Northern NY Agricultural Development Program
2018-2019 Project Report

Advancing Nitrogen Management and Soil Health in Northern New York

Project Leaders:

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Cooperating Producers:

Essex County: Juniper Hill Farm, Wadhams, NY
Lewis County: Conway Dairy Farm, LLC, Turin, NY

Background:

The purpose of this project is to research, develop, and facilitate the adoption of practical decision tools and solutions that simultaneously improve farm profitability and minimize negative environmental impacts.

Nitrogen is an essential nutrient for crop production and the manufacture of synthetic nitrogen has facilitated impressive advances in food production. But this nutrient also causes major environmental concerns with nitrate contamination of groundwater in agricultural regions and hypoxia in estuaries that cause dead zones in late summer. Also, a gaseous form of nitrogen is a potent greenhouse gas and contributes to climate change. Anthropogenic N pollution has large social costs, with estimated ecosystem and health damages of $157 billion per year. Despite many mitigation efforts, the N loss from agricultural systems continues to be a major concern. Farmers, supply-chain entities, and policymakers are increasingly in need of a simple, yet robust, metric of progress in reducing N pollution associated with food production.

New York's 1.15M corn acres generally have low fertilizer nitrogen (N) uptake efficiency, which suggests high potential N losses. To the farmer, this means the loss of a costly input, potential yield deficits, and a reduction in income. To society, concerns exist for excessive nitrate levels in groundwater, N-induced hypoxia, high energy consumption, and N_2O (a greenhouse gas) losses.

Win-win opportunities exist for more sustainable soil health and N management that will benefit both the farmer and the environment. It has been established that N inputs beyond the economic optimum N rate (EONR) cause the largest environmental impacts, but the EONR itself is an elusive target. Our earlier research revealed how variability in the EONR is also highly influenced by early-season weather, especially rainfall quantities and timing interacting with soil and management factors. The associated risk and uncertainty perceptions move growers to apply "insurance N" in the majority of years, and thus promote large environmental losses. We have developed and implemented two important tools, originating with research at the Cornell Willsboro Research Farm in Northern New York, to address uncertainties due to weather and to buffer soil functioning under extreme events - Adapt-N and the Cornell Comprehensive Assessment of Soil Health framework.

Adapt-N (http://adapt-n.cals.cornell.edu/) is a web-based computational tool that uses real-time high-resolution climate data, and field-specific management, soils, and crop information as inputs for a dynamic simulation model. It provides in-season N recommendations as well as graphs visualizing seasonal dynamics of soil N, crop growth, temperature, and precipitation for each management unit for entire fields down to 60x60ft gridded zones.

We determined from on-farm strip trials that Adapt-N is superior to conventional static N recommendation systems, like the Cornell N Calculator. In December 2017, Adapt-N was awarded $1M for its solution to reduce runoff of Nitrogen from the Tulane University Nitrogen Reduction Challenge. In November 2017, Yara International, a multinational chemical company, acquired Agronomic Technology Corporation, the license holder of

Adapt-N. The acquisition provided an opportunity for Adapt-N to scale globally, innovate across a wider product portfolio and crop base, and maintain focus on the success and sustainability of consultants and farmers.

The **Cornell Comprehensive Assessment of Soil Health** (CASH) (http://soilhealth.cals.cornell.edu/) is the first laboratory soil health test that has provided standardized, field-specific information on agronomically-important constraints in biological and physical processes in addition to standard nutrient analysis. Our soil health management planning framework with this assessment synthesizes results into a grower-friendly report.

To encourage adoption of these tools, we have developed innovative, complimentary software and management tools, such as integrating cover crop information, financial and environmental impact assessments (N-Insight), and enhanced efficiency compounds (N-inhibitors) into Adapt-N. There are also tie-ins between Adapt-N and soil health through the model's representation of C and N mineralization. Biological indicators (respiration and protein content) have been included in the CASH analysis since 2014 and we propose the integration of such results with N recommendations to help growers capitalize on soil health management as they can account for benefits through lower N fertilizer rates. **We postulate that *combining* management approaches will be attractive to farmers and have greater impact.**

Methods:

We worked directly with the Cornell Willsboro Research Farm, Cooperative Extension, NRCS and Soil and Water Conservation Districts to promote implementation of precision N management and improve soil health in NNY with three objectives:

- develop and demonstrate methods to accurately predict crop N requirements and enhance efficiency;
- research the use of adaptive nitrogen management tool's impacts on water quality and greenhouse gas losses; and
- demonstrate effective outreach programs for farm strategies to reduce loss to the environment.

1) Develop and demonstrate methods to accurately predict crop N requirements:
We proposed to demonstrate and quantify effects on N dynamics, soil health and corn yield of two nitrogen management rates and implementation of cover crops in long-term tillage experiments. Three major tasks were:

a) beta-testing the cover crop module in Adapt-N,
b) demonstrating and promoting N-Insight tool for nitrogen diagnostics, and
c) soil health testing.

In 2018, we focused on testing and calibrating Adapt-N's cover crop module. Furthermore, pre-sidedress Nitrogen Tests (PSNTs) were taken on cover-cropped fields going into corn to evaluate Adapt-N's performance of predicting the 'virtual PSNT' and N supply from the cover crop and/or manure. PSNTs were taken at sidedress time and later in the season and compared to the virtual value given in Adapt-N.

The Cornell Comprehensive Assessment of Soil Health (CASH) approach was implemented to assess soil biological, physical and chemical differences between different management practices on each of the plots at the Willsboro Farm to evaluate the impact of implemented soil management practices on a soil's overall health and yield.

2) Research the use of Adapt N impacts on water quality and greenhouse gas losses: Sixteen plots each on loamy sand and clay loam soils, in continuous corn, under no-till and plow-till have been implemented for over two decades. The N regime changed in 2011-2018 according to two N management strategies: the standard rate according to conventional static recommendations (Grower) and the dynamic Adapt-N recommendation rate. In the 2017 season, we added a cover crop treatment of a grass-legume cocktail (Cereal Rye @ 30lb/ac, Annual Ryegrass @ 15lbs/ac, Hairy Vetch @ 8lbs/ac and Red Clover @ 6lbs/ac) to evaluate and demonstrate additional benefits with the use of Adapt-N. The seed mixture was planted using a John Deere 10-foot no-till grain drill into all of the cover crop treatments. However, soil management of the plots varied based on the tillage practice and soil type. In the clay loam, plow-till plots, the soil was moldboard-plowed in the fall (2017), disced, and culitpacked prior to seeding. The seed was then no-till drilled. In the clay loam, no-till plots, the seed was simply no-tilled drilled. In both the loamy sand plow-till and no-till plots, the seed mix was simply no-till drilled. In the 2018 growing season, we implemented the same management plan.

Drainage water samples were collected from the lysimeters at key time points in the spring and fall of 2017 and 2018 following treatments, and N content was quantified to allow us to assess differences in water quality in Adapt-N vs Grower plots. Soil samples were collected in May 2017 and September 2018.

3) Demonstrate effective outreach programs for farm strategies to reduce loss to the environment: The use of adaptive N management (Adapt-N) and soil health management was promoted through presentations at field days and listening sessions in two NNY locations. Grower involvement was sought from all six NNY counties covered by the extension and consultant staff.

Results:

1) Development and demonstration of methods to accurately predict crop N requirements and enhance efficiency.

To promote and encourage Adapt-N use, we have incorporated important N loss reduction technologies, including the incorporation of cover crop information to estimate N release and availability for the subsequent crop, into Adapt-N to enhance adoption benefits. We believe this will further enhance Adapt-N's sustainability credentials and promote the use of cover crops by modeling N cycling benefits of using cover crops. Going forward, we are certain that the nitrogen leaching data collected under cover cropped plots will be invaluable in the integration of a cover crop module to Adapt-N.

In terms of soil health testing, the results demonstrated divergence in soil health between the plow-till (PT) and no-till (NT) treatments at the Willsboro Farm. The implementation

of soil health management, namely continuous no-till, has a strong positive effect on soil biological and physical indicators such as organic matter, soil protein, respiration, active carbon, and wet aggregate stability. This research comparing long-term PT and NT on two soil types at the Willsboro Farm was published in the Geoderma Journal in 2018.

Specifically, long-term NT resulted in 17% more organic matter, 65% more soil protein, 17% higher respiration, and 76% higher wet aggregate stability than long-term PT at the clay loam site.

Similarly, long-term NT resulted in 67% more organic matter, 49% more soil protein, 51% more active carbon, 82% higher respiration, and 92% higher wet aggregate stability than long-term PT at the loamy fine sand site.

Although work on direct impacts to economic benefits is beyond the scope of this project, it has been well documented that improving physical and biological properties of the soil can build and maintain resiliency to extreme weather events like flooding and drought.

2) Lysimeter study at Willsboro Research Farm.
Two N sidedress rates were implemented in 2017 and 2018. One was based on the standard rate according to conventional static recommendations (Grower) and the second was based on the dynamic Adapt-N recommendation rate (Adapt-N). During the project period we collected and submitted for analysis samples from seven different leaching events in 2017 (2/27, 4/6, 5/10, 6/1, 6/19, 10/10, and 10/31) and five different leaching events in 2018 (4/18, 4/30, 10/3, 10/12, and 11/2).

We found that Cornell's Corn N Calculator (CNC) N rates were on average 59 lbs acre^{-1} higher than Adapt-N rates, but did not result in increases to corn yield (Figure 2). As a result, we calculated that Adapt-N rates would result in savings to a farmer of $29 acre^{-1} compared to CNC N rates.

In addition to higher fertilizer costs per acre, CNC N rates led to 58% higher nitrate leaching in clay loam soils (10.32 vs. 6.55 mg NO_3^-+NO_2^- L^{-1}) and 68% higher nitrate leaching in loamy sand soils (20.69 vs. 12.29 mg NO_3^-+NO_2^- L^{-1}) compared to Adapt-N. Despite considerable variability in nitrate concentrations in drainage water, there was a positive relationship between N rate and nitrate concentrations in drainage water (Figure 2). A more complete description of the results can be found in a December 3, 2018 article in What's Cropping Up? (v28, No.5).

We were unable to implement the evaluation of the effectiveness of N-inhibitors on yield, profit and water quality in this project due to the complexity of implementing tillage, cover crop, and N inhibitor treatments all at once and the small size of the research plots. In an effort to focus on successfully integrating the cover crop portion of the experiment, we had to remove the N-inhibitor portion of the experiment.

3) Demonstration outreach and production of training materials.

The use of adaptive N management (Adapt-N) and soil health management was promoted through presentations at the Lewis County Soil and Water Conservation District Free Soil Health/Cover Crop Seminar in Lyons Falls, NY, on October 26, 2017, with 20 in attendance; and the Essex County Soil Health Listening Session in Essex, NY, on October 26, 2017, with 15 in attendance.

In 2018, we worked with Amy Ivy to organize and fund a reduced tillage field day at the Cornell Willsboro Research Farm on July 31. Seventy-one growers from New York and Vermont came out to learn about reduced tillage tools and the strategies to implement them. Amy Ivy compiled a reduced tillage handbook, featuring resources from the presenters of the workshop, which is available at: https://enych.cce.cornell.edu/submission.php?id=600&crumb=soil_health|soil_health.

See "Outreach" and "Reports" sections of this report for extension articles and training materials made available at the grower meetings, on our website, and other outlets.

Conclusions/Outcomes/Impacts:

Adapt-N (http://adapt-n.com) is a nitrogen technology solution that offers benefits for farmers, consultants, and fertilizer retailers, while effectively addressing multiple environmental concerns. The tool uses models and biophysical data to simulate field conditions and derive an optimum N rate recommendation. Adapt-N focuses on an important component of the solution: getting farmers to apply the right N fertilizer rate for a particular production environment that optimizes crop uptake and minimizes environmental losses, while also facilitating the use of other beneficial technologies like better N application timing, cover cropping, and use of enhanced efficiency products.

We have demonstrated "win-win" capabilities for Adapt-N's precise N management approach: reduced environmental impacts with higher producer profits. Based on 152 multi-year on-farm strip trials in the Midwest and Northeast, we have demonstrated average reductions in N inputs by 29 lbs/ac, with the same yields and higher farmer profits ($29/ac). This research comparing Adapt-N and Corn N Calculator at Willsboro confirms these earlier findings.

We have also demonstrated that the use of Adapt-N can result in 35-40% reductions in leaching and gaseous losses of nitrogen. Adapt-N offers an estimated 5-20x return on investment for growers, depending on the production environment.

Primary beneficiaries of Adapt-N are Northeast and Midwest corn producers using a variety of management styles and scales (Adapt-N is scale-neutral), but particularly those who already have sidedressing equipment. However, collaborators report that the Adapt-N tool, and associated learning opportunities, are encouraging growers in their areas to shift N application toward sidedressing, away from pre-plant application. This project is also benefiting agricultural service providers including consultants, extension personnel, NRCS and SWCD staff, and researchers, who can use the tool to teach about N dynamics and to provide better N management advice. Society is a secondary beneficiary through improved water quality, reduced greenhouse gas losses, and mitigation of climate change associated

with better N management on the most common and environmentally impactful crop in the U.S.

Outreach:

In-person presentations at regional field days and listening sessions, as well as informal visits and phone conversations with collaborators, and articles in a number of publications as follow. Please note that additional publications as well as recorded webinars are available on online at http://adapt-n.cals.cornell.edu/ and for the Cornell Comprehensive Assessment of Soil Health at http://soilhealth.cals.cornell.edu/.

Journal Publications

van Es, H.M., A.J. Ristow, M.R. Nunes, R. Schindelbeck, M. Davis. 2019. Nitrate Leaching Reduced with a Dynamic-Adaptive over a Generalized Nitrogen Management Tool Under No-Till and Plow-Till. Soil Science Society of America Journal. *In Review*

Nunes, M.R., H.M. van Es, R. Schindelbeck, A.J. Ristow, M. Ryan. 2018. No-till and cropping system diversification improve soil health and crop yield. Geoderma. 328:30-43. https://doi.org/10.1016/j.geoderma.2018.04.031

Eileen L. McLellan, Cassman, K.G., Eagle, A.J., Woodbury, P.B., Sela, S., Tonitto, C., Marjerison, R.D., van Es, H.M. 2018. The Nitrogen Balancing Act: Tracking the Environmental Performance of Food Production. http://fdslive.oup.com/www.oup.com/pdf/production_in_progress.pdf

Sela, S., H. M. van Es, B. N. Moebius-Clune, R. Marjerison, D. Moebius-Clune, R. Schindelbeck, K. Severson, E. Young. 2017. Dynamic model improves agronomic and environmental outcomes for maize N management over static approach. Journal of Environmental Quality. JEQ-2016-05-01822-TR.R2. doi:10.2134/jeq2016.05.0182.

Fine, A.K., H. van Es, R. Schindelbeck. 2017. Statistics, Scoring Functions, and Regional Analysis of a Comprehensive Soil Health Database. Soil Science Society of America Journal. Published online June 30, 2017. https://dl.sciencesocieties.org/publications/sssaj/pdfs/81/3/589

Books

Moebius-Clune, B.N., D.J. Moebius-Clune, B.K. Gugino, O.J. Idowu, R.R. Schindelbeck, A.J. Ristow, H.M. van Es, et al. 2016. Comprehensive Assessment of Soil Health – The Cornell Framework, Edition 3.2, Revised June, 2017. Cornell University, Ithaca, NY.

Fact Sheets

Cornell University Comprehensive Assessment of Soil Health Laboratory Soil Health Manual Series. January 2017. Schindelbeck, R.R., A.J. Ristow, K.S. Kurtz, L.F. Fennell, H.M. van Es

Webinar Workshops and Educational Materials

http://adaptn.cals.cornell.edu/webinars/index.html
http://adapt-n.cals.cornell.edu/pubs/index.html
https://blogs.cornell.edu/soilhealthinitiative/.

The commercial version of Adapt-N is available at http://www.adapt-n.com/.

The Agricultural Consulting Services (ACS), one of the largest consulting firms in NY, has worked with a few farms in Northern New York.

Next Steps:

Adapt-N has shown economic and environmental benefits, and some promising initial increase in adoption by growers. The acquisition of Adapt-N through the purchase of ATC by Yara International shifts the focus of our work from research to implementation of the tool on a large number of acres, including several outside of the U.S.

Hurdles that need to be considered in the next years:

- Farmers, consultants and retailers' general perception that hardware (e.g., sensors) is the future for precision nutrient management (although most have not shown accurate recommendations for corn production). Based on the literature, Adapt-N performs better than all other technologies.
- Research concerns: limited farm data availability for analytics, the small researcher community and limited funding at universities in promising areas of data analytics, limited capacity for highly innovative research initiatives and new management recommendations, and limited partnerships between the present research-extension community and private sector agriculture and technology companies.

We believe that Northern New York would benefit from a focus on:

- Integrating soil health indicators into Adapt-N to better inform N sidedress recommendations.
- Coordinating soil health assessment and management outreach, including nutrient management through establishment of a regional network of farmers, ag service providers, and conservation agency personnel as a clearinghouse for local resources, and to provide advice and recommendations; determine and set priorities for research, equipment needs, programmatic gaps, etc.; and reach out to underserved members of the ag community.
- Facilitating farmer-to-farmer and interagency communication by building additional partnerships with regional research farms, agri-businesses, growers and NGOs.
- Develop a consensus and promote a consistent message around what soil health means to Northern New Yorkers and acceptable ways of measuring soil health using indicators.
- Securing additional funding and provide support for on-farm research and demonstration through sources such as the Northern New York Agricultural Development Program, New York Farm Viability Institute, Northeast Sustainable Agriculture Research and Education, and the USDA-NRCS Conservation Innovation Grants
- Promoting technical and financial assistance and training that supports soil health through developing coordinated annual planning events such as the Willsboro Farm annual field day and others. In addition, there should be financial and technical support for local and regional soil health field days and workshops through providing topics, speakers and providing equipment. Staff from Northern NY conservation districts, CCE offices, and NRCS offices could support this work (great work is already being done, but we believe that a greater emphasis would greater benefit Northern New York).

- Developing a seasonal soil health curriculum for growers, ag-retailers, consultants, etc. and the distribution of existing conservation agency brochures on soil health management at an initial point of contact.

Acknowledgments:

In addition to NNYADP funds, funding and resources for Adapt-N and soil health assessments and outreach have been provided by the New York Farm Viability Institute, USDA-NRCS Conservation Innovation Grant, USDA-NIFA, Northeast Sustainable Agriculture Research and Education, Walmart Ag, General Mills and the New York State Department of Agriculture and Markets Soil Health Initiative.

Articles in Which Results of This Project Have Been Published:

Department Publications:

Amsili, J., A. Ristow, M. Nunes, H. van Es, R. Schindelbeck, M. Davis. 2018. Adapt-N tool leads to reduced nitrate leaching compared to Corn N Calculator. What's Cropping Up? Vol. 28 No. 5, November/December, A newsletter for NY field crops and soils, Soil and Crop Sciences Section, Cornell University, Ithaca, NY.

Schindelbeck, R., A. Ristow, M. Ryan and H. van Es. 2017. Reduced Tillage and Cover Crops Have Additive Effect for Improving Soil Health. What's Cropping Up? Vol. 27 No. 3, May-June, A newsletter for NY field crops and soils, Soil and Crop Sciences Section, Cornell University, Ithaca, NY.

Kinoshita, R., L. Fennell, M. Davis, A. Ristow, R. Schindelbeck, and H. van Es. 2017. Whole-profile soil health in long-term corn residue and tillage management. What's Cropping Up? Vol. 27 No. 2, March-April, A newsletter for NY field crops and soils, Soil and Crop Sciences Section, Cornell University, Ithaca, NY.

Fennell. L., A. Ristow, R. Schindelbeck, K. Kurtz, and H. van Es. 2017. The Soil Health Manual Series: Fact sheets from the Comprehensive Assessment of Soil Health Training Manual. What's Cropping Up? Vol. 27 No. 1, Jan-Feb, A newsletter for NY field crops and soils, Soil and Crop Sciences Section, Cornell University, Ithaca, NY.

Kinoshita, R., A. Ristow, H. van Es, J. Dantinne, and M. Twining. 2017. Within-Field Profitability Analysis Informs Agronomic Management Decisions. What's Cropping Up? Vol. 27 No. 1, Jan-Feb, A newsletter for NY field crops and soils, Soil and Crop Sciences Section, Cornell University, Ithaca, NY.

In addition to articles published about Adapt-N and Soil Health, we are keeping the Adapt-N and Soil Health websites up to date. The Cornell Soil Health Website continues to provide up-to-date content on soil health testing available to the public at http://soilhealth.cals.cornell.edu, and a blog, e-list, and social media presence were established: facebook.com/soilhealth1 and twitter.com/soilhealth1.

Handouts at field days and workshops:

Cornell Soil Health Slake Test.pdf, 2017EFDSoilHealthPRs2-1.pdf, Soil Health Listening Session 10-26-17.docx, Cover Crop Seminar Flyer.pdf , and others.

Select Media (several articles were removed to shorten the report length)

Lisa Heacox. 'Taking Nitrogen to the Max' *PrecisionAg*. January 27th, 2017.

Agriculture Economy. 'Soil Health is becoming an increasing challenge and crisis for New York State agriculture' *nysenate.gov*. May 23, 2017.

Cindy Zimmerman. 'Adapt-N Brings Big Data Value to Farmers a Million Times a Day' *precision.agwired.com*. July 7, 2017.

Kristin Nordal. 'Yara acquires leading crop nutrition recommendation platform to strengthen Digital Farming offering' *globenewswire.com*. November 6, 2017.

Emma Cosgrove. 'BREAKING: Fertilizer Giant Yara International Acquires Adapt-N Nitrogen Modeling Tech' *agfundernews.com*. November 6, 2017.

Steve Hardy. 'Cornell Group wins Tulane contest to devise effective ways to reduce Gulf dead zone' *theadvocate.com*. December 12, 2017.

Matt Hayes. 'Digital agriculture tech Adapt-N nets $1M Tulane prize' *cals.cornell.edu*. December 18, 2017.

Cornell University. 'Cornell team wins $1 million award. Wins the international Tulane Nitrogen Reduction Challenge Award' *morningagclips.com*. December 18, 2017.

Amy Ivy. 'July 31: Reduced Tillage Field Day in Willsboro' *blogs.cornell.edu/ccefieldcropnews.* July 3, 2018.

Cedric Mason. 'Organic Farmers, Educators and Researchers Gather to Discuss Soil Health in Essex County' *blogs.cornell.edu/soilhealthinitiative.* August 15, 2018.

Richard Gast. 'Advancing a soil-health movement' *pressrepublican.com.* August 26, 2018.

For More Information:

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