University of Georgia

U.S. Department of Agriculture

# The Georgia Phosphorus Index

## Introduction

The Georgia Phosphorus (P) Index is a tool to assess the risk of bioavailable P loss from grasslands and cropped fields to surface waters. Loss of bioavailable P to surface waters is of concern because it can accelerate eutrophication in lakes and streams of the state.

The P Index considers the main pathways of P loss, namely I) soluble P in surface runoff, II) particulate P in surface runoff, and III) soluble P in leachate. For each of these pathways, the P Index estimates the risk of P loss by considering the sources of P and the transport mechanism involved, as well as management practices that can reduce losses. The total risk of P loss from a field is computed by adding the risk from each of the three pathways.

Although Georgia has five physiographic provinces and soils differ across provinces, the data currently available do not justify the development of a separate P Index for each region. Following is a description of the procedures and definitions needed to compute the P Index in all five provinces.

## I. Soluble P in Surface Runoff

Water-soluble P is defined as phosphorus that passes through a 0.45-µm filter. It can be present in inorganic and organic forms and although only the inorganic P is directly bioavailable algae, both forms can be important in accelerating eutrophication because organic P can become bioavailable through mineralization. The P Index estimates the risk of soluble P loss in surface runoff by considering a) all sources that can contribute soluble P, b) the volume of surface runoff, and c) the width of any vegetated buffer strip present downslope from the field.

## *a. Sources of Soluble P in Runoff*

The three main sources of soluble P in surface runoff are 1) soil P, which is measured by soil test P (STP), 2) inorganic fertilizer P (IP), and 3) organic fertilizer P (OP). The risk of P loss in surface runoff from each of these sources is proportional to the level of each source. Therefore, the P Index uses a relationship between the level of each source and the concentration of soluble P (SP) in surface runoff to obtain a risk rating for each source.

### *1. Soil Test P (STP)*

Soil test P for the P Index should be determined by analyzing soil samples from the upper 4 inches of grasslands and from the upper 6 inches of cropped fields (Mehlich 1). These samples should have been taken within the last six months, and preferably after the last manure or fertilizer application. If the soil samples were taken before the last manure or fertilizer application, the amounts of P added in that last application should be included in the computation of the P Index.

**Risk rating for STP = 0.06 + 0.0021 STP (lb P/A)**

### 2. *Organic Fertilizer P (OP)*

Organic fertilizer P refers to the total amount of P added with animal manures or organic amendments. The total P added is the amount which is planned to be added in the coming year or that has been added since the last measurement of soil test P. The amount of water-soluble P applied is calculated by multiplying total P applied with the organic source (lb $P_2O_5$/A) by the fraction of P present in water soluble form (WSF;Table 1).

Table 1. Water-soluble P in selected manures.

| Manure | Water-Soluble P |
|---|---|
| | Fraction of Total P (WSF) |
| Poultry Litter with alum | 0.15 |
| Poultry Litter without alum | 0.30 |
| Layer Manure | 0.40 |
| Dairy Manure | 0.65 |
| Swine Manure | 0.40 |
| Layer Slurry | 0.40 |
| Dairy Slurry | 0.65 |
| Swine Slurry | 0.25 |

The soluble P in surface runoff associated with a given application of organic P is reduced when the application is banded, incorporated, or surface applied at a time of the year when the probability of surface runoff is low (Table 2).

**Table 2. Application method factor (AF) for inorganic and organic fertilizer P.**

| Banded or injected > 2 inches | Incorporated immediately or sprinkler applied | Surface applied, incorporated < 30 days | Surface applied, not incorporated May-Oct | Surface applied, not incorporated Year-round | Surface applied, not incorporated Nov,Mar,Apr | Surface applied, not incorporated Dec-Feb |
|---|---|---|---|---|---|---|
| **0.1** | **0.2** | **0.4** | **0.6** | **0.75** | **0.8** | **1** |

The risk rating for organic P is calculated taking into account total water-soluble P applied and application method.

**Risk rating for OP = 0.07 x Total P (lb $P_2O_5$/A) x WSF x AF**

***3. Inorganic Fertilizer P (IP)***

Inorganic fertilizer P refers to the total amount of P added with inorganic (conventional) fertilizer. The total P added is the amount which is planned to be added in the coming year or that has been added since the last measurement of STP. The amount of water-soluble P is calculated by multiplying total P applied with the inorganic source (lb $P_2O_5$/A) by the fraction of P present in water soluble form, which is assumed to be 0.9. The soluble P in surface runoff associated with a given application of inorganic fertilizer P is reduced when the application is banded, incorporated, or surface applied at a time of the year with a low probability of runoff (Table 2). The risk rating for inorganic P is calculated taking into account total water-soluble P applied and application method.

**Risk rating for IP = 0.07 x Total P (lb $P_2O_5$/A) x 0.9 x AF**

***4. Overall Source Risk Rating for Soluble P in Runoff***

The risk rating for all soluble P sources is computed by adding the risk rating for each of the P sources.

**Overall Source Risk Rating = STP Risk + OP Risk + IP Risk**

### *b. Volume of Surface Runoff*

The P Index uses a curve number approach to obtain an estimate of the risk of runoff from a particular field.

**Runoff Risk Rating = [1.846618E-10 x $CN^{5.6440364}$] x 0.254**

### *c. Effect of Buffer Width on Soluble P*

The index reduces soluble P losses in runoff when a vegetated buffer is used at the edge of the field. A vegetated buffer to reduce soluble P is defined as a vegetated area under the producer's control, with >= 80% ground cover, no channelized flow, no P application, and a soil test P < 450 lb P/A (Mehlich 1). Above a soil test P of 450 lb P/A, the buffer may become a significant source of P and therefore would no longer be efficient at adsorbing soluble P from the field. The width of the buffer to be used in the equation presented below is the minimum width measured in the field.

**Buffer Effect (BE) = exp (-0.042 x Width (feet))**

This equation generates a value of 1 for a 0-ft buffer, a value of 0.12 for a 50-ft buffer, and a value of 0.01 for a 100-ft buffer. A value of 1 indicates no retention of soluble P whereas a value of 0 indicates complete retention of soluble P by the buffer.

### *d. Risk of Loss of Soluble P in Surface Runoff*

The risk of soluble P loss in surface runoff is computed by multiplying the overall source risk rating by the risk rating for runoff and by the buffer effect (BE).

**Risk of Soluble P in Runoff = Source Risk Rating x Runoff Risk Rating x BE**

# II. Particulate P in Surface Runoff

Particulate P is defined as phosphorus that does not pass through a 0.45-μm filter. It can be present in inorganic and organic forms. Although particulate P is not in solution and therefore is not directly bioavailable, it can play an important role in accelerating eutrophication by releasing bioavailable P. The P Index estimates the risk of P loss through particulate P by a) estimating sediment loss from a field, b) using that value to calculate the bioavailable P that can be released from particulate P, and c) taking into account retention of P by the presence of a vegetated buffer.

### *a. Sediment Loss*

Sediment loss from a field (ton/A) can be computed with the Revised Universal Soil Loss Equation (RUSLE; ton/A/year).

### *b. Bioavailable P in Particulate P*

Bioavailable P in soil is estimated from STP (Mehlich 1) and then combined with sediment loss to obtain an estimate of bioavailable P loss.

**Bioavailable P Loss = Sediment loss (ton/A/year) x 0.0009 STP**

### *c. Effect of Vegetated Buffer Width on Particulate P Losses*

The P index reduces particulate P losses in runoff when a vegetated buffer is used at the edge of the field. A vegetated buffer that can reduce particulate P is defined as a vegetated area under the producer's control, with 80% ground cover, no channelized flow, and no P application. The width of the buffer to be used in the equation presented below is the minimum width found in the field.

**Buffer Effect (BE) = exp (-0.042 x Width (feet))**

This equation generates a value of 1 for a 0-ft buffer, a value of 0.12 for a 50-ft buffer, and a value of 0.01 for a 100-ft buffer. A value of 1 indicates no reduction in particulate P whereas a value of 0 indicates complete retention of particulate P by the buffer.

### *d. Risk of Loss of Bioavailable P in Particulate Form*

The risk of loss of bioavailable P in particulate form is computed by multiplying the bioavailable P loss by the buffer effect.

**Risk of Particulate P Loss = Bioavailable P Loss x BE**

## III. Soluble P in Leachate

Soluble P present in water percolating through the soil profile can contaminate a shallow water table or tile water directly connected to surface water. The P Index estimates the risk of soluble P loss in percolating water by considering a) all sources that can contribute soluble P, b) the volume of percolating water, and c) the depth to the water table or drainage tiles.

## *a. Sources of Soluble P in Leachate*

The three main sources of soluble P in percolating water are 1) soil P, which is measured by soil test P (STP), 2) inorganic fertilizer P (IP), and 3) organic fertilizer P (OP). The risk of P loss from each of these sources is related to the concentration of P in solution that is associated with the level of each source. Therefore, the P Index uses a relationship between each of the P sources (STP, IP, OP) and the concentration of soluble P in solution to obtain a rating for the risk of P loss.

### *1. Soil Test P*

The risk rating for soil test P is computed with the same equation used to estimate risk rating for soil test P in surface runoff.

**Risk rating for STP = 0.06 + 0.0021 STP (lb P/A)**

### *2. Organic Fertilizer P (OP)*

Addition of organic fertilizer P may increase significantly the concentration of soluble P in percolating water when the soil already has an elevated level of STP. When STP is low, a large proportion of the water-soluble P released from the organic fertilizer is adsorbed by the soil. Consequently, the effect of organic fertilizer P on the concentration of soluble P in leachate is not taken into account when STP < 450 lb P/A. At or above 450 lb P/A, the following equation is used to compute risk. This equation uses water soluble fraction (WSF) from Table 1, as described below.

**Risk rating for OP = 0; if STP < 450 lb P/A**
**Risk rating for OP = 0.035 x Total P (lb $P_2O_5$/A) x WSF; if STP >= 450 lb P/A**

### *3. Inorganic Fertilizer P (IP)*

As in the case of organic fertilizer P, the addition of inorganic fertilizer P is not considered to have an effect on soluble P in leachate while STP < 450 lb P/A. At or above 450 lb P/A, the following equation is used to compute risk. This equation uses water soluble fraction (WSF) from Table 1, as described above.

**Risk rating for IP = 0; if STP < 450 lb P/A**
**Risk rating for OP = 0.035 x Total P (lb $P_2O_5$/A) x 0.9; if STP >= 450 lb P/A**

### *4. Overall Source Risk Rating for Soluble P in Leachate*

The risk rating for all soluble P sources is computed by adding the risk rating for each of the P sources.

**Overall Source Risk Rating = STP Risk + OP Risk + IP Risk**

### b. Volume of Percolating Water

The P Index uses the Percolation Index (PI) developed by Williams and Kissel (1991) to estimate a risk of leaching from a particular field.

$$\text{Leaching Risk} = [ (50 - 0.4\ s)^2 / 50 + 0.6\ s] \times 0.254$$

where CN = curve number for percolation (Table 3)
s = (1000/CN) -10

**Table 3. Percolation Curve Numbers for different soil hydrologic groups.**

| Hydrologic Group | A | B | C | D |
|---|---|---|---|---|
| CN for Percolation | 28 | 21 | 17 | 15 |

### c. Depth to Water Table or Drainage Tiles

When the depth to water table or drainage tiles is < 0.5 ft (plow layer), it is assumed that all the soluble P in percolating water is transmitted to the water table or tile. Below a depth of 0.5 ft, the transmission decreases, reaching a value near zero at 8 ft.

$$\text{Effect of Depth to Water Table} = e^{-(\text{Depth} - 0.5)}$$

### d. Risk of Soluble P Loss in Leachate

The risk of soluble P loss in leachate is computed by multiplying the overall source risk rating by the risk rating for leaching and by the effect of depth to water table.

**Risk of Soluble P in Leachate = Source Risk Rating x Leaching Risk Rating x Effect of Depth to Water Table**

## IV. Computation of the P Index

The P index for a given field is computed by adding the risks associated with the different pathways of P loss.

**P Index = Risk of Soluble P in Runoff + Risk of Particulate P in Runoff + Risk of Soluble P in Leachate**

The P index should be computed for each field taking into account the planned P applications for the upcoming year (as well as those that may have been made after the last soil sampling). The value obtained should be interpreted according to the table presented below.

# V. Interpretation of the P Index

| Range | Category | Generalized Interpretation |
|---|---|---|
| 0 to < 40 | Low | Low potential for P movement from this site. |
| 40 to < 75 | Medium | Medium potential for P movement from this site. Use management practices that maintain a P Index < 75. |
| 75 to < 100 | High | High potential for P movement from this site. Add conservation practices or reduce P applications to achieve a P Index < 75. If this cannot be achieved with conservation practices and reduced P rates, then develop a management plan with the goal of achieving a P Index < 75 within 5 years. |
| >= 100 | Very High | Very high potential for P movement from this site. No P applications. Add conservation practices to achieve a P Index < 100. Develop a management plan with the goal of achieving a P Index < 75 within 5 years. |

# VI. Use of the P Index

The P Index is a tool to facilitate the nutrient management planning process that takes place between the land manager and the resource planner. It is intended to communicate concepts and expected outcomes from management practices that impact P losses to the environment. **The P Index is not intended to determine compliance with water quality or nutrient management standards established by local, state, or federal agencies.**

# VII. Examples

Following are examples with their P Index values and proposed management .

| Variable | Example 1 | Example 2 | Example 3 |
|---|---|---|---|
| **Crop** | pasture | pasture | corn |
| **Soil Test P (lb P/A)** | 450 | 450 | 20 |
| **Fertilizer P (lb P2O5/A)** | 0 | 0 | 0 |
| **Fertilizer P Method** | | | |
| **Organic P (lb P2O5/A)** | 300 | 300 | 240 |
| **Type of Organic P** | Poultry litter | Poultry litter | Poultry litter |
| **Organic P Method** | Surface, not incorporated, Nov-Apr | Surface, not incorporated, Nov-Apr | Surface, incorporated < 30 days |
| **Curve Number for Runoff** | 70 | 75 | 80 |
| **Soil Hydrologic Group** | B | B | B |
| **Yearly Erosion (ton/A/year0** | 0.1 | 0.1 | 2 |
| **Buffer Width (feet)** | 0 | 0 | 0 |
| **Soil test P of Buffer (lb P/A)** | | | |
| **Depth to Water Table (feet)** | 8 | 8 | 8 |
| **P Index Value** | **89** | **132** | **55** |

**Example 1.**

This a tall fescue pasture (with a soil test P of 450 lb P/A) that is scheduled to be fertilized with 5 ton of broiler litter per acre. The P Index is 89, which is in the High category. The recommended management is to reduce the P Index below 75 by reducing P applications or using a buffer. Reducing broiler litter applications to 4 ton/A would reduce the P Index to 74. Also, keeping the application at 5 ton litter per acre and using a buffer of 10 ft would reduce the P Index value to 59 (if the soil test P of the buffer is below 450 lb P/A).

**Example 2**.

This field is also a tall fescue pasture scheduled to receive 5 ton broiler litter/A, but it has a higher Curve Number than the field in Example 1 (75 vs 70). As a result, the P Index is 132, which is in the Very High category. The recommendation is to reduce it below 100 in the short term. This can be accomplished by reducing applications to 3.5 ton litter/A, which would reduce the P Index to 98. Also a management needs to be implemented to achieve a P Index below 75 within the next 5 years.

**Example 3.**

This is a conventional-till, corn field that is scheduled to be fertilized with 4 tons broiler litter/A. Although this field has a high Curve Number (80) the P Index is 55 (Medium Category) because the litter is incorporated within 30 days. The suggested management is to use practices that maintain the P Index < 75.

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