2024 FINAL REPORT (ongoing project)

PROJECT TITLE: : **Past the Learning Curve: does long-term soil health management lower N requirements?**

PROJECT NUMBER: 6130-24DD

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ABSTRACT

Provide a project summary describing an overview of the project including principle findings. Include a statement on how the project was of benefit to corn farmers.

The overarching goal of the project is to evaluate how corn N needs vary among long-term and short-term soil health management systems, and conventional management systems, and explore potential soil biological properties that could drive those differences. Soil health management systems are defined as those using cover crops and reducing tillage to no- or strip-till corn.

In our first year, we evaluated some data from on-farm corn N rate trials in SE MN to explore the relationships between soil biological activity and N response. We did not find much relationship between corn N needs (optimum N rate, yield at optimum N rate, yield at 0N) and biological activity, as measured by CO_2 burst. This suggests that corn farmers should use caution in applying N rate recommendations based on soil biological tests.

We also selected and prepared sites for N rate trials on working farms varying in management in Renville and Mower counties. Agronomic and soil data collected during the 2025 corn growing season will inform future years' recommendations.

INTRODUCTION

Provide background information related to the project including such item as the problem statement, knowledge gaps, and relevant previous work completed on this issue.

Lots of anecdotes from farmers claim that fertilizer inputs can be reduced with cover crops, no-till, or a full-fledged soil health system (Fredericks, 2022). Since fertilizer is the second highest expense after land rent in Minnesota corn production (FINBIN, 2018-2022), ways to reduce this expense are always a top priority across the state.

So how might soil health make it possible to reduce crop fertilizer needs? Here, we focus on N, as a primary yield-limiting nutrient for corn production. Organic N is widespread in the soil- 1,000 lbs/ac per 1% OM! But it must be transformed, or mineralized, by soil organisms into plant-available nitrate or ammonium for corn to use it. If it is true that soil health systems have increased N supply, it would be due to greater, or perhaps more timely, mineralization of organic N by soil organisms. Enhancing mineralization would be facilitated by reduced disturbance of soil habitat and consistent food supply from crop residues and living cover crops in the shoulder season.

Soil biological activity is assessed indirectly through measurement of pools of organic C and N commonly associated with soil health. These pools represent rapidly cycling pools of organic matter, and have been used as proxies for microbial biomass, activity and food source. Some of these, such as permanganate-oxidizable C (Malone et al., 2023) and 24-hour C mineralization (Culman et al., 2013; Franzluebbers, 2018) have been shown to correlate with corn yield, but this connection has not been as strong in Minnesota (Clark et al., 2019). In year 1 of this study, we found that 24-hour C mineralization did not predict ENOR, but did correlate with yield at 0N applied, proving that this indicator is linked to organic N supply to corn. However, the lack of connection between the 24-hour C mineralization (an indicator of microbial activity) and EONR means this is not useful for management, as the microbial connection to N supply is overwhelmed when fertilizer is applied. It is possible that the indicators may perform better as predictors of corn yield in soil health systems where reduced tillage and diverse cropping systems have altered microbial communities and activity, but no study to date has focused on that potential gain. Clark's work was exclusively in tilled 2-crop rotation systems. Indeed, a multistate study including MN N rate trials from 1995-1998 found that corn N need and yield could be predicted using a combination of biological and chemical N extraction (McDaniel et al., 2020).

Our experimental approach is designed to meet 3 goals:

1. Assessment of N needs in corn in varying systems (long-term soil health, short-term soil health, and conventional)
2. Partial budget assessment of cost of corn production in each system
3. Exploration of soil factors which predict N response to corn across systems.

OBJECTIVE AND GOAL STATEMENTS

Objective 1: Determine the economic optimum N rate (EONR) in long-term soil health, short-term soil health, and conventional (LTSH, STSH, CONV) fields

Objective 2: Develop a partial budget for corn production for each field.

Objective 3: Evaluate soil health indicators as predictors of corn N needs and yield in long-term soil health, short-term soil health, and conventional (LTSH, STSH, CONV) fields

MATERIALS AND METHODS

Field selection is the heart of this study. During 2024, Cates and De worked closely with soil scientists and SWCD professionals at Mower and Renville SWCDs, as well as consulting NRCS, to place sites on similar soils across the three treatments. We located experimental plots within fields based on equipment size, row spacing and direction, and soil heterogeneity within each field to maximize our ability to detect differences in the small-plot N rate study while minimizing logistical challenges for the farmers.

Triplet location/soil type	LTSH	STSH	CON

Mower 2025 1/silt loam	~30 yrs strip-till corn, no-till beans, >10 years cover crops	2 yrs cover crops, reduced till	Full-width tillage
Mower 2025 2/silt loam	~30 yrs strip-till corn, no-till beans, >10 years cover crops	2 yrs cover crops, 3-yr rotation, reduced till	Full-width tillage
Renville 2025/silty clay loam	~30 yrs no-till, reduced input, 3-yr rotation	~3 yr no-till, cover crops	Full-width tillage

The LTSH site in Mower county, on Oran silt loam, has a multi-decade history of strip-till corn/no-till beans with consistent cover crops added for more than a decade. This Mower farmer will supply 2 separate fields for the study for two LTSH sites on similar loess soils. Two Mower corn farmers who use full-width tillage and no cover crops in corn-soybean systems will supply CONV sites. One conventional farmer who has been experimenting with cover crops for Mower SWCD's cost-share program will supply a STSH sites (2 years of cover crops).

Objective 1: Determine the economic optimum N rate in long-term soil health, short-term soil health, and conventional (LTSH, STSH, CONV) fields

The research team, in consultation with SWCD personnel and farmers, built individual plot maps. Exact sizes varied by equipment, but in most cases the plots are 1-2 planter passes wide (~60-90 ft) and 200-500 ft long, for a total of approximately half an acre. Four blocks were delineated and within each block, one of 8 N rates (0, 40, 80, 120, 160, 200, 240, 280 lb N/ac) was randomly assigned to each plot. In 4/9 sites, farmers requested applications of elemental phosphorous (triple-super-phosphate) to replace standard applications of MAP and DAP, which are being spread in late November. In most cases, farmers will be able to eliminate all N from planting operations, though up to 10 lbs will be allowed if necessary. This N will be subtracted so that the final N rates remain consistent (with the exception of the 0N. All N fertilizer will be applied by hand broadcast spring urea at planting, to minimize variability due to N source, timing, and placement.

Corn planting will be done by the farmer, using their equipment and hybrid of choice.

Harvest data will be collected by harvesting the middle 2 rows of each plot by hand shortly after physiological maturity (R6). Corn grain will be separated from stalks, dried, and weighed. A subsample of grain and tissue from each plot will be analyzed for total N.

A detailed management survey will be administered for each farmer cooperator including five years of tillage, crop rotation and fertility/manure inputs. The Cates lab has used this particular survey instrument in the past to develop quantitative indices of soil health practice use intensity, which may help to explain differences among fields in response to N better than the length of time in soil health practices.

Statistical analysis: A N rate response curve will be created for each field, and both linear and quadratic plateau curves will be fit. The best fitting curve (based on R^2) will be used to determine the EONR, the rate at which increasing N rate does not result in increased yield. The EONR will be compared among treatments using a mixed model, with site-triplet as a random effect, and treatment (LTSH, STSH, CONV) as a fixed effect.

Objective 2: Develop a partial budget for corn production for each field.

Using management information gathered in Objective 1, we will use the American Farmland Trust Soil Health Economics Calculator (SHEC) to create a partial budget analysis. The SHEC is limited to comparing differences between 2 systems, so we will enter data for CONV vs LTSH, CONV vs STSH, and LTSH vs STSH. Comparisons will be performed separately for each of 9 fields, unless data from the same treatments at different site-triplets is so similar that an average across sites is judged appropriate by researchers. Lazarus will advise the interpretation of this tool’s outputs in Extension products such as blog posts and presentations.

Objective 3: Evaluate soil health indicators as predictors of corn N needs and yield in long-term soil health, short-term soil health, and conventional (LTSH, STSH, CONV) fields

In 2024, Cates will work with a dataset from MN Department of Ag, including N rate trials conducted from 2019-2024, with soil respiration analyzed in plots with no N applied. Cates will use this data to asses the relationship between soil respiration, a major part of the N recommendations generated by the Haney test, and the maximum return to N rate (MRTN) as well as yield at MRTN, yield and N uptake at 0 N applied. These analyses will be conducted in collaboration with Jeff Vetsch, Kevin Keuhner, and the MDA Nutrient Management Initiative team, which has been responsible for collecting the N rate data for several years.

In 2025 and 2026, spring pre-plant soil samples will be taken in each plot to estimate soil N availability at planting. Three 1” dia samples would be taken in each plot down to 36”, separated into 12” increments, and composited to one sample per plot for nitrate and ammonium analysis.

Soil health samples will be collected prior to planting, at stage V5, and stage V10 (Culman et al., 2013) in only 0N and 150N rate plots, to assess organic N supply and soil biological activity. In these plots, 10 0-6” cores will be taken, homogenized in the field, and preserved fresh until sieving to 8 mm in the lab. Samples for potentially mineralizable N, microbial biomass C and N, and soil respiration will be transported on ice to MSU-Mankato to be processed in the De Lab. Samples for aggregate stability will be taken to 6” with a spade, and transported fresh to the lab. Aggregate stability will be determined by wet-sieving (Yoder et al) to determine aggregate distribution into >2mm, 0.5-2mm, and <0.5mm size classes.

Some assessments of the effects of soil health practices will be done outside the N rate plots, as they require larger areas. Crop residue will be assessed at the time of planting using a transect. Weed pressure will be assessed at V5. Researchers will count all weeds seedlings visible in a 1 ft2 quadrat, placed randomly 5 times within 100 ft of the N rate block (or within another area of the same soil type in the field). Insect predation levels will be assessed using sentinel prey (wax worms/wax moth larvae). In each field, we will place 10 cubes of clay with grubs affixed to them for 3 hours. At the end of 3 hours, prey will be categorized as gone, intact, or partially eaten. Any insects visible on the prey will be identified in the field to taxonomic family, or photographed for later identification.

Statistical analysis: To compare among treatments, weed pressure, predation, residue, EONR, yield at EONR, and soil parameters will each be considered response variable with treatment (LTSH, STSH, and CONV) as a fixed effect and site and site*treatment as random effects.

To evaluate the relationship between soil parameters and corn N needs, we will build a model for each farm field, performing a regression tree analysis or stepwise model selection with EONR and yield at EONR as response variables, and all soil health indicators as independent variables, to evaluate which parameters are most impactful in corn N needs.

RESULTS AND DISCUSSION

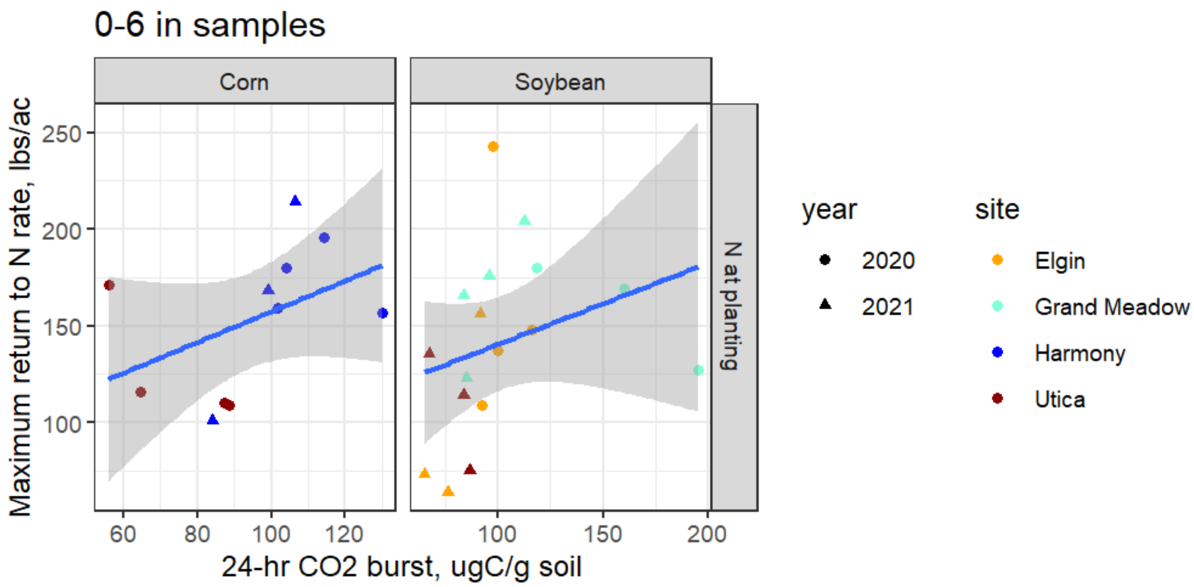
In year 1, we focused on setting up plots to meet Objectives 1-3, and evaluating data from a related study as background information to inform Objective 3 in future years.

In the MDA SE MN dataset, we found very little relationship between corn N needs and biological activity. We would expect the corn N needs to go down with higher biological activity, instead, across sites there was a positive correlation between the maximum return to N rate and CO_2 burst values. The statistical relationship was not significant, however, suggesting that CO_2 burst is a poor predictor of corn N needs. One possible exception is when corn follows soybean, and N is split-applied: in that case, the expected negative relationship was observed, and more data may confirm whether this is a reliable outcome farmers could expect.

We also explored relationships between 24-hour CO_2 and corn yield or corn N uptake at 0N applied in these trials. Again, the relationship was stronger when corn followed soybean. This suggests that while the biological activity does indicate the soil's ability to supply N, that ability is overrun by adequate N fertilization.

Stronger relationships with biological activity in 0-6" soils suggest we would do well to focus on these depths going forward. Site-year variability is a big factor here, and continuing to collect data from different sites may allow us to identify sites where biological activity is more likely to be a relevant factor in predicting corn N use.

Figure 1: Relationship between 24-hour CO_2 and MRTN at 0-6 in and 0-12 in samples.



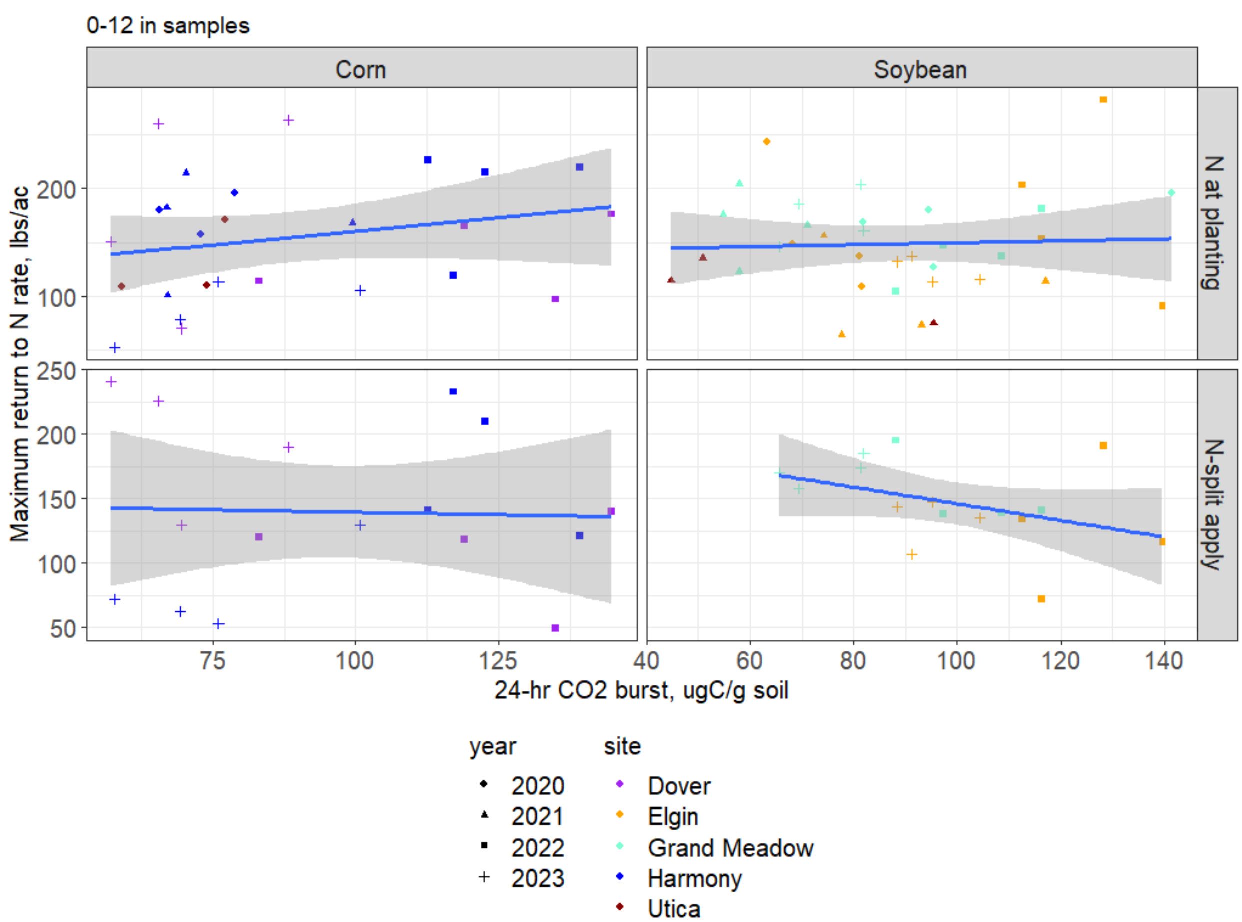
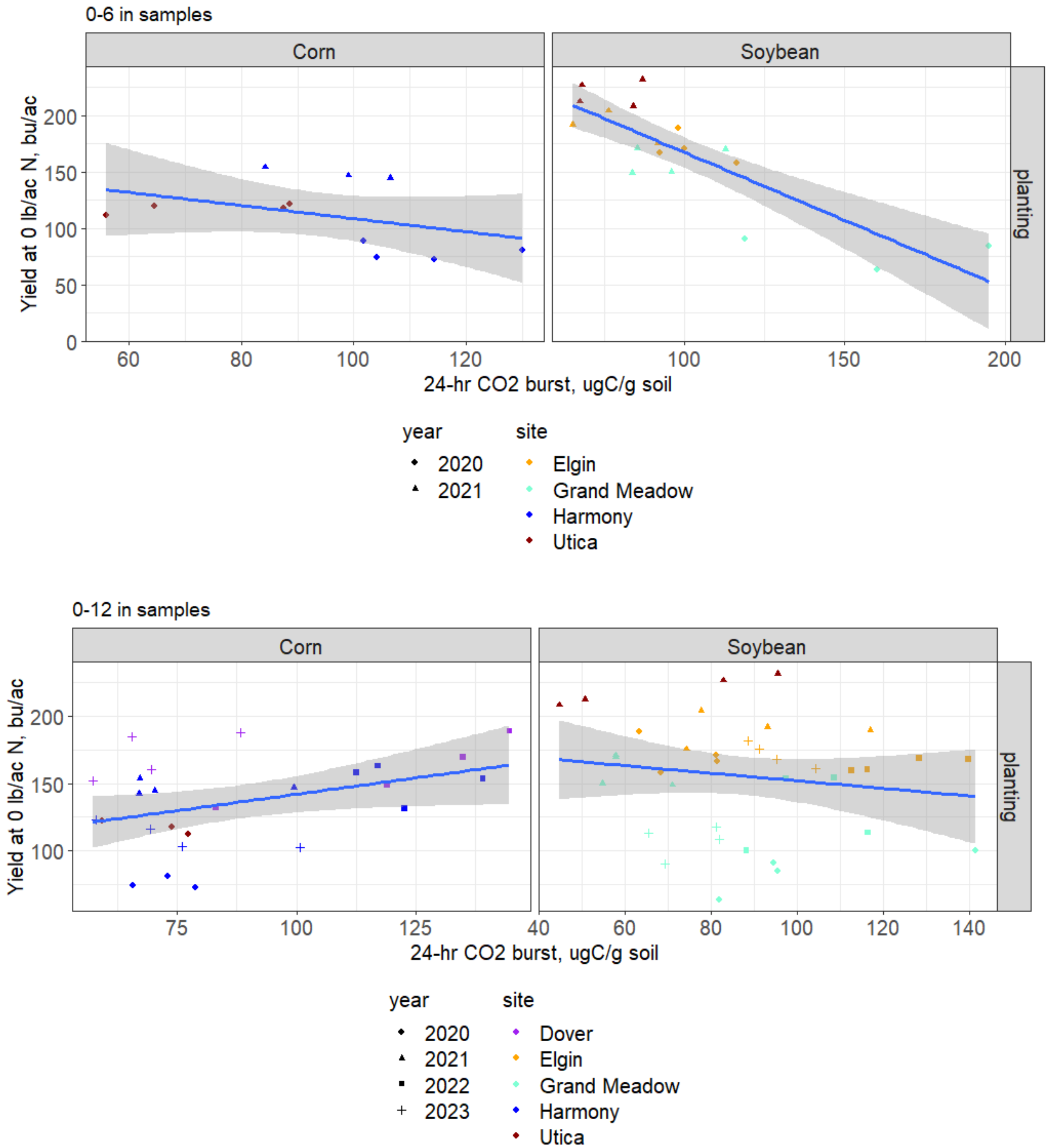


Figure 2: : Relationship between 24-hour CO_2 and MRTN at 0-6 in and 0-12 in samples.



CONCLUSIONS

EDUCATION, OUTREACH, AND PUBLICATIONS

Identify conferences, workshops, field days etc. at which project results were presented. Include number of farmers estimated to be present. List articles and/or manuscripts in which project results were published.

Cates, A.M. Predicting corn nitrogen needs with biological testing- what's possible in MN? Feb 4, 2025. Nitrogen: Minnesota's Grand Challenge & Compelling Opportunity Conference. Mankato, MN. 80 people

Cates, A.M. Predicting corn nitrogen needs with biological testing- what's possible in MN? Feb 20, 2025. Slayton Winter Crops Day. Slayton, MN. 25 people

Cates, A.M. Predicting corn nitrogen needs with biological testing- what's possible in MN? March 27, 2025. Central Minnesota Organic Crops Day. St. Cloud, MN. 12 people

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