Integrating Management Zones and Canopy Sensors to Improve Nitrogen Recommendation Algorithms

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Introduction

Active canopy sensors are one tool for directing spatially variable nitrogen (N) applications in maize, with the goal of improving N use efficiency (NUE). However, N recommendation algorithms can be inaccurate in subfield regions due to local spatial variability. Modifying these algorithms by integrating soil-based management zones (MZ) may improve their accuracy by allowing the sensors to accommodate the entire spectrum of field conditions. Research is needed to determine if and how these algorithms can be improved with a MZ approach.

Objectives

- Delineate field-specific MZ using measured soil and crop variables.
- Determine maize yield response to N at a spatially dense level.
- Validate MZ delineation across multiple sites and years.

Methods

- Experiments were conducted in 2016 on 4 producers' irrigated fields in south central Nebraska, USA (Fig. 10), each with differing topography and soils. Results are shown for only two sites.
- Soil apparent electrical conductivity (EC_a), reflectance, and landscape position data were collected in the spring of 2016 with a Veris® MSP3 on-the-go soil sensing platform (Figs. 1-3, 6-7).
- Ten to 16 N response blocks (45 m x 12 or 18 m) were placed end to end in a field-length strip. Strips were positioned in field areas with large spatial variability.
- Six plots were arranged within each block in a 2 x 3 randomized complete block design. N rates ranged from 0 to 280 $kg \cdot ha^{-1}$ in 56 $kg \cdot ha^{-1}$ increments.
- A 56 $kg \cdot ha^{-1}$ base rate of N fertilizer was applied between the V2 and V5 growth stages. Remaining N was sidedressed between V9 and VT. N fertilizer source was either 28 or 32% urea ammonium nitrate (UAN).
- Hybrid selection and field management were carried out by each producer.
- Canopy reflectance was recorded during each sidedress application using an AgLeader OptRx® active sensor mounted on a high-clearance applicator ~0.3 m above the crop canopy.
- Fifteen meters of the center two rows of each plot was harvested using a two-row plot harvester. Grain yield was corrected to 0.155 $kg \cdot kg^{-1}$ moisture.
- Check yield (Yld_{chk}) was calculated for each block as the yield of each plot receiving no N. Relative yield (Yld_{rel}) was calculated within each block by dividing each yield by the yield obtained from the plot receiving the highest N rate (280 $kg \cdot ha^{-1}$).
- MZ were delineated using Management Zone Analyst 1.0.1 (USDA-ARS and University of Missouri, Columbia, MO).
- Soil and elevation data were interpolated using the ordinary kriging method in ArcGIS® 10.2 (ESRI, Redlands, CA).
- Pearson correlations were calculated using PROC CORR in SAS 9.4 (SAS Institute, Cary, NC).
- A quadratic-plateau function was used to describe maize yield response to N for each MZ using PROC NLIN in SAS 9.4.

Results and Discussion

Site 1: Silt loam, eroded slopes

- All measured soil properties—shallow EC (EC_s), deep EC (EC_d), OM, and relative elevation ($Elev_{rel}$)—were significantly correlated to mid-season NDRE (P<0.001) (Table 1, Figs. 1-3). Two MZ were delineated using EC_s, OM, and $Elev_{rel}$ (Fig. 4).
- Both Yld_{rel}, NDRE, and EC_d were significantly correlated to Yld_{chk} (P<0.001) (Table 2).
- Agronomic Optimal Nitrogen Rate (AONR) was 90.8 $kg \cdot ha^{-1}$ for Zone 1 and 96.7 $kg \cdot ha^{-1}$ for Zone 2 (Fig. 5).
- Yield plateaued at 14.8 $Mg \cdot ha^{-1}$ for Zone 1 and 15.3 $Mg \cdot ha^{-1}$ for Zone 2 (Fig. 5).
- MZ for Site 1 did not have a significantly different yield potential or response to N during the 2016 growing season.

Site 2: Sandy loam, relatively level

- EC_s and EC_d were significantly correlated to mid-season NDRE (P<0.0001) (Table 2, Figs. 6-7). Two MZ were delineated using these properties (Fig. 8).
- Yld_{rel}, NDRE, and EC_s were significantly correlated to Yld_{chk} (P<0.0001) (Table 3).
- AONR was 249.4 $kg \cdot ha^{-1}$ for Zone 1 and 304.9 $kg \cdot ha^{-1}$ for Zone 2 (Fig. 9).
- Yield plateaued at 11.5 $Mg \cdot ha^{-1}$ for Zone 1 and 14.9 $Mg \cdot ha^{-1}$ for Zone 2 (Fig. 9).
- MZ for Site 2 showed great differences in both yield potential and N need during the 2016 growing season.

Tables and Figures

Site 1: Silt loam, eroded slopes

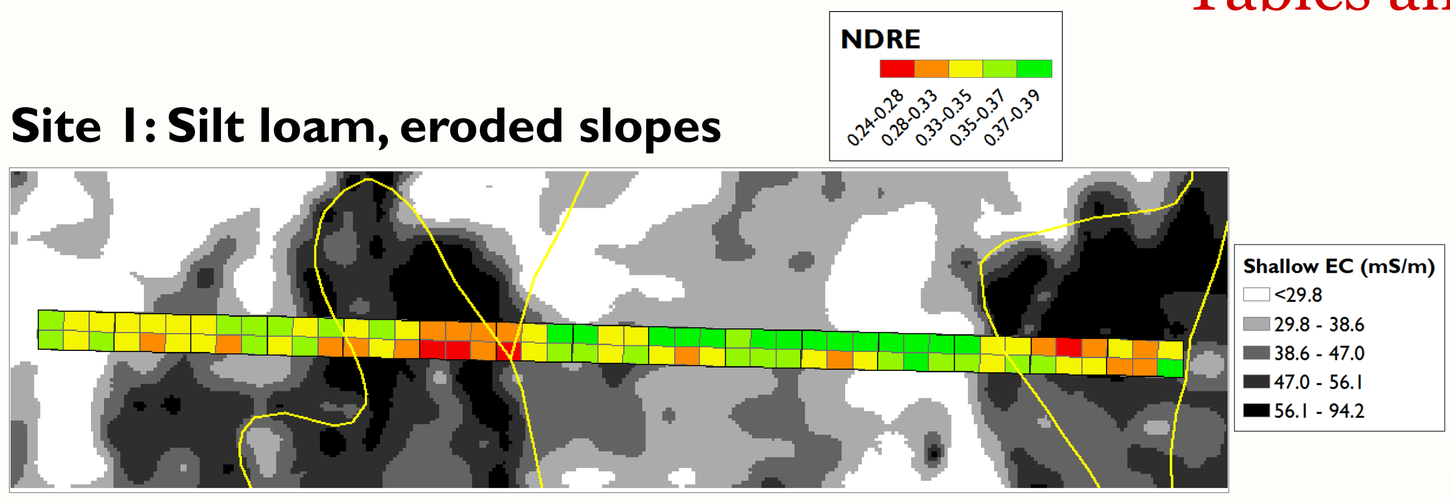

Fig 1. Plot average mid-season NDRE with kriged EC_s in the background.

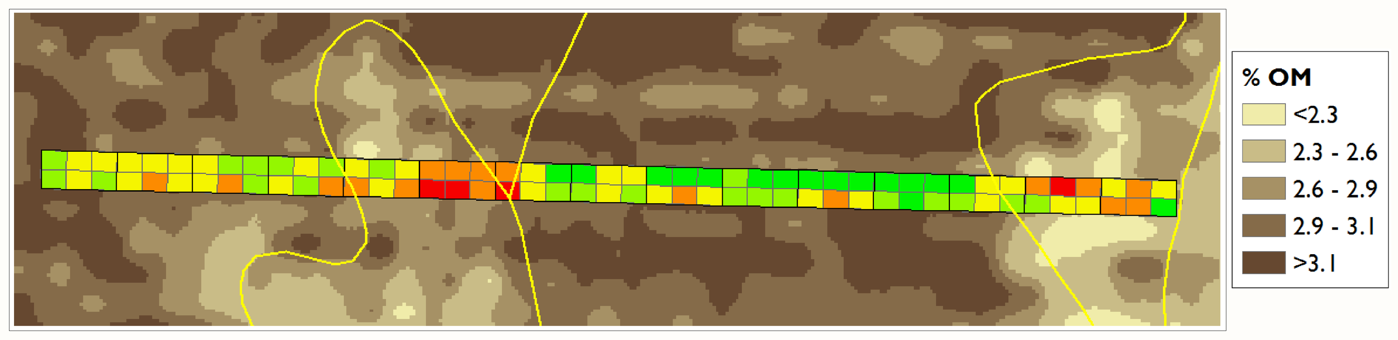

Fig 2. Plot average mid-season NDRE with kriged OM in the background.

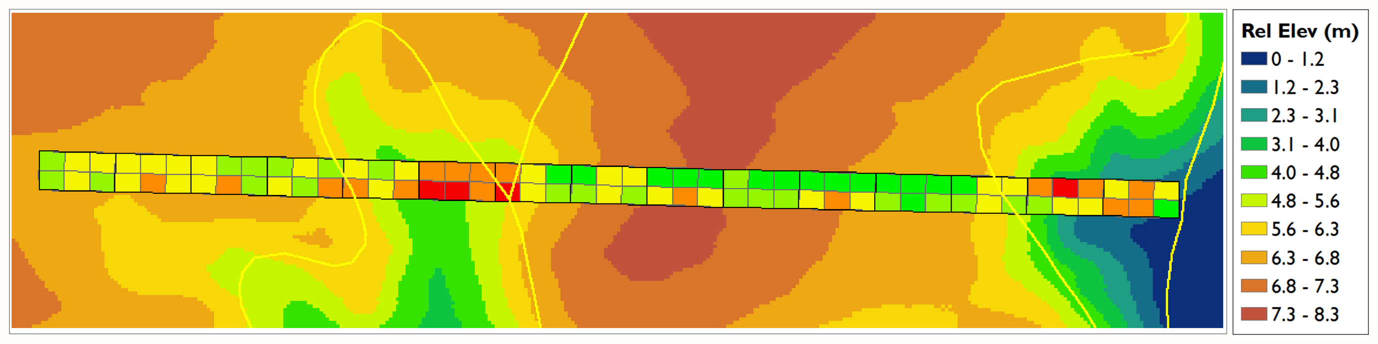

Fig 3. Plot average mid-season NDRE with kriged $Elev_{rel}$ in the background.

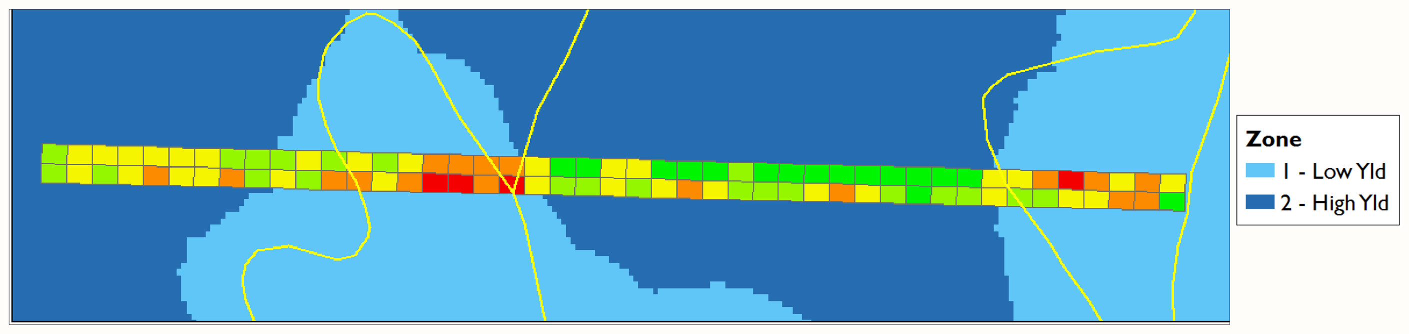

Fig 4. Management zone delineation using the soil data layers depicted in Figs. 1-3.

Site 2: Sandy loam, relatively level

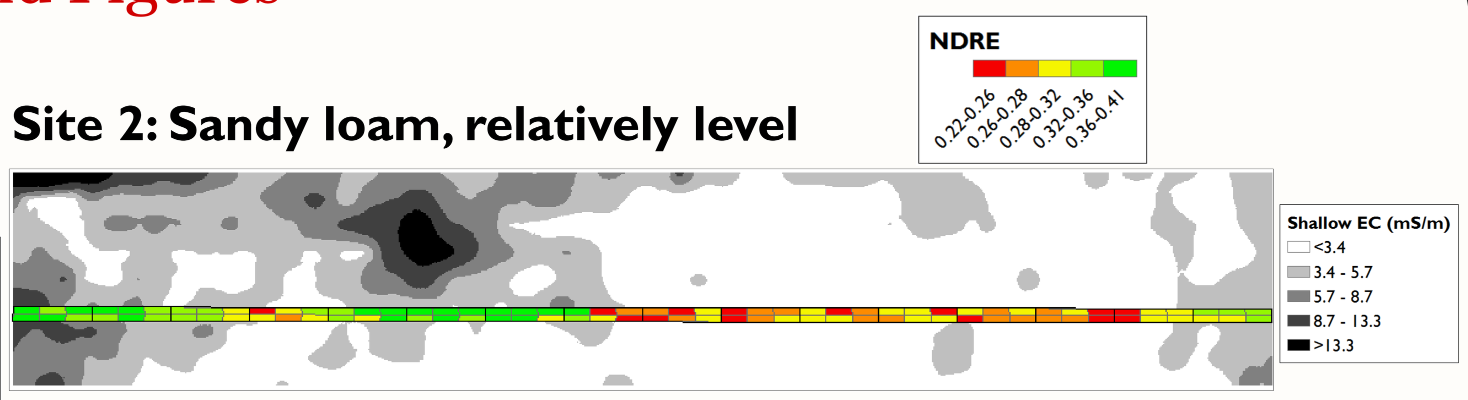

Fig 6. Plot average mid-season NDRE with kriged EC_s in the background.

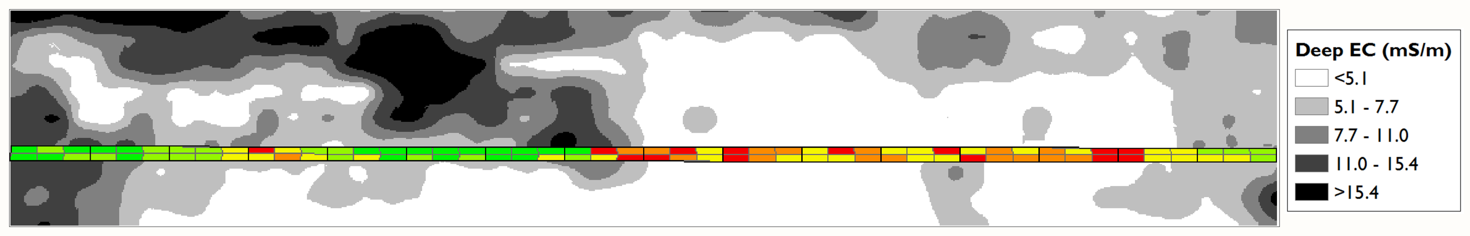

Fig 7. Plot average mid-season NDRE with kriged EC_d in the background.

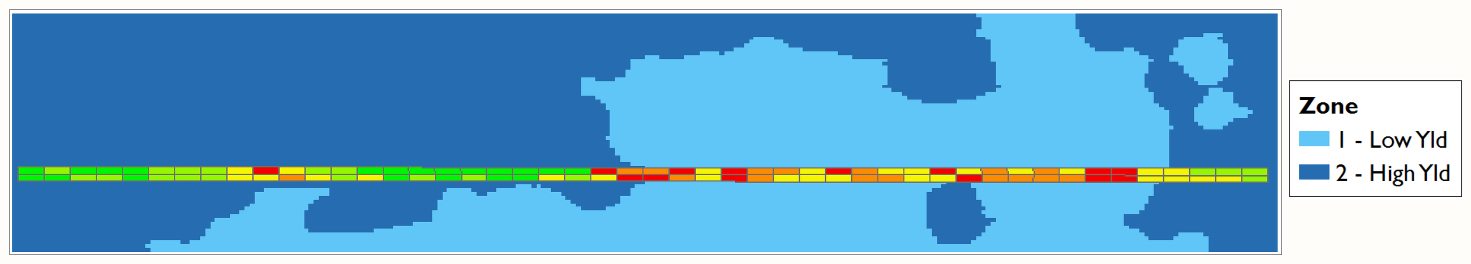

Fig 8. Management zone delineation using the soil data layers depicted in Figs. 6-7.

Table 1. Pearson correlation matrix of mapped soil properties and mid-season NDRE for both sites (n_1=90 and n_2=96).

	Site 1 NDRE	Site 2 NDRE
EC_s	-0.543***	0.614***
EC_d	-0.593***	0.557***
OM	0.393**	N/A
$Elev_{rel}$	0.369**	0.181

# P<0.05 * P<0.01 ** P<0.001 *** P<0.0001

Table 2. Pearson correlation matrix of soil and crop variables for check treatment at Site 1 (n=12).

	Yld_{chk}	Yld_{rel}	NDRE	EC_s	EC_d	OM	$Elev_{rel}$
Yld_{chk}	1						
Yld_{rel}	0.910***	1					
NDRE	0.906***	0.873**	1				
Ec_s	-0.685#	-0.743*	-0.638#	1			
EC_d	-0.841**	-0.882**	-0.809*	0.888**	1		
OM	0.550	0.623#	0.526	-0.836**	-0.701#	1	
$Elev_{rel}$	0.525	0.629#	0.532	-0.757*	-0.666#	0.921***	1

# P<0.05 * P<0.01 ** P<0.001 *** P<0.0001

Table 3. Pearson correlation matrix of soil and crop variables for check treatment at Site 2 (n=16).

	Yld_{chk}	Yld_{rel}	NDRE	EC_s	EC_d	$Elev_{rel}$
Yld_{chk}	1					
Yld_{rel}	0.916***	1				
NDRE	0.904***	0.840***	1			
EC_s	0.915***	0.872***	0.735*	1		
EC_d	0.720*	0.685*	0.628*	0.837***	1	
$Elev_{rel}$	0.245	0.418	0.126	0.204	0.272	1

# P<0.05 * P<0.01 ** P<0.001 *** P<0.0001

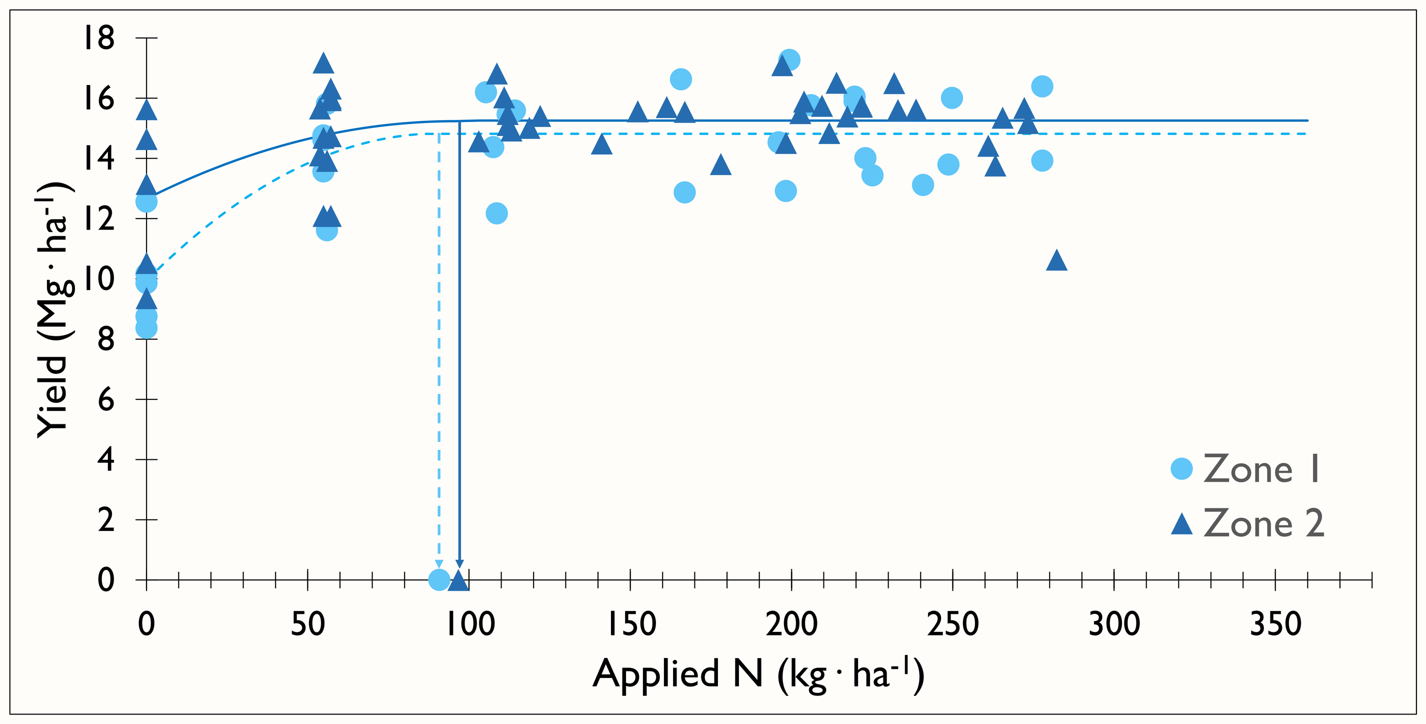

Fig 5. Yield response to N for zones 1 and 2 at site 1. AONR for each zone is designated on the x-axis.

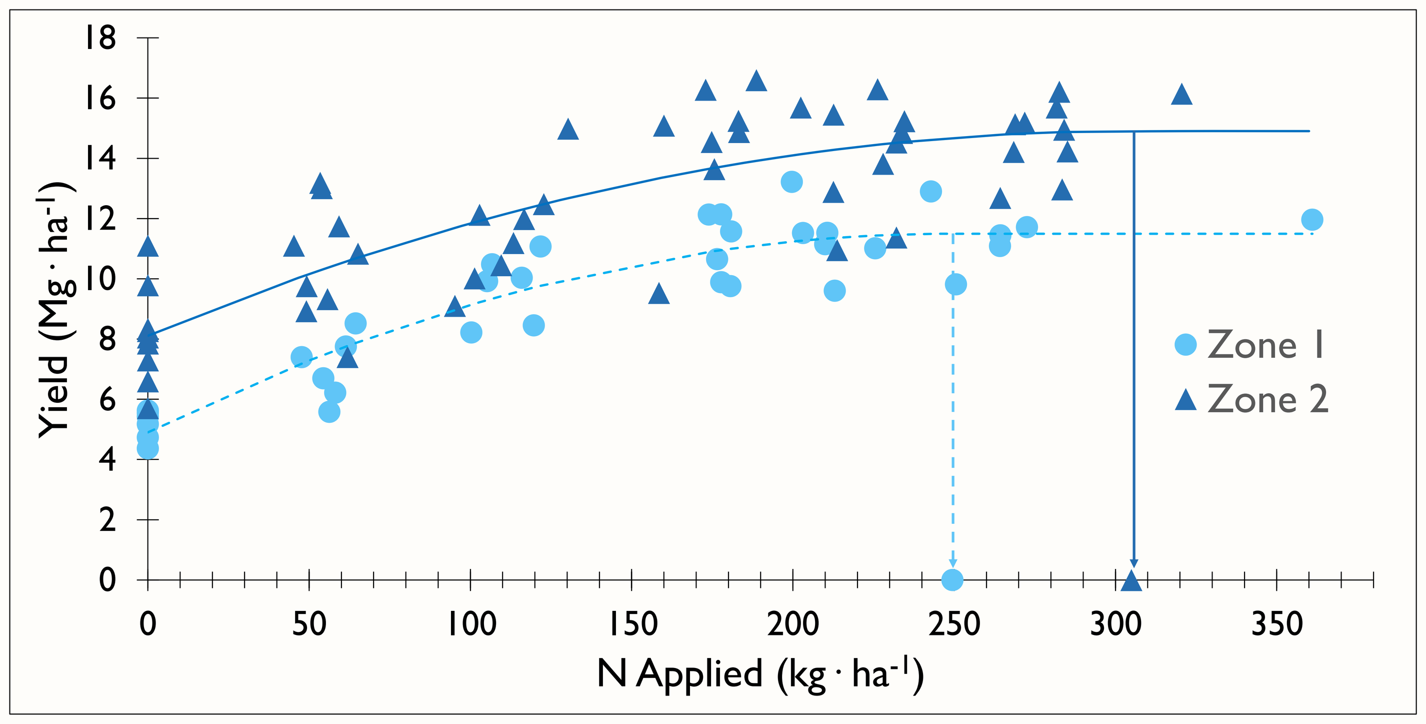

Fig 9. Yield response to N for zones 1 and 2 at site 2. AONR for each zone is designated on the x-axis.

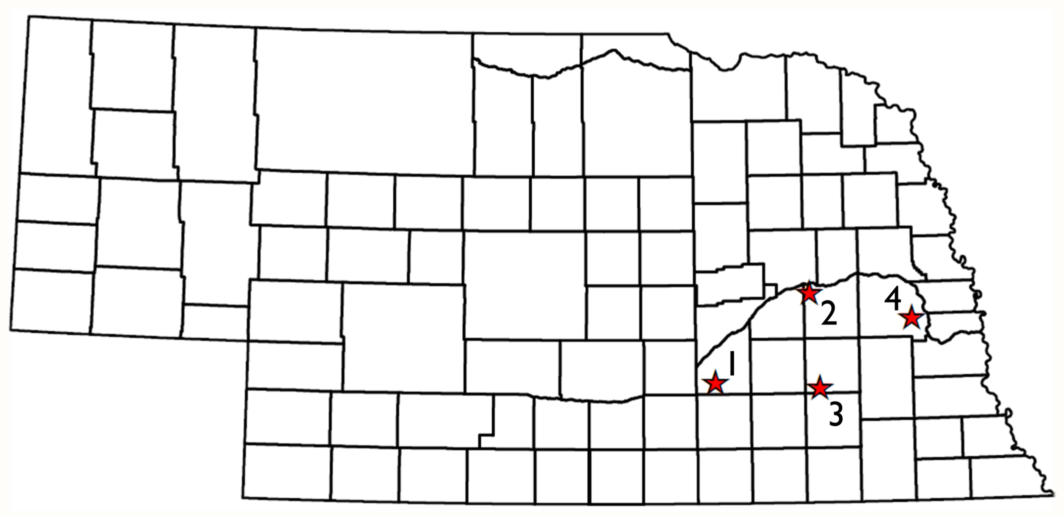

Fig 10. Study site locations, 2016.

Conclusions

- For both sites, soil EC was significantly correlated to both mid-season canopy NDRE and Yld_{chk}. However, this relationship was positive for one site and negative for the other.
- Site 2 could potentially benefit greatly from a combined MZ/canopy sensor approach, while Site 1 showed no difference in N need between MZ.

Acknowledgements

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USDA