Prediction of no-till corn N requirement that considers soil health

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Background

- Corn (*Zea mays* L.) is harvested from nearly 2 million ha land in South Dakota (SD) generating the value over $4 billion, yearly (USDA-NASS, 2022). Moreover, nearly 45% of the SD cropland uses no-till cropping system.
- Many farmers spend 35% of their production costs on fertilizers (Davis, 2021).
- In South Dakota, the N recommendation is calculated with the yield goal model (Equation 1). Many farmers believe that this model does not adequately consider soil health.

  NFR = (1.2 x Yield goal) – Soil Test N – Legume Credits ….. (Eq. 1)
- Soil organisms can accelerate the mineralization of soil organic matter, thereby reducing the N requirement.

Study Objectives

- To compare the corn yield and economic optimum N rates (EONR) across experimental sites.
- To optimize the prediction of N fertilizer recommendations using yield data for no-till corn based on soil health measurements.

Materials and Methods

- The study was conducted across seven sites for three years, 21 site-years, from 2019 through 2021 in a randomized complete block design with 4 replications. The experimental sites had diverse soil texture, length of no-till, and management practices along with varying weather pattern.
- Average cumulative precipitation, across the sites, during the growth season were 49, 32, and 28 cm in the years 2019, 2020, and 2021, respectively; the long-term (1901-2000) average precipitation for SD is 48.4 cm.
- Treatments included six N rates (0, 45, 90, 134, 179, and 224 kg N ha^{-1}) applied as urea fertilizer in between V2 and V4 corn growth stages.
- Pre-plant soil samples from various depths (0-5, 5-15, 15-30, and 30-60 cm) were collected for soil nitrate-N (NO_3-N), ammonium-N (NH_4-N), pH, and EC analysis, whereas 0-5 cm soil samples were collected to analyze soil microbial community structure using phospholipid fatty acid (PLFA) analysis method (Buyer & Sasser, 2012).
- Soil respiration was measured using the CO_2 Solvita® approach.
- Corn yield at 15% moisture was measured.
- Quadratic plateau model was used to calculated the EONR for each site using N cost at $0.85/ kg N and corn price at $0.15/ kg (based on 2020).
- Non-metric multidimensional scaling (NMDS) plot was used to compared soil microbial community structure across the sites.
- Linear regression and random forest models were used to predict the corn yield using different explanatory variables, including soil NO_3-N, NH_4-N, pH, EC, and microbial biomass.

Literature Cited:

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Results

Table 1. Economic optimum N rates (EONR) and the corn yield at EONR varied by the sites in 2020.

Sites	EONR ($kg\ N\ ha^{-1}$)	Yield at EONR ($Mg\ ha^{-1}$)
Farm-1	151	8.24
Farm-2	121	10.61
Farm-3	109	10.53
Farm-4	29	3.99
Farm-5	108	10.35
Farm-6	93	17.59
Farm-7	161	13.33

Fig 1. Correlation matrix between various soil properties, including soil microbial biomass and chemical properties, and corn yield.

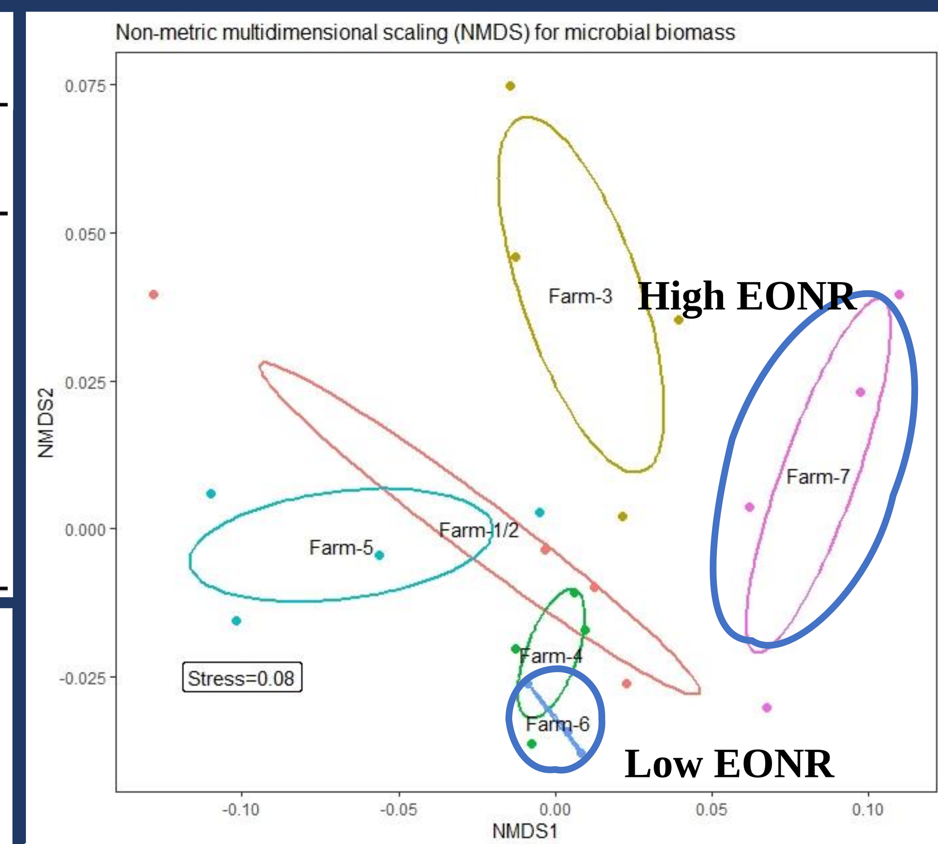

Fig 2. Non-metric multidimensional scaling (NMDS) plot comparing the pre-plant soil microbial biomass across the experiment sites in 2020.

Table 2. Comparison of pre-plant soil inorganic N, microbial biomass, and corn yield, between low and high EONR sites, 2020.

Parameters	Irrigated Low EONR	Dryland High EONR
Location	Central SD	Eastern SD
Nitrate-N, Spring ($kg\ ha^{-1}$)	12.40	14.76
Ammonium-N, Spring ($kg\ ha^{-1}$)	2.27	11.06*
Nitrate-N to total inorganic N ratio	0.82*	0.55
Fungal biomass, Spring (µg C/g soil)	2.27	3.58*
Bacteria biomass, Spring (µg C/g soil)	15.74	22.16
Corn yield ($Mg\ ha^{-1}$)	17.19*	11.91

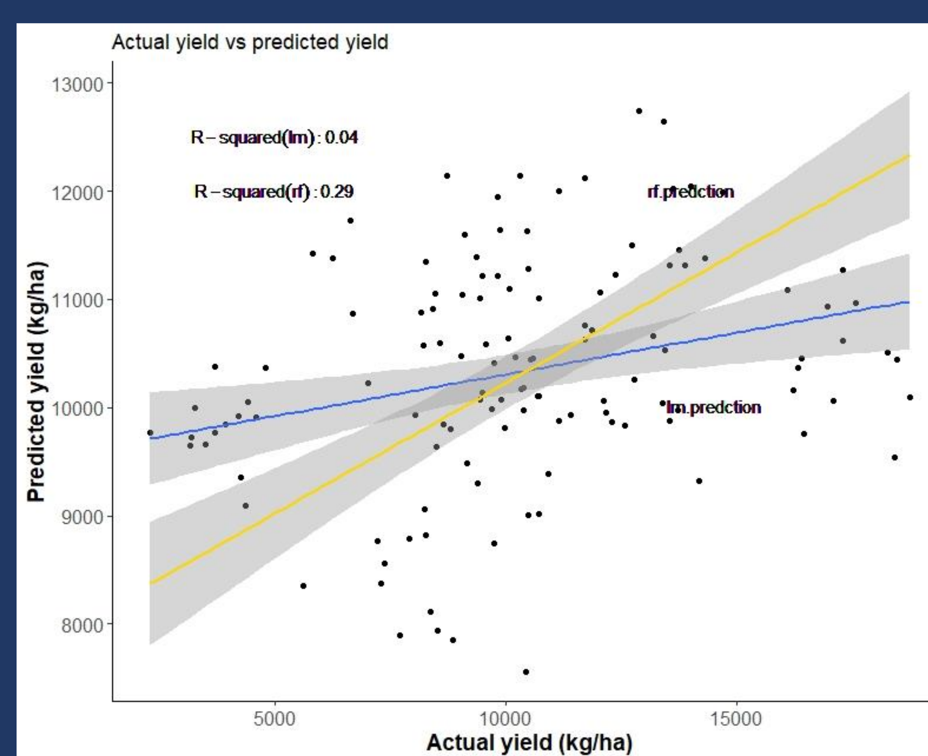

Fig 3. Plot showing the actual vs predicted corn yield using linear regression and random forest model for 14 sites for 2019 and 2020, including microbial biomass.

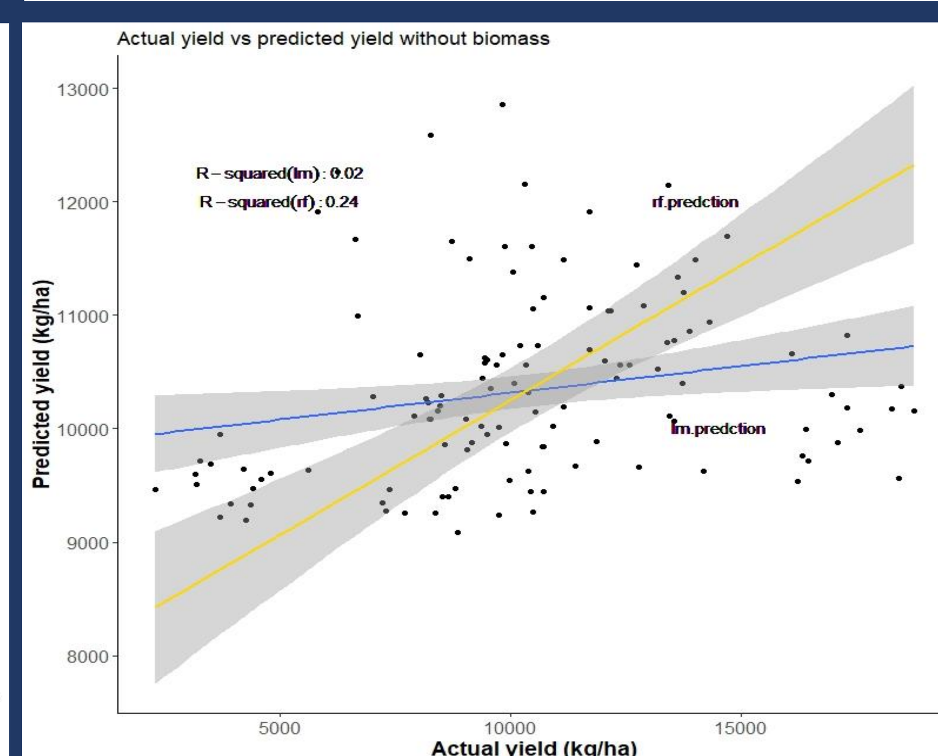

Fig 4. Plot showing the actual vs predicted corn yield using linear regression and random forest model for 14 sites for 2019 and 2020, excluding microbial biomass.

- The EONR varied by sites, for example, Farm-6 had low EONR of 93 kg N/ha with higher yield of 17.59 Mg/ha, however, Farm-7 had high EONR of 161 kg N/ha with lower yield of 13.33 Mg/ha (Table 1).
- Fig 1 showed that the corn yield was highly correlated with soil respiration and NO_3-N to total inorganic N (TIN) ratio. In addition, soil inorganic N were highly correlated to soil microbial biomass.
- Soil microbial biomass varied by sites (Fig 2), which was supported by the higher NO_3-N to TIN ratio in the low EONR site resulting in higher corn yield (Table 2).
- Random forest model was better in predicting yield as compared to the linear regression. In addition, model considering soil microbial biomass showed a better fit (Fig 3) in comparison to the model without microbial biomass (Fig 4).

Summary

- Nitrogen response to corn yield and soil microbial community structure varied by location.
- Greater yield at lower EONR site, which was irrigated, could be attributed to higher nitrate to total inorganic N ratio in spring, which could have occurred due to higher mineralization.
- Management practices influence soil microbial community structure, which can better predict the corn yield when included in machine learning algorithms.