Calibration of the P Index – Northern New York

Assessment of P fertility Status, P Release, Storage Capacity and Distribution

Annual Report, January 2005

Quirine Ketterings, Jason Kahabka, Karl Czymmek, Larry Geohring,
Peter Barney, Mike Hunter and Jen Beckman

Introduction

Phosphorus (P) from agricultural soils, fertilizer and manures can contribute to the eutrophication of lakes if it moves from fields into surface waters. New York State has taken numerous steps to help minimize agricultural nutrient losses to the environment, including the development and implementation of the New York Phosphorus Runoff Index (NY-PI). While many of the processes that drive P losses are physical, inherent chemical properties of the different soil series can be a significant source of variability in determining the risk associated with P loss. The current NY-PI uses the agronomic soil test P (Cornell Morgan P) as predictor for the contribution of the soil to P runoff and indicator of past management practices (application versus crop removal). What is the current status of P fertility for New York soils and how good of a predictor is soil test P for P release from our agricultural soils?

Trends in soil fertility status of Northern New York agricultural soils

Recent studies regarding New York State trends in phosphorus soil fertility (Ketterings et al., 2005) showed that the highest soil test levels occur in vegetable production regions on Long-Island and the highly productive dairy, vegetable and fruit areas in Western New York and that there has been a steady increase in the percentage of fields testing high or very high in P where agronomic P recommendations would be limited to no more than small starter applications (Figure 1). The greatest increases over time took place in the dairy-dominated northern and northeastern regions, and further analyses funded with Northern New York Agriculture Development Program funds showed that this increase was very well correlated to the increase in intensity of milk production (milk per acre cropland) (Figure 2). Over time, P accumulation in soils leads to increased P saturation levels of soils. The reason this is of concern is that this could lead to increased P runoff and leaching losses from agricultural fields to surface and ground water. *Thus, as these Northern New York soils reach progressively higher P levels, they may require more attentive management to ensure that environmental thresholds are not exceeded.*

Do soils differ and is soil test P the correct indicator for runoff/leaching risk?

The current NY-PI uses the agronomic soil test P (Cornell Morgan P) as a predictor for the contribution of soil P to runoff risk and indicator of past management practices (application versus crop removal). Our results on P trends show that soil test P is a good indicator of past management practices and that we need to monitor soil test levels over time and adjust our P application rates (whether from manure or from fertilizer) to avoid soils from becoming saturated. However, can we regard all soils to be equal? Can soil test P serve as an indicator of P release independent of other soil chemical characteristics?

Recent literature shows that soil chemical characteristics such as the amount of extractable Fe, Al and Ca, total sorption capacity of the soils and P saturation level may improve our predictions of P release from soils beyond what is possible with agronomic soil test P assessment only. Northern New York counties, as well as other parts of the state, are characterized by a wide diversity of soil series; and thus for more accurate P loss assessment it could be that we may need to incorporate soil specific characteristics in the NY-PI. Consequently, we set out to determine the extent of the differences in current P fertility status, P release, storage capacity and distribution over depth among 10 soil types in the 3 country region of Northern NY.

In 2004, we worked in conjunction with the with Cornell Nutrient Analysis Laboratory and the Western NNY counties to collect over 1000 soil samples from the region. We worked with collaborating field crop educators from Jefferson Co., Lewis Co. and St Lawrence Co. to select several representative soil series that are prevalent in their county's agricultural production areas. The main question was: do these soil series differ in soil chemical parameters that are thought to impact P dynamics. We selected a subset of 132 soils and analyzed those for Mehlich-3 extractable P, Al, Fe, and Ca (in addition to Cornell Morgan extractable nutrients). Although calibration studies are needed for accurate determination of the soils' sorption capacity, initial assessment of Mehlich-3 extractable Fe, Al, and Ca allows us to determine if soil series specific studies may be needed; i.e. whether or not it is likely that soil series differ in their ability to hold on to P.

The Morgan and Mehlich-3 soil test summary statistics were done (complete tables are shown in our 2005 progress report). If we look at Tables 3-5, we see a substantial range in Mehlich-3 Fe, Mehlich-3 extractable Al and ratio's of Fe to Al. With regards to Mehlich-3 extractable Fe, soils ranged from 92-301 ppm. The Farmington soils had the lowest average Fe concentrations. The highest Fe levels were seen for Rhinebeck, Herkimer and Muskellunge soils (Table 4). There was a substantial amount of variability among the samples within each soil series but the mean Al concentration of the four Croghan soils was significantly higher than those of the others soil series. Collamer soils also contained on average more extractable Al than the Farmington, Kingsbury, Galway, Rhinebeck, Hogansburg and Herkimer soils.

A decrease in extractable Fe and Al is generally seen with an increase in pH but for the soils investigated in this study, the inherent soil properties apparently have greater effects than pH. There is no correlation of extractable Fe with pH, and only a weak correlation for Al. Perhaps including more acidic soils would be beneficial to better quantifying this relationship, but other factors such as soil mineralogy and even the extraction method are also most likely involved.

Several studies have indicated that the extractable P levels of soils high in Fe are more likely to be impacted by the water saturation status of the soil rather than soils with correspondingly high Al levels. This is because phosphorus is released into solution when iron is reduced from Fe^{3+} to Fe^{2+} in saturated soils. Thus, the soils where P release is most likely influenced by soil moisture conditions are those with the highest Fe to Al ratio (Table 6).

Although extractable Fe can be indicative of sorption capacity as well, it is generally the much higher levels of extractable Al that are thought to dominate the P sorption capacity estimates (Table 4). Studies reported in the literature seem to suggest that P saturation may be a better predictor of P loss than agronomic soil test P levels. The results of our studies of the 10 NNY soil series shows that we may need to treat our soils differently (versus relying on soil test P only).

One issue that has not been studied much with regards to predictors of P sorption and holding capacities of different soils is the contribution of extractable Ca. However, it is known that P can precipitate as Ca-P forms in calcareous soils or in soils with a high pH and large amounts of extractable Ca. Preliminary data from laboratory studies using soils from a farm in Southern NY show that Ca should be included in sorption capacity assessment of soils. Therefore, we looked at exchangeable Ca and the molar sum of Al, Fe, and Ca as well.

Our 2004 soil sampling and analyses results to date show that the soils in NNY vary significantly in extractable Al, Fe, and Ca. This warrants studies that are soil series specific and raises question like: can we quantify how our soils differ in their reaction to additional P (either as manure or as fertilizer)? Or in other words: how much would a Morgan soil test P increase with P addition and how easily is that additional P released in solution? And the most important question, are there chemical soil characteristics that can be used as indicators for soil specific accumulation and P release dynamics? Additional research is needed to now relate these data to P saturation levels and the potential for P loss for the Northern New York Counties. *Our initial assessment points us towards the hypothesis that Northern New York soils do differ and it is our intention to investigate this further for the major soil series in 2005 with NNYADP funds*.

Rainfall Simulation Studies

In conjunction with the soil test evaluations described above, we used NNYADP funds to look at actual runoff from farm fields. The NY-PI is a management tool designed to rank fields based on their potential to create runoff P losses. Although laboratory studies are essential, validation and improvement of this tool requires also the direct field measurements of P losses. The objective of this part of our phosphorus studies was to determine actual P concentrations in runoff water from Northern New York farm fields under different management systems. A simulation approach was used to ensure that all sites would receive identical precipitation rates and to make certain that sampling could continue throughout the growing season with less dependence on the weather.

The protocol for the rain simulation was developed by the National Phosphorus Project to characterize the relationship between soil test phosphorus and surface runoff P. This protocol was chosen because it is designed to facilitate data collection on all major land resource areas in the US that receive manure, and allows New York data to be pooled with other research data for additional comparisons. A picture of the setup is shown below.

During the initial phase of this study three farms were selected based on their soil test P levels, soil type, proximity to surface waters and farmer interest in on-farm research. The selection of farms and fields was done with considerable input from field crops extension educators in Jefferson, Lewis and St. Lawrence counties. The sampling sites that we selected for our initial assessment are described in Table 9. At each site, we established 2-4 plots. Each plot consisted of a 2 x 2 meter frame (79 by 79 inches) pounded into the ground and bisected by a divider that split the main plot into two equal sized subplots. The downslope end of each subplot contained a runoff collection trough where water was collected for measurement.

Simulated rainfall was applied to the plots for three consecutive days at a rate of 4.15 cm hr^{-1} or 1.63 inches per hour. Water samples were collected from plots on days 2 and 3 during simulated rain events with the sample collection lasting 30 minutes from the time of initial runoff. This water was then analyzed for ortho-phosphorus, the directly available form of P.

The on-farm rainfall simulations were conducted over the course of three weeks, beginning at the Williams Farm in Lewis County on September 1 2004. Set-up and data collection at each farm takes approximately 4 days, including 1 day to install the plot frames, one day to saturate the soils and two days to collect runoff. This initial assessment gave us very valuable information for both understanding P transport and for further refining measurement technique. Both runoff volume and P concentrations in the runoff were measured.

One observation was that the extreme labor and capital requirements in collecting this type of data necessitate carefully focused research plans, a generally limited number of observational sites and a degree of innovation. To facilitate working in NNY where research sites may span across large distances, the project manufactured an improved rain simulator design that is permanently mounted on a trailer. This innovation allowed us to collect significantly more data than would otherwise be possible using the standard National Phosphorus Project equipment.

We propose to continue our rainfall simulation work using a carefully designed sampling schedule in 2005. The data are needed to place our laboratory studies and soil test P assessments in a wider framework of P dynamics and calibration of the NY-PI.

Outreach

To enable local communities to participate in the study and to increase awareness of phosphorus issues and ongoing research, field days were held in conjunction with the rainfall simulations. The Lewis County field day involved approximately 15 participants and was coordinated by Jen Beckman. Peter Barney arranged a field day in St Lawrence County with eight attendees on September 17 at the Greenwood Farm. The Jefferson County site was sampled beginning on September 21 with a field day arranged by Mike Hunter held two weeks later on October 5 to coincide with the FFA Land Judging competition. Over 250 students participated in a demonstration of the rain simulator and discussed phosphorus management. A field meeting later that same day drew a group of 10 people to learn more about efforts to refine the P index.

A newspaper article appeared in the Watertown Daily Times on the event that included the 250 students, further exposing the region to our work. Fact sheets were generated under leadership of Kara Dunn, NNADP, and in collaboration with us. Current fact sheets include:

- Why is phosphorus an issue for New York farms?
- Trends in soil phosphorus status.
- Developing a phosphorus index for NNY soils.
- Limiting phosphorus use for corn growing in Northern New York.

We created a website that lists our ongoing Northern New York projects and allows those interested to download extension documents such as the soil test summaries and the fact sheets: http://nmsp.css.cornell.edu/projects/nny.asp. We hope to expand the website with additional fact sheets and project updates and to will continue our on-farm work including local extension offices and the farming communities in 2005.

Major Conclusions to Date

- Northern New York soils are steadily increasing in soil test P levels
- The increase is correlated to the intensity of farming (most rapid increase in Clinton County where milk production per acre cropland has increased most over the past 20 years.
- Major soil series in Northern New York differ in the chemical composition (extractable Fe, Al, Ca).
- These differences are likely to cause soils to react differently to P application.
- On-farm rainfall simulations studies give us very valuable information for both understanding P transport and for further refining measurement techniques.
- Strong response to our outreach efforts demonstrates increasing grower interest in environmental and agronomic P management.

Proposed Work in 2005

- Whole farm nutrient balance assessment (6-10 farms, more depending on local participation in the assessment).
- Laboratory studies to quantify increase in soil test P and P saturation with addition of fertilizer and manure P; investigation of the role of extractable Fe, Al and Ca as predictors. This involves sampling of major soil series in the counties and incubation studies in the laboratory.
- Laboratory studies that let us relate soil test P, Fe, Al, and Ca to total sorption capacity and P saturation and P release (development of a tool that could possibly replace soil test P in the P index).
- Continuation of on-farm runoff assessments to link findings in the laboratory with in-field assessments of runoff.

Tables

Table 1: Distribution of soil test classifications for Northern New York agronomic soil samples submitted to the Cornell Nutrient Analysis Laboratory in 1995-2001.

County	No. of Samples	Soil test P classification for field crops Frequency, %				
		Very Low + Low	Medium	High	Very High	High+ Very High
Jefferson	2,526	32.1	29.2	33.5	5.2	38.7
Lewis	2,070	33.4	29.0	33.3	4.3	37.6
St. Lawrence	4,323	39.5	25.6	30.7	4.2	34.9
Clinton	6,034	20.5	23.3	41.7	14.5	56.2
Essex	1,180	41.4	36.2	17.4	5.0	22.4
Franklin	1,956	30.2	31.4	35.4	3.0	38.4
Total	119,326	27.7	24.9	37.3	10.1	47.4

Table 2: Acreage of major soil series in Jefferson, Lewis and St Lawrence counties.

Soil Series	Jefferson	Lewis	St Lawrence	Total
Muskellunge	4720	0	107811	112531
Nellis	12575	14082	0	26657
Collamer	29280	0	0	28280
Farmington	27920	7098	0	35018
Kingsbury	35960	0	0	35960
Croghan	0	6703	33815	40518
Rhinebeck	44635	1503	0	46138
Herkimer	0	5107	0	5107
Galway	42280	9811	0	52091
Hogansburg	0	0	78018	78018

Table 3: Characteristics of the field sites selected for initial rainfall simulation studies.

Farm	Plot	Cover	Soil Type	Slope (%)	STP
Greenwood	Plot 1	Alfalfa	Madrid	5	Very High
	Plot 2	Alfalfa	Madrid	5	Very High
	Plot 3	Alfalfa	Madrid	4	Very High
	Plot 4	Alfalfa	Madrid	6	Very High
Porterdale	Plot 1	Fallow Sod	Galway	10	Very High
	Plot 2	Alfalfa	Galway	4	Very High
	Plot 3	Alfalfa	Galway	6	Very High
	Plot 4	Killed Sod	Galway	8	Very High
Williams	Plot 1	Alfalfa	Kendaia	5	Very High
	Plot 2	Alfalfa	Kendaia	7	Very High

Table 4: Mehlich-3 extractable Fe (ppm)[1].

Soil Series	SMG[2]	N	Mean		Median	St Dev	Min	Max
Rhinebeck	2	12	200	a	194	54.4	136	301
Herkimer	3	10	182	ab	185	24.8	143	213
Muskellunge	3	15	181	ab	175	31.3	138	246
Collamer	3	14	173	bc	174	19.7	142	207
Nellis	4	14	173	bc	162	37.1	118	244
Hogansburg	4	14	170	bc	167	21.0	131	214
Kingsbury	1	15	169	bc	168	26.7	129	215
Croghan	5	4	161	bc	164	27.6	128	189
Galway	4	14	148	cd	138	38.4	107	240
Farmington	3	15	122	d	121	24.5	92	171

Table 5: Mehlich-3 extractable Al (ppm)[1].

Soil Series	SMG[2]	N	Mean		Median	St Dev	Min	Max
Croghan	5	4	1248	a	1366	274.1	839	1422
Collamer	3	14	1069	b	1035	111.1	905	1277
Nellis	4	14	1003	bc	966	200.1	619	1308
Muskellunge	3	15	948	bcd	917	200.4	659	1353
Farmington	3	15	905	cd	927	170.7	604	1308
Kingsbury	1	15	901	cd	899	186.5	628	1442
Galway	4	14	886	cd	821	212.4	661	1375
Rhinebeck	2	12	880	cd	881	128.9	697	1219
Hogansburg	4	14	865	cd	879	135.5	542	1082
Herkimer	3	10	836	d	777	139.5	660	1051

Table 6: Molar ratio of Mehlich-3 extractable Fe and Al (Fe/Al)[1].

Soil Series	SMG[2]	N	Mean		Median	St Dev	Min	Max
Rhinebeck	2	12	0.111	a	0.105	0.029	0.074	0.155
Herkimer	3	10	0.109	ab	0.108	0.028	0.070	0.149
Hogansburg	4	14	0.097	abc	0.089	0.022	0.072	0.162
Muskellunge	3	15	0.096	abc	0.091	0.024	0.066	0.151
Kingsbury	1	15	0.093	abc	0.096	0.020	0.061	0.129
Nellis	4	14	0.089	bc	0.081	0.037	0.044	0.190
Galway	4	14	0.085	cd	0.073	0.031	0.050	0.166
Collamer	3	14	0.079	cd	0.080	0.013	0.056	0.101
Farmington	3	15	0.067	d	0.061	0.017	0.050	0.110
Croghan	5	4	0.066	d	0.060	0.026	0.043	0.103

[1] Means followed by the same letter are not significantly different at $\alpha = 0.05$.

[2] Soil Management Group.

Figures

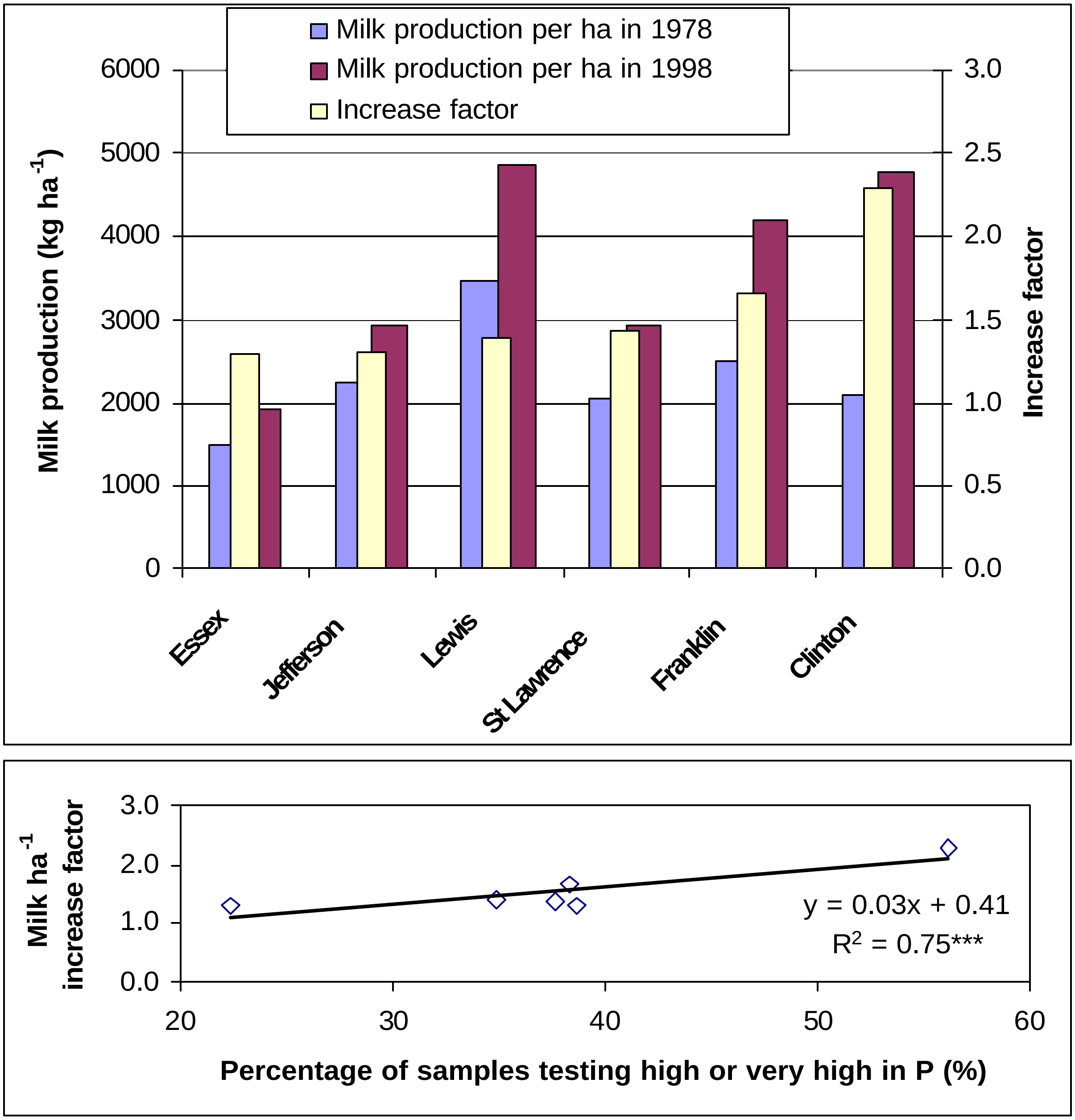

Figure 1: Percentage of the samples testing beyond the agronomic threshold and increase in milk production per area cropland for 6 dairy dominated northern and northeastern counties. Increase factors (ratio of milk production per acre cropland in 1998 and 1978) were derived from New York Agricultural Statistics Service (2003).

Photos

Rainfall simulation setup at Greenwood Farms.

Field days at the Williams farm in Lewis County (left) and at the Porterdale Farm in Jefferson County (right).