What's Cropping Up?

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Series: Phosphorus and the Environment

1. An Introduction to Phosphorus

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In 1999, "*What's Cropping Up?*" featured a series of articles on phosphorus (P) and agriculture. At the time, P and water quality was a big topic. New York had just released its first Concentrated Animal Feeding Operation (CAFO) Permit and the United States Department of Agriculture Natural Resources Conservation Service (USDA-NRCS), the New York State Department of Environmental Conservation (NYSDEC), and the New York State Department of Agriculture and Markets (NYSDAM) and Cornell University personnel worked closely together to frame up New York's version of the Comprehensive Nutrient Management Plan (CNMP) system. This system has continued to evolve and now serves the 4th generation of the New York CAFO Permit that takes effect in July 2017. The P and agriculture series was initiated in recognition of the role of P, not just as a necessary nutrient for crop growth, but also as a as a contributor of P in water bodies to such levels that it can support harmful algal blooms, excessive weed growth and other issues. Proper management of P as a resource is therefore essential, for both economic and environmental reasons.

The articles in the first series on P and agriculture made the case for the New York Phosphorus Index (NY-PI), a tool designed to help identify and better manage farm fields that are at high risk for P runoff. The first NY-PI, which was based on the principles set out in the series of articles, has served the state well, resulting in changes to rates, timing and application methods for manure, among other things. Through changes in fertilizer use and feeding practices on dairy farms, and changes in the way manure is handled, New York agriculture has significantly reduced P imports over the past ten years. Every pound of P not imported onto farms represents reduced risk of loss of P to the environment. Yet, we must continue to look for ways to improve P management on and off farms, to protect New York's water resources.

Here, we initiate a new series of articles entitled "Phosphorus and the Environment". Phosphorus as a topic of discussion had died down for a while, taking second place to nitrogen (N) in years with extreme weather. However, because concerns about harmful algal blooms have resurfaced over the past years, and P is usually the limiting nutrient in these freshwater systems, P has returned to the forefront for many. This series of articles will range more broadly than the first. We will address some basic soil P related issues, provide an update on statewide and Upper Susquehanna P balances, and have a closer look at whole-farm nutrient mass balances of dairy farms that are improving sustainability while maintaining or increasing productivity. We will discuss proposed revisions to the NY-PI as well, and touch upon some unconventional topics such as shoreline septic systems and characteristics of human waste, to keep P management at the landscape level in perspective. In this first issue, we provide a refresher on P basics and compare excretion of dairy cows to that of people in terms of total volume, N and P.

Phosphorus is an essential macronutrient which means that plants, animals, and humans cannot go without it; P is a structural element of DNA and it is used in energy transfer processes in plants. Within farming systems, where economic security is directly linked to crop yield, animal health, and milk or meat production, it is crucial these systems have sufficient levels of P. To ensure that farms have an adequate P supply to support healthy animals and crops, P often needs to be imported in the form of fertilizer and/or animal feed.

Phosphate rock is the main source for the P fertilizers that are applied on agricultural fields throughout the world. In its natural state, phosphate rock is not very soluble, making it somewhat ineffective as a direct fertilizer source. This is why phosphate rock is normally ground and treated with sulfuric acid to obtain more effective fertilizer sources like superphosphates. Phosphate rock is mined from pits, and the major part of the global supply is located within just a few countries, such as Morocco/Western Sahara, China, South Africa, United States, and Jordan. Over the past century, the global use of, and dependency on, P fertilizers has increased exponentially. In modern crop-based agriculture, the application of P fertilizers is often standard procedure. However, like other resources such as fossil fuels, sources for rock phosphate are finite. It is uncertain how long these sources will last and predictions about the size and availability of global P reserves vary widely. Some projections estimate that the world's reserves could be depleted within the next 50 years, whereas others expect they will last for

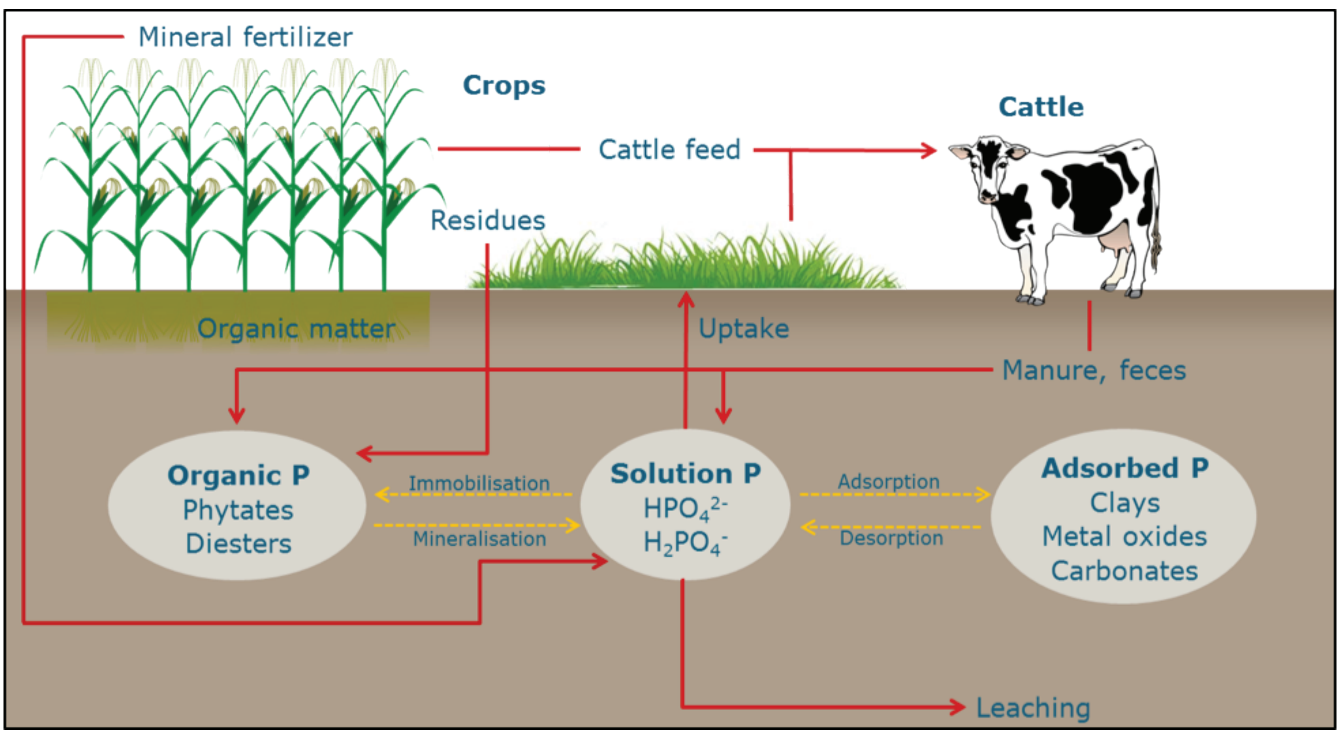

Fig. 1. Phosphorus cycle among mineral, organic and inorganic pools in the soil. Plants require P in solution for optimal growth and production.

fertilizer costs will increase over the coming decades. This, combined with the indispensability of P for agricultural productivity calls for careful use of the resource, which is prudent for long-term sustainability.

Distribution and application of mineral fertilizers and other P sources such as manure over the world varies greatly. This results in different P-related problems depending on location. In large parts of Africa and Australia, soils are very poor and contain little P. In these areas, low P inputs and strong binding of P to soil particles prevent plants from taking up enough P, which can strongly limit crop yield. In other parts of the world, such as temperate climate zones in North America and Europe, P fertilizers and manure have been applied consistently over a long period. For some farm fields, this has resulted in a substantial buildup of P in the soil beyond crop needs (often referred to as 'residual P' or 'legacy P'), which increases the risk of losing the P to the environment. In the case of animal manure, continued excessive application of fertilizer beyond what is already applied with manure can result in unnecessary loss of P to the environment. The application management of manure and fertilizer P can also contribute to P losses, regardless of soil test P level.

One way to improve P management (in cases of P excess as well as deficiency) is through a good understanding of P dynamics in soils. The soil contains many different pools of P. Plants however, can only take up P from the soil solution pool (Figure 1). It needs to be dissolved and in its inorganic form (orthophosphate). The fraction of P that is in solution (and thus directly available) is usually very small. With adequate soil P levels, crops can source much of the needed P from small amounts released from the soil supply over the growing season. This can occur through several processes, like desorption of P from binding agents such as iron and aluminum oxides and clays, the dissolution of P from calcium phosphates, or the mineralization of organic matter. These processes that determine the availability of P to crops all depend on soil characteristics such as pH, organic matter content and soil structure. This is why proper soil management, in addition to P source management (for example, not importing P if it is not needed for animal or crop production), is key to sustaining a healthy, profitable business.

Managing P in soils, on the farm, across the landscape, and in streams and lakes is an extremely challenging job. We need a better understanding of P movement and how management impacts P uptake by plants and loss to the environment, so we can reduce the risk of P loss and improve agricultural production. In the meantime, farmers and other members of the community will be called upon to take the steps they can to reduce P loading to our waterways, where P can be too much of a good thing.

Nutrient Management

Series: Phosphorus and the Environment

2. Setting the Record Straight: Comparing Bodily Waste Between Dairy Cows and People.

Michael Van Amburgh and Karl Czymmek. Cornell University Animal Science Department.

A lawsuit filed against the New York State Department of Environmental Conservation in March 2017 incorrectly compares the amount of waste produced by 200 cows to that produced by a city of 96,000 people. This error is more than 10-times too high and has been picked up and repeated by the media. In order to make a legitimate comparison it is necessary to answer the question: how much urine and feces are excreted each day by a dairy cow and a person and what are the nutrient contents of that excretion that are an environmental concern?

Background

Simply put, the type of digestive system along with the quantity of food and water consumed by an individual cow or human drives the quantity and *nutrient content* of what is excreted. Based on a survey of the scientific literature, there seems to be a lot more information about excretion by cattle than humans. For both cattle and people, the amount of fiber consumed determines fecal weight and volume. The human diet of North Americans and Europeans tend to be lower in fiber and higher in protein than humans in other parts of the world. Since cows are ruminants, they are especially adapted to extracting nutrients from high fiber diets that would not sustain a human. Cows have four stomachs and the first is a large fermentation vat, known as the rumen with a capacity of about 50 gallons, which produces billions of beneficial microbes that can digest high fiber feeds that cannot be digested by humans. The microbes help the cow to partially break down forages like grass, alfalfa and corn silage that comprise much of the diet.

A single mature dairy cow, depending on her breed, can weigh 900-1,800 pounds. Holsteins are the predominant dairy breed in NYS and mature cows can weigh 1,600-1,800 pounds. A 1,600 pound cow can consume about 120-170 pounds of feed per day or 52-62 pounds of dry matter (all water removed). Ultimately, this simply means that pound for pound, a cow excretes more feces than a human does. Similarly, urinary excretion is a function of fluid intake. The fact that cows are able to digest bulky, high fiber feeds that we cannot makes a direct comparison difficult. For this discussion, we compare excretion between cows and people in three different ways: 1) pound for pound of urine and feces (“wet basis”); 2) total nitrogen; and 3) total phosphorus.

Dairy Excretion Basics

According to 2016 data from the USDA Economic Research Service, the average NYS dairy cow produced more than 23,000 lbs of milk per year, or about 75 lbs of milk per day. Using a typical diet at this production level, total excretion of urine and feces as well as nitrogen and phosphorus was calculated using the Cornell Net Carbohydrate and Protein System (CNCPS) animal nutrition model. The CNCPS has been under development for more than 40 years, is based on numerous published scientific studies, is widely recognized to accurately predict how a cow will respond to a particular diet, and is used in the US and across the world to formulate diets for millions of dairy and beef cattle. In addition, because the model was developed to more accurately predict the nutrients required by the cow and the supply from the diet to meet these nutrient needs, application of the model has helped farms significantly reduce nitrogen and phosphorus excretion and related losses to the environment. According to CNCPS evaluations and predictions, an average mature milking cow producing 75 lbs of milk per day on a typical NYS diet generates about 63.5 liters of urine and feces per day (16.8 gal) and this contains 415 grams (0.9 lbs) of nitrogen and 57 grams (0.13 lbs) of phosphorus.

The Herd

The lawsuit analysis appears to be based on a herd of 200 milking cows and does not include calves and heifers. In NY and the Northeast, most dairy herds also raise calves and heifers as the replacement animals. For this analysis, we assume the 200 milking cow farm includes 140 calves and heifers. The calves and heifers do not consume as much feed and water as a lactating cow, and the CNCPS predicts their excretion and we converted them to a “lactating cow equivalent” for easier calculations. After considering the calves and heifers, the overall excretion is similar to 242 lactating cows so the comparison below includes this for a sensitivity analysis ensuring all animals on the farm are accounted for.

The People

In terms of human waste, there are a limited number of studies and the literature reports an extremely wide range of output across individuals. The data are actually much better for cattle than for people. The reference for human excretion data used in this analysis comes from a paper referenced below and is based on European diets, which are expected to be similar to North American diets. This paper provides the most clear cut statement of the median excretion volume of urine and feces by humans, as well as nitrogen and phosphorus content. The median daily excretion rate of feces and urine reported for humans is 1.51 liters (0.4 gallons) per day, for nitrogen, the rate is 11.9 grams (0.026 lbs) per day and for phosphorus, 1.5 grams (0.003 lbs) per day.

The Comparison – volume basis

On a volume basis in a direct comparison to the analysis in the court filing, a herd of 200 milking cows is about the same as 8,400 people, not 96,000. Even when the herd of 200 milking cows includes an additional 140 head of calves and heifers, the volume of urine and feces amounts to that produced by 10,736 humans.

The Comparison - Nitrogen and Phosphorus basis

On a nitrogen and phosphorus basis, the comparison changes because cows consume a bulky, very high fiber diet. Calculating the values on an N and P basis aligns with the way we evaluate manure for application as a fertilizer for crop fields. It is also in keeping with the regulations that are used to manage and monitor how manure nutrients are used at the field level for nutrient management plans. Using the per capita N excretion rate, the average human excretes approximately 0.026 lb of nitrogen per day, and compared to our 200 cow herd with calves and heifers, this equates to about 8,400 people.

For phosphorus, the average human excretes a very small amount of excess P because our diets are very digestible compared to a cow and we consume modest amounts of phosphorus to begin with. For our example herd, per cow excretion is about 0.13 lb of phosphorus per day, mostly in the feces. On a phosphorus basis, our example herd compares to 9,196 people.

Conclusion

Increasingly, there are calls to require farms to build wastewater treatment plants, like towns and cities have. However, there is one important, fundamental difference that should be considered: unlike our dairy and livestock farms in NYS, cities do not have a land base where nutrients are recycled. When people congregate in cities, they also concentrate nutrients that are excreted in our waste. It was not all that long ago that this waste was simply released into the nearest waterbody. Even today, despite the best efforts of the skilled people who manage wastewater treatment facilities, a significant quantity of human waste ends up in our surface waters. According to a 2004 report by USEPA, combined sewer systems (CSS's), annually discharge 850 billion gallons of sewage plus storm water, with a range of 3-10 billion additional gallons of undiluted sewage from sanitary sewer overflows (SSOs). The report also states that while large cities like New York, Philadelphia, and Atlanta have CSSs, most communities with combined sewer overflow problems have fewer than 10,000 people. Even when functioning properly, discharge from municipal wastewater treatment contains a portion of the phosphorus from human waste. These plants also generate sludge that must be land applied or sent to a landfill. Additionally, most homes outside of towns and villages utilize on-site septic systems that can also be sources of contamination.

NYS requires each regulated dairy and livestock farm to have a nutrient management plan ensuring, at a minimum, that there is an adequate land base for nutrient recycling and includes prescribed manure rates and practices to reduce risk of loss. Just as municipal treatment plants cannot always guarantee losses will not occur, farms are in a similar position. Many farms strive very hard to keep nutrients on the land and they continue to look for better solutions to make best use of the nutrients from manure to replace fertilizer required for optimum plant growth.

By averaging all three methods in our calculations above, waste from the 200 cow example herd compares to 9,444 people, substantially below the figure provided in the lawsuit. To make sound policy decisions, we need a picture of the true value of these systems that is as accurate and complete as possible. Making comparisons like the one presented here in a careful and precise way, is key to preventing misconceptions that can have big and potentially detrimental impacts.

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Series: Phosphorus and the Environment

3. Protecting Our Lakes: Shoreline Septic System Concerns.

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Nutrient Management

Introduction

Phosphorus (P) chemistry is very complex in farm fields as well as streams and lakes. Only a small portion of the total quantity of P in the environment is bioavailable, meaning that it is readily available to living organisms. In this article two methods or tests that water chemists use to measure P are referred to: Total Phosphorus (TP) and Soluble Reactive Phosphorus (SRP). The TP represents most or all of the various forms of P that are present, while SRP is a fraction of TP, representing what is immediately available to organisms in the lake. The SRP acronym is often used as shorthand for bioavailable P. There are other forms of P considered by scientists, such as Dissolved Organic P (mostly available) and Particulate P (partial or limited availability), but these are topics for another time.

In the temperate freshwater ecosystems found in this region, P is usually the nutrient that limits algae growth. As water temperatures rise in the summer, SRP tends to be in such high demand that it is very rapidly used by lake organisms. The natural P cycle in a lake creates a continuous source of SRP used by water life. Lake-recycled SRP in the upper waters is supplemented when a summer storm carries a fresh surge of P, some of which is SRP, from the land (watershed) that drains into the lake. While it is critical to manage all forms of P that reach a lake (readily available or not), for the most part, it is the quantity of that bioavailable SRP supplied from and to a lake that feeds the organisms and drives algae blooms. Paying attention to and understanding all SRP sources is an important part of lake management.

It is well established in the scientific literature that runoff from a watershed, including farms and forests, contributes to the TP and SRP loading in lakes. This has been well publicized in communities across the Finger Lakes region as well. While significant attention has been devoted to agricultural contributions, the serious nature of water quality challenges that have been observed in recent years requires a better understanding of all watershed sources of P. This third article in the Phosphorus and Environment Series focuses on P sources from septic systems on lake shores.

Septic systems

Many people dismiss the notion that septic systems can have an impact on the lakes. After all, the quantity of nutrients shed by any individual human directly to lakes is small and local agencies may report rigorous testing and a record of high compliance for shoreline septic systems. While it is widely believed that a septic system is working properly so long as effluent does not show up on the surface, what goes on underground, unseen, may be a real concern. Septic related outbreaks to the yard surface are not the only indicator of poorly functioning or failing systems, and for a variety of reasons, the situation for shoreline septic systems may be more complicated. For a general review of shoreline septic system issues, see: http://waterquality.cce.cornell.edu/septic/CCEWQ-YourSepticSystem-Shoreline.pdf. A broad description of P and onsite wastewater systems is provided in an article by the National Environmental Services Center (2013) and can be found here: http://www.ct.gov/dph/lib/dph/environmental_health/pdf/pipeline-wastewater_issues_explained_to_the_public.pdf). This second article indicates that many shoreline communities with closely sited homes and leach fields in well-drained soils that are close to the shoreline have experienced problems with noxious algal blooms (page 6).

For septic systems, part of the issue lies in how they are designed to work. For many non-sewered homes, all the drainage from toilets, showers, laundry, sinks and dishwashers flow into a septic tank. Liquids are held here temporarily, while the solid materials settle in the tank. The solids should be removed every 1-3 years (if not, then the system risks failure or is in such porous soil that it is likely not properly treating the waste). Liquids pass through the tank and are distributed to a leach or drain field through pipes with drainage holes that distribute the liquids into what should be moderately permeable soil. In the right conditions, soil chemistry and biological activity are expected to treat the nutrients and bacteria released from the system. To ensure proper treatment, much of the focus for septic system function relates to making sure the soil drains sufficiently well that the liquids do not rise to the surface, yet does not drain so rapidly that poorly treated liquids reach the water table.

Problems can arise when septic systems are installed into well-drained situations, especially on shorelines, where the water table is often close to the soil surface and where the separation distance of 100 feet from the leach field to the surface water (New York State Department of Health, 2016) cannot be met. Lakeshore soils can be variable but there are many areas of gravelly, well-drained soil types near shorelines with unsuitably rapid percolation rates that are close to the water table. Other shoreline locations may have shallow bedrock or rock outcrops with cracks that allow liquids to pass with little or no treatment. Lakeside property owners have reported finding older cottages and camps with perforated 55 gallon drums for disposal systems with little or no pipe distribution system for a leach field at all. The only way these systems could have worked, often for decades, is if they were (or are) sitting in very porous material which implies that septic flows could be in direct contact with the lake. In other cases, old systems, overuse and other factors suggest that septic systems along local lakes can contribute SRP to the water that promote near-shore algae and nuisance aquatic vegetation growth. Some newer full collection systems may contribute as well if they have difficult to detect (and illegal) overflow/bypass connections.

Another key part of the issue lies in the characteristics of the P in human urine and the P content of septic outflow. First, about 2/3 of the P that humans excrete is in urine (Meinzinger and Oldenburg, 2009) and this P is highly bioavailable (Kirchmann and Pettersson, 1995). According to the National Environmental Services Center (2013), the median TP level in the liquid that flows out of the typical septic tank measures about 10 parts per million (ppm). It is unclear how much of septic outflow is in the SRP form, but since the P we excrete is highly bioavailable, it seems probable that a portion of the P in septic outflow is also highly bioavailable.

Changes have occurred in intensity of use of shoreline septic systems over the years. Many seasonal camps have been removed and replaced with larger, year-round homes. Properties that were single family with 3 or 4 children in the 70's and 80's are now shared by multiple families. Also, many properties are rented and now occupied up to 7 days per week, sometimes week after week. The increased "person days" on shorelines may be contributing to the changes in water quality that have been observed in some locations.

Considerations for Owasco Lake

A review of the USDA soil survey for Cayuga County shows that all of the major Owasco lakeshore points sitting at the mouth of streams south of Buck Point and Martin Point are mapped as having well-drained soils, and many of these locations consist of soils that are described as having a significant gravel content. Such soil conditions are identified as a risk for water pollution by various reference sources, and there may be other locations along the shore with soil conditions that are not well suited to septic treatment.

According to the 2016 Owasco Lake Report (Halfman et al., 2016), the NYSDEC threshold for impairment is 20 parts per billion (ppb) TP, and the lake-wide summer average TP has been approximately 15 ppb for the last few years. In comparison, 10 ppm TP median septic outflow is 500 times the TP impairment threshold of 20 ppb, and approximately 660 times the lake-wide summer average TP of approximately 15 ppb (Halfman et al., 2016). Given that septic outflow P concentration is hundreds of times higher than lake-wide summer average TP, and combined with the high bioavailability of P in our urine, it seems very possible that poorly functioning septic systems can be an important contributor to lakeshore hot spots of SRP that support algae and nuisance weed growth.

It should also be noted that several lakes with TP levels below 10 ppb, much lower than Owasco Lake, have also experienced algal blooms in recent summers, suggesting that TP for the lake may not be the best algae growth indictor and that SRP from shorelines or other sources could be involved. A better understanding of P in our water bodies is critical.

In Summary

In the short term, when it comes to growing algae and weeds in our lakes, the quality of P may be more important than the quantity: SRP represents the main form of immediately available P that is used by nuisance weeds and microorganisms such as the cyanobacteria that contribute to harmful algal blooms. Human urine contains a high proportion of bioavailable P and shoreline septic systems are often in close proximity to the water and may be situated in unsuitable soil conditions. The series of factors described here suggest that shoreline septic systems can contribute to elevated levels of SRP in our lakes and further investigation is warranted. As we work to understand and manage P from all sources, including agriculture, addressing shoreline septic contributions will be an important part of the solution.

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Nutrient Management

Series: Phosphorus and the Environment

4. Greatly Improved Nutrient Efficiency Demonstrates New York Dairy Farmers' Environmental Stewardship

Lisa Fields, Cornell Nutrient Management Spear Program Contract Writer

The deadline has been looming for years: all states that are part of the Chesapeake Bay Watershed must reduce nitrogen (N) and phosphorus (P) loads from agricultural sources by 2025. The Environmental Protection Agency (EPA) has set a Total Maximum Daily Load (TMDL) for N and P for each state to achieve water quality goals for the Chesapeake Bay region. The headwaters of the Chesapeake Bay Watershed originate in New York's Upper Susquehanna Watershed (USW) and include part or all of 17 New York counties (Figure 1).

In 2009, the annual nutrient load delivered to the Chesapeake Bay from USW agriculture was estimated to be 4.54 million pounds of N and 0.53 million pounds of P. The EPA set the 2017 target nutrient load for the USW at 3.79 million pounds of N and 0.45 million pounds of P, with target annual 2025 TMDLs at 3.04 million pounds of N and 0.36 million pounds of P. The 2025 target represents N and P reductions of roughly 33% from the 2009 estimation of these nutrient inputs from USW farms.

Although it is too soon to know if the 2017 total nutrient load targets from USW farms will be achieved, a recent study published in the Journal of Soil and Water Conservation ('Upper Susquehanna watershed and New York State improvements in nitrogen and phosphorus mass balances of dairy farms.'[1]) suggests that, collectively, farms have already significantly reduced N and P use over the past ten years without sacrificing productivity. The reported downward trend in N and P imports onto dairy farms means a reduced risk of N and P losses to the environment, as well as greatly improved nutrient efficiency.

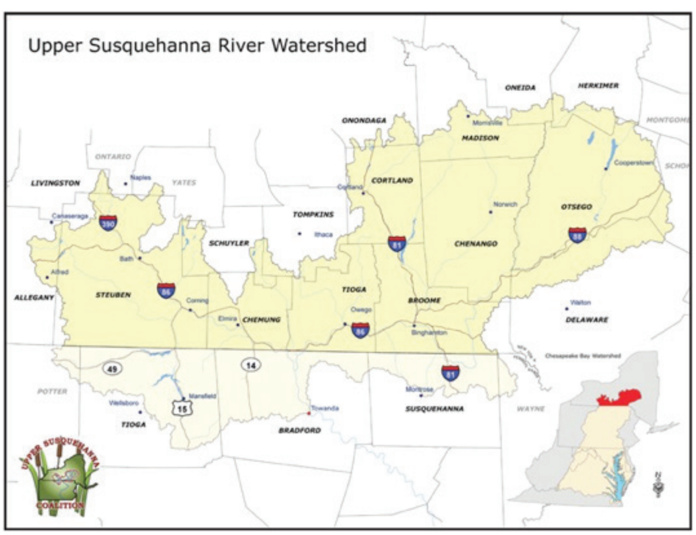

Fig. 1. Upper Susquehanna watershed. Courtesy of Chris Yearick, Upper Susquehanna Coalition.the soil. Plants require P in solution for optimal growth and production.

Table 1. Reduction in total N and P imports estimated for New York State and Upper Susquehanna Watershed dairy farms as reported by Cela and colleagues in a recent article in the Journal of Soil and Water Conservation.

State + Watershed Assessments

Reductions in total N and P imports when comparing 2013 vs 2004

	New York State		Upper Susquehanna Watershed	
Nutrient	Million lbs	(%)	Million lbs	(%)
Nitrogen	66.0	26	9.5	30
Phosphorus	6.6	19	0.9	20

The study reports the analyses of whole-farm nutrient mass balances (NMBs) completed by 189 New York dairy farms, including 91 located in the USW. The NMBs were completed through the collaborative effort of farmers, private sector certified crop advisors and nutrient management planners, Soil and Water Conservation District staff, and the Upper Susquehanna Coalition (a network of the 17 Soil and Water Conservation Districts in New York and 3 in Pennsylvania). Cornell Cooperative Extension staff, and Cornell faculty and staff were also highly involved. The trend study shows that, in 2004, the USW farms averaged an N balance of 77 lbs/acre and a P balance of 9 lbs/acre. In 2013, that average decreased to 46 lbs N/acre and 5 lbs P/acre. These reductions represent a significant effort of successful nutrient conservation by the farms in the study. In addition, assuming all USW dairies can achieve similar reductions, an extrapolation of these findings shows nutrient imports onto farms could be reduced to 9.5 million lbs of N and 0.9 million lbs of P when comparing 2013 versus 2004 (Table 1). This indicates that USW farms may be able to achieve the 2025 TMDL goals.

The whole-farm NMB diagnostic tool was developed over 30 years ago to quantify the nutrient status of New

York dairy and livestock farms.[2] Over the past 15 years, it evolved under the direction of the Cornell Nutrient Management Spear Program, led by Professor Quirine Ketterings. The NMB reports that farmers receive after they submit their data include the N, P, and K balances (imports minus exports) in pounds per tillable acre and pounds per 100 pounds of milk produced. Typically, the imports are dominated by concentrate feed purchases, with fertilizer nutrients playing a secondary role. The nutrients in milk are the largest source of exports, with exports in the form of animal and crop sales playing a smaller and more variable role among individual farms. The 189 farms that comprised the NMB dataset represented the wide range of farm sizes and management practices found across New York. Herd size ranged from 20 to well over 1,000 animals, with 71% at less than 200 cows and 29% CAFO sized herds (more than 300 animal units; one animal unit is 1,000 lbs). Milk production across all farms and the 10 years of NMB data ranged from just under 8,000 to over 30,000 pounds per cow per year. Ten percent of all New York dairy farms are CAFO sized, so the non- USW farms in the NMB dataset had a higher percentage of CAFO farms than dairy farms overall in New York. The NMBs from the USW farms closely represented average New York farm size and milk production, with 88% animal feeding operations (AFO) and 12% CAFO, and an average milk production of just over 18,500 pounds per cow per year.

The NMB data from the 189 farms reveal that feed efficiency was the largest factor in the nutrient reductions achieved by New York farms over the ten years of the study. This was accomplished by the fine-tuning that occurred from adopting precision feed management practices that led to higher forage diets. Feeding higher levels of homegrown forage reduced both the quantity and nutrient concentration of purchased concentrate feeds. Decreased imports of fertilizer nutrients also played a role on farms where manure management efficiency was improved and some farms increased nutrient exports in the form of forage sales over the study period as well. Although improved efficiencies reflected by lower NMB numbers are no guarantees of a better economic bottom line, they can contribute to improved financial sustainability. Farm participation

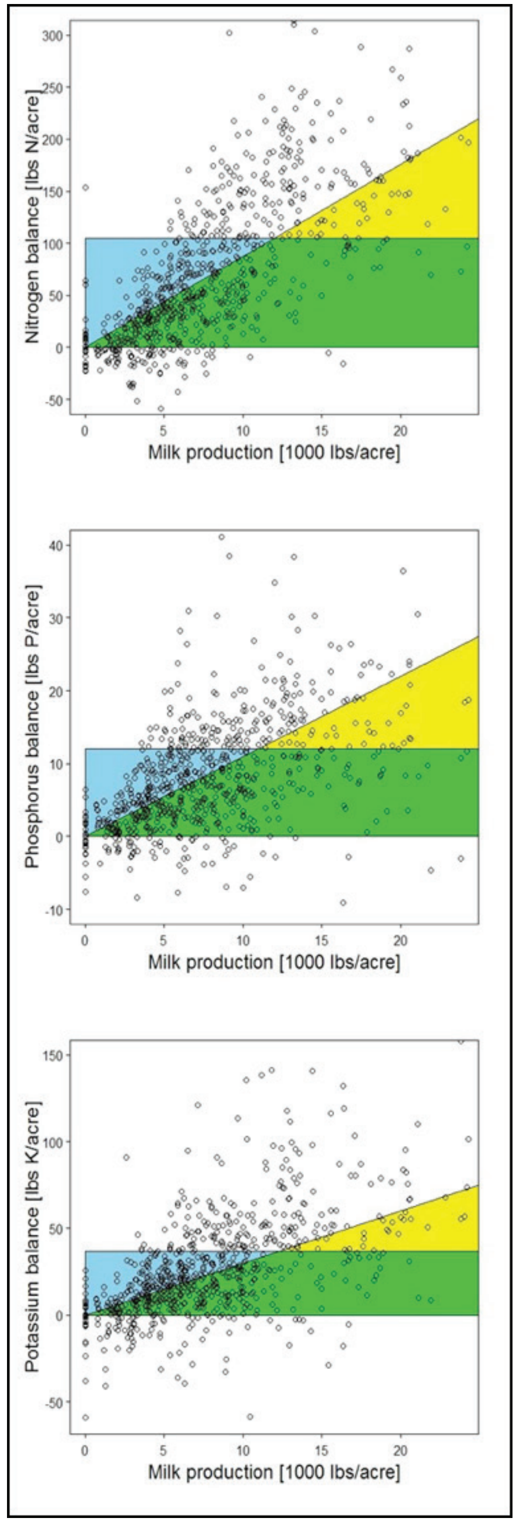

Fig. 2. Feasible balances for N, P, and K for New York. Farms that meet the feasible balance per acre and per 100 lbs of milk produced are in the "green box".

in the annual NMB program has been, and remains, voluntary, so trends shown are a testimony to farmers' opinion that the time involved is a sound investment.

In recent years, the authors of the Journal of Soil and Water Conservation article defined guidelines for interpretation of NMBs by combining balances per tillable acre and per 100 pounds of milk produced. Those farms that meet the "feasible balances" for both the balance per acre and the balance per 100 pounds of milk, are operating in the "optimal operational zone," termed "the green box" (Figure 2 shows the green box for N, P, and K).

Numbers falling below the green box are not desirable over the long term, as they imply that soil nutrients are not being replenished (mining of soil resources over time). Numbers above the green box can indicate lower efficiency and the opportunity for improved economic returns. The feasible NMBs (within the green box) have been identified as 0-105 lbs N, 0-12 lbs of P and 0-37 lbs of K per tillable acre, and 0-0.88 lbs N, 0-0.11 lbs P and 0-0.30 lbs K per 100 pounds of milk shipped. Due to the variable conditions that occur on farms from year to year, these numbers have been termed as "feasible" rather than absolute goals. However, the feasible NMB numbers can be viewed as benchmarks, as they represent nutrient balances proven to be achievable by most farms.

Having a robust dataset of farm NMBs has clearly been critical for validating the positive change in nutrient efficiency and progress toward meeting watershed TMDL goals. Capturing nutrient conservation accomplishments can answer regulatory demands, but it is also highly useful to the farms that use their annual NMBs to determine their individual farm goals. Farmers have consistently reported the following benefits from completing annual whole-farm NMBs:

1. The NMB captures the overall results of management practices, and reflects the degree of nutrient efficiency in the balance numbers and milk exports.
2. Trends are illustrated, so the impacts of management changes, such as reduced feed protein levels, are reflected in a reduced N balance.
3. A feedback loop is created between NMB report results and management decisions: the tracking process required to complete a NMB causes feed and forage production changes to be considered in light of their potential impacts on the farm's nutrient efficiency, which is then captured in the NMB report. This adaptive management process has been highly effective in implementing positive change.
4. The impacts of manure and fertilizer management practices on soil levels of P and K are reflected in homegrown forages and quantified in the NMB diagnostics. This information is useful to both crop and feed management.
5. The NMB results, and their position compared to the green box, give farmers an indication of their progress toward nutrient efficiency goals and validate results of management decisions.

The authors of the NMB trend study reported a need for a larger dataset that will better represent the nutrient balance status of New York farms. The current dataset shows that nutrient efficiency can improve over time, and illustrates the impressive progress already made by farmers. However, a larger number of farms would provide a more robust dataset to compare the nutrient conservation progress of farms to the nutrient reductions expected by regulatory entities.

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Rotary Hoe Operation at the V1-2 Stage Decreases Organic Corn Plant Densities by 5.5% but Has Limited Effect on Organic Soybean Plant Densities

Crop Production

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We initiated a 4-year study at the Aurora Research Farm in 2015 to compare different sequences of the corn, soybean, and wheat/red clover rotation in conventional and organic cropping systems under recommended and high input management during the 3-year transition period (2015-2017) from conventional to an organic cropping system. We provided a detailed discussion of the various treatments and objectives of the study in a previous corn article (http://blogs.cornell.edu/whatscroppingup/2015/07/23/emergence-early-v4-stage-and-final-plant-populations-v10-psnt-values-v4-and-weed-densities-v12-in-corn-under-conventional-and-organic-cropping-systems/). Unfortunately, we were unable to plant wheat after soybean in the fall of 2016 because green stem in soybean compounded with very wet conditions in October and early November delayed soybean harvest until November 9, too late for wheat planting. Consequently, corn followed soybean as well as wheat/red cover in 2017 (Table 1). This article will focus on corn and soybean plant densities after the rotary hoeing operation in the organic cropping system.

We reported in a previous article (http://blogs.cornell.edu/whatscroppingup/2017/06/05/organic-and-conventional-corn-have-similar-emergence-and-early-plant-densities-in-2017/) that organic corn and conventional corn had similar plant densities in all treatments at the V1-2 stage (June 2), a couple of hours before the rotary hoeing operation (Table 2). Results were surprising because we presumed that the seed treatment of conventional corn, P96AMXT, would result in higher plant establishment rates compared to the non-treated organic isoline, P9675. In contrast, organic soybean (P92Y21) with no seed treatment had greater plant establishment rates compared with conventional soybean (P22T41R2) with seed treatment (Table 3). We attributed difference due to variety or genetic factors and not to organic management factors (http://blogs.cornell.edu/whatscroppingup/2017/06/06/soybean-emergence-and-early-plant-densities-v1-v2-stage-in-conventional-and-organic-cropping-systems-in-2017/).

Table 1. Amended crop rotations because of the inability to plant wheat after soybean in the fall of 2016 (green stem in soybean compounded with excessively wet conditions in October and early November prevented a timely soybean harvest and wheat planting). Consequently, we will now compare a corn-soybean rotation with a corn-soybean-wheat/red clover rotation (without wheat in the first transition year, 2015) in conventional and organic cropping systems.

	CROP ROTATION		
2015	RED CLOVER (RC)	CORN	SOYBEAN
2016	CORN	SOYBEAN	WHEAT/RC
2017	SOYBEAN	CORN	CORN
2018	WHEAT/RC	SOYBEAN	SOYBEAN

Fig. 1. Corn damage after rotary hoe operation on June 12.

Conventional corn had similar plant densities at the V3 stage compared to the V1-2 stage (Table 2). In contrast, organic corn had 5.5% lower plant densities on June 12 compared to June 2. Although we observed limited visual plant damage when inspecting the organic plots during the operation, the rotary hoeing must have reduced plant stands, especially because conventional corn plant densities remained similar.

Conventional soybean had similar plant densities at the V3 stage compared to the V1-2 stage (2.4% higher at V3 compared to the V1-2 stage in the field with a small grain in 2014 probably because of uneven and delayed emergence in soybean, Table 3). Likewise, organic soybean generally had similar plant densities at the V3 stage compared to the V1-2 stage. Apparently, the rotary hoeing operation results in limited damage to soybean, unlike corn, at the V1-2 stage.

We have recommended seeding rates of ~30,000 kernels/acre for conventional corn in New York, despite criticism from some industry personnel, farmers, and academic colleagues in other states. We have maintained these recommended seeding rates because on most occasions final stands of 26,000 to 28,000 plants/acre result in maximum economic yields (https://scs.cals.cornell.edu/sites/scs.cals.cornell.edu/files/shared/documents/wcu/WCUvol23no1.pdf). After the rotary

Table 2. Early plant densities of corn at the 1st to 2nd leaf stage (V1-2) and again at the V3 stage (after the rotary hoe operation in organic corn plots) under conventional management (P9675AMXT-GMO hybrid treated with insecticide and fungicide) and organic management (P9675-non-GMO hybrid) at recommended inputs (~29,600 kernel/acre seeding rate) and high input (~35,500 kernels/acre plus the organic seed treatment, Sabrex, in the organic cropping system) in fields with final conventional crops in 2014 before the transition years.

	PREVIOUS CROP (2014)					
TREATMENTS/2016 CROP	**SMALL GRAIN**		**CORN**		**SOYBEANS**	
	Plant densities-(plants/acre)					
CONVENTIONAL	**V1-2**	**V3**	**V1-2**	**V3**	**V1-2**	**V3**
Recommended-soybean	26,244	26,272	25,682	26,383	26,653	26,644
Recommended- wheat/RC	26,315	25,702	25,337	24,778	26,610	27,037
High Input-soybean	31,348	31,009	30,527	31,733	31,518	32,170
High Input- wheat/RC	31,776	31,032	29,600	31,053	30,329	30,723
Mean	28,920	28,503	27,787	28,487	28,755	29,143
ORGANIC						
Recommended-soybean	26,623	**25,438**	26,741	**24,873**	25,965	**24,627**
Recommended- wheat/RC	26,827	**25,526**	25,559	**23,879**	25,823	**25,065**
High Input-soybean	31,170	**28,993**	30,518	**29,099**	30,337	**29,100**
High Input- wheat/RC	31,580	**30,021**	30,815	**28,489**	31,097	**28,906**
Mean	29,050	**27,495**	28,408	**26,562**	28,305	**26,924**

hoeing operation, however, most of the plant densities of organic corn at the V3 stage ranged from ~24,000 to 25,500 plants/acre. This is before the close cultivation, performed on June 12, and 2 in-row cultivations that occurred on June 27 and again on July 5, which will further reduce plant densities. We attributed the 7% lower yield in organic compared with conventional corn in 2016 to lower plant densities (http://blogs.cornell.edu/whatscroppingup/2016/11/28/organic-corn-only-yields-7-lower-than-conventional-corn-during-the-second-transition-year/). Organic corn apparently should be planted at seeding rates of at least 33,000 plants/acre to maintain final plant densities above 26,000 plants/acre after the myriad of weed control operations, including rotary hoeing, close cultivation, and in-row cultivation.

We have recommended seeding rates of ~150,000 seeds/acre for soybeans in New York based on numerous studies (https://scs.cals.cornell.edu/sites/scs.cals.cornell.edu/files/shared/documents/wcu/WCU21-2.pdf). Some organic soybean producers and researchers believe that seeding rates should be higher, ~200,000 seeds/acre, because of the delayed planting date and more importantly for improved weed control. Data from this study in 2015 and 2016, however, indicated that organic soybean with recommended management practices (~150,000 seeds/acre) compared with high input management (~200,000 seeds/acre) yielded similarly (http://blogs.cornell.edu/whatscroppingup/2016/11/28/organic-soybean-once-again-yields-similarly-to-conventional-soybean-during-the-second-transition-year/). Weed densities were indeed higher in organic soybean at the lower seeding rate in both years but seed yield did not correlate with weed densities in 2016. We are only in the 3rd year of growing soybeans organically and perhaps weed densities will increase to such an extent that higher seeding rates will be justified. At this time, however, we see no justification for increasing the recommended organic soybean in 30-inch rows from ~150,000 seeds/acre to ~200,000 seeds/acre, especially because the rotary hoeing operation did not lower early plant densities in soybean as it did in corn.

Table 3. Early plant densities of soybean at the 1st -2nd node stage (V1-V2) and again at the V3 stage (after rotary hoe operation in organic plots) under conventional management (P22T41R2-GMO variety treated with insecticide and fungicide) and organic management (P96Y21-non-GMO variety with no seed treatment) at recommended input (~150,000 seeds /acre seeding rate) and high input (~200,000 seeds/acre plus the organic seed treatment, Sabrex, in the organic cropping system) in fields with final conventional crops in 2014 before the transition years.

	PREVIOUS CROP (2014)					
TREATMENTS	**SMALL GRAIN**		**CORN**		**SOYBEANS**	
	Plant densities- (plants/acre)					
CONVENTIONAL	**V1**	**V2-3**	**V1**	**V2-3**	**V1**	**V2-3**
Recommended	118,166	118,771	123,000	123,372	123,667	118,771
High Input	142,166	147,789	140,365	134,967	144,833	147,789
Mean	130,166	133,280	131,682	129,170	134,250	133,280
ORGANIC						
Recommended	120,833	126,689	116,071	116,089	123,333	126,689
High Input	153,667	155,212	153,862	148,463	157,833	155,212
Mean	137,250	140,950	134,967	132,276	140,583	140,953

Close Cultivation Followed by Three In-Row Cultivations Reduce Organic Corn Plant Densities by another 3.5% or ~1000 Plants/Acre

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Crop Production

Fig. 1. Cultivating soybean close to the row. This operation may have contributed to the 3.5% further reduction in organic corn plant densities between the V3 and V9 stages.

We initiated a 4-year study at the Aurora Research Farm in 2015 to compare different sequences of the corn, soybean, and wheat/red clover rotation in conventional and organic cropping systems under recommended and high input management during the 3-year transition period (2015-2017) from conventional to an organic cropping system. We provided a detailed discussion of the various treatments and objectives of the study in a previous news article (http://blogs.cornell.edu/whatscroppingup/2015/07/23/emergence-early-v4-stage-and-final-plant-populations-v10-psnt-values-v4-and-weed-densities-v12-in-corn-under-conventional-and-organic-cropping-systems/). Unfortunately, we were unable to plant wheat after soybean in the fall of 2016 because green stem in soybean compounded with very wet conditions in October and early November delayed soybean harvest until November 9, too late for wheat planting. Consequently, corn followed soybean as well as wheat/red cover in 2017 so we are now comparing different sequences of the corn-soybean-wheat/red clover rotation with a corn-soybean rotation (Table 1). This article will focus on corn plant densities at the V9 stage after rotary hoeing (V1-2 stage), a close to the row cultivation (V3 stage), and three subsequent in-row cultivations (V5, V6-7, and V7-8 stages) in organic corn.

We reported in a previous article (http://blogs.cornell.edu/whatscroppingup/2017/06/05/organic-and-conventional-corn-have-similar-emergence-and-early-plant-densities-in-2017/) that organic corn and conventional corn had similar plant densities in all treatments at the V1-2 stage (June 2), a few hours before the rotary hoe operation. Organic corn, however, had 5.5% lower plant densities 10 days later at the V3 stage, whereas conventional corn had similar plant densities at the V3 stage compared to the V1-2 stage (Table 2). We attributed the 5.5% reduction in plant densities to rotary hoe damage (http://blogs.cornell.edu/whatscroppingup/2017/07/06/rotary-hoe-operation-at-the-v1-2-stage-decreases-organic-corn-plant-densities-by-5-5-but-has-limited-effect-on-organic-soybean-plant-densities/). Consequently, organic corn with recommended inputs (~30,000 kernels/acre seeding rate) had plant populations of only ~24,500 to ~25,500 plants/acre at the V3 stage, too low for maximum yields in New York. We speculated in the previous rotary hoe article that organic corn seeding rate recommendations may have to be increased to ~33,000 kernels/acre.

Unfortunately, after a close to the row cultivation and three subsequent in-row cultivations, plant densities in organic corn were further reduced by 3.5% with final plant stands now below 24,600 plants/acre in all six recommended organic corn treatment combinations (Table 2). Again, conventional corn had similar plant densities at the V3 and V8 stages, so we attributed the 3.5% reduction in organic corn to cultivation damage. We are not sure which of the four subsequent cultivations after the rotary hoe operation resulted in most of the 3.5% reduction. We did see some corn tipping damage at the V7-8 operation because of the height of the corn but the damage was estimated to be only ~0.5%. We suspect that most of the damage came

Table 1. Amended crop rotations in a 4-year crop rotation study at the Aurora Research Farm because of the inability to plant wheat after soybean in the fall of 2016 (green stem in soybean compounded with excessively wet conditions in October and early November prevented a timely soybean harvest and wheat planting). Consequently, we will now compare a corn-soybean-wheat/red clover (RC) rotation (without wheat in the first transition year, 2015) to a corn-soybean rotation in conventional and organic cropping systems.

	CROP ROTATIONS		
2015	RED CLOVER (RC)	CORN	SOYBEAN
2016	CORN	SOYBEAN	WHEAT/RC
2017	SOYBEAN	CORN	CORN
2018	WHEAT/RC	SOYBEAN	SOYBEAN

Table 2. Corn plant densities at the 1st to 2nd leaf stage (V1-2), at the V3 stage (10 days after the rotary hoe operation in organic corn plots), and at the V9 stage (after a close cultivation to the row and three cultivations in the row in the organic plots) under conventional management (P9675AMXT-GMO hybrid treated with insecticide and fungicide) and organic management (P9675-non-GMO hybrid) at recommended (Rec.) inputs (~29,600 kernel/acre seeding rate) and high input (~35,500 kernels/acre plus the organic seed treatment, Sabrex, in the organic cropping system) in fields with final conventional crops in 2014 before the transition years.

PREVIOUS CROP (2014)									
Treat.	**SMALL GRAIN**			**CORN**			**SOYBEANS**		
	Plant densities-(plants/acre)								
Convent	**V1-2**	**V3**	**V9**	**V1-2**	**V3**	**V9**	**V1-2**	**V3**	**V9**
Rec. wheat/rc	26244	26272	26800	25682	26383	25781	26653	26644	27377
Rec. soybean	26315	25702	26633	25337	24778	25708	26610	27037	27351
High-wheat/rc	31348	31009	31381	30527	31733	30719	31518	32170	31642
High-soybean	31776	31032	31185	29600	31053	29777	30329	30723	30924
Mean	28920	28503	29000	27787	28487	27997	28755	29143	29323
Organic									
Rec. wheat/rc	26623	**25438**	**24804**	26741	**24873**	**24619**	25965	**24627**	**24110**
Rec. soybean	26827	**25526**	**24608**	25559	**23879**	**22172**	25823	**25065**	**24108**
High wheat/rc	31170	**28993**	**28244**	30518	**29099**	**28831**	30337	**29100**	**28419**
High soybean	31580	**30021**	**29117**	30815	**28489**	**28250**	31097	**28906**	**27015**
Mean	29050	**27495**	**26693**	28408	**26562**	**25568**	28305	**26924**	**25913**

during the in-row cultivation when thrown soil from the close cultivation buried some of the corn plants.

We have recommended seeding rates of ~30,000 kernels/acre for conventional corn in New York, despite criticism from some industry personnel, farmers, and academic colleagues in other states. We have maintained these recommended seeding rates because on most occasions final stands of 26,000 to 28,000 plants/acre have resulted in maximum economic yields (https://scs.cals.cornell.edu/sites/scs.cals.cornell.edu/files/shared/documents/wcu/WCUvol23no1.pdf). Ironically, the high input organic corn treatments (seeding rates of ~35,000 kernels/acre) had final plant stands of ~27,000 to ~29,000 plants/acre in this study (Table 2), close to optimum for maximum yields in New York. Apparently, organic corn in New York should be planted at ~34,000 kernels/acre. We attributed the 7% lower yield in organic compared with conventional corn in 2016 to lower plant densities (http://blogs.cornell.edu/whatscroppingup/2016/11/28/organic-corn-only-yields-7-lower-than-conventional-corn-during-the-second-transition-year/). Likewise, organic corn with high inputs yielded 6.5 to 7.0% greater than organic corn with recommended inputs in two of three treatment comparisons in 2016, presumably because of the low final stands in the organic recommended input treatment. If high input organic corn yields greater than organic corn with recommended inputs in 2017, we will change the recommended seeding rate for organic corn to ~34,000 kernels/acre in the *2018 Cornell Guide for Integrated Field Crop Management*.

Wheat/Red Clover Provides N and May Help with Weed Control in the Organic Corn-Soybean-Wheat/Red Clover Rotation

Crop Production

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Fig. 1. Organic corn with high inputs in the corn-soybean (2015)-wheat/red clover (2016) rotation had very few weeds on July 29, 2017, a few days after silking.

We initiated a 4-year study at the Aurora Research Farm in 2015 to compare different sequences of the corn, soybean, and wheat/red clover rotation in conventional and organic cropping systems under recommended and high input management during the 3-year transition period (2015-2017) from conventional to an organic cropping system. We provided a detailed discussion of the various treatments and objectives of the study in a previous news article (http://blogs.cornell.edu/whatscroppingup/2015/07/23/emergence-early-v4-stage-and-final-plant-populations-v10-psnt-values-v4-and-weed-densities-v12-in-corn-under-conventional-and-organic-cropping-systems/). Unfortunately, we were unable to plant wheat after soybean in the fall of 2016 because green stem in soybean, compounded with very wet conditions in October and early November, delayed soybean harvest until November 9, too late for wheat planting. Consequently, corn followed soybean as well as wheat/red cover in 2017 so we are now comparing different sequences of the corn-soybean-wheat/red clover rotation with a corn-soybean rotation (Table 1). This article will focus on weed densities in corn in 2017 at the V14 stage, the end of the critical weed-free period for corn.

The red clover green manure crop (~3.25 dry matter tons/acre), which was interseeded into the 2016 wheat crop, was mowed on May 16. The fields were plowed on May 17, then cultimulched on the morning of May 18, the day of planting. We planted a treated (insecticide/fungicide seed treatment) GMO corn hybrid, P96AMXT, in the conventional system; and its isoline, the untreated non-GMO, P9675, in the organic cropping system at two seeding rates, ~29,600 kernels/acre (recommended input treatment) and ~35,500 kernels/acre (high input). The high input organic treatment also received the organic seed treatment (in-hopper), Sabrex.

Conventional corn received ~250 lbs. /acre of 10-20-20 as starter fertilizer, whereas organic corn received about ~315 lbs. /acre of Kreher's composted manure (5-4-3) through the planter. Organic corn also received a broadcast application before plowing of ~50 lbs. N/acre of Kreher's composted manure in high input organic corn following wheat/red clover (none in the recommended input treatment); and ~100 lbs. N/acre in the recommended input and ~140 lbs. N/acre in the high input organic treatment following soybean. Conventional corn was side-dressed on June 15 (V3-4 stage) with ~50 lbs. N /acre in the recommended input and ~100 lbs. N /acre in the high input treatments following wheat/red clover; and ~90 lbs. N/acre in the recommended input and ~140 lbs. N/acre in the high input treatments following soybean.

We applied Roundup (Helosate Plus Advanced) on June 21 (Replication I) and June 26 (Replications II, III, and IV) at ~32 oz. /acre for weed control in conventional corn (V4-V5 stages) under both recommended and high input treatments. We used the rotary hoe to control weeds in the row in recommended and high input organic corn at the V1-2 stage (June 2). We then cultivated close to the corn row in both recommended and high input organic treatments at the V3 stage (June

Table 1. Amended crop rotations in a 4-year crop rotation study at the Aurora Research Farm because of the inability to plant wheat after soybean in the fall of 2016 (green stem in soybean compounded with excessively wet conditions in October and early November prevented a timely soybean harvest and wheat planting). Consequently, we will now compare a corn-soybean-wheat/red clover (RC) rotation (without wheat in the first transition year, 2015) to a corn-soybean rotation in conventional and organic cropping systems in fields that had spring grain, corn, or soybean as the last conventional crops in 2014.

	CROP ROTATIONS		
2015	RED CLOVER (RC)	CORN	SOYBEAN
2016	CORN	SOYBEAN	WHEAT/RC
2017	SOYBEAN	CORN	CORN
2018	WHEAT/RC	SOYBEAN	SOYBEAN

Table 2. Weed densities at the 14th leaf stage (V14 stage) under conventional management (P9675AMXT-GMO hybrid treated with insecticide and fungicide and a Roundup application at the V4-V5 stage for weed control) and organic management (P9675-non-GMO hybrid with one rotary hoeing, a close cultivation, and three in-row cultivations for weed control) at recommended inputs (~29,600 kernel/acre seeding rate) and high input (~35,500 kernels/acre plus the organic seed treatment, Sabrex, in the organic cropping system) following three different previous crops in 2014. Red highlighted values are significantly higher for comparisons within a column (i.e. previous crops), based on the interaction LSD.

	PREVIOUS CROP (2014)		
TREATMENT/Previous crop	**SPRING GRAIN**	**CORN**	**SOYBEAN**
	Weed densities (weeds/m^2)		
CONVENTIONAL			
Recommended-wheat/RC	**2.01**	0.95	0.74
Recommended-soybean	**1.55**	0.70	1.19
High Input-wheat/RC	1.50	0.51	0.72
High Input-soybean	1.07	0.90	1.00
ORGANIC			
Recommended-wheat/RC	0.81	1.15	0.09
Recommended-soybean	**1.76**	**3.01**	**2.68**
High Input-wheat/RC	0.82	0.67	0.12
High Input-soybean	**1.83**	**2.84**	**2.18**
LSD 0.05	0.60	0.87	0.75

12) with repeated cultivations between the rows at the V4-V5 stage (June 22), the V5-V6 stage (June 28), and the V7-8 stage (July 5). We estimated weed densities (greater than ~2 inches in size) at the V14 stage (July 20) by counting all the weeds along the 100 foot plot between the two harvest rows.

Unexpectedly, weed densities were lower in organic corn following wheat/red clover in fields with a spring grain (0.81-0.82 weeds/m2) or soybean (0.09-0.12 weeds/m2) in 2014 compared with conventional corn in 2017 (Table 2). Weed densities in organic corn when following soybean in the rotation, however, in fields with corn (2.84-3.01 weeds/m2) or soybean (2.18-2.68 weeds/m2) in 2014 were greater than weed densities in conventional corn in 2017 (Table 2). Weed densities were 5 to 6 times higher in organic corn compared with conventional corn in 2015, (http://blogs.cornell.edu/whatscroppingup/2015/07/23/emergence-early-v4-stage-and-final-plant-populations-v10-psnt-values-v4-and-weed-densities-v12-in-corn-under-conventional-and-organic-cropping-systems/) and 4 to 10 times higher in 2016, regardless of inputs (http://blogs.cornell.edu/whatscroppingup/2016/07/27/emergence-plant-densities-v3-stage-and-weed-densities-v14-stage-of-corn-in-conventional-and-organic-cropping-systems-in-2016/).

It is not completely clear why weed densities were so much lower in organic corn following wheat/red clover compared to following soybean (separated only by a 10 foot border row) across all three fields with different 2014 previous crops. Perhaps, there were fewer seeds in the weed seed bank in the corn-soybean wheat/red clover rotation compared with the corn-soybean rotation in the spring of 2017. In 2015, weed densities in organic soybean were so low (~0.5 weeds/m2) that we successfully no-tilled organic wheat into soybean stubble in the fall of 2015 (http://blogs.cornell.edu/whatscroppingup/2015/11/23/wheat-emergence-early-plant-populations-and-weed-densities-following-soybeans-in-conventional-and-organic-cropping-systems/). Likewise, weed densities were very low in organic wheat in the spring of 2016, (~0.05 weeds/m2), even lower than conventional wheat with recommended inputs, which also received no weed control measures (http://blogs.cornell.edu/whatscroppingup/2016/04/05/no-till-organic-wheat-continues-to-have-low-weed-densities-in-early-spring-march-31-at-the-tillering-stage-gs-2-3/). In contrast, weed densities at the V14 stage in organic corn in 2015 (corn-soybean rotation) averaged ~2.5 weeds/m2, much greater than the ~0.5 weeds/m2 in organic soybean (corn-soybean-wheat/red clover rotation) in 2015. Weed densities, however, averaged only ~0.35 weeds/m2 in the subsequent organic soybean crop in 2016. Consequently, it is not clear if the organic corn-soybean-wheat/red clover rotation had fewer seeds in the weed seed bank compared with the organic corn-soybean rotation. Another possibility is increased weed seed predation by seed predators (birds, rodents, ground beetles, etc.) in the corn-soybean-wheat-clover rotation, which unlike the corn-soybean rotation, had complete ground cover from the spring of 2015 through the spring of 2017.

Wild buckwheat was the dominant weed (>80% of the weed density) in conventional corn. Unfortunately, we only sprayed Replication I when corn was at the V4 stage on June 21, but then delayed spraying Replications II, III, and IV until June 26, when corn was at the V5 stage. Weed densities in conventional corn, specifically wild buckwheat, were much lower in Replication I compared with the other three replications. Perhaps the somewhat larger wild buckwheat size at the V5 stage resulted in more difficult weed kill with Roundup. Also, corn grew taller and had an extra leaf during the intervening 5 day period, which may have resulted in poorer spray coverage on this prostrate weed.

Dominant weeds in organic corn included wild buckwheat (~40%), with barnyardgrass, Pennsylvania smartweed, pigweed spp., common lambsquarters, green foxtail, and common ragweed comprising the other ~60%. Wild buckwheat in conventional corn had a pale green look but certainly was still growing. In contrast, weeds in organic corn, including wild buckwheat, were quite robust and had much greater leaf area and biomass. It is not clear if greater weed densities in conventional corn (fields with a spring grain and soybean as the last conventional crops in 2014), would reduce yields more when compared with fewer weeds with greater leaf area and biomass in organic corn following wheat/red clover. If the wet growing conditions (3.81 inches in June and 7.33 inches of precipitation in July at the experimental site) persist in August, weed densities in conventional and organic corn may not influence yields in 2017.

Organic corn with high inputs (high seeding and N rates) following wheat/red clover is poised to yield as well as conventional corn in 2017. Final stands after rotary hoeing and cultivation averaged ~28,500 plants/acre, pre-sidedress nitrogen values (PSNT) values averaged ~30 ppm, and weed densities averaged ~0.55 weeds/m2. Organic corn with recommended inputs also had PSNT values above 25 ppm and weed densities of only ~0.70 weeds/m2, but final stands averaged only ~24,500 plants/acre, too low for maximum yields in NY (http://blogs.cornell.edu/whatscroppingup/). As of this writing (July 31), there are another 4 weeks before final yields of corn will be determined in this experiment so speculation on yields is premature.

Precision Agriculture Research

NYCSGA Precision Ag Research Update: Year One of Model Validation

Savanna Crossman
New York Corn and Soybean Growers Association

The 2016 field season marked the first year of testing for the variable rate planting model that is being developed by the Precision Ag Research Project. Growers across New York State know the challenges that the severe summer drought brought to our region. Crop yields were impacted across the state and the research was no exception. While unfortunate, it is advantageous to be able to test the model during a dry year and learn from how the crops reacts to the stress.

Across the board, the mid-to-lower seeding rates fared the best in the corn and soybean trials. The model was tested on five fields this year and only four made it to grain harvest due to severe drought stress. The results revealed that in three of the fields, there was not a significant difference in the profit produced by the model. While the average yield of the model was significantly less, the model was able to achieve similar profit per acre by using lower seeding rates. (Table 1)

A variation of the model design was planted on one field, Beach 2, in a split planter fashion with two contrasting hybrids. This varied design was used as it allowed for of multiple points of comparison, including hybrid comparison. Check strips were integrated every two passes to allows direct comparison of how the model performed to the typical grower practice rate. From there, the design becomes more complicated. The first pass would be planted at the model optimized rate for hybrid A, which meant hybrid B was also being planted at that same rate. Then the next pass would plant at the rate optimized for hybrid B while hybrid A was being planted at that rate as well. This allows us to examine the hybrid response to population in more depth. (Figure 1)

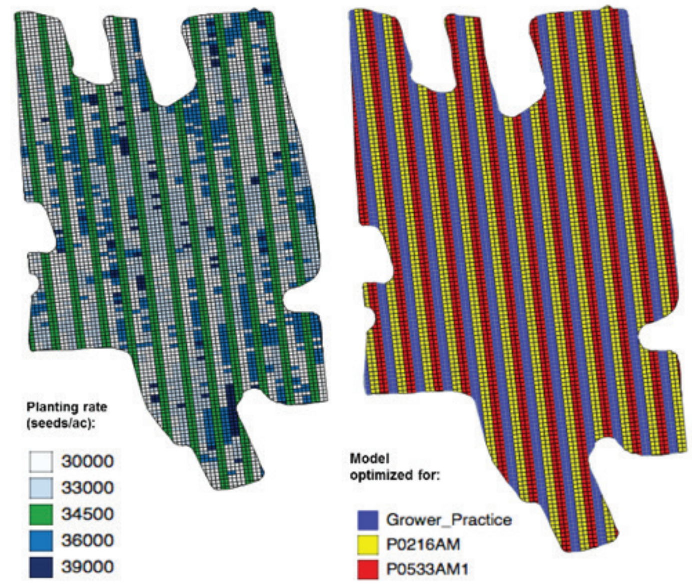

Fig. 1. 2016 Beach 2 model design. The left image displays the planting rate map and the right image displays the hybrid map.

Table 1. 2016 Model Validation Results by Crop

Soybean						
Field	**Variety**	**Flat Rate Average Yield (bu/ac)**	**Variable Rate Average Yield (bu/ac)**	**Flat Rate Average Profit ($/ac)**	**Variable Rate Average Profit ($/ac)**	**Difference**
MC 3	AG2035	46.6	44.9*	$401.62	$396.79	($4.83)
Kuney	P24T05	34.1	33.6	$432.25	$441.19	$8.94
Corn						
Field	**Hybrid**	**Flat Rate Average Yield (bu/ac)**	**Variable Rate Average Yield (bu/ac)**	**Flat Rate Average Profit ($/ac)**	**Variable Rate Average Profit ($/ac)**	**Difference**
Overhill	P0157AM	169.5	165.5 *	$572.89	$567.63	($5.26)
Beach 2	P0216AM	172.9	167.5*	$1,045.36	$1,022.46	($22.90)
Beach 2	P0533XR	146.1	154.4*	$854.58	$918.74*	$64.16

*Denotes statistical significance

The hybrids P0216 and P0533 were selected due to their differences in plant architecture and responses to stress. In years of excellent growing conditions, the tight leaf structure and short stature of P0533 will produce aggressive yields. The hybrid P0216 will produce average yields in years of stress as well as in excellent conditions.

A 4,000 foot view of this field would show that there was not a significant yield difference between the model and the grower's flat rate. The model yielded about 2 bu/ac more than the flat rate, but that difference was not statistically significant. When we separate the results

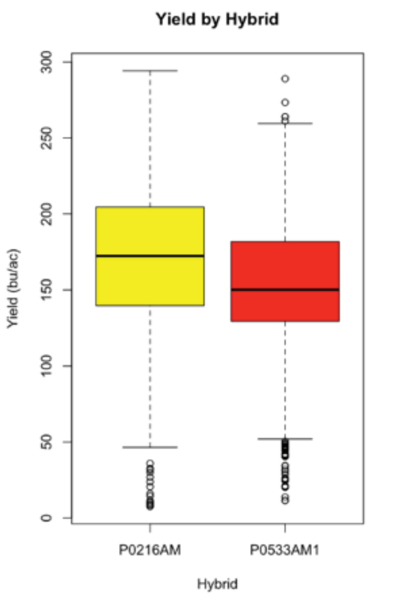

Fig. 2. P0216 optimized yield versus P0533 optimized yield.

out by hybrid, we see a much more telling story.

These hybrids resulted in a wonderful side-by-side comparison this year. When compared to the flat rate, P0533, regardless of optimization, yielded significantly more per acre and yielded an astounding $64/ac more. Conversely, P0216, regardless of optimization, yielded less than the flat rate and produced a profit $22/ac less than the flat rate.

A deeper look into the results showed that that when both hybrids were planted optimally, P0216 yielded almost 18 bu/acre higher than P0533 (Figure 2). It also demonstrated that P0533 exhibited a statistical significant response to model optimization. Meaning, when it was optimized the yield significantly improved over not being optimized (Figure 3). This is likely due to the fact that in a stressful year, P0216's yields will not fall apart due to seeding rate while P0533 benefited from precise placement.

These same hybrids in Beach 2, however, exhibited the exact opposite hybrid response in 2014 which was a normal year in terms of weather conditions. Knowing this emphasizes the importance of multiple years of testing and data collection to create a robust algorithm. The biggest gain from the 2016 season has been the strong design and analysis process that has been developed. What the project has accomplished in these terms, is at the leading edge of the scientific community.

In order to build upon what the project has already accomplished, the project is still looking to get more producers involved and participating. The project aims to get fields in the research that have a large amount of variation and are fifty acres or greater. Any interested growers are highly encouraged to get in touch with the Project Coordinator, Savanna Crossman, at 802-393-0709 or savanna@nycornsoy.com.

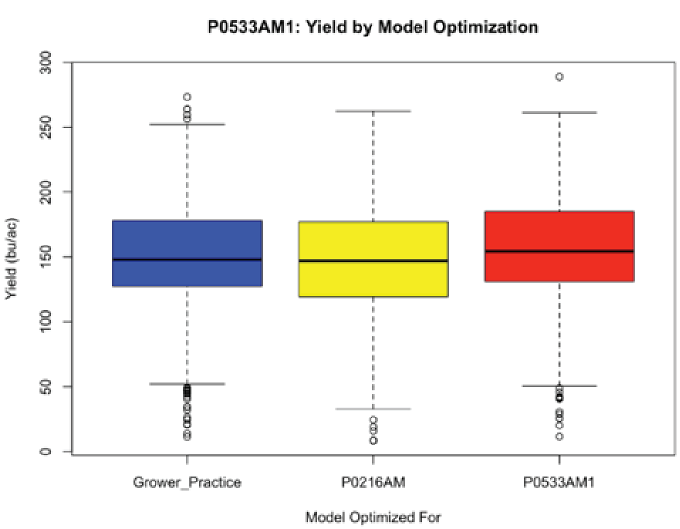

Fig. 3. P0533 exhibited a hybrid response to population.

Calendar of Events

AUG 29	Rotational Dairy Grazing - Canajoharie, NY
OCT 26	Basic Farm Business Management Planning - Greene Co.
NOV 8	Field Crop Dealer Meeting - Syracuse, NY
NOV 8 & 9	First Annual Cover Crops Meeting sponsored by Northeast Cover Crops Council - Ithaca, NY

Have an event to share? Submit it to jnt3@cornell.edu!

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What's Cropping Up? is a bimonthly electronic newsletter distributed by the Soil and Crop Sciences Section at Cornell University. The purpose of the newsletter is to provide timely information on field crop production and environmental issues as it relates to New York agriculture. Articles are regularly contributed by the following Departments/Sections at Cornell University: Soil and Crop Sciences, Plant Breeding, Plant Pathology, and Entomology. **To get on the email list, send your name and address to Jenn Thomas-Murphy, 237 Emerson Hall, Cornell University, Ithaca, NY 14853 or** jnt3@cornell.edu**.**

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