USING THE IOWA PHOSPHORUS INDEX FOR AGRONOMIC AND ENVIRONMENTAL MANAGEMENT OF FERTILIZER AND MANURE PHOSPHORUS

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Introduction

The Iowa phosphorus (P) index is a risk assessment tool that was developed to assess potential P loss from fields to surface water resources. In 1999, the United States Department of Agriculture Natural Resources Conservation Service (NRCS) issued a national policy and general guidelines on nutrient management to include risk assessments for P. These guidelines apply to nutrient management where nutrients are applied with organic by-products and animal manure sources. The national guidelines suggested the use of soil-test P values, threshold limits, or a P risk index. The Iowa State Technical Committee chose the P index approach based on advice from an interdisciplinary task force that involved scientists, technical personnel, and representatives from various interest or commodity groups. All NRCS staff or third-party technical service providers use this guidance when providing financial or technical assistance to producers enrolled in several federal conservation programs. The Iowa legislature mandated the Iowa Department of Natural Resources (IDNR) to begin using the Iowa P Index in late 2003 for manure management plans for confined animal feeding operations. The specific rules and guidelines are being prepared by IDNR at this time. The purpose of this presentation is to provide a brief overview of how the Iowa P index can be used to identify reasons for high risk of P loss from fields and to choose among alternative management practices for improving agronomic and environmental P management.

Why is a P Environmental Assessment Tool Needed?

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. Increasing concentration of animal production in certain areas is increasing the amount of manure being applied to the land. Often, manure is applied at frequencies and rates that exceed the P required for optimizing crop yield or the amount of P removed with crop harvest. Animal manure can supply the nitrogen (N) and P needed by crops as well as other nutrients. Due to its N and P content, potential N losses, and crop nutrient requirements continued use of rates that supply the N removed in harvested grain may result in P accumulation in soils. In turn, soil P accumulation in excess of crop needs may increase the potential for eutrophication of surface waters. Eutrophication occurs when nutrient levels in water are high and stimulate excessive algae growth. Excessive algae growth reduces water oxygen levels, creates ecological imbalances, and reduces the drinking and recreational value of lakes and streams. The upper limit for amounts of manure that can be applied with minimal nutrient loss could be ultimately determined by potential P loss through soil erosion, surface water runoff, and subsurface drainage. Thus, better estimates of the potential for P loss from agricultural soils, especially from manured soils, are needed.

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

The soil-test P level and the P application rate are the most frequently mentioned factors in relation to potential P loss to surface water and as subjects of regulation. Guidelines or regulation based only in these two factors have serious limitations, however. The amount of P lost from a field depends only partly on the soil P concentration and the P application rate. Other factors include soil P release characteristics and 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 a stream or lake, and any other factor affecting the transport of soil or water off a field are also important. Additional factors such as the depth from which the soil sample is collected, the sampling depth that is relevant to predict losses of P, and the method of manure or fertilizer application further complicate interpretation of soil-test P values for environmental purposes. The P index approach is more comprehensive and provides a field-specific means of identifying high risk of P loss through erosion, runoff, or subsurface drainage. Therefore, the P index provides information that is needed to decide among several soil conservation and manure or fertilizer P management practices that could reduce the risk of P loss.

Major Characteristics of the Iowa P Index

The Iowa P index (NRCS Iowa Technical Note No. 25) and complementary support articles (Mallarino et al., 2001 and 2002) are available to the public, and details will not be discussed here. The index considers P source and transport factors to estimate P that can reach surface water resources and to establish five risk classes. The P source factors are arranged within three major components related to three major P transport mechanisms: Erosion Component (P loss with sediment), Runoff Component (P dissolved in surface runoff), and Subsurface Drainage Component (P lost with water flow through tiles and/or coarse subsoil/substrata). At an intermediate stage, the index yields partial risk values for each transport mechanism. The outputs from the three components are summed to get an overall estimate of P loss. In a second step, the resulting numbers are placed into five risk classes ranging from very low to very high.

The index is based on commonly used tools by NRCS field staff to estimate the impact of landscape forms, soil types, and management practices on soil and water loss from fields. Thus, it 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 erosion; sediment delivery ratios or sediment traps (terraces, ponds, filter strips) to estimate sediment delivery off fields; runoff curve fractions to estimate water runoff; and historical precipitation data to estimate precipitation for each county. This approach utilizes background information already available through NRCS field offices and simplifies the implementation of the P index as much as possible.

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. 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 at this time does not differentiate between commonly used fertilizer or organic sources. There is general agreement among scientists in that the P source is not a major factor in determining long-term P loss when the P is incorporated into the soil and for cropland conditions. Differences in water solubility of P across sources may influence the short-term P loss after P application to the soil surface without injection or incorporation into the soil. Ongoing research is investigating, for example, if dissolved P loss through surface runoff immediately after applying solid manure mixed with bedding or poultry manure is lower than for sources such as fertilizer or liquid swine manure.

The index accounts for soil-test P as well as manure or fertilizer application rate, method, and timing. A soil-test P value based on tests and soil sampling methods recommended for Iowa is needed for the index. These tests include the Bray-1, Mehlich-3, or Olsen tests, a 6-inch sampling depth, and commonly used soil sampling strategies (Sawyer et al., 2003). The soil-test P value is used to estimate dissolved P losses through runoff and subsurface drainage as well as total soil P loss with eroded soil particles. Data from Iowa and neighboring states have been used to obtain relationships between total or dissolved P loss and soil-test P for commonly used field and lab procedures. The index recognizes that injecting or incorporating manure or fertilizer into the soil with tillage as soon as possible after application reduces the risk of P loss, as long as the operation does not result in excessive soil erosion. The index also recognizes that surface application of any P source to frozen, snow covered, or water-saturated ground will sharply increase the risk of P loss with surface runoff.

The computer spreadsheet (Microsoft Excel) 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 soil and crop management practices, the user can obtain erosion estimates from the local NRCS office. This information together with soil-test P, the distance to the nearest stream, and other information provided in the printed or computer index versions allow for calculating risk values and ratings. The P index can be calculated for an entire field or, even better, for different within-field conservation management units or zones. These zones are field portions with different soil types, soil-test P values, or landscape that justify different land use and nutrient management plans. In some fields the zones will have contrasting risk ratings either because of large variation in soil-test P levels or landscape with very different potential impact on P transport. In other fields, most or all field zones may fall into the same risk rating class, but results could still be useful because each risk class consists of a wide range of risk values that can be used to make changes in management practices.

The index summarizes the risk of P loss through erosion, surface runoff, and subsurface drainage (mainly tile drainage) into the following five general risk classes.

1. Very Low (0-1): Soil conservation and P management practices result in small impacts on surface water resources.

2. 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.

3. 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.

4. 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.

5. Very High (15 or higher): 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 application, must be implemented.

Interpretation of P Index Risk Ratings to Improve P Management Practices

The P index does not directly provide management recommendations, but partial index values for the three components provide indication of the major causes of high P loss risk and changes needed to reduce P loss. Observation of partial index values for the erosion, runoff, and subsurface drainage components reveals the transport mechanism responsible for the highest risk of P loss. Study of P index results for many Iowa fields shows that loss of sediment-bound P through erosion is the most common mechanism explaining high P loss. The second most important factor is the loss of dissolved P through surface runoff. The P lost through subsurface drainage usually contributes the least to the overall risk rating. Undoubtedly, reducing soil erosion and surface runoff is among the most effective ways of reducing the risk of P loss and improving water quality in Iowa.

Observation of the impact of various factors on P index values for each transport mechanism provides clues about the soil or nutrient management practices that are responsible for high risk of P loss. Our research suggests that soil conservation practices, soil-test P level and the method and timing of the P application (in this order) are the key factors to watch. For loss of sediment-bound P, controlling soil erosion through conservation structures (terraces, ponds, vegetative filter strips, etc.), using better tillage and crop residue management practices, and avoiding too high soil-test P levels will result in the most significant reduction of the risk of P loss. For loss of dissolved P in surface runoff, key factors that usually increase P loss include too high soil-test P level, tillage and residue cover resulting on large water runoff, and applying fertilizer or manure to frozen, snow covered, or water-saturated ground.

Data in Fig. 1 illustrate the sensitivity of the most important P index component (erosion component) to various factors. The index calculations were based on management practices and values typical of Iowa. The data show that a specific soil-test P value has a markedly different impact on P index ratings depending on erosion levels and the presence of a vegetative filter strip. This striking difference appears because soil-test P is used to estimate the total soil P (not only the plant-available fraction) that can be transported through erosion to promote algae growth in a water body. Similar types of interactions occur between soil-test P and surface runoff to determine loss of dissolved P. Other important factors of the runoff component are the P rate and the method or time of P application since the last soil sampling date. Our results suggest that the impacts of the P rate and the method or time of application since the last soil test on index values are less important compared with impacts of soil-test P, erosion, and water runoff volume. But the impact of long-term P applications on index values is evaluated mainly by measuring soil-test P, and this is one major reason for the need of a recent soil test value.

If one assumes that soil and crop management practices and rainfall are uniform over a field, the most important factors related to high P loss are soil type and landscape characteristics that increase sediment and water loss. The information available in Iowa soil survey maps includes soil series names as well as 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, high flood risk, etc.) when soil-test P is above optimum for crop production or to apply a lower rate. Because soil survey maps sometimes do not include sufficient detail due to the scale used for their preparation, information collected using precision agriculture technologies could be used to improve the information provided by the soil survey maps. A previous presentation (Mallarino and Wittry, 2001) discussed the value of using this type of information to identify different management zones within a field for soil sampling and fertilization purposes. Yield maps, high-precision elevation maps, electrical conductivity maps, or aerial and satellite images of bare soil or crop canopies can complement the information from soil survey maps. However, even considering only the information in soil survey maps is useful to complement site-specific soil-test P information when deciding P fertilizer or manure application rates over a field. A previous presentation (Mallarino et al., 2001) showed how variable-rate liquid manure or fertilizer P application can be used to apply P across a field according to soil-test P or P index ratings.

Summary and Conclusions

Producers can use Iowa P index ratings and knowledge of factors that influence P loss from fields to identify causes of high P loss and to choose among alternative soil conservation and P management practices that minimize P loss. Study of factors determining high partial index values will reveal the soil or nutrient management practices that cause a high risk of P loss for a specific field or field zone. This study will also suggest, on a field-specific basis, the most economically effective management practices for reducing the risk of P loss. Because the P index has no built-in limits for soil-test P or P application rate, it is a flexible and useful tool producers can use to identify agronomic management practices that minimize P loss from their fields and improve water quality in Iowa.

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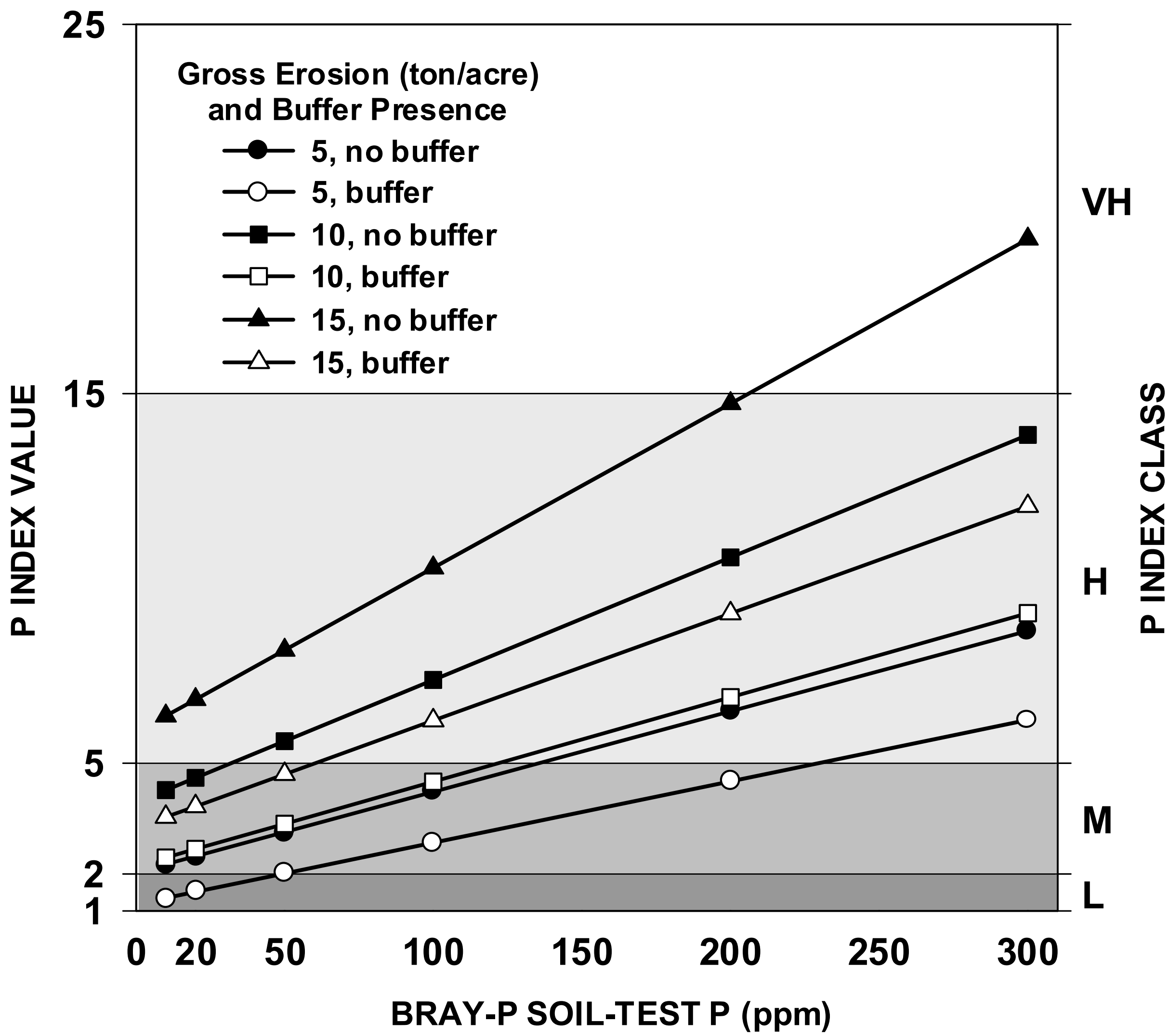

Fig. 1. Effect of soil-test P, soil erosion, and filter strips on P index values for hypothetical fields in South Central Iowa. The assumed filter strips width was 75 feet and the distance to the nearest perennial or intermittent stream was 1000 feet. Values for other factors were maintained constant to reflect typical values for Iowa.