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J.T. Sims
A.B. Leytem
Department of Plant and Soil Sciences
University of Delaware
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# The *Phosphorus Site Index:* A Phosphorus Management Strategy for Delaware's Agricultural Soils

***Phosphorus and** Delaware Agriculture*

Phosphorus (P) is one of the most important plant nutrients required by Delaware crops. It is essential for most physiological processes in plants, such as photosynthesis, energy transfer, genetic regulation of cell division and growth, and the production of seeds and fruits. If soils are deficient in P, plants may become stunted, with poorly developed root systems, and significant reductions in yield may occur.

Profitable crop production requires that plants be provided with an adequate supply of P, either from the soil or from soil amendments such as commercial fertilizers or animal manures. The amount of fertilizer or manure P needed for optimum crop yields has been documented through long-term field research with most of the soils and crop management systems found in Delaware. Research has also been conducted to determine the most effective sources of P, timing of P application, and placement methods for P fertilizers. Because of this research, successful agronomic management practices for P are now available for Delaware agriculture.

At present, the consensus of most agricultural scientists is that maximizing the return on an investment in P fertilizers begins with the use of a soil test-based P fertilizer program. Soil testing is a reliable, inexpensive way to evaluate the P fertilizer requirement of most crops. The University of Delaware Soil Testing Program uses the criteria shown in Table 1 to rate soils according to the likelihood of an economic response to P fertilization. Actual fertilizer recommendations received by farmers will vary slightly depending on factors such as crop, soil type, tillage, irrigation, and manure use.

**Table 1. General P fertilizer recommendations for Delaware.**

| Soil P Rating | UD Fertilit Index Value' | Typical P Recommen (lb $P_2O_5$/acre) |
|---|---|---|
| Low | 0-25 | 100 |
| Medium | 26-50 | 50 |
| Optimum | 51- | 25 |
| Excessive | > 100 | 0 |

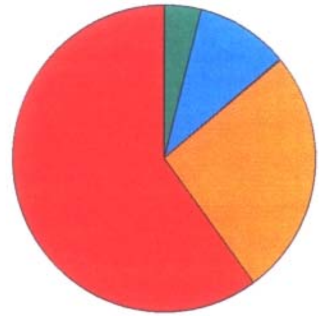
Fertility index value = soil test P (Mehlich 3) in ppm.
P fertilizer recommendations are for a <u>broadcast</u> application. If the P fertilizer is banded, recommendations are halved.

***Prepared by:* J. T. Sims and A. B. Leytem, Department of Plant and Soil Sciences, University of Delaware, Newark, DE 19717. Revised on January 1, 2002.**

### ***Phosphorus and the Environment***

Environmental concerns with P center around ***eutrophication,*** defined as "...an *increase in the fertility status of natural waters that causes accelerated growth , of algae or water-plants".* In most fresh surface waters (lakes, ponds, rivers), and some estuaries. the growth of algae or aquatic plants is limited by inadequate levels of P. Inputs of P to surface waters from nonpoint sources by erosion, runoff, or subsurface groundwater flow, can remove this limitation and induce eutrophic conditions. Point sources of P, such as municipal wastewater systems, can also contribute to eutrophication. The most common undesirable effects of eutrophication are algal blooms, foul odors, insect problems, impeded water flow and boating due to aquatic weeds, sediment buildup in shallow lakes, low dissolved oxygen levels, and the disappearance of desirable species of fish.

The University of Delaware has always advocated an agronomically sound P management program, one that has traditionally focused on maximizing profitable crop responses to P. Today, however, the situation is more complex. As seen in Figure 1, it is apparent that most of Delaware's agricultural soils are now rated as optimum or excessive in P. Soils in these categories have little, if any, need for fertilizer or manure P. Indeed, many Delaware soils have soil P levels high enough to meet crop P needs for 10 years or more without any inputs of P. Because in some situations high P soils contribute to eutrophication of surface waters, P management strategies that maintain both agricultural profitability and environmental quality are badly needed. This fact sheet describes one such approach, the ***Phosphorus Site Index.***



**■ Low ■ Medium 0 Optimum ■**

**Excessive**

Figure 1. Percentages of agricultural soil samples in each soil test category in Delaware (based on 15,000 soil samples submitted to the University of Delaware from 1992-1999)

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### *The* ***Phosphorus Site Index***

In 1990, the USDA Soil Conservation Service (now the USDA Natural Resources Conservation Service or USDA-NRCS) formed a national work group of scientists from Universities, Cooperative Extension, and the USDA Agricultural Research Service to develop a P-indexing procedure that could identify soils, landforms, and management practices with the potential for unfavorable impacts on water bodies because of P losses from agricultural soils. The long-term goals of this national work group were:

- *To develop an easily used, site-specific, field rating system (referred to as the* ***Phosphorus Site Index)*** *for USDA-NRCS technical specialists, Cooperative Extension, crop consultants, farmers and others that rates soils according to their relative potential for P loss to surface waters.*
- *To relate the P Site* ***Index*** *to the sensitivity of receiving waters to eutrophication.*
- *To develop agricultural management practices that minimize the buildup of soil P to excessive levels and the transport of P from soils to sensitive water bodies.*

**The *P Site Index* is** designed **to** assess the relative risks of P loss from differing fields, not to estimate the actual quantity of P lost in runoff. This risk assessment allows us to design best management practices (BMPs) to reduce agricultural P losses to surface waters and to prioritize the locations in a watershed where BMPs will have the greatest water quality benefits.

### ***Using the Phosphorus Site Index***

The *P Site* ***Index*** evaluates 12 characteristics, which are separated into two groups: Part A (site factors affecting P transport) and Part B (P source and management factors) to obtain an overall rating of the potential for P loss at a site (Table 2). By doing this it is possible to obtain separate risk assessments for P transport from a site, based on factors such as topography, hydrology, and proximity to surface waters (Part A), and for P source and management practices (soil test P, fertilizer/manure P management - Part B).

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Each of the 12 characteristics in the *P* ***Site Index*** is assigned a numerical value from an *interpretive rating scale:* VERY LOW, LOW, MEDIUM, HIGH, or VERY HIGH or from calculations using *a weighting factor* based on the relationship between the characteristic and the potential for P loss from the site. At present, the interpretive ratings and weighting factors are based on the best professional judgment of the scientists who are developing the ***P Site Index.*** The final *P* ***Site Index*** value for the site integrates the effects of factors from Part A and Part B (see below for the actual steps used to calculate the *P* ***Site Index).***

Table 2. **Site characteristics and management factors used to determine the *P Site Index.***

**<u>Part A - Site and Transport Characteristics</u>**
Soil Erosion
Soil Surface Runoff Class
Subsurface Drainage
Leaching Potential
Distance from Field to Surface Water
Priority of Receiving Water

**<u>Part B - Source and Management Characteristics</u>**
Soil Test P Value
P Fertilizer Application Rate
P Fertilizer Application Method
Organic P Source Application Rate
Organic P Source Application Method

Note that variations in P availability/solubility between different types of organic P sources are accounted for by use of a Phosphorus Availability Coefficient (PAC).

### *Calculation of* ***the Phosphorus Site Index***

The current version of the *P* ***Site Index*** (Table 3) is provided in this fact sheet, along with two example calculations. Use the following steps to determine the ***P Site Index*** for a site. The University of Delaware also provides a *Technical Guidance Manual for the Phosphorus Site Index* that has more detailed information on this process. Contact your local Cooperative Extension office to obtain this manual.

1. Calculate field values for all of the site and transport characteristics in Part A, using data obtained from a county soil survey manual, the revised universal soil loss equation (RUSLE), and necessary field

measurements (i.e., distance from field to surface water).

2. Add all Part A factors together and multiply them by *a scaling factor (0.02).* The scaling factor is used to convert the overall P transport potential at the site to a scale of 0 to 1.0 (highly erodible sites may have a final Part A value > 1.0).

3. Calculate field values for the P source and management characteristics in Part B using information collected from the farmer and recent soil test results (obtain new soil test data if current results are over three years old or a significant addition of P has occurred since the last test).

4. Multiply the final site values for Part A and Part B together to obtain the overall *P* ***Site Index*** **value.** Compare the *P* ***Site Index*** value obtained with the interpretations in Table 4, which categorizes site vulnerability to P loss. Then determine the BMPs needed at this site to reduce the risk of P loss to waters (see Table 5 for examples of BMPs).

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**Table 3. The** *Phosphorus Site* ***Index for*** **Delaware.**

*Part A: Phosphorus loss potential due to site and transport characteristics.*

| ***Characteristic*** | ***Phosphorus Loss Rating*** | | | | | *Value* |
|---|---|---|---|---|---|---|
| **Soil Erosion** | 2 x [ Soil erosion value from RUSLE (tons/acre) ] | | | | | |
| **Soil Surface Runoff Class** | Very Low 0 | Low 2 | Medium 4 | High **6** | Very High **8** | |
| **Subsurface Drainage** | Very Low **0** | Low **2** | Medium **4** | High **6** | Very High **8** | |
| **Leaching Potential** | Low **0** | | Medium **2** | High **4** | | |
| **Distance from Field to Surface Water** | > 100 ft 0 | <100 ft AND > 50 ft vegetated buffer *OR* < 100 ft AND > 25 ft vegetated buffer AND > 25 ft additional no P application zone 2 | <100 ft AND > 25 ft vegetated buffer AND < 25 ft additional no P application zone 4 | <100 ft AND < 25 ft vegetated buffer AND > 25 ft additional no P application zone | <100 ft AND < 25 ft vegetated buffer AND < 25 ft additional no P application zone **8** | |
| **Priority of Receiving Water** | Very Low 0 | Low 1 | Medium 2 | High **3** | Very High 4 | |

***Sum*** *of Site and Transport Characteristics:* *Scaling factor: x 0.02*

*Total Site and Transport Value for Part A:*

*Part* ***B:*** *Phosphorus loss potential due to P source and management practices.*

| ***Characteristics*** | ***Phosphorus Loss Rating*** | | | | | ***V*** |
|---|---|---|---|---|---|---|
| **Soil Test P Fertility Index Value (FIV)** | [ 0.2 ] x [FIV from University of Delaware Soil Test] | | | | | |
| **P Fertilizer Application Rate** | [ 0.6 ] x (lbs $P_2 0_5$ applied per acre) | | | | | |
| **P Fertilizer Application Method and Timing** | None applied 0 | Injected/Banded below surface at least 2" 15 | Incorporated within 5 days of application 30 | Surface applied March through November OR incorporated in > 5 days 45 | Surface applied December through February 60 | |
| **Organic P Source Application Rate** | Availability default-A.6) applied per acre [Phosphorus Availability Coefficient (PAC; ) ] x (lbs P205 per | | | | | |

*Total P Source and Management Value for Part B:*

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|---|---|---|---|---|---|---|
| **Organic P Source Application Method and Timing** | None applied<br><br>0 | Injected/Banded below surface at least 2"<br><br>15 | Incorporated within 5 days of application<br><br>30 | Surface applied March through November OR incorporated in > 5 days | Surface applied December through February | |

**Table 4. Generalized interpretation of the *Phosphorus* Site *Index.***

| *P Site Index* | **Generalized Interpretation of** *P Site Index* |
|---|---|
| **50** | **LOW** potential for P movement from this site given current management practices and site characteristics. There is a low probability of an adverse impact to surface waters from P losses from this site. Nitrogen-based nutrient management planning is satisfactory for this site. Soil P levels and P loss potential may increase in the future due to N-based nutrient management. |
| **51 -** 75 | **MEDIUM** potential for P movement from this site given current management practices and site characteristics.Practices should be implemented to reduce P losses by surface runoff, subsurface flow, and erosion. Nitrogen-based nutrient management should be implemented no more than one year out of three. Phosphorus-based nutrient management should be implemented two years out of three during which time P applications should be limited to the amount expected to be removed from the field by crop harvest or soil test P based application recommendations,whichever is greater. |
| **76 - 100** | **HIGH** potential for P movement from this site given current management practices and site characteristics. Phosphorus-based nutrient management should be used for this site. Phosphorus applications should be limited to the amount expected to be removed from the field by crop harvest or soil test P based application recommendations. All practical management practices for reducing P losses by surface runoff, subsurface flow, or erosion should be implemented. |
| > **100** | **VERY HIGH** potential for P movement from this site given current management practices and site characteristics.<br>No phosphorus should be applied to this site. Active remediation techniques should be implemented in an effort to reduce the P loss potential of this site. |

***PHOSPHORUS** SITE INDEX : EXAMPLE CALCULATIONS FOR*

*DELAWARE* *Scenario #1:* An agricultural field located in the upper coastal plain, in

New Castle County.

***Site and Hydrologv:*** The dominant soil type is a Matapeake silt loam, a well-drained soil with moderate permeability and a depth to the seasonal high water table > 6'. The field has slopes of 5 to 7% that lead to an adjacent stream. There is a riparian buffer between the edge of the cultivated field and stream that varies in width from 8' to 12' and either a gully or steep grade leading down to the stream.

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***Phosphorus Source and Management:*** The crop rotation at this site is wheat (conventional till) – double cropped soybeans (no-till) – corn (no-till). The soil test P value is 75 FIVs (UD Fertility Index Values), which is in the "optimum" range for crop production. Starter fertilizer is used only with the corn at an application rate of 25 lbs $P_20_5$/acre. No manure is used at this site.

| ***Site Information*** | ***Information Used to Determine** P **Loss*** | ***Value for** P **Site Index*** | |
|---|---|---|---|
| *Part A:* ***Site and Transport Factors*** | | | |
| Soil Erosion | RUSLE: 2.5 tons/acre | 5 | MEDIUM |
| Surface Runoff Class | Slope, soil permeability | 4 | MEDIUM |
| Subsurface Drainage | Drainage, water table depth | 2 | LOW |
| Leaching Potential | USDA-NRCS rating scale based on soil series | 0 | LOW |
| Distance to Water | Distance from field to surface water | 8 | VERY HIGH |
| Priority of Receiving Water | State watershed categorization scale | 3 | HIGH |
| | ***Sum** of Part A* | *22* | |
| | *Scaling factor* | *x **0.02*** | |
| | *Part A Value* | *0.44* | |
| *Part B: P* ***Source*** *and* ***Management*** | | | |
| Soil Test P | UD soil test value: 75 FIVs | 15 | HIGH |
| P Fertilizer Rate | 25 lbs $P_20_5$/acre | 15 | LOW |
| P Fertilizer Application Method | Banded below surface | 15 | LOW |
| Organic P Rate | | 0 | n/a |
| Organic P Application Method | None applied | 0 | n/a |
| | *Part **B** Value* | *45* | |
| | *P Site Index* **(Part A Value x Part B Value) = [0.44] x [45]** | ***20 (LOW)*** | |

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*Scenario #2:* An agricultural field located in the coastal plain region of Sussex County.

***Site and Hydrology:*** The dominant soil type is a Pocomoke sandy loam — a very poorly drained soil with moderately slow permeability and a depth to the seasonal high water table of 0-1'. The field has slopes of 0.5% and is bordered by drainage ditches. There are no buffers between the edge of the cropped field and the ditches.

***Phosphorus Source and Management:*** The crop rotation at this site is corn-soybeans-corn (all conventional till). The soil test P value is 400 FIVs (UD Fertility Index Values), which is in the "excessive" range for crop production. Starter fertilizer is used only with the corn at an application rate of 25 lbs $P_2 0_5$/acre. Poultry manure is applied in March each year at a rate of 3 tons/acre.

| ***Site Information*** | ***Information** Used to Determine P Loss Rating* | *Value for **P Site Index Calculation*** | |
|---|---|---|---|
| *Part A:* ***Site and Transport Factors*** | | | |
| Soil Erosion | RUSLE: 0.5 tons/acre | 1 | LOW |
| Surface Runoff Class | Slope, soil permeability | 0 | VERY LOW |
| Subsurface Drainage | Drainage, water table depth | 6 | HIGH |
| Leaching Potential | USDA-NRCS rating scale | 2 | MEDIUM |
| Distance to Water | Distance from field to surface water | 8 | VERY HIGH |
| Priority of Receiving Water | State watershed categorization scale | 4 | VERY HIGH |
| | ***Sum** of Part A* | *21* | |
| | ***Scaling factor*** | ***x 0.02*** | |
| | ***Part** A **Value*** | *0.42* | |
| *Part* ***B: P Source and Management Factors*** | | | |
| Soil Test P | UD soil test value: 400 FIVs | 80 | VERY HIGH |
| P Fertilizer Rate | 25 lbs $P_2 0_5$/acre | 15 | LOW |
| P Fertilizer Application Method | Banded below surface | 15 | LOW |
| Organic P Rate | 180 lbs $P_2 0_5$/acre | 108 | VERY HIGH |
| Organic P Application Method | Surface, March through November | 30 | HIGH |
| | *Part **B** Value* | ***248*** | |
| *P Site* ***Index*** **(Part *A Value x Part B Value) = [0.42] x* [248]** = **104** | | **104** (VERY **HIGH)** | |

## *Management Options for the Two Example Scenarios*

Information on best management practices to consider after *P Site* ***Index*** evaluation is found in Table 5. Some management options that would be appropriate for the two scenarios above are:

*Scenario #1:*
Follow a nitrogen-based nutrient management plan. Review the need for soil conservation measures that can reduce the risk of P loss in certain areas on the farm (e.g., consider widening buffer strips in some areas near surface waters). Monitor soil test P values to prevent the buildup of soil P to excessive levels. Consider effects of any major changes in agricultural practices on P losses before implementing them on the farm.

*Scenario #2:*

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Follow a phosphorus-based nutrient management plan. Avoid applications of P at this site from any source (fertilizers or manures). Use a starter fertilizer that only contains nitrogen (N). Review and/or update soil testing results for the entire farming operation to identify areas where P can best be applied. Apply manure to other fields that have lower *P* ***Site Index*** values. Implement soil conservation practices that will reduce the likelihood of P loss to surface or shallow ground waters. Monitor changes in soil test P with time to determine when N- and P-based management practices can be followed.

***Soil Management Options Based on the Phosphorus Site Index***

Minimizing nonpoint source pollution of surface waters by P from agricultural cropland requires management practices that control both the *supply* and *transport* of soil **P. The basic objective of environmentally sound P management is to maintain soil P fertility levels in a range that is optimum, but not excessive, for crop growth while reducing the loss of particulate and soluble P by processes such as erosion, runoff, or drainage.** Determination ***of the P Site Index*** for soils near to sensitive surface waters is the first step in this strategy because this prioritizes the efforts needed to reduce P losses. Once this has been done, management options that are appropriate for soils with different *P Site Index* ratings can be implemented. Some general recommendations are given in Table 5; however, P management is very site-specific and requires a well-planned, coordinated effort between farmers, extension agronomists, and soil conservation specialists.

**Table 5. Management options to minimize nonpoint source pollution of surface waters by soil P.**

| ***Phosphorus Site Index Value*** | ***Management Options to Minimize Nonpoint Source Pollution*** *of* ***Surface Waters*** *by* ***Soil*** *P* |
|---|---|
| < *50*<br><br>***(LOW)*** | *Soil testing:* Have soils tested for P at least every three years to monitor build-up or decline in soil P.<br><br>***Soil conservation:*** Follow good soil conservation practices. Consider effects of changes in tillage practices or<br>land use on potential for increased transport of P from site<br>implementing them on the farm. Examples include increasing the number of animal units on a farm or changing<br>to crops with a high demand for fertilizer P. |
| **51 - 75**<br><br>**(MEDIUM)** | *Soil testing:* Have soils tested for P at least every three years to monitor build-up or decline in soil P. Conduct<br>a more comprehensive soil testing program in areas that have been identified by the *P* ***Site Index*** as being most<br>sensitive to P loss by erosion, runoff, or drainage.<br><br>***Soil conservation:*** Implement practices to reduce P losses by erosion, runoff, or drainage in the most sensitive<br>fields (i.e., reduced tillage, field borders, grassed waterways, and improved irrigation and drainage management). |
| 76 - **100**<br><br>**(HIGH)** | *Soil testing:* A comprehensive soil testing program should be conducted on the entire farm to determine fields<br>that are most suitable for further additions of P. For fields that are excessive in P, estimates of the time required<br>to deplete soil P to optimum levels should be made for use in long range planning. Consider using crops with<br>high P removal capacities in fields with high soil test P values.<br><br>*Soil conservation:* Implement practices to reduce P losses by erosion, runoff, or drainage in the most sensitive<br>fields (i.e., reduced tillage, field borders, grassed waterways, and improved irrigation and |

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|---|---|
| **>100**<br><br>**(VERY HIGH)** | ***Soil testing:*** For fields that are excessive in P, estimate the time required to deplete soil P to optimum levels for use in long range planning. Consider using new soil testing methods that provide more information on environmental impacts of soil P (contact UD Cooperative Extension for information on new soil P tests). Consider using crops with high P removal capacities in fields with high soil test P values.<br><br>***Soil conservation:*** Implement practices to reduce P losses by erosion, runoff, or drainage |

**For more information on how to use the *Phosphorus Site Index* please contact University of Delaware Cooperative Extension, the USDA Natural Resources Conservation Service, or your local conservation district.**

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