Supplemental Materials

Table S1. Soil characteristics for one site in 2017 (ZP17) and two sites in 2018 (YL18 and DA18), located in Richardson County, Nebraska. Cropping information including soil subgroup and texture, soil pH, organic matter, extractable P and K, residual NO_3-N and field location are provided.

Site ID	Predominant soil subgroup	Soil texture	Soil organic matter†	Soil pH	Buffer pH	Bray I-P Extract	Extractable K	NO_3-N	Location
			g kg^{-1}			----------mg kg^{-1}----------			
ZP17	Mollic Udifluvents	Silt Loam	2.5	6.6	-	45	134	-	40.040, -95.504
YL18	Typic Hapludolls	Silt Loam	3.0	6.5	6.9	29	165	6.7	40.085, -95.500
DA18	Cumlic Hapludolls	Silt Loam	3.2	6.6	6.8	46	211	-	40.027, -95.503

†Soil sample values reported represent the average of samples in the study area. ZP17 soil samples were collected on 1.0 ha grids in 2015. YL18 soil samples were collected on 1.0 ha grids in November 2017. DA18 soil samples were collected on 1.0 ha grids in 2017.

Table S2. Agronomic practices including hybrid planting, planting date, harvest date, planting population, and tillage for one site in 2017 (ZP17) and two sites in 2018 (YL18 and DA18).

Site ID	Hybrid	Planting Date	Harvest Date	Planting Population	Tillage
				------seeds ha^{-1}------	
ZP17	Pioneer® 1197	5/8/17	10/20/17 and 10/26/17	81,050	No-Till
YL18	MOEWS® 3751	5/1/18	9/28/18	72,896	Strip-Till
DA18	Pioneer® 1197	5/1/18	10/2/18	81,545	Strip-Till

Table S3. Mean monthly air temperature and long-term averages. Annual and long-term average data was obtained from High Plains RCC CLIMOD for Falls City Brenner Field, Neb, NOAA weather station.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
	---------- Mean monthly temperature, °C ----------											
2017	-1.6	5.0	7.7	12.6	17.3	23.6	26.0	21.8	21.6	13.6	5.8	-1.4
2018	-3.0	-2.2	5.4	7.3	22.6	24.9	24.8	24.3	20.4	11.4	0.8	0.3
100+ year average†	-3.3	-0.7	5.2	12.0	17.6	23.0	25.5	24.3	19.7	13.4	5.3	-1.0

†Long-term averages represent data from 1917-2019.

Table S4. Description of how values were obtained for UNL algorithm used to calculate EONR for use in the sensor algorithm.

UNL algorithm input	Description of how values were obtained
a) Yield goal determination.	For ZP17, a spatial yield goal was determined for the field using Management Zone Analyst (MZA; University of Missouri, Columbia, MO), a program utilizing fuzzy c-means unsupervised clustering [94] which has been utilized for classification in previous agricultural studies [95–97]. Fifteen data layers were available for inclusion in MZA: EC shallow, EC deep, EC difference (deep-shallow), EC ratio (deep:shallow), 2016 soybean yield, 2009 corn yield, 2005 corn yield, 2003 corn yield, 2002 soybean yield, normalized yield, CV of normalized yield, relative elevation, red band of bare soil image from May 2017, green band of bare soil image from May 2017, and blue band of bare soil image from May 2017. All fourteen layers were rasterized on a common, aligned 7.62 meter grid using AgLeader SMS Advanced (Ag Leader Technology, Ames, IA), then exported as a CSV file for analysis in MZA. Statistics were computed in MZA and data layers which were not strongly correlated were eliminated (blue band of bare soil image and 2005 yield). After elimination, the remaining thirteen data layers were clustered using diagonal distance similarity measure. Performance indices including the fuzziness performance index and normalized classification entropy indicated that two zones were optimal. Yields were assigned to these two productivity zones by calculating the normalized yield for each of these zones and consulting with the cooperating producer. Yield goals of 15.7 and 16.6 Mg ha^{-1} were selected for the two zones. For YL18 documented yield history was not available for the field, therefore the cooperating producer estimated their expected yield was 12.55 Mg ha^{-1} based on previous experience farming the field. For DA18, 8 years of spatial yield files were available (2002, 2003, 2004, 2006, 2008, 2010, 2016, and 2017). The cooperating producer referenced these historic yields and estimated an expected yield of 15.69 Mg ha^{-1}.
b) ***Organic matter***	For ZP17, the 1 ha grid soil samples collected in 2015 were krigged in AgLeader SMS Advanced (Ag Leader Technology, Ames, IA). Organic matter point values ranged from 1.7 g kg^{-1} to 3.6 g kg^{-1}. For YL18, organic matter (OM) point values collected on a 1 ha grid in November 2017 ranged from 2.6 to 3.3 g kg^{-1} in the plot area. For DA18, 2017 OM soil samples were collected (presented in Table 1), but they were not available at the time when ONR files were prepared, therefore 2014 soil sample data was used in the ONR algorithm calculation. The 2014, 1 ha grid soil samples ranged from 2.1 to 2.9 g kg^{-1} for OM in the plot area. Because the range in OM was much less for DA18 and YL18 than for ZP17, an average OM was used to determine ONR rather than krigging than determining a spatial ONR.
c) ***Nitrate-N concentration***	Because Nitrate-N concentration for the root zone (1.2 meters) was not available, the suggested default value of three mg kg^{-1} was used [50].
d) ***Other credits***	Other nitrogen credits may be added for legumes, manure, other organic materials, and irrigation water. Legume crop residues decompose faster than cereal crop residues and therefore result in improved N supply to the subsequent corn crop. Each field had a preceding soybean crop, therefore the recommended credit of 50 kg ha^{-1} was input in the ONR algorithm.

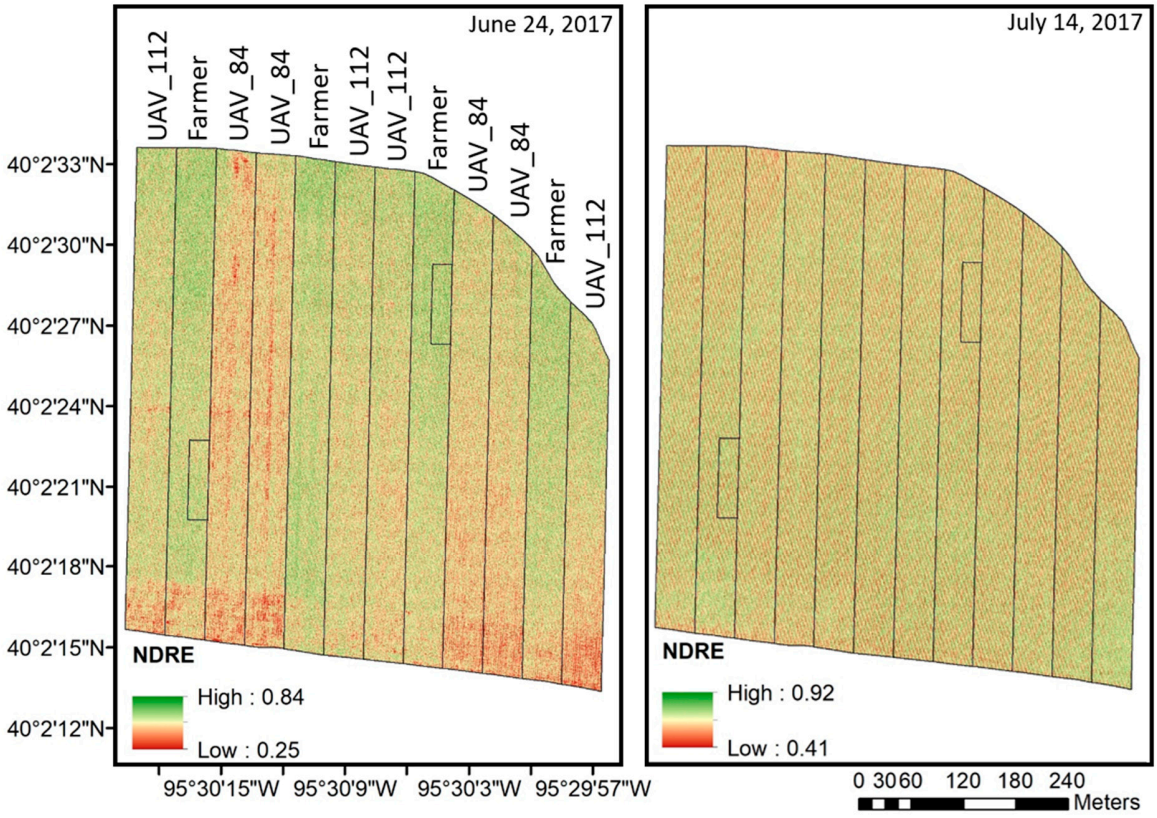

Figure S5. NDRE imagery for the ZP17 site before (June 24) and after (July 14) N application. Image display was set to standard deviation, and was applied independently for each image date.

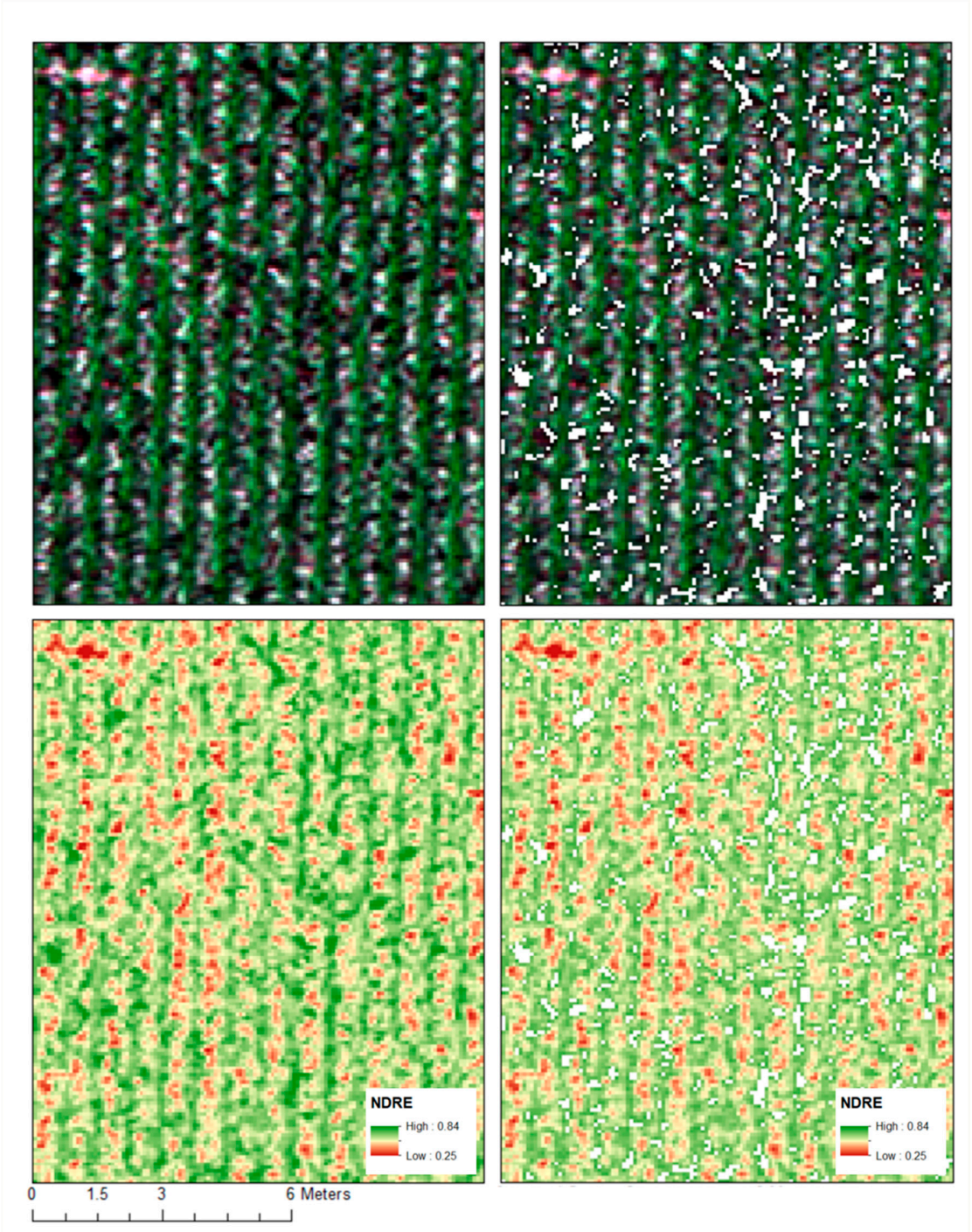

Figure S6. June 24, 2017 imagery from ZP17 showing a close up view of the corn crop canopy as RGB imagery (top left), RGB imagery with white highlighted pixels corresponding to those selected for the VR_HS reference (top right), NDRE imagery (bottom left), and NDRE imagery with white highlighted pixels corresponding to those selected for the VR_HS reference (bottom right). Examination of the two images reveals that pixels selected for the VR_HS are primarily composed of non-plant pixels.