INTRODUCTION
What advantage does a Minnesota wheat producer have over producers in other parts of the world? The ability to grow higher quality wheat, which makes higher quality breads, resulting in a premium price compared to other wheats. Until these things change, protein premiums and discounts will remain on the forefront of growers’ minds.

To get a better understanding of the spread in protein percentages across a field and to start the process of correcting the areas that are hurting a grower’s bottom line and their quality wheat reputation, the MN Wheat OFRN started a project for on-the-go protein sensing.

MATERIALS AND METHODS
This research is not new but it is new to much of Minnesota and the Dakotas, especially research using Next Instruments CropScan 3000H. The On Combine Quality Analyzer first came to the US in 2015 to a farm in Montana. Next Instruments is a company out of Australia that specializes in agriculture and food analyzers.

The CropScan 3000H works by taking a small sample of grain off the clean grain elevator every 7-12 seconds, dropping it into a remote sampling head where light passes through it. A fiber optic cable collects the transmitted light and sends it to the NIR spectrometer in the combine cab. The combine operator can then see the real-time grain quality data on a separate monitor in the cab. This real-time data is also geotagged, timestamped, recorded, and saved.

There is currently one U.S. dealership for this technology, Triangle Ag Services, which is located in Great Falls, Montana. A CropScan 3000H analyzer retails for about $23,000 USD. There are some other expenses associated with paying a technician to travel from Montana to install and calibrate the machine. For multiple combine operations, it is best to have an analyzer on every machine but a full-field map can still be made if not every combine is equipped. In order to get the best map with one analyzer, the field has to be harvested in an overlapping pattern.

The OFRN had one analyzer installed on a 2006 John Deere 9660 STS with RTK guidance on one farm in Roseau County. The 2017 season was successful in that wheat and canola quality data was collected with few obstacles. This report presents data collected within five wheat fields in 2017. Corn and soybean data collection was attempted, but proved problematic with high grain moisture contents.

Our goal for 2017 was simply to get the equipment installed and calibrated on one combine and successfully collect data. To aid this, a team was put together and they went through training from Triangle Ag on how to operate the equipment and what to do if problems occur. The team includes the farm owner, his mechanic, an additional combine operator for the farm and a local John Deere technician.

The producer that we worked with had a fair bit of time committed to this project from many initial conversations, install and training, some problem solving during harvest, transferring and working with the data, and interpreting the results. This research takes that level of dedication; however, we do not want to scare away growers interested in the research. This project is being looked at with a long-term approach knowing that answers will not likely come in the first few years.

The CropScan 3000H exports protein data in CSV text files. While GIS software can display spatial data from CSV files, conversion to other formats may be necessary to view this data in precision agriculture software programs. For this project, protein CSV files were converted to the GeoPackage format. Yield data, field boundaries, and soil type boundaries were also stored within the same GeoPackage files. Before storage within the GeoPackages, yield monitor output was processed using the automated functions of USDA Yield Editor 2.0.7, which removes errors and suspected outliers from yield monitor output files.

RESULTS AND DISCUSSION
On average, the John Deere 9660 STS combine used by our cooperator gathered yield data every second, with the combine traveling at a speed of 3.3 – 3.8 ft/sec (2.3 – 2.6 MPH). Thus, with an effective header width of 34 ft, each data point returned by the yield monitor represents 112 – 129 ft2 within the field. In contrast, the CropScan 3000H protein analyzer gathered protein data every 8 seconds, with each data point representing 896 – 1032 ft2. The yield data set being 8 times more precise than the protein dataset creates challenges in comparing yield monitor and protein analyzer outputs, even if 100% of a grower’s acreage were harvested with a machine featuring a protein analyzer. Proper aggregation and summarization of the collected data is necessary to overcome these challenges.

Figures 1–5 present aggregated and mapped protein analyzer outputs from the five wheat fields in 2017. Protein maps are presented alongside maps of yield, elevation, NDVI, and soil types from Web Soil Survey (SSURGO). All maps were aggregated or resampled to a resolution of 1076 ft2, matching the resolution of the SSURGO dataset. NDVI maps were created from a Landsat satellite im-
age taken July 14, 2017, approximating the pre-heading period of wheat development. The pre-heading development stage is optimum for sensing difference in greenness among wheat plants (Joel Ransom, NDSU, personal communication). Gray-colored areas represent areas where data was not collected or where data was removed due to presence of an OFRN test plot.

There are no grain protein trends consistent across all five fields. However, protein trends can be found within individual fields. The southeast portion of ‘Roseau 2’ displayed lower yields and higher protein content than the remainder of the field, illustrating the negative relationship between yield and grain protein oftentimes found with wheat. The westernmost soil type of ‘Roseau 5’, which also had a higher elevation than the rest of the field, displayed elevated protein content when compared to the rest of the field. However, this was not associated with lower yields relative to the rest of the field, suggesting that yield and protein content are not negatively correlated in all circumstances. ‘Roseau 3’ displayed surprisingly consistent yield and protein across the field, but this field also consisted of just a single soil type.

Visual examination of maps is aided by interpolation of protein analyzer data and smoothing of yield monitor data (Figure 6). However, such maps may not display fine-grained variability in grain protein and yield that is relevant for interpreting the yield-protein dynamics within a given field. In addition, the output values from the smoothing and interpolation procedures are estimates of yield and protein content, not measured values, which may hinder efforts to compare these two variables using statistical analysis.

CONCLUSIONS
MN Wheat OFRN staff and cooperators successfully performed installation, operation, data collection, and mapping from the CropScan 3000H on-the-go protein analyzer. For the 2018 season, there are plans to expand the project to one more farm. The added data and information will ramp up efforts to understand what influences protein and what can be done to make improvements (such as nitrogen management zones). The next steps in data analysis and mapping will focus on developing methods to 1) properly aggregate yield and protein data, 2) perform statistical analyses of yield and protein data, and 3) display analysis outputs in a form usable to a grower.
Figure 1. Protein, yield, elevation, NDVI, and soil types for field ‘Roseau 1’, 2017. Gray-colored areas represent areas where data was not collected or where data was removed due to presence of an OFRN test plot.
Figure 2. Protein, yield, elevation, NDVI, and soil types for field ‘Roseau 2’, 2017. Gray-colored areas represent areas where data was not collected or where data was removed due to presence of an OFRN test plot.
Figure 3. Protein, yield, elevation, NDVI, and soil types for field ‘Roseau 3’, 2017. Gray-colored areas represent areas where data was not collected or where data was removed due to presence of an OFRN test plot.
Figure 4. Protein, yield, elevation, NDVI, and soil types for field ‘Roseau 4’, 2017. Gray-colored areas represent areas where data was not collected or where data was removed due to presence of an OFRN test plot.
Figure 5. Protein, yield, elevation, NDVI, and soil types for field ‘Roseau 5’, 2017. Gray-colored areas represent areas where data was not collected or where data was removed due to presence of an OFRN test plot.
Figure 6. Examples of smoothed protein and yield data, 2017. Note the lack of fine-grained detail when compared to Figures 1 and 5.