College of
Agriculture and Life Sciences

Nutrient Management Spear Program

Applied Research, Extension and Teaching in
Nutrient Management for Dairy/Cash Grain Farms

Program Update

7/12/2018

Department of Animal Science
Cornell University

Cornell Nutrient Management Spear Program

A collaboration among the Department of Animal Science, Cornell Cooperative Extension and PRODAIRY.

http://nmsp.cals.cornell.edu

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Cornell University Nutrient Management Spear Program

Applied Research, Extension, and Teaching in Nutrient Management for Dairy/Cash Grain Farms
http://nmsp.cals.cornell.edu

NSMP Vision:

To assess current knowledge, identify research and educational needs, conduct applied field- and laboratory-based research, facilitate technology and knowledge transfer, and aid in the on-farm implementation of strategies for field crop nutrient management, including timely application of organic and inorganic nutrient sources to improve profitability and competitiveness of New York State farms while protecting the environment.

Justification:

Agriculture is one of New York State's largest businesses, and keeping farms sustainable is critical to the economy of the state, particularly in rural areas. Maintaining economic viability, while ensuring environmental quality, is key to sustainability. Sustainability of New York State farms can be improved through applied research to address knowledge gaps and increased application of existing knowledge to create comprehensive nutrient management plans (CNMP's) for farms of all sizes. The College of Agriculture and Life Sciences' Nutrient Management Spear Program (NMSP) applied research program focused on improving our understanding of soil and environmental parameters that affect the accuracy of existing nutrient management guidelines and the risk for environmental pollution. Such understanding will allow for refinement of the guidelines. The NMSP extension program aims to improve communication, information exchange, and knowledge transfer between Cornell University's research programs, extension field staff, agricultural consultants, the fertilizer industry and regulatory agencies and to develop joined applied research projects that address current and future challenges. Further, the NMSP teaching and mentoring program prepares Cornell undergraduates and graduates in animal science and agronomy to better address environmental issues impacting the farming community now and in the future.

NMSP Program Goals:

1. ***Extension Program:*** Improve grower and agricultural industry awareness of field crop nutrient needs, crop quality, management of organic amendments, environmentally sound nutrient management practices, and overall soil fertility management in New York State, and provide methods and tools to integrate and apply accumulated knowledge about field crop nutrient guidelines to optimize yield and quality while minimizing risk to the environment.
2. ***Research Program:*** Improve understanding of nutrient dynamics, development of risk identification tools and best management practices that reduce runoff, leaching and volatilization losses from inorganic and organic amendments as affected by soil type, hydrology, time and rate of application, and use of specific soil and fertilizer amendments.
3. ***Teaching and Mentoring Program:*** Prepare Cornell undergraduates for careers in agriculture focusing on increasing farm income while protecting the environment. Instill upon Cornell graduate students with a major or minor in soil science the skills, attitude and enthusiasm needed to conduct sound science using interdisciplinary and integrated approaches to address environmental issues related to soil science and nutrient management.

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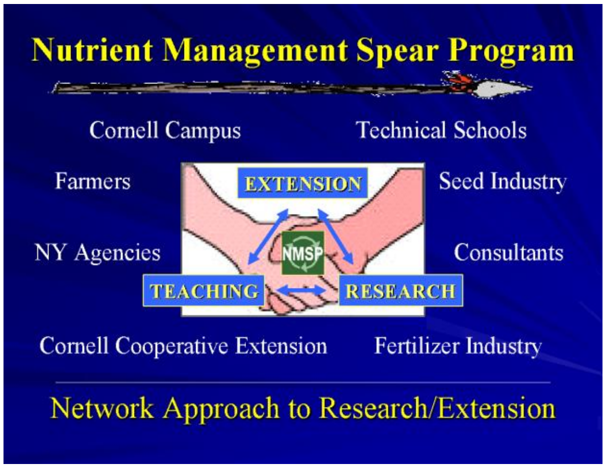

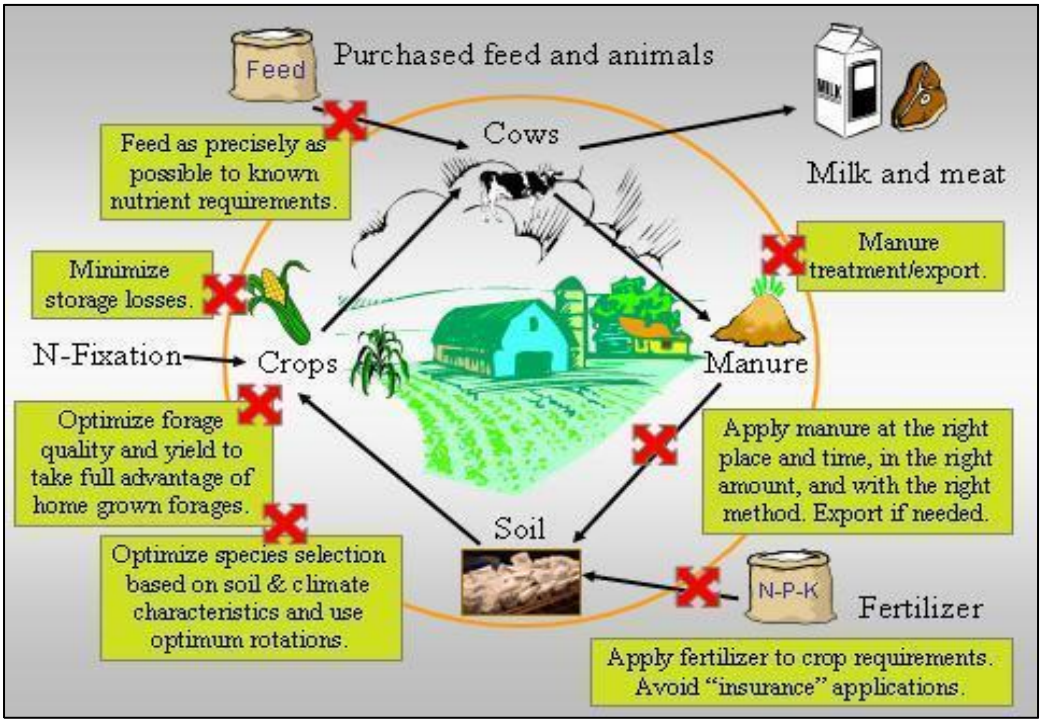

To assess current knowledge, identify research and educational needs, conduct applied field- and laboratory-based research, facilitate technology and knowledge transfer, and aid in the on-farm implementation of strategies for field crop nutrient management, including timely application of organic and inorganic nutrient sources to improve profitability and competitiveness of New York farms while protecting the environment.

Impact through collaboration and integration of teaching, extension and research.

NMSP Extension and Applied Research Projects

-----------------------------ON-FARM RESEARCH PARTNERSHIP ------------------------------

2018 New York On-Farm Research Partnership

In spring of 2012, we launched the "New York On-Farm Research Partnership".

There is great power in coordinated on-farm research where field data are generated through well designed, repeated and widely implemented trials, with proper data collection and statistically valid analyses. Consider being an on-farm research partner! Our motto is: "*Relevant Questions and Sound Science for Agricultural Profitability and Protection of the Environment*". The On-Farm Research Partnership is a partnership of producers, the Cornell Nutrient Management Spear Program, PRODAIRY, Cornell Cooperative Extension, crop and nutrient management consulting firms, and other farm advisors and agencies. We aim to establish a statewide research partnership that enables us to pose relevant questions (farmer and farm advisor driven priorities) and get these questions answered efficiently (large datasets), aiding in development of science-based guidance and implementation of on-farm and whole-farm nutrient management practices.

2018 On-Farm Research Projects

1. Whole Farm Nutrient Balance Assessment
2. Updating of the New York Corn Yield Database
3. Forage Yield Monitor Data Processing for Accurate Maps
4. Getting the Most out of On-Farm Research
5. Yield Stability Zones for Improved N Management of Corn
6. Active Crop Sensor Use for Corn and Sorghum
7. Drones for Yield Predictions and N Management Decisions
8. Brachytic Dwarf Brown Midrib Forage Sorghum in Double Crop Rotations
9. Winter Cereals as Double Crops in Corn or Sorghum Rotations
10. Phosphorus Index Evaluation in The Northeast
11. Land Application of Acid Whey
12. Corn and Hay Yield, Quality and Soil Health as Impacted by Manure Management
13. Greenhouse Gas Emissions from Alfalfa/Grass and Corn Fields

If you would like to receive more information, have suggestions for future projects, would like to sponsor a project, or have general questions, contact Quirine Ketterings (qmk2@cornell.edu or 607-255-3061). You can also write to: Quirine Ketterings, Nutrient Management Spear Program, Department of Animal Science, Cornell University, 323 Morrison Hall, Ithaca NY 14853.

http://nmsp.cals.cornell.edu/NYOnFarmResearchPartnership/index.html

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NMSP

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NMSP Extension and Applied Research Projects

--ONGOING PROJECTS --

Whole Farm Nutrient Balance Assessment

A whole-farm nutrient mass balance (NMB) is calculated by subtracting all nutrients in exports from a farm, such as milk or crops sold, from those in the farm imports, like feed and fertilizer (Figure 1). The NMB of a farm tells us how efficiently a dairy operation uses nitrogen (N), phosphorus (P), and potassium (K), and whether it has the land base to effectively recycle these nutrients. It also indicates opportunities for improvements that lead to more sustainable farming. Conducting a NMB can be attractive for farmers as it provides a nutrient efficiency assessment and requires relatively little time and data. Since 2003, we have worked with producers in New York to collect whole-farm balance data. This project is conducted in collaboration with CCE extension educators, Soil and Water Conservation District (SWCD) employees, and agricultural consultants. Funding has come from Northern New York Agricultural Development Program (NNYADP) and United States Department of Agriculture-Conservation Innovation Grants (USDA-CIG). Additionally, the New York State Department of Agriculture and Markets (NYSDAM) has sponsored a project on identification of nutrient management efficiency indices in support of performance-based planning of nutrient use on dairy farms and Northeast Sustainable Agriculture Research and Education (NESARE) funded our current work on development of a more streamlined process and professional development curriculum for farm advisors. Throughout the past decade, we have continued to run NMBs for farmers and provided them with useful information about their operations' nutrient management. This has generated a 700+-farm database to date, as well as several papers in scientific journals including the Journal of Dairy Science, Soil and Water

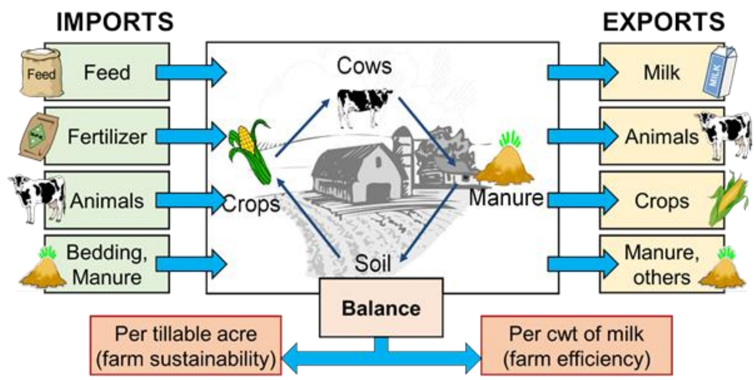


Figure 1: Schematic overview of the nutrient mass balance. The nutrients in the exports are subtracted from those in the imports. The difference is then expressed per tillable acre or per cwt of milk sold to indicate how sustainably and efficiently the dairy farm is using its nutrients.

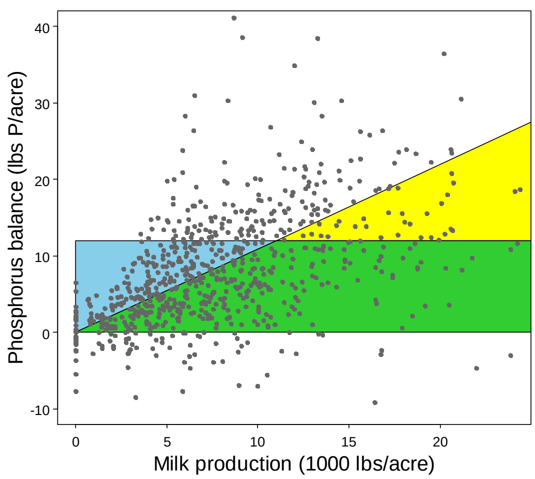


Figure 2: The Green Box for phosphorus The blue rectangle covers the range of feasible balances per cwt. The green area where they overlap is the optimal operation zone, or Green Box. The dots represent dairy operation in New York.

Conservation Journal, and the Journal of Agricultural Science; see http://nmsp.cals.cornell.edu/NYOnFarmResearchPartnership/MassBalances.html for more information). Additionally, we have introduced the Green Box concept (Figure 2), which indicates the feasible limits for N, P, and K whole-farm nutrient balances on a per acre and per cwt basis. Currently, we work with about 75 farms to provide NMB assessment (others welcome to join). Additionally, our latest efforts are directed toward integrating the NMB with P index assessments to ensure that farms with feasible P balances, indicating long-term sustainable P use, have the opportunity to allocate farm-produced manure on their land base.

Updating of the New York Corn Yield Database

In 2013, we initiated a 2-year pilot study based on two questions identified by Northern NY farmers and researchers alike: (1) with gains in corn genetics and overall crop production, should the corn yield potentials that currently drive Cornell guidelines for N fertilizer and manure use for corn be raised?; and (2) does higher productivity mean more N needs to be supplied with manure and/or fertilizer or are new varieties just better able to make use of existing N, requiring a change in the Cornell University N guidelines for corn? In the first 2 years we gathered yield and corn stalk nitrate test (CSNT) data, pioneering a new "adaptive management" approach in which farmers can override the Cornell recommendation if yield is measured and documented, and CSNT management over time is targeted to be below 3000 ppm (agronomic cutoff is 2000 ppm). Fourteen fields yielded less than 90% of the Cornell yield potential for the soil type, nine fields exceeded the Cornell yield potential by more than 10%, while another eleven were within 10% of the listed yield potential. On average, yield across all sites equaled the listed yield potential for the sites. The project showed that a much larger database is needed as well as better ways of collecting yield data. We are currently working with producers and planners to collect whole-farm yield map data for all corn fields harvested with yield monitors across multiple years and processing the data to determine average yield for each field and within the field by soil type (Figure 3). This project was initially sponsored by multiple years of funding from the Northern New York Agricultural Development Program (NNYADP) and federal formula funds, and more recently also by the Corn Growers Association of New York. Farmers participating in the project receive yield data reports with values per field, per field excluding the headland areas, and per soil type within fields. Farmers' data are also summarized per soil type on the farm (as yield frequency distributions for each soil type). Farms with at least three years of yield data for a specific field can use these data to adjust fertility management decisions (Adaptive Management Guidelines) while research is ongoing to update the soil type specific yield potentials for New York for grain and develop a standalone yield database for corn harvested for silage.

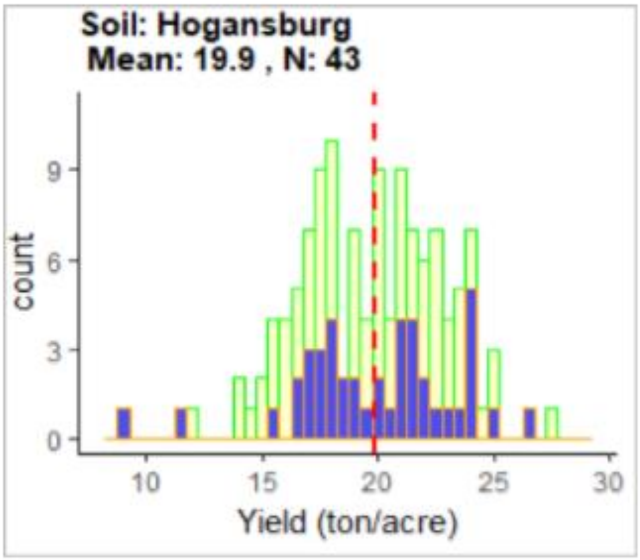


Figure 3: Histogram of yields of Hogansburg soils (N=43) in northern New York. Blue are fields harvested in the year of reporting. In green are all fields of this soil type harvested and recorded to date, previous years included.

Forage Yield Monitor Data Processing for Accurate Maps

Yield monitor data are increasingly available. Linking geospatially recorded, long-term, yield monitor data with causal factors (including soil and management factors) can help identify and manage those potential constraints in a more precise way. Forage yield monitors can provide accurate and precise yield records when calibration is done regularly and data obtained at harvest are evaluated and cleaned before use. Cleaning of yield monitor data is the first step towards making management decisions based on the data. Even with well-calibrated equipment, yield data from monitors need to be combed for obvious errors through a cleaning process, especially for silage yield monitors (Figure 4) to ensure the most accurate data are being used for decision making. Cleaning protocols were developed recently for both grain and silage that now allow for fairly quick checking and cleaning for all corn grain and silage yield data in a particular harvest year. A manual that will help producers or consulting companies do this was released in early 2018 (http://nmsp.cals.cornell.edu/publications/extension/ProtocolYieldMonitorDataProcessing2_8_2018.pdf). This research is currently being sponsored by the Northern New York Agricultural Development Program, Federal Formula Funds, and a multistate USDA-Agriculture and Food Research Initiative (USDA-AFRI) foundation.

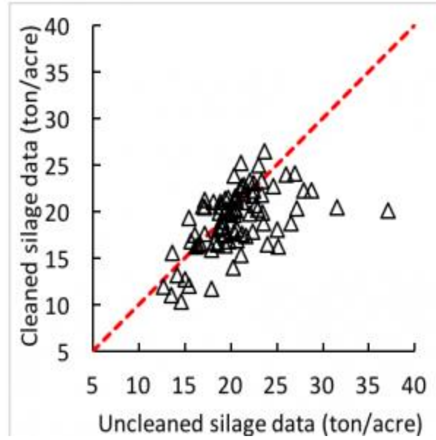


Figure 4: A consistent data cleaning process is essential for creation of reliable multi-field and multi-year yield maps.

Getting the Most out of On-Farm Research

To date, on-farm research typically uses strip trial designs with treatments randomized in blocks in the field. In this project we evaluate the use of advanced statistical approaches and tools to analyze on-farm data (single or multiple strips), making use of spatial information including yield stability zones, soil analyses data (grid sampling), elevation mapping, NDVI scans, and satellite imagery. This project addresses a problem "of national, regional and multi-state importance" by increasing farm efficiency, profitability and sustainability. This project is a collaboration among the University of Missouri, the Iowa Soybean Association, and Cornell University. It is sponsored by a grant from the Agriculture and Food Research Initiative (AFRI).

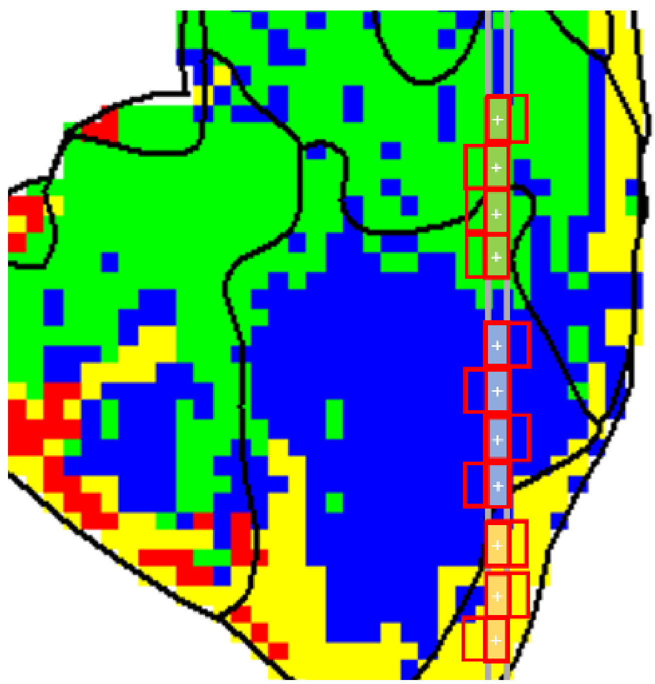


Figure 5: Strip trial layout and analysis strategy. A single strip is placed to cover a maximum number of yield/stability zones and a statistical analysis approach is under development.

Yield Stability Zones for Improved N Management of Corn

Zone management within fields can result in much better use of resources and/or more stabilized yields over time. The best indicator to design zones around is yield itself, and yield stability over time (consistency in yields from one year to another). Until recently we did not have a good way to identify such management zones due to lack of consistent equipment (yield monitors), yield data cleaning protocols, and limited number of farmers with multi-year yield records. In 2016 we introduced the concept of "yield stability zones". In this approach, three or more years of yield data for a field are combined into on e yield stability map, which contains four yield zones. Fields (or areas within fields) in quadrant 1 (Q1) yield above the farm average and do so consistently across years. The fields (or areas within fields) in Q4 are consistent as well over years, but yield less than the average of the farm. Fields or areas within fields in Q2 and Q3 are much more variable from year to year. If a farmer can identify what keeps production areas in Q3 and Q4 from being higher yielding and what reduces the year to year variability of Q2 areas, there could be options to increase the overall yield of the farm over time. Basically, yield stability zones can help allocate resources better, including nitrogen (N). The release of a data cleaning manual in February of 2018 now allows for standardized cleaning of farmer-collected yield data for corn silage and grain, and with that we can now more easily develop management zones and test what drives yield stability differences and if management needs to be adjusted among management zones. Our goals for the zone-based management evaluations in 2018 and 2019 are to (1) create a multi-agency capacity to obtain and clean yield monitor data from farms (corn grain and corn silage) and to develop yield stability zones for fields with 3 or more years of data; (2) implement N-rich strips (manure or N fertilizer) at planting, for evaluation of N needs for corn for each of the management zones on the farm. The N rich strips with fertilizer and/or manure (farmer driven selection) allow for assessment of crops response to N addition in each of the zones. This will answer the question whether higher yielding areas need more N and/or whether low yield can be increased with N addition. We are developing protocols for integrating spatial and hierarchical Bayesian statistical methods as a standard approach for analyzing and interpreting results from these N rich strip trials, and working with Dr. Erasmus Oware of the University of Buffalo on prediction models for yield and crop N responsiveness, based on soil EC mapping, LiDAR, grid soil sampling, and sensor data obtained from active sensing (Greenseeker), and passive sensors via drone-mounted cameras and satellite imagery. Our 2018 network consists of 26 farm fields spread over 12 farms. The work is funded by Northern New York Agricultural Development Program (NNYADP), New York Farm Viability Institute, and federal formula funds.

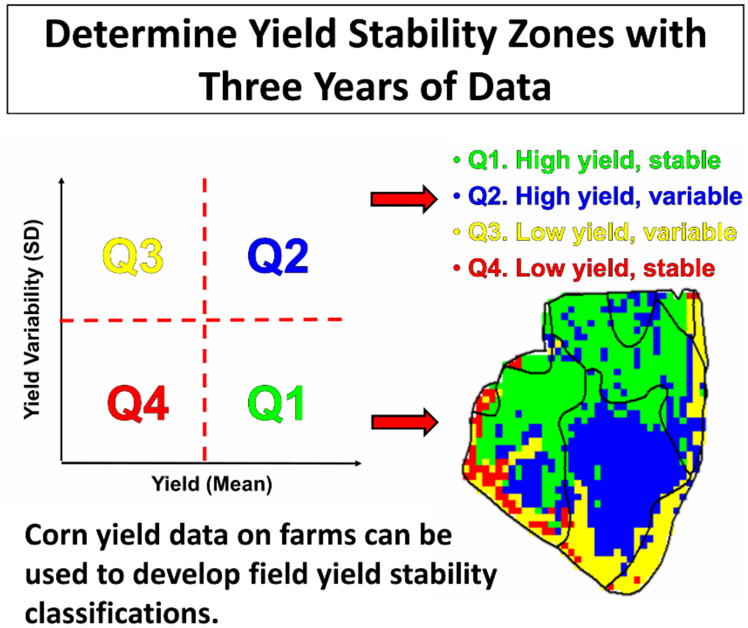


Figure 6: Field or areas within a field can be classified into yield stability zones, based on yield data from three or more years.

Active Crop Sensor Use for Corn and Sorghum

An increase in corn yields and a better balance between cost of production and yield in New York has been limited by our inability to assess soil resources, crop nitrogen (N) needs and yields on a more spatial and temporal basis. With the introduction of forage yield monitors, precision planting, electrical conductivity (EC) and pH mapping equipment, and now Greenseeker technology, such barriers can be addressed, allowing us to answer the questions "how do we do this?" and "how much do we gain?" Implementation of a technology-driven management package for planting, side dressing, harvesting, as well as an accurate assessment of soil N resources (soil mapping) will enable fine-tuning of N applications for greater yields and reduced losses. Examples from grain belt states show the potential for both a yield increase and an increase in the efficiency of N use. There is increasing awareness of the need for reference strips and locally developed algorithms to correctly predict yield and N needs. Various approaches have been implemented, including the use of a high N reference strip (upfront application of an amount of N that will not be crop yield limiting) with or without the use of a low N reference strip (no early season N addition). More recently, the use of "Ramp Calibration Strips" has been proposed. In 2014, with funding from the New York Farm Viability Institute, and in collaboration with Cornell Cooperative Extension field crop educators Mike Stanyard and Mike Hunter, and Agrinetix LLC staff, we embarked on the development of a New York set of equations for the use of crop sensors for corn. That year four farmers implemented 4-times replicated rate studies with N applications (5 rates) at the side-dress time. We collected NDVI images were and yielded data. This work was continued into 2015 and 2016 with additional replicated N rate trials on farms and replicated studies at research farms where multiple N rates were applied at planting. Results from these trials supported the development of a calibrated set of equations for use in New York that was published in the Agronomy Journal in 2017 and the Computers and Electronics in Agriculture in 2018. Currently, with funding from Northern New York Agricultural Development Program (NNYADP), New York Farm Viability Institute, Dupont-Pioneer, Cornell Cooperative Extension (student internships), and Federal Formula Funds, the aim of this project is to evaluate the performance of the algorithm for independent sites.

Figure 7: Hand-held Greenseeker unit for active crop sensing and NDVI mapping.

Drones for Yield Predictions and N Management Decisions

Precision agriculture is moving toward the implementation of technology-driven farm management packages that also help in making better decisions about crop fertility management (decision agriculture). Of all nutrients essential for crop growth, N is most challenging to manage due to varying crop nitrogen (N) demands throughout the season and the inability to accurately predict N supply. Use of drone-obtained multispectral images and indices such as Normalized Difference Vegetation Index (NDVI) has the promise to aid in quick and accurate decision making for better N management of field crops like corn and forage sorghum that have large and well-timed N needs, but require accurate estimation of (1) end-of-season yield; (2) soil N supply; and (3) crop N needs. Our overall objective here is to evaluate the use of drone-collected images as tools for predicting yield and N needs for both crops. In 2016, in collaboration with Dr. Elson Shields of the Entomology Department at Cornell, we conducted our first flights. The initial objectives were determining the optimum flight height for the image collection, the best time of the day to fly, and to evaluate changes over time as corn and forage sorghum grow (weekly flights). We established that a 300 ft flight height was optimum: it provided enough images with clear resolution while maximizing the area of the field that can be covered by an individual drone flight. The amount of light during flight time affected the NDVI as well. That first year, 2016, was a dry year, and due to the high water-stress of the plants, grain yield and NDVI during the midday flights were poorly correlated. Plants suffering from water stress curled their leaves in the middle of the day to reduce evapotranspiration, and this impacted the images. Thus, flights in the afternoon had to be discarded. The drought also negatively impacted yield predictions for corn silage and corn grain, while forage sorghum yield was predicted more accurately. In 2017, three experiments were conducted to determine the optimum N rate for forage sorghum and corn (two different locations), and to determine the timing of application of a fixed amount of N fertilizer for corn. Weekly flights were used to gather images for corn and sorghum. Yield predictions with 70% accuracy were obtained with the drone-collected NDVI when the corn had 12 developed leaves (V12 stage). The challenge that year was to estimate N deficiencies at an early stage of corn development. Despite the extremely wet growing conditions early in the season, N deficiencies only became visible at V10-12; earlier scans did not correlate well with end-of-season yields. The timing of application data showed that corn responded fast to the N application independent of the timing of application. Also, this experiment showed that a late application of N (at V10) served as a “rescue application” that resulted in corn grain yields almost as high as the yield obtained with early season side-dress applications. However, the late application of N (at V10) showed a decrease in the corn silage yield. The sorghum experiment was planted later than corn, and thus, the early wet season did not affect the crop. From V7, good correlations were found between NDVI and forage sorghum yield (60% accuracy), and NDVI was able to distinguish among N status. The third year of yield data is being collected in 2018, in collaboration with Don Specker of Dupont-Pioneer and participating farmers in central and western New York (one dairy and one cash grain operation). This work is funded through grants from the Northern New York Agricultural Development Program (NNYADP), New York Farm Viability Institute, Federal Formula Funds, and in-kind support by DuPont-Pioneer.

Figure 8: Drone-mounted NDVI and multispectral cameras can be used to quickly obtain scans of fields.

Brachytic Dwarf Brown Midrib Forage Sorghum in Double Crop Rotations

The practice of double cropping is increasing in popularity in New York due to many environmental, economic, and production benefits. Winter cereal double crops provide the environmental benefits of cover crops, such as reduced risk of erosion and nutrient loss, as well as increasing per acre crop yields by up to 3.5 tons of dry matter in the spring for forage. Because of the short growing season in upstate New York, harvesting the winter cereals in time for corn planting in the spring can be a challenge. Brachytic Dwarf Brown Midrib (BMR) forage sorghum is a promising alternative to corn silage in double cropping rotations due to both its nutritional value and the potential for earlier harvest, thus allowing for more flexibility in spring planting. We have three main questions regarding growing BMR forage sorghum as an alternative to corn silage: (1) how much N do we need to apply at planting for optimal economic yield, (2) what are the tradeoffs between yield and quality at different stages of harvest, and (3) how does it compare to a short season corn silage variety in both yield and quality? Spearheaded by Tom Kilcer (Advanced Agricultural Systems, Inc.), on-farm trials (4 times replicated) were implemented to quantify crop response to N addition (5 N rates at planting: 0, 50, 100, 150, and 200 lbs N/acre) and the tradeoffs between yield and quality at different timings of harvest (3 harvest times, at growth stages 5-7). In total, 14 trials were established from 2014-2017 in collaboration with Cornell Cooperative Extension educators. One factsheet and two farmer impact stories were produced to date. Ongoing work includes developing a nitrogen recommendation system, determining optimal timing of harvest, and investigating how sorghum fits into a double cropping rotation. This work is funded through grants from the Northern New York Agricultural Development Program (NNYADP), New York Farm Viability Institute, Northeast Sustainable Agriculture, Research, and Education (NESARE), and Federal Formula Funds. This project is conducted in collaboration with Tom Kilcer, Advanced Ag Systems, and Cornell Cooperative Extension educators in Northern New York.

Figure 9: Forage sorghum can be a viable alternative to corn silage.

Winter Cereals as Double Crops in Corn or Sorghum Rotations

Due to the drought in 2012, more farmers became interested in growing winter cereals as double crops, benefiting from the protection offered by the cereal as a cover crop and harvesting the cereal as forage in May to increase per acre crop yields. Properly managed, these crops have supplied, on average, 2 tons of dry matter per acre, while in some fields in 2012 and 2013, we measured up to 4 tons of dry matter of high quality forage from winter cereals planted after corn silage, even with little growth in the fall. Our two main nutrient management questions with growing winter cereals for forage is: (1) how much N do we need at green-up for optimal economic yield, and (2) how does planting date, fall N availability and spring N addition influence fall growth and N uptake and spring performance? For the first question, on-farm trials (4 times replicated) were implemented in 2013-2016 to quantify crop response to N addition (5 N rates at Greenup: 0, 30, 60, 90, and 120 lbs. N/acre). In total, 63 on-farm trials were established and harvested from 2013-2016 in collaboration with Cornell Cooperative Extension educators. For the second question, 4 on-farm trials were established from 2012-2014 to see how planting date (before or after 9/20) and available N in both the fall and spring (5 N rates at planting and green-up: 0, 30, 60, 90, and 120 lbs. N/acre) influenced N uptake and growth in the fall and spring performance. Two journal articles were published (Agronomy Journal, 2017 and 2018), and a number of fact sheets, farmer impact stories, and extension articles were produced as well. Additional work is ongoing to determine what drives differences in optimum N rate across sites and evaluate a triticale-forage sorghum rotation with varying dates of harvest for the sorghum.

Figure 10: Sixty-three N rate studies were completed to develop a recommendation system for N application at green-up in New York.

Phosphorus Index Evaluation in the Northeast

In 2009, as part of their effort to revise the 590 Nutrient Management Standard, the Natural Resources Conservation Service (NRCS) requested that a Working Group of scientists within the Southern Extension-Research Activity Group 17 (SERA-17) make recommendations for ways to evaluate and improve P Indices. Specifically, that group concluded that a rigorous evaluation of P Indices is needed to determine if they are directionally and magnitudinally correct. While the use of observed P loss data under various management scenarios would be ideal, such data are not widely available. Alternatively, use of a locally relevant and validated water quality model may be the most expedient option for conducting Index assessments in the short time required by the newly revised 590 Standard. As a result of this, three regional consortiums were developed to evaluate, assess, validate, and refine P Indices in the Heartland, Chesapeake Bay, and Southern Regions. The Chesapeake Bay proposal (NRCS CIG project) stems from a national call for P Index advancement and builds upon a long, strong history of collaboration amongst project partners. Members of the project team worked closely in coordinating the development of P Indices in the

Chesapeake Bay region. Building upon these efforts, we proposed to further unify nutrient management planning within the region by harmonizing state P Indices within the major physiographic provinces of the Chesapeake Bay watershed. This approach reflects the common conditions and management practices that are found within these regions, consistent with NRCS's MLRA classification, and provides a model for extrapolating project outcomes outside the bounds of the Chesapeake Bay watershed. The project has five primary objectives: (1) establish a network of 11 watersheds within the four major physiographic provinces of the Bay watershed for foundational evaluation of nutrient management site assessment tools; (2) for each physiographic province, identify site conditions and practices of priority concern and corresponding remedial practices of greatest efficacy and adaptability; (3) evaluate P site assessment tools in the 11 watersheds by comparing their output with water quality monitoring data and fate-and-transport models; (4) use water quality data (monitored or predicted by model) to refine P Indices, improving their prediction of P loss potential, ensuring consistency across state boundaries and within physiographic provinces, and promoting effective recommendations for P management; and (5) predict the management impact of P Indices (existing and refined) on nutrient management practices and water quality. We are currently working with our counterparts in the watershed and local stakeholders on the evaluation of the performance of the current P index and possible refinements.

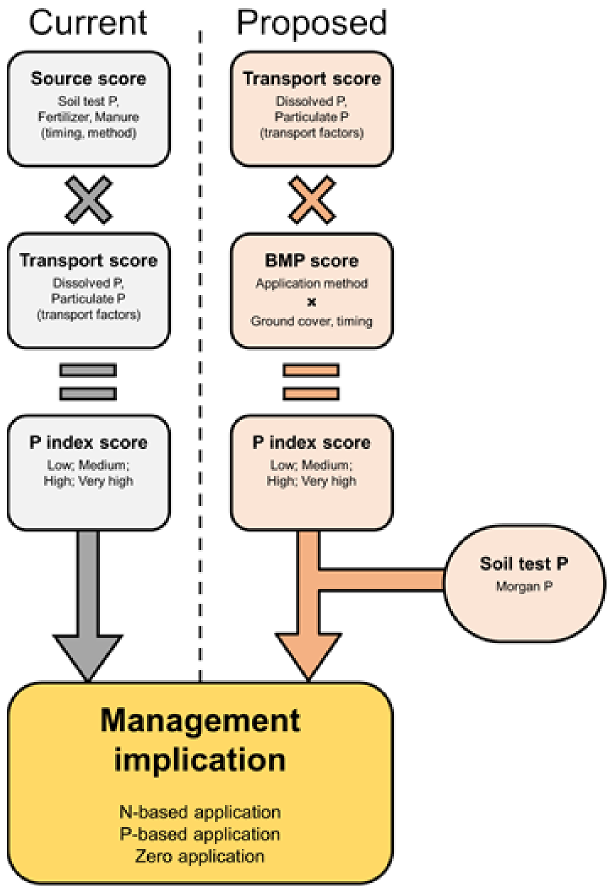


Figure 11. Schematic overview of the current (left) and proposed (right) New York P index.

Land Application of Acid Whey

The activities in this project aim to assist the dairy and Greek yogurt industries in New York State in dealing with acid whey. Over 1.2 billion pounds of whey are produced annually in New York State today (every 4 pounds of milk processed results in 3 pounds of whey). Finding economical, environmentally protective means to manage the whey is crucial to the viability of the industry and is needed to support the expansion of yogurt manufacturing in the State. Our component of the project includes the development of a guidance document for on-farm use of whey, requiring evaluation of the impact of its acidity on soils and the impact of the low solids content of whey and whey amended materials on infiltration and runoff when land applied. Specifically, we conducted research (1) to determine ranges in acidity and nutrient content of acid whey, (2) to evaluate changes in pH over time after application to representative NY soil types with a range of pHs and their potential need for added lime if whey is applied, and (3) to evaluate infiltration rates of whey sources for various soil types as compared to liquid manure of varying solids content and water. Key deliverables include science-based Guidelines for Land Application of Acid Whey for direct land application of whey and whey amended materials as well as two factsheets. This project is funded by the New York State Department of Agriculture and Markets (NYSDAM).

Corn and Hay Yield, Quality, and Soil Health as Impacted by Manure Management

Subset: Manure injection

This project is intended to assess the impact of different manure application methods on alfalfa and grass yield, soil fertility and stand survival. Manure injection is being compared with surface application. Injection can reduce runoff and volatilization of manure nutrients, but the impact on stands in our climate has not been quantified. Such information is needed prior to the adoption of manure injection technologies. In past years, we conducted studies comparing injection with surface application and no manure treatments. These on-farm trials were conducted in collaboration with **Scott Potter** using a modified Veenhuis injector with a drag hose system. This year we have set up trials in grass and alfalfa fields at the Musgrave Research Farm with application of manure with a smaller Veenhuis unit (tank-mounted). Additional sites were added in the fall of 2014 at the Cornell Ruminant Nutrition Center in Harford, NY. This project is a component of a multistate collaboration: "SAM Initiative: Subsurface Application of Manures in the Chesapeake Bay Basin", funded by a USDA Conservation Innovation Grant with the National Fish and Wildlife Foundation. The project includes states with all or part of their agricultural land in the Chesapeake Bay Watershed but focus of the other states is on dry poultry litter rather than liquid dairy manure.

Figure 12. Tanker-mounted Veenhuis liquid manure injector which was used in trials in Aurora.

Subset: Nutrient boom

Doug Young of Spruce Haven Farm and Research Center (Union Springs NY) developed an innovative drag boom able to apply liquid manure into crops as tall as 7 feet. This new technology has great promise as it allows for manure application in a hydrologically less sensitive time of the year, at a time

Figure 13. Nutrient boom for liquid manure application in a growing corn crop.

where crops can take advantage of the manure nutrients, and, due to its application timing and method, can reduce ammonia emissions. In collaboration with Agricultural Consulting Service (ACS) we are conducting an assessment of the impact of the later-season application of manure to corn. This project is done at a Cayuga County farm, funded through in-kind contributions by the farm and Spruce Haven Farm and Research Center, and funds from USDA Conservation the Innovation Grant with the National Fish and Wildlife Foundation. A new proposal was submitted for continued work in three states (Ohio, Indiana, New York) in 2015/2016 (USDA-CIG multistate submission).

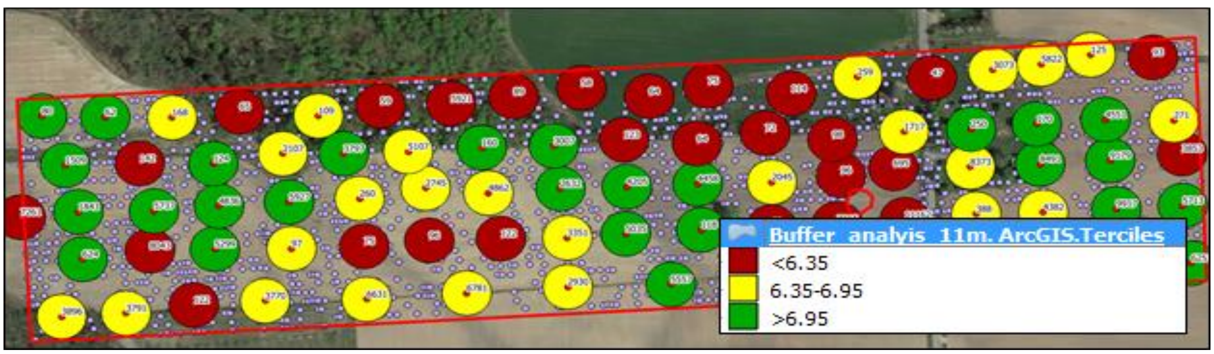
Greenhouse Gas Emissions from Alfalfa/Grass and Corn Fields

Dairy production systems can play a key role in both reducing agricultural greenhouse gas emissions and leading to more resilient agricultural systems that can adapt to a changing climate. In 2013, a new project, a collaboration of many universities and institutes, was initiated under the name "Climate change mitigation and adaptation in dairy production systems of the Great Lakes region" (funded as a USDA/NIFA AFRI project (2013-68002-20525) titled "Dairy Cap"). The overall project leader is **Dr. Matt Ruark**, University of Wisconsin. The overall project aims to: (i) reduce the life cycle environmental impact from dairy production systems, (ii) identify opportunities to increase the resiliency of dairy production systems, (iii) further develop a decision-support tool for producers to identify opportunities and implement management practices that mitigate greenhouse gas emissions at the farm level, and (iv) educate farmers, agricultural industry, policy makers, teachers, students, and the general public on sustainable management practices for dairy operations. For our component in the NMSP, we quantified greenhouse gas emissions (N_2O, CH_4 and CO_2) as impacted by manure or compost application method, rate and timing for corn, and manure application method (injection versus surface application) for grass and alfalfa. We were able to expand on the scope with additional funding from federal formula funds, a USDA conservation innovation grant (4782-CU-USDA-2226), and funds from the Atkinson Center for Sustainable Future at Cornell University. In 2014 and 2015, greenhouse gas emissions were measured in corn, grass and alfalfa systems. This work was published in the Soil Science Society of America Journal in 2017.

---------------------------------------COMPLETED PROJECTS ---------------------------------------

Spatial variability of yield, corn stalk nitrate test results, and Illinois soil nitrogen test results

Nitrogen (N) is an essential macronutrient in plant growth and the primary nutrient limiting corn production in New York. Conversely excess N contributes to harmful runoff and is costly to farmers. Thus N management has an impact upon yields, fertilizer expenses, and the environment. A recent addition to New York State N management policy allows for farmers to override land-grant university recommendations in favor of an adaptive management approach using the Corn Stalk Nitrate Test (CSNT). The CSNT indicates the adequacy of N supply to a corn crop in the past season. Current CSNT sampling protocol requires a minimum of 1 stalk per acre and was determined without assessing the within field variability of the CSNT. The aim of this study was to (1) determine a minimum sampling protocol for adaptive management of N using the CSNT and (2) determine if yield maps can be used to develop field management units for CSNT sampling. We worked with a local dairy farm to evaluate the feasibility and accuracy of "targeted sampling" for CSNT and are expanding the work with two additional farms in Northern NY funded by the Northern New York Agriculture Development Program (NNYADP). Similar, we evaluated the spatial distribution of the Illinois soil nitrogen test (ISNT) using two fields that were sampled (regular grid and targeted sampling to obtain variograms) in central NY.



Potassium (K) needs for alfalfa

Potash prices reached historic highs a couple of years ago ($800-$1,000/ton), and are forecast to remain strong for the foreseeable future. Dairy producers often apply supplemental fertilizer K to alfalfa in rotation with corn because: (1) alfalfa removes large amounts of K; and (2) there are concerns about stand survival through the winter for low K alfalfa. Cornell K guidelines are soil-specific and reflect the strong K supplying capacity of many NYS soils. Consequently, the K guidelines are lower than industry K recommendations. For the reasons listed above, it is however not uncommon for dairy producers to apply 150-250 lbs/acre K_2O ($100-$200/acre in 2008). This is reflected in high whole farm K balances on some dairy farms. Research at the Aurora Farm the past three years showed no yield response to K for fields testing even low or medium in soil test K, suggesting potential for large fertilizer savings. Crop removal-based applications required $200/acre in K fertilizer costs while the K saturation based approach used on some farms would have resulted in even larger K applications. Field trials and an extension program were needed to evaluate soil test K versus K saturation and crop removal based management for impact on yield, quality, stand survivability, fertilizer costs. We initiated such a project in 2009. We worked with six farms funded by a grant from the New York State Farm Viability Institute (NYFVI) and Federal Formula Funds. Our specific research objectives were to: (1) determine likeliness of a K yield or

quality response of alfalfa fields in a corn-alfalfa rotation, with and without manure application in the corn years; (2) evaluate three approaches for K management (soil test K based, percent K saturation based, crop removal based) for their validity as tool for optimizing K management for alfalfa in corn-alfalfa rotation and for predicting economic return to K; (3) assess the impact of each approach on whole farm K balances and return to fertilizer investments. We conducted a statewide K status assessment of agricultural soils in New York State using current and past soil test records. Our extension objectives focussed on creating awareness for K needs (or lack thereof) for alfalfa in corn-alfalfa rotations, awareness of the three approaches and their benefits and disadvantages, and fine-tuning of our K guidelines taking into account yield, quality and stand survival. This study resulted in an honor's theses by Chang Lian, Agricultural Sciences major, and Yike Bing, Animal Science major. The studies were conducted in collaboration with **Agricultural Consulting Service, ConsulAg, Miner Institute, and Cornell Cooperative Extension field crop educators**. A continuation that combines field validation for findings for K and sulfur (S) management followed.

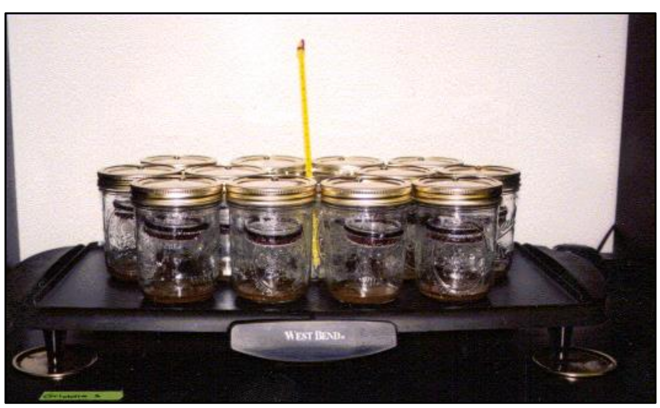
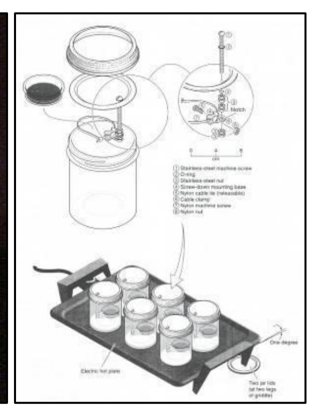
Nitrogen dynamics following cover crop incorporation in corn silage cropping systems.
Cornell N guidelines for corn recognize N benefits of alfalfa/grass in the rotation and hence reduced N fertilizer need for first year corn but specific N discount is given to N credits from cover crops. Dairy producers often apply 100-150 pounds or more of actual N to 2nd or higher year corn, especially if no manure is applied. If a cover crop can reduce N use, saving for farmers can be substantial ($20-$30/acre). A survey was conducted to document cover crop success stories and identify barriers to implementation as well as document farmer input on extension and research related to cover crop use in corn silage systems. Preliminary monitoring of N dynamics following turnover of a cover crop showed that both clover and rye cover crops can accumulate a considerable amount of N. Monitoring of N dynamics following clover cover crops in 2007 and 2008 in the organic cropping systems trial showed large nitrate peaks mid-June and no crop response to additional N while work in NNY indicated no difference in N release from rye versus triticale and equal N release from chemically and mechanical termination of the cover crop. Nitrogen release from a 4 ton rye crop rolled in June was limited versus a large N supply following plowdown of 2 ton of rye early May. Laboratory incubations showed the importance of the carbon (C) to N ratio in determining the timing of N release and monitoring of a rye crop on a central NY farm: rye had to be turned over before mid-May for a C:N ratio less than 30 to avoid N immobilization. The research was completed and results of the survey were published in Crop Management in 2013. This project was funded with Federal Formula Funds and resulted in a recent journal article (review paper) published in the Agronomy Journal (2015).

Sulfur (S) needs for alfalfa

In 2007, we initiated a new project to: (1) determine the S status and S removal by alfalfa grown in New York; (2) develop critical levels for tissue and soil testing using a new $CaCl_2$ method; and (3) stimulate S use where needed for improved alfalfa production, enhanced farm profitability, and protection of the environment. Field work for this project was completed (8 sites in 2008 and 2009) in collaboration with **Cornell Cooperative Extension field crop educators**, resulting in critical values for a new soil test and documentation of S deficiencies for New York State. Two factsheets were developed and two journal articles were published (Soil Science Society of America Journal, 2011 and 2012). This project was continued as a joint project that combined field validation for potassium and sulfur management, supported by NESARE.

Tools for nitrogen management for corn

The Illinois Soil Nitrogen Test or ISNT was developed in Illinois. It was modified to reduce test variability in the laboratory (enclosed boxes for assessments). Field trials were conducted in 2002-2008. This project involved many **CCE field crops educators** and had both research station trials for more controlled treatments and on-farm trials (33 trials in 2002-2005 for development of critical levels, 16 trials to address first year corn sites, and 19 trials for second/third year corn or corn after soybean). The project showed great promise for the new soil N tool and is currently being offered as a tool for N management by the NMSP. In addition, we calibrated a corn test (late season corn stalk nitrate test, CSNT) for use in New York as a "post-season" evaluation of N management. The results of the ISNT work were published in the Soil Science Society of America Journal (2006-2009) and presentations on New York ISNT and CSNT work were given in New York and elsewhere. This project was made possible by grants from the New York Farm Viability Institute (NYFVI), with additional support from the Northern New York Agricultural Development Program (NNYADP) and federal formula funds. Four journal articles were published for work in the ISNT. In 2013, two new factsheets were developed to introduce adaptive management for corn as a strategy for nitrogen management: #77: Nitrogen for Corn; Management Options and #78: Adaptive Management of Nitrogen for Corn. Additional guidelines were developed over the winter of 2018 and release for use in New York in June of 2018 (http://nmsp.cals.cornell.edu/publications/files/AdaptiveManagementGuidelinesFor2018.pdf).



Impact through collaboration and integration of teaching, extension and research.

Cornell Nutrient Management Spear Program

A collaboration among the Department of Animal Science, Cornell Cooperative Extension and PRODAIRY.

http://nmsp.cals.cornell.edu

Peer-reviewed publications (*indicates NMSP staff or current/former student advisees):

Total	'18	'17	'16	'15	'14	'13	'12	'11	'10	'09	'08	'07	'06	'05	'04	'03	'02	'01	'00	'99	'97
118	1	20	8	5	4	5	6	10	5	10	3	8	9	11	2	1	4	1	2	2	1

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6: Lime Recommendations (3/4/2006)
7: Liming Materials (7/21/2006)
8: Starter Phosphorus Fertilizer for Corn (10/22/2005)
9: Cornell Cropware (8/18/2005)
10: Phosphorus Index (12/12/2005)
11: Nitrogen Leaching Index (2/2/2006)
12: Phosphorus Basics - The Phosphorus Cycle (1/16/2006)
13: Phosphorus Runoff (1/16/2006)
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15: Phosphorus Soil Testing Methods (9/30/2006)
16: Application of Manure to Established Alfalfa (12/18/2006)
17: Nutrient Management for Pastures (6/28/2006)
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22: Cation Exchange Capacity (3/2/2007)
23: Estimating CEC from Cornell Soil Test Data (3/2/2007)
24: Teff as Emergency Forage (3/22/2007)
25: Mass Nutrient Balance Software (6/7/2007 revised 8/13/2010)
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43: Nitrogen Benefits of Winter Cover Crops (11/26/2008)
44: Nitrogen Fertilizers for Field Crops (8/23/2009)
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47: Boron (12/18/2009)

48: Buffer pH for Lime Guidelines (1/8/2010)
49: Manganese (4/30/2010)
50: Buckwheat Production: Planting (7/7/2010)
51: Buckwheat Production: Harvesting (7/7/2010)
52: Web Soil Survey (8/26/2010)
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55: Tissue Testing for Corn, Alfalfa and Soybeans (10/28/2010; currently in review)
56: Winter Triticale Forage (12/17/2010)
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74: Soybean Fertility Management (12/13/2012)
75: Field Crop Fertilizer Management (12/13/2012)
76: Manure Use for Soybeans (12/13/2012)
77: Nitrogen for Corn; Management Options (10/2/2013)
78: Adaptive Management of Nitrogen for Corn (10/2/2013)
79: Zone/Strip Tillage (12/19/2013)
80: Urea Fertilizer (12/19/2013)
81: Red Clover for Quality Forage for Dairy (1/11/2014)
82: Harvest and Storage of Malting Barley (12/20/2014)
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