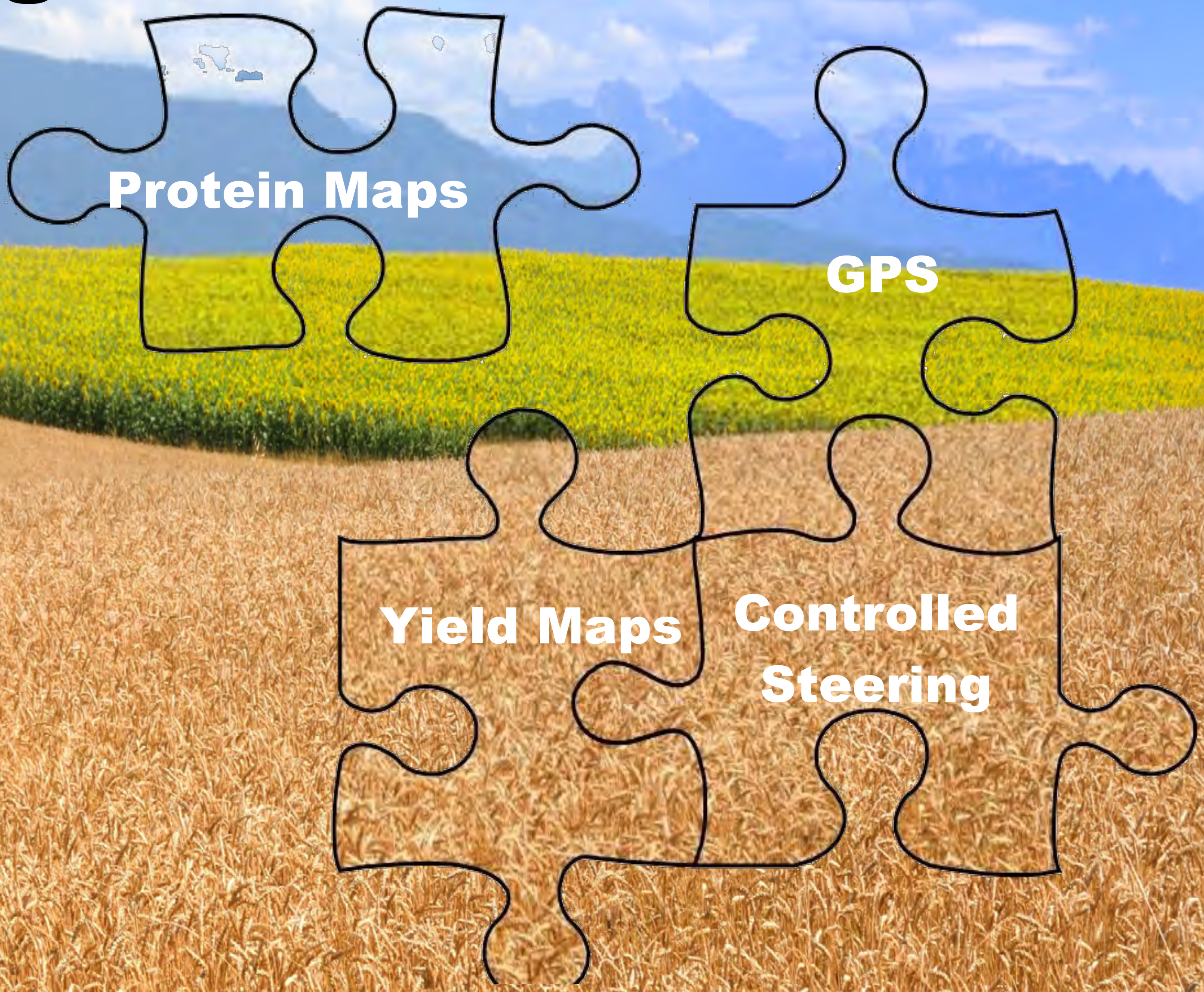
The Missing Piece of the Precision Agriculture Puzzle



Protein and Yield Maps give you:

Nitrogen Removal Maps

Gross Margin Maps

Variable Rate Fertilization

The Missing Piece in the Precision Agriculture Puzzle

There are many definitions of the term Precision Agriculture. The USDA definition of PA identifies the parameters that can be used in PA to achieve a profitable outcome.

"precision agriculture is defined as: a management system that is information and technology based, is site specific and uses one or more of the following sources of data: soils, crops, nutrients, pests, moisture, or yield, for optimum profitability, sustainability, and protection of the environment (adapted from Precision Ag. 2003)."

Protein data is the Missing Piece of the PA puzzle.

The link between Nitrogen and Protein is that for every kg of protein in the grain that is harvested, there is 175grams of Nitrogen in the grain. By collecting protein data using an on combine NIR analyzer, then the following information can be generated:

- High density spatial data showing the variation in quality based on protein of the crop in the paddock.
- Differential harvesting and storage based on quality.
- Protein, Moisture and Yield Maps enable creation of true site specific Gross Margin Maps.
- Nitrogen Removal Maps can be used to calculate fertilizer application rates.
- Overlaying Protein and Yield maps with other data for better diagnostic insights into availability and uptake of Nitrogen.
- N trials and VRF applications can be measured and evaluated using real data.

The importance of measuring protein as a key parameter for PA implementation has been recognized for many years. Dr. Dan Long, USDA, Pendleton, Oregon, has written many papers on the importance of protein measurements in wheat and barley production. He has also been a strong advocate of using on combine NIR analyzers to measure protein as the grains are stripped and to generate protein maps. By overlaying Yield and Protein Maps he has shown the value of collecting real-time protein data from the field or paddock.

Associate Professor, Brett Whelan, Precision Agriculture Laboratory, Sydney University, has been a strong advocate of Protein Mapping. He has combined the Yield and Protein Maps to generate Correlation and Significance Plots which can show a simple three color relationship between optimal Nitrogen fertilization and soil condition.

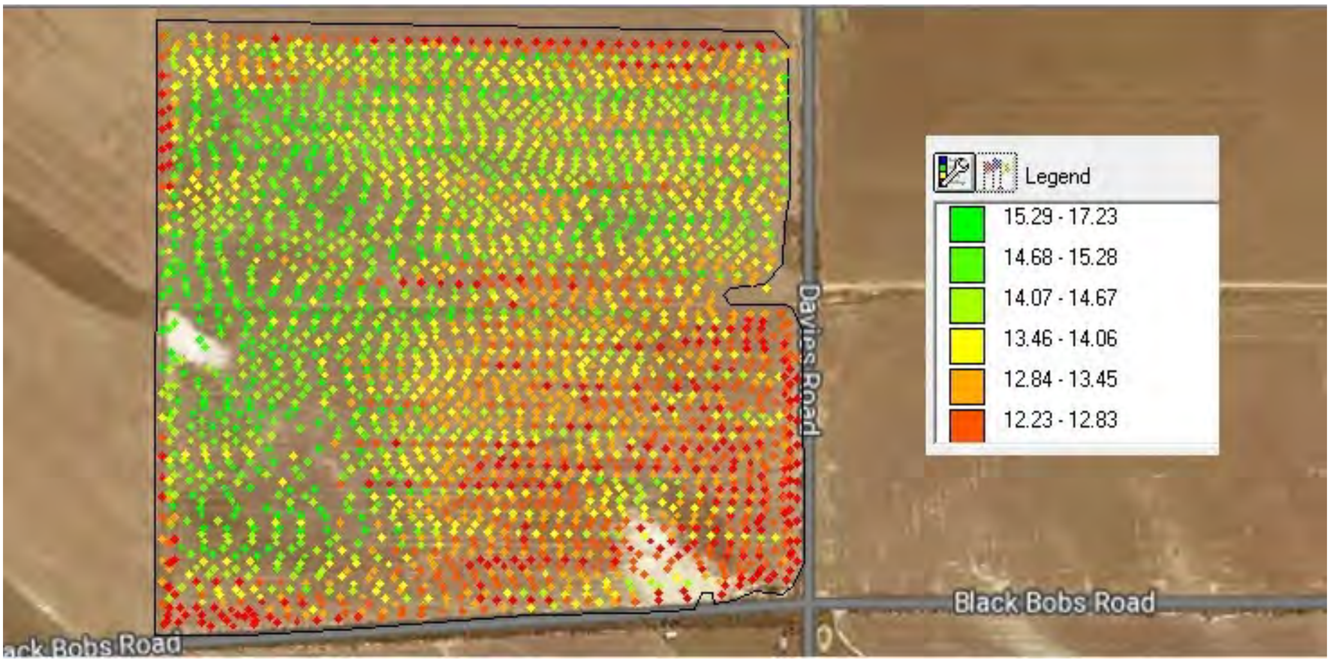
History of Precision Agriculture

1982	Global Information System (GIS) available for research
1990	Global Positioning Systems (GPS) available for public applications.
1992	Yield Monitor for use on combine harvesters.
2003	Satellite Imaging available for farmers
2007	Automatic Steering Control: Tramline Farming
2009	Variable Rate Spraying
2010	Variable Rate Fertilization
2010	Selective Weed Spraying
2011	Topography Mapping
2011	Electromagnetic Inductance Soil Testing
2011	Nuclear Magnetic Soil Scanning
2012	pH Soil Testing
2013	Spectroscopic Soil Testing
2013	On Combine Protein Monitor.

Since the introduction of GPS into combine harvesters in 1982, Precision Agriculture technology has seen Yield Monitors, Controlled Steering and PC controllers become standard equipment in combine harvesters. Now real-time protein measurements are available using the Model 3000H On Combine Analyzer.

High Density Spatial Data shows the variation in quality based on protein of the crop in the field.

A common misconception by growers is that the protein concentration in the grain is level across the field. This is definitely not true and the first time a grower sees a real-time protein map they will shake their heads in disbelief.
High density spatial data as collected by an on combine NIR analyser can show the true protein variation in the field. On reflection, often the grower then rationalizes the Protein Map and thinks about the topography, the history and the soil types. The grower can then start to make sense of the Protein Map. For example, lower protein areas are commonly found



along a fence line or where a boundary fence between two paddocks has been removed. The explanations may be that machinery has passed over these areas less often may have resulted less soil compaction. Or the boundary fence area has not receive as much N fertilizer. An old creek bed or area prone to flooding may have resulted in nutrients being washed away.

An On Combine NIR Analyzer provides data at approximately every 17meters down the field. In comparison to taking 5 in field samples and analysing them using a bench top NIR, an on combine analyser provides a comprehensive picture of what is happening across the field.

Protein and Moisture in cereal crops such as wheat, barley, oats and sorghum as well as Protein, Oil and Moisture in oil seed crops such as canola can be measured in real time. Data is collected approximately every 11 seconds as the crop is being stripped. On average, this means data is collected at a rate of 15 measurements per hectare. This high density special data for Protein provides a means of generating Protein Maps, Nitrogen Removal Maps and Gross Margin Maps.

The map above shows that the Protein distribution in the grain varies considerably, from 12.5 to above 15%. The bottom right hand corner of the paddock shows the lowest Protein areas.

There is also a strip across the paddock where the protein is lower than the immediate areas on either side. This strip coincides with the entrance gate on the right hand side. As such this strip may have received long term heavier traffic than the rest of the paddock, causing more compaction of the soil.

As compared to the traditional method f collecting a few sample readings throughout the paddock, a complete Protein Map provide insight into the real variation across the paddock.

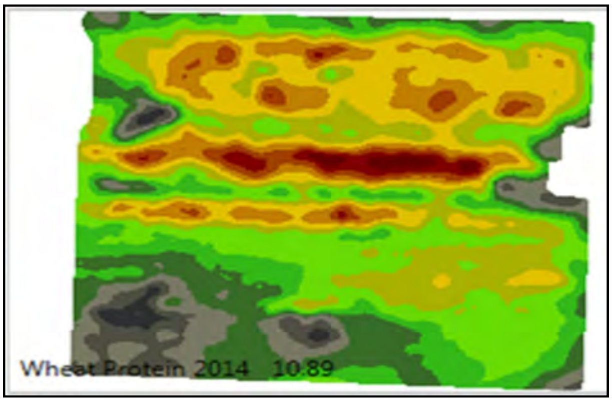
Differential Harvesting and Storage based on Grain Quality

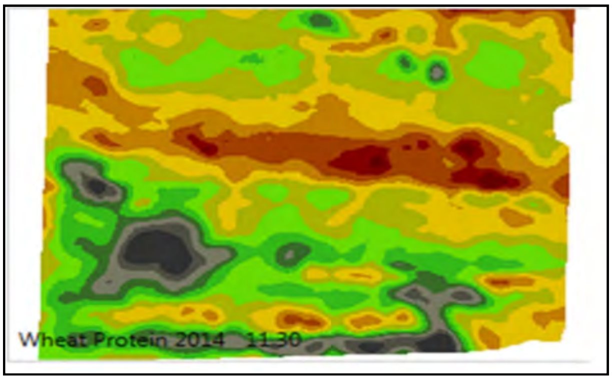
With the high density spatial data related to the protein content of grain, growers can differentially strip the grain from the paddock and segregate the grain into on farm storage silos based on the quality and therefore the value of the grain. Several strategies that can be used;

1. Strip grain from each corner of the paddock and the middle and plot the protein content. Then use the map to identify areas where high protein grains can be stripped and stored into field bins. The areas where the protein content is low, can be stripped and stored into other field bins. Then trucks can be filled from selected bins in order to achieve specific grades.
2. Use the Bin Average data as the grain is stripped. When the Bin Average drops below a set level, e.g., 13% protein, then the driver turns back to the area where the protein is higher. As such the bin can be out loaded into a field bin or truck allocated for high protein grain.
3. Use the on board screen to make decisions on where to out load the grain based on the Bin Average for protein. The combine driver can radio the chaser bin driver to out load the grain into segregated field bins or trucks based on protein. The Truck Load data feature in the software allows the operator to record which Bin Loads have been placed into each Silo, Field Bin or Truck so that the operator can recall the running averages for any storage location.

Return on Investment (ROI)

The fastest return on investment from using an On Combine NIR analyzer comes from in-field segregation of the grain. The Cost Analysis table below shows where a grower used an On Combine NIR analyzer to collect the protein data to segregate bin loads into two field storage bins. The wheat was blended in the field from the two bins to ensure that truck loads taken to the silo were graded as APW (Protein >10.5%) rather than some loads graded as ASW (Protein <10.5%). The price difference was $30 per tonne between ASW and APW grades. Out of the 18 truck loads delivered to the silo from this paddock, 17 were accepted as APW. Historically the grower would have expected half to go ASW and half APW. The net result was an additional $6900 generated from this field by blending based on protein, or an additional $37.29/h profit.





Cost Analysis: Wheat Fields, Urana, SA.
• Fields 221A & 221B
• Total area 185ha
• Average Yield = 4.5t/ha =832.5t
• Top Half of each field was reading below 10.5% protein
• Bottom half of field was reading above 10.5% protein
• By blending, delivered 17 out of 18 truck loads as APW grade ($185/T) over ASW Grade ($155/T).
• Increased Profit by blending: = $6900 $37.29/ha

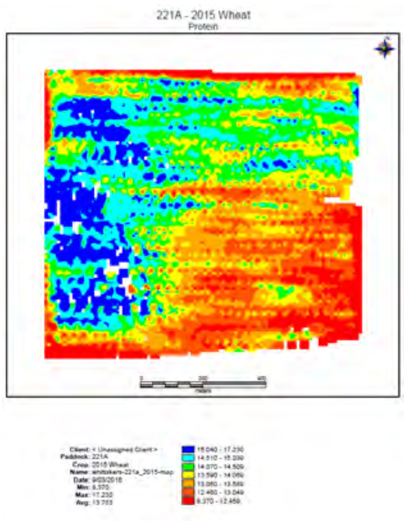
Nitrogen Removal Maps can be used to calculate fertilizer application rates.

In cereal grains, the bulk of the protein is found in the seeds rather than the stem or roots. As such, when the grain grows, Nitrogen is taken from the soil and used by the plant to produce protein in the seeds. In crops such as corn, there is a far higher proportion of protein retained in the stem and leaves than in crops such as wheat or barley. None the less, the amount of protein that is in the seeds and therefore stripped during harvesting has come from the soil. Using the concept that what Nitrogen you take out of the soil is at least what you have put back into the soil, then a Nitrogen Removal Map provides a means of then generating a Variable Rate Fertilization application which is related to the amount of Nitrogen removed from the soil as opposed to a general or average loading of N fertilizer across the paddock.

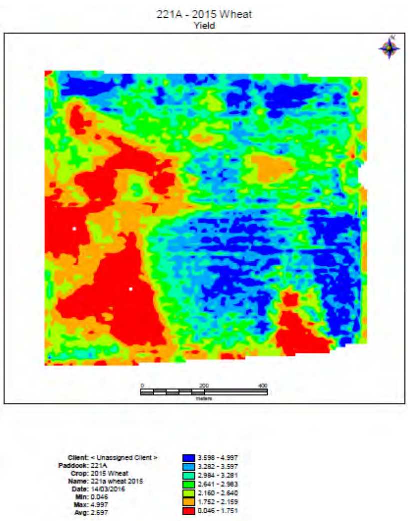
Using a simple formula: Nitrogen Removed = Yield * Protein% * 17.5% Nitrogen/Protein

A Nitrogen Removal Map can be created from a Protein Map and Yield Map. The possible savings in using VNF over blanket fertilization are between -22 and 39% depending on the field and the blanket loading of Urea.

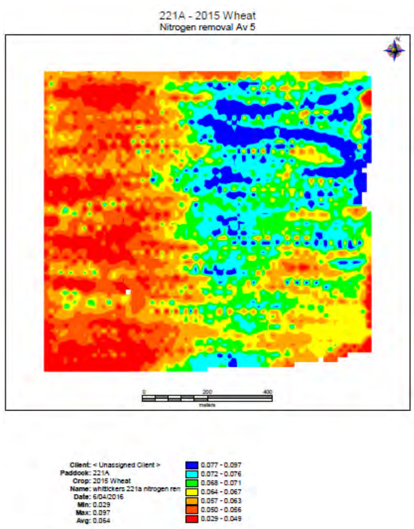
Data collected from a 185 hectare field, York Peninsula, SA, 2015 harvest, compares the costs of Urea loading using blanket rates of 40, 56, 60, 70 and 80 kg per hectare vs. Applying Variable Rate Fertilization based on the Nitrogen Removal Map to apply urea. The Protein, Yield and Nitrogen Removal maps are shown below.



Protein Map



Yield Map



Nitrogen Removal Map

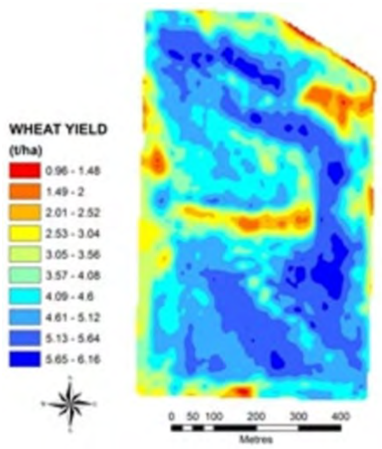
Based on a price for Urea of $430/tonne and the percentage of Nitrogen in Urea of 47%, the cost of the Urea loading was calculated. The table below shows the savings of using the Variable Rate Fertilization based on the Nitrogen Removed Map vs a number of blanket rates.

	VRF Loading		Blanket Urea Loading			
	Cost of Urea using Nitrogen Removal Map	Cost of Urea at 40kg/H	Cost of Urea at 56kg/H	Cost of Urea at 60kg/H	Cost of Urea at 70kg/H	Cost of Urea at 80kg/H
Cost	$10,632	$8,710	$12,194	$13,065	$15,243	$17,420
Savings		-$1,922	$1,562	2433	4611	6789
Savings/H		-10.4	8.4	13.2	24.9	36.7
% Savings		-22	13	19	30	39

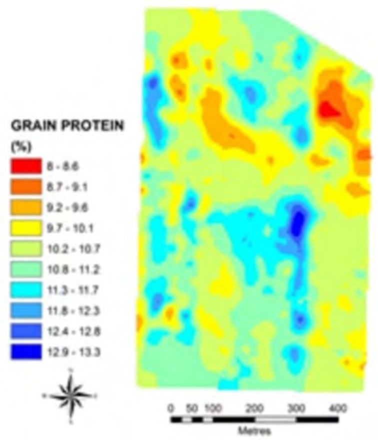
Overlaying Protein and Yield maps with other data for better diagnostic insights into availability and uptake of Nitrogen

The Dilution Theory suggests that if the Yield is high then the Protein will be low. This may not always be the case where soil and moisture may be the limiting factors rather than Nitrogen availability. By overlaying the Protein and Yield Maps, and then computing a Correlation Map and a Significance Map, then simple Green, Red and Blue Zones can be identified.

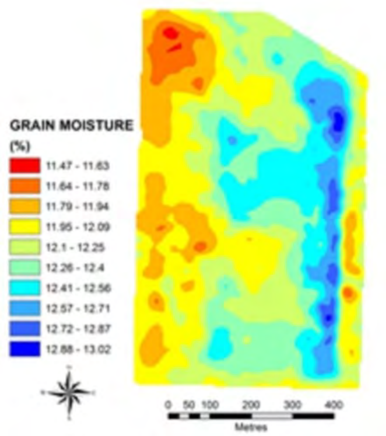
The plots below show the Yield, Protein, Moisture Maps for a field in the Malley region of Victoria.
The field is approximately 200 hectares and the crop is wheat grown in the 2015 harvest.



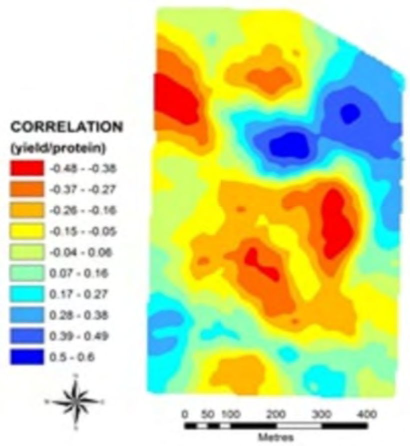
Yield Map



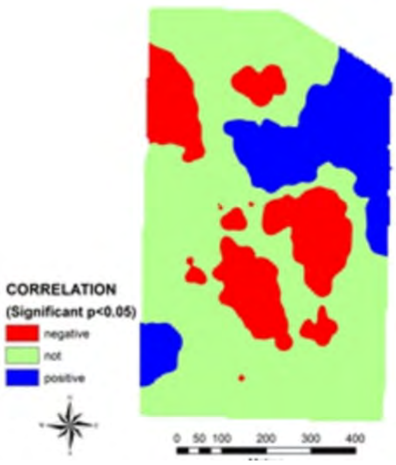
Protein Map



Moisture Map



Correlation Map



Significance Map

The Correlation Map is generated by comparing the Yield vs the Protein within a zone of approximately 50 meters diameter. The Significance Plot simply shows Red as being a negative correlation, Blue being a positive correlation and the green as being no correlation.

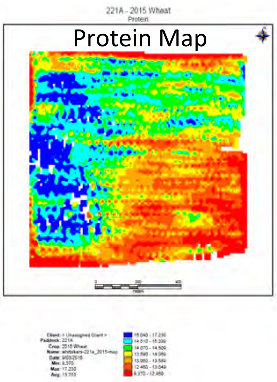
Green is where additional fertilizer will probably not result in significantly higher yields and protein. Red is where additional Nitrogen should realize an increase in both protein and yield. And Blue is where there are other problems effecting the crop, i.e., soil, pH, moisture. In the Blue areas, the grower should consult his agronomist and get soil samples tested or even dig a pit to get an understanding of what is occurring in these areas.

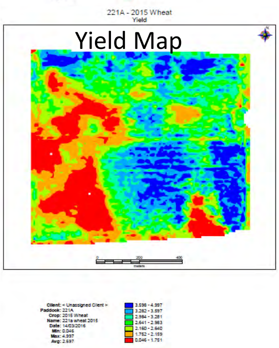
Protein, Moisture and Yield Maps enable creation of true Site Specific Gross Margin Maps

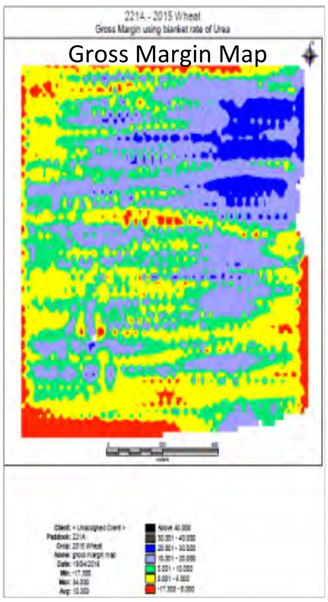
One of the most enlightening pieces of information for a grower is the Gross Margin Map of a paddock. The profit generated from a paddock depends on the yield and the price that the grower gets paid for the grain versus the cost of the inputs required to plant, grow and strip the grain. Since the price paid for wheat and barley is dependent on the protein content, then using Protein and Yield Maps provides a means of calculating the profit or margin across the paddock, not just overall average. By identifying areas in the paddock that do not generate a positive margin, then it can enable the grower to take action that will reduce the loss or turn it into a profit.

The Gross Margin was calculated based on the Yield and the price of wheat as the Protein content increases. Protein, Yield and Gross Margin Maps are shown below. The Gross Margin Map shows that in the Red areas, the grower is losing money. In the Yellow areas, the margin is between 0 and $5 per hectare. Progressively the margin is increased from Green ($5 to $10), Pale Blue ($10 to $20), Blue ($20 to $30) and Purple ($30 to $40). The total profit generated on this field was calculated to be $29,329, however the potential profit would have been $33,164 if the Red areas had not been sown.

A more practical approach would be that some remedial action be taken to ensure that the Red and Yellow areas become profitable in the future.





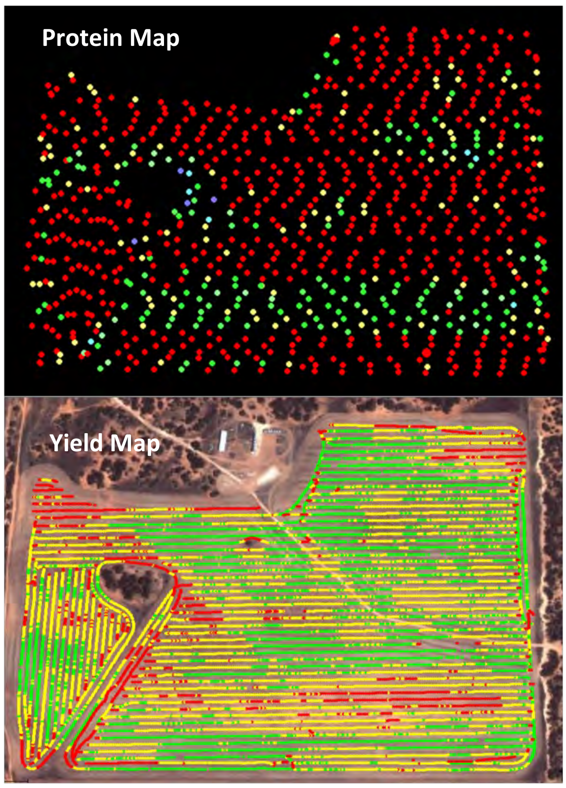


N trials and VRF applications can be measured using an On Combine NIR Analyser.

Many farmers run field strip trials for Nitrogen, Phosphorous, Sulphur and other nutrient. An On Combine NIR Analyzer can provide quantitative data which can show the real impact and effects of these strip trials. By combining the Yield and Protein data, the farmer can quantify the benefits of making changes to their fertilization plans or even the varieties of seed they plant.

Likewise, Variable Rate Fertilization applications can be accessed in the subsequent harvest. By collecting Protein and Yield Maps during the next harvest should show that a more consistent level of Yield and Protein were produced using a VRF program.

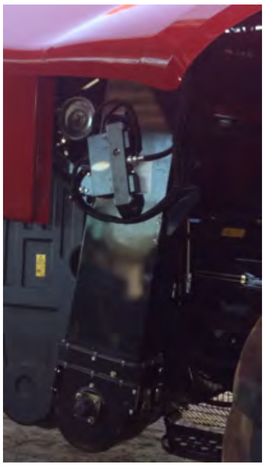
A grower in the Malley region of Victoria, trialed a new fertilizer in a wheat paddock. He applied the new fertilizer along seven rows in the paddock. The Protein Map shows a green strip where the new fertilizer was laid. The Protein Map shows that the new fertilizer increased the protein content, however the Yield Map shows that the additional fertilizer reduced yield. The reduced yield offset the incremental price of the crop due to increased protein. The farmer concluded that this new fertilizer was not of benefit to him.



Model 3000H
On Combine Analyser

The Model 3000H On Combine Analyser is rugged NIR spectrometer that has been combined with a remote

sampling head in order to collect measurements of protein, moisture and oil in grains and oil seeds as they are stripped in the paddock.

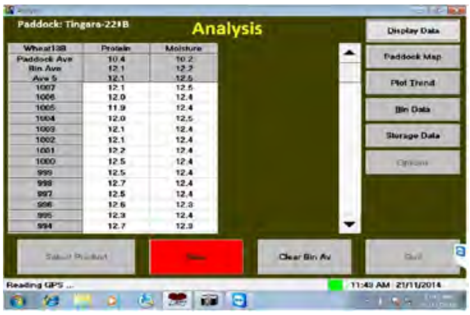


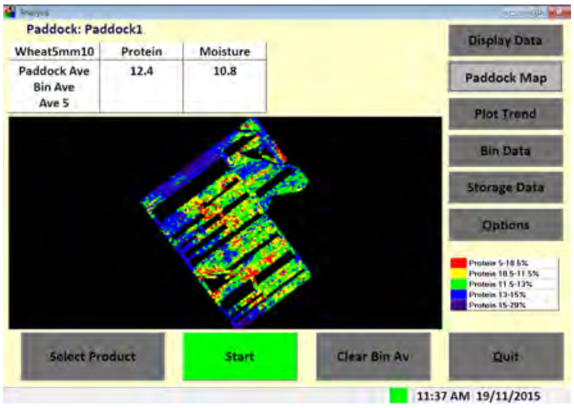
The system consists of a Remote Sampling Device located on the clean grain elevator, a NIR Spectrometer and a Touch Screen PC that combines the protein, oil and moisture data with GPS signals to produce real time paddock maps.

Grain travelling up the clean grain elevator falls into the Remote Sample Device. Flaps at the top and bottom of this device control the flow of grain in and out of the mechanism. The grain is trapped in the sample chamber where light passes through the grain and is collected in a fibre optic cable and transmitted back to the NIT spectrometer located inside the cabin. The bottom flap opens to release the grain and then closes, ready for the next sample. The cycle time is approximately 7-11 seconds depending on the grain. The Model 3000H is controlled and operated by a Touch Screen PC located in the cabin. The data is displayed on the screen as a moving average, a bin average and a paddock average. The protein and oil data from the analyser can be also plotted in Real-Time Paddock Maps on the screen.

The protein, moisture and oil data can be stored in the Model 3000H Touch Screen PC , exported directly to a remote PC and posted to the CropNet web site where the data can be viewed from a smart phone or tablet As well a summary report can be sent by email or SMS.

The Model 3000H is fully automated. A light sensor in the Remote Sampling Head detects if there is grain flowing through the system. If the header has stopped and there is no grain then the system sits and waits until it sees grain flowing again. When the out loading auger is extended, a sensor notifies the PC to reset the bin average and displays a window for the operator to select the location where the grain is to be stored. By selecting from a Pull Down Menu , the operator can record the tonnage, protein, oil and moisture stored in each silo, grain bag or bunker. A report can then be generated and sent to a remote PC.





The Remote Sampling Head located on the clean grain elevator has been designed for easy access for cleaning. Simply unclip the top cover and the cell can be cleaned out with compressed air.

The Model 3000H Touch Screen PC can be connected to the internet whereby a program called Team Viewer allows Next Instruments to perform remote diagnostics, upload and download software, calibrations and data.