Michigan Technical Note
USDA-Natural Resources Conservation Service

AGRONOMY #60
Subject: Michigan Phosphorus Risk Assessment, (Phosphorus Index, Version 2)
Date: August 2007 (REV October 2013)

Introduction

There are environmental concerns when phosphorus, from any source, is applied to a crop field and may be detached, transported, and deposited in surface water. The chief resource concern with phosphorus application is eutrophication, the process of surface water enrichment of nutrients.

The Michigan Phosphorus Risk Assessment (MPRA) is a field-level assessment tool designed to evaluate the relative potential for off-site movement of phosphorus into surface water, which can be included in the conservation planning process. The objective of the MPRA is to estimate potential risk from the existing or baseline condition and to provide the landowner with various mitigation practices to lower the potential risk.

History of the Michigan Phosphorus Risk Assessment

Lemunyon and Gilbert (1993) proposed the framework for the original Phosphorus Index (PI), which included factors for transport such as soil erosion, soil runoff potential and irrigation erosion, and factors for source such as soil test phosphorus value, fertilizer and manure application rate, method and timing. A weighting factor was assigned because all factors do not have the same influence on phosphorus loss. The overall PI value represented the cumulative site vulnerability to phosphorus loss calculated from the rankings of source and transport factors. Since the publication of this paper, 33 states have developed Phosphorus Indices for use in nutrient management planning (Weld, 2003).

The Michigan Phosphorus Index (PI), Version 1.0 was developed by a working group of scientists and technicians, representing Michigan State University, Michigan State University Extension, Michigan Department of Agriculture, Michigan Department of Environmental Quality, Technical Service Providers, and the Natural Resources Conservation Service (NRCS). This effort was led by Dr. Michael Gangwer, NRCS Nutrient Management Specialist.

The authors of the Michigan PI field-tested it on 75 crop fields in 11 Michigan counties in 2007.

Changes in NRCS National Nutrient Management Policy occurred in 2012, and required states to update their Phosphorus Indices for consistency between states. The tool was renamed the Michigan Phosphorus Risk Assessment Tool (MPRA), Version 2.0. It was developed from original field test data to meet national requirements and was released in the Michigan Field Office Technical Guide in January 2013.

Phosphorus Movement in the Landscape

The Michigan Phosphorus Risk Assessment includes the two primary factors influencing phosphorus movement: transport and source. Within these two factors are the following categories:

Transport

- Water erosion
- Runoff Curve Number (RCN), which reflects infiltration potential.
- Distance to surface water and/or surface inlet from field edge.
- Subsurface drainage.
- The presence and width of buffer practices.

Source

- Soil test phosphorus (STP).
- Phosphorus fertilizer method.
- Manure method.
- Phosphate rate from all sources.

The MPRA is built in Microsoft Excel as a stand-alone spreadsheet capable of one page printing per field evaluation. The nine categories listed above appear as rows (Figure 1). Each category is assigned one of five numerical risk scores; 0, 1, 2, 4, and 8. These risk scores are based on a 2X risk factor system, which assumes a curvilinear relationship. As each category is evaluated, the risk factor increase is greater on the right hand side of the matrix as compared to the left hand side. The factor scores of 0, 1, and 2 are relatively lower in risk than are the 4 and 8 scores. The development team chose this mathematical relationship based on the assumption that for each category, scores of 4 and 8 could be mitigated to a lower score.

Based on field observations, scores of 12 and 17 was selected as breakpoints. Planners will evaluate a field by placing the correct score for each category in the right hand column of the matrix. The values are automatically summed for each factor (transport and source) and then these are added for the MPRA Total score at the bottom right hand side of the matrix.

For all field evaluations, MPRA scores of 18 or higher indicate that there is a "High" potential risk of offsite phosphorus movement, and no manure can be applied to the field. A field that is "Medium" (between 12 and 17 points) is one that is managed by a landowner in such a way that the risk of moving phosphorus into surface water is low enough that water quality is maintained or enhanced. Manure can be applied at the **phosphorus** crop uptake rate for the current year's crop. A field that has a score less than 11 points is considered "Low" risk; manure can be applied at the **nitrogen** crop uptake rate for the current year's crop. To reduce the MPRA score, landowners can choose between different conservation and management practices, to lower their overall score.

Uses for the Michigan Phosphorus Risk Assessment

For Nutrient Management Plans and Comprehensive Nutrient Management Plans, planners must use the MPRA on a field specific basis. **The Michigan Nutrient Management (590) conservation practice standard requires the planner to use the MPRA to determine the phosphorus application rate**. It is a

tool of choice for crop fields identified by the planner and landowner for evaluation of transport risk of phosphorus into surface water.

There are two scenarios where there is an advantage to using the MPRA:

1. One scenario where the MPRA could be used for a crop field with soil test phosphorus (STP) concentration 75 to 149 ppm that has been selected by the landowner to receive greater than 2 years' crop removal phosphate. **The Michigan conservation practice standard Nutrient Management (590) does not allow application of more than two years phosphorus as manure unless the MPRA is used.** If the MPRA score is 11 or lower, the landowner can apply a rate of phosphate that is 3 to 4 years of crop removal. This strategy is useful for those manure volumes that are particularly high in P concentration, or the landowner is applying manure at frequencies greater than two-year intervals. One example is all phosphate requirements for an alfalfa crop in the next four years are applied just prior to seedbed preparation. This strategy is consistent with Michigan's Nutrient and Manure Generally Acceptable Agricultural Management Practices (Manure GAAMPs). The application rate will, at no time, be greater than the plant available nitrogen for the next crop in the rotation. **The MPRA does not allow manure applications on crop fields at a rate supplying greater than 4 years phosphate crop removal.**

2. **The Nutrient Management (590) conservation practice standard does not allow manure applications on crop fields with a STP $\geq$ 150 ppm, with one exception.** The Manure GAAMPs allow for application of on-farm generated dilute wastewaters (< 1% solids) to cropland if applied at rates that supply 75% or less of the annual phosphorus removal for the current crop or next crop to be harvested. **The Michigan conservation practice standard Nutrient Management (590) does not allow phosphorus application as manure to fields testing over 150 ppm (300 lb P/acre) soil test Bray P1 unless the MPRA is used.** If the MPRA score is 17 or lower, the landowner can apply dilute wastewater on fields with over 150 ppm soil test Bray P1. In addition, the Manure GAAMPs require the following: annual sampling of the applied wastewater to determine phosphorus content; soil phosphorus test levels must show a progressive decline over time; no other phosphorus can be applied to the crop field from other sources; when using irrigation as an application method, the GAAMPs for Irrigation Water Use must be followed; and tile drained fields must be monitored.

Limitations of the Michigan Phosphorus Index

The MPRA can be used by planners for evaluating all cropland fields where two nutrient sources are applied: fertilizers and animal manures. The MPRA does not provide evaluation of risk using any other organic material or biosolids. It is a qualitative measure of potential risk, not quantitative. The use of the MPRA cannot determine whether landowners or land managers are in compliance with water quality regulations or standards that have been established by local, state, or federal agencies. Any attempt to use this index for regulatory purposes is beyond the intent of this assessment tool and the concept and philosophy of the group that developed it.

The MPRA provides an estimate of potential risk of surface waters from phosphorus runoff, in either the soluble or adsorbed forms of phosphorus. It does not estimate risks to ground water. There is a factor for subsurface drainage, which estimates the risk of subsurface mass flow of phosphorus-containing drainage water that may reach surface waters via subsurface drainage outlets.

Descriptions of Phosphorus Index Categories

Transport

Erosion

Water erosion is predicted using RUSLE2. Planners will use the profile method and select the portion of the field that could potentially yield the greatest transfer of soil sediment off the field. A field may be segmented into smaller fields, e.g., the portion of the field next to surface water and the remaining portion of the field at some distance further from surface water. Planners will predict erosion on all segments using RUSLE2 or select the field segment under evaluation by the MPRA.

The MPRA, however, is based on the single crop year method. The rationale is based upon linking the MPRA with the actual field conditions at the time of evaluation rather than over the entire rotation. One example is the difference between erosion prediction on a corn silage field with no cover crop, and at some later year in the crop rotation when that crop field is in alfalfa.

The MPRA does not include wind erosion as a transport component.

Runoff Curve Number

The Runoff Curve Number (RCN) is a dimensionless number that ranks the relative infiltration, or water intake rate, of a field surface based on hydrologic group, land use, and farming practices. An evaluation includes identifying the soil map unit; predominant hydrologic group, e.g., A, B, C, or D (progressively lower intake rate and therefore greater potential for ponding on the soil surface); selecting the land use, e.g., cultivated crop land, permanent pastureland; and then selecting farming practices that define land cover description, e.g., straight row, cover crop. The RCN category is weighted to give a lower score for a lower RCN, which may favor infiltration of rainfall and liquid manure application into the soil. If the landowner can alter management practices that lower the RCN, the likelihood of surface runoff is lowered, thereby reducing the potential for P transport into surface water.

Planners will use the table given under the tab 'RCNSheet' in the MRPA spreadsheet to choose an appropriate RCN, after selecting the appropriate hydrologic group, the land use, and then the field land cover description. Planners will determine the land cover description based on fallow (bare soil), residue, or crop type (cover crop, row crop, small grain). Note that some hydrologic group soils with a B, C or D can be mitigated to an A if the field is artificially drained with subsurface tile.

Distance to Surface Water

Planners will measure the distance, in feet, that is the flow path distance to surface water from the field edge or the application edge if a setback is used. For instance, if the landowner normally uses a 100 foot setback of manure application as part of a CNMP, then this distance is used even though the field edge may be within a few feet of surface water. **However if the setback distance of 100 feet is fertilized with a P containing fertilizer, then the distance to surface water is adjusted to the application edge of the fertilizer application. The MPRA assumes equal risk potential from both sources of P.** Planners will note that in the source factor, the two sources are listed in terms of timing and placement. Landowners may use a manure setback, then apply fertilizer in the setback portion of the field so crop yield is obtained, then mitigate the distance to surface water in this category by adjusting the timing (within 2 days) and placement (inject or incorporate) in the source section. The landowner may shift to a

manure application in the setback area by the mitigation in the source section; this assumes the MPRA total score is acceptable (17 or less).

Subsurface Drainage

Subsurface drainage refers to the presence of artificial drainage that was installed in either a patterned (herringbone or laterals or parallels) or random method, approximately 3 to 4 feet below the field surface. Its purpose is lowering the water table especially during spring so internal drainage can occur more rapidly. The drainage system is emptied into surface water.

For the field evaluation, planners will determine if artificial drainage is present and, if so, is it random or patterned. Note the greatest risk for subsurface drainage is broken tile and/or blowouts. These may be mitigated to a 4 once the landowner repairs them. However, for many fields in Michigan, the presence of some artificial drainage will add points in the MPRA. Many farms may have fields that are completely drained with lateral drains emptying into ditches; these fields will be a 4 in this Index. The presence of artificial drainage cannot be mitigated.

The potential of P moving downward (from any source but more likely liquid manure) via cracked dry soils or through macropores in the soil matrix is a serious concern. This category was included in the MPRA because if the source is great enough (high application rates or high soil test phosphorus concentrations), P could enter surface waters through the artificial drainage system thereby degrading surface water quality.

Buffers

Vegetated buffers provide two benefits; they are effective at trapping sediment-bound P in runoff during an erosive event driven by intense rainstorms, and they provide a physical setback by extending the application edge some additional distance from surface water. Both benefits help mitigate the movement of P into surface water. For this category, planners will measure the width of the buffer in feet. If the field edge or application edge is greater than 300 feet, then no buffer is required for a factor score of 0. If the field edge or application edge is within 300 feet, then a 35 foot buffer will mitigate any risk and also carry a factor score of 0. If the field edge or application edge is within 300 feet and there is no buffer, this factor score of 8 carries the greatest risk.

Planners will also determine if there are surface inlets that landowners have installed for draining water from ponded areas of the field. These surface inlets carry the same risk as if they were surface water, given their function of transferring surface water into a subsurface drain that empties into surface water.

Landowners can mitigate an 8 score by installing some width of buffer. The width may be a function of how high the existing MPRA score is in relationship to the acceptable score of 17 or less. For instance, if the existing score is 19 with a 6-foot buffer and the landowner chooses to install a 20-foot buffer along the field edge (adding 14 feet of permanent vegetation), the score is reduced by 2 points. The field now has an MPRA score of 17, in the ‘Medium’ category.

The NRCS Filter Strip (393) conservation practice standard and Michigan Agronomy Technical Note #58, “Filter Strip Design Tables” are the guiding document for explaining the use of a vegetative area, or buffer, next to a sensitive area. The authors of this MPRA wrestled with defining a perennial crop like alfalfa or pasture as a buffer. Their conclusion is the planner will answer this question; the assessment criteria include the length and rigidity of the above ground biomass at the time of application, the slope of

the buffer area, and if the overland flow entering the buffer area is primary sheet flow that is the result of dispersing or mitigating concentrated flow.

Source

Soil Test Phosphorus (STP)

Soil Test Phosphorus (STP) is a prediction of soil phosphorus that will be readily available for crop uptake over the growing season. In Michigan, the Bray P1 soil laboratory method is used. Generally, the STP can increase if application rates of P, especially manure P, are much greater than crop removal and the existing soil is already high.

If current STP is below the agronomic threshold of 40 ppm, then large applications of P from either source (fertilizer or manure) have less potential transport risk than a soil with greater amounts of STP. Planners will use the STP concentration for the field or field segment. **Refer to the second scenario discussed earlier in the section 'Use for the Michigan Phosphorus Risk Assessment', for a discussion of rate limitations based on soil test phosphorus levels.**

P Fertilizer Method

The timing and method of fertilizer is evaluated in this category. Generally, as the time period of incorporation increases from application time, the risk increases. We assumed the source risk is a function of exposure of fertilizer on the surface of a crop field, along with the likelihood of transport during a rainstorm event. Fertilizer P is highly soluble as compared to manure P. Planners will note that the MPRA encourages injection at application or incorporation within 2 days. Also, note the score of 8 is used if the fertilizer application is surface applied greater than 15 days before planting, or, at any other time of the year with no incorporation.

Manure Method

This category addresses the timing and method of application of animal manures on crop fields. Planners will select the ranking score based upon placement of manure (method) with application timing. The MPRA encourages manure injection or incorporation within 2 days for a score of 1. The highest risk is incorporation of manure greater than 30 days after application. A fall application that is left on the surface over winter is an example. The rationale is based upon the exposure of manure P to detachment, transport, and deposition in surface water after the first rainfall event.

Landowners may choose a long-term surface application (example above) if the transport factors and other source factors yield a total PI score of 17 or less. Conversely, if the transport and other source factors are at a higher risk, then landowners may choose incorporation within 2 days after application rather than the long-term surface application.

No-till, including alfalfa and pasture fields that receive manure require a score of 8 for this category. Landowners may use an injection system for liquid manure, minimal tillage equipment such as Aerway or DynaDrive for both liquid and solid manure, or any kind of minimal disturbance harrow or cultivator that mixes the manure in the surface soil layer to at least the 2 inch depth. We do not want to discourage the use of no-till or mulch-till farming systems. We do recognize, however, that some form of manure-soil mixing helps reduce the potential of manure leaving the field surface after a rainfall event.

P_2O_5 Rate

The final source category is based upon application rates for both fertilizer and manure, expressed as units of phosphate. The phosphate rate the landowner chooses is based upon crop rotation or cost, or may select a higher application rate if other source and transport categories are low enough that the overall MPRA score is 17 or less.

Planners will select scores of 0 if no phosphate is applied. Planners will select 1 if the phosphate application is 1 or 2 years crop removal. Planners will select 2 or 4 if the phosphate application is 3 or 4 years crop removal. A phosphate application exceeding 4 years is not allowed. In Michigan, typical values range from 40 to 65 pounds per acre of phosphate removed at harvest. **Refer to the second scenario discussed earlier in the section 'Use for the Michigan Phosphorus Risk Assessment', for a discussion of rate limitations based on soil test phosphorus levels.**

References

Lemunyon, J.L. and R.G. Gilbert. 1993. Concept and need for a phosphorus assessment tool. Journal of Production Agriculture 6:483-486.

Weld, J.L. 2003. Summary of Phosphorus Indices. USDA- Agricultural Research Service. Pasture Systems and Watershed Management Research Unit, PSWMRU Available at: http://www.ars.usda.gov/sp2UserFiles/Place/19020500/PhosphorousImages/Summary_Pindices.pdf

Figure 1. Michigan Phosphorus Risk Assessment tool

Michigan Phosphorus Risk Assessment		April 8, 2013	Landowner:		Soil Test Phosphorus:	
Version 2.0, Nov. 2012	County:	Field ID:	Soil Map Unit:		Soil test date:	
	Township:	Section:	Developed by:		Baseline or Planned?	
Transport	**0**	**1**	**2**	**4**	**8**	**Select column**
Water Erosion (RUSLE2) Single Year	< 1 ton/acre-yr	1 - 2 tons/acre-yr	2.1 - 4 tons/acre-yr	4.1 - 6 tons/acre-yr	> 6 tons/acre-yr	0
RCN	< 75	75 - 78	79 - 82	83 - 86	> 86	0
Distance to surface water and/or surface inlets	> 300 feet	150 - 300 feet	100 - 149 feet	50 - 99 feet	< 50 feet	0
Subsurface drainage	no subsurface drainage		random subsurface drainage present	patterned subsurface drainage present	random or patterned subsurface drainage present with broken and/or tile blowouts	0
Buffers	buffer is permanent vegetation > 35 feet width from surface water and/or tile inlets, or > 300 feet from surface water and/or surface inlets	buffer is permanent vegetation 26 - 35 feet width from surface water and/or surface inlets	buffer is permanent vegetation 20 - 25 feet width from surface water and/or surface inlets	buffer is permanent vegetation < 20 feet width from surface water and/or surface inlets	no vegetative buffer from surface water and/or surface inlets	0
					Transport total	**0**
Source	**0**	**1**	**2**	**4**	**8**	**Select column**
Soil Test P	< 20 ppm	20 - 40 ppm	41 - 74 ppm	75 - 149 ppm	≥ 150 ppm *	0
P fertilizer method	no P fertilizer applied	P fertilizer injected or surface applied and incorporated < 2 days before planting	P fertilizer surface applied and incorporated 3 - 7 days before planting	P fertilizer surface applied and incorporated 8 - 15 days before planting	P fertilizer surface applied or incorporated > 15 days before planting, or no incorporation	0
Manure method	no manure applied	inject or incorporate manure within 2 days of application	incorporate manure 3 - 7 days after application, or surface applied on a growing crop	incorporate manure 8 - 30 days after application	incorporate manure >30 days after application, or no incorporation	0
P_2O_5 rate all sources	no P_2O_5 application (crop is harvested)	1-2 year P_2O_5 crop removal application	3 year P_2O_5 crop removal application ***	4 year P_2O_5 crop removal application ***	> 4 year P_2O_5 crop removal application **	0
*** If Field STP ≥ 150 ppm then no manure application allowed except for dilute wastewater (MDARD Manure GAAMPs)**					**Source total**	**0**
**** No P2O5 application greater than four year crop removal (MDA Nutrient and Manure GAAMPs).**					**MPRA Total**	**0**
***** P2O5 rate: manure application allowed this rate (3 - 4 years) only if MPRA is Low (≤ 11).**					**≤ 11 is Low; 12-17 is Medium; ≥18 is High**	