Developments in on-harvester quality monitoring

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Summary

Near Infrared Transmission spectroscopy is used throughout the world to measure protein, moisture and oil in cereal grains and oil seeds. In recent years, there has been a growing trend amongst Australian growers to set up their own on-farm storage systems and to use portable or benchtop NIR analysers to assess the quality and therefore the value of their crops.

Over the last three years, Next Instruments, an Australian company that designs and manufactures NIR analysers for farmers and grain processors, has been finalising the development of an On-Combine NIR analyser. This system, called the CropScan 3000H On-Combine Analyser, has been designed to measure grain collected from the clean grain elevator every 11 seconds and report the protein, moisture and oil in real time on a touch screen PC located inside the combine's cabin. By collecting the GPS readings at the same time as the NIR data is generated, then real time protein paddock maps can be displayed on the in cabin screen. This has provided users with the ability to segregate grain in the paddock as well as make decisions on which silos or bins to store their grain.

As for Precision Agriculture, the benefit of the system is to provide Protein Paddock Maps that can be compared with the yield and moisture maps in order to optimize the use of Nitrogen fertilizer through variable-rate fertilization application.

This paper presents a review of the CropScan 3000H On-Combine Analyser and provides examples of two paddocks where protein, moisture and yield data was collected using the system during the 2014 harvest.

Instrument Description

Figure 1 shows a schematic of the CropScan 3000H system. The Sampling Head is a device that is mounted to the clean grain elevator so that grain falls into the top of the sample head from the up side of the elevator. Light passes through the trapped grain and is collected using a fibre optic bundle and passed back to the CropScan Near Infrared spectrometer that is located inside the cabin. The grain is released into the down side of the elevator. The protein, moisture and oil data are sent to the Touch Screen PC which also takes the GPS coordinates from a GPS transponder. This cycle is repeated at a frequency of approximately 5 times per minute, i.e. 11-14 seconds per measurement.

The data is combined to generate Protein paddock maps, real time tables showing the each protein, moisture and oil reading, a moving average and the bin average. A proximity sensor located on the out loading auger is activated when the auger is extended in order to empty the bin. This signal tells the CropScan PC to calculate and

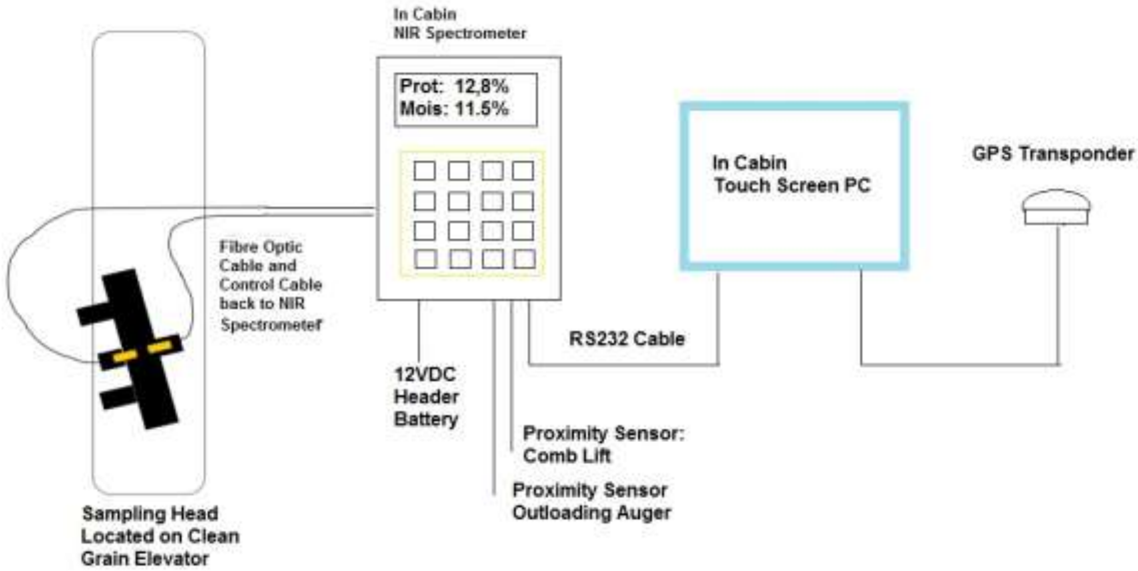

Figure 1. CropScan 3000H schematic.

then reset the bin averages. This data is then sent to the Cloud where it can be viewed remotely using a smart phone, an Ipad or a PC located in the office or weighbridge shed.

The first CropScan 2000H On Combine analyser was introduced in 2005. The major developments of the new CropScan 3000H lie in the design of the Sampling Head, the software and communications options. The Sampling Head (Figure 2) has a wide flow chamber with steel flaps located at the top and bottom of the chamber to trap and release the grain. In comparison with the original designs, this new Sample Head has proven to be extremely rugged and reliable. Whereas chocking of the grain was always a problem in previous designs, the new Sampling Head allows grain to flow freely through the system.

The CropScan NIR spectrometer is based on our proven diode array optics and electronics that has been installed in over 1500 benchtop analysers over the last 15 years. The major benefit the CropScan NIR spectrometer lies in that calibrations developed on a master instrument can be transferred to all of our NIR analysers. This means that new calibrations can be download to installed CropScan 3000H analysers around the world. The extremely high performance of this NIR spectrometer is a very important consideration. The system collects the spectral scans in less than 2 seconds where as the total time to collect a reading is 11 seconds due to the time required to fill and empty the chamber. The extremely high signal to noise ratio of our NIR spectrometer enables the CropScan 3000H to collect a large number of data points across the paddock.

Figure 2. Sampling Head.

Figure 3 shows the user interface on the Touch Screen PC located in the cabin. Real-time protein and moisture readings collected (Figure 3a). Figure 3b shows the real time protein paddock map based on the data from Figure 3a.

Once the data has been posted to the internet, a grower, broker or even a buyer can view the data by connecting to our CropNet web site. Figure 4 shows the CropNet user interface with plots for each bin load shown in real time.

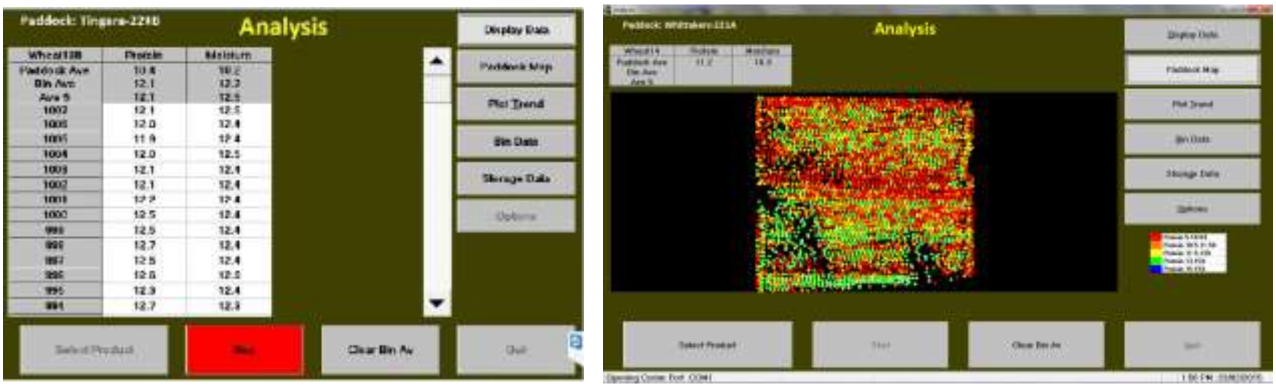

Figure 3. (a) Protein and moisture in wheat (b) Protein paddock map.

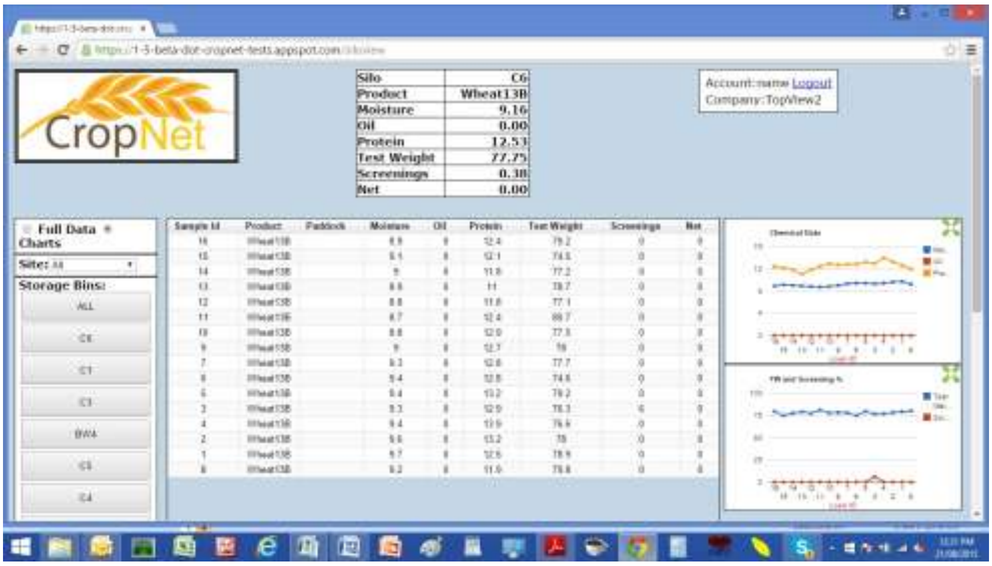

Figure 4. CropNet screen.

Precision Agriculture

As for the relevance to Precision Agriculture, there are a number of angles where benefits can be identified.

- The ability to monitor grain quality at a high spatial density means that differential harvesting or storage partitioning based on quality parameters becomes possible.
- Taking it a step further and mapping the data means that in combination with yield and moisture maps, true site-specific gross margin maps can be created.
- By knowing that for every 1kg of protein produced, there is 0.175kg of Nitrogen removed from the soil, then N-removal maps can be constructed and used in mass-balance fertiliser requirement calculations.

- The full impact of N trials or VRA applications on crop production and profitability can be accounted.
- Overlaying protein paddock maps with yield and other data can provide diagnostic insights into the changes in availability and uptake of Nitrogen from across a paddock.

An example of the payback potential for farmers using the CropScan 3000H for in field segregation and blending are shown below.

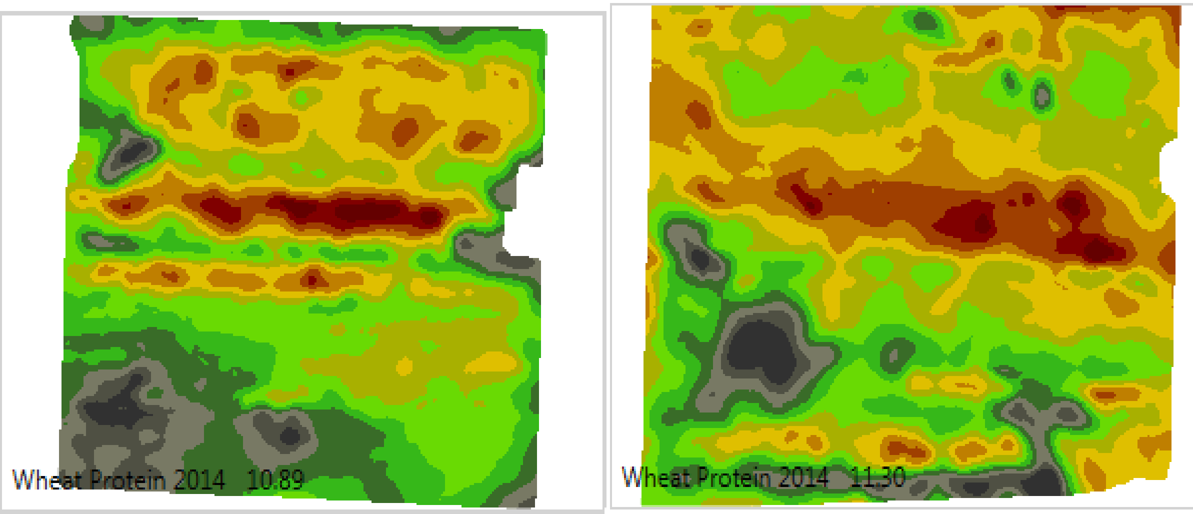

Figure 5. Protein Paddock Maps, a) 221A, b) 221B.

- **Paddocks 221A & 221B**
- **Total area 185ha**
- **Average Yield = 4.5t/ha =832.5t**
- **Top Half of each paddock was reading below 10.5% protein**
- **Bottom half of paddock was reading above 10.5% protein**
- **By blending we delivered 17 out of 18 truck loads as APW grade over ASW**
- **Increased Profit by blending:**
- **= $6900 $37.29/ha**

These two paddocks shown in figures 5a and 5b were stripped such that the grain was segregated based on the protein readings from the CropScan 3000H analyser. The low protein grain, ie, ASW grade, was placed into one field bin where as the higher protein grain, ie, APW grade was placed into a second bin. The grain from the two bins were then loaded into the truck so that the protein level averaged out to be above 10.5%, ie, APW grade. The grower reported that 17 out of 18 loads taken to the Viterra silo, were accepted as APW. The grower believed that without in field segregation and blending there would most likely have been 9 ASW and 9 APW loads. As such he estimated that he received an extra $6900 revenue from these two paddock or $37.29/ha.

The agronomic insights afforded by the final point are based on the observation that the relationship between protein and yield is in general considered to be the result of a process whereby the total grain protein is diluted to a site-specific extent by the total carbohydrate stored in the seeds. The total grain protein and the total carbohydrate production are predominantly driven by soil Nitrogen and moisture availability. Increasing N supply in N-limited situations with a non-limiting soil moisture supply will predominantly increase grain yield, while where soil moisture is severely limited, the same changes to N supply will be predominantly focused into increased protein.

Protein, moisture and yield data collected from two paddocks on the York Peninsula during the 2014 harvest are used to explore this potential benefit. The data is shown in Figures 6 and 7. It can be seen from Figure 6a and 6b that there is a significant inverse relationship between the yield and protein at the whole paddock scale (r = -0.46). This general relationship follows the dilution theory, and given the average protein content for the paddock is relatively low (10.3%) for a variety with AH classification, suggests that in general the N-supply was limited and an increase in N across the paddock would be warranted

However, a closer look using local correlation analysis (Figures 6d and 6e) shows that within this paddock the areas where the relationship is significantly negative are areas where the yield is lower than average and the protein higher than average. In these areas it appears that effective access to N has been relatively uniform within the area but the access to available moisture has been variably limited by soil/landscape conditions. Applying more N in these areas within the paddock, before ascertain the cause of the yield reduction, may be a waste.

A neighboring paddock shows a slightly different story. It can be seen from the maps in Figure 7a and 7b that there is little relationship obvious between the yield and protein at the whole paddock scale (r = -0.02) and the implications for N management are difficult to extract. On closer examination with the local correlation analysis (Figure 7d and 7e) it

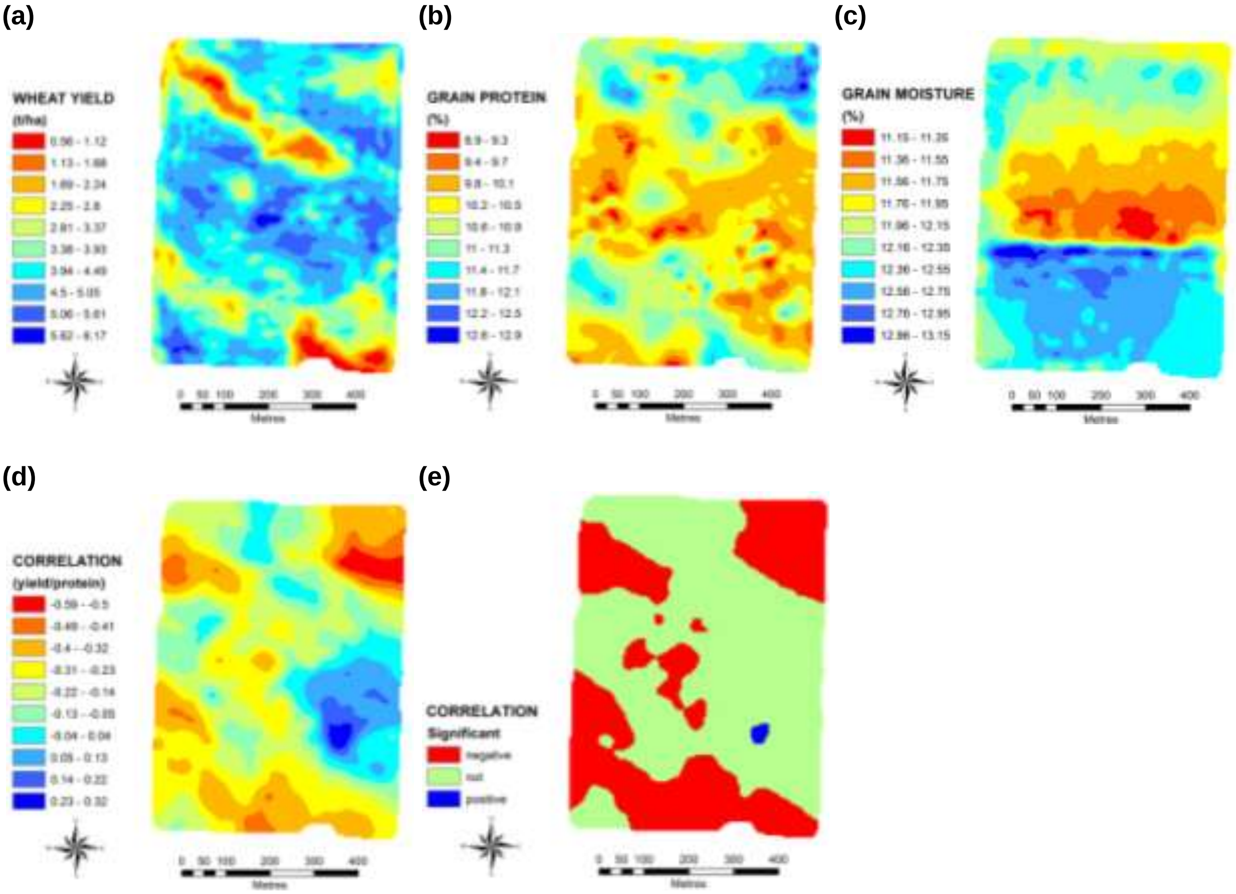

Figure 6. Data for paddock 146B (a) wheat yield, (b) grain protein, (c) grain moisture, (d) local correlation between yield and protein, (e) local areas with significant correlation values.

becomes obvious that there are areas with positive relationships and areas with negative relationships between yield and protein. Areas with negative relationships at this scale again identify areas were access to available moisture has been variably limited by soil/landscape conditions. Areas with a positive relationship suggest that N supply was limiting and these areas should be considered for increased N application in future.

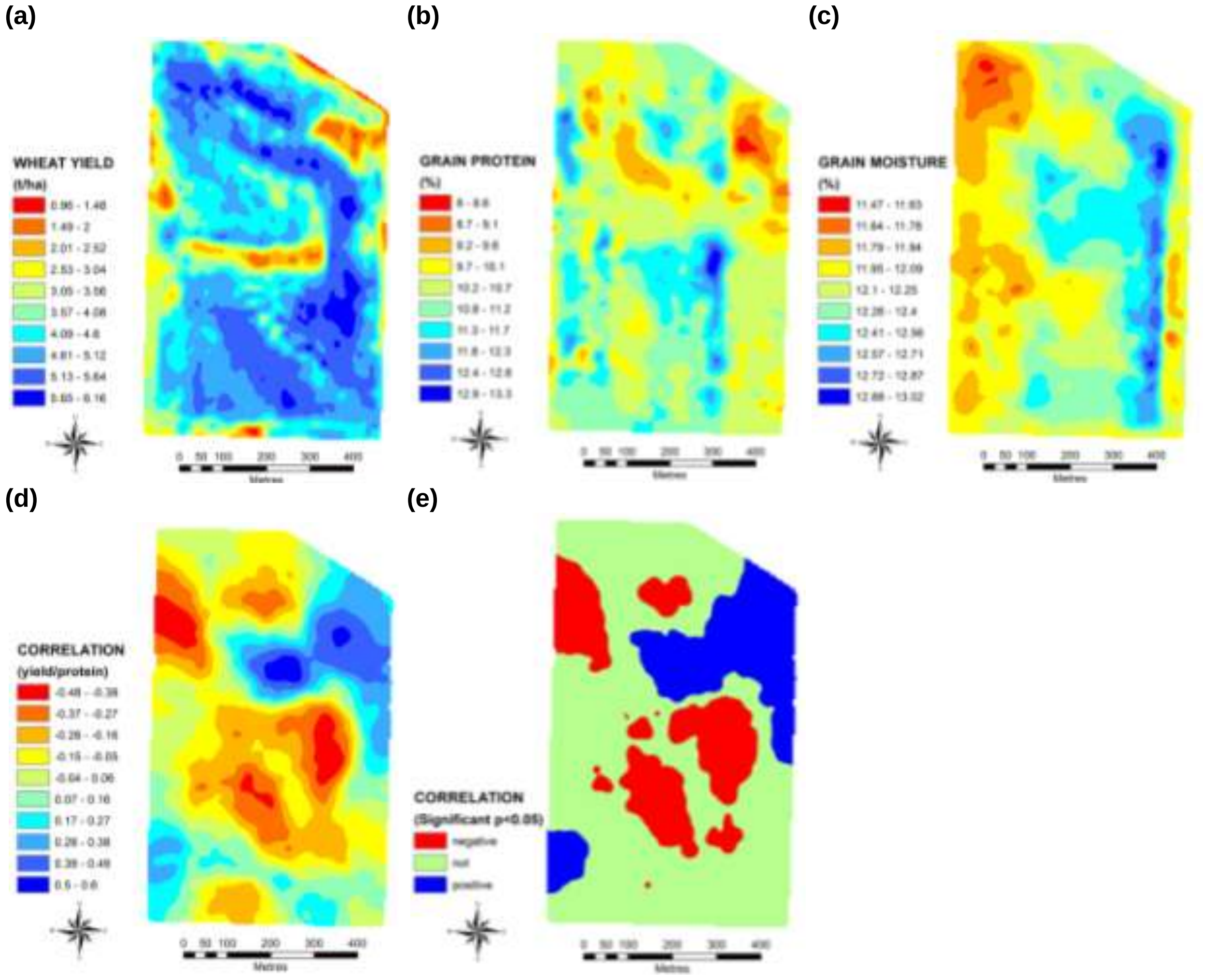

Figure 6. Data for paddock 146A (a) wheat yield, (b) grain protein, (c) grain moisture, (d) local correlation between yield and protein, (e) area with significant correlation values.

Conclusion:

The application of Near Infrared technology to a combine harvester has not been trivial. The development project began in 2003 and after several years of trials and tribulations, we placed the project in the too hard basket. Thanks to the perseverance of Ashley Wakefield, (SA), Paul Hicks(WA) and Graham Popperwell (WA), we took up the challenge and finally in 2013 came up with a system that was reliable and accurate.

There are 23 CropScan 3000H system in use, both in Australia and overseas. The data collected from these systems shows conclusively that this technology is now viable. The ROI based on in paddock segregation shows that a system can pay for itself in one harvest. Moreover the agronomic information that is available through the use of this technology adds a complete other layer of economic justification.