A R K A N S A S

# Predicting Annual Phosphorus Losses from Fields Using the Phosphorus Index for Pastures

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Non-point P runoff from pastures receiving animal manure applications is believed to play an important role in accelerated algal growth in nearby water bodies. Therefore, concerns have arisen over proper P management. According to the Environmental Protection Agency (EPA) Concentrated Animal Feeding Operations (CAFO) draft regulations, manure application rates for P may be determined using soil test P levels, threshold soil test P levels, or a P Index (PI).

The original PI was implemented by the Natural Resources Conservation Service (NRCS) as a risk assessment tool for use across the country. The PI combines the effects of both P sources and P transport factors in determining the risk of P runoff. Several states are now modifying the original PI in order to better assess the risk of P loss in local regions. Some states are attempting to determine threshold soil test P levels above which animal manures or commercial P fertilizer may not be applied due to increased risk of P runoff. The objective of this study was to develop a PI for pastures in the Ozark Highlands.

Runoff studies showed that soil test phosphorus (P) is poorly correlated to soluble reactive P (SRP) runoff concentrations after P applications of manure and commercial fertilizer have been made. Soluble P in the nutrient source was shown to be the most important factor affecting P loss.

## Calibration Using Small Plots

Seventy-two small runoff plots (5 ft. x 20 ft., 5 percent slope) were constructed on a Captina silt loam at the University of Arkansas Agricultural Research Station in Fayetteville. Tall fescue was established on each of the runoff plots. Six runoff studies were conducted to determine the effects of the following treatments on P runoff:

1. Soil test P (six levels of soil test P)
2. Soluble P in poultry litter (four levels of soluble P)
3. P in diet [normal diet, phytase, high available P (HAP) corn, and phytase + HAP]
4. Fertilizer type [triple superphosphate (TSP; 0-46-0) vs. poultry litter]
5. Poultry litter application rate
6. Timing (first runoff event 1, 7, 21, or 49 days after fertilization)

Rainfall simulators were used to provide a 2 in./hr. storm event sufficient in length to cause 30 minutes of continuous runoff. Runoff water was collected and analyzed for SRP.

In order to obtain a wide range of soil test P levels, TSP was incorporated into 24 plots during construction at rates equivalent to 0, 344, 687, 1,374, 2,061, and 2,748 lb $P_2O_5$/A. Although these rates are high for pasture and hay producers without access to manure, the soil test P levels resulting from these rates are realistic and typically found in pastures which have received annual poultry litter applications for many years.

## Small Plot Research Results

**Study 1:** Average soil test P levels (Mehlich 3, 0- to 6-in.) were 233, 318, 439, 609, 737, and 946 lb/A following additions of 0, 344, 687, 1,374, 2,061, and 2,748 lb $P_2O_5$/A. The first rainfall simulation was conducted prior to any manure applications. Results show that runoff P concentrations are well correlated to soil test P (**Figure 1a**). Rainfall was applied to the same plots one week later, and a similar relationship was found (data not shown). Prior to the third rainfall simulation, poultry litter was applied at rates equivalent to 2.5 tons/A. No relationship was found between soil test P and SRP runoff concentrations after manure application (**Figure 1b**). However, a good relationship was found between SRP runoff concentrations and SRP concentrations in the litter applied (**Figure 1c**). These data provide evidence that P solubility of the litter is much more important in regulating P runoff than soil test P of recently manured fields.

**Study 2:** The effect of SRP in litter was determined using various rates of aluminum sulfate (alum). Mean SRP runoff concentrations were 0.88, 13.4, 15.1, and 26.0 parts per million (ppm) P for litter treated with 20 percent alum, 10 percent alum, 5 percent alum, and untreated litter, respectively (data not shown). Previous research (Self-Davis and Moore, 1998, *Better Crops*, Vol. 82, No. 4) has shown that alum additions to poultry litter reduced SRP runoff concentrations. Increasing litter alum rates resulted in reductions in SRP concentration in runoff.

**Study 3:** Diet manipulated litter resulted in the highest SRP runoff concentrations among all of the manure treatments. Total P application rates are listed in **Table 1**. Runoff P concentrations may be expected to be highest from plots receiving litter from the normal diet due to a high total P content. However, SRP runoff concentrations were actually highest from the phytase and HAP corn diets (**Table 1**). This is because SRP concentrations in the manure were highest in the phytase and HAP corn diets.

These results show that SRP

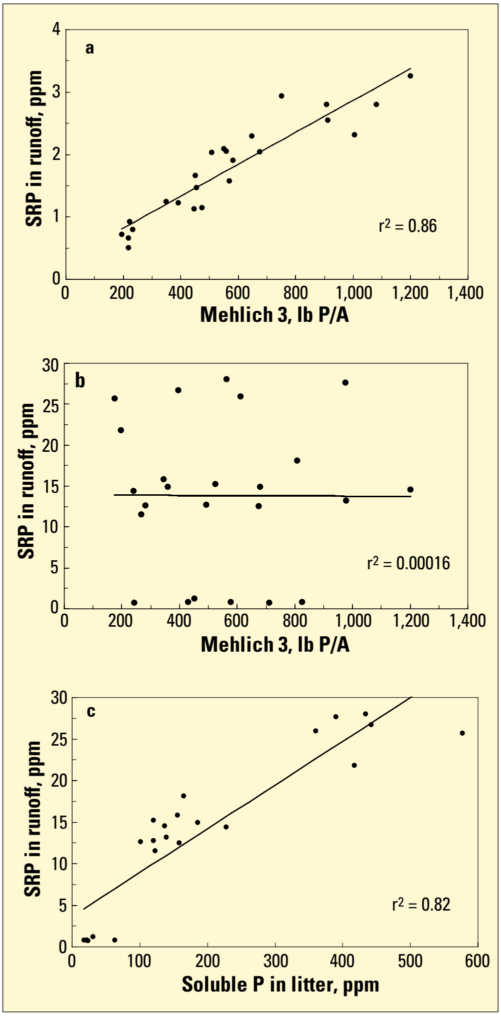


**Figure 1.** Effect of soil P on SRP runoff concentrations with (a) no manure; (b) manure application; and (c) effect of litter P solubility on SRP runoff, based on small plot research using simulated rainfall.

**TABLE 1.** Phosphorus application rates and P runoff concentrations of different poultry diets.

| Diet | Total P applied, lb/A | SRP applied, lb/A | SRP in runoff, ppm |
|---|---|---|---|
| Normal | 111.0 | 8.0 | 39.1 |
| HAP | 83.9 | 13.7 | 65.9 |
| Phytase | 66.5 | 17.9 | 84.6 |
| HAP + Phytase | 56.3 | 4.5 | 36.5 |

application rates are more important in affecting P runoff from pastures than total P application rates. Previous research studies have also shown that P runoff from perennial grass pastures is predominantly of the soluble form because there is little erosion and minor loss of sediment-bound P.

**Study 4:** Mean runoff SRP concentrations were 13.4, 26.0, and 103 ppm P for plots which received alum-treated poultry litter, normal poultry litter, and TSP at 160 lb $P_2O_5$/A (data not shown). This is expected since the P solubility of commercial fertilizer is much higher than that of animal manures. As much as 94 percent of TSP is SRP whereas only 2 to 4 percent of the total P in normal poultry litter is SRP.

**Study 5:** Runoff SRP concentrations resulting from three rainfall simulations increased linearly with increasing poultry litter application rates (**Table 2**). Soil test P levels were similar for each of the plots. Mean SRP runoff concentrations for the third rainfall simulation from plots receiving 1 ton/A rates remained higher than that of unfertilized controls, thus showing that soluble P of applied litter is an important factor in regulating P runoff even after three runoff events.

**Study 6:** Mean runoff SRP concentrations were 3.0, 8.8, 14.3, and 17.6 ppm P for 49, 21, 7, and 1 days until the first runoff event occurred after litter application. If several small, non-runoff storm events occurred before the first runoff event, then P runoff could be greatly reduced. However, data on large fields show that as much as 12 to 18 months may be needed to reduce P runoff concentrations to background levels. Applying poultry litter at times having a low P runoff risk, such as July or August, would also be the worst period to apply with respect to volatile ammonia nitrogen ($NH_3$-N) loss. Therefore, results from this study were not utilized to develop the P source term of the PI for pastures.

**TABLE 2.** Runoff P concentrations (ppm) from various poultry litter applications rates.

| Litter application rate, tons/A | Rainfall simulation, (Days after litter application) 1 (<1) | 2 (7) | 3 (14) |
|---|---|---|---|
| 0 | 1.2 | 0.9 | 0.9 |
| 1 | 8.8 | 5.2 | 4.8 |
| 2 | 16.6 | 8.9 | 5.4 |
| 3 | 27.8 | 14.9 | 8.2 |
| 4 | 33.0 | 20.0 | 8.8 |

**TABLE 3.** Phosphorus Index for pastures – interpretation and recommendations.

| Risk of P runoff | PI rating | Interpretation/recommendation |
|---|---|---|
| Low | < 0.6 | N based |
| Medium | 0.6 - 1.2 | N based |
| High | 1.2 - 1.8 | P based |
| Very high | > 1.8 | No P application |

## Pasture PI Development

The PI for pastures, based on the template initially proposed by the USDA-NRCS, is a multiplicative matrix that includes P source factors, P transport factors, best management practices (BMPs), and a precipitation factor. The PI for pastures is calculated from the four terms as follows:

PI = (P sources) x (P Transport) x (BMPs) x (Precipitation)

Data from runoff studies discussed above (Studies 1-5) were used to develop weighting coefficients for P source factors

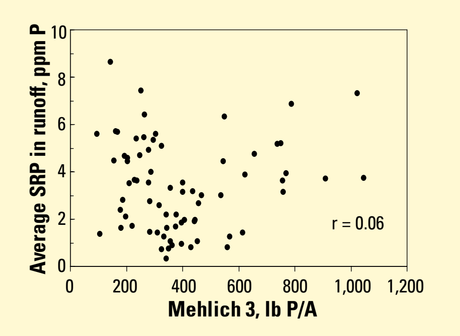


**Figure 2.** Relationship between Mehlich 3 P and SRP runoff concentrations from rainfall simulations conducted in farmer pastures.

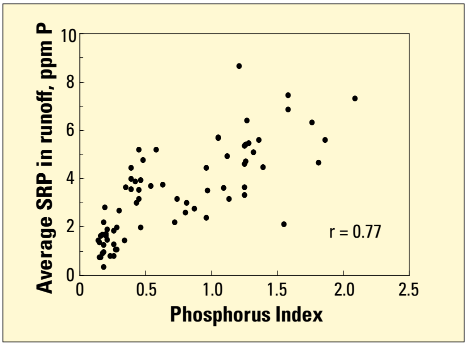


**Figure 3.** Relationship between the PI and SRP runoff concentrations from rainfall simulations conducted in farmer pastures.

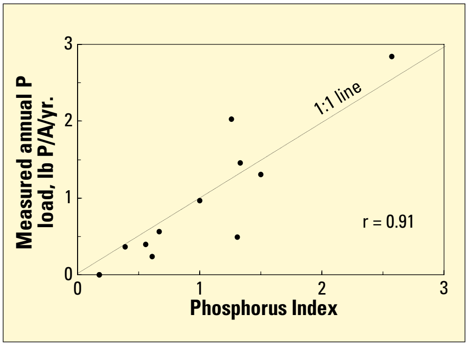


**Figure 4.** Relationship between measured annual P load from one-acre, pastured watersheds and the PI.

(soil test P and soluble P application rate). Multiple regression analysis showed weighting coefficients to be 0.000666 for soil test P and 0.404 for soluble P application rate.

Transport factors include soil erosion, runoff class, flooding frequency, application method, application timing, and grazing management. Based on the calculated PI, fields are assigned a class of low, medium, high, or very high potential for P movement. Once a high PI rating is achieved, it is recommended that nutrients be applied at rates no higher than current crop P needs. Furthermore, no P application should be made on fields having a very high PI rating (**Table 3**).

## Small Plot Validation of the Pasture PI

Validation studies were conducted on six farms of various forage cover and slope in Arkansas and Oklahoma. Twelve small plots were constructed on each farm, and portable rainfall simulators were used to provide a 2.8 in./hr. storm event. Plots were built on various soil test P levels determined from previous intensive soil sampling. Poultry litter was applied based on the PI for pastures to half of the plots and NRCS guidelines (no P application with 0- to 6-in. soil test P > 300 lb/A) to the other half. Litter was applied to provide PI values ranging from low to high. Six runoff events were conducted on each of the 72 plots, three before litter application and three afterwards. The average SRP runoff concentrations from the six runoff events at each farm were poorly correlated to 0- to 6-in. soil test P (**Figure 2**). This trend is similar to that found in runoff studies in the development of the PI. However, a much better correlation was found between SRP runoff concentrations and the PI for pastures (**Figure 3**). These results show that soil test P is a poor predictor of P runoff concentrations once manure is applied. The PI for pastures was a much better predictor of P runoff than soil test P, showing that P applications, as well as transport factors, should be taken into account.

## Watershed Validation of the Pasture PI

Although the PI was shown to be a better predictor of P losses, these studies were conducted on small plots under simulated rainfall. Therefore, annual P loads (lb P/A/yr) were measured for two 1-acre watersheds which had received litter applications annually since 1994. Each watershed is hydrologically isolated with earthen berms and equipped with flumes and automated water samplers. Since soluble P application rates were recorded each year, the PI could be calculated. Runoff volume, runoff P concentrations, and runoff P loads were measured each year. The relationship between measured annual P loads and the PI

*(continued on page 23)*

**TABLE 3.** Spring wheat grain yield response to Cl fertilizer (40 lb Cl/A) addition across the sites and years in Brandon, MB.

| Cultivar | Fine sandy loam 1996 | 1997 | 1998 | Mean | Clay loam 1996 | 1997 | 1998 | Mean |
|---|---|---|---|---|---|---|---|---|
| | Yield response, bu/A | | | | | | | |
| **Canada Western Red Spring** | | | | | | | | |
| AC Barrie | 7.5 | 7.0 | 5.7 | **6.7** | -1.0 | -0.2 | 0.5 | **-0.2** |
| CDC Teal | -0.7 | 4.9 | 3.8 | **8.0** | -5.2 | -1.2 | 2.1 | **-1.4** |
| AC Cora | 5.0 | -1.1 | 6.5 | **3.5** | -0.1 | 0.4 | 1.6 | **0.6** |
| AC Domain | 5.0 | -1.0 | 8.4 | **4.1** | 1.3 | 2.4 | -1.3 | **0.8** |
| AC Majestic | 10.9 | 3.5 | 1.1 | **5.2** | 2.8 | -1.8 | 1.6 | **0.9** |
| Roblin | 4.9 | 2.9 | 1.7 | **3.2** | -3.6 | -3.3 | 0.2 | **-2.2** |
| **U.S. Hard Red Spring** | | | | | | | | |
| Grandin | -5.5 | -0.4 | 4.8 | **-0.4** | -0.5 | 0.4 | -0.9 | **-0.3** |
| Pioneer 2375 | 6.6 | 2.2 | 1.9 | **3.6** | -3.3 | 6.8 | 0.4 | **1.3** |
| Marshall | 0.4 | 3.0 | 0.6 | **1.3** | -3.9 | 5.9 | -3.0 | **-0.3** |
| Guard | 0.0 | -3.0 | 6.2 | **1.1** | 0.5 | 5.8 | -0.6 | **1.9** |
| **Canada Prairie Spring** | | | | | | | | |
| AC Karma | 14.9 | -4.8 | 6.7 | **5.6** | 8.5 | 10.2 | 6.3 | **8.3** |
| AC Taber | -6.0 | 6.1 | 4.1 | **1.4** | -0.4 | -3.6 | -2.2 | **-2.1** |
| **Canada Western Extra Strong** | | | | | | | | |
| Glenlea | -3.9 | 4.8 | 1.8 | **0.9** | 1.2 | 5.0 | -1.7 | **1.5** |
| **Canada Western Amber Durum** | | | | | | | | |
| Kyle | 7.4 | -3.4 | 7.1 | **3.7** | 2.7 | 7.3 | -1.1 | **3.0** |
| Plenty | 9.0 | 7.5 | 2.2 | **6.2** | 1.9 | 3.9 | 5.5 | **3.8** |

the majority of the cultivars evaluated in this study. BC

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## Phosphorus Index... *(continued from page 19)*

is shown in **Figure 4**. Results show that the PI for pastures closely predicted annual P loads from pastures receiving natural rainfall and poultry litter applications (r=0.91). These results confirm that the PI for pastures predicts P loads well under field conditions with natural rainfall.

### Summary

Since P runoff from perennial pastures is predominantly soluble P, the SRP concentration in the source and the amount applied are more important than the total P content of the source. Validation studies showed the pasture PI predicts annual P losses very well from fields receiving natural rainfall. BC

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