When the Penny Drops…

The Protein/ Nitrogen/Yield Balance.

Why should farmers measure protein directly on the combine

CropScan

NextInstruments

Introduction:

Farmers have commented that if they bought everything that was going to save them money, then they would go broke. No wonder farmers are sceptical about new claims from suppliers that their new product, invention or service is the next big thing in agriculture. So is this article guilty of the same promise. Hopefully not.
This article sets out a number of research findings going back for more than 50 years about the importance of getting the Yield and Protein Balance correct in cereal crops.

What is the Yield and Protein Balance:

The growth and development of plants undergoes a number of stages; Emergence, Tillering, Flowering, Filling

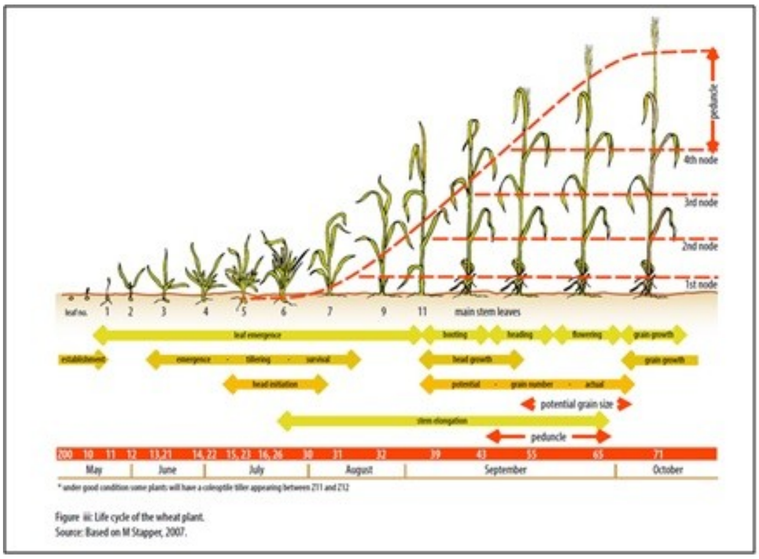

Fig 1. Plant Growth Cycle

Water is the major driver for successful plant and seed development. There are many other nutrients that influence the plants development, but Nitrogen is the definitely the next most important driver for pant development.

The primary objective of all plants is to reproduce themselves by producing seeds to carry forward the genetic information in the next crop. Plants are programmed through millions of years of evolution to modify the plants growth cycle to ensure that some seeds are produced to procreate the next crop. As such if there are not sufficient nutrients available at the various stages of development, then the plant will reduce the number of stems, heads or even seeds to ensure that what nutrients are available are used to ensure that seeds are eventually produced and released. These changes to the plants development effect the Yield potential for the plant. Nitrogen is the key nutrient that dictates how the plant will make these changes during the stages of the plant development.

Wheat proteins are composed of approximately 17.5% of Nitrogen by weight. As such measuring the Protein in the seeds at harvest provides a direct measurement of the availability and uptake of Nitrogen in the plants. By measuring protein in real-time on a combine harvester and combining the data with the yield and GPS coordinates, provides a means of generating field maps including: Protein, Yield, Nitrogen Removal, Gross Margin and Protein/Yield Correlation. These maps provide a means of establishing zones where Nitrogen has been deficient and has caused either or both yield and protein to be less than the field average. Figure 2 shows Protein/Yield Correlation Quadrant map for a wheat field in South Australia. The four quadrants are:

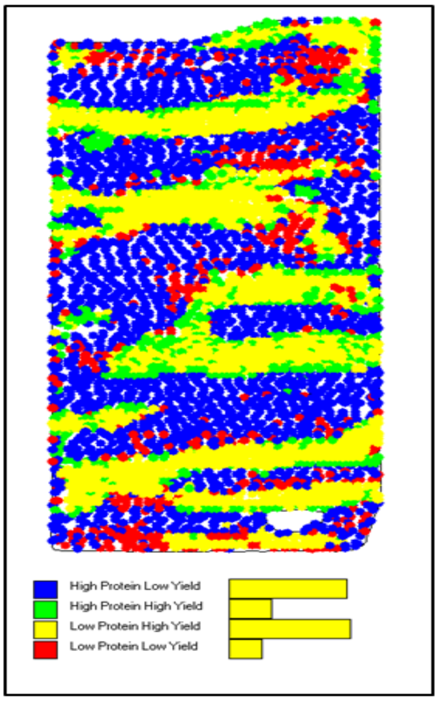

Fig 2 Protein/Yield Correlation Map

- High Protein/Low Yield
- Low Protein/High Yield
- Low Protein/Low Yield
- High Protein/High Yield

A discussion of the causes for each quadrant is complex because there are several inter-related parameters that influence the development of the plant. A simplistic yet meaningful explanation is presented below;

- High Yield and Low Protein: There was sufficient Nitrogen available for emergence and tiller formation but not enough to fill the grain and produce higher protein.
- Low Yield and High Protein: There was sufficient Nitrogen available in the reproductive and grain filling stage to

produce protein in the seeds. However there is something else limiting the Yield such as low rainfall or poor rainfall distribution, sandy soil texture, or some problem with the soil compaction, pH or salinity.

- Low Yield and Low Protein: The yield has been limited by insufficient Nitrogen in the soil at leaf emergence and then in the growth phase. Other nutrient deficiencies may also be impacting the yield.
- High Yield and High Protein: There was sufficient Nitrogen available for development of tillers and through the entire plant development to achieve the full yield potential and to produce higher protein in the seeds, ie, "Sweet Spot".

What is the significance of Protein to Yield Balance.

In 2013, Greg McDonald and Peter Hooper, University of Adelaide, School of Agriculture, wrote an article for the GRDC titled: Nitrogen Decisions – Guidelines and rules of thumb. They referenced a paper written in 1963 by JS Russell for the Australian Journal of Experimental Agriculture and Animal Husbandry where he "described the idea of using grain protein concentration to assess the likelihood of N responsiveness in wheat cropping systems. He suggested that yield responses were most likely when grin protein concentration was < 11.4%". McDonald and Hooper went on to say, "Based on recent trial data, the general conclusion still appears valid: 100% of all trials where grain protein concentration of the unfertilised control was <8.5% were responsive to N and would have given yield response of 14kg/kg N. When grain protein concentration was >11.5%, only 32% of the trials were responsive to N and the mean yield response was zero". They concluded; " While this relationship can't be used to make in-season N decisions it may be useful in helping to assess the degree of N stress during the previous season and making post-harvest assessments of N management strategies, which can help in future plannings."

Steve Larocque, Beyond Agronomy, Alberta, Canada, publishes a newsletter that is read by more than 8000 precision farmers and agronomists. Mr Larocque pointed out in his newsletter that there is a fine balance in applying Nitrogen to a barley crop where the objective is to optimize the yield and restrict the protein to less than 13%. He states, "The hard part is finding the right nitrogen rate to produce maximum yield with a protein that falls below 13% but higher than 12%. When you're malt protein is lower than 12.5% you know you're leaving yield on the table. If you shoot too high you end up with high protein and no malt selection." Mr Larocque referred to the balance as the "Sweet Spot" where the yield was optimized and the protein grade realised the highest crop payments,

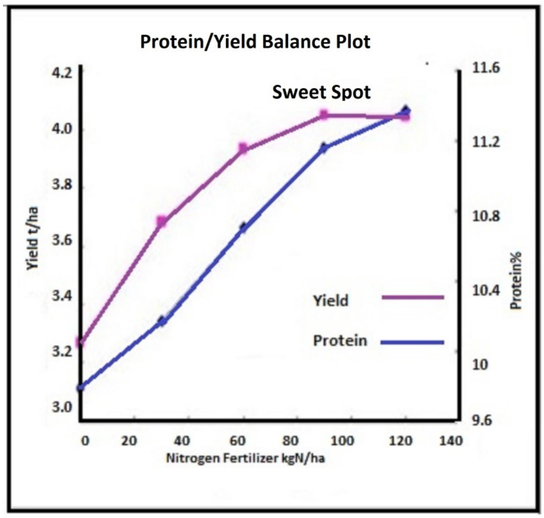

Figure 3. Grain yield (t/ha) and protein concentration (%) from 10 wheat varieties with 0, 30, 60, 90 and 120 kg/ha applied nitrogen in a trial at Parkes in 2011.(Brill et al,

Thane Pringle, Independent Precision Agriculture, made a presentation to explain how Nitrogen is used by plants and how Nitrogen is made available in soil to the plants. He showed a plot (Figure 3.) of Yield vs Nitrogen Fertilizer Application vs Protein content of the grain. Brill et al state in their original paper, "As the rate of N supply is increased, yield will generally increase to a maximum level, whereas protein may continue to increase with further N application. This is demonstrated by the results from a trial at Parkes in 2011, sown as part of the GRDC- funded Variety Specific Agronomy Project (Figure 3). Wheat yield was responsive to N fertiliser but at a reducing rate where N was applied in 30 kg/ha increments. Yield was maximised with N application of 90 kg/ha. Protein increased linearly for each 30 kg/ha increment up to 120 kg/ha N. In this trial, yield appeared to be maximised at a grain protein concentration of 11.2 %, a useful 'rule of thumb' in deciding whether a crop was yield limited by N. "

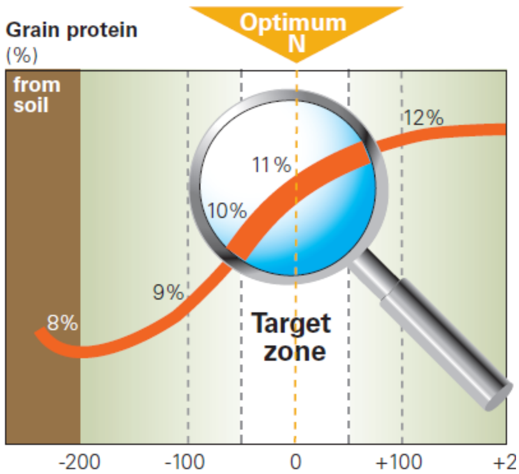

Figure 4. Nitrogen For Winter Wheats—Management Guidelines, Sylvester-Bradley, 2009

Professor Roger Sylvester-Bradley, UK, in HGCW booklet titled Nitrogen for Winter Wheats—Management Guidelines, 2009, states,
"Grain protein with optimum N for yield in feed varieties is consistently about 11% (1.9%N). Breadmaking varieties optimise for yield at around 12% protein and often need extra N to achieve a market specification of over 13%. Low grain protein – less than 10% for feed

The yield map shows a large area where the yield is high, i.e., the blue areas. The protein map shows that these same areas had the lowest protein levels. This scenario could suggest that in these areas the Nitrogen was available for early growth and Tiller development, but there was not enough Nitrogen at the Grain Filling phase.

As well, in these areas the protein levels are less than 10.5%, making it ASW grade. In 2015 the difference in price between ASW and APW grades was $30/tonne. A top dressing of Nitrogen towards the later phase of plant growth could have increased the protein levels and thereby raised the grade to APW or even H2. Top dressing at this stage would have increased payment revenues significantly by several thousand dollars for this field.

The soil moisture profile, rain fall history, soil types and fertilization history are important factors in understanding what has driven the plant growth in this field. A look at the Nitrogen Removal map shows that there are three zones, i.e., Red Zone 1: left hand side, Blue Zone 2: top right hand corner, Green Zone 3: bottom right hand corner. Reviewing the soil types in these three zones may lead to better timing of fertilizer application so that Nitrogen is not leached from the root zones by rain shortly after planting. Reviewing the fertilizer history for the field may show that top dressing towards the end of the growth phase would have ensured fully developed plants followed by complete grain filling.
In the following season, the Nitrogen Removal map could be used to fertilize the field more effectively so that the three zones are more consistent in terms of yield and protein. Although reduction of Nitrogen fertilizer usage may be possible, it is more likely that the fertilizer could be applied more effectively and results in higher yield at the optimum protein grade.

Case Study 1. Using Protein Maps to develop a simple Variable Rate Nitrogen Fertilization prescription for a wheat field in central NSW

Broden Holland, Young, NSW, installed a Model 3000H Grain Analyser with his new CaseIH 7240 Combine leading up to the 2016 harvest. The Model 3000H collected protein, oil and moisture data at approximately every 15-20 meters across their 4500ha farm where they grow wheat and canola. Combining historical yield data and protein data they have been able to develop three zones to apply Urea at three different rates as top dressing. Broden quickly linked low protein response to crop performance, he developed a simple application strategy:

Urea Application (kg/ha)

Blue Zone: Protein < 10.5 = 120 kg

Yellow Zone: Protein 10.6 -11.5 = 100 kg

Red Zone: Protein 11.5 - 13.0 = 80 kg

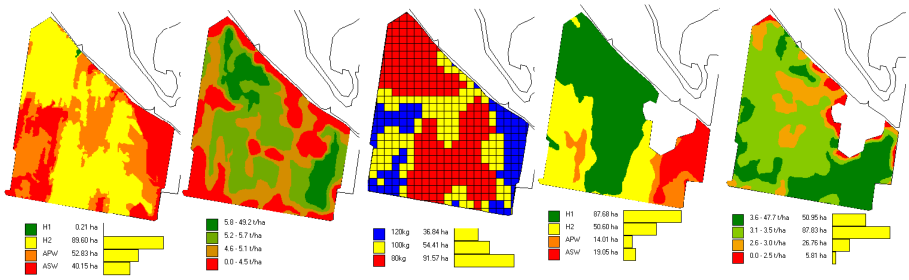

Fig 10. Protein 2016 Yield 2016 Urea Application Fig 11. 2017 **Protein 2017 Yield**

By simply converting protein data collected from the Model 3000H into a zonal Urea application, he was able to increase the protein levels across the fields. In 2016 the field shown in Figure 10 had only .21 hectares that produced H1 grade wheat. Where as in 2017, 87.9 hectares realized H1 grade. As well, there were 38.8 hectares that realized APW grade in 2016 and H2 grade in 2017. A rough estimate of the increase in crop payments from this field were $2482, or $13.60 /ha.

Assessing the yield and protein response post harvest is critical to assess whether the VRA had a positive or negative out come. Figure 11 shows the protein and yield response and statistics from the variable rate application of Urea in 2017. The 2017 yield response shows to be 40% reduction in the variation in yield across the field as compared with the 2016 yield map.

Case Study 2: How to turn Yield and Protein maps into Variable Rate Fertilization prescriptions.
Leeton Ryan, Woomalang, Victoria, fitted a CropScan 3000H Grain Analyser to a CaseIH 8240 combine in the 2016. The 3000H recorded protein, moisture and oil, along with the longitude and latitude every 8-12 seconds as the combine strips the grain. The yield data was collected by the on board yield monitor.

So what is the message that all these agronomist and researchers are stating?

If the protein concentration in the final grains seeds is less than 11.5% in wheat and 12% in barley then the crop has not had sufficient Nitrogen available to achieve the full yield potential. The soil Nitrogen may have been low or it may not have been accessible to the plant at the correct times. Nonetheless, all the research supports the premise that Yield Response would have been positive to N fertilization if the protein levels in the grains is less than 11.5%.

Relationship between Nitrogen and Protein:

Protein is a generic terms used to characterise a large class of bio molecules that have common chemical characteristics. In truth, proteins are polymer chains formed from Peptides which are made up of Amino Acids. Humans and animals eat proteins so that they can digest the proteins and release the amino acids from them in order to rebuild body tissues, e.g., skin, muscle, organs etc. Plants such as wheat, soy beans, corn, rice etc make amino acids which after digestion in the human or animal gut, then go to make peptides which then go to make proteins.

The proteins found in the seeds of a plant have approximately 16-18% Nitrogen in them. As such for every load of grain stripped from a field, then there is a portion of the load that is protein and Nitrogen. For example, if the protein content of the soy beans is 20% then 200 kg of each tonne of grain is protein. And out of this 200 kg of protein there is 16% Nitrogen, i.e., 32kg. This means that for every tonne of soy beans harvested, 32kg of Nitrogen is removed from the soil. Of course Nitrogen is found in other parts of the plant tissue, but in the majority of plants Nitrogen ends up in the seeds as protein.

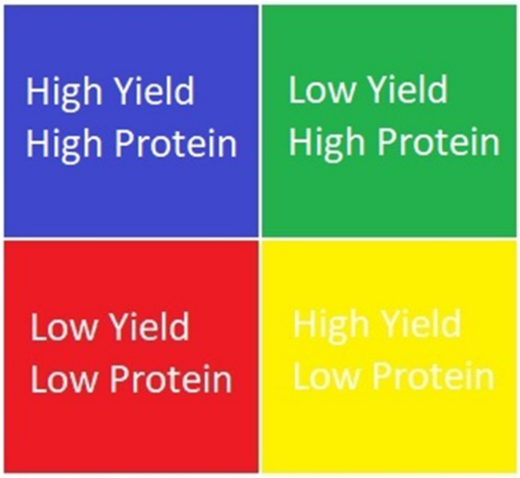

Fig 5. Possible Scenarios for Protein and Yield combinations.

Protein/Yield Correlation:

The chart shows 4 scenarios for the correlation between Protein and Yield. There are four implications for these scenarios as were discussed above. Based on these four scenarios, a field can be mapped by the correlation between Protein and Yield.

Figures 6 and 7 are Protein and Yield maps for a wheat field in central NSW. Figure 8 shows the plot of the correlation between Protein and Yield within a 50m diameter. In other words, the correlation, R, for the Protein and Yield collected within 50m diameter circles in the field are plotted for each 50m diameter circle. The plot has four colours, i.e. Blue: High Yield/High Protein, Red: Low Yield/Low Protein, Green: Low Yield/High Protein, Yellow: High Yield/Low Protein.

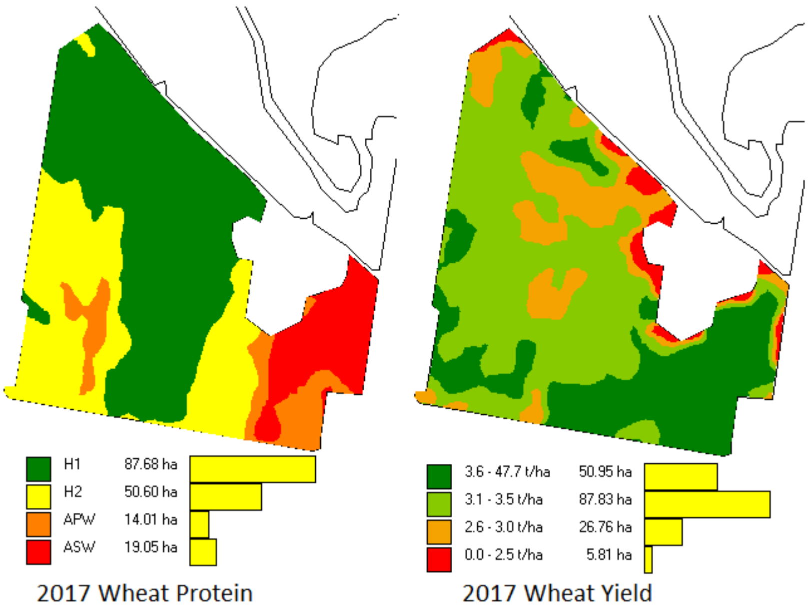

Fig 6 Protein and Yield Maps for a Wheat field in central NSW

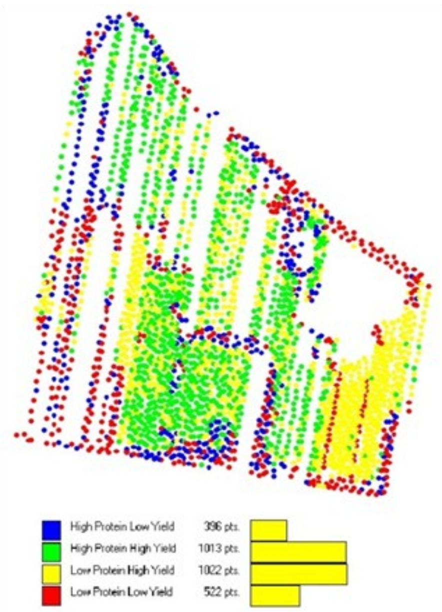

Fig 7 Protein/Yield Correlation Map

The green areas in the Correlation map are the "Sweet Spots", i.e. High Yield and High Protein. The Red areas are the worst for Yield and Protein. Since the fertilizer application was a blanket rate in 2017, the question that must be asked, "Why does 50% of the field produce 3.5tonne per ha where as some areas produce only 2.5 tonne per ha. The answer most likely lies in the soil types in these areas. By examining the soil types and the geography in the Blue, Red and Yellow areas, it may be possible to understand why there was not sufficient Nitrogen available to achieve the optimum Yield and Protein. Next year, this information may be used to try a Variable Rate N Fertilizer application in these areas.

Protein and Yield tell a more complete story:

Yield maps measure the mass of grain that is stripped per acre or hectare. Yet for the last 25 years yield maps have been used as a proxy for Nitrogen Uptake. Protein maps provides an assessment of the plant's performance as a function of the available Nitrogen. Together Protein and Yield Maps provide a more complete picture of the Nitrogen Uptake and Availability across the fields.

Michael Ayres, Injecta, Adelaide, SA, stated "The Yield map correlates directly to soil performance and the Protein map is a very good proxy for plant performance. The Nitrogen data is what makes everything else fit together, ie, productivity and performance. The on combine protein analyser is a tool of exceptional value whose true value is only just starting to be well enough understood"

In a perfect world there needs to be an instrument that measures the Nitrogen in the soil throughout the plants growth and development cycle. At this time, there is no instrument that can perform such a measurement in real-time. However an On Combine NIR Analyser such as the CropScan 3300H, is designed to measure protein, oil and moisture in grain and oil seeds as they are harvested. Since protein is a direct measure of the Nitrogen in the seeds, then this instrument can be used to generate a Nitrogen Removal Map. Figure 9 shows a Protein map, a Yield map and Nitrogen Uptake map for a wheat field in South Australia.

Fig 8 CropScan 3300H installed on a CASE combine

The yield map shows that there are large areas where the yield is low, i.e., red areas. Based on the yield map, the conclusion would be that more Nitrogen is needed in these areas. However the protein map shows that the same areas had high protein, i.e., blue areas. From the discussion above, it can now be seen that there was sufficient Nitrogen to fill the grain with protein. The yield map and the protein maps appear to be contradictory. There may be several reasons including soil moisture effects or other nutrient limiting factors. It might also be that the plant could not access there sufficient Nitrogen from the soil at the time of planting and up to the end of the Tiller phase, thus limiting the development of Tillers. However the story is not finished yet.

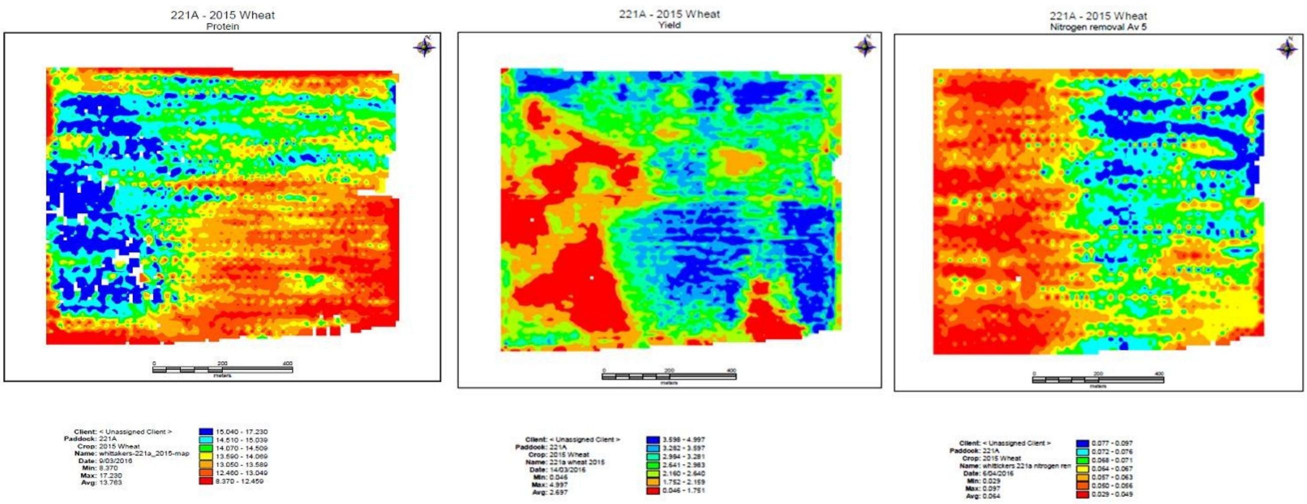

Fig 9 Protein, Yield and Nitrogen Removal Maps for a field on the York Peninsula, SA.

Based on the 2016 maps, Leeton determined three zones in the field whereby he could apply Nitrogen in the form of Urea at rates related to the amount of Nitrogen removed from the field.

2017 Urea Application (kg/ha)
Blue Zone: Protein < 10.5 = 80 kg
Yellow Zone: Protein < 11.5 = 60 kg
Red Zone: Protein < 13.0 = 40 kg

Leeton's objectives are to use this simple VRF strategy to top dress his fields so that he can increase his yield and protein payments.

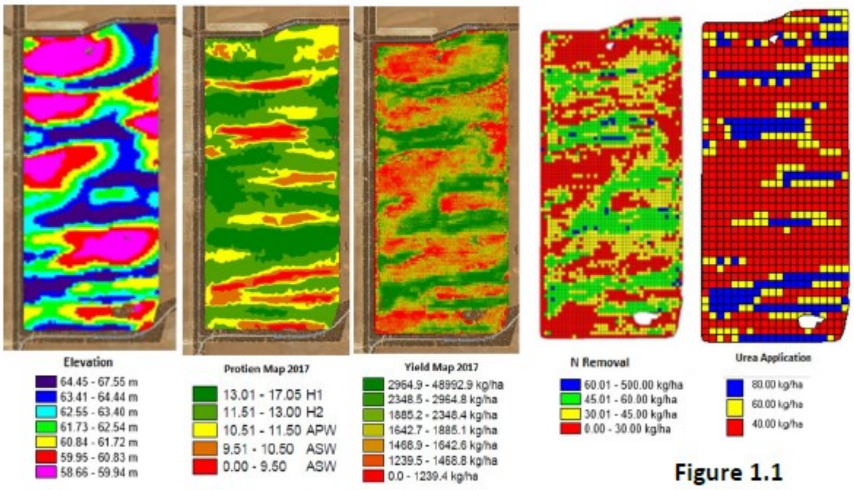

Fig 12 Maps from a Wheat field in western Victoria,

Case Study 3: Protein/Yield Correlation Maps for Canadian Soybeans.
Adam Gurr, Brandon, Manitoba, installed a CropScan 3000H in 2017 onto his Claas Lexion combine. His soybean maps provide examples of how Protein varies in crops other than cereals. Figure 13, 14, 15 and 16 show maps for Protein, Yield, Protein/Yield Correlation and a VFR prescription for Nitrogen prescription based on these maps.
The protein varies across this field from 20% to 37% with an average of 32% for loads delivered to the elevator. It is generally expected that soybeans will exhibit an inverse relation between Yield and Protein, i.e. the Dilution Theory. Figure 15, Yield/Protein Correlation Map, shows areas in the field based on the correlation between Protein and Yield. The Green and Red areas do not follow the Dilution Theory. The Yellow areas are where the yield was above the average for the field and the protein was less than the average.

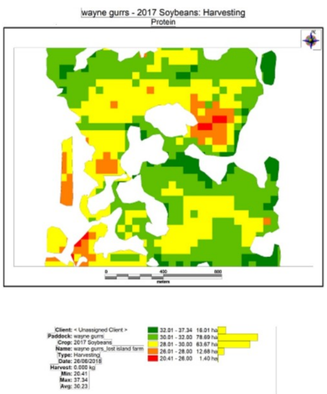

Fig 13 Protein

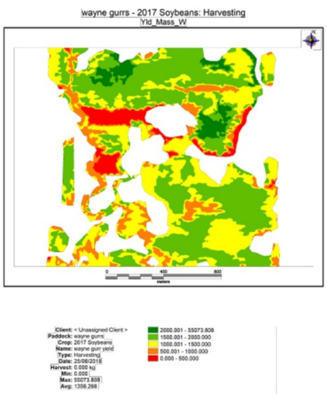

Fig 14 Yield

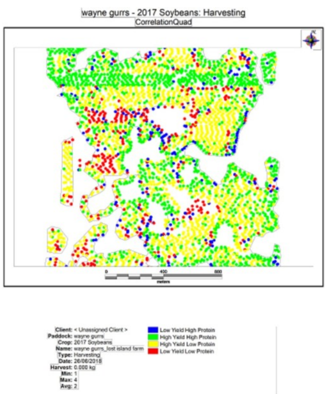

Fig 15 Protein/Yield Correl

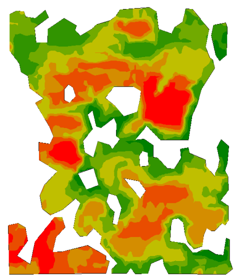

Fig 16 N Prescription

Conclusion:

Farmers generally farm for 40 harvests. As such they only get 40 chances to "Get it Right". In order to change things, then they need tools to be able to measure the parameters that influence their crops. The CropScan 33300H On Combine Analyser provides the missing piece of the PA puzzle, the Nitrogen Uptake and Availability.

As one farmer recently remarked. "20 years of Yield data… cool but what do I do with it. 2 years of Protein data and it all makes sense."