Journal of Environmental Quality SPECIAL SECTION

EVALUATION OF PHOSPHORUS INDICES: TWENTY YEARS OF SCIENCE AND DEVELOPMENT

Using a Phosphorus Loss Model to Evaluate and Improve Phosphorus Indices

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In most states, the phosphorus (P) index (PI) is the adopted strategy for assessing a field's vulnerability to P loss; however, many state PIs have not been rigorously evaluated against measured P loss data to determine how well the PI assigns P loss risk—a major reason being the lack of field data available for such an analysis. Given the lack of P loss data available for PI evaluation, our goal was to demonstrate how a P loss model can be used to evaluate and revise a PI using the Pennsylvania (PA) PI as an example. Our first objective was to compare two different formulations—multiplicative and component—for calculating a PI. Our second objective was to evaluate whether output from a P loss model can be used to improve PI weighting by calculating weights for modified versions of the PA PI from model-generated P loss data. Our results indicate that several potential limitations exist with the original multiplicative index formulation and that a component formulation is more consistent with how P loss is calculated with P loss models and generally provides more accurate estimates of P loss. Moreover, using the PI weights calculated from the model-generated data noticeably improved the correlation between PI values and a large and diverse measured P loss data set. The approach we use here can be used with any P loss model and PI and thus can serve as a guide to assist states in evaluating and modifying their PI.

Accelerated eutrophication due to phosphorus (P) loading is widespread among freshwater bodies of the United States (Dale et al., 2010; Environmental Defense, 2007; National Research Council, 2008), with a portion of the P loading originating from agricultural fields (Dubrovsky et al., 2010; USEPA, 2010). In response to concerns over agricultural P export, the USDA and the USEPA developed a strategy for implementing nutrient management plans for animal feeding operations (USDA and USEPA, 1999). As a result, the USDA–NRCS revised its 590 Nutrient Management Conservation Standard to include P-based planning strategies that restricted P application to fields based on that field's risk of P loss. The resulting 590 Standard prescribed three strategies states could adopt to rate a field's vulnerability to P loss: agronomic soil test P (STP), environmental threshold STP, and a P index (PI), with a PI being the most commonly adopted strategy (Sharpley et al., 2003).

A PI is an applied assessment tool used to identify agricultural fields most vulnerable to P loss by accounting for the major source and transport factors controlling P movement (Sharpley et al., 1994; Lemunyon and Gilbert, 1993). A PI can account for location-specific factors known to contribute to P loss, including runoff; erosion; and type, timing, and placement of P applications (Sharpley et al., 2011). Because each state was encouraged to develop its own index, significant structural differences exist among PIs (Buczko and Kuchenbuch, 2007; Osmond et al., 2006; Sharpley et al., 2003). State-specific factors affecting PI development include differences in soil, landscape, and land uses; state regulations; political climate during PI development; and objectives identified for the PI. The many variations in PI mathematical formulation also reflect competing and evolving perspectives on the best formulation of the PI concept (Osmond et al., 2006; Sharpley et al., 2003).

The diversity in PI structure among states, inconsistency in recommendations and interpretations for similar situations (Kovzelove et al., 2010; Osmond et al., 2006), and a lack of sufficient evaluation and validation of many PIs has led to calls to

J. Environ. Qual. 41
doi:10.2134/jeq2011.0457
Received 8 Dec. 2011.
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Abbreviations: APLE, Annual Phosphorus Loss Estimator; CI, component index; MAE, median absolute error; MAPE, median absolute percent error; MI, multiplicative index; PA PI, Pennsylvania phosphorus index; PI, phosphorus index; RMSE, root mean square error; STP, soil test phosphorus.