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The Nebraska Phosphorus Index (2012): Background And Users Guide

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This publication provides the basis and procedure for using a phosphorus (P) index to assess risk of P delivery from agricultural land to surface waters. The P index is intended for planning as well as regulatory and educational purposes.

Phosphorus is an essential nutrient for the growth of both crops and aquatic vegetation. Phosphorus, either in inorganic form such as with fertilizer or in organic form as with animal manures, often needs to be applied to the land for optimal crop growth. An important byproduct of animal feeding is manure that contains P. Land application of manure can be beneficial to crop production but can result in increased risk of P loss to surface waters. Fortunately, P is easily managed compared with nitrogen which can be easily lost to the environment through several pathways including leaching, volatilization, denitrification, emission of nitrous oxide, and runoff and erosion, while P loss to the environment is through transport by runoff and erosion with generally negligible losses through sub-surface drainage.

Phosphorus indexes are tools for the assessment of the potential for P delivery from agricultural lands to surface waters. Therefore, operators of large concentrated animal feeding operations (CAFOs) in Nebraska need to assess the risk of P delivery to surface waters from each field before manure can be applied by using a P index. This assessment needs to be done once every five years. The Nebraska P Index (2012) is a tool for risk assessment, land management planning, education of factors contributing to P loss, and regulation of P application to agricultural land. The Nebraska P Index was developed using the Iowa P index as a base (Iowa NRCS, 2004) with adaptation to Nebraska conditions and with revisions in consideration of current information.

Table 1. Source and transport factors that contribute to potential P loss from agricultural lands to surface waters.

Site and management factors	*Transport factors*[1]
Soil P level	Runoff volume
P application practices including time, rate, and method of application	Erosion from rainfall and snowmelt , and from irrigation
Field management practices such as tillage practices and use of cover crops	Distance from P source to concentrated water flow or a water body

[1]Other possible transport factors that are not considered in the Nebraska P index (2012) include surface and sub-surface drainage, percolation and underground movement of P to seepage areas, and atmospheric deposition that may be associated with wind erosion. These are relatively minor transport factors, as compared to runoff volume and water erosion, for P delivery from fields to surface waters in Nebraska.

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The P index considers source and transport factors to estimate P loss to surface waters. The source factors allow assessment of the quantity and forms of P present at the site (*Table 1*). The transport factors allow assessment of the potential for transport of P from the site to a water body.

The P index was designed to be used on the basis of a whole field or sub-fields. In many fields, risk of P loss is often considerably greater for one or more sub-fields than for the whole field. Sub-fields are determined by considering within-field variation that affects the P index rating, such as differences in soil type, slope, landscape position, tillage and crop management practices, crop rotation, manure application history, irrigation, conservation practices, soil test P, and yield. Where such variability in P index rating exists, the P index is to be applied by sub-field with subsequent manure management by sub-field, or with uniform management by groups of sub-field or on a whole field basis according to the limitation posed by the highest risk sub-field within this larger field. From here we will refer to sub-fields but realizing that assessment on a whole field basis is often justified.

The Nebraska P-Index (2012) is UNL Extension's recommendation for assessment of risk of P runoff from agricultural land based upon the state of the science. The soil sampling depth recommendation and the interpretation of the results are under review by the USDA Natural Resources Conservation Service and the Nebraska Department of Environmental Quality. Individuals using this version should confer with NRCS and NDEQ as to its acceptability for issues addressed by these organizations.

The Structure of the P Index

The Worksheets

The P index (*http://water.unl.edu/web/manure/software#pindex*) is developed as a spreadsheet to ease calculations. Tabs of five worksheets are found at the bottom of the screen.

1. **Nebraska P-Index** is the worksheet of greatest concern to the user. All data is entered here and the results are presented.

2. **Report** contains the summarized record of P index evaluations for up to 30 sub-fields. The records are numbered one to 30 and coincide with the run number at the top of the **Nebraska P-Index** worksheet.

3. **Ephemeral** is a worksheet that contains two tools for estimating sediment loss due to ephemeral gully (gullies of 3- to 18-inch depth) erosion. The first tool calculates an estimate of mean annual ephemeral gully erosion after entering values for total length of all ephemeral gullies in the sub-field and their average width and depth. The second tool automatically calculates an estimate of ephemeral erosion, considering the rate of sheet and rill erosion, location in the state and conservation practices. The user can access this worksheet from the **Nebraska P-Index** worksheet. Ephemeral erosion is very important to P loss on many sub-fields and needs to be estimated. However, the amount of gullies from ephemeral erosion is highly variable throughout the year as they are regularly closed with tillage and there is much year-to-year variation in ephemeral erosion. Therefore, the first option often cannot be used with accuracy and the second option is recommended.

4. **Landform Regions** contains an interactive map of Nebraska showing the regions. The user can access this from the **Nebraska P-Index** worksheet.

5. **Help and Instructions** contains information about the inputs as well as examples and links to other useful references.

The Components

The P index has erosion and runoff components which integrate source and transport factors to give component risk values. The irrigation and manure components modify the risk values for the erosion and runoff components. An estimate of sheet and rill erosion is calculated once data entry for a sub-field is completed. The sum of the risk value of both the erosion and runoff components is the P index score. It is shown at the bottom of the **Nebraska P-Index** worksheet.

The **erosion component** (potential delivery of sediment P to surface water) gives an approximate estimate of the P delivered in sediment (lb P/ac/yr) which will eventually be available for use by aquatic vegetation (Mallarino et al., 2002). It assumes that 70 percent of sediment P will become bio-available to aquatic vegetation over time. The erosion component is a function of six factors.

1. Rate of sheet and rill erosion is estimated in tons per acre per year. This erosion rate is best estimated with RUSLE2 but other means of estimating sheet and rill erosion, such as the Universal Soil Loss Equation or RUSLE1, may be acceptable. The Nebraska P Index (2012) does, however, calculate an estimate of sheet and rill erosion as a function of county precipitation, soil erodibility, slope length and gradient, cropping system, tillage practices, conservation practices, and irrigation; this estimate is accurate enough for most sub-fields.

2. Ephemeral gully and classical gully erosion (t/ac/yr) are estimated and prorated over the sub-field. The P index provides two tools for estimation of ephemeral gully erosion; see the section on the **Ephemeral** worksheet.

3. The sediment delivery ratio is estimated in consideration of land form, conservation practices, and the straight-line distance from the center of the sub-field to a water body or perennial or intermittent stream lying adjacent to or in the sub-field, or to the nearest road ditch or other man-made conveyance lying outside the field with a connection to intermittent or perennial streams, lakes or other water bodies.

4. Use of conservation practices is indicated by selection from a drop-down list, and credit is given to their sediment trap efficiency.

5. Phosphorus enrichment of runoff is estimated considering tillage, surface cover, and vegetative buffer or filter strip width.

6. Soil test P (STP; Bray-P1, Mehlich 3, or Olsen) is used to estimate total soil P (TP). Soil P becomes stratified with relatively high concentrations in the surface 1 or 2 inches with certain management practices. The soil sample depth is 0 to 8 inches for the Nebraska P index (2012) for many fields but is 0 to 2 inches (or soil test P for the 0- to 8-inch depth is multiplied by 2.5) if:[1]

    1) tillage is conservation tillage or no-till, including perennial grass or forage;

    2) applied P is not injected (e.g., for surface application of manure rather than injection of slurry manure); and

    3) STP is greater than 25 ppm Bray1-P. The equations to estimate soil TP for medium and fine textured soils are TP = 400 + (2.5 x STP) when using the Bray-P1 or Mehlich-3 soil test, and TP = 400 + (3.6 x STP) when using the Olsen test. For sandy soils, TP = 250 + (2 x STP) with the Bray-P1 or Mehlich-3 test, and TP = 250 + (3 x STP) with the Olsen P test.

The **runoff (water loss) component** estimates the amount of dissolved P (orthophosphate P and other dissolved P) delivered with runoff water. It is a function of:

1. Mean county precipitation and percent of rainfall events that are greater than 0.75 inch;

2. Runoff curve numbers which are calculated from soil property, land use, and management information;

3. An estimate of dissolved soil P (DP) estimated from soil test P where DP = 0.05 + (STP x 0.005); and,

4. P application rate, time, and method.

The **irrigation component** considers sprinkler and furrow irrigation. The runoff P risk factor is increased by 10 percent with sprinkler irrigation due to increased runoff potential should heavy rainfall occur when the soil is wet following irrigation. Risk with furrow irrigation is primarily due to increased erosion potential and the irrigation erosion factor is determined considering soil erodibility, rate of water flow (gal/min/furrow), furrow slope, use of polyacrylamide (PAM), and the presence of a re-use pit for recycling of irrigation water.

The erosion and runoff components are adjusted by the **manure component** which accounts for soil amendment due to previous applications of manure. The values for the erosion and runoff components are reduced by 2 percent per ton of the mean annual rate of manure application on a dry weight basis with the total reduction capped at 50 percent which would require an unrealistic mean annual application rate of 20 ton per acre of dry matter. Data cells for the **manure component** should be left blank if sheet and rill erosion is estimated using RUSLE2 as it already credits manure application for reducing erosion.

Interpretation of the P Loss Ratings

The P index risk value is the sum of the erosion and runoff components. The risk scores fall into four risk levels.

- **Low (0-2).** Current practices keep water quality impairment due to agricultural P pollution low. Manure can be applied at rates sufficient to meet crop N needs.

- **Medium (2-5).** Delivery of agricultural P may cause some water quality impairment and consideration should be given to alternative conservation and P management practices. Manure can be applied at rates sufficient to meet crop N needs **if the P index rating of the field or sub-field will not become high**[†].

[1]NRCS and NDEQ accept P-Index versions that do not adjust a 0-8 in soil sampling depth to represent the STP of the 0-2 in soil depth.

[†]The bolded parts of the interpretation for Medium and High risk are recommended by University of Nebraska–Lincoln Extension but are not yet in NDEQ regulations.

Table 2. Form for collection of data required to run the P index. Assessment may be on a whole field basis or on management zones within fields.

Field name	*County*	*Field area (acres)*	*Conservation practice*	*Ephemeral gullies (gullies 3-18" deep)*			*Distance (ft) field center to nearest water, stream or road ditch*	*Filter strip width*	*Land use/cropping system*
				Total length	*Mean depth*	*Mean width*			
West 1/4	Colfax	40	none	1,200 ft	0.5 ft	1 ft	600 ft	7 ft	Row crops, conservation tillage, no contouring

Soil type and slope	*Soil P*			*Fertilizer+manure P_2O_5 application,*		*Sprinkler irrigation*	*Furrow irrigation*				*Manure Application*		
	Test	*Depth*	*ppm*	*lb/ac/yr*	*Method*		*Rate gpm*	*Furrow slope*	*PAM*	*Reuse pit*	*Tons/ acre*	*# years*	*% Dry matter*
Nora silty clay loam 6-11 %	Bray	2"	95	100	Surf app	—	—	—	—	—	10	1	80

- **High (5-15).** Phosphorus loss from the field causes much water quality impairment. Remedial action, such as alternative conservation measures or P management practices, is recommended. Manure can be applied at a P removal-based rate to this field or sub-field **if recognized P best management practices are adopted to reduce the P index rating to medium within five years**[†].

- **Very high (>15).** Impairment of water quality is extreme and remedial action is urgently recommended. Phosphorus application should be discontinued. Improved conservation measures should be implemented.

Using the Nebraska P Index (2012)

Information is needed for each sub-field to calculate a P index value (*Table 2*). The information may be obtained from the farm operator, records and reports, and observation. The information is entered into the white cells or selected from drop-down lists in the pale blue cells of the **Nebraska P-index** and **Ephemeral** worksheets. This information is used to calculate the values appearing in yellow boxes. Phosphorus index values appear in yellow boxes at the bottom of the worksheet. Moving the cursor over small red arrows in the **Nebraska P-Index** worksheet opens notes that provide further explanation.

1. At the top of **Nebraska P-Index** worksheet, enter appropriate information including: sub-field name; option if more than one assessment is done for a sub-field such as to evaluate alternative management practices; person using the P index; the client; and the run number (1-30).

2. Select the **County** in which the field is located from a dropdown list. The P index then accesses relevant rainfall and soils information.

3. For **Landform Region**, choose from the dropdown list or select the correct part of Nebraska by clicking **Find Landform Region**. Click on a white number on the map for the correct landform region; this will return you to the main worksheet.

4. From the **Soil Type** dropdown list, select the predominant soil unit, including the correct slope class, for the sub-field. You may select your soil type by name or by map unit. The NRCS Web Soil Survey is an excellent tool to get soil type and slope information on specific fields.

5. For soil test P, select **Phosphorus Test** type (Bray-P1, Mehlich 3, or Olsen) from the dropdown list, select the soil sampling depth, and enter the soil test P level for the sub-field.

6. Select **Type of Irrigation** from the dropdown list. If furrow is selected, a blue box will appear where **flow rate** in gallons per minute per furrow and **furrow slope** can be entered.

7. Enter a value for **Manure Component**. Enter the typical manure application rate on an as-is basis. Enter the number of years between applications and the percent dry matter. The P index will then calculate the average annual application rate of a dry weight basis. If using RUSLE2 to estimate sheet and rill erosion, the manure component in the P index should not be used.

8. There are three dropdown lists for tillage and cropping system**.** In the **Tillage 1** dropdown list, select to indicate if the sub-field is tilled, no-till, or in perennial vegetation. This choice affects the options offered in the **Tillage 2** and **Cropping System** dropdown lists.

9. Enter the total mean annual **Application Rate** for phosphate in fertilizer and organic materials, e.g., manure, compost, and bio-solids. Select the application time and method from the dropdown list.

10. **Gross erosion** is determined next.

    a. Give estimates for **Ephemeral** and **Gully** erosion and the number of acres for the sub-field. Clicking on **Estimate Ephemeral Erosion** provides guidance and two options for estimating ephemeral erosion. Enter the number of acres in the Nebraska P-Index sheet prior to using option 2.

    b. An estimate for classical or perennial **Gully** erosion can be given. If such a gully exists in the field and has not been well stabilized, e.g., with perennial vegetation, seek assistance to estimate the mean annual rate of erosion due to cutting the gully wider, deeper, and/or longer.

    c. Give an estimate of mean annual loss of soil to **Sheet and Rill** erosion for the sub-field. The P Index has an erosion calculator which gives an estimate once all other information for the sub-field has been entered. To use this option, nothing needs to be done. If you have a more accurate number such as one determined using NRCS RUSLE2 or by other means, or obtained from the local NRCS office, the box can be overwritten.

11. Select a relevant **Conservation Practice,** such as terraces, from the dropdown list.

12. Enter the straight-line distance from the center of the sub-field to the nearest intermittent or perennial stream, canal or a road ditch, or to another surface water body if nearer than the channelized flow.

13. Select the **Grassed Filter Strip Width** from the drop-down list.

14. The overall **P Index Value** is given in the yellow box at the bottom of the worksheet. If you used the built-in sheet and rill estimator and the P Index Value borders on a risk class, e.g., between 14 and 16, you will receive a message indicating that actual RUSLE2 values should be used for a more accurate sheet and rill erosion estimate.

15. The **Nitrate Leaching Potential** can be qualified by selecting the time of nitrogen application from the drop-down list.

16. Click the **Add Result to Report** button to create a summary report, at which time you will be directed to the report. Click the **Report** worksheet tab to go back to this worksheet at any time in order to view, save and print one or more summaries.

Repeated scenarios can be run for a sub-field, changing management practices to assess the effectiveness of various management practices and combinations of practices. Each scenario is given a name and the data from the previous scenario can be carried forward so that only the variable or variables that are changed for the new scenario need to be entered. Detailed outputs for these scenarios are tabulated in a worksheet that can be saved and printed for further study.

Using the P Index to Compare Management Scenarios: Example

Consider the information presented in *Table 2* for a hypothetical sub-field to create a base scenario. For the information given, the P index score is 6.8 with a risk rating of *High*. Let's consider the effects of several alternatives on the base scenario. After each change, return to the base scenario before making another change.

1. If manure application continues and Bray P is increased to 160 ppm, the P index score is 8.6 with a risk rating of *High*.

2. If the land is protected with tile inlet terraces, the P index score is 1.4 with a risk rating of *Low*.

3. If 75-foot buffer strips are established between this field and concentrated water flow or the surface water body, the P index score is 4.3 with a risk rating of *Medium*. This score is near to the transition to *High* risk and the P index advised that RUSLE2 be used to more accurately estimate sheet and rill erosion.

4. If P (including manure) is incorporated within 24 hours of application, and assuming no increase in erosion, the P index score is 6.4 with a risk rating of *High*.

5. If distance from the middle of the sub-field to concentrated water flow is reduced from 600 to 150 feet, the P index score is 9.1 with a risk rating of *High*.

This publication has been peer reviewed.