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The Manager

MARCH 2022

Moving forward with technology in forage production and nutrient management

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INSIDE

ON THE COVER

Eric Severy (Matthew's Trucking LLC) inspects the results of using a grassland shallow slot manure injector with NRCS and Extension staff at Cream Hill Farm in Shoreham, Vt. This technology allows for subsurface liquid manure applications in perennial crops without damage to the crop. Photo by Kirsten Workman.

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New Cornell faculty

LOUIS LONGCHAMPS

Assistant Professor, School of Integrative Plant Science Soil and Crop Sciences Section

Louis Longchamps (ll928@cornell.edu) is an Assistant Professor of Digital Agronomy in the School of Integrative Plant Sciences' Soil & Crop Sciences Section.

Longchamps previously worked for Agriculture and Agri-Food Canada, where his research focused on the optimization of nitrogen management using remote sensing, and reduction in nitrous oxide emissions by variable rate nitrogen management. He was also co-leader of a Living Laboratory co-creating solutions with farmers to reduce the environmental impacts of agriculture on the St. Lawrence River's ecosystems.

He earned his Ph.D. at Laval University where his thesis research focused on "Spatial structure of weed populations in corn fields and measure of the potential for site-specific weed management." He followed that with postdoctoral work in the Department of Soil and Crop Sciences at Colorado State University.

His research involves the development of precision agriculture using soil and crop sensing to improve input use efficiency in field crops. He is also conducting interviews and surveys to assess the current state of on-farm experimentation in New York, as well as the needs in terms of digital technologies to enhance profitability and environmental stewardship.

VIRGINIA MOORE

Assistant Professor, School of Integrative Plant Science Plant Breeding and Genetics Section

Virginia Moore (vm377@cornell.edu) is an Assistant Professor in the School of Integrative Plant Science Plant Breeding and Genetics Section.

Moore comes to SIPS from the USDA Sustainable Agricultural Systems Lab where she was a NIFA-AFRI postdoctoral fellow and a project manager for the Cover Crop Breeding (CCB) network. She earned her Ph.D. in Plant Breeding & Plant Genetics from the University of Wisconsin in Madison.

Her research program at Cornell will focus on plant breeding for sustainable cropping systems. She takes multiple approaches, including breeding for organic systems, for intercropping and polyculture systems, for pest resistance, and for ecosystem services. She works in a range of species, including cover crops, perennial forages, bioenergy crops, and hemp.

Moore started her career in agriculture as a farm apprentice and worked on both vegetable and dairy farms, and she became interested in the technical hurdles limiting farmer adoption of sustainable practices. She studied these issues from a social science perspective, but she was increasingly drawn to plant breeding as a way to provide tangible solutions to sustainability challenges. Her main interest as a researcher is to develop plant varieties and plant breeding approaches that improve the feasibility for farmers to adopt sustainable practices, including planting more perennials and cover crops, increasing diversity in their rotations, and reducing tillage and pesticide inputs.

Joe Lawrence.

Climate-smart farming tools

Arthur DeGaetano, Kitty O'Neil, and Joe Lawrence

Last year was one of the warmest on record in the Northeast. It was the third warmest year in the last 127 years in New York behind only 2012 and 1998. Every state in the Northeast experienced one of their top-10 warmest years, except for West Virginia where it was the 11th warmest year on record. Warmer-than-normal temperatures were a common theme in all seasons across the region.

Year-to-year changes in the weather on the farm is nothing new and farmers are known for being in tune with the weather. However, with conditions changing so quickly and increased variations in weather conditions both within a growing season and from one year to the next, having quick and easy access to the most recent weather data and tools (websites) that can assist in applying these weather data to on-farm decisions is becoming more important.

This is why Cornell's Climate Smart Farming Program (CSF) Decision Tools (climatesmartfarming.org/) were created. The tools have been developed through a partnership between the CSF program and the Northeast Regional Climate Center (NRCC). The NRCC archives and supplies daily temperature observations from the National Weather Service (NWS) and daily precipitation from NWS radar data. These data are interpolated to a 4-km-by-4-km grid allowing farmers in the region to access accurate information for their farm even without a weather station on their site.

GROWING DEGREE DAY (GDD) CALCULATOR

This tool tracks GDD accumulated based on a user-provided starting (planting) date and provides a forecasted accumulation over the next six days (Figure 1). On the left side of the screen, the user can select their exact field location and enter data specific to their farm and crop. Using the gridded weather data associated with the farm, a chart on the right summarizes the average and extreme GDD accumulations for the long-term climate record of the site, plots the current season's GDD accumulation, and provides supplemental data on the likelihood of below-freezing temperatures at different points during the season. Users have consulted the GDD tool to make decisions about varieties, predict harvest dates and decide on alternative crop feasibility at the start of the growing season.

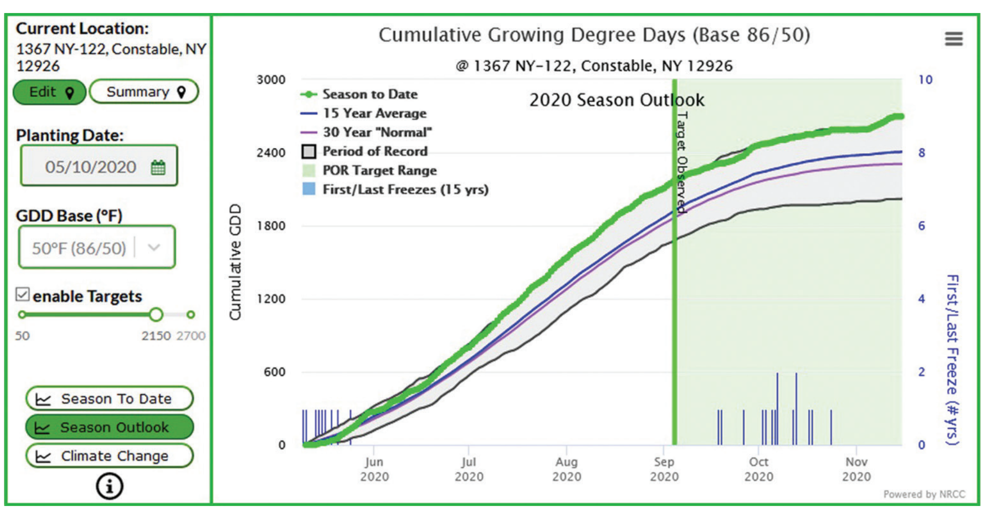
In the example depicted, 95-day corn (2050 GDD to maturity for silage) was planted on May 25 in 2020. In this warm growing season, the target of 2050 GDD was reached on September 6 as shown by the vertical green line, well before the historical date of the first fall frost which is shown by the blue lines at the bottom of the graph. 2020 was an especially warm year, notice the green curve follows the top portion of the gray area indicating that 2020 was comparable with the highest GDD accumulations observed at this station. The farmer also notices that on average (the blue curve shows the average GDD accumulation) the accumulation of the targeted 2050 GDD, also occurred before the first frost in most years. However, in the colder seasons, when fewer GDD accumulate, there is still the risk of not achieving the required 2050 GDD. This is shown by the shaded green area which runs past all the observed first frost data and through the end of the year.

Nonetheless in an effort to maximize silage yield, the farmer may opt for a 105-day (2150 GDD) variety. This can be simulated by changing the target on the left to 2150 and perhaps selecting an earlier planting date, say May 10. With these changes, the graph refreshes and shows that the longer-season corn would have matured in 2020, but the risk of not

Continued on page 4

FIGURE 1

The Growing Degree Day (GDD) Calculator tracks accumulated GDD based on a user-provided starting (planting) date and forecasts accumulation over the next six days



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Climate-smart farming tools
cont'd from page 3

achieving enough GDD before the first frost increases in other seasons, which may negate the potential benefits of selecting a longer-season corn variety.

The GDD tool has several other applications. During a cool summer, a grower may wonder if the crop will reach maturity before the first frost. In this case, the silking date can be used in place of the planting date and the target GDD changed to 775 as research for New York determined this is the approximate GDD interval between silking and maturity for silage corn. Figure 2 shows that in this example, enough GDD would accumulate if the remainder of summer was very warm, but even if average temperature conditions occurred, the crop would likely reach maturity, since in only one previous year did frost occur before Sept. 23, the average date of maturity determined by the tool. If the weather continues through the summer, the chances of reaching maturity before the frost decrease considerably.

Finally, suppose the planting window was delayed during a cool wet spring. One option might be to consider an alternative crop such as summer-planted forage oats, if the forage oat maturity requires 1,700 base 32°F GDD. In the tool, the GDD base and targets can be set, and the planting date of August 1 entered. Figure 3, shows the decision to plant oats would be feasible, in 13 of the last 15 years.

COVER CROP SCHEDULER

The Climate Smart Farming website includes a number of other tools that growers may find useful. The cover crop selector – climatesmartfarming.org/tools/csf-winter-cover-crop-planting-scheduler/– calculates how late into the growing season cover crops can be successfully planted to achieve their intended goals. These goals can include reaching critical amounts of biomass, reaching developmental stages that ensure overwintering success, etc. This tool helps to quantify the risk involved to maximize the chances of success. At this time, the cover crop tool uses models that are optimized for rye, buckwheat and mustard production. Like the GDD tool, this site provides a chart showing the chances of reaching important levels of cover crop growth by the end of the growing season. Probability of success decreases as later planting dates are chosen, allowing the user to see the consequences of waiting several days or weeks to plant.

WATER DEFICIT CALCULATOR

The water deficit calculator – climatesmartfarming.org/tools/csf-water-deficit-calculator/ – estimates soil water content within a crop's effective root zone to inform decision makers about current and forecasted water deficits. This information can be used to determine the optimum frequency and duration of watering that is necessary to avoid plant stress.

IN SUMMARY

Weather-related risks are a constant threat to agriculture, especially as the climate changes. Conditions during past growing seasons are quickly becoming a poor guide for what to expect in the current or future years

FIGURE 2

The Growing Degree Day (GDD) Calculator tracks accumulated GDD based on a user-provided starting (planting) date and forecasts accumulation over the next six days

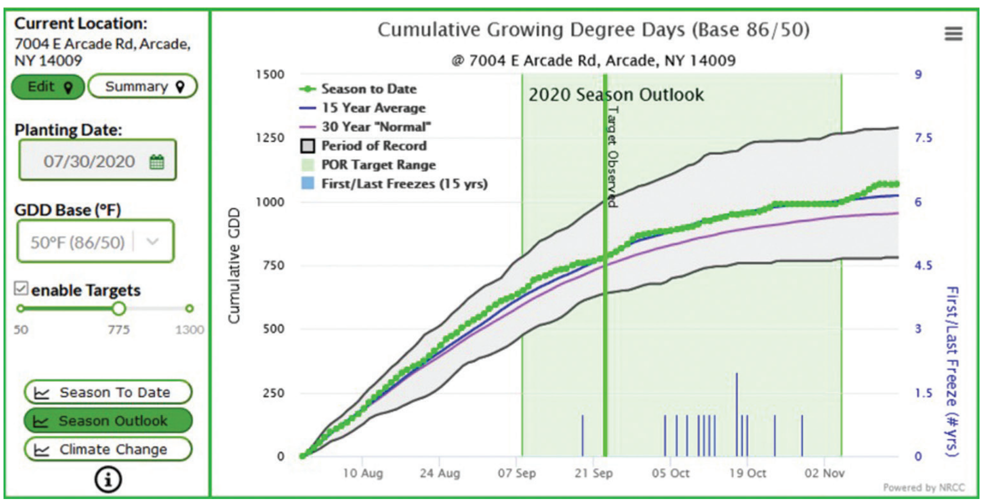
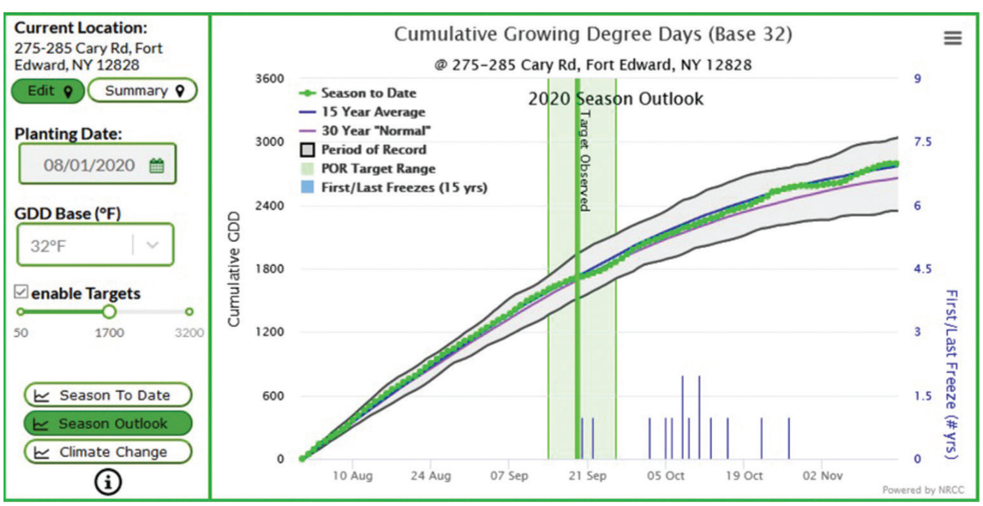


FIGURE 3

The Growing Degree Day (GDD) Calculator tracks accumulated GDD based on a user-provided starting (planting) date and forecasts accumulation over the next six days



and increases in weather variability complicate management decisions. Incorporating real-time weather data and historical climate information into the decision-making process, offers one way to mitigate these ever-changing weather risks. Climate-smart farming tools make accessing and applying high-quality weather data and agricultural models to on-farm decisions no more than a click away from your computer, tablet, or phone.

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PRO-DAIRY
Education & Applied Research

Managing diet nutrient variability through improved forage sampling practices

Jorge Barrientos-Blanco, Joe Lawrence, and Kristan Reed

LOW DIET ACCURACY DECREASES PROFITABILITY

High feed prices and volatility due to market and supply chain disruptions caused by the COVID pandemic are restating the importance of maximizing feed use efficiency. Diet accuracy is one management factor that can improve feed efficiency. In this context, we define accuracy of the delivered diet as the alignment in nutrient composition of the formulated diet and the diet delivered to the feedbunk. Low accuracy of delivered diets increases the risk of underfeeding and overfeeding cows due to high uncertainty and inconsistency of the nutrients delivered to the bunk and available to the cow. Underfeeding and overfeeding cows can decrease milk yield, increase nutrient waste, and increase the risk of health issues that affect the use efficiency of dietary nutrients. Low accuracy of formulated diets can result from poor mixing management and ingredient composition variability. However, better mixing management practices and better understanding and management of ingredient variability can improve diet accuracy. For example, optimizing sampling practices will identify important changes in feed composition and enable timely adjustments to diet formula to minimize the risk of underfeeding or overfeeding cows. Production and feed efficiency losses due to diet variability may seem small when considered for an individual cow, but these losses add up, and improved diet and feed management can lead to real savings. For example, in a simulation study, St-Pierre and Cobanov (2007) found that implementing optimum sampling practices in a 1,000-cow farm could decrease the costs related to the changes in forage composition by $250 a day.

IMPACTS OF MIXING AND INGREDIENT COMPONENT VARIATION

Ingredient loading error, loading order, mixing time, mixer blade and kicker plate condition, and mixer scale accuracy are key sources of variability introduced during the mixing process (Mikus, 2012, Trillo et al., 2016). Good maintenance protocols and record-keeping will help to maintain accuracy of the delivered diet and prevent unnecessary losses at the feedbunk. Feed ingredients contribute to the variation of the delivered diets in proportion to the square of the inclusion rate and the degree of nutrient variability in the ingredient. Byproducts have the highest level of nutrient variability, followed by forages, and grains have the lowest levels. Due to the high inclusion rate (40 to 60 percent), forages often account for the largest proportion of diet nutrient variation and thus are the focus of an on-going study to develop management protocols to minimize the impacts of forage nutrient variation.

UNDERSTANDING AND MANAGING FORAGE NUTRIENT VARIABILITY

Our project includes three main goals:

1. Improve understanding and quantify the factors that influence variability
2. Optimize sampling practices for farm-specific conditions
3. Develop a tool to guide implementation of optimized practices and monitor forage nutrient composition

During the summer of 2020 and spring 2021, we collected corn silage and haylage samples at harvest and feedout from eight New York dairy farms with three silage storage methods (bunker, bag, and drive-over pile). During harvest, we collected samples from each truck load delivered to the silo and composited samples for every 15 to 20 acres within each field. We recorded the location within the bunkers and silo bags of the forage from each field, the weather conditions

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Managing diet nutrient variability through improved forage sampling practices, *cont'd from page 5*

during growth and at harvest, and the soil type and texture of each field. During the spring of 2021, we collected two independent corn silage, haylage, and TMR samples at feedout, 3x per week for a period of 16 weeks, from the same eight N.Y. dairy farms sampled at harvest. We recorded the weather conditions on the day of feedout and identified the fields-of-origin of the forages fed that day. We used a mixed-model analysis for harvest and feedout datasets to identify the most relevant factors causing variation in the nutrient composition of corn silage and haylage.

Unsurprisingly, the mixed model analyses identified field as the highest source of variation in forage nutrient content during harvest and feedout. This suggests that reformulating diets when forage from a new field is fed could improve diet accuracy. Therefore, we estimated the average field-of-origin feeding time for each silage type at each farm and used those values as inputs to an optimization algorithm. Using this method, our estimates for the average stable time of forage nutrient composition for corn silage and haylage ranged from four to 18 days, which is a much shorter time frame than the 30 days suggested by St-Pierre and Cobanov (2007) and varies with the farm size and silo type. If true, the shorter stable periods suggest that forage composition changes more frequently than previously suggested, which will impact diet accuracy and associated costs.

OPTIMUM SAMPLING PRACTICES AT DAIRY FARMS

To illustrate the influence of the expected stable time, we found optimal sampling practices for corn silage and haylage on a small (100 milking cows) or large farm (1,200 milking cows) with either bunk or bag silos using the renewal reward model and genetic algorithm suggested by St-Pierre and Cobanov (2007) to minimize the Total Quality Cost. Total Quality Cost refers to the cost related to sampling and changes in forage components. It includes the costs of labor associated with sample collection and reformulation, sample analysis costs, and expected losses in milk production or increases in feed costs due to underfeeding or overfeeding. To optimize the sampling methods, we found the number of samples to collect, sampling frequency, and acceptable limit of variation before diet reformulation for each combination of management practices that minimized the Total Quality Cost.

Consistent with results from St-Pierre and Cobanov (2007), our analysis suggests different sample numbers, sampling frequency, and tolerable level of variation minimize the Total Quality Cost for farms of different sizes and different expected variation in forage nutrient composition (Table 1). Also, in alignment with previous reports, the recommended number of samples ranged from one to two samples, and farms with a greater number of cows benefit from more frequent sampling. However, our results suggest that smaller ranges of acceptable variation are needed to minimize the Total Quality Cost associated with forage nutrient variability. In practice, this recommendation means that a forage monitoring and diet reformulation protocol would be more sensitive to smaller changes in corn silage and haylage nutrient composition. The Total Quality Cost estimates from our approach to quantifying the expected forage variability through average stable time are higher than estimates from St-Pierre and Cobanov (2007). These higher costs are a result of increased sampling and lab analysis costs due to smaller tolerable level of variation and expected higher frequency of overfeeding and underfeeding.

MONITORING FORAGE COMPONENTS VARIABILITY

Nutritionists and farm managers can use the recommended sampling practices produced from the optimization method under development to monitor forage nutrient composition with x-bar charts. This tool can help nutritionists and farmers detect abrupt changes in forage components and determine

Jorge Barrientos-Blanco.

if the changes warrant action. The optimal limits of variation for each farm provided by our algorithm can be used as inputs to set the upper and lower limits for the allowable change in a forage component. When a sample analysis indicates that a forage component exceeds the acceptable level of variation, the industrial process control methods recommend taking another sample to verify the result and exclude the possibility of sampling or laboratory error. If a second sample analysis confirms the abrupt change in forage composition, the recommended action is to adjust the diet formulation. However, to ensure that process control recommendations translate effectively to dairy cattle diet formulation and delivery, our next steps will be to implement our proposed sampling and diet management protocol in a commercial farm setting and measure changes in diet accuracy and milk production. If confirmed, we will implement the protocol optimization method and x-bar chart in a decision support tool to help guide forage management and sampling and diet reformulation timing. ∎

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TABLE 1

Optimum sampling practices for corn silage and haylage in farms with different herd size, ensiling method, and average stable time

Optimization approach	Forage	Ensiling method	Herd size	Average stable time (d)	Number of samples	Sampling frequency (d)	Factor to estimate the limits of variation	Total quality cost ($/d)
Our estimates of variation	Haylage	Bag	100	7	1	18	0.25	$62
			1,200	4	1	2	0.78	$615
		Bunker	100	14	1	14	0.63	$53
			1,200	7	2	3	0.92	$532
	Corn Silage	Bag	100	18	2	15	0.96	$50
			1,200	6	2	3	0.88	$556
		Bunker	100	7	1	18	0.25	$62
			1,200	6	2	3	0.88	$556
Previous assumptions	Standard	Standard	100	30	2	15	1.098	$42
			1,200	30	2	4	1.17	$327

REFERENCES

Mikus, J. H. 2012. Diet Consistency: Using TMR Audits™ to deliver more from your feed, equipment, and people to the bottom line. Pages 28-36 in Proc. High Plains Dairy Conference, Amarillo, Texas.

St-Pierre, N. R. and B. Cobanov. 2007. A Model to Determine the Optimal Sampling Schedule of Diet Components. Journal of Dairy Science 90(12):5383-5394.

Trillo, Y., A. Lago, and N. Silva-del-Río. 2016. Deviation from the formulated target weight of ingredients loaded into high milk yield cow recipes on California dairies. Journal of Dairy Science 99(7):5866-5878.

TECHNOLOGY

Maximize fertilizer use efficiency for peak fertilizer prices of 2022

Kitty O'Neil, Joe Lawrence, Kirsten Workman, and Quirine Ketterings

Record high fertilizer prices this winter have driven a lot of creative thinking about cost-cutting strategies for 2022. Dairy farmers are at an advantage as manure is a tremendous source of all essential nutrients, and typical rotations of corn and alfalfa/grass result in nutrient and other benefits for corn following sod. But how do we know where cuts in fertilizer are appropriate and where they are not?

HERE ARE SOME STRATEGIES TO CONSIDER

- Begin your farm-wide fertility plan with an assessment of all on-farm nutrient resources.

- Look at past yields to plan using realistic yield goals for your farm and fields - and fertilize accordingly.

- Tune-up equipment so you can apply accurate and appropriate rates on your fields. Spending shop time this winter calibrating lime, manure and fertilizer spreaders ensures accurate applications and can save real dollars.

- Compile recent soil and manure tests. Soil tests (Figure 1) from the past three years are generally considered 'recent' and are critical to identify amounts and types of lime and fertilizer needed for any planned crop. If soil or manure analyses are needed, sample as soon as conditions permit and submit them for appropriate analyses immediately. The cost of collecting and analyzing soil and manure samples is lower than the price you pay when over- or under-estimating lime and fertilizer needs.

- With soil test results as a guide, correcting soil pH to recommended crop-specific levels is the top priority, using ag lime sources that are also tested and reliable. Periodic application of ag lime is needed on most Northeastern soils, but not all, to maintain optimum pH and optimal nutrient availability to growing crops. Strive for a minimum pH of 7.0 if you have alfalfa or soybeans in your rotation. For corn and grass rotations, strive for a minimum pH of 6.0-6.2, but using 6.5 as a target for fields with both corn and alfalfa rotation is a good management strategy.

- An appropriate soil test will also report levels of phosphorus (P) and potassium (K) equivalents (P_2O_5 and K_2O), calcium, magnesium, and some micronutrient levels for comparison to crop-specific university research-based fertility recommendations. Be sure to request the soil test that is used to derive recommendations by the land grant university of your state. Soil test conversions from one soil analysis to another can sometimes be done, but any conversion adds uncertainty to the recommendation. Fields with soil test results for P or K in the adequate or high ranges do not need any supplemental P or K beyond a small amount in starter fertilizer. Starter fertilizer should be banded and should contain all the P needed for the season, with small amounts of nitrogen (N) and K, if needed while heeding salt injury and ammonia burn guidance.

- The top expense in most farm fertilizer budgets is N. To minimize the need for fertilizer N, maximize its use efficiency by crediting N from all sources. Fertilizer N use efficiency is subject to management, crop rotation, manure use, soil type, and the weather. Consider realistic yield potential of each field. Soil organic matter, manure applied in the current and previous seasons, sods and crop residues can contribute significantly to plant-available N, as those materials decompose during the growing season. They simultaneously provide organic carbon and other macro- and micronutrients. Northeast soils can typically supply 30 to 80 pounds of plant-available N per acre annually depending on soil type and field conditions. Sods may contribute 50 to 90 lbs N per acre, depending on stand vigor and legume content. Plant-available N from manure ranges widely, depending on animal source,

"Manure is a tremendous source of all essential nutrients, and typical rotations of corn and alfalfa/grass result in nutrient and other benefits for corn following sod."

manure type, application rate and timing. *See accompanying article on the Value of Manure on page 12.* In fields where rotation credits are expected and manure has been applied, the Pre-Sidedress Nitrate Test (PSNT) can be used to identify fields where sidedressing of additional N is not needed, which is another money-saving strategy. This can only be done when starter and at-planting N fertilizer application rates are limited to no more than 30 lbs N per acre.

- Timing of N application is a large factor in its use efficiency. In humid climates, N applications outside the growing season are not recommended due to the high risk of inorganic N loss to the environment and minimized availability for its uptake by a subsequent crop. For corn, applying a small amount of N in the starter (30 lbs N/acre or less) combined with sidedressing at V4-V6 can help reduce fertilizer loss before the plants can take up the nutrients. When additional sidedress N is needed beyond starter, and when applications are delayed due to weather conditions, a late sidedress application will still lead to a yield response, but it will be lower than with an on-time sidedress application as shortage of N earlier in the season will impact final season yield. Consider nitrification and/or urease inhibitors when N is needed but incorporation is not possible (urease inhibitors) or when you want to apply all N at planting rather than sidedress and leaching or denitrification losses early in the season are likely (nitrification inhibitors). Controlled-release fertilizer could also be considered. If weather and soil conditions are not conducive to N losses, or if N fertility is excessive, there is no benefit from either inhibitor.

- Plan in the longer term to develop guidance for your fields by implementing N rich or control strips or plots in fields, by measuring yield and calculating N supply for some or all fields. When you use crop yield and N supply data to determine N balances for each field, you may also rank fields and identify where N was limiting and where changes can be made in future seasons. *See the March 2021* Progressive Dairy *article "In pursuit of improved nitrogen management for corn silage: Tracking field nitrogen balances" on this topic (Berlingeri et al., March 2021).*

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Joe Lawrence (jrl65@cornell.edu) and **Kirsten Workman** (kw566@cornell.edu) are Senior Extension Associates with PRO-DAIRY, and **Quirine Ketterings** (qmk2@cornell.edu) is a Professor with the Nutrient Management Spear Program in the Department of Animal Science at Cornell University.

Quirine Ketterings.

Soil sampling is key to identifying where additional fertility is needed and where not.

Remote sensing to estimate yield of field crops

Sunoj Shajahan, Jerome Cherney, Louis Longchamps, and Quirine Ketterings

Up until the 1990s, estimating how much a field yielded in forage crops like corn silage and alfalfa required the use of a weigh wagon, truck, or farm scale. While knowing yield per field is useful for inventory management and to identify where field-based management changes can be made, knowing where high and low or variable yielding areas are within fields facilitates zone-specific management, which is likely to benefit yield, reduce the environmental impact of overapplication, and increase return on investment of inputs like seed and fertilizer over time.

YIELD MONITOR SYSTEMS

Harvester-mounted yield monitor systems were developed in the early 1990s, with the advent of sensors and information technologies. A yield monitor system is a suite of three sensors attached to the harvester for measuring the harvested mass flow, moisture, and location using a GPS unit. The first yield monitor systems were installed on combines to harvest grain crops like corn, wheat, and soybeans. Systems have advanced since then, and sensors suitable to determine not just grain but also forage yield were brought to the market. For corn silage, such systems are mounted on the chopper. For crops like alfalfa and grass, the sensors are located on the harvester and not the mower. This increases the accuracy of the flow measurement but reduces the ability to locate yield values to smaller grid cells as mowed rows are typically merged into larger rows.

While errors occur with sensor-based collection of yield data, forage-based systems are inherently more prone to data errors. Accurate maps can be generated with proper in-field calibration and post-harvest data cleaning. Data cleaning software such as Yield Editor (USDA-ARS; data.nal.usda.gov/dataset/yield-editor-207) have been developed to simplify data cleaning. Work is ongoing to facilitate automated data cleaning, so that farmers do not have to become data-cleaning experts.

REMOTE SENSING

Not everyone has harvesters equipped with yield monitor systems and as mentioned, maps that have not been properly cleaned can be misleading. In addition, when a crop is mowed first and then merged into rows, yield monitor systems on the harvester will generate low-resolution maps. Such challenges could potentially be eliminated if yield estimation can be done remotely using drones and satellites (remote sensing).

Remote sensing (Figure 1) is acquiring data using sensors that are not in contact with the object. A simple example is an infrared thermometer versus a traditional thermometer. In both cases the temperature is being measured, but the infrared thermometer does not touch the object while the traditional thermometer does.

With corn, several studies have shown the potential of using remotely sensed images from drones and satellites as a proxy to estimate crop yield at different scales county, whole-field, sub-field, and plot scale. Currently, there is no straightforward process to accurately estimate the yield on a sub-field (zone-based) scale across a large range of farms and fields. Early studies focused typically on grain-crop yield estimations for a limited geographic area, using models that fit the specific locations and conditions. Work is ongoing at Cornell University to evaluate the accuracy of various approaches to estimate yield across multiple years and multiple fields and regions, for both grain and silage corn, and to derive yield-stability-based management zones from satellite imagery.

With perennial forage crops, the primary interest in remote sensing relates to the estimation of both yield and forage quality, with the goal of predicting optimum harvest date. Previous research determined that data gathered with a spectrometer (an instrument that measures reflectance over a specific portion of the light spectrum) positioned above an alfalfa canopy can estimate forage quality and yield reasonably well.

DRONES WITH SENSORS

Over the years, sensors attached to drones have been used to capture crop responses by scanning above the canopy. These sensors capture color and infrared signals of the crop in the form of images. These signals (basically a grid of numbers) are mathematically manipulated to calculate vegetation indices. The vegetation indices are used as an approximate measure for crop yield and other crop responses (crop stress, nutrient deficiencies). Earlier work, at a smaller scale, has shown that normalized difference vegetation index (NDVI) derived from drone images can be a good proxy to estimate yield. This can be useful for estimating yields for smaller areas, and especially research plots. Current work at Cornell University is focused on including weather and topographic information for developing models to estimate corn grain and silage yield across multiple fields.

SATELLITES FOR AGRICULTURE

Unlike drones, satellites in space do not need pilots to capture images of Earth's surface at frequent intervals. Before 2015, there were satellites that provided images at five- to 15-days intervals. In 2015, Planet Labs© launched the "Doves" satellite constellation that provides images every single day. Moreover, the image resolution (the ground distance that each image pixel covers) of earlier satellites ranged from 10 to 30 m per pixel (medium), while the Doves satellites produce images at three m per pixel (high). Satellite data may now allow an estimate of the yield and quality of alfalfa with a precision and accuracy similar to that of a field spectrometer. Collaborative projects are ongoing to evaluate the use of satellite imagery for the estimation of corn silage and grain yield (Box 1) and for alfalfa yield and quality (Box 2).

Because satellite satellite images can only be collected on a fixed schedule, cloud cover is a major issue, but with daily imagery from Planet's Dove imagery, it is often possible to get cloud-free images on a weekly basis. Another challenge for forage crops is that the dense vegetation cover can saturate optical sensors. Such signal saturation can make data less meaningful. For perennial forage crops with multiple harvests per season, changes in canopy structures over the season can increase the complexity of yield and quality estimation.

STAY TUNED

Because of greater accessibility and technological advancements in remote sensing and imagery processing, we can now tap into high-resolution and high-frequency imagery. Remotely sensed data will become more useful for farmers over time as we explore the data and learn to estimate and predict yield and forage quality at farm, field, and within-field scales. Stay tuned for advances in yield and quality prediction models for your farm as science develops.

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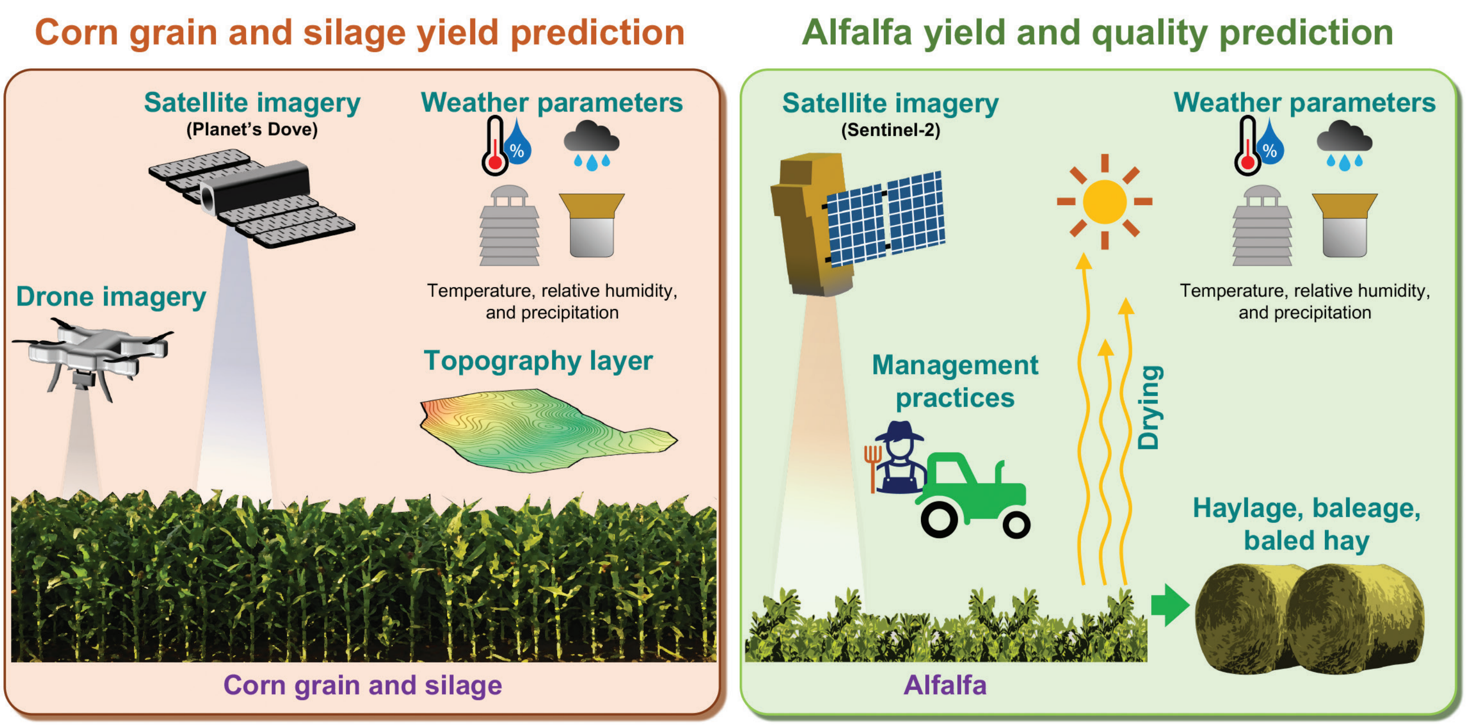
FIGURE 1

Yield prediction approaches for corn grain, silage, and alfalfa yield and quality prediction using remotely sensed data may make yield estimation accessible to more farmers in future years.



BOX 1: CORN GRAIN AND SILAGE PREDICTION PROJECT

This Northern New York Agricultural Development Program (NNYADP) and USDA-NIFA funded project was initiated in 2020 by Cornell University and is conducted in collaboration with researchers at the Rochester Institute of Technology. The focus is to develop models to convert drone imagery, satellite imagery from Planet's CubeSat platform, weather (precipitation, temperature, growing degree days, etc.), and topographic information into yield maps for corn grain and silage.

BOX 2: ALFALFA YIELD AND QUALITY PREDICTION PROJECT

A USDA project was initiated in 2021 by the University of Wisconsin, Purdue University, and Cornell University. A web-based program will be developed to provide timely estimates of alfalfa yield and quality at the field scale for optimizing harvest scheduling. Data collected by Sentinel-1 (radar sensor) and Sentinel-2 (optical sensor) satellites will be combined with CubeSat data, along with weather data, to generate models for predicting economically optimum harvest date.

Manure – A valuable nutrient asset

Kirsten Workman, Quirine Ketterings, Joe Lawrence, and Kitty O'Neil

Manure is a valuable source of nutrients and soil-building organic matter. It is always important to manage manure nutrients to maximize availability for crops and minimize environmental losses, but that is especially true this spring as fertilizer prices have skyrocketed. Several strategies and practices can be used on the farm to realize the full value of those manure assets.

SAMPLING MANURE FOR ANALYSES

The first step to manage manure nutrients effectively is to have it analyzed for nutrient content. Manure is an inherently variable nutrient source, changing composition with animal type, weather, and rain additions to open storages. Annual manure analyses will allow you to build three-year running averages for the farm, which is more reliable than using book values. See Agronomy Factsheet #38 for guidance on proper sampling procedures and analysis.

With accurate manure analysis and knowledge about fertilizer prices, we can quantify the economic value of manure. The calculation shown in Table 1 is an example. Keep in mind that the value of ammonium-N in manure can be impacted by how and when manure is applied (Table 2).

MANURE SPREADER CALIBRATION

Proper manure spreader calibration takes the guesswork out of achieving target application rates. If flow meters are being used, they too should be calibrated. Agronomy Fact Sheet #18 was recently updated and includes several methods for calibrating spreaders and flow meters. Manure spreader calibration is a weak link in many operations. It is easy to overestimate what is being spread if relying only on spreader capacity ratings. If you are overestimating application rates, even by a small percentage, it can add up significantly over the course of a cropping season, possibly shorting the crop. If you've taken the time to soil sample, manure sample, and follow a nutrient management plan – calibrating your spreader is the final step for accurate planning, application and record-keeping.

NUTRIENT CREDITS FROM MANURE

Crediting nutrients from manure applications can get complicated. The first thing to remember is that manure nutrients applied last fall count towards this year's crop. For example, if you applied manure containing 50 lbs P_2O_5 in November, all 50 lbs will count towards this year's crop nutrient budget. Similarly, P and K in manure applied this spring will count as 100 percent available.

Nitrogen is a much more complicated equation. As livestock manure is made up of both urine and feces, there are two forms of nitrogen to account for (Figure 1). Ammonium-N (sometime reported on manure analyses as inorganic N or ammonia-N) is the more plant-available form, behaving like urea fertilizer. Organic N is the form that mineralizes more slowly. Determining N credits from manure applications involves knowing how much of each form was applied.

In New York, we assume 35 percent availability of organic N in the year of application and 12 and 5 percent two and three years after application, respectively (see FS#4 for organic N credits). For proper crediting of ammonium-N, timing of incorporation has a big effect on how much will be available to the crop. Table 2 shows the ammonium-N credits used in New York. It illustrates how quickly ammonium N losses can occur following application, similar to what is expected to happen with fertilizer N. Consult your state's guidelines for appropriate credits for organic and ammonium N in manure.

If you have adequate storage, spreading during the growing season is the best way to maximize nutrient value of manure and avoid environmental losses. If you spread last fall or winter, it is highly likely that all that readily available inorganic N is gone before the spring-planted crop can get to it. By far, the most efficient and effective method to retain manure nutrients is direct injection or immediate incorporation close to planting or into a growing crop. Getting the manure in direct contact with the soil right before (or during) crop growth will provide the biggest bang for your buck. There are several ways to accomplish this depending on your situation and equipment, as discussed below.

To calculate total N availability from manure for this year's crop, you should account for all the organic N and ammonium-N credits. See Figure 1 and the calculation below for how that is done in New York. For a more complete discussion of nitrogen credits from manure, see Fact Sheet #4.

This year's ammonium N (x availability factor) + this year's organic N (35%) + last year's organic N (12%) + two years ago organic N (5%) = total N available for this year's crop from manure.

EXAMPLE

A field receiving a 6,000-gallon-per-acre manure application for three years in a row would calculate nitrogen credits as follows (using manure nutrient values as shown in Table 1):

Manure incorporated within 24 hours of spreading:

13 lbs ammonium-N (0.65) + 7.3 lbs organic (0.35) + 7.3 lbs organic (0.12) + 7.3 lbs organic (0.05) = 8.5+2.6+0.9+0.4 = 12.4 lbs available N/1000 gallons x 6000 gallons = **74 lbs available N**

Manure surface applied without incorporation:

13 lbs ammonium-N (0) + 7.3 lbs organic (0.35) + 7.3 lbs organic (0.12) + 7.3 lbs organic (0.05) = 0+2.6+0.9+0.4 = 4 lbs available N/1000 gallons x 6000 gallons = **24 lbs available N**

APPLICATION METHOD

Split Applications

Splitting up manure applications on hay fields is a tried-and-true way of maximizing nutrient use by perennial crops. Multiple smaller applications are more expensive than a single pass but in this economy, it can pencil out. In addition to reducing the need for purchased fertilizers, utilizing manure between hay harvests during the summer can help relieve manure storage capacity limitations, optimize yields, and increase forage quality by keeping protein levels in forages high. There are challenges that need to be considered in this scenario. These include the potential spread of pathogens, notably Johne's disease, and potential feed hygiene issues if manure residue is picked up in subsequent cuttings. This can be managed by the type and rate of manure application along with proper setup of harvest equipment to minimize the pickup of surface debris with the forage.

In corn and other annual crops, spreading in the spring before planting isn't the only option. Recent studies from Ohio State University Extension and elsewhere show that you can top-dress corn and cereal grains through emergence and up through the early vegetative stages without damaging the plants, using careful planning. Manure applied as a sidedress in corn showed promise for increased yields and the elimination of nitrogen fertilizers in New York too (Godwin et al., 2018), but such equipment is currently not commercially available.

Incorporation & Injection

Getting manure in contact with soil as soon as possible is key to conserving nutrients. Choosing the right approach will depend on your crop rotation, equipment, and tillage regime. Incorporation through tillage is simple

Continued on page 14

FIGURE 1

Manure N consists of ammonium and organic N. Taken from Agronomy Fact Sheet #4.

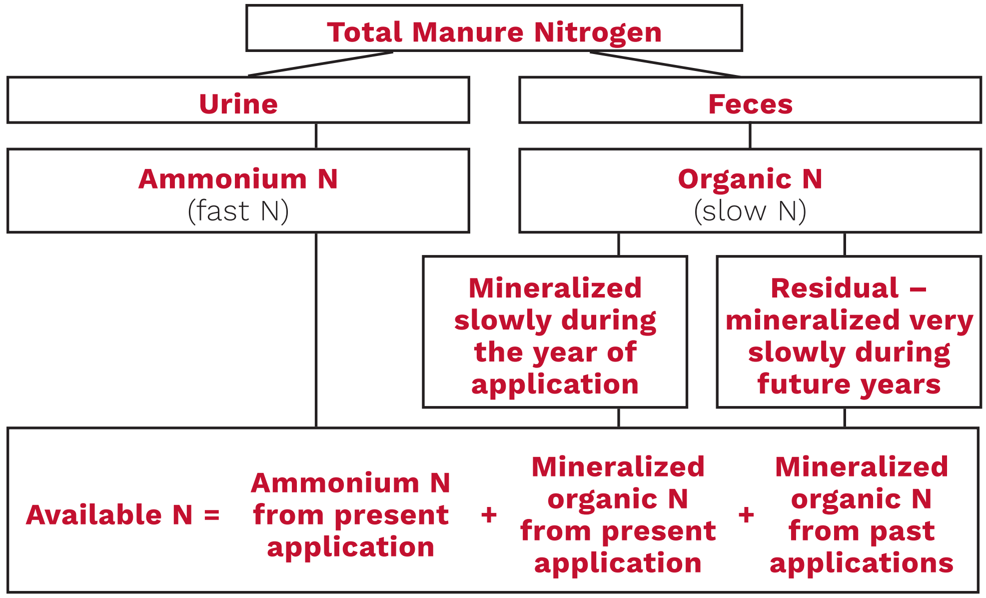


TABLE 1

Accurate manure analysis allows for calculation of the economic value of manure (an example). See Agronomy Fact Sheet #61 for specific instructions to perform this analysis. P_2O_5 and K_2O equivalents refer to the phosphorus and potassium fertilizer value of the manure.

	Manure Nutrient (lbs/1000 gallons)	Manure Value ($/1000 gallons)[a]
Ammonium-N	13.00[b]	$ 13.26
Organic-N	2.50[c]	$ 2.55
P_2O_5 equivalent	7.13	$ 5.13
K_2O equivalent	21.21	$ 14.42
Total value		$35.36
Total value	10,000 gallons/acre	$353.60/acre
Total value	5000-gallon spreader	$176.80/load

[a] based on typical New York liquid dairy manure and DTN fertilizer prices February 14-18, 2022. ($1.02, $0.72 and $0.68 per pound of N, P_2O_5 and K_2O respectively.)
[b] assuming 100 percent availability before any losses associated with application method/timing
[c] assuming 35 percent availability during the season of spreading

TABLE 2

Estimated ammonium losses as affected by manure application method and example ammonium-N credit from a 6,000-gallon-per-acre application based on those losses. Adapted from FS #4 using numbers applicable for New York.

Manure application method	Percent ammonium remaining	Lbs/acre ammonium-N available
Injected during growing season	100%	80
Incorporated within 1 day	65%	52
Incorporated within 2 days	53%	42
Incorporated within 3 days	41%	33
Incorporated within 4 days	29%	23
Incorporated within 5 days	17%	14
No conservation or fall injected	0%	0

Manure – A valuable nutrient asset, *cont'd from page 13*

and straightforward in theory. The downside is, in practice it can be difficult to spread manure and incorporate it immediately if the incorporation equipment is not integrated with the manure spreader (i.e., if you need a separate tillage pass). In addition, spring tillage can be tricky, often causing significant compaction and detrimental soil conditions if done when soils are still wet. But with good preparation, adequate labor and tractors available, it can be accomplished by having the tillage tractor follow immediately behind the spreader.

Direct injection is the most efficient method – accomplishing the best nutrient retention and most efficiency for labor, fuel and equipment use. Paired with a drag-hose system, this is a win-win. This combination reduces compaction, increases efficiency, and even helps with neighbor relations (reducing truck traffic and odors associated with spreading). Disc and shank injectors have many different options for setups that can be adjusted for depth, disturbance, and spreading width. They can be mounted directly to tank spreaders or used with a drag hose. Manure injection matches well with reduced and no-till cropping systems. Research looking at direct seeding of corn after manure injection on farms that have improved soil health practices shows that yields can be maintained while eliminating all other field passes between manure application and planting (Battaglia et al., 2021). An intermediate approach is to incorporate manure through shallow tillage but retain surface residue in reduced tillage systems. Previous work in New York using an aerator toolbar in the spring after manure application (and set under maximum angle) showed shallow mixing of soil conserved as much N as a chisel plow, but retained 30 percent more residue at the surface in corn grain systems (Ketterings et al., 2013).

Shallow Disc Injection in Perennial Crops

While injecting and incorporating manure in annually cropped fields is common, it is more complicated in perennial hay fields. Until recently the options were to spread on the surface and accept significant ammonium-N loss, as well as risk of P losses (and higher P-Index scores); or inject using equipment that was designed for annually cropped fields that could damage the stand and create conditions difficult for subsequent harvest operations. Newer shallow disc injection technology has allowed direct injection in perennial grasses and alfalfa without those disadvantages. Initial concerns about the discs damaging alfalfa crowns and negatively impacting yields have proven unfounded. Yield response of older grass and alfalfa stands to these manure applications was positive, while newer high-yielding alfalfa stands were not impacted (Sadeghpour, et.al. 2017).

MANURE ADDITIVES

Several commercially available products are designed to increase availability or preserve manure nutrients. Many of them also purport to prevent crusting and reduce odors associated with spreading. Before investing in these products, it is important to understand which conditions they are designed to work in and what potential problems they may mitigate. In the end, the best bet is to apply manure at agronomic rates to growing crops with good soil health and nutrient management strategies.

ADDITIONAL BENEFITS

Sound manure management has benefits beyond good nutrient stewardship.

- Maximizing N efficiency allows lower rates of manure per acre, which can mean spreading manure nutrients across more fields, reducing the need for fertilizer across the farm.
- Injection or timely incorporation of manure not only maximizes nutrient retention, but will lower P-indices dramatically, allowing more flexibility in choosing which fields receive manure.
- Similarly, applying manure during the growing season and in split applications will allow for lower P-indices and address risk in high-nitrate-leaching soils.
- Many of the practices outlined in this article are also aligned with reducing the odors associated with manure spreading. This along with drag hose applications can help with neighbor relations, decreasing the off-farm 'nuisance' factors of odor and manure tanks on the road.
- Whole farm nutrient balances will improve when nitrogen is fully utilized and off-farm inputs can be reduced.
- Good manure nitrogen management can also equate with lower greenhouse gas emissions. Maximizing crop uptake of N will reduce N_2O losses from the actual manure application and avoid N_2O emissions associated with fertilizer that is no longer needed.

SUMMARY

- Know the nutrient content of manure and know how much is being applied (sample and calibrate.)
- Apply manure during the crop growing season whenever possible and get it incorporated quickly. Most of the ammonium-N loss from manure applications happens within the first 24 to 48 hours.
- In perennial crops, split applications make the most sense and will pencil out, especially this year with fertilizer prices high.
- Take credit for previous years' manure applications for N.
- Sound manure management has many benefits beyond reducing fertilizer costs – including more flexibility in your nutrient management plan, good neighbor relations, and environmental compliance and sustainability.
- Manure is a valuable nutrient asset – protecting it will benefit your bottom line, your soil health, and your farm's environmental footprint.

FACTSHEETS & RESOURCES

Cornell Agronomy Fact Sheets are posted online at nmsp.cals.cornell.edu/publications/factsheets

#4 – N Credits from Manure
#16 – Application of Manure on Established Alfalfa
#18 – Calibrating Manure Spreaders
#38 – Manure Sampling, Analysis & Interpretation
#42 – Manure Use for Alfalfa-Grass Establishment
#53 – Manure Cost, Value and Time Management Calculator
#61 – Valuing Manure N, P, and K Applications
#67 – Can Manure Replace the Need for Starter N?
#76 – Manure Use for Soybeans
#87 – Liquid Manure Injection

Manure Cost, Value and Time Management Calculators: nmsp.cals.cornell.edu/software/calculators.html

OTHER CITATIONS

Greg Godwin, Quirine Ketterings, Karl Czymmek, Todd Dumond, and Doug Young. Nutrient boom allows for mid-season manure application in corn. What's Cropping Up? August 2018. blogs.cornell.edu/whatscroppingup/2018/08/03/nutrient-boom-allows-for-mid-season-manure-application-in-corn/

Quirine Ketterings, Greg Godwin, Peter Barney, Joseph Lawrence, Brian Aldrich, et al.. Shallow mixing of surface soil and liquid dairy manure conserves nitrogen while retaining surface residue. Agronomy for Sustainable Development, Springer Verlag/EDP Sciences/INRA, 2013, 33 (3), pp.507-517. 10.1007/s13593-013-0141-1.

Amir Sadeghpour, Quirine Ketterings, Gregory Godwin, and Karl Czymmek. Impact of manure injection on alfalfa and grass hay stands. What's Cropping Up? December 2016. blogs.cornell.edu/whatscroppingup/2016/12/22/impact-of-manure-injection-on-alfalfa-and-grass-hay-stands/

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PRO-DAIRY WELCOMES KIRSTEN WORKMAN AS NUTRIENT MANAGEMENT AND ENVIRONMENTAL SUSTAINABILITY SPECIALIST

Kirsten Workman (kw566@cornell.edu) joined PRO-DAIRY in January 2022 and brings a depth of experience and a strong understanding of how farming and environmental sustainability are inextricably connected. Prior to joining PRO-DAIRY, she worked with farmers in Washington and Vermont for 20 years, helping them improve the nutrient management and environmental sustainability of their farm businesses. She has a bachelor's degree in Environmental Studies from Pacific Lutheran University and a master's degree in Plant, Soil Science and Agronomy from the University of Vermont. Workman is an effective collaborator and has served on coalitions to devise solutions for water quality, soil health, climate resiliency, policy and regulatory decisions, and public education. She is an experienced educator and most recently served as a senior Agronomy Outreach Professional at the University of Vermont Extension. She has investigated, demonstrated techniques, and performed applied research to increase implementation of conservation practices on dairy farms. Her certifications include Certified Crop Advisor (American Society of Agronomy, Northeast Region CCA) and Vermont Certified Pesticide Applicator (Research & Demonstration and Agricultural-Plant).

PRO DAIRY Education & Applied Research

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When: April 4 - 5, 2022
Where: Doubletree by Hilton - East Syracuse, New York

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