**Evaluation of in-season tools for detecting nitrogen stress in corn**
Year 1 Report
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## 2017 Research Summary Points

- ***Results for On-farm field trials***
  - Cordova: Modeled data suggested a reduction of 12 or 18 lbs of N for the North and South field block, respectively, versus 70 lbs of N applied pre-plant and 70 lbs of N applied side-dress. Corn grain yield did not differ whether among the fixed-pre plant or the two side-dress treatments indicating that 140 lbs of N applied pre-plant would be sufficient for this location. The reduction in the amount of N based on the variable rate treatment did not cover the additional cost for using the crop model plus additional application costs.
  - Clarks Grove: Side-dress N application resulted in an increase in yield of 5 bu/ac compared to 140 lbs N applied all before planting. Modeled data suggested a reduction of 13 lbs of N versus 70 lbs of N applied pre-plant and 70 lbs of N applied side-dress. There was no yield difference on average between the variable rate and fixed side-dress N application treatments. Similar to Cordova, the cost reduction in N for the model and variable rate technology did not cover their cost and a planned flat rate split application would have been sufficient at this location.
  - The models all predicted a lower N requirement than the flat rate treatment. Any benefit to the model would thus be associated with cost savings on N as it would not be expected to get a yield increase when less N is applied. Application rates based on the models were consistent with current MRTN suggested rates for corn production in Minnesota.
- ***Results for the small plot trial***
  - The data collected at Waseca found no evidence that side-dress application of N would result in a lower N requirement for corn. The total amount of N required for the pre-plant was the same as the combination of pre-plant plus N side-dressed at V5 or V10. Model output tended to under predict N requirement at the small plot location. Sensor technology also was used to assessed N requirement but did not perform better than models (data not included).

## Introduction

An increased emphasis for reducing nitrate loss to surface and ground water has increased the number of tools available to farmers to help reduce the potential of nitrate loss through fine-tuning of nitrogen (N) rates in-season. Currently, split application of N is suggested in South-central and Southeastern Minnesota where climates and soils make nitrate more prone to leaching (Randall et al., 2008 a&b). Farmers are recommended to split apply N with a portion applied pre-plant and the remaining applied some time before the V5 growth stage. Rate decisions are based on the maximum return to nitrogen (MRTN) approach. While the MRTN will give farmers a general average of optimal N rates, the actual rate within a field can still vary from year to year. With more farmers interested in variable rate N some of the new tools available need to be researched better to determine if they can provide a better estimation of optimal N rates compared to the current practices suggested with the MRTN approach.

Active sensors have been available for many years and, in cases such as the Greenseeker, have gained a small level of adoption around the state even though most data collected does not support the use of technology that only collects red/NIR data. Red and NIR data is used to generate normalized difference vegetative index (NDVI) maps which give an estimate of total amount of green biomass in a given area and not the greenness of the plant. Other technologies have been developed that measure different wavelengths that can give a better estimate of chlorophyll content, which is typically related to N sufficiency. Measuring reflectance in the green and near-red edge areas of the spectrum has typically shown a better correlation to N sufficiency (Mulla 2013). The Crop Circle is an active sensor that can measure reflectance in the red-edge while multi-spectral cameras allow for users to potentially select wavelengths to collect data within. While more flexibility exists, these other options also present challenges and must be further researched.

More recently, N models have been developed for use for farmers to help them predict N loss and potentially aid in directing side-dress application of N. Companies such as DuPont-Pioneer, Monsanto, John Deere, and Adapt-N are offering subscription services to farmers that allow them to access these models that were developed based on crop growth and N uptake. All these models have to make assumptions on crop N uptake, N mineralization from soil, and N loss. While these models were developed based on research data, there needs to be an evaluation to see if they can accurately predict the amount of N taken up by a crop at a point in time and the amount of N that should be applied. Most of the current evaluations of models such as work on Adapt-N (Laboski et al., 2014) were conducted using previous N rate trials and were not used to predict N need. This fact has been reasonably criticized, and further illustrates the need to research these models for their capacity to effectively predict N needs.

Excessive rainfall in May and June in recent years has hastened the need for research on tools that can aid in the determination of when fertilizer should be applied and at what rate. A planned study on rescue N treatments is difficult as it hinges on climatic conditions that are difficult to predict. While it can be difficult to fully simulate a situation of excessive N loss, a low rate of fertilizer can be applied to fields to simulate low availability of N. This low rate should allow us to compare some of the currently available tools for use in predicting N needs. The objectives of our proposed project are to:

Goals and Objectives

1. Compare the effectiveness of models of adjusting corn N rates in-season for corn

2. Determine if late season rescue N can increase corn grain yield

## **Materials and Methods**

Two sets of on-farm strip trials will be conducted. Study 1 will compare the effectiveness of models (or active sensors if we cannot get access to a crop model) for predicting in season N requirement. Three strips will be used. Strip 1 will consist of pre-plant N applied at the rate suggested by the corn N rate calculator, strip 2 will be a base rate of N 45-50 lbs followed by a single rate of side dress N, strip 3 will be the 45-50 lb base rate plus N applied based on a crop model (or active sensor) where N will be variable applied along the strip based on soil properties. All treatments will be applied with commercial equipment and replicated 3 times. Strip lengths will ideally be a minimum of 900 feet long to allow for sub-divisions along the reps to compare treatment differences by soil type or location within the field. Funds are budgeted to take soil samples to fine tune model or active sensor data. All side-dress will be planned for between the V5-V10 growth stages. Two locations will be planned.

On-farm study 2 will be established if needed in southern Minnesota where excessive N loss has occurred due to heavy rainfall in May or June. These sets of studies will be established only if necessary. Funds requested will cover the cost of yield loss for leaving three check strips within fields where N will be applied at V10 or later or to cover the costs associated with fertilizer and application. Check strips will ideally be compared to a single rate of rescue N applied across the field. However, variable N rates could be used for this study. The important treatment will be the no N strips in the field to give use a yes/no comparison. Funds are requested for potentially 2-4 sites per year. We are not targeting a specific placement of source of N for study 2 (such as y-drops versus coulter injection of UAN). Evaluations of placement options need to be made in more controlled environments. Strip lengths will be 900 feet long or greater.

Both on-farm strip trials will be harvested with a combine with a yield monitor. Strip widths for both studies would ideally be wide enough for two passes of the combine at harvest.

## Results and Discussion

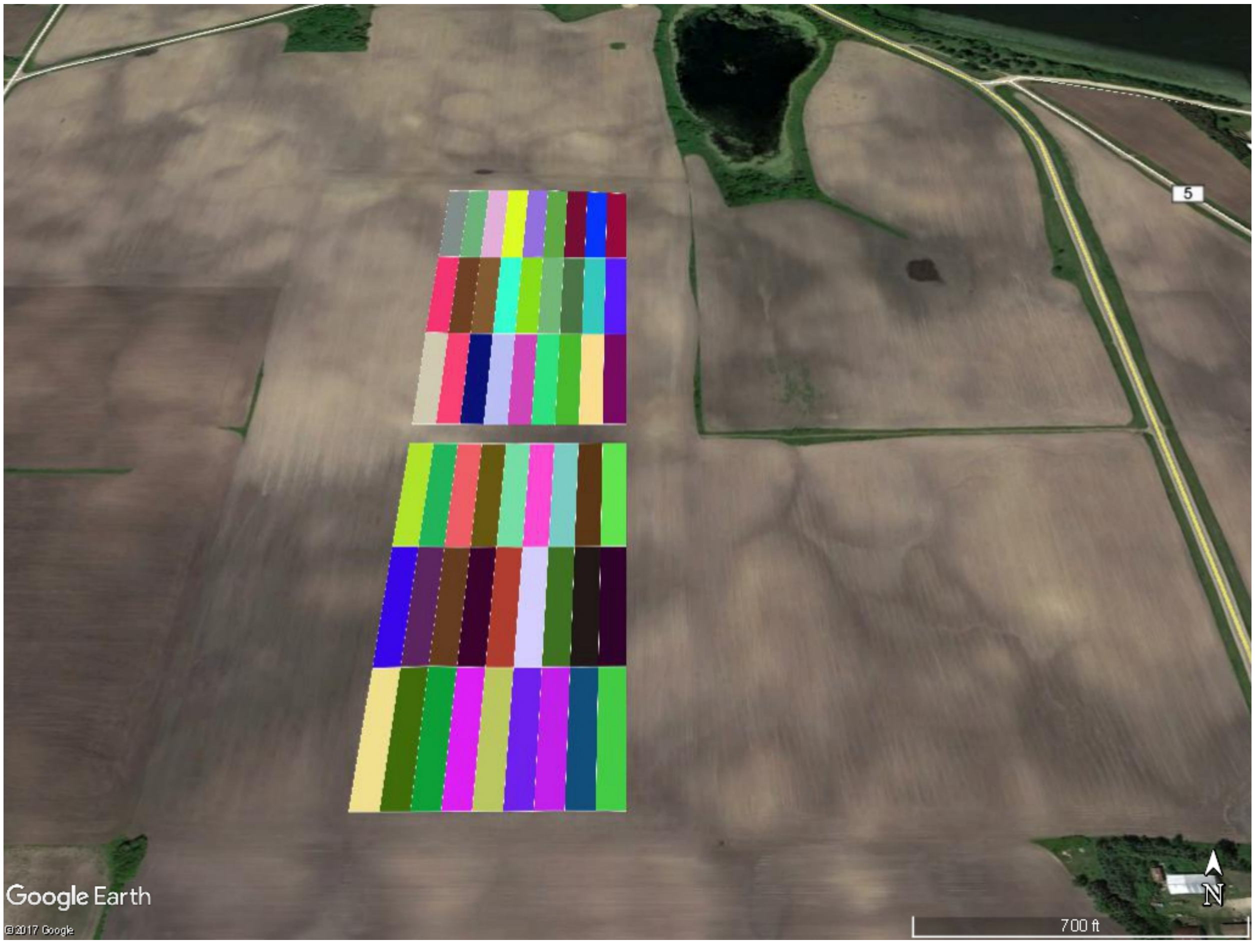


**Figure 1. aerial view of the study location at Cordova, MN in 2017**

An aerial image is given in Figure 1 for one of the strip trial location in 2017 located near Cordova. The Cordova site was split into two halves due to differences in soils and the fact that there were end rows running the width of the field in the center between the two block. Clarks Grove (not shown) was arranged as a single blocked area. Arbitrary zones were established dividing the site into 3 or 6 zone for the purpose of collecting soil sampled. Soil samples were collected across the zone replications and a single variable rate fertilizer guideline was used. The replication within the zones was needed in order to compare treatments on an even basis. Table 1 summarizes the amount of Nitrogen applied based on the model assessment of the N deficit from 70 lbs of N applied pre-plant. The suggested value accounts for the difference between the amount of N where the model suggests there would be roughly 10 lbs of N left in the soil profile at the end of the growing season. The model suggestions raged from 12 to 18 lbs less N on average based on the sites. At $0.30 per lb of N the model would have resulted in a cost savings between $3.60 to $5.40 an acre in reduced nitrogen cost.

**Table 1. Summary of the average rate of N applied per location at side-dress for the fixed side-dress (SD) and variable rate, modeled, side-dress treatment.**

| | Fixed Pre | Fixed SD | Variable SD |
|---|---|---|---|
| Clarks Grove | 0 | 70 | 57 |
| Cordova North | 0 | 70 | 58 |
| Cordova South | 0 | 70 | 52 |

**Table 2. Summary of average pre-side-dress nitrate test values for the treatments at the three locations. The PSNT samples were collected at a 0-1' depth.**

| Location | Fixed Pre | Fixed SD | Variable SD |
|---|---|---|---|
| Clarks Grove | 19.2 | 17.7 | 18.1 |
| Cordova North | 18.8a | 10.6b | 11.1b |
| Cordova South | 18.2a | 11.7b | 11.6b |

Pre-side dress nitrate samples were collected at approximately the V4-V5 growth stage at each location (Table 2). There was no difference among the treatments at Clarks Grove. However, clear differences were found for the north and south block at Cordova where the Fixed pre-plant treatment resulted in higher soil nitrate values due to double the application rate of N. It is typically suggested that a PSNT value above 26 would suggest adequate N is in the soil for the crop and values less than 20 would suggest a N deficient situation. This the case of all treatments, values were all less than 20 ppm suggesting supplemental N would be required for all situations.

**Table 3. Treatment average corn grain yield data collected from the three strip trial locations.**

| | Fixed Pre | Fixed SD | Variable SD |
|---|---|---|---|
| Clarks Grove | 206b | 211a | 211a |
| Cordova North | 194 | 190 | 184 |
| Cordova South | 203 | 200 | 200 |

Corn grain yield averages are summarized in Table 3 across all management zones at the three locations. Corn grain yield only differed among the treatments at Clarks Grove. At Clarks Grove, both side-dress treatments resulted in the same yield and were greater than the 140 lb at planting N rate. There was no difference among treatments at Cordova. Individual yield data by management zone was not available from Cordova as the yield monitor used did not have GPS functions and could not record point data. Strip averages are listed in Table 4. It is likely that there may have been differences among treatments by zone but averaged across zone there was not enough statistical differences to determine variations among treatments.

**Table 4. summary of data by replication at the Cordova location.**

| Block | Treatment | Rep 1 | Rep 2 | Rep 3 |
|---|---|---|---|---|
| North | Pre-plant | 197 | 191 | 193 |
| | Fixed SD | 186 | 187 | 199 |
| | Variable SD | 174 | 196 | 182 |
| South | Pre-plant | 207 | 207 | 196 |
| | Fixed SD | 211 | 196 | 193 |
| | Variable SD | 208 | 200 | 192 |

A zone by zone analysis could be conducted for the Clarks Grove location (Table 5). Yield differences by treatment were only statistically different for two of the six management zones. The PSNT values still did not differ among treatments considering the different management zones.

**Table 5. Summary of corn grain yield and pre-side dress nitrate data analyzed by management zone for the Clarks Grove location.**

| **Zone** | **Fixed Pre** | | **Fixed SD** | | **Variable SD** | | ***P*>F** | |
|---|---|---|---|---|---|---|---|---|
| | Yield | PSNT | Yield | PSNT | Yield | PSNT | Yield | PSNT |
| 1 – West | 201 | 13 | 208 | 15 | 209 | 16 | 0.11 | 0.56 |
| 2 | 203b | 16 | 209a | 18 | 213a | 15 | <0.01 | 0.73 |
| 3 | 208 | 22 | 211 | 20 | 213 | 20 | 0.41 | 0.67 |
| 4 | 207ab | 18 | 211a | 19 | 205b | 21 | 0.07 | 0.53 |
| 5 | 211 | 23 | 213 | 17 | 214 | 18 | 0.72 | 0.54 |
| 6 - East | 204 | 23 | 212 | 19 | 212 | 18 | 0.45 | 0.68 |

One item that needs to be addressed with any technology is the cost versus potential benefits of the technology. If we assume the cost to run the model is around $5-10 per acre and the cost of a variable rate side-dress application is $9 per acre versus $7 for a flat rate application, the use of the technology would have to result in a cost savings for N of between $7-12 per acre or the flat rate has to be under-predicting N resulting in a 1 to 2-bushel reduction in yield (assuming a corn price of $4 per bushel). For the two locations, there was no benefit to applying N side-dress at Cordova and paying even the flat rate cost for the application. A pre-plant application of N was enough to maximize yield at this location. At Clarks Grove there was a benefit to side-dress which, at the flat rate application, would have resulted in a $20 per acre increase in crop value for the $7 investment in the side-dress application. Using the crop model with variable rate would reduce the net profit at Clarks grove to roughly 0. The variable rate N treatment did reduce N application rates by 13 lbs N per acre at Clarks Grove reducing cost by roughly $4 assuming a N price of $0.30. However, for both locations, the cost savings for the variable rate could not cover the estimated cost of using the model and would still not result in any more profitability as the flat rate side-dress treatment.

What is not addressed in this rough economic analysis is the potential impacts of reducing inputs on water quality. It would not be expected that the small reduction in N applied using the model would result in a large decrease in the potential for N loss. Where this technology could benefit farmers is in situations where the N rate applied is well over suggested values (50 lbs N or more). One other caution with this data is that there was no control applied to the locations so it is not known what the optimal N rate is at any of the locations. Since the model rates we used applied less N it is likely that the optimal N rate was within 20 lbs of the 140 lb N rate used for the flat rate. The current MRTN suggested rate for the locations would be 120-140 lbs of N thus the application rates are consistent with current guidelines.

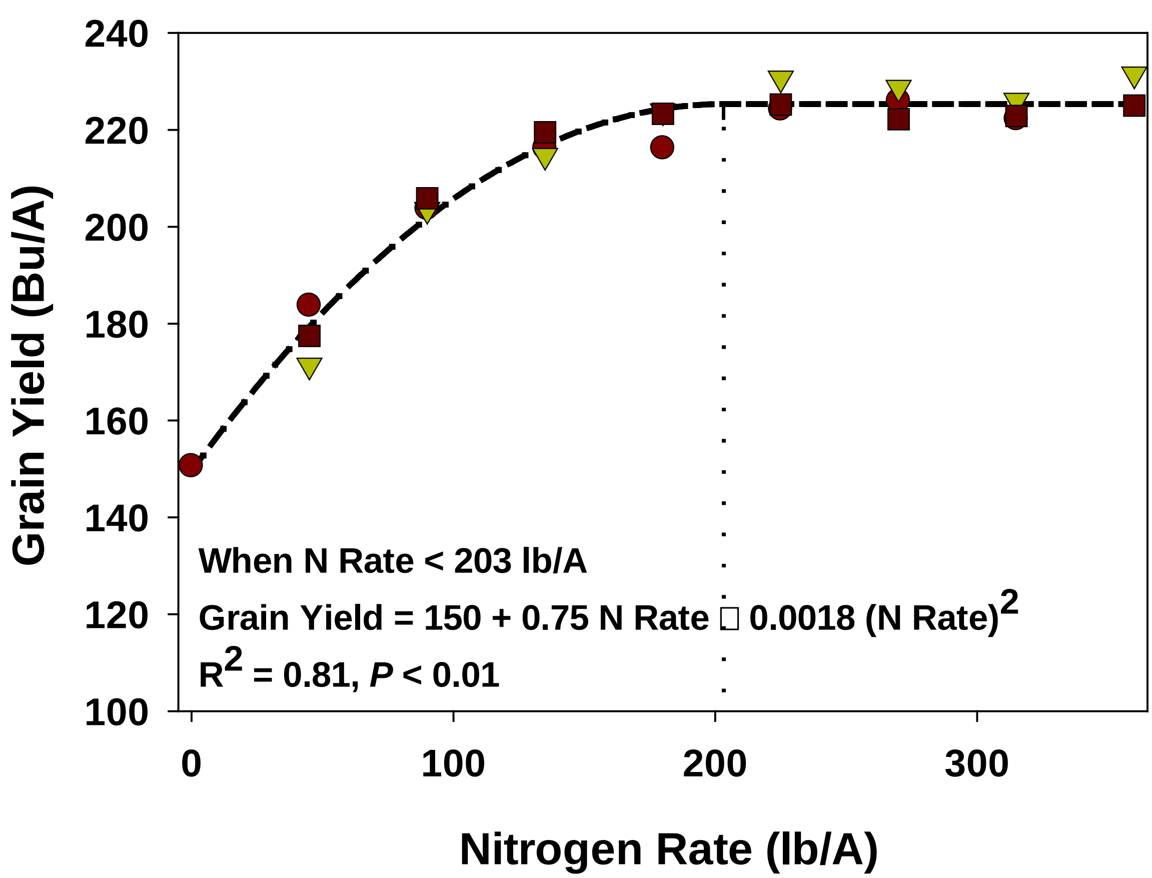


**Figure 2. Corn response to nitrogen applied at planting and side-dressed at V5 and V10 for a continuous corn study near Waseca, MN in 2017.**

An additional trial was conducted west of Waseca. In this study a small plot trial was established where N was applied either pre-plant or side-dress applied at the V5 or V10 growth stage by broadcasting urea treated with NBPT to the soil surface. Eight nitrogen rates were applied ranging from 0 to 280 lbs of N per acre. All side-dress plots received 45 lbs of N at planting and with the remaining rates applied at the specified growth stage. The 2017 version of Climate Pro was run at two target yield levels, 200 and 220 bushels per acre and soil data collected at planting was used to adjust SURGO values to give more accurate soil organic matter levels at the study location. Yield was collected by harvesting the middle two rows of each plot with a plot combine.

Figure 2 summarizes the yield data for the Waseca location. The 2017 growing season was the third cropping year at the Waseca site.  However, plots were not in the same field are for the three years of the study. One item of note from all three years is that there was no evidence of a difference in the total amount of N needed (pre-plant with or without side-dress) based on the various site dress times. The optimal rate of N required was near 200 lbs of N per acre for all three years and it did not matter if all the N was applied pre-plant or some was applied pre-plant and the remaining side-dress. The 45 lb N application rate for the side-dress treatments was selected based on past research and it was assumed this rate of N would be sufficient to supply the crop until N was applied later in the growing season. A slight yield decrease was anticipated with the V10 application but timely rainfall all three years of the study made it possible to apply N late and get it to the plant in time to avoid reductions in yield.

**Table 6. Summary of model output data using Climate pro from the Waseca trial ran at V5 and V10 growth stage assuming a 220 bu/ac yield goal. Side-dress N represents the amount of N applied at either the V5 or V10 growth stage. Low and High values represent the confidence interval range around the predicted surplus or deficit in soil N.**

| Growth Stage | Pre-Plant N | Side-dress N | Surplus/Shortfall | Low | High |
|---|---|---|---|---|---|
| | ----------------------------lb N/ac---------------------------- | | | | |
| V5 | 45 | 0 | -91 | -105 | -75 |
| | 180 | 0 | -11 | -30 | 5 |
| | 45 | 135 | 15 | 5 | 30 |
| V10 | 45 | 0 | -90 | -105 | -75 |
| | 180 | 0 | -10 | -25 | 5 |
| | 45 | 135 | -8 | -25 | 5 |

The model output summary for a 220-bushel yield goal is summarized in Table 6 for the 2017 growing season. Maximum yield for the location was around 220 bushels in 2017. What has bene interesting about this particular location is that in three years of research the N model has consistently under predicted N need. Predicted deficits from the 45 lb N rates were much greater in 2017 which is likely due to adjustments in the model between the 2016 and 2017 growing season. At V5 and V10 the model was predicting a shortfall of around 90 lbs of N when 45 lbs of N was applied at planting. What is interesting is that when 180 lbs of N were applied at planting, there was a predicted shortfall of 10 to 11 lbs of N at the end of the season. This would indicate that the model is significantly penalizing the pre-plant treatment even though the data has consistently shown that the amount of N required does not change with a pre-plant only versus a side-dress application. What also was interesting is that the model did not change much as to the predictions from the two growth stages. In fact, runs at R2 showed similar predictions (not shown). In any event this research has brought up two questions about using models. The Climate Pro model only give a predicted surplus or deficit and did not provide any guidance on application rate. So determining the actual need for N is difficult. In addition, if the data clearly shows that the amount of N required is more important than when it is applied, there should be not impact of timing on the surplus or shortfall of N unless the measured values are at shallower soil depths. However, if roots are taking up nitrogen at deeper depths then the amount of N remaining at shallower depths may not be overly critical. While the on-farm data does show the models can be used to achieve maximum yield the cost benefit needs to be accounted for as well as the accuracy across multiple field locations.

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**Figure 3. Model output summary for 140 lb N applied pre-plant ran on 7/18/17 at Cordova.**

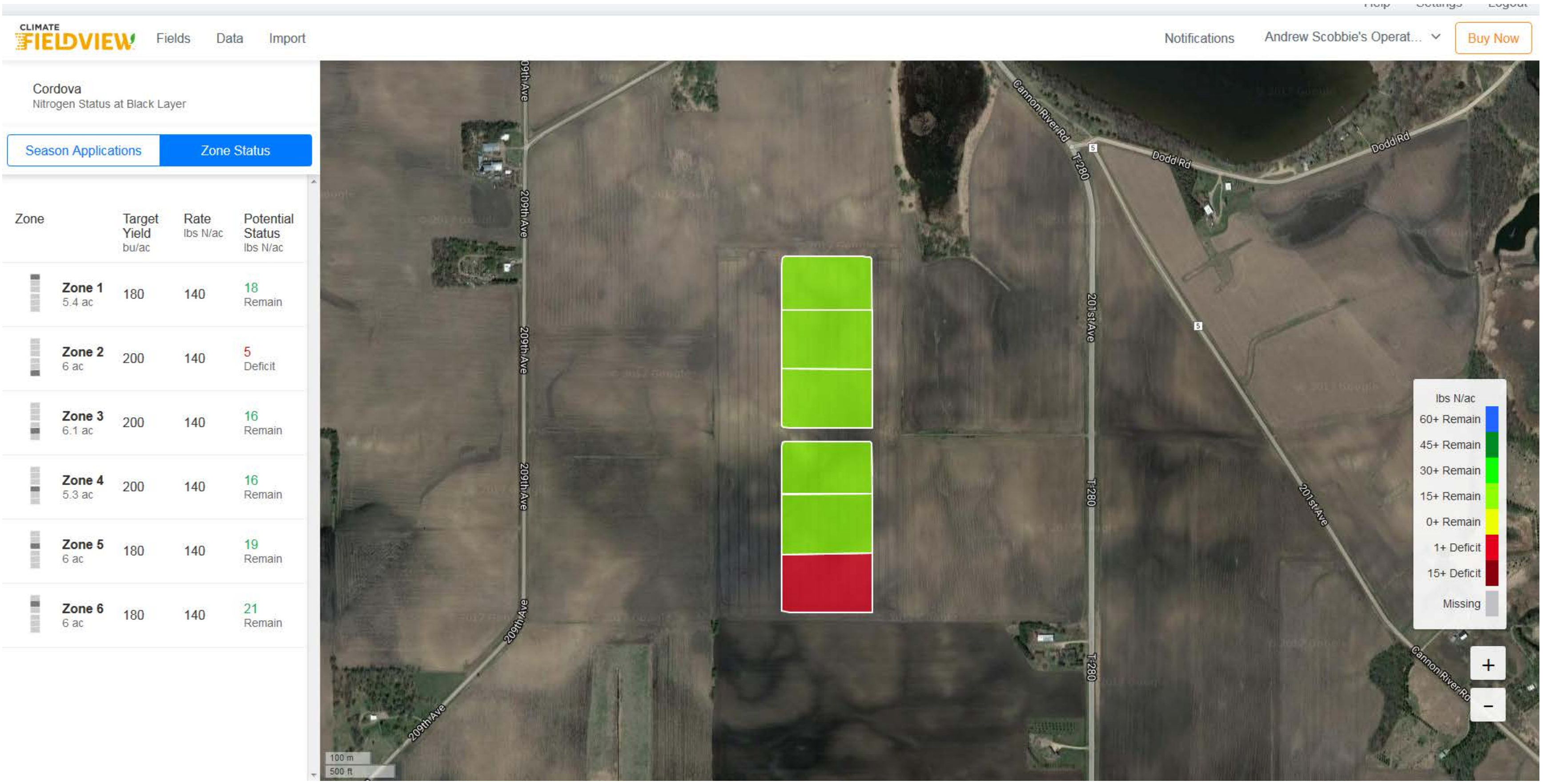

**Figure 4. Model output summary for 70 lbs N applied pre-plant plus 70 lbs N applied around V10 ran on 7/18/17 at Cordova.**

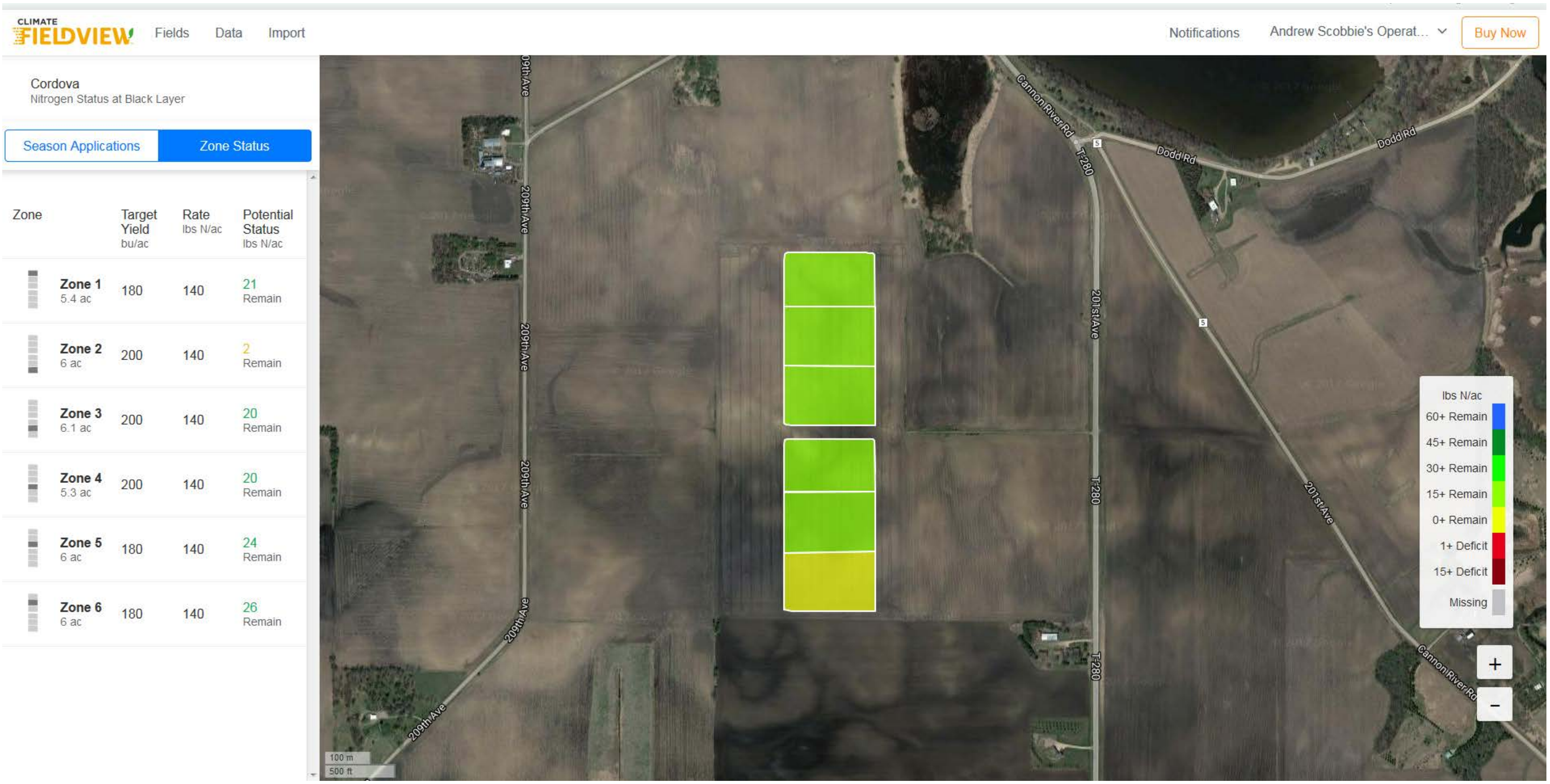

**Figure 4. Model output summary for 70 lbs N applied pre-plant plus variable rate N applied around V10 ran on 7/18/17 at Cordova.**