Northern NY Agricultural Development Program
2016-2017 Project Report (1/1/17-1/31/18)

Advancing Nitrogen Management and Soil Health in Northern New York

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Cooperating Producers:

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

Background:

New York's 1.15M corn acres generally have low fertilizer nitrogen (N) uptake efficiency, suggesting high potential for N losses (a costly input), potential yield deficits, a reduction in farm income, the risk of excessive nitrate levels in groundwater, N-induced hypoxia, high energy consumption, and N2O (greenhouse gas) losses.

Soil Health drives N availability and thus, the soil health status of a particular management unit can impact the right N rate. A more comprehensive understanding of soil health status, through identifying field-specific constraints, can better guide farmer's soil and nitrogen management decisions. Many of the practices that alleviate soil health constraints, such as implementing cover crops, reducing tillage, using crop rotations, and adding amendments, will impact the N rate.

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 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 (see here). In December 2017 Adapt-N was awarded $1M from the Tulane University Nitrogen Reduction Challenge for its solution to reduce the runoff of N. In November 2017, Yara International, a multinational chemical company, acquired Agronomic Technology Corporation, the license holder of Adapt-N. The acquisition will provide 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. It is regarded as a key tool for soil health management by several national initiatives. In addition, we have developed a soil health management planning framework associated with the assessment that includes results synthesized into a grower-friendly report.

Despite the expansion of these tools on a national scale and their origins from research at the Cornell Willsboro Research Farm in Northern New York , their implementation in the region is lagging. To enhance adoption, we have developed innovative, complimentary

software and management tools such as integrating cover crop information to estimate N release and availability for the subsequent crop, 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 work directly with the Cornell Willsboro Farm, Cooperative Extension, NRCS, and Soil and Water Conservation Districts to promote implementation of precision N management and improved soil health in Northern New York with three objectives:

1) develop and demonstrate methods to accurately predict crop N requirements and enhance efficiency,
2) research the impact of use of the adaptive nitrogen management tool on water quality and greenhouse gas losses, and
3) demonstrate effective outreach programs for farm strategies to reduce N loss to the environment.

1) Development and demonstration of methods to accurately predict crop N requirements and enhance efficiency: 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, we are:

1) beta-testing the cover crop module in Adapt-N,
2) demonstrating N-Insight tool for nitrogen diagnostics, and
3) conducting related soil health testing.

In 2017, we tested and calibrated 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 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 impact of use of the adaptive nitrogen management tool on water quality and greenhouse gas losses: 16 plots each on sand and clay soils, in continuous corn, under no-till and plow-till have been implemented for over two decades at the Willsboro Farm. The N regime changed in 2011-2017 according to two N management strategies:

1) the standard rate according to NYS conventional static recommendations (CNC) ,and
2) the dynamic Adapt-N recommendation rate (Adapt-N).

In 2017, we added a cover crop treatment of rye and 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 plow-till plots the soil was moldboard plowed in the fall (2017), disced and cultipacked prior to seeding. The seed was then no-till drilled. In the clay no-till plots, the seed was simply no-tilled drilled. In both the sand plow-till and no-till plots, the seed mix was no-till drilled.

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

Soil samples were collected in May 2017, when the soil was at approximately field capacity. The samples were composited by mixing six randomly collected within-interrow soil subsamples from the surface 0-to- 6 inches of each plot in a bucket, and then sub-sampling into a plastic bag. Samples were kept in a cooler, transported to the laboratory and stored at 39 degrees F until analysis.

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 Northern New York locations. Grower involvement was sought from all six NNY counties covered by the extension and consultant staff. New extension articles and training materials (fact sheets) were made available at grower meetings, on our website, and through other outlets.

Results:

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

The funding cycle for this project was such that the cover crop was not planted until the fall of 2017 and is currently over-wintering in the plots at Willsboro. Extension of funding into the summer of 2018 will allow the cover crop information to be integrated into the Adapt-N tool.

We have farms lined up for a spring 2018 demonstration of the implementation, ease of use, and accuracy of the N-Insight tool that was built on Adapt-N to help growers understand how to adapt to in-season weather conditions, how soil conditions impact N loss, and how changes in management practices may improve yield and environmental performance (bit.ly/N-InsightOverview).

Our soil health testing results demonstrated divergence in soil health between the plow-till (PT) and no-till (NT) treatments. The implementation of soil health management, namely, continuous no-till, has a strong positive effect on soil and physical

indicators such as organic matter, soil protein, respiration, and active carbon. 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. The results of this study have currently been accepted in a peer-reviewed publication (Nunes et. al, 2018).

2) Lysimeter study at Willsboro Research Farm

Two Nitrogen sidedress rates were implemented in 2017. One was based on the standard rate according to conventional static recommendations (CNC) 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 7 different runoff events. (2/27, 4/6, 5/10, 6/1, 6/19, 10/10, and 10/31/17). However, we have data from 14 events over 4 seasons (2014-2017). The results have been analyzed and the data is currently being written up for submission to a peer-reviewed paper. See Table 1 for a summary of the means for corn silage yield and amount of nitrogen in the water leached for both the clay loam soil and sandy loamy soil.

Table 1. Means of yield and leachate concentration of nitrogen from two soil types.

Clay loam		**Yield** (Mg ha^{-1})		**No_3 + NO_2** (mg L^{-1})	
Plow-Till					
	AdaptN	34.51	a	7.99	a
	CNC	35.08	a	12.02	a
	Plow-Till Mean	34.79	A	10.01	A
No-Till					
	AdaptN	34.16	a	5.12	a
	CNC	31.97	a	8.62	a
	No-Till Mean	33.06	A	6.88	A
N Supply					
	AdaptN Mean	34.33	A	6.55	B
	CNC Mean	33.52	A	10.32	A
	N Supply Mean	33.92		8.43	
Clay loam mean		**33.93**		**8.34**	
Loamy sand					
Plow-Till					
	AdaptN	37.23	b	14.17	b
	CNC	40.93	a	19.60	a
	Plow-Till Mean	39.08	A	16.89	A
No-Till					
	AdaptN	40.54	a	10.41	b
	CNC	38.36	a	21.78	a
	No-Till Mean	39.45	A	16.09	A
N Supply					
	AdaptN Mean	38.89	A	12.29	B
	CNC Mean	39.65	A	20.69	A
	N Supply Mean	39.27		16.49	
Loamy sand mean		**39.26**		**16.47**	

Means of each property followed by the same lowercase letter within a column are not significantly different at $\alpha = 0.05$ based on LSD test. Capital letters show significance of overall tillage and Cover Crop management treatment comparisons.

Results demonstrate substantial environmental advantages with Adapt-N. Regardless of the soil tillage, the amount of NO3 + NO2 was almost two times greater for the CNC treatment than for AdaptN in the clay loam soil. For the loamy sand soil, the amount of NO3 + NO2

also was two times greater for the CNC tool than AdaptN. The same results can be observed inside of each tillage. The results from Table 1 Clearly show that AdaptN can reduce the amount of nitrogen in the water leached from the corn crops, without reducing corn yield. A description of preliminary results can be found in April 5, 2016 article in corn yield. A description of preliminary results is found in What's Cropping Up Vol 26. No. 2.

The evaluation of the effectiveness of N-inhibitors on yield, profit, and water quality will begin in the spring of 2018.

3) Outreach and training materials: see Outreach section of this report

Conclusions/Outcomes/Impacts:

The results of trial work mentioned earlier are pending completion of analysis. However, the soil health data is currently accepted as a manuscript in a peer-reviewed journal.

From data collected during previous NNYADP projects leveraged with other funding, the project team concludes that use of the Adapt-N tool for informing sidedress application rates in corn should be strongly recommended and widely implemented in corn systems.

The New Hampshire NRCS has already written the Adapt-N tool into their advanced 590 nutrient management practice options, and there is potential for the tool's use to be widely incentivized through cost-shares by NRCS, non-profit, and other organizations. Implementing such additional incentives along with the inherent risk- and profit-related incentives from Adapt-N will aid in improving water quality, decreasing greenhouse gas emissions, and helping producers adapt to variable early-season weather and maintain profitability on broad acreages.

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 nitrogen 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.

Adapt-N was developed at Cornell University and has been extensively documented in the scientific literature. It was licensed for commercial use by the start-up company Agronomic Technology Corporation (ATC) in 2014 and was recently acquired by the multinational fertilizer company Yara International. Adapt-N is Cloud-based and accessible through any internet-connected device that supports a web browser. It was the first such technology solution based on the pioneering research of the Cornell-based team, starting in 2002. It is the only computational N technology that has scientifically proven its benefits in extensive on-farm validation studies (Sela et al., 2016; 2017) and the only N decision tool that has been positively evaluated by the Environmental Defense Fund's NutrientStar program (http://nutrientstar.org/tool-finder/adapt-n/) for demonstrating gains

in nitrogen use efficiency and return to profit when compared with farmer practice. The tool was also selected as a finalist in the Tulane Nitrogen Reduction Challenge to combat hypoxia (bit.ly/Adapt-NTulaneChallenge) and received the AgProfessional Top Product of the Year Award for 2013. A video summary of the Adapt-N development process as part of lead inventor Harold van Es' presentation at the 2016 World Economic Forum can be viewed at https://www.youtube.com/watch?v=LfpWpZtv3Kk.

Adapt-N addresses system complexity to generate location-specific recommendations, and integrates real-time weather information, as well as local soil and crop management factors. It is the result of long-term research efforts involving model development, parameter calibration, and field validation, which are documented in peer-reviewed publications. It also offers estimates of uncertainty around the recommended rate and provides tabular and graphical outputs that provide additional diagnostic information on simulated nitrogen dynamics.

Adapt-N implementation through Cloud computing technologies facilitates the desire for mobility, universal communication, and data transfer through web services, allowing user access through any device (desktop, mobile, etc.) in any location with internet access. In crop production, this is especially attractive as many users of computational services are often outside the traditional office environment (field, vehicle, etc.), but still desire direct access to web-based information.

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).

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 allows for co-branding with agricultural retailers and thereby effectively engages the fertilizer trade sector, breaking down traditional barriers between the retail and environmental interests. Adapt-N partners with several farm data platforms (DTN, agX, Agrian and FieldAlytics) to increase availability and ease of use. An additional strength is its ability to enhance the benefits of other N management tools (cover crops, enhanced efficiency products, etc), thereby making them more attractive.

The tool has gained attention from several environmental and sustainability-oriented initiatives that regard the tool as an important component of nutrient reduction strategies.

Soil health drives N availability and thus the soil health status of a particular management unit can impact the right N rate. A more comprehensive understanding of soil health status, through identifying field-specific constraints, can better guide farmers' soil and nitrogen management decisions. This can be done through a Soil Health Management Planning Framework. Many of the practices that alleviate soil health constraints, such as

implementing cover crops, reducing tillage, using crop rotations, and adding amendments, will impact the N rate.

Relevant interacting soil health inputs in the Adapt-N tool include OM percentage, N supplied by use of a cover crop, tillage type, rooting depth, manure inputs, crop rotation and associated in-field variability of N needs. Other inputs related to N dynamics such as source, timing, and placement of N; planting date; and expected yield are also used. We determined from on-farm strip trials that a dynamic tool like Adapt-N is superior to conventional static N recommendation systems, e.g., the Cornell Corn N Calculator which does not account for any of the changes like inhibitors, timing, placement or soil health status. Work is underway to allow this dynamic tool to be more readily used with site-specific information from soil health reports that will allow a more direct connection between the field soil health status, the optimal N rate and other 4R+ factors.

In conclusion, the integration of difference dynamic decision tools, such as the Cornell Comprehensive Assessment of Soil Health and Adapt-N, provides a way forward to managing N more efficiently and to fully incorporate the different elements of the 4R+ concept.

Primary beneficiaries of the Comprehensive Assessment of Soil Health and 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, many of our collaborators report that the Adapt-N tool, and associated learning opportunities, encourage growers in their areas to shift N application toward sidedressing, away from pre-plant application.

The project is 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.

In 2018, we will continue examining how data from soil health assessments can be used in a beta version of Adapt-N to better inform Nitrogen sidedress recommendations.

Outreach:

Grower involvement was sought from all six NNY counties covered by the extension and consultant staff. The use of adaptive N management (Adapt-N) and soil health management was promoted through presentations at field days and listening sessions: Lewis County Soil and Water Conservation District Free Soil Health/Cover Crop Seminar, Lyons Falls, NY, October 26, 2017, 20 in attendance, and Essex County Soil Health Listening Session, Essex, NY, October 26, 2017, 15 in attendance. Extension articles and training materials (fact sheets) were made available at the grower meetings, on our website, and through other outlets. See the "Reports" sections of this report for articles made available to NNY growers during the course of the project year.

Handouts at field days and grower workshops

- Cornell Soil Health Slake Test.pdf
- 2017EFDSoilHealthPRs2-1.pdf (Empire Farm Days Agenda)
- TestSH Manual Pamphlet v4 063016 with Bleeds.pdf (Soil Health Tri-fold brochure)
- 011_Active_Carbon_040517.pdf (Active Carbon Fact Sheet)
- 12_Standard_Nutrient_Analysis Factsheet_UPDATE_060717.pdf (Standard Nutrient Analysis Factsheet)
- 13_Root_Pathogen_Pressure_Factsheet 040517.pdf (Root Pathogen Pressure)
- 14_Heavy_Metal_Contamination_Factsheet 040517.pdf (Heavy Metals Fact Sheet)
- 15_Potentially_Mineralizable_N_Factsheet 040517.pdf (PMN Fact Sheet)
- 16_CASH_SH_Series_Salinity_and_Sodicity_072717.pdf (Salinity Fact Sheet)
- Soil Health Listening Session 10-26-17.docx (Essex, NY)
- Cover Crop Seminar Flyer.pdf (Lyons Falls, NY)

Related publications and webinars are available at http://adapt-n.cals.cornell.edu/ and http://soilhealth.cals.cornell.edu/.

Next Steps:

Also see notes in the Results section of this report.

- 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 US. Although marketing of Adapt-N will be conducted by Yara, we will continue to partner with stakeholders where appropriate.

- Results from the lysimeter data analysis are currently being written for submission to a peer-reviewed journal by June 2018.

Acknowledgments:

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

Reports and/or articles in which results of this project have been published.

- 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

- 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., 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

- 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

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.

Select Media

- Lisa Heacox. January 27, 2017. "Taking Nitrogen to the Max." *PrecisionAg*.
- Laurie Bedrod. March 29, 2017. "Better Manage Nitrogen with Software." *Successful Farming at Agriculture.com*.
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- Douglas L. Karlen, Goeser, N.J., Veum, K.S., Yost, M.A. March, 2017. "On-farm soil health evaluations: Challenges and opportunities." *www.researchgate.net*.
- Kristin Nordal. November 6, 2017. "Yara acquires leading crop nutrition recommendation platform to strengthen Digital Farming offering." *globenewswire.com*.
- Emma Cosgrove. November 6, 2017. "BREAKING: Fertilizer Giant Yara International Acquires Adapt-N Nitrogen Modeling Tech." *agfundernews.com*..
- Margy Eckelkamp. November 28, 2017. "Adapt-N Team from Cornell Wins Tulane Nitrogen Reduction Challenge." *agprofessional.com*.
- Matt Hayes. December 18, 2017. "Digital agriculture tech Adapt-N nets $1M Tulane prize." *cals.cornell.edu*.
- Cornell University. December 18, 2017. "Cornell team wins $1 million award. Wins the international Tulane Nitrogen Reduction Challenge Award." *morningagclips.com*.
- Mollie Cramer. January 26, 2018. "Cornell Researchers Win $1 Million for Solution to Reduce Fertilizer Runoff." *cornellsun.com*.

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Soil Health Contacts: Michael S. Durant, Lewis County Soil and Water Conservation District; and David Komorowski, USDA-NRCS: see contact info on page 1.

Photos:

Photo 1, left: 10/27/17: Plow-till, cover crop cocktail seed (cereal rye @ 30lbs/ac, annual ryegrass @ 15lbs/ac, Hairy Vetch @ 8lbs/ac, Red Clover @ 6 lb/ac), planted 09/12/2017, into spring plow-tilled treatment after a relatively dry August and September. In this sandy plot, no ground work was done to prepare the soil, the cover crop cocktail was planted with a 10' John Deere no-till grain drill. The corn was harvested August 29, 2017. Willsboro Research Farm. Essex County. Photo: Aaron Ristow

Photo 2, right: 10/27/17: No-till cover crop cocktail (cereal rye @ 30lbs/ac, annual ryegrass @ 15lbs/ac, Hairy Vetch @ 8lbs/ac, Red Clover @ 6 lb/ac), planted 09/12/2017, into no-till treatment after a relatively dry August and September. In this sandy plot, no-tillage takes place and the soil is disturbed as little as possible. The seed mix was planted with a 10' John Deere no-till grain drill. The corn was harvested August 29, 2017. Willsboro Research farm. Photo: Aaron Ristow

Photo 3: 10/26/17: Cover crop cocktail containing Daikon Radish (3lb/ac), Red Clover (8lb/ac) and Annual Rye (12lb/ac) was planted with a 15-foot interseeder (Interseeder Technologies) between July 6 and 10, 2017. Conway Dairy, Lewis Co. NY. Photo: Aaron Ristow