A Primer to the University of Maryland Phosphorus Management Tool

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Objective

Our original objective was to develop a phosphorus (P) site index (PSI) that uses readily available information to evaluate the relative risk of P transport from agricultural fields, including vegetable and row crop production and pasture systems where P may be applied either as inorganic or organic fertilizer. The PSI was constructed to be applicable in all of Maryland's physiographic provinces. Phosphorus transport is controlled by site characteristics (e.g. hydrology and slope), climate, and P sources (e.g. manure, inorganic fertilizer, and soil P). The revised PSI, or the University of Maryland – Phosphorus Management Tool (UM-PMT), includes new science relative to site and P source factors and highlights management decisions so that the learning opportunities associated with performing a P loss risk assessment are more pronounced. The overall objective remained unchanged, which is to identify critical areas where there is high P loss potential due to a combination of high transport potential and a large source of P. As a result, the UM-PMT identifies and encourages the use of management practices that minimize P loss from those critical areas and protects water quality.

Timeline

1990 A national cooperative workgroup of scientists was organized to develop a procedure that could identify soils, farm management practices, and specific locations within a farm where P losses in field drainage water may pose the potential for negative environmental impacts on nearby surface waters. The cooperative workgroup established the following goals:

1. To develop an easily used field rating system that rates farm fields according to the potential for P loss to surface water (the P Index).
2. To relate the P Index to the sensitivity of receiving surface waters to eutrophication and degradation resulting from nonpoint source P enrichment.
3. To facilitate adaptation and modification of the P Index to regional and site-specific conditions.
4. To develop agricultural management practices that will minimize the buildup of soil P to excessive levels and the transport of P from soils to sensitive water bodies.

1993 Publication of the first framework for development of P Index assessment tools. Citation: Lemunyon, J. L. and R. G. Gilbert. 1993. Concept and need for a phosphorus assessment tool. Journal of Production Agriculture 6:483-486.

1994 Coale et al. begin research and development of a P Index specifically tailored to Maryland's soils, agricultural management practices, climate, topography, hydrology and surface water characteristics.

1998 Requirement for incorporation of a P Index into Maryland nutrient management plans was prescribed by the Water Quality Improvement Act of 1998.

2000 Original publication of the Maryland Phosphorus Site Index. Citation: Coale, F.J. 2000. The Maryland Phosphorus Site Index Technical Users Guide. Soil Fertility Management Information, SFM-7, Maryland Cooperative Extension Service, College Park, MD.

2000 Phosphorus Index tool requirement regulations codified in COMAR 15.20.08.05.E(4)(a).

2002 Journal publication of the Maryland Phosphorus Site Index. Citation: Coale, F.J., J.T. Sims and A.B. Leytem. 2002. Accelerated deployment of an agricultural nutrient management tool: The Maryland Phosphorus Site Index. Journal of Environmental Quality, 31:1471-1476.

2005 Revision of the Maryland Phosphorus Site Index. Citation: Coale, F.J. 2005. The Maryland Phosphorus Site Index Technical Users Guide. Soil Fertility Management Information, SFM-7, Maryland Cooperative Extension Service, College Park, MD.

2010 The State of Maryland includes "revision of the Phosphorous Index" as a non-quantitative deliverable in the Watershed Implementation Plan (WIP) developed to satisfy U.S. EPA's TMDL (Total Maximum Daily Load) nutrient loading requirements for the Chesapeake Bay.

2011 MDA funds a scope and time-limited research project to support revisions to an updated P site index.

2013 Revision of the Maryland Phosphorus Site Index and conversion to and publication of the University of Maryland Phosphorus Management Tool. Citation: McGrath, J.M, F.J. Coale and N.M. Fiorellino. 2013. University of Maryland Phosphorus Management Tool: Technical Users Guide. Extension Bulletin EB-405.

2013 Multiple UM-PMT technical training sessions are scheduled.

Major structural changes between the Phosphorous Site Index (2005) and the UM Phosphorus Management Tool (2013)

<u>Phosphorus Site Index (2005)</u>

- 11 site-specific soil and landscape physical characteristics are assessed to determine relative risk for P loss due to off-site P transport potential via surface runoff, erosion and subsurface drainage.

- 8 site-specific P source management characteristics are assessed to determine relative risk for P loss due to the P sources present at the site.

- The risk for off-site P transport potential is averaged across the surface runoff, erosion and subsurface drainage pathways.

- The averaged risk for off-site transport is multiplied by the relative quantity of the P sources present to produce the overall P loss risk rating for the site.

- (Average transport risk) X (P source quantity) = P Loss Risk Rating.

<u>UM Phosphorus Management Tool (2013)</u>

- 10 site-specific soil and landscape physical characteristics are assessed to determine relative risk for P loss due to off-site P transport potential via surface runoff, erosion and subsurface drainage.

- 11 site-specific P source management characteristics are assessed to determine relative risk for P loss due to the P sources present at the site.

- The risk for off-site P transport is determined independently for surface runoff, particulate loss (erosion) and subsurface drainage pathways.

- The independent risk for off-site P transport for surface runoff is multiplied by specific dissolved P source risk factors for runoff; the independent subsurface drainage risk is multiplied by specific dissolved P source risk factors for subsurface drainage; and the independent risk for particulate-bound P transport is multiplied by sediment P concentration, distance to water and buffer factors.

- The overall risk for P loss for the site is determined by adding the risk for P loss by surface runoff, particulate losses by erosion, and P loss by subsurface drainage.

- (Surface runoff P loss rating) + (particulate P loss rating) + (subsurface drainage P loss rating) = P Loss Risk Rating.

Changes in interpretation of the P loss rating categories between the four interpretation categories of the Phosphorous Site Index (2005) and the three interpretation categories of the UM Phosphorus Management Tool (2013).

P Loss Rating	P Site Index (2005) P Loss Rating Interpretation
0-50	**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 continued nitrogen-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 planning 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 based P 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 planning 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 based P 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. • No phosphorus should be applied to this site. • Active remediation techniques should be implemented in an effort to reduce the P loss potential from this site.

P Loss Rating	UM Phosphorus Management Tool (2013) P Loss Rating Interpretation
0-50	**LOW** potential for P movement from this site given current management practices and site characteristics. • Soil P levels and P loss potential may increase in the future due to continued nitrogen-based nutrient management. • Total phosphorus applications should be limited to no more than a three-year crop P removal rate applied over a three-year period.
51-100	**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. • Phosphorus applications should be limited to the amount of P expected to be removed from the field by the crop harvest immediately following P application or soil-test based P application recommendations.
> 100	**HIGH** potential for P movement from this site given current management practices and site characteristics. • No phosphorus should be applied to this site. • Active remediation techniques should be implemented in an effort to reduce the P loss potential from this site.

The UM-PMT is a planning tool. It is an integral part of the agricultural nutrient management planning process. It is not suitable for retrospective assessment purposes. Although many UM-PMT input components for a particular soil or field are fixed, plausible management decisions can be multiple and varied. The UM-PMT calculation should be run multiple times with various combinations of input data in order to identify the most efficient suite of implementable management practices that produce the lowest risk for P loss from the site. Following is a listing of the information needed to determine the UM-PMT.

Information Source #1: Farm Operator

- Soil-test P converted to Maryland Fertility Index Value (FIV) units from soil-test report
- Soil degree of P saturation (DPSM3) predicted by Mehlich 3 from soil test report
- Amount, analysis and type of P fertilizer applied
- Application method and timing of P fertilizer application
- Amount and type of manure, compost or biosolids applied
- Application method and timing for manure, compost, or biosolids application
- Manure, compost, or biosolids analysis
- Type and width of vegetated field buffers
- Crop rotation sequence
- Tillage rotation sequence
- Conservation practices such as strip or contour cropping, buffer strips, etc.
- Artificial drainage areas (drainage ditches, tile drains, or mole drains)

Information Source #2: Web Soil Survey

- Predominant soil mapping unit in the field
- Soil permeability class
- Soil drainage class
- Hydrology soil group

Information Source #3: Field Visit

- Distance from edge of the field to the nearest down gradient surface water (feet)
- Slope of field (length and steepness)

Information Source #4: RUSLE or RUSLE2 Calculation

- RUSLE “P” practices: ridge height, furrow grade, cover management condition, number of crop strips across RUSLE slope, width of crop and/or buffer strips

Following is an abridged overview of the UM Phosphorus Management Tool (UM-PMT) calculation of site-specific risk for P loss from agricultural production fields. For a more comprehensive description, see: McGrath, J.M, F.J. Coale and N.M. Fiorellino. 2013. University of Maryland Phosphorus Management Tool: Technical Users Guide. Extension Bulletin EB-405.

Equation 1. General equation for the UM-PMT

$$UMPMT = 0.1 * (SUBSURFACE + RUNOFF + PARTICULATE)$$

Where,

$$SUBSURFACE = SD * DPR_{sub}$$
$$RUNOFF = DBF * SR * DPR_r$$
$$PARTICULATE = DBF * SED * FIV$$

SD = subsurface drainage risk factor
DPR_{sub} = dissolved P source risk factor for subsurface losses
DBF = combined distance to water and buffer condition factors
SR = surface runoff transport factor
DPR_r = dissolved P source risk factor for runoff
SED = sediment transport factor derived from RUSLE or RUSLE2
FIV = soil test fertility index value

Equation 2. Calculation of the combined distance to water and buffer condition Distance Buffer Factor (DBF)

$$DBF = DF * BF$$

Distance from edge of field to surface water and resulting distance factor. Surface water includes any permanent, continuous, physical conduit for transporting surface water, including permanent streams and ditches even if they only flow intermittently during the course of the year.

Distance from Surface Water	Distance Factor (DF)
>500 feet	0.2
350 to 500 feet	0.4
200 to 349 feet	0.6
100 to 199 feet	0.8
<100 feet	1.0

Types of buffers and resulting buffer factors that modify the Distance Factor to yield the combined Distance Buffer Factor.

Type of Buffer	Buffer Factor (BF)
>50 feet permanent vegetated buffer meeting USDA-NRCS standards	0.8
>35 feet permanent vegetated buffer	0.9
<35 feet vegetated buffer or no buffer	1.0

Equation 3. Subsurface and runoff Dissolved P Risk source factor calculations.

$$DPR_{sub} = WSP_{app} + (2 * DPS_{M3})$$
$$DPR_{r} = WSP_{app} + (2 * DPS_{M3})$$

DPR_{sub} = dissolved P Risk source factor for subsurface drainage losses
DPR_{r} = dissolved P Risk source factor for surface runoff losses
WSP_{app} = Water Soluble P factor for applied P sources
DPS_{M3} = soil Degree of P Saturation by Mehlich 3 P/Fe+Al ratio

Equation 4. Water Soluble P application factor for subsurface and runoff dissolved P source risk factors. Summed over all application events.

$$\Sigma\ WSP_{app\text{-}sub} = \Sigma\ PSC * TP * AM_{sub}$$
$$\Sigma\ WSP_{app\text{-}r} = \Sigma\ PSC * TP * AM_{r}$$

PSC = P Source Coefficient for each applied P source. See Equation 5.
TP = total P application rate.
AM_{sub} = Application Method factor determined from physical placement and seasonal timing for subsurface loss pathways (range 0 to 0.8).
AM_{r} = Application Method factor determined from physical placement and seasonal timing for surface runoff loss pathways (range 0 to 0.8).

Equation 5. P Source Coefficient calculation.

$$PSC = 0.117 * WEP_{100}$$

PSC = P source coefficient for each P source
WEP = Water Extractable P for P source per Elliott et al., 2006.

Equation 6. Subsurface dissolved P discharge calculation.

$$SUBSURFACE = SD * DPR_{sub}$$

SD = Subsurface Drainage factor is a multiplicative combination of hydrologic soil group rating (range 1.0 to 1.2) and soil drainage class (range 5 to 8) resulting in SD range 4.2 to 8.0.
DPR_{sub} = Dissolved P Risk source factor for subsurface losses. See Equation 3.

Equation 7. Surface runoff dissolved P component calculation.

$$RUNOFF = DBF * SR * DPR_r$$

DBF = Distance Factor (DF) * Buffer Factor (BF). See Equation 2.
SR = Surface Runoff risk factor. A function of field surface slope (%) and soil permeability to water (inches per hour). Range 0.1 to 10.0.
DPR_r = dissolved P source risk factor for runoff. See Equation 3.

Equation 8. Particulate P transport component calculation.

$$PARTICULATE = DBF * SED * FIV$$

DBF = Distance Factor (DF) * Buffer Factor (BF). See Equation 2.
SED = Sediment transport factor based on RUSLE (Revised Universal Soil Loss Equation (USDA, NRCS). Range 2 to 10.
FIV = Soil test fertility index value.