conjunction with the P index. The P index rating does not directly provide management recommendations, but the partial index ratings for the three components provide clues as of the major causes of a certain risk of P loss. Factors that contribute to the transport of P off the field can also be used to decide the rates of P application. This is especially useful when the producer is applying either manure for its N value or when there is the need of spreading manure following considerations other than supplying nutrients for crops. If it is assumed that previous management and rainfall are uniform over a field, the most important factors are those soil and landscape characteristics that increase sediment and water loss. The information available in Iowa soil survey maps does not include only the soil series name, but also erosion and slope phases. This information can be combined with soil-test P information

and used as additional criteria to decide not to apply manure to the more critical areas (areas with high soil P levels, near waterways, steep slopes, flood-prone areas, etc.) when soil-test P is above optimum for crop production or to apply a lower rate.

This can be achieved in two different ways. One involves using the P index concepts and factors mentioned above to approximately adjust the application. A more involved way is to calculate index ratings for the soil map units of soil survey maps within a field. This information can provide a risk of P loss for all the soil map units present in the field. Because soil survey maps sometimes do not include sufficient detail due to the scale used for their preparation, other information layers collected using precision agriculture technologies should be used when available to adjust and improve the information provided by the soil survey maps. A complementary presentation to this workshop (Mallarino, 2001, Management zones soil sampling: A better alternative to grid and soil type sampling?) discusses the value of using this type of information to identify different management zones within a field for soil sampling and fertilization purposes. The information from digitized soil survey maps can be complemented by high-precision elevation maps (from which more accurate estimates of slopes can be obtained using GIS software), electrical conductivity maps (using EM or Veris systems), or aerial photographs of bare soil or crop canopies. For example, Fenton (2000) showed the usefulness of electrical conductivity maps to identify sets of soil properties, to show the spatial distribution of these properties, and to improve soil survey maps. Use of these layers of information will result in a more accurate classification of the risk level for various parts of the field. However, even considering the information in soil survey maps can be useful to complement site-specific soil-test P information when deciding P fertilizer or manure application rates over a field.

Application of these concepts to various fields showed, as expected, that the variation in the risk of P loss over a field varied greatly depending on the soil associations, topography, and soil-test P levels of each field. It should not be surprising that in some fields the zones will have contrasting risk ratings either because of large variation in soil-test P levels or contrasting soil map units with contrastingly different potential impact on P transport. In other fields, most or all field zones will have the same risk rating but the result could still be useful because each risk class consists of a range of approximate P losses which can be used to make small changes in the rates of application.

## **Conclusions**

The Iowa P index, related concepts concerning P source and transport factors that influence the risk of P loss from fields, and variable-rate technology are useful tools available to producers to improve P management practices. Research has demonstrated that varying the rate of P fertilizer and liquid swine manure based on intensive soil sampling for P can greatly improve P agronomic and environmental P management. Expanding this concept to include soil and landscape properties relevant for estimating the risk of P loss should result in even better nutrient management.

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