Phosphorus Use

Working Metric Version 1.0 | Adopted July 31, 2013

Phosphorus (P) is a key nutrient for crop production. However, when transported off the farm, it poses an economic loss to the grower and can have detrimental impacts to surface and groundwater quality. Both nitrogen and phosphorus were chosen for the nutrient metrics as they are widely recognized as pollutants and are a higher priority for environmental improvement than potassium (see separate Nitrogen Use metric).

Soils vary a great deal in the amount of phosphorus they contain that plants can access. A field that is exceedingly rich in available P could lose considerable P to the environment even though inputs might equal removal in harvest.[1,2] In some fields, the excess P is so large that even if one were to eliminate inputs altogether while continuing to grow and harvest crops, it could easily take decades to draw down the soil P reserves to a point where levels would be considered "optimum" rather than "very high."[2] Good stewardship includes taking advantage of existing soil P reserves before adding more P fertilizer to fields.

The approach taken in the Phosphorus Use Metric differs from that of the Nitrogen Use Metric because these two elements behave very differently in the environment. First, as described above, P can accumulate in soils to an extent that is much less common for nitrogen. Nitrogen is much more mobile than phosphorus because nitrate dissolves easily in water, and because nitrogen oxides escape from soils as a gas. In contrast, most forms of P are less soluble than nitrate and P has no significant gas phase. Second, compared to plant needs for N and P, manure is relatively high in P. Therefore, in fields that receive manure additions over many years, in the absence of additional N inputs to the soil, plants take up the N and leave P behind to accumulate.[3]

The **Phosphorus Use** metric takes advantage of the fact that when labs return results of P tests to growers they also return a recommendation for how much P a grower should apply. These recommendations are based on several factors, including the crop the grower intends to plant during the next season, but the amount of P already available in the soil is a major determinant of these recommendations. The metric, therefore, looks at how much P the grower has applied *above* that recommended value.

[1] Similarly, a field that has P-poor soils could benefit from greater inputs in excess of outputs.

[2] Kleinman, P. J. A., et al. (2011). "Soil controls of phosphorus in runoff: Management barriers and opportunities." Canadian Journal of Soil Science **91**: 329_338. McCollum, R. E. (1991). "Buildup and Decline in Soil Phosphorus: 30-Year Trends on a Typic Umprabuult." Agronomy journal **83**: 77-85.

[3] Vitousek, P. (2004). Nutrient Cycling and Limitation: Hawai'i as a Model System, Princeton University Press. National Research Council (2010). Toward Sustainable Agricultural Systems in the 21st Century. Washington, DC, National Academies Press. Sims, J. T. and A. N. Sharpley, Eds. (2005). Phosphorus: Agriculture and the Environment, American Society of Agronomy-Crop Science Society of America-Soil Science Society of America.

Proposed Metric:

Phosphorus Use	$\frac{\text{Pounds P added – Pounds P recommended}}{\text{Ton of product harvested}}$

Notes:

- *Pounds P added includes total synthetic and organic P applied*
- *Pounds P recommended is the agronomic recommendation received with results of soil P test (based on P available in soil, cropping history, and production plans)*
- *Includes all fertilization events from the end of the previous harvest to the current harvest.*
- *For educational purposes, metric can also be presented on a per acre basis as:*
  (Pounds P added – Pounds P recommended)/acre planted

Recommended Issues to Consider in Future:

Through working group discussions, academic technical review, and Metric Technical Advisory Committee discussions, the following items have been identified as issues to be considered in future iterations of this metric:

- Examine and/or develop methods for putting results from various P availability tests on a common scale in order to more directly relate P availability tests to in-field P addition
- Develop allocation method for organic N and P over multiple cropping periods to more accurately reflect their release times
- Create comparison of P additions to P use by plant
- Consider including some recognition of locations where there is a pathway for P to surface waters. (i.e., P Index used by NRCS low). Could be checklist (Risk of movement to surface waters – low, medium, high).

Technical Notes:

The Phosphorus Use Metric evaluates the amount of P used above the agronomic recommendations that are included in P soil test results. Guidance on the P added and P recommended components are included here.

Component 1: P Added

Phosphorus from both organic and synthetic fertilizers is included in the total for the P added component, evaluated as the total amounts applied during the harvest-to-harvest period. If the SISC Calculator is used, data is collected in the form of the N-P-K ratio for individual organic and synthetic fertilizers and pounds of P are determined by summing all product applications for each crop.

P From Synthetic Fertilizers

- All fertilizer applied during the harvest-to-harvest period should be included.
- If growers do not know the density of liquid fertilizers, an average density of 11.11 lbs/gal is used to convert liquid fertilizers into dry weight. This value was derived by averaging the density of several common liquid fertilizers as published by the Fluid Fertilizer Foundation. [4]

P from Organic Fertilizers

- The entire nutrient value applied during the harvest-to-harvest period is attributed to the crop. While it is recognized that organic fertilizers often have slow-release properties, at this time SISC does not attribute applications to multiple crops.
- Where a nutrient analysis has been conducted, the N-P-K value from this analysis should be used. A protocol for how to convert from volume to weight and how to account for moisture content is described in Alternatives 1 and 2 of the Protocol for Estimating N and P for Organic Fertilizers (found on the metrics page).
- If the nutrient analysis gives information in the form of P2O5, convert to straight P using the following conversion: 1 pound P2O5 = 0.44 pounds P.
- Where growers do not know the nutrient value of the material, they should follow Alternatives 3 or 4 in the Protocol for Estimating N and P for Organic Fertilizers (found on the metrics page).

Component 2: P Recommended in Soil Test Results

There are a number of tests used to estimate the amount of plant-available P in an agricultural soil. These include, for example, the Olsen test, the Mehlich-1 test, the Mehlich-3 test, the Bray test, and the Morgan test. Controls on P-availability in the field vary with soil type and chemistry (e.g., soil acidity), and methods for estimating P-availability (e.g., the chemistry of the solution) vary accordingly. However, the diversity of tests can complicate direct comparison of soil P tests among fields and growers.[5]

Therefore, the metric uses the agronomic recommendations from these tests, not the P evaluations themselves.

Other guidance for the soil tests includes:

- Soil tests should be consistent with land grant recommendations.
- Soil test should be conducted annually.
- Soil sampling should follow the "SISC Metrics Guidelines: Soil Sampling" at www.stewardshipindex.org.
- Any of above-mentioned soil tests can be used.

[4] "Estimated Physical Characteristics of Fertilizer Material", Fluid Fertilizer Foundation, http://www.fluidfertilizer.com/pdf/Fluid%20Characteristics.pdf

[5] Sharpley, A. N., et al. (2003). "Development of phosphorus indices for nutrient management planning strategies in the United States." Journal of Soil and Water Conservation **58**(3): 137-152.