



The Minnesota Phosphorus Index



Assessing Risk of Phosphorus Loss from Cropland

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For more information

Visit <http://www.mnpi.umn.edu> to learn more about the Minnesota Phosphorus Index, and to download a current version of the program.

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The Phosphorus Challenge

Minnesota lakes and streams are a key part of the state’s economy and quality of life. When excess phosphorus (P) gets into surface water, recreational uses and aquatic life are impacted. The excess P causes increased algae growth. In turn, there is less clear water, lower oxygen content, and shading of aquatic plants that are habitat and food for fish and water fowl.

Excess P may come from many sources including municipal and industrial waste, urban runoff, septic systems, wind-eroded sediments, stream bank erosion, and runoff from feedlots and agricultural fields. This publication only considers runoff from agricultural fields.

Phosphorus is essential for crop production but can be lost to runoff from soil, plant residue, and surface-applied fertilizer and manure. The challenge is to keep phosphorus on the land and out of the water.

Many farm fields are not significant sources of P by themselves but contribute to the

cumulative P loss to Minnesota’s waters. Other fields are significant individual sources of P loss. This publication describes how to estimate P loss risk for individual fields and identify site-specific management practices that are likely to reduce risk.



Excess phosphorus in surface water reduces water quality for many uses.

The MN P Index and Other Assessment Tools

Direct measurements of P loss are rarely practical. Instead, models or indicators are used to estimate current or future P losses under various management scenarios (**Table 1**). Because models are mathematical representations of systems, the quality of an

Table 1: Phosphorus Loss Assessment Tools

	NRCS 590 standards and MPCA 7020 rules*	Rapid P Index	MN P Index
Type	Indicators and practices	Indicators	Mechanistic model of three pathways
Uses	To control major P loss risk factors related to manure application	To reduce the number of sites where the MN P Index will be applied	Farm nutrient management planning, and watershed planning to control P loss
Inputs	Distance to water, Soil test P, Erosion, Filter strip, Manure method and timing	Distance to water, Soil test P, Erosion, P fertilizer and manure rate and method	Distance to water, Soil test P, Erosion, P fertilizer and manure rate and method, Tillage type and direction, County, Crop rotation
Output	Manure application rate restrictions	Indicates whether field is above or below risk threshold	Relative rating of risk of P loss

*These are not primarily P loss assessment tools, but comprehensive feedlot and nutrient management guidelines.

estimate depends on the quantity of inputs. Thus, a user must choose between models that are quick and easy to use but only generate crude estimates, and models that generate higher quality estimates but require far more time to learn and use. The models in Table 1 estimate risk of P loss. More elaborate models, such as the Agricultural Non-Point Source (AGNPS) model, will estimate actual P delivery. In any case, interpreting model outputs requires understanding the assumptions and research behind the model.

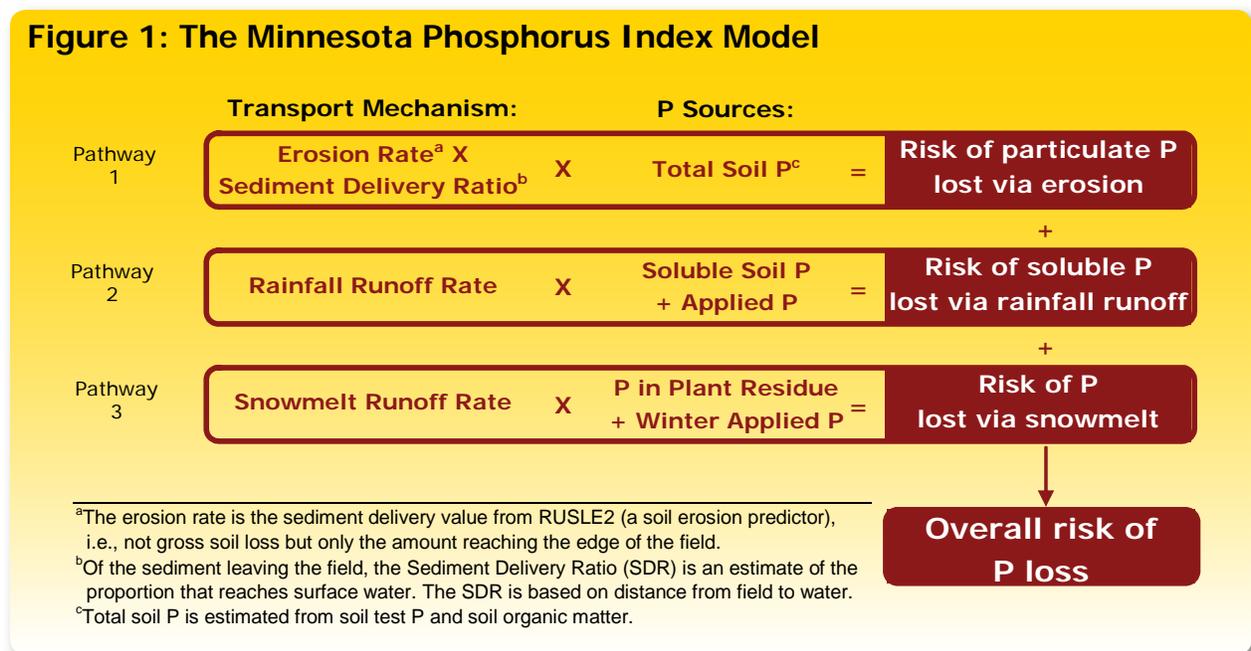
The simplest method for preventing P loss is to apply the requirements in the *Minnesota Pollution Control Agency (MPCA) Chapter 7020 Feedlot Rules* or the standards in the *USDA Natural Resources Conservation Service (NRCS) 590 Nutrient Management Standard*. These two documents provide comprehensive guidance for feedlot and nutrient management. They are not principally P loss assessment tools, but they include guidance aimed at preventing P loss and thus can be used to infer high risk situations. Manure application limits related to P loss are based on four to five

indicators: erosion rates, soil test P, distance to water, presence of vegetated buffers, and method of application.

The Minnesota Phosphorus Index (MN P Index) is a model with the primary purpose of estimating P loss risk. A computerized version of the model is available at <http://www.mnpi.umn.edu>. The MN P Index is used when a more accurate estimate is needed (e.g., on sites with multiple risk factors), or to estimate P loss risk unrelated to manure applications (e.g., to identify P loss sites within a watershed). The MN P Index helps users identify and refine site-specific methods to reduce P loss by considering the interaction of a wide range of risk factors including landscape characteristics, cropping and tillage practices, and P application methods.

The MN P Index assesses P loss risk by modeling three major pathways of P movement from fields to water: erosion, rainfall runoff, and snowmelt runoff (**Fig. 1**). For each pathway a transport mechanism is multiplied by P sources to calculate a P loss risk for that pathway. The three pathways are summed

Figure 1: The Minnesota Phosphorus Index Model





to get a total P loss risk value. Usually one pathway plays a bigger role in overall P loss risk than others. Management changes that address that pathway will be the most effective method for reducing the overall risk.

Phosphorus can travel by other pathways not considered by the MN P Index including leaching through the soil, which is generally a minor concern, and via wind or gully erosion, which can be significant concerns but are difficult to model at a field scale.

The MN P Index is a management decision-making tool. The inputs are easily available and it generates results that are reliable for making farm-level decisions or for watershed planning. The output is an estimate of the relative risk of P loss from a farm field, not a quantitative estimate of P delivery.

The strengths of the MN P Index are in comparing the level of risk between sites, determining how management practices affect P loss risk, and in assessing the interaction of risk factors that may not seem significant when considered alone.

How to Assess P Loss Risk

The method of P loss risk assessment differs for a farm manager planning practices that do not threaten water quality, and for a watershed planner identifying and addressing sources of P to a lake or stream.

Farm manure and nutrient management

Planning the location, timing, and method of manure application should begin with state (MPCA) regulations outlined in *Applying Manure in Sensitive Areas*. This document is based on the *MPCA Chapter 7020 Feedlot Rule* and the *NRCS 590 Nutrient Management Standard* (See *Resources*). The MPCA rules



Statewide, agriculture is one of several sources of phosphorus to lakes and streams.

pertain to anyone applying manure while NRCS standards are used by producers who are enrolled in NRCS-administered conservation programs and others who have requested nutrient management assistance. NRCS standards and MPCA rules consider nitrogen and pathogen concerns along with phosphorus.

After using the MPCA rules and NRCS standards, the MN P Index may be used to give producers more flexibility in some situations. Specifically, at the largest category of livestock farms, manure applications are generally not allowed in the winter or on soils testing extremely high in P unless the field is beyond 300 feet from lakes and streams and additional practices are installed to reduce P movement. In these situations, the MN P Index can be used to demonstrate that P loss risk is low. For more details about use of the MN P Index in these contexts, see the *MPCA 7020 Rule*, the *General National Pollutant Discharge Elimination System (NPDES) Permit* (the permit required for large feedlots), and the *NRCS 590 Standard*.

Watershed and Total Maximum Daily Load (TMDL) planning

Phosphorus loss risk assessment for a watershed involves two levels of effort. The first level is an assessment of the use of good stewardship practices that keep P on cropland



The MN P Index is a field scale tool. To analyze P loss risk from larger areas, analyze results from many fields within the watershed or farm.

and out of water. These include runoff and erosion control practices and the use of University of Minnesota recommended nutrient management practices (soil testing, applying fertilizer and manure at agronomic rates, timely incorporation, and appropriate setbacks).

The second level of assessment is identifying specific sites that may be the source of relatively higher amounts of P to a lake or stream.

The MN P Index can be used to identify high risk sites and to determine the management changes that will be effective in reducing P loss from both high- and low-contributing sites. The MN P Index is a field-scale assessment tool, so watershed-scale inputs should not be used and Index results should not be summed across a watershed. It should be used in tandem with other measurements and models that assess P loss for the whole watershed. The MN P Index can be used in either of the two ways described below to determine the relative impact of various fields and practices on P delivery within a small watershed.

What is “high risk”?

Generally, a site with a MN P Index value over 4 has a high risk of P loss. Users may set a different threshold depending on their objective and the sensitivity of the receiving water. A threshold of 2 or 3 may be appropriate if a lake or stream is highly sensitive to P or if watershed planners aim to eliminate most all P inputs.

Method 1: Field-based assessment

Step 1. Choose sites by using the *Rapid Phosphorus Index* (see page 10) to identify the low risk fields.

Step 2. Use the MN P Index computer program to calculate P loss risk for the remaining fields across the watershed.

Step 3. Examine the sites with high P loss risk. What proportion of the total sites have elevated risk? What factors are causing the higher risk?

Step 4. Test proposed solutions. For example, rerun all the scenarios assuming that a specific best management practice was adopted. Would there be significantly fewer high-risk sites?

Step 5. Monitor changes in the number of high-risk sites over time.

Method 2: Sensitivity assessment

Step 1. Consider the variety of landscapes and cropping systems in the watershed. For each input to the MN P Index program define a range of attributes that represents the watershed. For example, there may be two or three major types of soils and landscapes, a few crop rotations, two main tillage systems, and a couple of manure and fertilizer practices.

Step 2. Run the MN P Index program on scenarios using the defined input ranges.

Step 3. Examine results by using the *Export scenario data* function in the *File* menu. Which scenarios have the highest P Index? What factors or combinations of factors are most important in determining P loss risk in this watershed? For example, perhaps moderate manure applications are only a problem on one landscape type.

Step 4. Target the factors identified in Step 3 during data collection, monitoring, and education.



Education

The MN P Index can be used to help explain the movement of phosphorus across the landscape and to illustrate the effect of various management practices. Here are some examples of educational uses.

- Run scenarios in the MN P Index program with an individual or group of land managers. Allow them to choose the management inputs. Show how the changes do or do not affect the P loss risk estimate.
- Use the *Reports* function in the program to create graphs comparing the effect of alternative management practices for your local soils and cropping systems. Illustrate the effect of the interaction of multiple P loss risk factors.
- Use diagrams of the MN P Index model to explain sources and transport of phosphorus.

Using the MN P Index Computer Program

The basic steps of running the program are shown below. Consult the user's guide or online help for full instructions.

Gathering the inputs

Like any model, getting good results requires good inputs. A *Data Collection Sheet* is available at <http://www.mnpi.umn.edu>. Completing this form ensures you have all the information needed to run the MN P Index. Two important inputs are the distance to water and the description of the field slope.

Distance to nearest surface water

The user must decide what is the nearest body of water where P enrichment could be a problem. Generally, the nearest permanent stream, lake, or wetland is the primary water quality concern. In addition, any drainage ditch

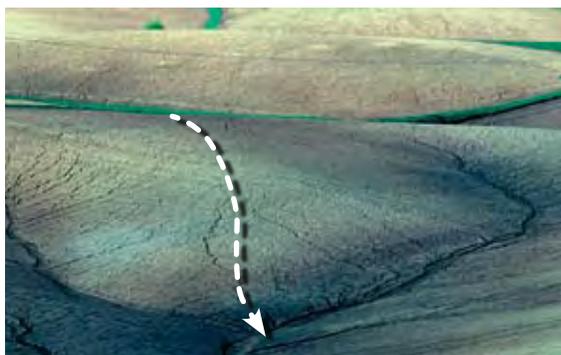
or other watercourse should be considered the nearest surface water if it is wet most of the year. In other words, if all of the phosphorus reaching a watercourse is likely to travel to a lake or stream, then that watercourse can be considered the “nearest water” for purposes of estimating P loss risk. If there is no concern about the water quality in a closed depression (i.e., water with no connection to other surface water), then it does not need to be considered the “nearest surface water.” Although some consider surface tile inlets a direct conduit to surface water, inlets should not be used as the “nearest surface water” in the MN P Index. Instead, indicate the presence of depressions with inlets. Due to their different method of P delivery, the program accounts for inlets and overland runoff separately.

Slope length and gradient

Erosion is an important cause of phosphorus loss, so a good erosion estimate is critical to

Running the Program

1. Download and install the program from <http://www.mnpi.umn.edu>. A user's guide is also available there.
2. When you start the program the first time, a “Quickstart Guide” will open to show the basics of the program.
3. Select “New” from the File menu to create a new field.
4. Double-click on the newly created field to open the Editor Window. Enter information about the site, the crop rotation, and tillage and manure management practices. Online help is available by pressing F1 or using the Help menu.
5. On the last page of the Editor Window (the Yearly Data and Results tab), decide how many years to evaluate. If there are heavy manure applications, run an evaluation for as many as 20 years to learn whether P loss risk increases as soil P levels build up.
6. View the P loss risk index results on the last page of the Editor Window.



Identifying a critical slope is an important step in generating a good erosion estimate and a good P Index estimate.

generating a good P loss risk estimate. The MN P Index program uses the *Revised Universal Soil Loss Equation 2* (RUSLE2) model to estimate erosion. An important input into RUSLE2 is the description of a cross-section of a slope in the field.

Estimates of erosion and P loss risk represent the whole field, yet only a single runoff path in the field is used to estimate erosion. This is appropriate because sediment and phosphorus are not lost evenly from all parts of a field, but come from a few critical source areas called the “most limiting areas of significant extent” (Minnesota NRCS, 2004). These are the areas of the field that most limit management because they have the greatest risk of erosion. Characterization and treatment of the field should focus on those critical areas, which are

generally the areas with the steepest slope. “Of significant extent” means that the “most limiting area” selected should represent the characteristics of at least 20% of the field.

After identifying the “most limiting area of significant extent,” determine the soil type(s) and define the length and percent of slope(s) for this area. The slope length begins where overland flow originates and the slope ends where concentrated flow begins (i.e., the location where sides of a hillslope intersect to collect overland flow in defined channels, such as grassed waterways or gullies). This hillside may contain several slope segments, such as a gentle gradient near the top of the hill, a steeper side slope, and then a gentler toe slope. Estimate the length and gradient of each slope segment, or determine a typical slope gradient and length for the soil type. Typical slope information is available from your local NRCS Service Center (see *Resources*).

People familiar with RUSLE2 should note that the MN P Index uses the sediment delivery value, not the soil loss value. Both are estimates of erosion. Soil loss is a measure of soil movement within the field and is used for conservation planning. Sediment delivery is a measure of the soil delivered to the edge of the field or to the end of the defined runoff pathway. Sediment delivery may be less than soil loss if a toe slope is included where some of the soil is deposited.

Table 2: Interpreting MN P Index Results

Total P Index	Risk Rating	Recommended Response
0 to 1	Very Low Risk	No management changes are recommended.
1 to 2	Low Risk	Minor management changes are recommended.
2 to 4	Medium Risk	Small improvements in management may be needed to lower P loss risk. Avoid practices that increase P loss risk.
4 to 6	High Risk	Moderate improvements in management are recommended.
>6	Very High Risk	Multiple and possibly large improvements in management practices recommended.

This is why it is sometimes important in the MN P Index to model a complex slope with multiple sequential slopes in the defined runoff pathway. RUSLE2 sediment-delivery numbers from the MN P Index should not be used for conservation planning because they 1) may be lower than soil loss values when a complex slope is used in the MN P Index, or 2) may be higher than values generated in the RUSLE2 program because the MN P Index simplifies the inputs to RUSLE2.

Interpreting results

What the numbers mean

The results of the MN P Index are an estimate of the relative risk of a field being a source of phosphorus pollution to a nearby body of water. They are not quantitative estimates of P delivery although they correlate with P delivery. Low, medium, and high risk can be defined as shown in **Table 2**, but the user may adjust these depending on objectives and sensitivity of the receiving water.

Management recommendations

In addition to the total result, note which pathway (erosion, rainfall runoff, or snowmelt) contributes most to P loss risk. This will allow you to identify which management practices will be effective at reducing the risk (**Fig.2**).

To reduce risk of sediment-bound P losses:

Decrease erosion by reducing tillage and increasing crop residue cover. Add sediment traps such as buffer strips, and reduce or prevent high soil test P levels.

To reduce risk of soluble P losses in rainfall runoff:

Decrease runoff by increasing surface cover, increasing infiltration, and by growing forages and other permanent vegetation.

Reduce manure application rates. Incorporate or inject all manure and fertilizer, and reduce or prevent high soil test P levels.

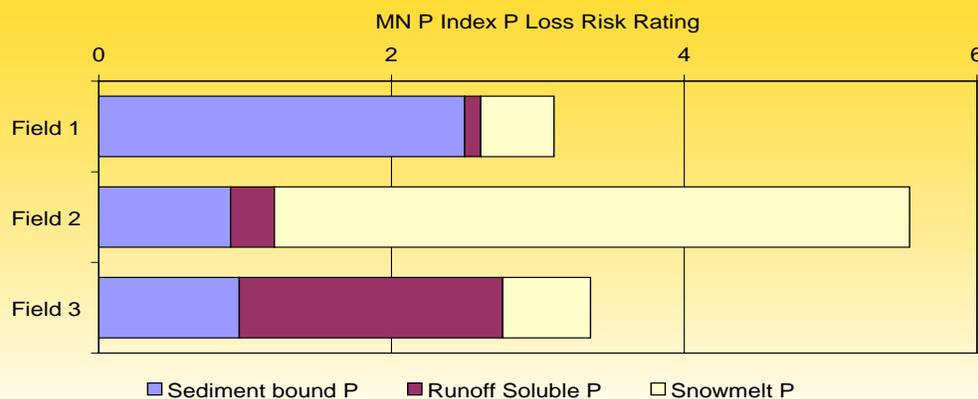
To reduce risk of snowmelt runoff P losses:

Eliminate application of manure on frozen ground. Leave soil surface rough in the fall and till across the slope rather than up and down.

Although P lost in snowmelt can be reduced by

Figure 2: Inferring Causes of P Loss Risk

This graph shows P Index results for three fields. Explanations for high risk can be inferred by noting which P loss pathway is dominant. For example, Field 1 has a moderate P loss risk with most of the risk coming from sediment bound P. This suggests high erosion rates. Field 2 has high P loss risk associated with snowmelt losses. The field may be in a high snowfall region and receiving winter manure applications. P loss risk in Field 3 is due to high runoff losses. Surface fertilizer or manure applications and rainfall runoff may be high.





more aggressive fall tillage, burying most of the crop residue is not recommended because residue is needed after planting to prevent erosion and P loss by the other two pathways.

After identifying a suitable management change, use the MN P Index program to test the effect of the management change on P loss risk.

Limitations of the MN P Index

The MN P Index does not account for non-agricultural P losses, losses due to leaching, or losses due to gully or wind erosion. Leaching losses are normally insignificant, but may be a concern on coarse, irrigated soils where soil test P or P applications are very high or on fractured soils with preferential flow channels that minimize the interaction of water with soil.

MN P Index results are correlated with P delivery but do not indicate the absolute amount of P that will be delivered to surface water. The relative risk ratings support decisions about whether a management change will have a substantial impact on reducing P losses. Risk ratings, however, do not allow for direct comparisons to other sources of P such as municipal waste discharge.

The MN P Index does not indicate changes in surface water quality because it does not consider sensitivity of the receiving waters, sources of P such as municipal and commercial waste, or P-rich sediments previously deposited in the lake or stream.

The MN P Index does not consider the environmental costs of P delivery to surface waters nor the cost of adoption of different practices to reduce P losses from specific fields.

The Rapid Phosphorus Index

The MN P Index is easy to learn and use but requires a modest amount of time for collecting input data. When many fields need to be analyzed, the *Rapid Phosphorus Index* (RPI) (**Fig. 3**) can be used as a screening tool to quickly eliminate the lowest-risk sites or to focus on the highest-risk sites where the MN P Index will be applied. The RPI is a set of indicators and thresholds based on the MN P Index. It will identify high risk attributable to major risk factors but will not assess interactions among multiple factors.

The inputs needed for the RPI include estimates of manure and fertilizer application rates, P application method, soil test P, erosion rates, distance to water, and quality of soil drainage. The RPI is three separate tools of varying sensitivity. The high-sensitivity version is used to eliminate only the lowest-risk sites. The low-sensitivity version is used to eliminate all but the very highest-risk sites.

Summary

Farmland can be a significant source of the phosphorus that causes excess algae growth in lakes and streams. This publication explains when and how to assess the risk of phosphorus loss from cropland using the MN P Index.

Runoff of phosphorus from uplands into surface water can be influenced by many factors, especially erosion rates, manure application rates, soil test P levels, and distance between the field and the surface water. These major indicators can be used alone to roughly identify sites that are likely to lose phosphorus. The MN P Index is a user-friendly model that allows users to analyze the effect of interactions among the major factors as well as other considerations related to climate, landscape, and management practices. The MN

Figure 3: The Rapid Phosphorus Index

Choose one of the three tools below. Check the appropriate box if a criteria is met. If any one of the criteria are met in any year of the rotation, then the full MN P Index should be run on the field to calculate a more reliable estimate of P loss risk. (Available on-line at <http://www.mnpi.umn.edu/>)

High sensitivity screening tool

If the site meets any of these criteria, the Total P Index may be greater than 2.

- Any amount of manure or fertilizer unincorporated
- More than 100 lbs P₂O₅/ac/yr manure and/or fertilizer incorporated
- Soil test P is >100 ppm (Olsen) AND soil loss is >3 t/ac/yr
- Soil test P is >100 ppm (Olsen) AND infiltration is slow (i.e., Hydrologic Soil Group is C or D, or soil is clay or clay loam and without artificial drainage)
- Erosion is >8 t/ac/yr
- Distance to water is <100 ft and erosion is >5 t/ac/yr
- Distance to water is <10 ft and erosion is >3 t/ac/yr

Moderate sensitivity screening tool

If the site meets any of these criteria, or two of the criteria in the high sensitivity tool, the Total P Index may be greater than 4.

- More than 100 lbs P₂O₅/ac/yr manure and/or fertilizer unincorporated
- More than 200 lbs P₂O₅/ac/yr manure and/or fertilizer incorporated
- Soil test P is >100 ppm (Olsen) AND soil loss is >3 t/ac/yr
- Erosion is >10 t/ac/yr
- Distance to water is <100 ft AND erosion is >6 t/ac/yr
- Distance to water is <10 ft AND erosion is >4 t/ac/yr

Low sensitivity screening tool

If the site meets any of these criteria, or two of the criteria in the moderate sensitivity tool, the Total P Index may be greater than 6.

- More than 200 lbs P₂O₅/ac/yr manure and/or fertilizer unincorporated
- More than 200 lbs P₂O₅/ac/yr manure and/or fertilizer incorporated AND erosion is more than 4 t/ac/yr
- Erosion is >10 t/ac/yr
- Distance to water is <10 ft AND erosion is >6 t/ac/yr

P Index can be used to estimate which sites are most likely to lose phosphorus and what changes in management practices would be effective in reducing risk.

The MN P Index is a process-based model of three pathways of P transport: erosion, runoff, and snowmelt. Noting which pathway is important in a particular situation gives users

information about what management changes would be most effective in reducing losses. The results from the MN P Index represent the relative risk of P loss. For example, a doubling of the risk value suggests P delivery is likely to double given the same set of weather events. The MN P Index results should not be used to quantify actual P delivery, but can be used to



compare the relative delivery from different management scenarios. The MN P Index is a model of transport of P to surface water and thus does not predict the effect of the P on water quality once it enters the stream or lake.

The MN P Index analyzes P loss risk at a field scale. However, farmers, conservationists, and watershed planners manage land at a farm scale or at a small watershed scale. The MN P Index can be used at these larger scales by comparing MN P Index results for all the fields in a farm or watershed, or by examining scenarios that represent the potential conditions in the farm or watershed.

The quality and usefulness of the results of the MN P Index depend on the quality of inputs. For example, the slope used to estimate erosion and the identification of distance to surface water significantly impact the MN P Index result.

The *Rapid Phosphorus Index* (RPI) is a set of indicators and thresholds based on the MN P Index. It is less powerful but quicker to use than the MN P Index. It can be used to reduce the number of sites by eliminating the lowest-risk sites or focusing on the highest-risk sites where the MN P Index will be applied. The RPI is based on the MN P Index but does not analyze interactions among multiple factors.

Resources

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