# What's Cropping Up?

## Weed Seedbanks on Local Organic Farms

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**Fig. 1**. Flats of germinating weed seedlings in the greenhouse for the weed germination bioassay.

The goal of this project was to quantify soil weed seedbanks in the fields of four local organic farms. In particular, we have heard from organic farmers that red clover (*Trifolium pratense* L.) often volunteers profusely in some fields after tillage. This may be due to the common practice of harvesting red clover for seed on these farms, during which a substantial number of seeds shatter and are dropped on the field. Under these conditions, red clover could act either as a valuable nitrogen-fixing resource or perhaps as a weed.

We asked four organic grain farmers to identify "weedy", "clean", and "high clover" fields on their farms. We took soil samples from these fields, did greenhouse germination bioassays to allow weed seeds to germinate from the soil samples, and then counted the seedlings of each species. This report details the results from the first year of sampling, which is being repeated this year.

**Sampling Protocol**
Fields were sampled in the spring of 2015, before spring weed germination. Our sampling protocol was to divide each field into four evenly sized quadrants and take 30 soil cores from inside each quadrant. We avoided sampling from headlands. We used a 5/8th inch diameter soil probe and sampled to a depth of 8 inches. Field conditions generally made for easy soil sampling. Soil samples were kept in a cooler until greenhouse weed seedbank bioassay. We also dried separate subsamples of the soil to calculate gravimetric water content and estimate bulk density.

**Greenhouse Germination Bioassay**
In the greenhouse, 1 kg of soil from each quadrant was spread out in flats (10 x 10 inches) over a thin layer of vermiculite and watered daily (Figure 1). Weed seedlings were identified to species (or at least genus,
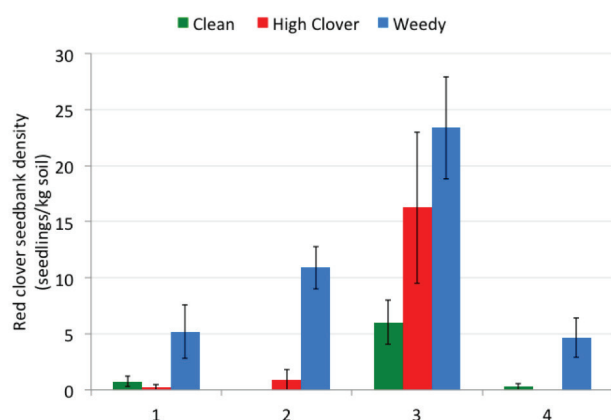
**Fig. 2.** Average red clover seedling counts standardized per kg of soil from three fields on four organic farms. Error bars indicate standard error.

if unknown), counted, and removed from the flat. After all weed seedlings were removed, the flats were left to dry for a few weeks, soil from each flat was mixed, and then watering began again to encourage a second flush of weeds. Data presented are from both flushes of weeds.

### Red Clover Seedbank
Red clover was the 6th most common species accounting for approximately 5% of all emerging seedlings. Our results show that these organic farmers do in fact have red clover in their seedbanks, bolstering their observations that the red clover seedbank likely increased via intentional planting and losses from seed harvest. The average density of red clover ranged from

0 to 23 seedlings per kg soil across all 12 fields (Figure 2). Half of the fields had over 4 seedlings per kg of soil, which is quite a lot. For example, one seedling per kg of soil equates to over 100,000 seeds per acre in the top inch of soil—enough for a good stand of red clover.

Interestingly, across all four farms, red clover populations were greater in the field chosen as "weedy" compared with the field chosen as "high clover." This suggests that these organic farmers might not be as good at identifying which fields actually have the highest red clover populations. The red clover seedbank was densest in the fields from Farm 3 (Figure 2). This farm has been under organic management for over 30 years, and occasionally they harvest red clover for seed. Compared with Farm 3, red clover seedling emergence was much lower in the "high clover" fields on the other farms. In the spring of 2016 on Farm 2 we observed an abundant stand of red clover in the "high clover" field, even though red clover was not planted the previous year (Figure 3). Oats had been the previous crop in this field in 2015.

### Weed Seedbank Density
On Farm 3, total weed seedlings were comparable to the other farms and similar among the three different fields chosen by the farmers (Figure 4). Specifically, the "weedy" field on Farm 3 was no weedier than either the "clean" field or the "high clover" field.



**Fig. 3.** Red clover volunteers in the "high clover" field at Farm 2 on March 25, 2016. Oats were grown in 2015 and no red clover seed was planted in 2015.
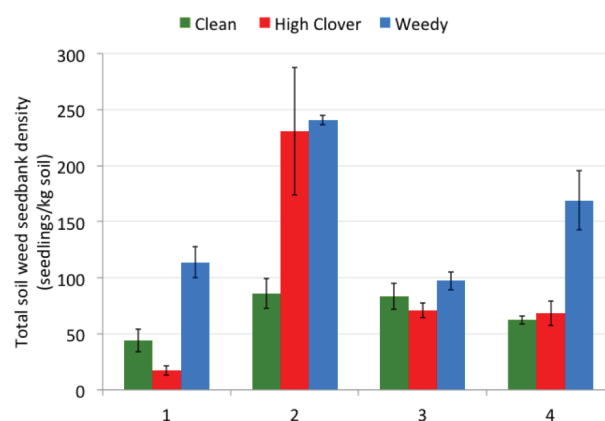


**Fig. 4.** Total seedling counts from four organic farms by field, standardized per kg soil, from greenhouse bioassay.
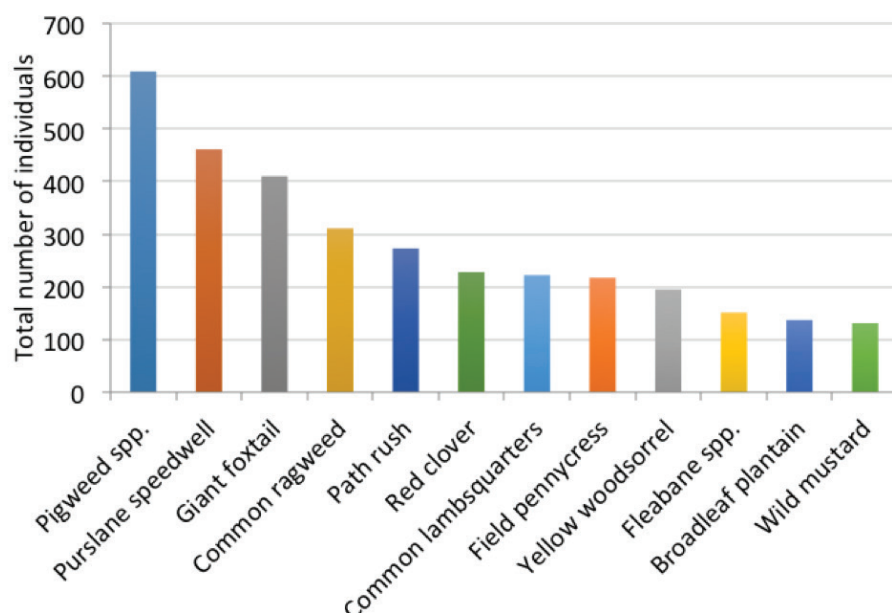
**Fig.5.** Total counts of the top 12 most frequently occurring weed species on all four farms.

were summer and winter annuals and there were fewer perennials (Figure 5). The top 12 species accounted for over 75% of all seedlings counted in the greenhouse bioassay. Pigweed (redroot and Powell), giant foxtail, common ragweed, and common lambsquarters dominated weed counts and are warm-season species. The winter annuals purslane speedwell and wild mustard also occurred at high density. Path rush, yellow woodsorrel, and broadleaf plantain are low-growing, relatively non-competitive perennials. Fleabanes (*Erigeron* spp.) include both annuals and perennials.

Because of the relatively diverse rotations on these farms, which include warm season grains, winter cereals, and perennial legumes, a high diversity of weed species was expected. The weed community that we observed would persist by reproducing and replenishing the soil weed seedbank when conditions allowed.

Total weed seed density in the "weedy" fields on farms 1, 2, and 4 tended to be higher than those in the "clean" fields. This indicates that the farmers were pretty good at knowing what fields were weedy and what fields were not. Although the total seedbank size might seem large, these densities are comparable to other studies in organic and non-organic fields. More importantly, experienced organic farmers are typically able to manage competition from weeds and grow high yielding crops, so even high weed seedbank densities are not necessarily a problem.

Average weed species richness (i.e. number of species per kg soil) ranged from 6 species per kg soil in the "high clover" field from farm 1 to 27 species per kg soil in "weedy" field from farm 4 (Figure 6). As some weed species might provide benefits similar to cover crops, and greater biodiversity is typically assumed to be beneficial, high species richness can be good, especially when combined with low weed seedbank

## Weed Species Diversity
Most weed species observed across the four farms

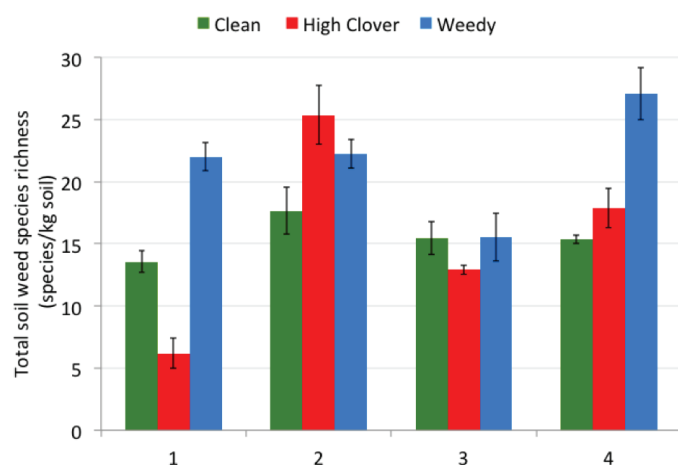| Farm 1 | Farm 2 | Farm 3 | Farm 4 |
|---|---|---|---|
| Purslane speedwell | Pigweed spp. | Giant foxtail | Giant foxtail |
| Path rush | Purslane speedwell | Red clover | Common ragweed |
| Pepperweed spp. | Field pennycress | Pigweed spp. | Wild mustard |
| Broadleaf plantain | | Common ragweed | Common lambsquarters |
| Common ragweed | | | |

# Weed Ecology



**Fig.6** Total weed species richness (i.e., number of species) standardized per kg of soil in three fields on four farms, from greenhouse bioassay.

density. However, as the number of weed species in a field increases, so does the probability that a highly competitive/problematic weed species will be present in the community.

As not all weed species are equal in terms of their potential to reduce crop yields, we list the top species accounting over 50% of all individual seedlings counted on each farm below. Species are listed in order of abundance.

Although no single weed was part of the top 50% across all farms, common ragweed was dominant at three farms and several other species were dominant at two farms. This indicates that these weeds are likely common on other organic farms in the region. We are currently repeating this study and will be evaluating the correlation between weed abundance and weed community composition between 2015 and 2016. We also analyzed a subsample of soil for soil health properties and will be testing the relationship between soil properties and weeds.

# Use of Adapt-N Results in Better Agronomic and Environmental Outcomes than the Corn N Calculator

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Nitrogen (N) management is important in corn production systems because of the high cost of N fertilization and public concerns over environmental impacts. Corn response to N is highly variable, so determining the optimum N rate is challenging. The economically optimal N rate (EONR) can often range from 0 to as much as 250 lb/acre for a field depending on many soil and management factors, as well as the weather. This variability leads to uncertainty which often results in excessive application of N fertilizer to reduce yield risks, thus adding unnecessary fertilizer costs and increasing the potential for environmental losses.

Several tools are available for growers to determine optimal fertilizer N requirements. These approaches can be categorized as either static or dynamic. Static tools offer generalized recommendations that do not consider seasonal conditions of weather and variation in crop management, while dynamic approaches account for the variable and site-specific nature of soil N dynamics.

This study focuses on two New York nitrogen recommendation tools: the dynamic Adapt-N simulation model and the static Cornell Corn Nitrogen Calculator. We evaluated whether accounting for weather effects and site-specific conditions improves N recommendation rates. The study had two objectives:

a) To compare the N recommendations of the Cornell Corn Nitrogen Calculator and the Adapt-N tools relative to the optimum rate, and

b) To compare the environmental losses resulting from these recommended N rates.

## Methods
### The Corn N Calculator
The Cornell University Corn Nitrogen Calculator (CNC) is a static approach that includes a calculation of N demand (yield-driven crop uptake) and N supply (soil organic matter, manure, previous crops), combined with efficiency factors. The CNC has been the conventional approach to corn N rate calculations in New York for several decades and estimates can be derived from a spreadsheet downloaded from http://nmsp.cals.cornell.edu/software/calculators.html.

The CNC tool allows the use of either a default yield potential from an embedded database, or a manually entered value for yield potential entered by the user. The CNC default yield potential depends on field soil type and drainage status. For this analysis we generated N recommendations using both the default yield potential and a manually entered realistic yield potential based on grower-estimates from historical yield performance.

### The Adapt-N tool
Adapt-N (Adapt-N.com) is a web-based dynamic simulation tool that combines soil, crop and management information with near real-time high resolution weather data to estimate optimum N application rates for corn. It is intended primarily as an in-season tool to provide recommendations for sidedressing. To generate N recommendations, the tool requires user inputs such as achievable yield, soil texture class or soil series name, organic matter content, crop variety, information on previous crops, manure or pre-plant N applications (if applicable), and the field tillage practice. Combining this information with early season weather data was expected to improve the precision of N recommendations and thus maximize farm profits while minimizing environmental N losses.

Data from 16 replicated field trials from multiple locations in New York between 2011 and 2015 were used to compare the sidedress N recommendations generated by the CNC and Adapt-N tools. The CNC tool generates a total N recommendation for the field conditions regardless of the timing of the N application. Therefore, in the case of the CNC tool, if the grower in the experiment opted to apply some of the N rate as a starter or pre-plant, this rate was subtracted from the total N recommendation and the rest was used as sidedress. For the case of Adapt-N, these early applied N rates were included in the simulations used to generate the sidedress recommendations.

### Field data
In each of the field trials, multiple N rate applications were used, allowing the EONR of each trial to be calculated
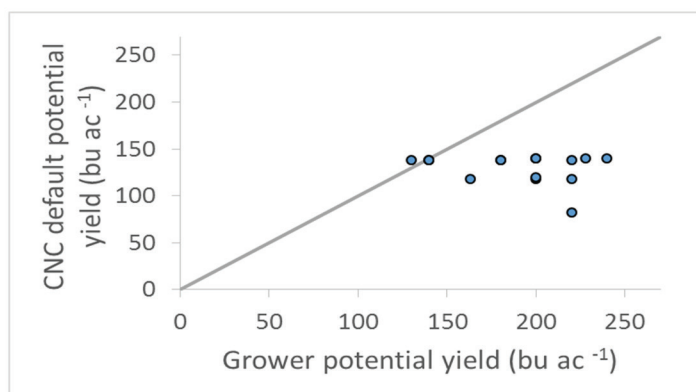
**Fig.1** Potential yields estimated by the Grower and those extracted from the CNC database for each field trial.

using quadratic function curve fitting. The economic losses from the EONR resulting from the CNC and the Adapt-N rates were calculated based on a price of $0.50 per lb of N fertilizer and $4.95 per bushel of corn. It should be emphasized that the EONR represents the optimum nitrogen rate that is determined at the end of the growing season.  It is therefore a reference point made in hindsight for evaluation of N recommendation tools that are used early in the season when fertilizer needs to be applied.

**Estimation of environmental losses**
Leaching losses from the bottom of the root zone and gaseous losses to the atmosphere due to denitrification and ammonia volatilization were simulated by the Adapt-N tool.  The trials used for the analysis had different N management approaches, depending on collaborator preferences, such as pre-plant N or manure applications in different quantities. While these management decisions might have led to high simulated N losses prior to sidedress time, these losses would have been the same for the Adapt-N and the CNC tools. Therefore, to compare the simulated environmental losses resulting from the Adapt-N or the CNC sidedress recommendations, only the environmental fluxes that occurred after the application of sidedress N and until the end of the year (Dec 31st) are reported.

## Results and discussion
### Potential yields and N recommendations
Figure 1 presents a CNC comparison between the default potential yields derived for each field and the realistic estimated yields supplied by the grower (Note: the 1:1 line indicates equal values, and data points below the line indicate lower values for the variable on the Y-axis, and vice versa). The potential yields supplied by the CNC tool were significantly lower (130 bu/ac) than the grower estimates (192 bu/ac), which were generally close to the actual achieved yields recorded at the end of the season (189 bu/ac). This indicates that growers generally have a good sense of a field's yield potential and that the default potential yields in the CNC tool are well below the actual yields.

Choosing between Grower-estimated and default potential yield was found to have a strong effect on
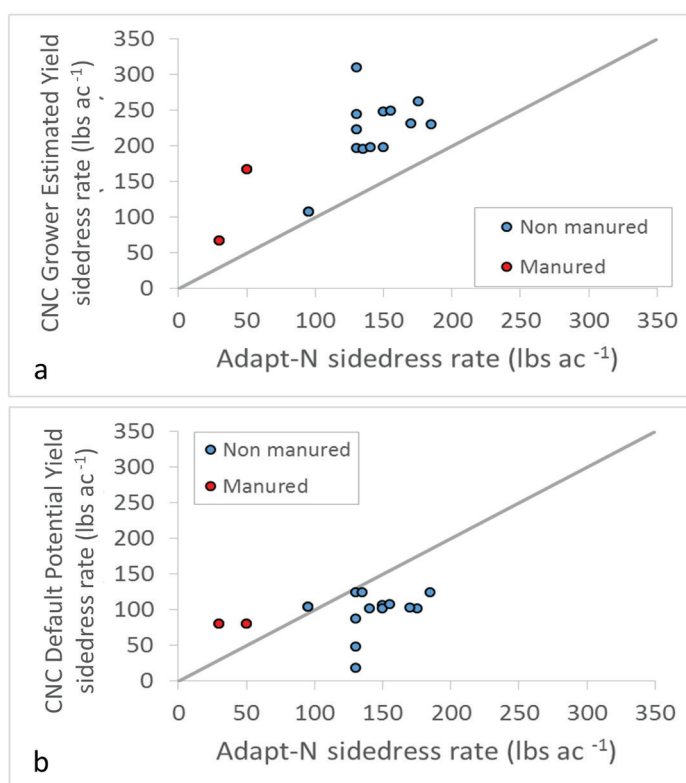


a



b

**Fig.2** Comparison of sidedress N rate recommended by the Adapt-N and CNC tools. The Adapt-N rate was calculated in both panels using potential yield supplied by the grower. The CNC rate was calculated either using the potential yield supplied by the grower (a) or the default potential yield from the CNC database (b).

the N rates recommended by the CNC, especially comparing both to the Adapt-N rate. Using the realistic, grower-estimated potential yield (Figure 2a), the CNC recommended on average 213 lb N/ac for non-manured trials and 117 lb N/ac for manured trials. The average recommendation rate for Adapt-N, which is driven by the grower-estimated potential yield, was 141 lb N/ac and 40 lb N/ac for the non-manured and manured trials, respectively, a substantial decrease of 72 lb N/ac (51%) and 77 lb N/ac (65%) from the CNC rate.

Using the default potential yield (Figure 2b), the CNC recommended on average 97 lb N/ac for the non-manured trials, a 44 lb N/ac (31%) decrease over the respective Adapt-N rate. For the manured trials the CNC tool recommendation remained higher than Adapt-N's recommendation, with an 80 lb N/ac (100% increase). However, as the CNC sidedress N recommendations result from a possibly outdated potential yield, these rates could be insufficient in fulfilling the actual crop needs, despite the higher recommendation.

**Economic analysis**
The CNC tool with the default potential yield considerably under-estimated the optimum N rate calculated from the quadratic function response curve, with an average rate of 120 lb N/ac compared with 159 lb N/ac for the EONR (Figure 3a). The lower recommendations lead to an average profit loss from the EONR of $44/ac. Conversely, when the CNC tool was supplied with a more realistic grower-estimated potential yield, the CNC recommendations were found to substantially overestimate the optimum rate, with an average of 229 lb N/ac, or 70 lb N/ac above the EONR (Figure 3b), leading to an average profit loss from the EONR of $38/ac.

Figure 3c presents the relation between the Adapt-N rates and the EONR, and shows that it accurately predicted the EONR with an average N rate of 153 lb N/ac, only slightly below the 159 lb N/ac calculated average value of the EONR. Consequently, the average loss from the EONR was $9/ac for Adapt-N, a significant improvement over the losses from the CNC rates. By basing recommendations on local conditions, Adapt-N improved the accuracy and precision of the N
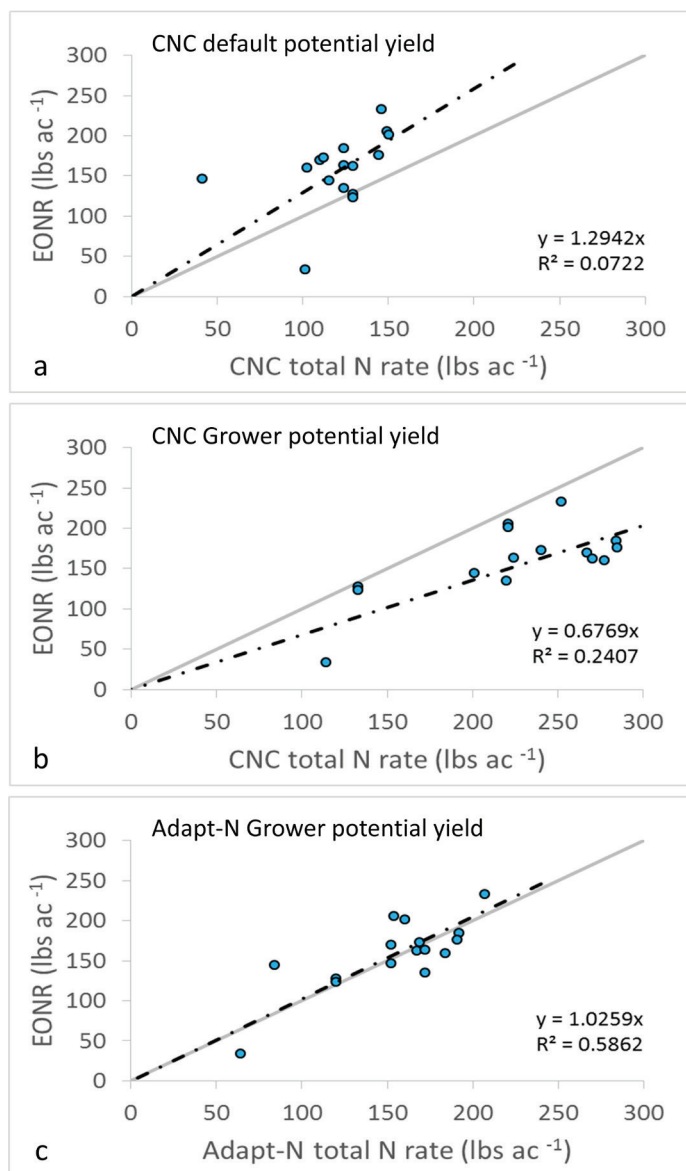


**Fig.3** C omparison between the EONR and (a) CNC recommendations based on the default potential yields, (b) CNC recommendations based on the Grower potential yields, and (c) Adapt-N recommended rates.

recommendations in these trials.

**Environmental N losses**
Simulated environmental losses that occurred following the application of the CNC and Adapt-N sidedress rates were divided almost evenly between leaching and gaseous losses for either tool (Figure 4), which reflects the medium texture of the soil at most sites. Adapt-N rates reduced on average 26 lb N/ac of
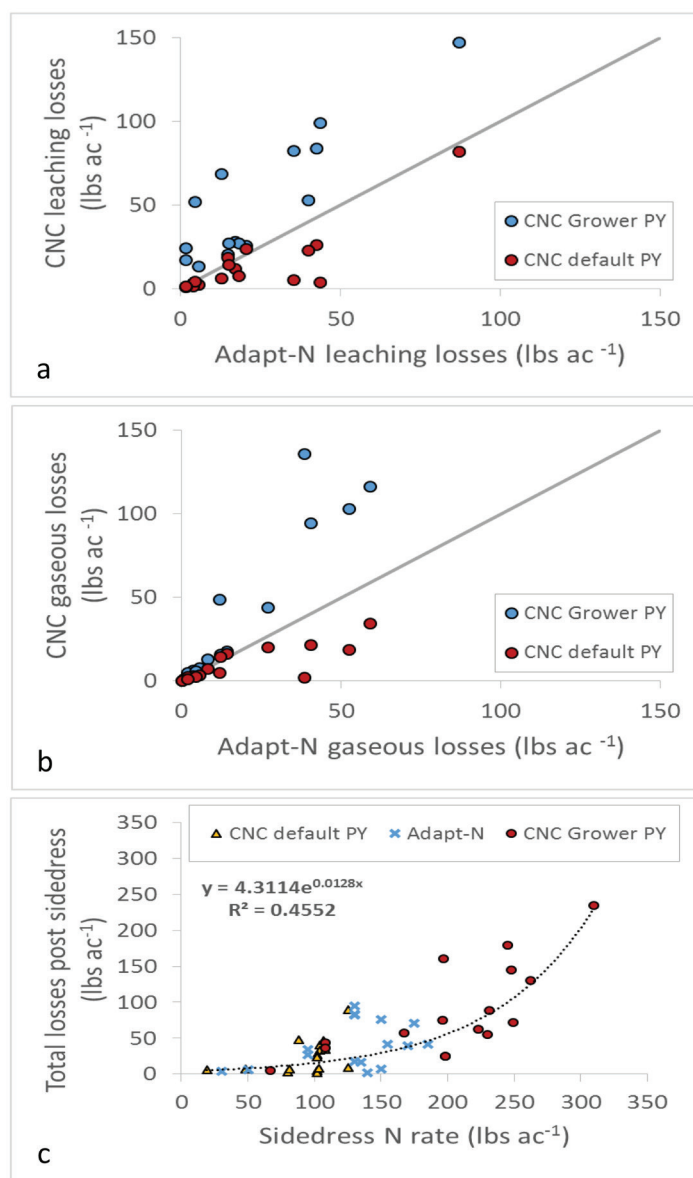
**Fig.3** Comparison between the Adapt-N and the CNC simulated leaching (a) and gaseous (b) losses. For the CNC tool, the losses from both the default potential yields and the grower-estimated potential yields are presented. Panel (c) presents the relationship between the total simulated losses post sidedress and the sidedress rate for the two tools.

leaching losses (Figure 4a, 53% reduction) and 21 lb N/ac of gaseous losses (Figure 4b, 54% reduction) compared to the CNC rates with realistic (Grower-estimated) yields. Conversely, when potential yields were derived from the CNC database, the lower CNC N recommendations only marginally reduced the environmental losses compared to the Adapt-N based

recommendations (Figure 4a and b, 8 lb/acre, on average).

The relation between total environmental N losses occurring post sidedress and the sidedress rate showed an exponential relationship between application amount and the simulated N losses (Figure 4c). This demonstrates that the relative amount of N lost to the environment is much larger when excessive N rates are applied. Apparently, under-fertilization does not accrue substantial environmental gains while reducing farmer profitability, while over-fertilization increases environmental losses without gaining profitability advantages. The Adapt-N tool was close to the EONR and mostly achieved both objectives.

**Conclusions**

This study presents a comparison between two N recommendation tools for corn nutrient management: CNC, which uses a static approach, and Adapt-N, which employs a fully dynamic simulation-based approach. Adapt-N recommendations were found to better account for the different production environments and weather effects, and were therefore superior to those of the CNC in terms of profitability and reconstructing the experimental EONR under the different management scenarios. The CNC default potential yield estimates were found to be unrealistically low compared with both the grower-estimated potential yields and the actual achieved yields in the experimental sites. However, using the CNC tool with more realistic grower-estimated yield estimates resulted in a substantial overestimation of the EONR and increased environmental losses. Our results suggest that adoption of a dynamic N recommendation tool in New York can significantly increase farmers' profits while reducing environmental N losses.

A full manuscript of this article titled "Dynamic model improves agronomic and environmental outcomes for Corn N management over static approach" is currently under review by the Journal of Environmental Quality.

# Buckwheat, a historic crop with modern opportunities

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**Photo:** A 2011 Buckwheat Field Day in Big Flats, NY.

Buckwheat is a historic crop in New York and Pennsylvania that has seen higher demand as a gluten-free food, and is financially attractive when commodity-crop prices are at today's lows. This article provides an update on the organization of the American buckwheat industry and some thoughts on how the crop fits in New York agriculture.

Recent interest in gluten-free foods has driven an increase in demand for buckwheat. The largest supplier of buckwheat to US food markets is The Birkett Mills right here in Penn Yan, NY. Birkett Mills has needed to contract supplies further from their mill in order to meet that demand. This year they have significant contracts as far away as Minnesota and Prince Edward Island. Their demand  could be met much closer to home if more New York farmers raised it.

The Birkett Mills has a long history in this area. It was founded in 1797 as a water driven mill at the outlet to Keuka Lake. At that time, many mills were established in central New York as the region was settled by Europeans. Birkett Mills has the distinction of being one of the few mills that remains, and is still in the original location.

Some of the buckwheat flour is used to make the iconic buckwheat pancakes, but that is far from the only use. A substantial amount becomes roasted groats, called kasha, a staple of Eastern European cuisine. The company's kasha is available in grocery stores nationally. Buckwheat meal, similar to cornmeal or cream of wheat, is used as an ingredient by food manufacturers. It is sold as "Cream of Buckwheat" breakfast cereal, but this versatile product is also used to make polenta. Polenta is well known in northern Italian cuisine as a corn dish. But before North American corn came to Italy, it was made with buckwheat.

There is one other mill of significance producing food ingredients from buckwheat, Minn-Dak in North Dakota. Much of their production is shipped to Asia. Two large growers in eastern Washington State export all of their production to Asia as whole grain. There are also a handful of small mills in the East that mill a few acres of buckwheat production. Overall, buckwheat marketing is highly concentrated.

There is also a thriving buckwheat seed industry to provide seed for cover crops and wildlife food plots. One of the major producers in this arena is Seedway. They process buckwheat seed at the historic AgriCulver mill south of Mecklenburg in Schuyler County. That mill served many growers in the Southern Tier when buckwheat was one of the primary crops in the region in the late 19th century.

Buckwheat breeding was privatized in the 1990s, so the premium varieties that are used for food have all been under total production contracts. Many find it surprising that this seemingly neglected crop is one of the pioneers in adopting this model of funding breeding and seed production.

Buckwheat for food is largely the proprietary variety, Koto, released by breeder Clayton Campbell in the late 1990s. Other users largely  produce Mancan, Dr. Campbell's first release, in 1972. Some growers, based on old production guides, go looking for 'Japanese' or 'Silverhull' varieties. These have not been in commerce for five decades or more.

A contemporary role for buckwheat in field-crop production is to manage glyphosate-resistant weeds. The essential principle for herbicide-resistance management is the weeds die from many different causes. When a buckwheat crop is in the rotation,

it effectively smothers a portion of the weeds. It is effective against most weeds that have developed glyphosate resistance in New York. For these annuals, the trick is to have the weed seed germinate just a few days after the buckwheat so that they are smothered. A good buckwheat planting should show greenline by the morning of the fourth day, and outcompete the many weed seeds that germinate then. Buckwheat is also used in organic production to suppress quackgrass, and prevent it from becoming a big problem.

Experienced farmers who have not raised buckwheat generally show an interest either when corn prices are low or planting season has been wet. When corn appears to be break-even or a money loser because prices are too low, buckwheat can be profitable because the input costs are so much less. For 2016, a 120-bushel corn crop would give a net loss of $100 per acre by my calculation; whereas, the same ground planted to buckwheat would net a profit of $100. In a wet spring, buckwheat can be a catch crop on unplanted ground. The time to sow buckwheat is at the beginning of July, after the opportunity to plant corn and soybeans has already passed.

Buckwheat's low input requirements made it the mainstay on early-20th-century hill farms with low soil fertility and weak finances. Much of that ground is now appropriately in either forest or pasture. The farming community began to associate buckwheat with farms having the toughest time, particularly during the Depression when buckwheat acreage was dropping elsewhere in favor of corn. In New York, that stigma persisted for decades and was still noticeable in the 1980s and 90s. The social factor likely prevented many people from trying buckwheat when it would have been a wise and profitable addition to their rotation. Some of the bigger buckwheat growers even put the crop in fields that were not visible from main roads. The stigma seems to be wearing off. Activities such as the Northeast Buckwheat Growers Association have helped bring buckwheat growers out of the shadows and bring them respect for their professionalism.

There is no "typical" buckwheat grower today, but a few common themes emerge. A few are specialized, where

buckwheat is a big part of their regular rotation and they have invested in equipment to make harvest as efficient and effective as possible. Many farmers raise a few acres of buckwheat from time to time as a catch crop on fields that could not be planted to their intended crop. Weekend farmers can start with buckwheat because it does not require day-to-day attention, the cost of basic equipment is low, and it grows satisfyingly fast even on the lower fertility fields that these farmers often own. A surprisingly large proportion of these weekend farmers are engineers who have worked at one of the Central New York's big technology firms. Organic field crops growers use buckwheat to diversify their rotation and reduce weed pressure.

Farmers today can take pride, and profit, in raising some buckwheat as part of their rotation. Production information is available at: www.hort.cornell.edu/bjorkman/lab/buck/.

# What is the Nutrient Balance of Your Dairy Farm?

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Nutrient balance is short for "whole farm nutrient mass balance". While this is a mouthful to say, knowing a whole farm nutrient mass balance for a farm can help managers identify opportunities for improvements that impact farm profitability and the environment. A whole farm nutrient mass balance or NMB is a way to track the difference between nutrients coming to the farm (mainly in feed and fertilizer) and nutrients leaving the farm (mainly in milk). Dairy farm NMBs range widely in the Northeast. Farms with a high balance often have opportunities to save money and reduce potential losses to the environment. Other farms may be mining soil nutrients (farms with negative balances) and need to import more nutrients to sustain productivity in the long term. Knowing the NMB status of your farm can tell you if there is too much, not enough, or about the right amount of nutrients in your farm's cycle.



**Fig.1** Whole farm nutrient mass balance assessments include accounting for nutrients brought onto the farm as feed, fertilizer, animals and/or bedding/manure, and nutrients exported off the farm as milk, animals, crops, and/or manure.

When a milk truck pulls out of the driveway, nutrients are being exported off the farm. The same holds if the farm exports crops or animals. Each animal, bushel or ton of crop, or gallon of milk contains nitrogen, phosphorus and potassium. No animal is able to extract 100% of the nutrients consumed in its feed. A crop cannot capture all the nutrients used to fertilize it either. As a result, a farm cannot remain productive in the long run without importing more nutrients than it exports. Knowing what balance to strive for and what areas to look at more closely can help you improve or maintain sustainability at your farm.
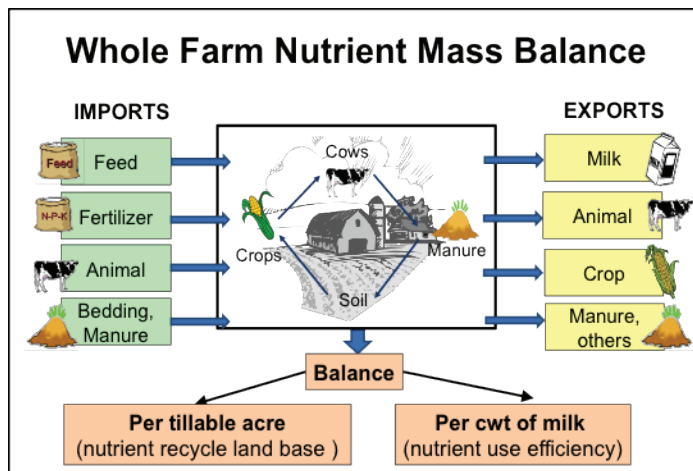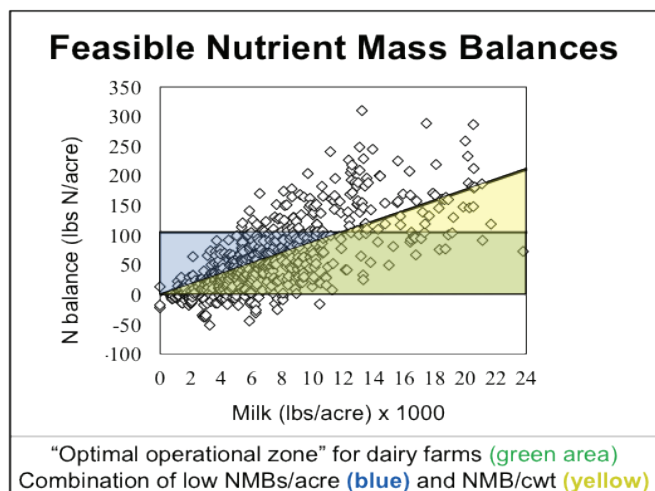
For the last 10 years, we have worked with many New York dairy farmers and their advisors to better understand what real farms in New York can achieve without giving up on milk production. First, let's look more closely at what a whole farm nutrient mass balance is.

**Whole Farm Nutrient Mass Balance**

A whole farm nutrient mass balance is the difference in nitrogen (N), phosphorus (P), and potassium (K) imported onto the farm in the form of feed, fertilizer, animals, and bedding, and nutrient exported off the farm in milk, crops, animals and manure. The difference between nutrients imported and nutrients exported can be expressed as N, P and K balance per acre of cropland, and per unit (cwt or hundred weight) of milk produced (Fig. 1). An NMB summary simply draws a boundary around the farm and accounts for only those nutrients being imported across the farm boundary and those exported off the farm. A whole farm nutrient mass balance calculator was first developed by Stuart



**Fig.2** Feasible balances (optimal operational zone) for nitrogen based on 102 dairy farms in New York. The farms in the green box are in the optimal operational zone with relatively high nutrient use efficiency and low risk of loss of nutrients to the environment.

# Nutrient Management

Klausner at Cornell University about 20 years ago and has been updated several times since. This calculator is targeted for use by dairy farms, though NMBs can be determined for any type of agricultural operation. We have a questionnaire available to help gather the data. Briefly, these inputs are listed in Table 1.

## Where Should Your Whole Farm Balance Be?

A sustainable nutrient mass balance should allow dairy farms to be economically profitable, environmentally sustainable, and flexible enough to allow for the many variations among farms. We defined "feasible" nutrient mass balances per acre and per cwt of milk produced as shown in Table 2, based on our work with a set of 102 New York dairy farms. Combining both balances (per acre and per cwt), the most efficient farms have balances in the green area (the "Optimum Operational Zone" or "Green Box") in Figure 2. This example in Figure 2 is for nitrogen. Evaluations so far have shown that farms operating outside of the green box have opportunities for improvements in nutrient use.

**Table 1** Information needed to complete a whole farm nutrient mass balance assessment.

| Category | Data Collected |
|---|---|
| **Farm Characteristics** | |
| Farm contact info | Name, address, phone, email |
| Balance year | Year |
| Farm land base | Total and tillable acres |
| | Acres in legumes and receiving manure |
| Animals | Group, average number, weight |
| **Farm Produced Feed** | |
| Farm produced crops | Acres and yield (tons/acre), %DM CP, P, and K (%DM) |
| | Acres in legume, % legume in stand |
| | Beginning + end year inventories (tons) |
| **Imports (Purchases)** | |
| Feed | Tons/year, %DM, CP, P, and K (%DM) |
| | Beginning and end year inventory (tons) |
| Fertilizer | Tons, %N, %P$_2$O$_5$, %K$_2$O |
| Animals | Number, weight (lbs) |
| Bedding | Tons/year, N, P, and K (%DM) |
| **Exports (Sales)** | |
| Milk sold | Lbs/year, milk protein (%) |
| Animals sold | Number, weight (lbs) |
| Crops sold | Tons/year, %DM, CP, P, and K (%DM) |
| Other sold | Tons/year, % DM, N, P and K (%DM) |

**Table 2** Feasible nutrient mass balances for NY.

| Nutrient Mass Balance | N | P | K |
|---|---|---|---|
| Per acre (lbs/acre) | 0-105 | 0-12 | 0-37 |
| Per cwt milk (lbs/cwt) | 0-0.88 | 0-0.11 | 0-0.30 |

## Farmer Feedback

Farms that complete the assessment for at least four years have shown great improvements over time without giving up on milk production. A number of farms have reduced balances while increasing milk production due to more precise feeding. We don't have farm financial records, but the fact that balances were improved without giving up on milk production strongly suggests that the farms gained by keeping track of their mass balances. Each farm is unique so management practices that allow a farm to become more efficient with nutrients were also farm specific. Some common themes for review are careful evaluation of cow feeding programs, change of feed imports where possible, focus on increasing homegrown forage production through better crop and pasture management and better allocation of fertilizers to fields to support the crops. Some farmers made crop rotation changes, while others decided to increase acreage, or export more crops and/or manure.

Farmers can do the assessment themselves by using the tool on our website and generate a report once all data are entered. The farmers that share their data with us or submit their completed input sheets to us receive a comprehensive report that includes a comparison of their farm data with the data of all other farms in the database (all farm names are kept confidential). Farmers can learn from each other by comparing their operations and by discussing the results in their own management team. Here is some feedback from participating farmers about the benefit of doing the balance and sharing results:

*"With enough farms in the database that are similar in size and cropping program to ours, we can make valid comparisons. It helps us to see what can be achieved and gives us a good sense of where we stand in our goal to be as nutrient efficient as is possible."*

*"Immediately it makes you think of things in a different light or from a different perspective, than we normally look at things in either dollars and cents or feed pounds or feed pounds wasted or what we are feeding the cows it steps back one step further and makes you look at the big picture."*

*"When we share the information with the whole farm team it sparks useful and important conversations about our farm's philosophy and practical applications to concrete practices such as manure application, crop sales and purchases."*

**Join Us!**

Don't hesitate, join us and let's learn together. The software and supporting information (manual, input sheets, etc.) are freely downloadable from the whole farm nutrient mass balance project page of the Cornell Nutrient Management Spear Program (NMSP) website: http://nmsp.cals.cornell.edu/NYOnFarmResearchPartnership/MassBalances.html. Download the input sheets and derive the balance yourself or let us join your evaluation! The software works on IBM computers and is currently not available for Macs.

## Nutrient Management

# Integrating Record Keeping with Whole Farm Nutrient Mass Balance: A Case Study

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## Introduction

Many farms in New York have participated in the whole farm nutrient mass balance (NMB) assessment in the past ten years. The data from these farms have shown that NMBs can help farmers make strategic decisions, aiding in evaluation of management alternatives that address the farm's long-term nutrient sustainability and farm profitability as was shown in earlier What's Cropping Up? articles (Ketterings et al., 2016; Cela et al., 2015a,b; Soberon et al. 2015a,b). An NMB assessment determines the difference between nutrients imported onto the farm (via feed, fertilizer, animals, bedding, and manure), and nutrients exported (as animal products, crops, and manure) divided by the total tillable acres (indicator of the potential environmental footprint of the farm), and divided by total milk production (reflecting the farm's overall production efficiency).

## Past Experiences

Earlier evaluations for a cross-section of New York dairy farms (102 farms) resulted in the identification of the "optimum operational zone" where farms meet (i.e. not exceed) the feasible NMBs per acre and per cwt milk produced (Table 1). Evaluation of NMB trends over 4 to 6 years for 54 New York dairy farms showed that 63 to 76% of the NMB decreased over time (depending on the nutrient), and >50% of the farms did so while increasing milk production per cow. Farms were able to improve their NMB by making changes in feed and fertilizer imports, animal density, percentage of farm-produced feed and nutrients, and feed nutrient use efficiency. In a follow-up study with a set of 27 farms with 6 to 10 years of data, the percentage of farms with N and P balances in the "optimal operational zone" increased from 22-26% over the first 2 years (depending on the nutrient) to 43-56% over the last 2 years of assessments. Similar improvements were shown in longer-term trends. Thus, farmers who participated in the annual NMB assessment for multiple years in a row tended to make changes that improved NMBs over time.

## Need for Automated Data Transfer

Despite recognition of the importance of knowing a farm's NMB on an annual basis, the time required to conduct a NMB can deter farmers from participating. The information necessary to complete the NMB requires the gathering of information from multiple sources, including from record systems already being used on farms. Where those records systems are software based, there is opportunity for electronic collection and transfer of the necessary information into a NMB calculator, making it quicker to conduct the assessment and reducing the risk of data entry errors.

## Project Goals and Methods

We evaluated software packages already in use on many dairy farms to see what information could be directly transferred into a NMB assessment tool. The software packages and data pieces evaluated included Fields & Crops Manager (information on acres, fertilizer, manure exports, yields), Dairy Comp 305, PCDART, and DHI Summaries (information on animal numbers), Feed Watch and TMR Tracker (information on purchased feeds fed) and Center Point Accounting and QuickBooks Accounting (information on purchased and sold feeds, fertilizer and livestock). The NMB assessment module was built into Fields and Crops Manager, an on-farm crop management program. The module used the algorithms of the Cornell NMB calculator (Soberon et al., 2015b). The software had to allow for entry of farm information as it became available (not all at once at the end), and needed a feature that allowed for easy identification of missing data. To address these issues, a spreadsheet-like data entry interface was created with color coded cells where cells with missing data were shown in orange, and cells with suspect data (outside of expected ranges) were in yellow. The interface allowed for addition and changing of information at will.

Six New York dairy farmers participated in the evaluation of the project by supplying their farm data for evaluation. The NMB results were presented and discussed in group meetings with each farmer. The

**Table 1** Feasible nutrient mass balances for dairy farms in New York based on Cela et al. (2015b).

| Nutrient Mass Balance | N | P | K |
|---|---|---|---|
| Per acre (lbs/acre) | 0-105 | 0-12 | 0-37 |
| Per cwt milk (lbs/cwt) | 0-0.88 | 0-0.11 | 0-0.30 |

farm teams present in the meetings included at a minimum the owner and one advisor, and for one farm included the owner, farm managers, the farm's crop consultant and nutrient management planner, and the nutritionist.

## Main Findings

Our main findings were:

- Animal inventory information was typically complete and up-to-date. Animal numbers for milking cows from DHI will be reliable but young stock numbers and weights have to be verified with the farm.
- Cropland acres were typically recorded in the farm's Comprehensive Nutrient Management Plan (CNMP).
- The best source for purchased and sold feed was the farm's accounting software but to be useful for NMB assessment, the entries require recording of both quantities and nutrient content as invoices are entered. Many farms do not record quantities in their accounting program, or keep records of nutrient contents of each feed purchased or sold, complicating data collection for the NMB assessment.
- An alternative to retrieve feed use is feed management programs such as Feed Watch or TMR Tracker. Caution is warranted when using such a feed management system to retrieve quantities of feed because any day the system is not functioning, the quantities of feeds fed are not recorded. Additionally, feeding systems only records what is loaded into the feed truck, not feed delivered to the farm but lost prior to feeding. Thus, the final accounting of total quantities fed will be lower than total feed imports.
- Due to inconsistencies in naming of feed sources, aligning feed composition data and feed quantities required help from the operators and nutritionists. As feed imports are typically a large driver for NMBs, only farms that regularly record quantities of feed purchases or use a well-functioning feeding management system can efficiently conduct a NMB.
- Fertilizer purchases were easy to retrieve from the farm's financial accounting system because there are relatively few products involved at any given farm and the transactions occurred typically in narrow windows of time.
- Crop acres, acres receiving manure, and manure exports (quantity and N, P and K content) were readily available from the farms' CNMP. However, none of the participants recorded their cropping operations completely enough to generate reliable totals for fertilizer and manure inputs.
- Bedding imports were difficult to determine as compositional data are typically absent but bedding is only a very small portion of the nutrient imports onto a farm and hence less important for NMB assessment. The only exception is when hay is purchased for bedding given its larger percentage and greater range in nutrient content.
- Crop yield records were often not maintained, unless crops were sold off the farm and sales records were kept. Use of yield monitoring equipment for silage harvest (corn and alfalfa/grass) will aid in collection of more accurate yield data in future years and allow for improvements in NMB assessment over time.

In general, we found that the records in the Fields and Crops Manager program and other software packages were not complete enough to allow for automated transfer of data into the NMB tool. Instead, the new NMB module within Fields and Crops Manager was used as a platform to enter, calculate, and store the NMB, without direct linkages to other programs.

## Farmer Feedback

Despite initial hesitation about participating, all six farmers concluded that (1) the NMB assessment was worth the data collection effort; and (2) meetings with farm advisors (crop planner, nutritionist) greatly improved the value of the NMB assessment. Survey results showed that the project made them think about changes in management that they could consider for the future:

*"It makes you think of things in a different light or from a different perspective, than we normally look at things. Rather than think in either dollars*

*and cents, or feed pounds, or feed pounds wasted, or what we are feeding, it makes you look at the bigger picture."*

*This is a good check on environmental stewardship and another way to find the proverbial "lowest stave in the barrel".*

The farm meetings were essential to gaining a greater appreciation of the NMB assessment. In the meetings, farmers identified issues and asked many questions. The most dynamic meetings were those where one or more of the farm's consultants attended the meeting. Some quotes from farmer feedback emphasized the value of the assessment and follow-up meeting:

*"My N Balance surprised me, I didn't think it would be as high as it was. This reinforces that we must export more manure."*

*"I want to get a better handle on feed shrink and amounts of feed we move through the farm"*

*"I am thinking more about manure incorporation to capture more of the manure N and will begin looking into direct injection rather than using an airway."*

*"I have to spend some time considering how to lower the %N in my rations and continue pursuing manure application on growing crops."*

### Conclusion

We conclude that successful adoption of the NMB assessments requires minimizing the amount of farmer time necessary to complete the assessment and maximizing the farm's understanding of the NMB results through farmer meetings. Year-round recording of quantities of purchases in the farm's accounting software as invoices are entered, and working with a knowledgeable NMB facilitator, are keys to successful adoption.

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### Join Us!

Farmers and farm advisors can access the NMB module via Field and Crops Manager. In addition, a stand-alone calculator and supporting information (manual, input sheets, etc.) are freely downloadable from the NMB project webpage of the Cornell Nutrient Management Spear Program: http://nmsp.cals.cornell.edu/NYOnFarmResearchPartnership/MassBalances.html. Download the input sheets and derive the balance yourself or let us join your evaluation! The software works on IBM computers and is currently not available for Macs.

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# Whole Farm Corn and Hay Yield Variability; a Dairy Farm Case Study

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Access to accurate yield records is essential if we want to identify limitations to crop production on individual farms, fields, or portions of fields, and to improve field and farm productivity over time. We also need to know yields to evaluate where investment of additional resources (labor, nutrients, seed, lime, tile, etc.) will result in an increase in yield.

Until the introduction of forage yield monitors, the only accurate way to determine whole-farm crop yields was with the use of farm scales combined with estimations of forage moisture obtained using microwave ovens or Koster testers. Portable axel truck scales can be used as well, but use of such scales (1) introduces greater error in yield estimates as typically not all axels can be weight simultaneously, and (2) slows down the harvest process. Driving trucks over permanent farm scales located close to the bunks causes less of a delay but still impacts the harvest process somewhat. Thus, few farms have long-term yield records. One exception is

Table Rock Farm in Western New York where all truckloads of all corn and hay fields have been weighed and recorded over the past fourteen years. Here we analyzed the yield data from this farm to: (1) determine the temporal variability of forage yields (corn silage, alfalfa/grass mixtures, and overall dry matter (DM) production); (2) assess yield and yield stability over time across all fields with at least two crop rotations; (3) evaluate soil physical and chemical properties as potential indicators of yield and yield stability over time; and (4) develop a method to analyze yield data.

## Yield Data and Analyses

Yield was measured between 2000 and 2013. Spatial (field to field) and temporal (same field over years) variability was determined using 107 fields of which 61 had yield data for six corn years each and 71 fields had five full production years for alfalfa/grass mixtures. The average yield and coefficient of variation (CV for means over time) were calculated for each field. The fields were divided into four groups called quadrants (Q1-Q4), using the overall weighted mean yield and mean CV as cutoffs for the quadrants: (1) above mean yield, below mean CV (Q1); (2) above mean yield, above mean CV (Q2); (3) below mean yield, above mean CV (Q3); and (4) below mean yield, below mean CV (Q4). This methodology allowed us to identify fields that are consistently high yielding versus fields that sometimes yield high, sometimes low, or are consistently low in yield. The consistently high yielding fields are the fields with the greatest biological buffering capacity, able to produce also under challenging weather conditions.
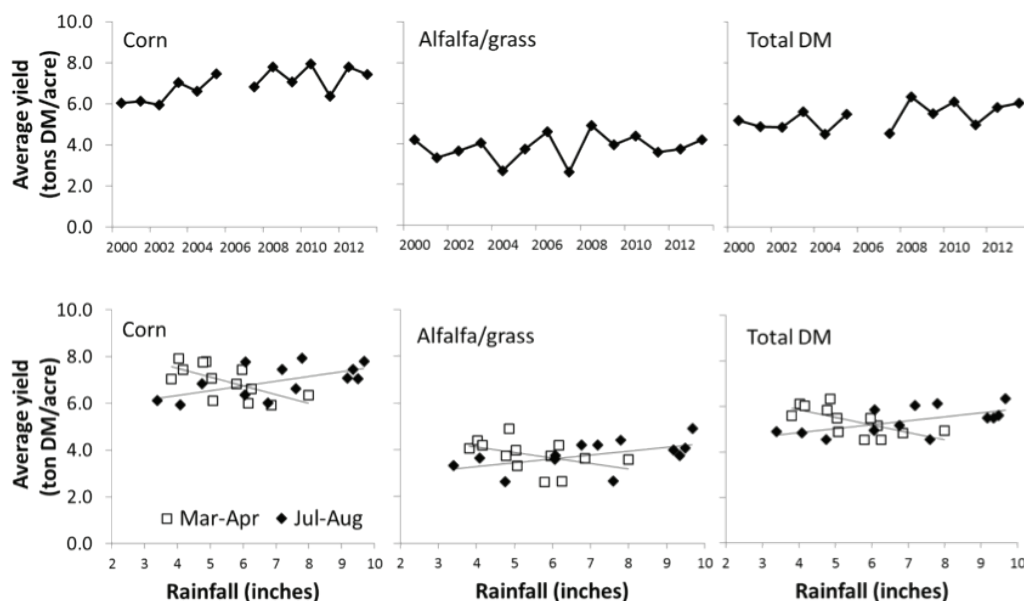


**Fig.1** Yield trends of corn, alfalfa/grass mixtures and total dry matter production on a western New York farm from 2000 to 2013 as impacted by rainfall during March-April and July-August. Corn silage yield increased during the time period. Yield of alfalfa/grass mixtures remained constant. Total dry matter production increased over time, reflecting trends in corn silage yield. Corn yield was impacted by rainfall during planting and tasseling. Alfalfa/grass yield was impacted by rainfall during July-August. Total dry matter was impacted by both March-April rainfall and July-August rainfall. Adapted from Long and Ketterings (2016).

## Findings

Corn yields increased over time from 5.9 tons/acre dry matter (DM) in 2000 to 7.9 tons/acre in 2013 (from 16.9 to 22.6 tons/acre at 35% DM). The yield of alfalfa/grass mixtures did not increase, averaging 3.8 tons/acre DM (4.5 tons/acre at 85% DM). In 2013, the average yields for corn silage and alfalfa/grass mixtures on the case study farm were 37% and 22% higher than the state average that year. Growing degree days since planting and whole-season (March through October) rainfall were not correlated with yield of either corn or alfalfa/grass mixtures. Corn silage yield was impacted by rainfall during March and April, and during July and August. An increase in rainfall during March and April, just prior to corn planting, caused a decrease in overall yield. In contrast, an increase in rainfall during July and August, a time period in which tasseling occurs, was correlated with an increase in overall yield (Fig. 1). The yield of alfalfa/grass mixtures was not correlated with rainfall during individual months (data not shown), but increased with total rainfall in July and August (Fig. 1).

Corn silage average yield across fields and years was 7.0 tons/acre dry matter, with a mean CV of 16.4% (Fig. 2). In contrast, the overall yield for alfalfa/grass mixtures was 4.4 tons/acre dry matter, with a mean CV of 21.6% (Fig. 2). For corn and alfalfa-grass mixtures yielding above the farm average, there was a 74% and 86% probability of a CV below the farm average, respectively, indicating that high yielding fields tend to be more consistent in yield over time than low yielding fields.

The fields in Q1 and Q2 had a higher percentage of well-drained soils, versus primarily moderately and somewhat well-drained soils for Q3 and Q4. These results suggest that drainage of the soil and field yield and stability are correlated; higher yields are expected in better drained soils. It is important to keep in mind that these results are based on the predominant soil type in the field, and may not be the only driving force behind the overall performance. It is therefore important to also consider chemical properties when quantifying spatial variability.
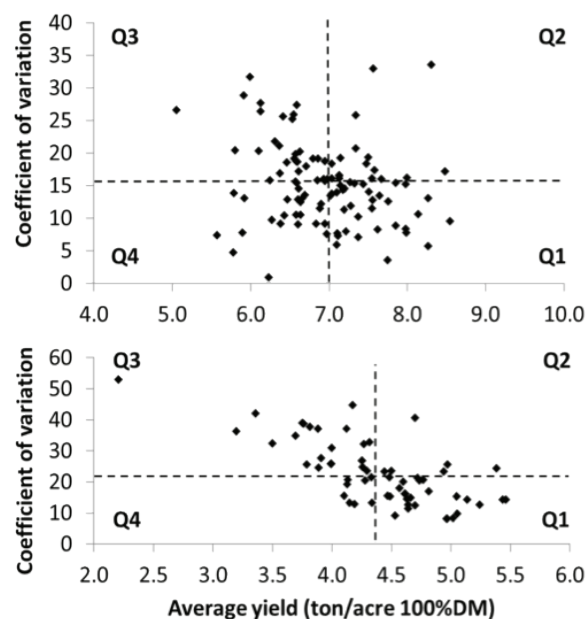


**Fig.2** Average yield of corn silage (a) and alfalfa/grass mixtures (b) and coefficient of variation for each field. Dotted lines represent the overall average yield and coefficient of variation. Quadrants are labelled 1-4 and identify those fields which are high or low yielding, and exhibit high or low variability. Adapted from Long and Ketterings (2016).

Organic matter for consistently high yielding fields averaged 2.9 and 3.2% for corn silage and alfalfa/grass mixtures, respectively, versus 2.7 and 2.8% OM for low and variable yielding fields. Fields in alfalfa/grass mixtures with a lower than average CV had significantly higher OM levels suggesting a positive link between OM and yield and yield stability over time.

Consistently high yielding fields averaged 36 and 40 lbs P/acre on the Cornell Morgan soil test for corn silage and alfalfa/grass mixtures, respectively, versus 18 lbs P/acre for low yielding and more variable fields. Corn silage fields with a below average CV (less variable over time) had higher mean soil test P than those with a higher than average CV. High yielding fields with alfalfa/grass mixtures had higher soil test P than low yielding fields. However, across all fields for both crops, yield increased as Cornell Morgan soil test P increased up to 32 lbs P/acre for corn silage, and 29 lbs P/acre for alfalfa/grass (Fig. 3); there was no relation between yield and soil test P at soil test levels that were higher
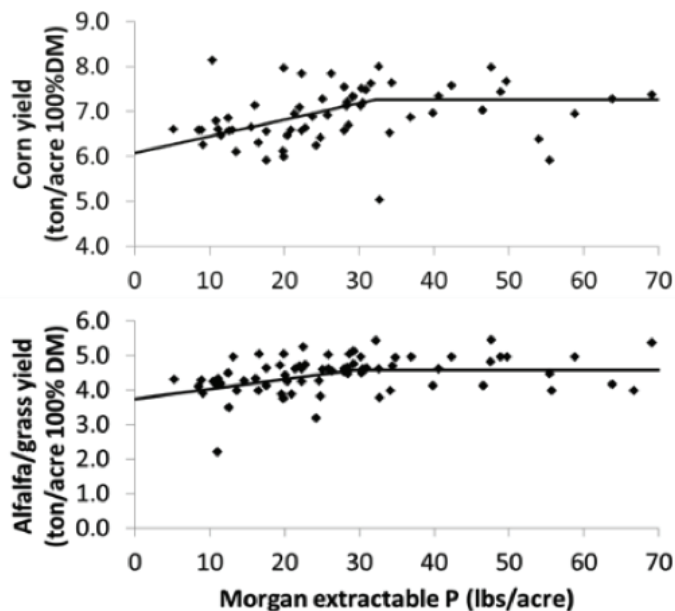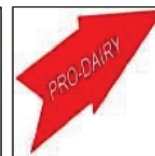
## Nutrient Management



**Fig.3** Yield of corn silage and alfalfa-grass mixtures on a western New York dairy farm, as impacted by Morgan extractable soil test phosphorus levels. As soil test phosphorus increases, the yield increased until approximately 32 lbs P/acre for corn silage and 29 lbs P/acre for alfalfa/grass. Adapted from Long and Ketterings (2016).

than these values reflecting past manure applications and indicating it is not the P in the manure that is linked with the high yielding fields but more likely the benefits of organic matter addition and stimulation of microbial activity with the addition of manure.

### Summary and Conclusions

Corn silage yields increased from 2002-2013, while yields of alfalfa-grass mixtures remained constant over time. Yield varied both temporally with rainfall throughout the growing season and spatially among fields. The consistently high yielding corn fields exceeded 7.0 tons/acre dry matter with a CV less than 16.4%. Fields in alfalfa-grass mixtures that were consistently high yielding exceeded 5.5 tons/acre with a CV less than 21.6%. The highest and most consistently yielding fields had better-drained soils, optimum or higher in soil test P, and higher OM levels than the lower yielding and more variable fields. These results could suggest that farmer practices that improve soil drainage (tile drainage), conserve or even increase organic matter

(reduced tillage and cover crops), and enhance soil test P (manure application) to optimal (not excessive) levels, might be effective in increasing the overall corn silage yield and yield stability. Similar assessments can be done (and much faster) when analyzing forage harvester yield maps. Such work is ongoing in the Nutrient Management Spear Program.

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