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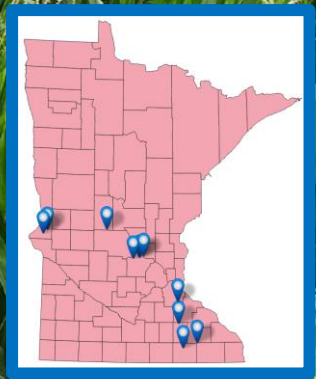
On-Farm Evaluation of a Remote Sensing and Calibration Strip-Based Nitrogen Management Strategy for Corn

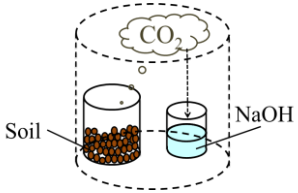
Katsutoshi Mizuta, Ph.D.
University of Minnesota
Precision Agriculture Center



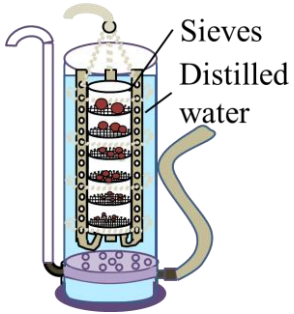
Research Background

Soka University, Tokyo, Japan
B.Sc. Environmental Engineering
Biogeochemistry Lab

Soil health and biofuel plant

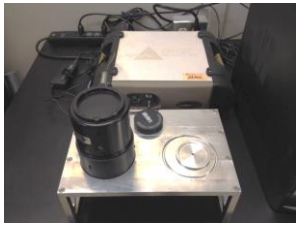


Soil respiration



Water-stable soil aggregation

University of Florida, FL,
US
M.Sc. and Ph.D.
Soil, Water, Ecosystem Sciences
(Minor: Food and Resource Economics)



Proximal/Remote Sensing, AI (Machine Learning), Econometrics, Ecological Theory…

Research and Extension Background

University of Minnesota, MN, US
Soil, Water, and Climate Dept.
Precision Agriculture Center

University of Minnesota Extension

Agronomy

Granular

USDA United States Department of Agriculture
Natural Resources Conservation Service

molitor
MOLITOR BROTHERS FARM
...respectfully growing

Department of Agriculture

ceres

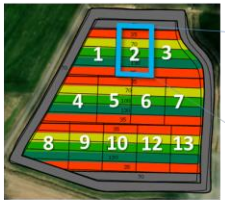
MinnesotaCorn Growers Association

Development and Promotion of In-Season PNM Practices (3-years)

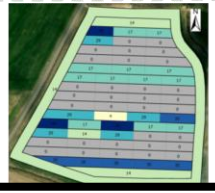
40 fields

A. BEFORE PLANTING
Different preplant N rates application based on normal farmer's N rate (FNR)

B. GROWTH STAGES V8-V10
Generation of **blocks** and **identification of agronomic optimum N rate (AONR) per each block** based on NDVI from satellite imagery



C. SIDEDRESS N APPLICATION FOR PLOTS WITH LESS THAN 100% FNR (35 AND 70% FNR)



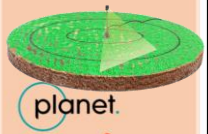
VRI x VRN (3-years)

1 field

Soil and landscape properties

Conditional Latin hypercube Sampling (cLHS) R

In-season variable rate irrigation based on dynamic IMZs and soil moisture sensors



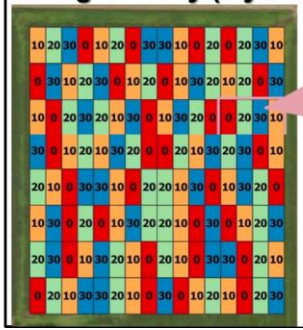
planet.

ARABLE

ALTUM by MicaSense

VR sulfur, seeding, and nitrogen study (3-years)

6 fields



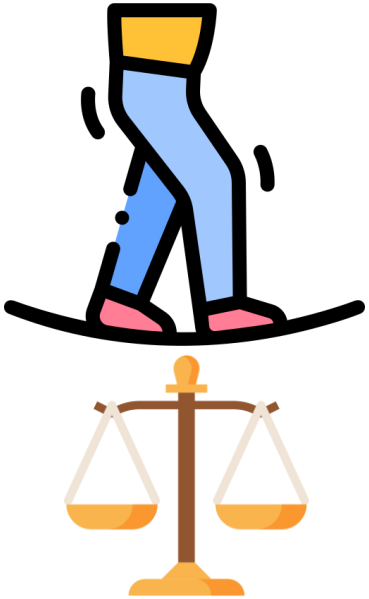
Randomized complete block design

Block with randomized treatment

Sulfur (lb/ac)

0
10
20
30

Underapplication



Overapplication

How Do You Determine Total Fertilizer Application Rate?

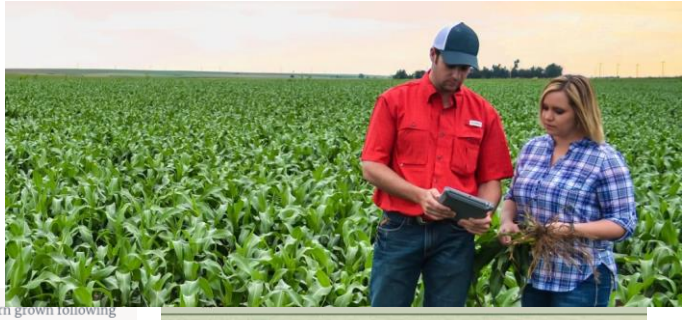
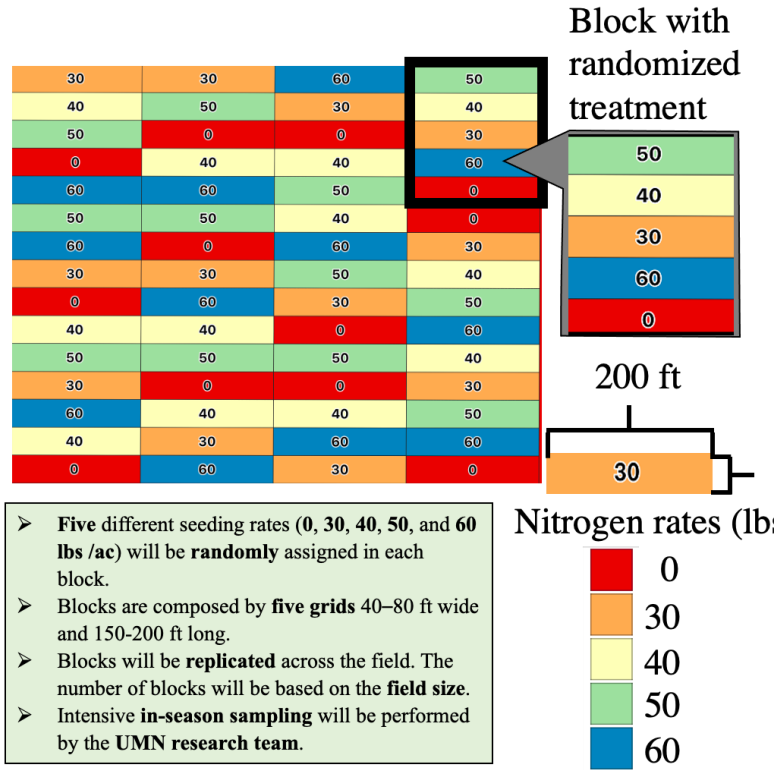


Table 1: Guidelines for use of nitrogen fertilizer for corn grown following corn or soybean when supplemental irrigation is not used

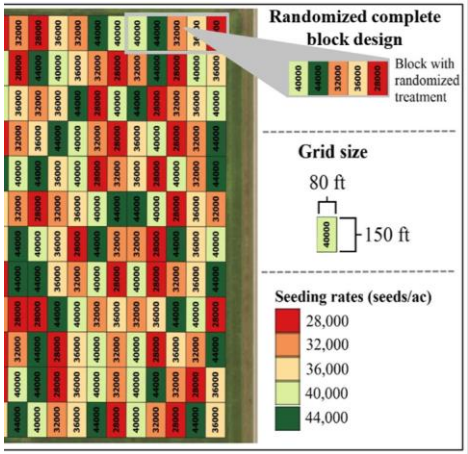
Prior crop	N price/Crop value ratio	MRTN	Acceptable range
Corn	--	lbs N/acre	lbs N/acre
	0.075	190	170-205
	0.100	175	160-190
	0.125	165	150-175
	0.150	155	145-165
Soybeans	--	lbs N/acre	lbs N/acre
	0.075	150	135-165
	0.100	140	130-150
	0.125	135	125-145
	0.150	130	120-140

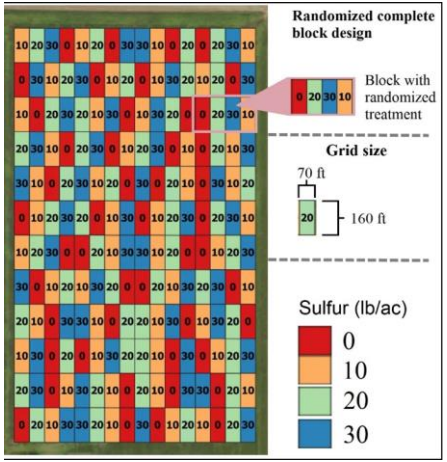
Which Approach Do You Take: One-time or Split Application?

Background

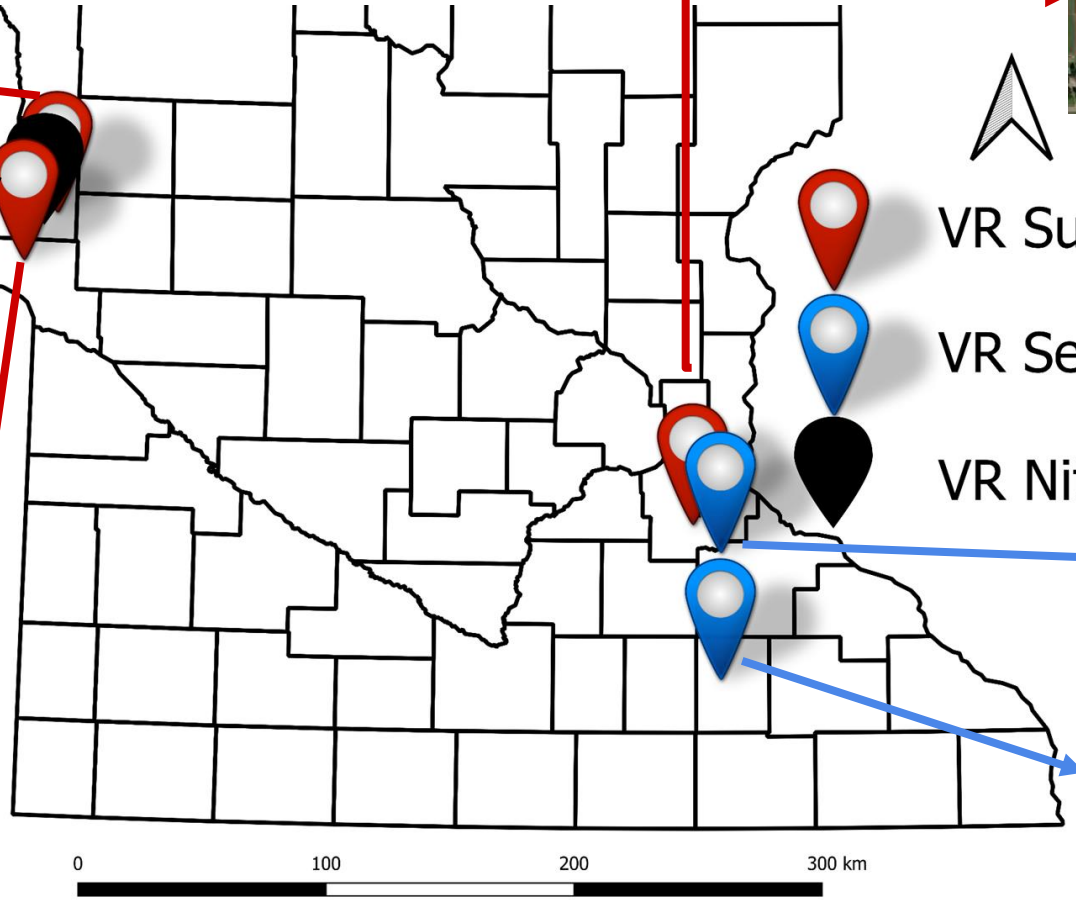


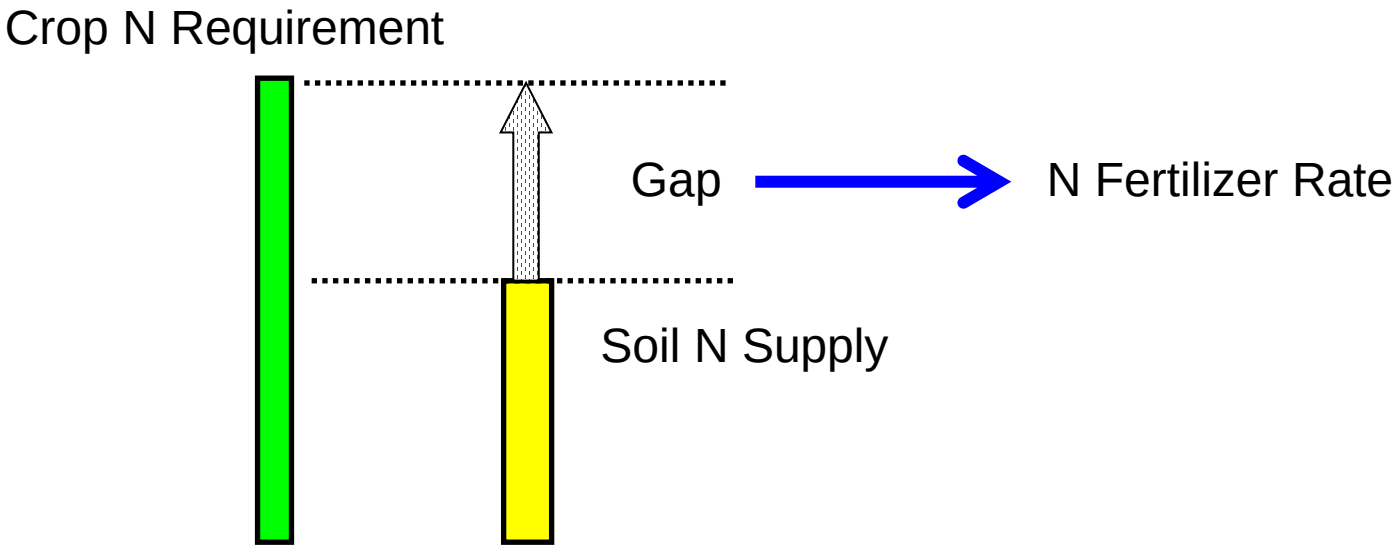
- **Five** different seeding rates (**0**, **30**, **40**, **50**, and **60 lbs /ac**) will be **randomly** assigned in each block.
- Blocks are composed by **five grids** 40–80 ft wide and 150-200 ft long.
- Blocks will be **replicated** across the field. The number of blocks will be based on the **field size**.
- Intensive **in-season sampling** will be performed by the **UMN research team**.

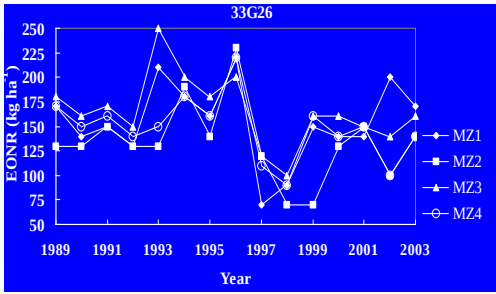




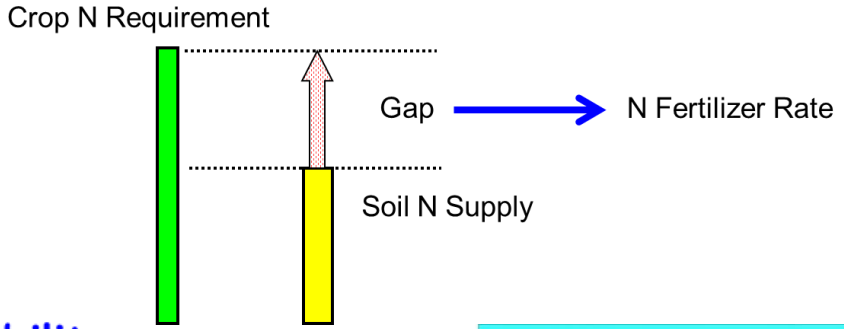
Locations of On-farm Trials



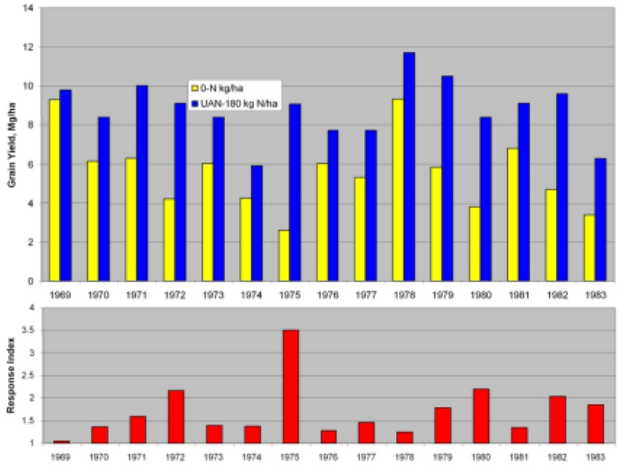

Crop N Requirement
Gap
N Fertilizer Rate
Soil N Supply


33G26
EONR (kg ha-1)
250
225
200
175
150
125
100
75
50
1989
1991
1993
1995
1997
1999
2001
2003
Year
MZ1
MZ2
MZ3
MZ4

Background

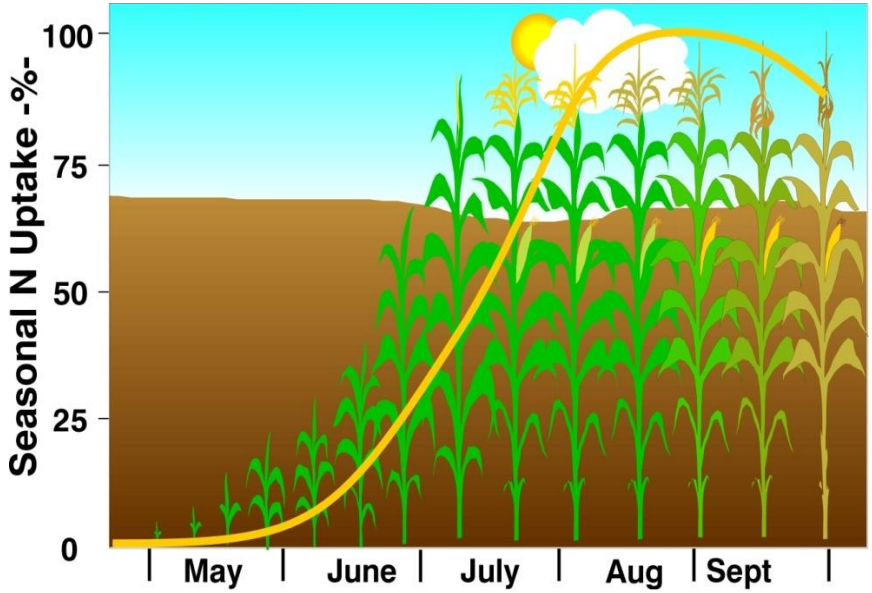


Temporal Variability



Corn Mead, Nebraska, USA

From http://nue.okstate.edu/Index_RI.htm



(Image from J. Schepers)

USDA NRCS
U.S. Department of Agriculture
Natural Resources Conservation Service

CIG
Conservation
Innovation
Grants

On-farm Demonstration and Evaluation of an Innovative Calibration Strip-based Precision Nitrogen Management Technology for Corn

Project Objectives

1) Improve corn N management at the farm level and significantly reduce N losses using an innovative, practical, reliable, and profitable PNM technology.

2) Quantify the agronomic, economic, and environmental benefits of the calibration strip-based PNM technology under diverse on-farm conditions and promote wider adoption by corn farmers.

3) Facilitate the adoption of the evaluated PNM technology by farmers.

A remote sensing and calibration strip-based precision N management (RS-CS-PNM) strategy

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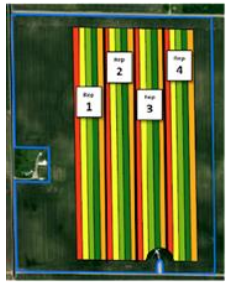
A. BEFORE PLANTING OR EARLY GROWTH STAGES

Different "**preplant" N rates application** based on normal farmer's N rate (FNR)

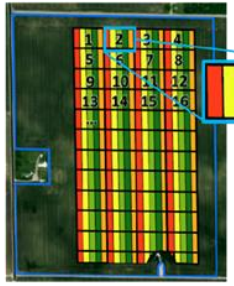


"Preplant" N	kg ha^{-1}
120% FNR	240
100% FNR	200
80% FNR	160
60% FNR	120
40% FNR	80

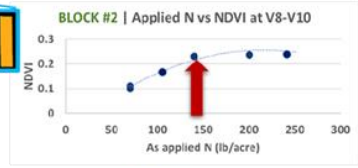
Normal farmer's nitrogen rate **(FNR) = 200** kg ha^{-1}

B. GROWTH STAGES V7-V8

Generation of **blocks** and **identification of agronomic optimum N rate (AONR) per each block** based on NDVI from satellite imagery



Identification of AONR for each block⁺



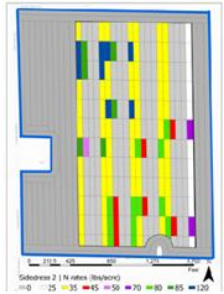
Example: AONR for Block #2 = 160 kg ha^{-1} (80% FNR)

*Each block contains all N rates. Number of blocks will vary depending on field size.

C. GROWTH STAGES V8-V9*

Sidedress N application for plots with less than 100% FNR (40, 60, and 80% FNR)

*May be delayed up to V14



SIDEDRESS N = AONR – AS APPLIED N

A. BEFORE PLANTING OR EARLY GROWTH STAGES

Different "**preplant" N rates application** based on normal farmer's N rate (FNR)

"Preplant" N	kg ha^{-1}
120% FNR	240
100% FNR	200
80% FNR	160
60% FNR	120
40% FNR	80

Normal farmer's nitrogen rate **(FNR) = 200** kg ha^{-1}

120%FNR: N Rich

If your current rate is under-applied and where

80%FNR:

If your current rate is over-applied and where

40%FNR and 60%FNR:

The main areas for in-season N management

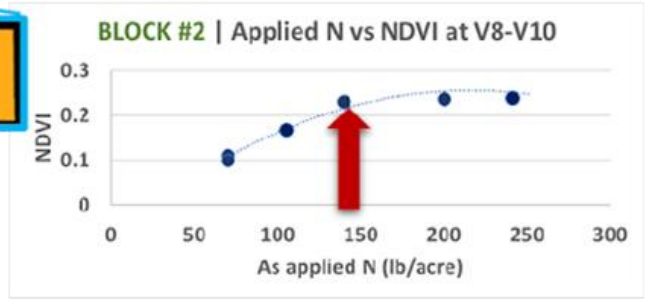
B. GROWTH STAGES V7-V8

Generation of **blocks** and **identification of agronomic optimum N rate (AONR) per each block** based on NDVI from satellite imagery

A. BEFORE PLANTING OR EARLY GROWTH STAGES

Different "**preplant**" N rates a
normal farmer's N

Identification of AONR for each block⁺



Example: AONR for Block #2 =

160 kg ha^{-1} **(80% FNR)**

⁺Each block contains all N rates. Number of blocks will vary depending on field size.

A. BEFORE PLANTING OR EARLY GROWTH STAGES

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"Preplant" N	kg ha^{-1}
120% FNR	240
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80% FNR	160
60% FNR	120
40% FNR	80

Normal farmer's nitrogen rate **(FNR) = 200** kg ha^{-1}

B. GROWT

Generation of **bloc** **agronomic optimum** **block** based on NDV

Identif

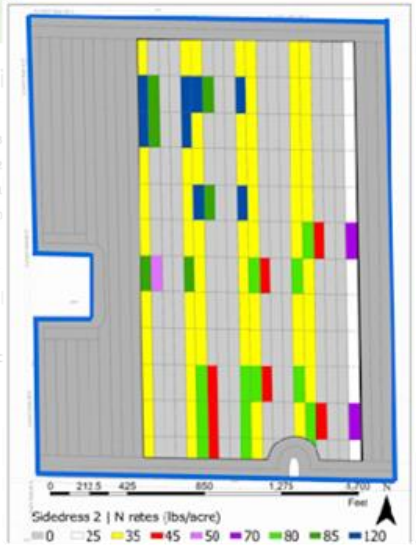
Exa

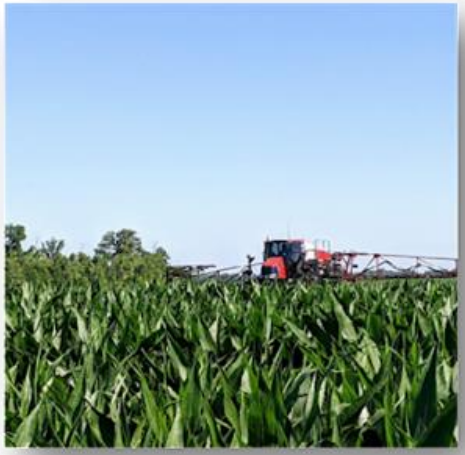
*Each bloc

C. GROWTH STAGES V8-V9*

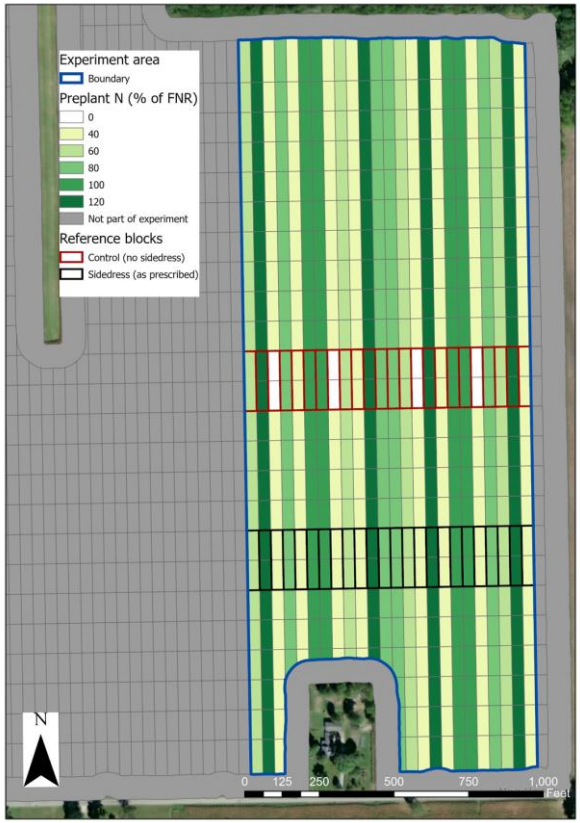
Sidedress N application for plots with less than 100% FNR (40, 60, and 80% FNR)

*May be delayed up to V14



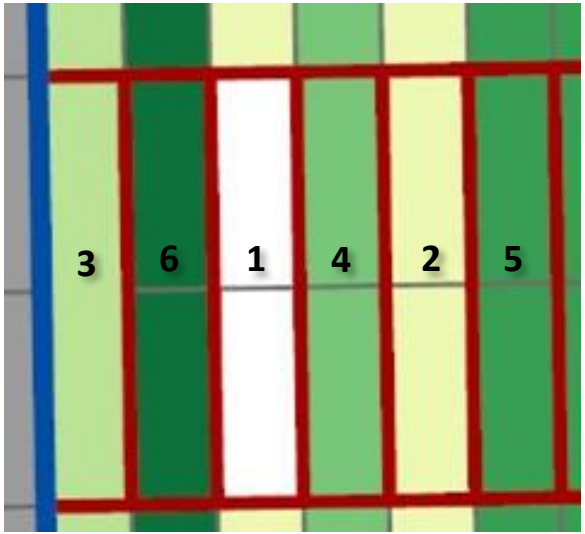


SIDEDRESS N = AONR – AS APPLIED N



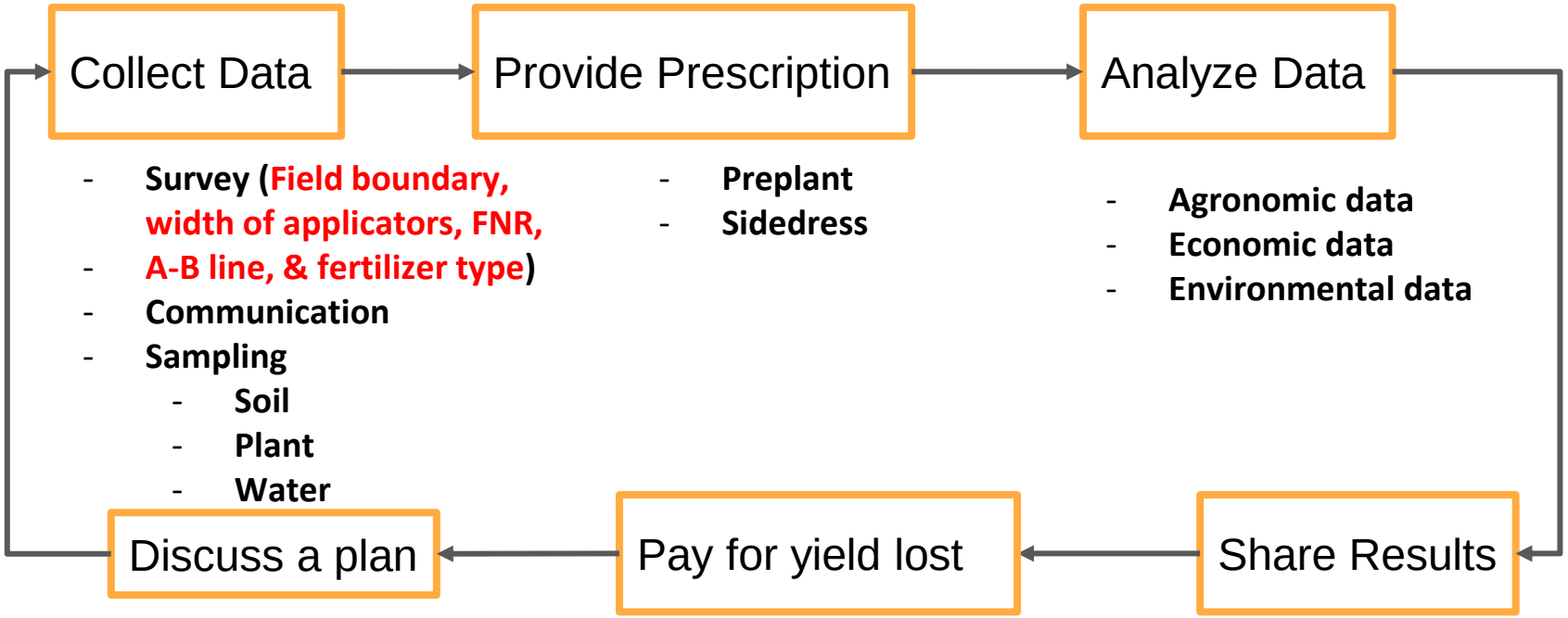
Compensation Calculation

1. 100% FNR
2. 40% FNR pre-N + sidedress N (satellite)
3. 60% FNR pre-N+ sidedress N (satellite)
4. 80% FNR pre-N+ sidedress 20% FNR
5. 100% FNR pre-N
6. 120% FNR pre-N

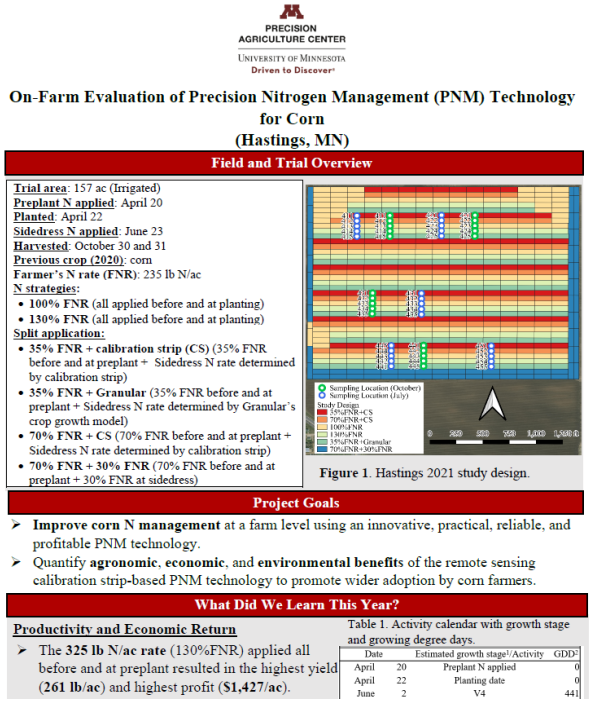


Profit	**$5**	**$20**	**$15**	**$30**	**$5**	**$2**
Compensation	**$10**	**$0**	**$0**	**$0**	**$10**	**$13**

Overall Research Approach



Deliverables from the Trial



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On-Farm Evaluation of Precision Nitrogen Management (PNM) Technology for Corn (Hastings, MN)

Field and Trial Overview

Trial area: 157 ac (Irrigated)
Preplant N applied: April 20
Planted: April 22
Sidedress N applied: June 23
Harvested: October 30 and 31
Previous crop (2020): corn
Farmer's N rate (FNR): 235 lb N/ac
N strategies:
- **100% FNR** (all applied before and at planting)
- **130% FNR** (all applied before and at planting)

Split application:
- **35% FNR + calibration strip (CS)** (35% FNR before and at preplant + Sidedress N rate determined by calibration strip)
- **35% FNR + Granular** (35% FNR before and at preplant + Sidedress N rate determined by Granular's crop growth model)
- **70% FNR + CS** (70% FNR before and at preplant + Sidedress N rate determined by calibration strip)
- **70% FNR + 30% FNR** (70% FNR before and at preplant + 30% FNR at sidedress)

Figure 1. Hastings 2021 study design.

Project Goals

- **Improve corn N management** at a farm level using an innovative, practical, reliable, and profitable PNM technology.
- Quantify **agronomic**, **economic**, and **environmental benefits** of the remote sensing calibration strip-based PNM technology to promote wider adoption by corn farmers.

What Did We Learn This Year?

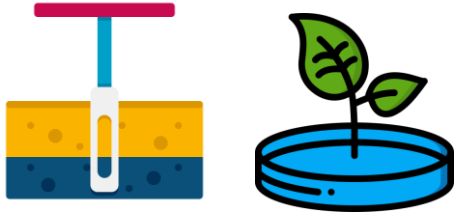
Productivity and Economic Return

- The **325 lb N/ac rate** (130%FNR) applied all before and at preplant resulted in the highest yield (**261 lb/ac**) and highest profit (**$1,427/ac**).

Table 1. Activity calendar with growth stage and growing degree days.

Date		Estimated growth stage[1]/Activity	GDD[2]
April	20	Preplant N applied	0
April	22	Planting date	0
June	2	V4	441

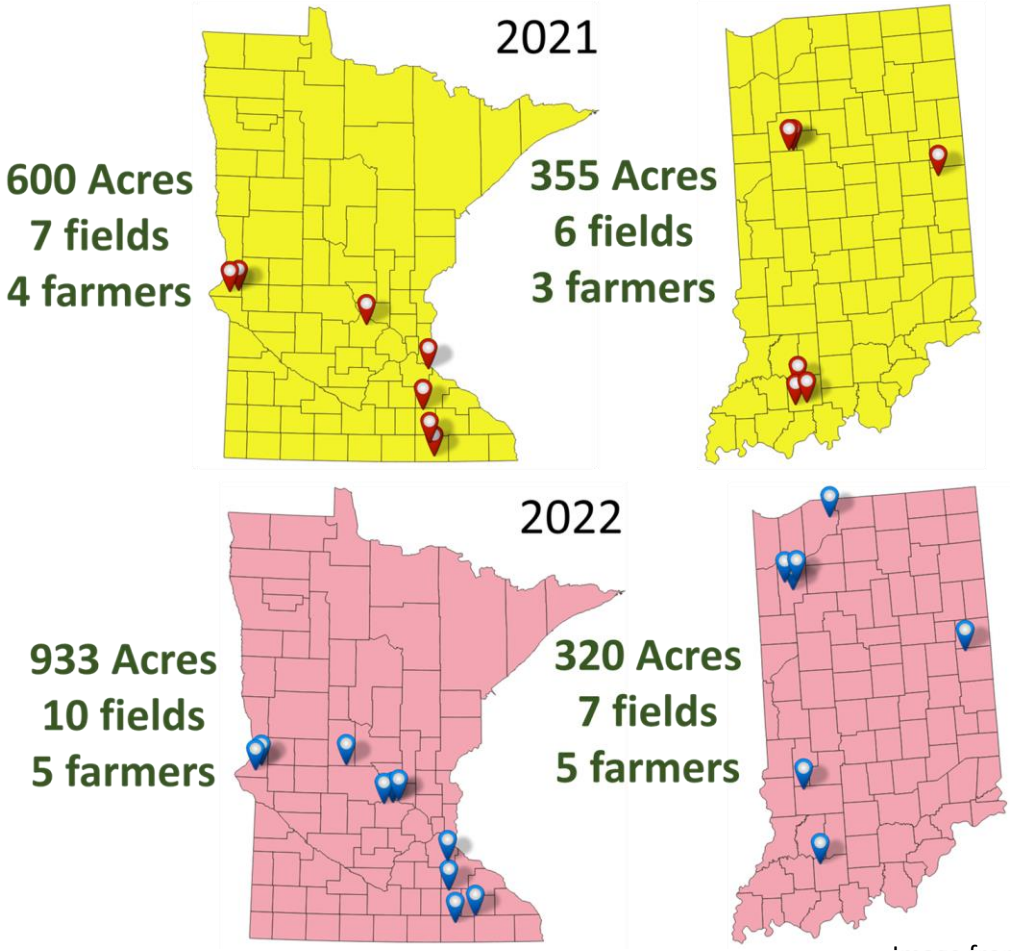
2022 On-farm Trial report for each field



Free soil and plant sampling

Provide recommendations
Discuss trials for this year (e.g., FNR, one-time vs split, best technology)

Compensation (yield loss, participartion)


2021
600 Acres
7 fields
4 farmers
355 Acres
6 fields
3 farmers
2022
933 Acres
10 fields
5 farmers
320 Acres
7 fields
5 farmers

Take home messages

What have we learned from the 2022 trials?

Agronomic related:

- What application method was the best for **yield**?

=> It varies depending on fields.

Economic related:

- What application method was the best for **profit**?

=> It varies depending on fields.

General:

- The higher the N fertilizer is, the lower the corn price is, the better our technology (split application) generally works than other uniform application.
- The drier the season is, the more weeds you can find in the field exist, the smaller the benefit of split application becomes.
- The more soil organic matter exists, the less the higher the uncertainty of the benefits of split application is.
- Our split application technology may work better toward wetter regions.
- Our RS-CS strip technology generally yielded higher profits than the farmer's normal fixed rate split application.

Advantages

1) Year-, site- and hybrid-specific in-season calibration:

2) High spatial and temporal resolution PlanetScope satellite remote sensing images:

✓More practical than current proximal sensor-, aerial or UAV remote sensing-based strategies for wide applications;

✓Compatible with aerial, UAV and other satellite remote sensing images;

3) Can be implemented in any farmer's field directly with no previous data required;

4) Farmers don't need to purchase new equipment such as new sensors, as long as they have or have access to variable rate applicators.

5) The RS-CS-PNM strategy is stable despite the unpredictable weather conditions for each growing season.

6) The RS-CS-PNM strategy is environmentally-friendly by improving the nitrogen use efficiency.

7) The RS-CS-PNM strategy is profitable especially when we have low corn price and high fertilizer price.

8) The RS-CS-PNM strategy is applicable for other crops, fertilizers, and areas as well.

Challenges

The RS-CS-PNM technology loses potential benefits especially when

- the field has **a weed/disease problem.**
- the corn price is high (Profit = Revenue – Cost)
- the FNR is low.
- the season is dry
- the application accuracy is low

Improvements for Future

- Accuracy of identifying right AONR using in-season vegetation index as a proxy for yield.
- Development of digital decision support tool for anyone to use the technology freely. (Version 1.0)

Next Steps and Plans for 2023

- More comprehensive analysis of the data
- On-farm trials:
  - PNM Trials: 15;
  - VR Sulfur: 3-4
  - VR Seeding: 3-4
  - VRN x VRI: 1
  - Other trials based on grower interests
- UAV application of fertilizers, pesticides, herbicides, seeds, plant growth regulators?
- Field Day

Feel free to bring us your ideas or interesting topics of research!

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THANKS TO ALL OF YOU WHO MAKE THIS PROJECT POSSIBLE

Growers

Crop Consultants

Student Workers and UMN Field Crew

USDA United States Department of Agriculture
Natural Resources Conservation Service

Granular

molitor
MOLITOR BROTHERS FARM
...respectfully growing

DEPARTMENT OF AGRICULTURE

ceres

AARHUS UNIVERSITY
DEPARTMENT OF AGROECOLOGY

Scan here for 2023 on-farm research protocols

https://drive.google.com/drive/folders/1JIuH-e0v-5jYFwZMojPbHV41WQLsDi7v?usp=share_link

Name

- 1 PNM On-farm Trial_Protocol-2023.pdf
- 2 Corn Sulfur On-farm Trial Protocol-2023.pdf
- 3 VRSeeding On-farm Trial Protocol_2023.pdf
- 20211110 AGREETT Nutrient Management.mp4

2023 On-farm precision nitrogen management trial

2023 On-farm Precision Nitrogen Management Trial Protocol

Introduction

Precision nitrogen (N) management (PNM) aims to match N fertilizer supply with crop N demand in both space and time, and thus has great potential to improve N use efficiency (NUE), increase farmer profitability, and reduce N losses and negative environmental impacts. However, the current adoption rate of PNM is still low for corn production. This on-farm PNM project aims to develop practical and efficient PNM strategies and technologies and evaluate these technologies under diverse on-farm conditions to facilitate the adoption of PNM by corn producers.

Objectives

- The primary goal of this project is to **improve corn N management** at the farm level and significantly **reduce N losses** using an innovative, practical, reliable, and profitable PNM technology.
- A secondary goal is to quantify the **agronomic, economic, and environmental benefits** of the remote sensing calibration strip-based PNM technology under diverse on-farm conditions in Minnesota and Indiana and promote wider adoption by corn farmers.

Field requirements for on-farm experiment

- A suitable field area **greater than 30 acres**.
- Auto-guidance using RTK (real-time kinematic) signal source for N applicator(s) and a combine harvester with GPS-enabled **yield monitor**.
- A **single hybrid** is planted across the experimental area.
- Access to a **variable-rate prescription-enabled N applicator** for preplant N rate applications:
  - Banded (knives, coulters) application preferred over broadcast N.
  - Calibration of applicator desirable.
- A **variable-rate prescription-enabled N applicator**, potentially high-clearance, for sidedress N rate applications.
- **As-planted and as-applied** data for the on-farm trials should be provided.

Data needed for the study

Historical data

- Yield maps from previous years.
- Soil tests (if applicable).
- Field history (e.g., crop planted in previous years).

In-season management data

- General field management information (e.g., drainage type, hybrid, tillage, planting rate, planting date, etc.).
- **Yield map** collected with a **GPS- enabled** yield monitor.
- **As-planted map** and **applied fertilizer maps** (GPS as-applied data)

2023 On-farm variable rate sulfur application trial

2023 On-farm Trial: Variable Rate Sulfur Application for Corn

Introduction

The application of sulfur (S) fertilizers in corn field is an increasing practice among corn farmers. Sulfur fertilizers are mainly applied at uniform rates across a field, which commonly results in under- or over-application. Despite the increased use of sulfur in corn fields, no studies have been reported on the within-field variability in corn responses to different S fertilizer application rates and the potential of variable rate S application. The overall goal of this project is to evaluate the possibility and potential benefits of variable rate S application in commercial corn fields in Minnesota.

Objectives

- Determine **within-field variability** of optimum S rates in commercial corn fields.
- Identify **soil and landscape factors** influencing corn responses to S fertilizer applications.
- Evaluate the potential benefits of **variable rate S fertilizer** applications for corn in Minnesota.

Field requirements for on-farm experiment

- A suitable field are **greater than 40 acres**.
- Competent with GPS **yield monitors**, yield mapping, and variable-rate technology
- **Uniform soil fertility** management across the trial area.

Data needed for the study

Historical Data

- **Field history** for the past 5 years (e.g., crop rotation information).
- **Yield maps** from previous years collected with a yield monitor.
- **Soil tests** (if available).

In-season management data

- **Yield map** collected with a **GPS-enabled** yield monitor.
- **As-planted map** and **applied fertilizer maps** (GPS as-applied data).
- A/B guidance line file.
- Remote sensing imagery, stand count, and plant and soil sampling (will be performed by the University of Minnesota (UMN) research team).

Farmer compensation

- Y**ield losses** due to **suboptimal fertilizer rates** will be fully compensated.
- Farmers will be compensated an additional **$1,000** per fully completed trial.

Farmer duties

- Farmers need to be **Environmental Quality Incentives Program (EQIP) eligible** to be compensated.
- Follow the **N and S fertilizer plans** according to prescription from the University of Minnesota.
- Maintain field and **provide data** needed for study.

2023 On-farm variable rate seeding application trial

2023 On-farm Variable Rate Seeding for Corn Trial Protocol

Introduction

New corn hybrids with higher tolerance to stress at higher plant densities are being constantly developed. However, the correlation between corn yield and different seeding rates is not always well established. In addition, the soil and landscape spatial variability present in most fields cause different areas a field to have varied agronomic optimal plant densities, and economic optimal seeding rates. Advances in precision agricultural technologies enable us to apply variable rate seeding to address agronomic and economical potential variability in a field. Thus, the main goal of this project is to evaluate the potential of developing and implementing variable rate seeding in commercial corn fields in Minnesota.

Objectives

- Evaluate **within-field variability** in corn yield response to different seeding rates and the potential of variable-rate seeding for corn in Minnesota.
- Identify key **soil**, and **landscape factors** affecting stalk lodging and yield response.
- Identify the economic optimal seeding rate for corn in Minnesota.

Field requirements for on-farm experiment

- A suitable field area **greater than 80 acres** preferred.
- Competent with GPS **yield monitors**, yield mapping, and variable-rate technology
- **Uniform soil fertility** management across the trial area.
- Preference for farmers interested in **multi-year studies**.

Data needed for the study

Historical Data

- **Past planting rates** and **hybrids** (GPS as-planted maps preferred).
- **Yield maps** from previous years collected with a yield monitor.
- **Soil tests** (if available).

In-season management data

- **Yield map** collected with a **GPS- enabled** yield monitor.
- A/B guidance line file.
- Remote sensing imagery, stand count, plant and soil sampling, stalk lodging analysis in the fall (will be performed by the UMN research team).

Farmer compensation

- Compensation for **yield losses** due to **suboptimal seeding rates** will be supplied to the farmer.
- Farmers will be compensated an additional **$1,000** per fully completed trial.