Montana Field Trials for On Combine NIR Analyzer

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Introduction:

A trial of the CropScan 3000H On Combine Analyzer, Next Instruments, Sydney, Australia, was organized by Trimble Agriculture, San Francisco, USA, Triangle Ag, Great Falls, Montana, USA and Jesse Wood, Great Falls, Montana, USA.

The objective of the trial was to assess the ease of installation, the operation, functionality and robustness as well as the accuracy and stability of the system.

This report provides an analysis of the data collected during the trial along with post harvest testing of samples collected during the harvesting.

Description:

Installation:

The CropScan 3000H On Combine Analyzer was installed onto a CASE IH 8240 Combine Harvester owned by Mr Jesse Wood, Great Falls, Montana for the 2015 wheat harvest. Figure 1 shows a picture of the Sampling Head mounted to the clean grain elevator. Figure 2 shows the NIT Spectrometer located inside the combine's cabin and figure 3 shows the Touch Screen PC mounted to the roof beam of the cabin.

Figure 1. Sampling Head

Figure 2. NIT Spectrometer

Figure 3. Touch Screen PC

A Fiber Optic Cable and an Electronics Cable, 4.5meters in length, were connected between the Sampling Head and the NIT Spectrometer. The cables were run along the super structure of the combine where existing cables were fitted. The cables were brought into the cabin through a hole in the floor and connected to the back of the NIT Spectrometer. Power was taken directly from the combine's battery. A RS232 Serial Cable was connected between the NIT Spectrometer and the Touch Screen PC. A GPS Nav Controller was connected to the Touch Screen PC via a Serial Cable. A Proximity Sensor was fitted near the Outloading Auger and the cable run back to the Sampling Head. Installation took approximately 4 hours.

Calibration:

The CropScan 3000H On Combine Analyzer has calibrations installed and tested for wheat, barley and canola(rape seed). 13 samples of wheat were collected from a local silo where they had a Foss Infratec 1241 NIR Analyzer to test for protein and moisture. The 13 samples were analyzed by the CropScan 3000H by pouring the samples directly into the Sampling Head using inlet and outlet hopper supplied with the system. Figure 4 and 5 show the calibration plots for protein and moisture, CropScan 3000H vs. Infratec 1241.

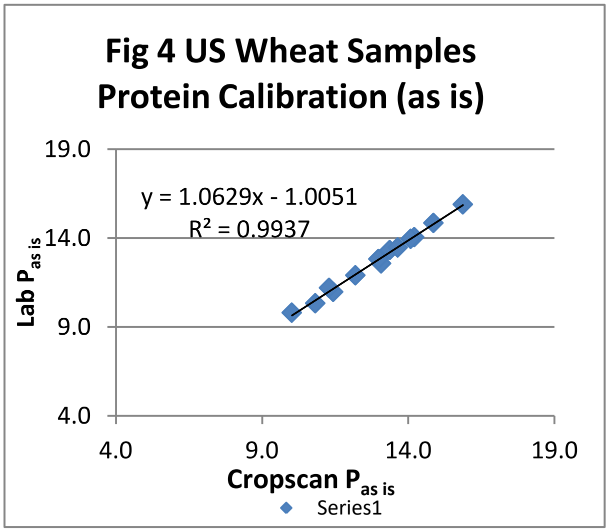


Fig 4 US Wheat Samples Protein Calibration (as is)

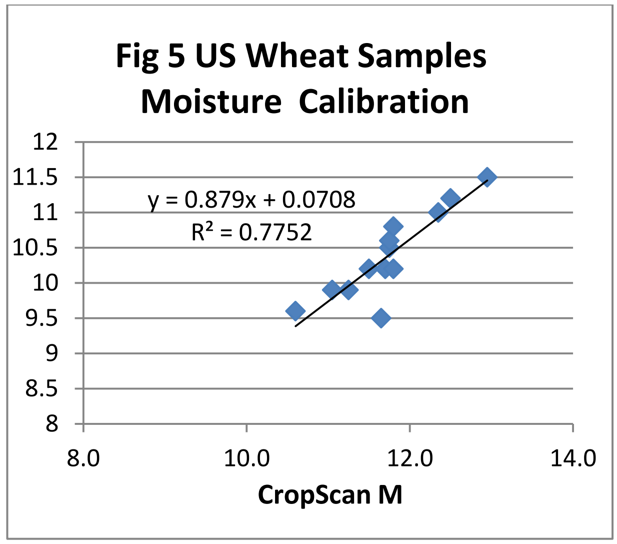


Fig 5 US Wheat Samples Moisture Calibration

The Slope and Bias adjustments are shown on each plot as the equation of the line of best fit between the two sets of data. These Slope and Bias adjustments were entered into the CropScan 3000H Analysis Software.

The 13 samples of wheat were then analyzed using the CropScan 3000H again in duplicate. Table 1 shows the results.

Reproducibility Tests							
	Test 1	Test 2	Difference		Test 1	Test 2	Difference
	Protein	Protein	Protein		Moisture	Moisture	Moisture
W1	9.3	9.3	0.0		12.4	12.3	0.1
W2	10.0	10.4	-0.4		11.3	11.2	0.1
W3	10.8	11.1	-0.3		11.2	11.1	0.1
W4	11	10.9	0.1		12.50	12.5	0.0
W5	12	12	0.0		11.80	11.7	0.1
W6	13	12.9	0.1		10.6	10.6	0.0
W7	13.1	12.9	0.2		11.7	11.8	-0.1
W8	13.5	13.5	0.0		11.8	11.8	0.0
W9	13.6	14.0	-0.4		11.5	11.5	0.0
W10	14.4	14.7	-0.3		11.7	11.7	0.0
W11	14.8	14.4	0.4		12.9	13.0	-0.1
W12	15.5	15.3	0.2		11.8	11.8	0.0
W13	16.5	16.8	-0.3		11.8	11.5	0.3
		Average Diff	-0.1			Average Diff	0.0
		SDD	0.26			SDD	0.10

Table 1 Protein and Moisture Reproducibility

Results:

The CropScan 3000H was run for approximately 20 days with 2 days down time due to a problem with the combine. Data were collected at approximately 10 second intervals during harvesting. 2 samples of grains were collected from the back of the bin each day, i.e., morning and evening. These samples were bagged and tagged so that they could be tested by an external laboratory and then compared with the predicted results from the CropScan 3000H. After harvest the 35 samples were analyzed using the CropScan 3000H in the same manner that had been done for the initial calibration and validation steps, i.e., poured into the Sampling Head. The predicted protein and moisture values were recorded as the CropScan Static Results.

Although all the data is available for examination, there were approximately 50,000 readings taken across the trial period. As such, the data has been summarized for ease of evaluation and commentary.

Since the CropScan 3000H collects as many as 120 readings per bin load, a single sample collected from the back of the bin, i.e., the sample port located near the cabin door, is not necessarily representative of the entire 8 tonne of grain in each bin. The CropScan 3000H Analysis software reports each reading for protein and moisture, along with a moving average of the last 5 readings and an overall bin average.

			Static CropScan	2015 Paddock Data from CropScan 3000H	Bin Average Protein	2015 Lab Sample Results
Sample	Date	Time	Protein	Protein	Protein	Protein
1	7/20/15	4:10	14.3	14.2	14.8	
2	7/20/15	8:30	10.6	10.7	11.5	
3	7/21/15	10:00	10.5	10.5	12.8	10.6
4	7/21/15	1:58	14.0	14.1	12.9	14.3
5	7/22/15	2:30	10.8	11.0	10.5	10.6
6	7/22/15	3:30	12.7		13.1	12.8
7	7/22/15	4:50	15.7	15.6	15.5	15.6
8	7/23/15	7:30	10.8	11.0	11.0	11
9	7/24/15	10:00	11.5	11.7	11.1	11.7
10	7/24/15	7:50	12.2			12.4
11	7/25/15	11:00	12.7	12.8	12.6	13
12	7/25/15	5:00	15.6	15.4	15.5	15.6
13	7/29/15	2:30	13.1	13.9	12.1	14.3
14	7/29/15	3:40	13.4	14.2	13.7	14.2
15	7/30/15	10:00	13.9	14.4	13.8	14.5
16	7/30/15	6:20	15.1	15.9	15.1	15.9
17	7/31/15	11:40	15.2	15.0	15.9	14.7
18	7/31/15	6:15	13.9	14.7	14.5	13.6
19	8/1/15	12:40	14.1	14.4	15.3	14
20	8/1/15	1:45	11.2			11.1
21	8/2/15	2:00	11.9	11.9	13.3	11.7
22	8/2/15	6:30	13.9	13.9	15.4	13.5
23	8/3/15	10:30	12.6	12.2	13.1	12.2
24	8/3/15	8:30	15.7	16.2	16	
25	8/4/15	10:45	15.0	14.5	14.6	15.1
26	8/6/15	2:20	17.5	18.2	17.2	18.5
27	8/6/15	7:50	14.1	14.2	15.2	14.2
28	8/7/15	11:00	11.6	12.1	14.5	12.1
29	8/7/15	5:30	15.1	15.0	14.2	15.1
30	8/8/15	N/A	15.8			15.3
31	8/8/15	8:00	12.5	13.0	12.5	13
32	8/9/15	3:00	14.6	16.8	17.8	15
33	8/9/15	6:10	15.5	15.3	15.5	15.2
34	8/10/15	11:10	15.3	15.7	16.1	15.6
35	10/08/2015	5:00	14.6	14.9	15.9	14.4

The CropScan Field Results were taken as the moving average of the last five readings approximately at the time the sample was tagged, i.e., +/- 5 minutes.

Table 2 shows the protein data for:

1) CropScan 3000H Static Results
2) CropScan Field Results
3) CropScan Bin Averages
4) External Reference Laboratory

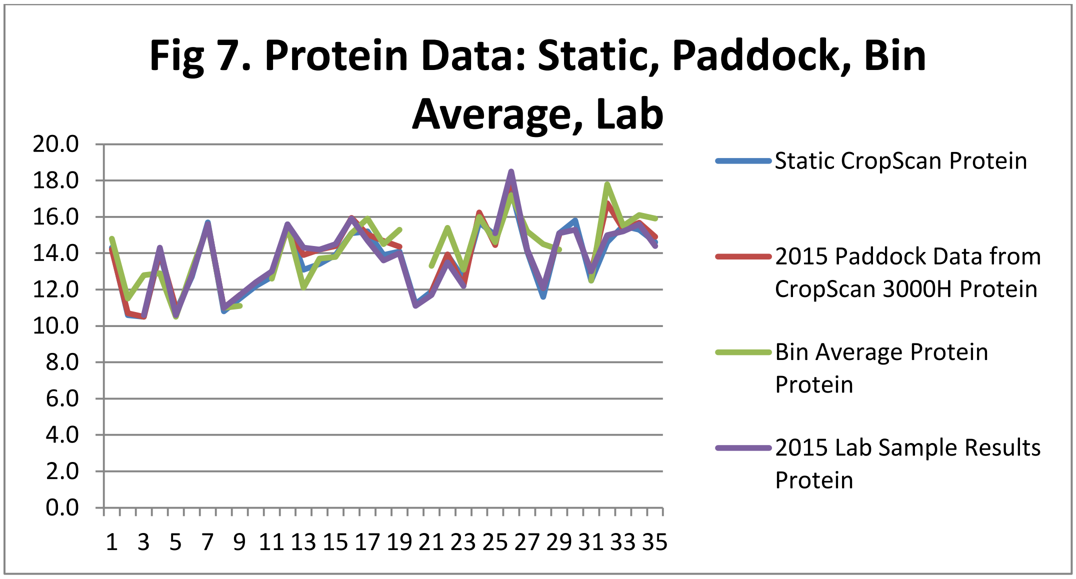
Note that there were no lab data for samples 1,2 and 24.

Note there were no CropScan data corresponding to the tagged samples 6,10, 20 and 30.

Table 2. Protein Data

Figure 7 shows the Line Plot of the CropScan Static Protein, Field Protein, Bin Average Protein and the

Lab Protein. It can be seen that the Static, Field and Lab Protein track each other very well, however the Bin Average protein shows larger difference for several bin loads. This is most likely due to the sample not being truly representative of the entire bin load.



Figures 8 shows the Correlation Plots between the CropScan Static Protein vs. Lab Protein. The correlation is excellent and the only sample that has a significantly high error is at the very top end of the protein range, i.e. 18%, which may be outside the calibration's range.

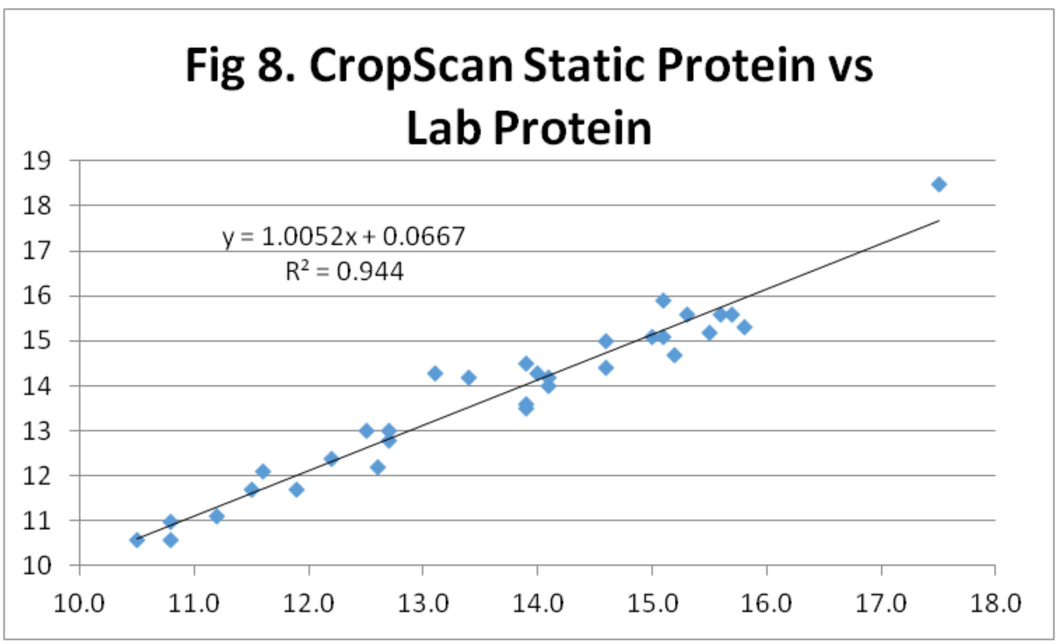


Figure 9 shows the Correlation Plot between CropScan Field Protein and the Lab Protein. Once again the correlation is very high and there is one outlier, i.e. Sample 32. On examination of the Field Map associated with Sample 32, it is observed that there is a 3% difference from the edge of the Field and the next two rows stripped. As such it is possible that the sample collected was from these inner rows, where as the CropScan Field data was taken while the combine was stripping in the edge row.

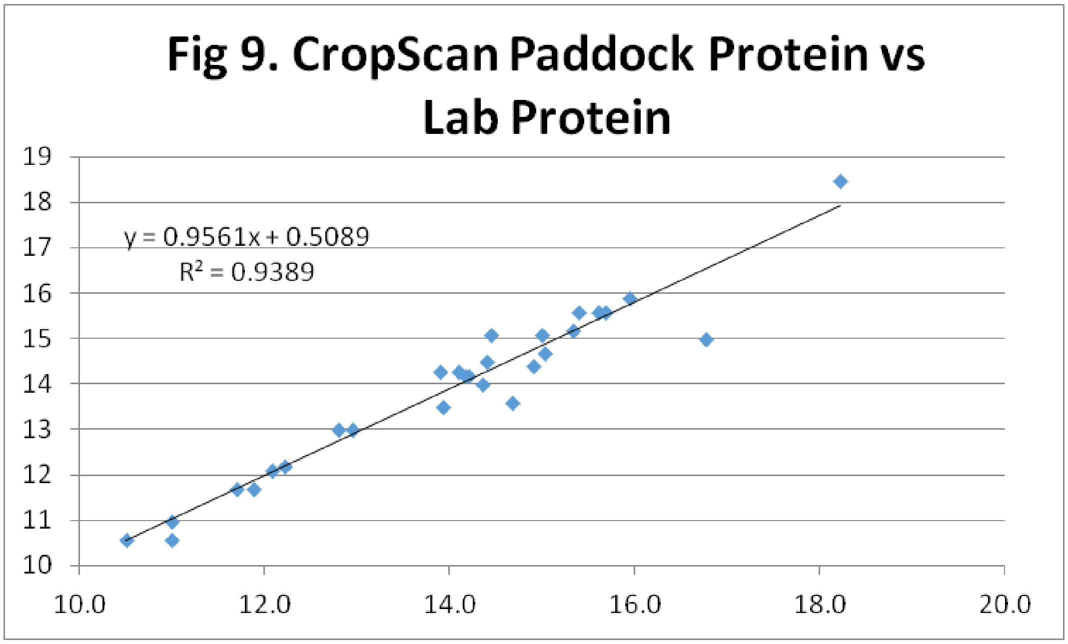


Table 3 shows the Moisture data for the Static, Field, Bin Average and Lab.

Sample	Date	Time	Static Moisture	Paddock Moisture	Bin Average Moisture	Reference Moisture
1	7/20/15	4:10	10.1	9.6	10.2	
2	7/20/15	8:30	9.8	9.8	10.0	
3	7/21/15	10:00	10.7	10.9	9.8	10.2
4	7/21/15	1:58	9.8	9.8	9.8	9.5
5	7/22/15	2:30	10.0	10.2	10.2	9.5
6	7/22/15	3:30	9.9		10.0	9.3
7	7/22/15	4:50	9.9	10.3	10.4	9
8	7/23/15	7:30	9.6	9.0	8.9	9.2
9	7/24/15	10:00	10.1	9.6	9.0	9.5
10	7/24/15	7:50	9.0			8.8
11	7/25/15	11:00	8.9	9.1	9.3	8.5
12	7/25/15	5:00	8.7	8.7	8.2	8.3
13	7/29/15	2:30	15.6	15.7	16.2	14.8
14	7/29/15	3:40	13.1	15.1	15.1	12.2
15	7/30/15	10:00	13.5	14.1	14.0	12.8
16	7/30/15	6:20	10.0	10.0	10.1	9.7
17	7/31/15	11:40	10.5	10.9	10.8	10
18	7/31/15	6:15	8.2	8.0	7.8	8.4
19	8/1/15	12:40	8.6	8.3	8.4	8.7
20	8/1/15	1:45	7.4			8.1
21	8/2/15	2:00	8.9	8.6	8.8	8.9
22	8/2/15	6:30	8.6	8.4	8.3	8.6
23	8/3/15	10:30	9.6	10.2	10.3	9.6
24	8/3/15	8:30	8.6	7.7	7.7	
25	8/4/15	10:45	9.3	9.7	9.8	8.8
26	8/6/15	2:20	10.4	9.9	10.5	9.7
27	8/6/15	7:50	9.9	9.8	9.7	9.6
28	8/7/15	11:00	10.7	10.4	10.0	10.2
29	8/7/15	5:30	10.4	9.4	9.7	9.8
30	8/8/15	N/A	10.8			10.7
31	8/8/15	8:00	10.4	10.5	10.4	10.1
32	8/9/15	3:00	10.1	10.0	9.9	9.7
33	8/9/15	6:10	9.4	9.5	9.4	9.3
34	8/10/15	11:10	9.9	10.2	9.9	9.7
35	10/08/2015	5:00	8.6	8.5	8.4	8.6

Table 3. Moisture Data

Figure 10 shows the Line Plot of the CropScan Static Moisture, Field Moisture and the Lab Moisture. The agreement for the moisture data is very good, however there is a bias observed between the Lab Moisture and the Field Moisture.

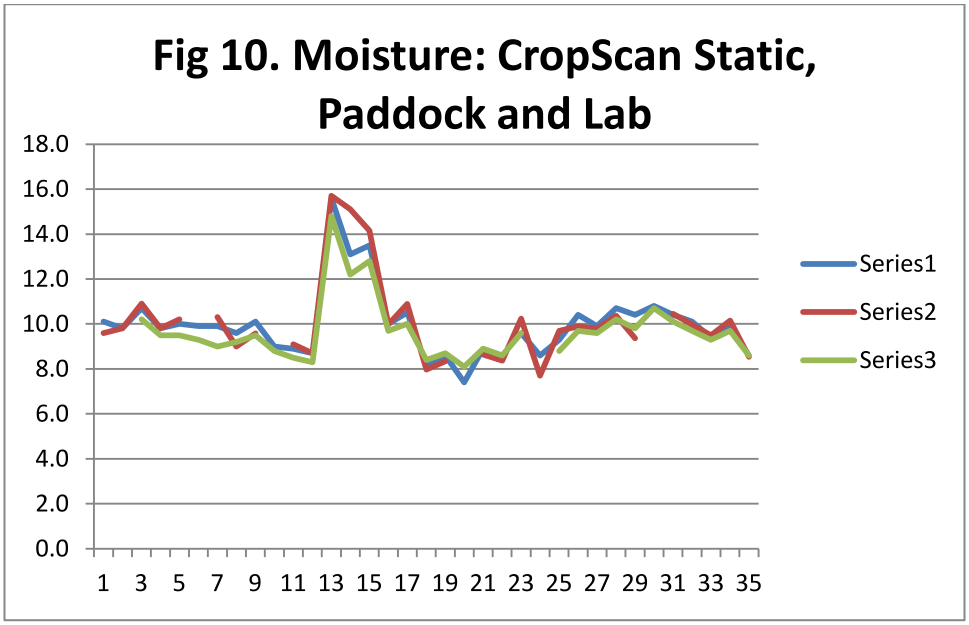


Figure 11 shows the Correlation Plot between CropScan Static Moisture and Lab Moisture. The correlation is excellent between the two sets of data.

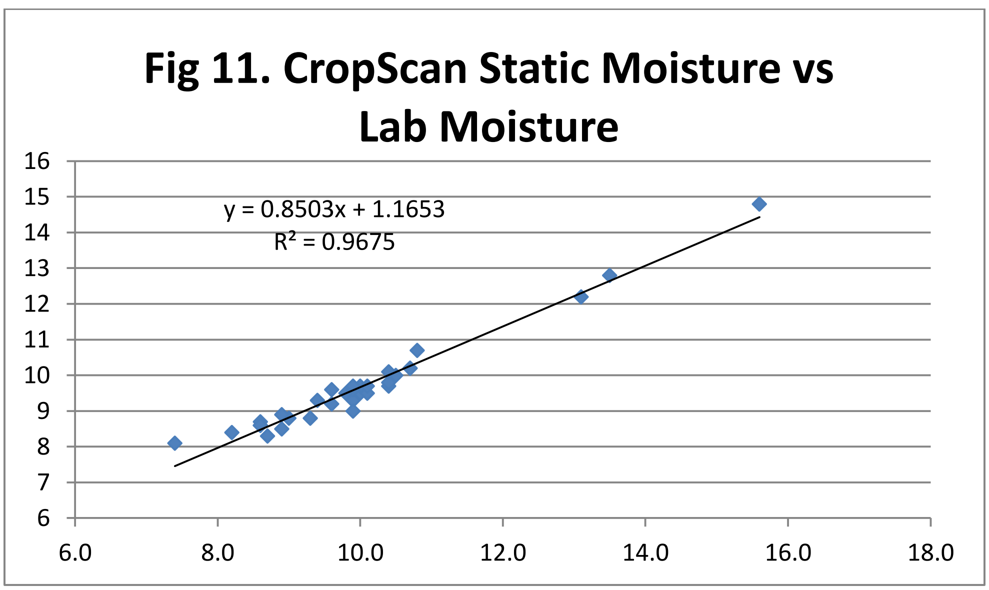


Figure 12 shows the Correlation Plot between the CropScan Field Moisture vs. the Lab Moisture. The correlation is not as strong but still significant between the two sets of data. There are two high moisture samples, i.e. 14 and 15, that have higher errors.

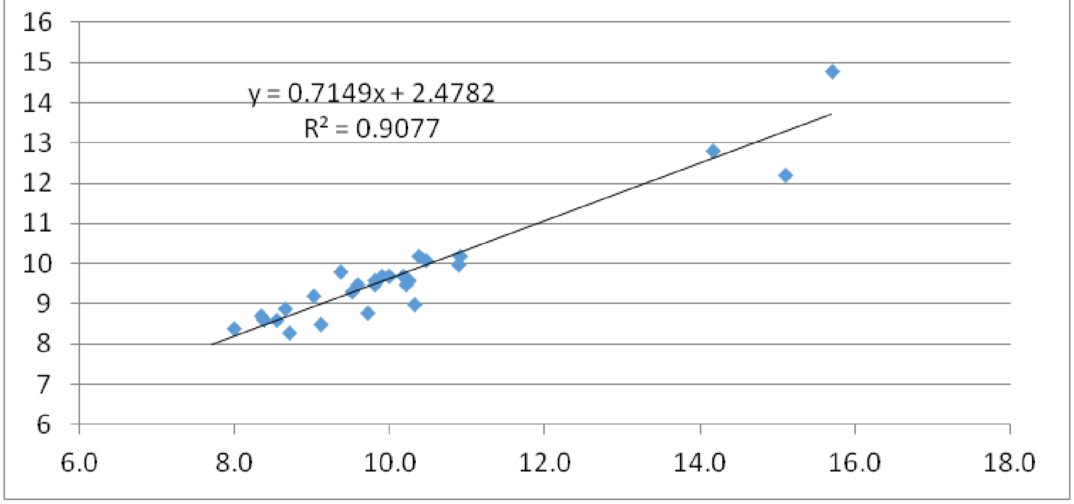
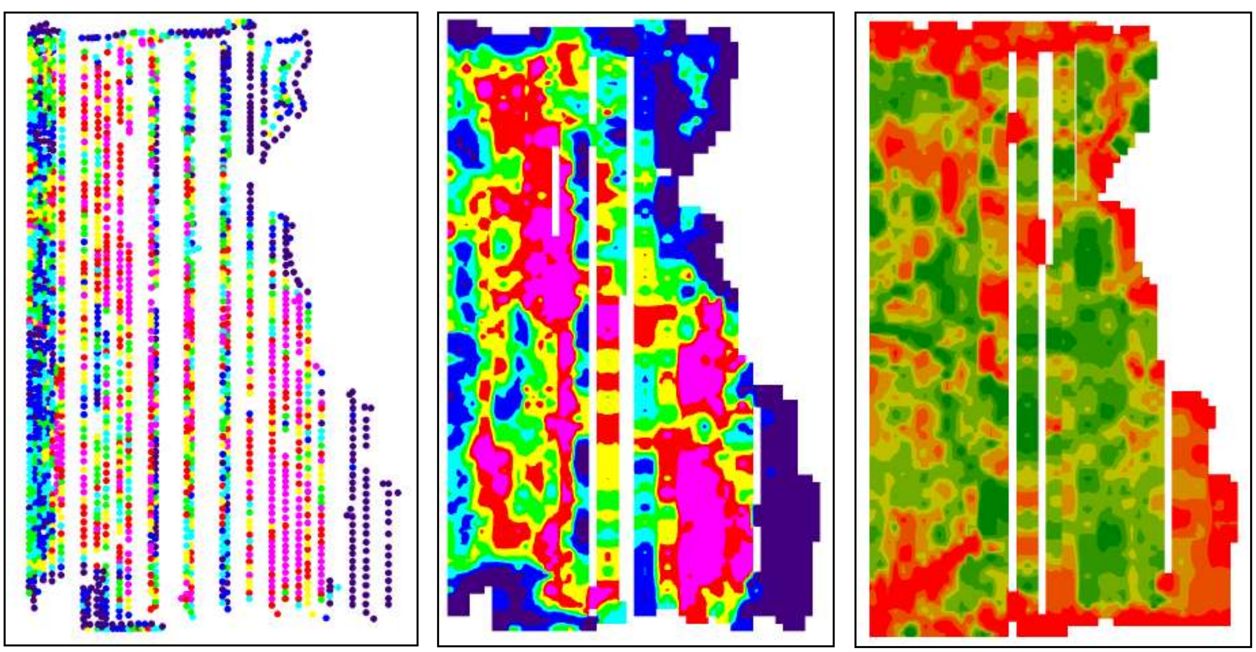


Fig 12. Paddock Moisture vs Lab Moisture

Field Maps

Figures 13 through 16 show Protein and Yield Field Maps for four fields, i.e. Bachelor, Carlin, Francis and Robinson. The Protein Maps show the raw data and an averaging of 20 meters. It should be noted that the CropScan 3000H was fitted to one of four CASE IH 8420 Combines. As such the data collected in these Fields is not complete. By averaging the data, it makes interpretation easier.



Protein Map, No Averaging | Protein Map, 20m Averaging | Yield Map, 20m Averaging

Client: < Unassigned Client >
Paddock: Batchelor
Crop: 2015 Wheat
Name: batchelor_2015-map
Type: Harvesting
Date: 28/08/2015
Harvest: 0.000 kg
Min: 8.110
Max: 18.776
Avg: 12.748

14.667 - 18.776
13.584 - 14.666
12.949 - 13.583
12.297 - 12.948
11.639 - 12.296
10.869 - 11.638
8.110 - 10.868

Client: < Unassigned Client >
Paddock: Batchelor
Crop: 2015 Wheat
Name: 15/07/20-14:59:37
Type: Harvesting
Area: 13.02 ha
Start Date: 20/07/2015 2:59 PM
End Date: 20/07/2015 5:40 PM
Engine Hours: 2.7 hr
In Operate: 2.1 hr
Harvest: 44998.641 kg
Avg: 3456.12 kg/ha

4440.3 - 47659.1 kg/ha
4125.9 - 4440.2 kg/ha
3862.9 - 4125.8 kg/ha
3569.5 - 3862.8 kg/ha
3116.8 - 3569.4 kg/ha
2403.0 - 3116.7 kg/ha
0.0 - 2402.9 kg/ha

Figure 13. Protein and Yield in the Bachelor Field with and without averaging.

In the Bachelor Field, there are zones where the protein content of the wheat is much higher and some zones where the protein is much lower. Along the fence lines it can be seen that the protein levels are higher than in the middle of the Fields. This could be as a result of a ridge or possibly less soil compaction by heavy machinery. The seeders, boom spray and harvesting machinery would be working at some distance from the fence and therefore there would be less compaction of the soil. The lower protein zones could indicate a gully or some difference in the soil structure.

The Yield Map shows an inverse correlation between the Protein and Yield. However there are some sections of the Field where the Yield and Protein are both low.

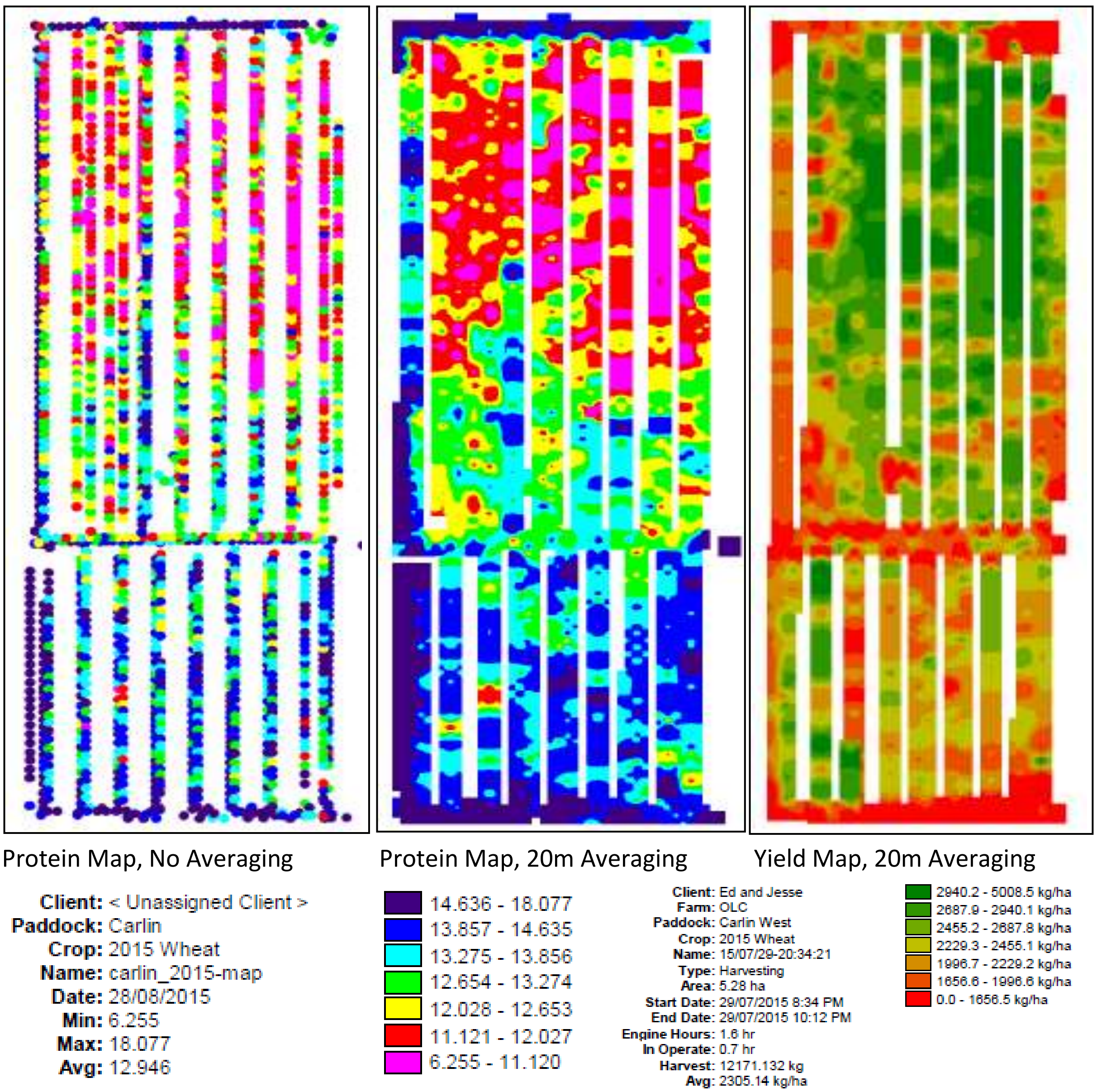


Figure 14. Protein and Yield in the Carlin Field with and without averaging.

The Carlin Field has three distinct zones of high, medium and low protein content in the wheat. The cause of these zones is not known, however the map clearly shows that stripping these zones separately and segregating the wheat could realize a payment premium based on protein. As well, the maps also suggest that there is scope for optimizing the crop production through variable rate fertilization.

The Yield Map shows an inverse correlation between the Protein and Yield.

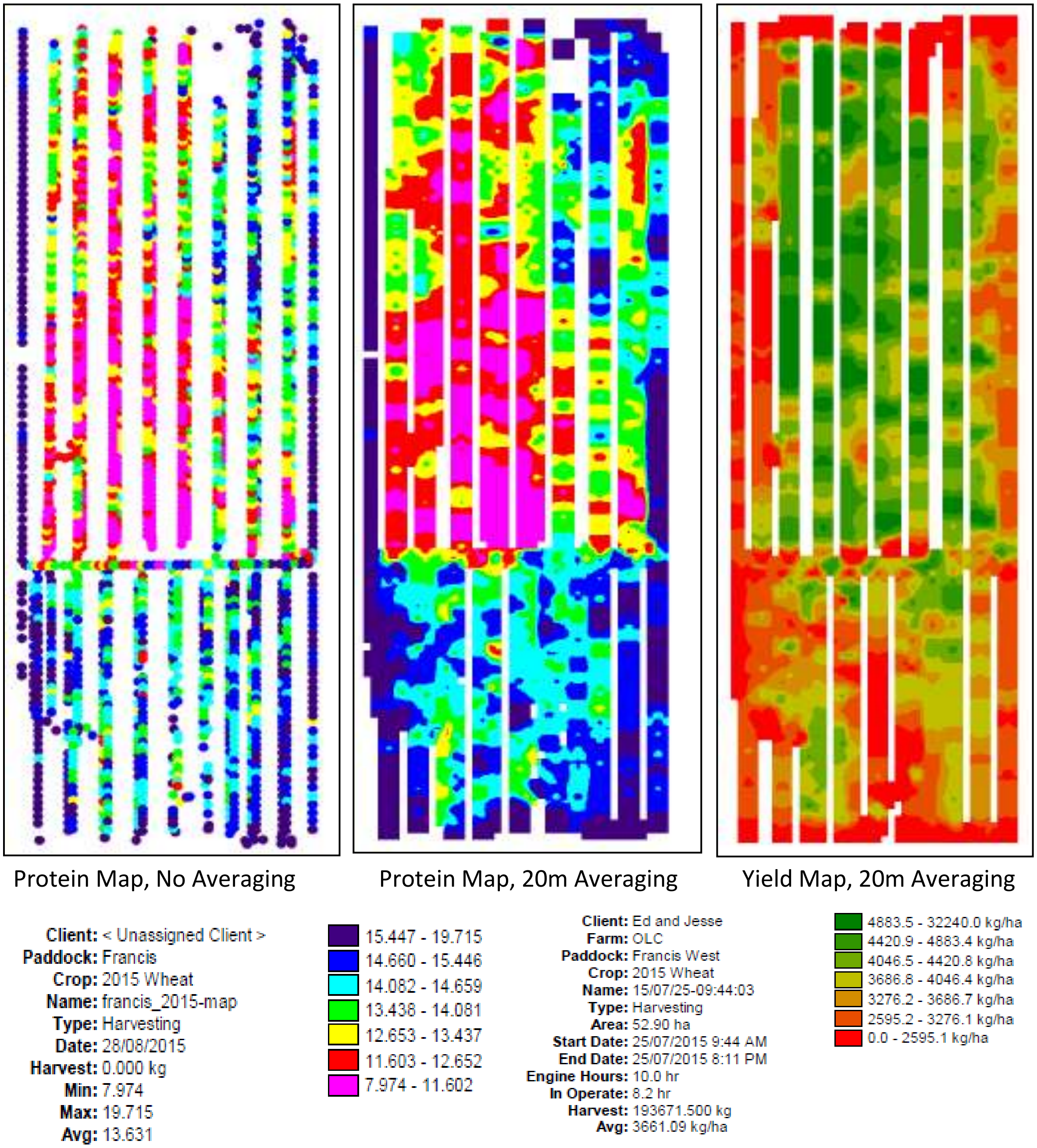


Figure 15 Protein and Yield in the Francis Field with and without averaging.

The Francis Field shows a distinct shift in the protein levels across the Field. It is difficult to interpret this data. The Yield Map shows an inverse correlation between the Protein and Yield for most of the Field, however there are sections near the borders which show low Protein and low Yield.

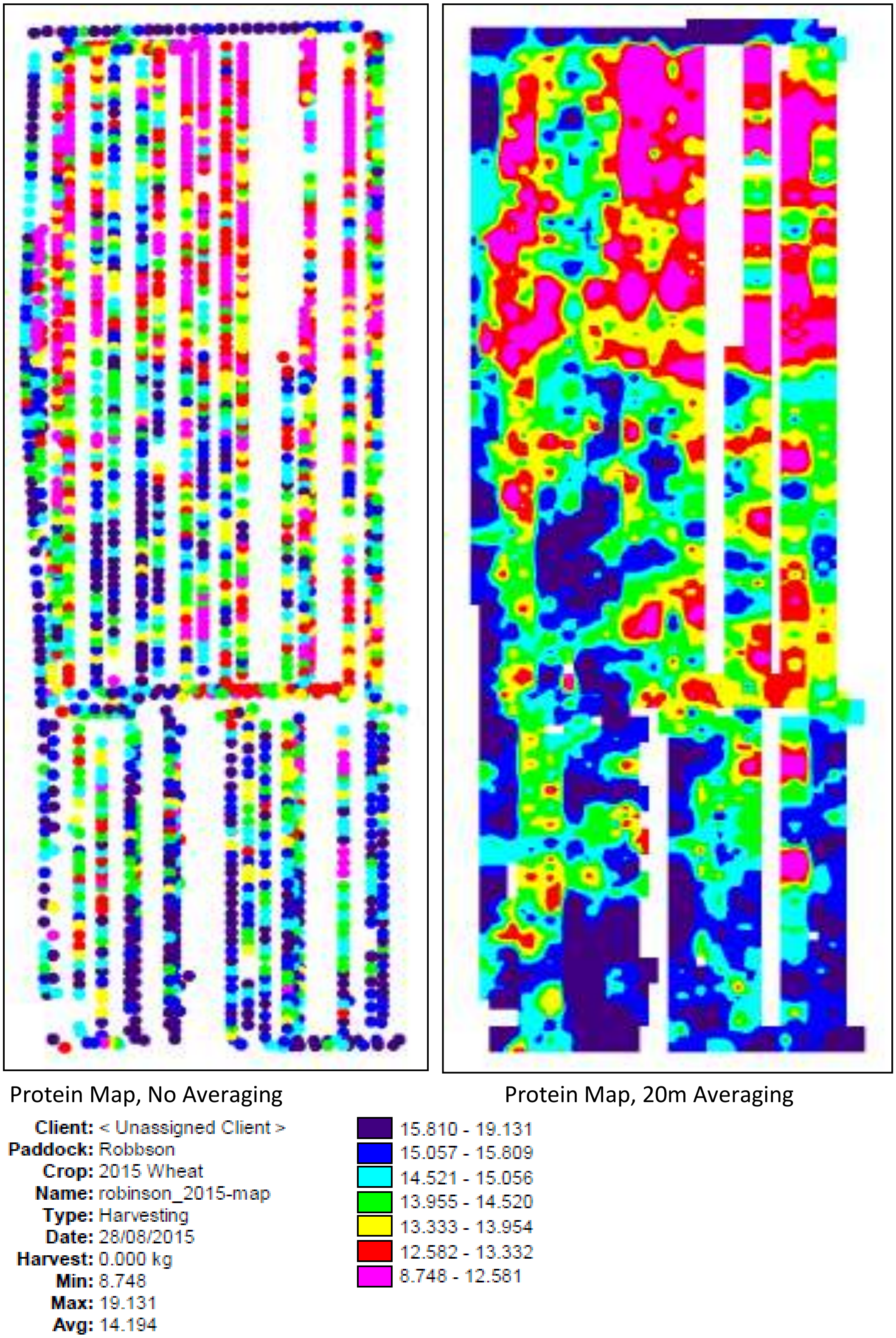
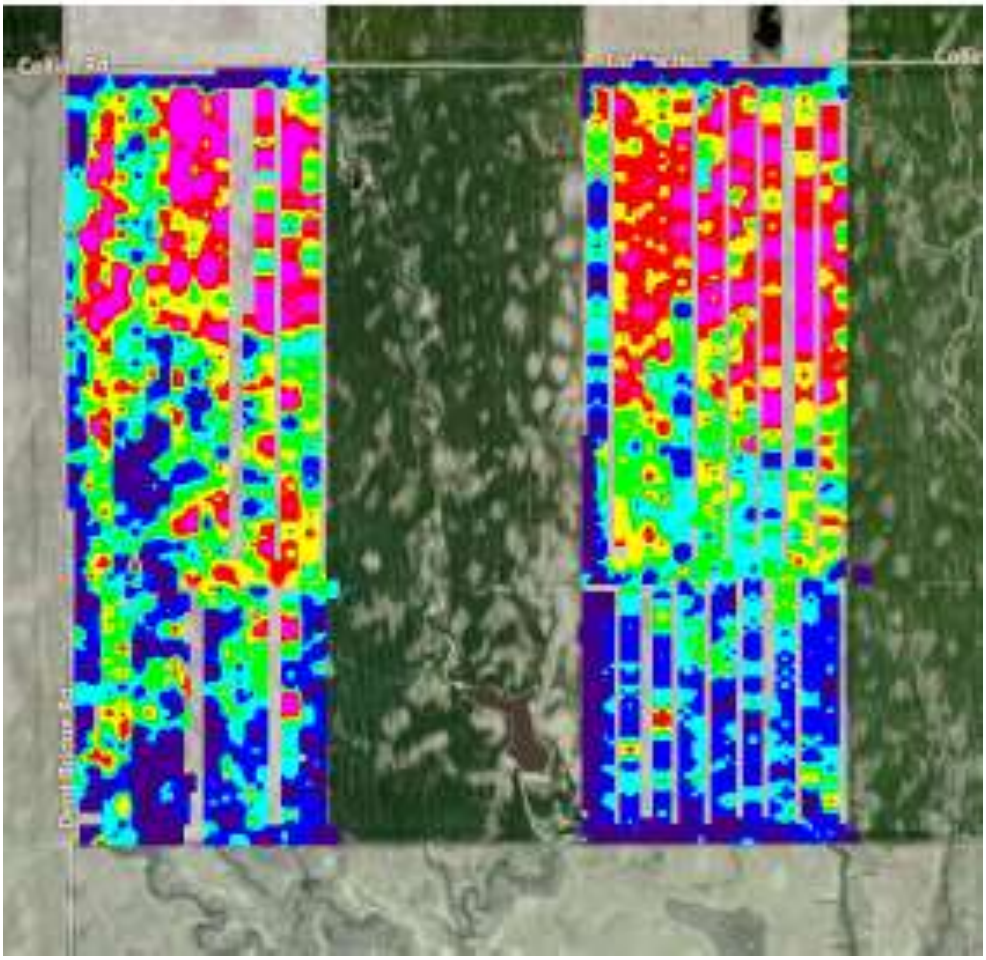


Figure 16.Protein in the Robinson Field with and without averaging.

The Robinson Field has three separate zones for high, medium and low protein. Like the Carlin Field, the Robinson Field could provide a premium payment for protein if the grain were segregated. Note that there was no Yield data available across the Robinson Field.

Figure 17 shows the Carlin and Robinson maps overlaid on the satellite image of the Wood property.



The Fields are part of the same field. As such the similarity in the three zones makes sense. It was noted that these Fields were stripped on consecutive days. The fact that the zones are reproduced demonstrates that the CropScan 3000H is reproducibly measuring the protein across and between Fields.

Conclusion:

The assessment of the performance of the CropScan 3000H to measure protein and moisture in wheat as it is stripped in a combine harvester is considered very positive. The data shows that the CropScan 3000H predicted protein and moisture to an accuracy of 0.35% and 0.34% respectively. The protein maps across four fields shows zones where the protein of the wheat could be selectively harvested and segregated in order to optimize payments. The potential use of these protein maps with yield maps to develop variable rate nitrogen applications, adds to the benefit of using the CropScan 3000H On Combine Analyzer to measure protein and moisture in real time.