THE PHOSPHORUS INDEX: BACKGROUND AND STATUS

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Introduction

Resource managers are struggling with developing and implementing equitable programs that will minimize phosphorus (P) loss to our nation's waters. One of the most promising management tools for accomplishing this difficult task is the P Index, a tool designed for use by resource managers to assess and rank fields as to their relative P loss potential. While the intent and fundamental framework of the P Index remain the same, many versions of the P Index exist and are in varying stages of evolution due to differing regional and geographic conditions. The purpose of this document is to provide a brief review and update of the present status of the P Index, using examples where possible, and to demonstrate the evolving nature of this complex process.

Current Iterations: Northeast Region Leadership

Transport and Source Factor Separation. Since the inception, several changes have occurred regarding the mechanics of calculating the P Index. One of the most fundamental changes is the separation of the factors affecting P loss into those directly affecting P transport (erosion, runoff, leaching, etc.) and those directly affecting the P source (soil test P, P application rate and method, etc.).

Multiplicative vs. Additive Calculation. To better represent actual site vulnerability to P loss, source and transport factors are related in a multiplicative rather than additive fashion. For example, if surface runoff does not occur, site vulnerability should be low regardless of soil P content. By contrast, in the original version, a site could be ranked as highly vulnerable even though no surface runoff or erosion occurred. However, some caution is advised for cases of catastrophic events that occur infrequently yet can greatly increase the amount of transport from a site. On the other hand, a site with a high potential for runoff, erosion or leaching but with low soil P is less at risk for P loss unless P as fertilizer or manure is applied.

Base Two vs. Linear Transport Factor Calculations. In the original version of the P Index, transport factors were assigned ratings of VL, L, M, H and VH using a base 2, (i.e., 0, 1, 2, 4, 8, and 16.) Since no scientific basis for using the base 2 approach was provided, current P index versions used in several Northeastern states have altered calculations to include the use of a linear approach (tons/acre or pounds/acre x factor), especially for those parameters such as erosion, whose impact could also be considered linear.

Transport Factors Normalized ($E+R+\ldots/3X_{E+R+\ldots}$). Recognizing the importance of the transport factor, the Northeastern states have developed a mechanism for normalization. This is accomplished by adding each transport factor rating (E + R + . . .) and dividing by the sum of the potential maximum of individual transport factors ($3X_{E+R+\ldots}$). The resultant quotient is then multiplied by the P source factor.

Distance or Proximity to Stream, Channel Connection, and Return Period. Designers of the initial and evolving versions of the index appreciate the importance of incorporating a mechanism that defines the geographic location of the field to the water body of concern. Therefore, a qualitative estimate is needed of the likelihood that direct runoff from a field will reach the water body in question. Inclusion of this concept receives broad support from index designers, but unfortunately, it is difficult to define. Some states simply use the

distance to a stream (Maryland and Delaware), while others try to take into consideration channel topography (Nebraska).

Leaching and Surface Drainage. The extent of P transport to the surface waters via solute movement through the vadose zone can be significant but differs in degree due to variation in local conditions. For example, it has been demonstrated to be an important transport mechanism in Maryland and Delaware, where regions of course-textured soils, high water tables and excessive soil P levels overlap. Where appropriate, some P Indexes address this concern by including a leaching and surface drainage component as part of the transport factor.

P Sensitivity or Watershed Priority. The P sensitivity of the surface water into which the field drains is clearly a critical factor in assessing the significance of whether or not P loss from the field is important. Incorporating the concept into a P Index in a workable manner is another matter. Some versions have included P sensitivity or priority of the watershed as a factor in the P Index (Maryland and Delaware). For example, USDA-NRCS policy requires that an assessment of P movement be performed if the watershed has been identified as P sensitive or if manure is applied to the field. Alternatively, the user could consider P sensitivity as a pre-condition for running the index.

Best Management Practices (BMPs). Effectiveness of BMPs in reducing P loss is well accepted, and a consensus exists as to their importance in the index. Some index architects suggest there should be a third component (transport, source and BMPs), while others design their efficiency into existing factors. For example, buffer width (Vermont) and P application methods (Pennsylvania and Vermont) are recognized as important aspects of the transport and source factors, respectively. Others recognize the role of feed and manure additives in altering the solubility of manure P or simply reducing P loss.

Other Iterations

P Index for Pastures. Another innovative program with broad geographic application is the P Index for pastures, which is multiplicative, with four terms: P Index for pastures = (P Source) * (P Transport) * (BMPs) * (Rainfall). Rather than use a relative scale such as 1-100, the P Index for pastures estimates P load in pounds $acre^{-1}$ $year^{-1}$.

Fields are assigned a P Index of low, medium, high or very high if the estimated P load is <0.6, 0.6-1.2, 1.2-1.8, and >1.8 pounds $acre^{-1}$ $year^{-1}$, respectively. When the value is low or medium, manure application can be based on nitrogen. When values reach the high or very high level, applications are based on P removal and no manure application, respectively.

P Index for Cropland. The Iowa P Index emphasizes estimating P delivery from cropland by incorporating characteristic elements common to most indexes, current research data, survey results and scientific judgement where data is lacking. Source and transport characteristics are considered in a multiplicative manner in three components to yield an overall relative risk index. The Erosion Component considers sheet and rill erosion (RUSLE), sediment delivery (based on modified watershed-level sediment delivery ratios and sediment trap factors), sediment P enrichment for various tillage and ground cover combinations, soil-test P, total soil P and vegetative buffers. The Runoff Component considers water runoff (modified runoff curve numbers), soil-test P, and rate, time and method of P application. An Internal Drainage Component considers the presence of tiles, an index of water flow through the soil profile, soil-test P, and rates of P application through their effect on soil-test P.

Others. While the Northeast Region remains one of the most active in modifying the P Index, other regions have been developing indexes suitable to their climate and geography. For example, because of the arid or semiarid climate of the Western region of the United States, P Indexes in these states reflect a low transport potential. Washington and Oregon are using the same set of P Indexes, but one P Index is used in the drier Western portions of these states and another is used in the wetter Eastern areas. Most of the Midwestern states are taking a more traditional approach with the P Index, while Iowa's approach is more

process oriented and designed to predict annual P loads. In addition to the common P Index parameters for identifying P loss potential via soil erosion and runoff, P export via field tile effluent can be a significant transport pathway in some Midwestern soils, and this loss mechanism is being included where appropriate.

Summary and Conclusions

As intended in the original design, the P Index will continue to evolve and reflect regional and local conditions. While subjective aspects of the index will remain, investigators are encouraged to field test their index and continue to seek the necessary interdisciplinary and multi-agency participation. Also, because the area is evolving so rapidly, the architects of the respective P Indexes are encouraged to reexamine their particular P Index to ensure that their version encompasses the latest concepts and technology. While the details of the indexes may differ from region to region, some consistency regarding approach appears to be evolving. The separation of the transport and source factors and normalization of the transport factor (0-1) and index scale (0-100) are examples. While the importance of the transport factor is recognized, adequately depicting the values in a quantitative way is proving most difficult. Resource managers and decision makers need practical screening tools to efficiently implement the P Index. More user-friendly software packages are also needed for automatic parameter input and computation of the index.

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