IMPROVING NITROGEN DECISIONS WITH CROP SENSING

FACT SHEET

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

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An overview of the different crop sensing options available to Australian growers for improving nitrogen decisions and for use in precision agriculture

Introduction

After soil moisture, available nitrogen is often the next limiting factor in crop production. Matching nitrogen application to the variation in crop needs within a paddock using variable-rate application (VRA) has the potential to improve profitability through improved average yield and reduced fertiliser wastage.

Making nitrogen application rate decisions

Nitrogen is an important macronutrient that is essential for plant growth. It is highly mobile within the plant and within the soil, and its availability to the plant is tied to soil moisture, soil texture, soil organic matter and soil temperature.

Nitrogen budgeting attempts to account for nitrogen available to the crop in the soil solution as it cycles between the organic and inorganic 'pools' in the soil. Soil organic matter and organisms contribute nitrogen from the organic pool, and synthetic nitrogenous fertilisers dominate the inorganic contribution.

Traditional soil nutrient analyses have long been used as the basis for 'mass balance' agronomic prescriptions for nitrogen fertiliser application rates across a paddock or management unit. The application rate being calculated by deducting the amount of nitrogen present in the soil from the rate required to achieve a yield and quality goal, tempered by a plant nitrogen uptake. Historical yield information, soil type maps, and soil and crop sensing data can provide additional information for growers to adjust their nutrient application rates according to likely crop needs. Growers can also use a range of online tools that include rate estimates based on crop growth simulation methods such as Yield Prophet.

Photo: Mark Branson

DJI Phantom 4 drone.

Steps towards site-specific nitrogen management

CROP REFLECTANCE DATA

Actively growing, well-fertilised plants reflect light differently to plants that are under stress. This difference in reflectance can be used to identify areas of a paddock where crop growth is strong/healthy and areas where there is a constraint on production. Information from reflectance sensors mounted on satellite, aerial or ground-based platforms can illustrate these differences in plant growth, allowing growers and their advisers to accurately scout, problem-solve and then plan any input applications to match the needs of the crop.

To gain the most benefit from using these technologies in nitrogen management, there must be a foundation of good general management in place. It is recommended to only use VRA to apply key nutrients such as nitrogen after any ameliorable soil constraints (topsoil pH, sodicity, compaction), weed and/or disease issues have been addressed.

SOURCES OF CROP REFLECTANCE DATA

Crop reflectance data acquired remotely from satellites is available from a number of commercial sources in Australia, often with a revisit time (length of time between consecutive satellite images taken at the same location) of less than seven days for

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Photo: Mark Branson

The Branson family follow no till principles on their farm.

the imagery, with a spatial resolution of 30 metres or less. Data from the Sentinel-2 satellites (15m spatial resolution) and the Landsat satellites (30m resolution) can be supplied at a relatively low cost. Data from higher resolution sensors on satellites, or light aircraft or unmanned aerial vehicles, are available at higher resolutions (up to 0.4m); however, the cost usually increases proportionally.

The commercial ground-based proximal sensor units currently available are Crop Circle™, CropSpec™, GreenSeeker and N-Sensor™ ALS2. These sensors supply their own light source and are designed to be held approximately 1m above the crop canopy. They can be handheld as individual units or as multiple units and boom-mounted on vehicles to cover greater areas. They operate slightly differently; however, they all emit light of a known wavelength, allowing operation any time of the day or night, and they can all collect multispectral reflectance data from the crop canopy.

Due to the similarities in the reflectance technology used on all platforms, growers can be confident that data from these proximal sensors will be comparable to imagery collected remotely using camera systems mounted on aircraft or satellite platforms. This means that when using these ground-based sensors, growers and their advisers can rely on historical research that has established the relationships between crop reflectance and crop physiology.

With the increased commercial availability of crop reflectance data and onboard yield monitors, growers can collect real-time data and build databases over time to make better-informed decisions regarding pre-sowing and in-season fertiliser.

USING CROP REFLECTANCE DATA FOR NITROGEN MANAGEMENT DECISIONS

An important aspect of the use of crop reflectance sensors is the calculation of vegetation indices from the multispectral data. The well-known normalised difference vegetation index (NDVI) uses information from the red and infrared segments of the spectrum to measure the light absorbed as part of photosynthesis and the light reflected from the vegetation's surface. NDVI is unique to live vegetation and provides a way of measuring vegetation density and health.

NDVI values are relatively high in higher biomass crops that are very green, and decrease when plants are lower in biomass, stressed, diseased or senescing. Bare soil and water bodies can be easily distinguished from vegetation using NDVI.

A relatively strong relationship exists between NDVI and the total nitrogen content (kilograms per hectare (kg/ha)) of the crop plant biomass. However, there is a growth stage in most crops at which the reflected light and density of the crop biomass overwhelms the index and it is said to be saturated. At this point, the NDVI ceases to distinguish incremental increases in the total nitrogen status of the crop. Sensor technology has more potential to assist with nitrogen management if it is deployed in situations where the crop canopy has not yet closed, such as early in the season or on less fertile sites where saturation is unlikely to be a problem.

NDVI readings can be influenced by a number of factors other than nitrogen, including:

- changes in germination/establishment;
- soil nutrition deficiency issues (for example, pH and nutrients other than nitrogen);
- weed patches;
- disease; and
- waterlogging.

So, these issues need to be ruled out as possible influences before proceeding to use crop reflectance data for nitrogen decisions.

NITROGEN TEST STRIPS (N-RICH STRIPS)

An N-rich strip is an early application of nitrogen fertiliser, usually applied as a strip that is as wide as the width of the farm application machinery. An N-rich strip is best located where the strip can be run across changes in soil type or identified production management zones. Their length will depend on the characteristics of each paddock

Photo: Mark Branson

Emerging crops, planted with autosteer RTK two centimetre guidance.

and multiple strips may be required in paddocks where the variability cannot be encompassed in a single strip.

N-rich strips are designed to provide an area where the crop response is non-limited by nitrogen, which can then be compared with the crop response to the applied fertiliser rate in the rest of a paddock. This can be used to identify whether the fertiliser rate is sufficient in the paddock for the current seasonal conditions and help gauge any top-up application rates if required/feasible.

When conducting a ground-based reflectance survey of a large paddock, it is good to re-scan the N-rich strip/s every two hours or so to account for changes in leaf orientation and environmental conditions during the survey period.

VARIABLE-RATE NITROGEN APPLICATION DECISIONS

Most nitrogen uptake in cereals occurs between mid-tillering and mid-stem elongation, so this is the time to ensure the crop has access to sufficient nitrogen to reach the target yield goal. Applying all the expected nitrogen required for the season prior to mid-tillering is one way of managing this process; however, this provides very little flexibility to deal with actual in-season impacts on nitrogen demand/supply. Crop sensing at the end of tillering offers a method to quantify how well the crop nitrogen uptake is going based on actual seasonal conditions.

This method relies on the split application concept where a proportion of the expected nitrogen requirement is applied before/at sowing – sufficient to establish the crop and support early growth. This is commonly about 50 per cent of the expected crop requirement. Obviously, this management option relies on in-season rainfall to be available when secondary fertiliser applications are required or, alternatively, the use of liquid fertiliser.

When using crop reflectance data from any sensing system, higher index levels in sections of a paddock will often indicate a higher biomass and associated higher uptake of nitrogen into the crop canopy. Areas with lower index levels, when no other issues as mentioned above are present, are therefore assumed to be more likely to respond to nitrogen fertiliser applications with improved crop biomass production. A response comparison between the crop in an N-rich strip and the rest of the paddock will provide information of potential responses to increased nitrogen above the paddock-applied rate.

This approach can be applied at a number of scales. At the whole-field scale, input rate changes can be calculated across a continuous range to deal with continuous variability in crop requirements as they are identified by the sensors across a paddock. At the management class scale, variability in response can be measured across a whole paddock and averaged over predetermined management classes/zones and an application rate calculated. Variability in response within pre-determined management classes can also be managed by calculating a base rate nitrogen requirement for each management class prior to the application operation, but the actual input rate is modified by a measure of variability gathered using the sensors within each zone/class.

All of the ground-based sensor systems come with in-built software that enables calculation of a user-defined crop reflectance index (for example, NDVI) to quantify the response differences. They also have proprietary algorithms that can use this information to prescribe a rate of application. With the sensors mounted at the front of a vehicle, the decision process can be carried out in real-time, which allows the process to control the rate of application from onboard or trailing application equipment. Particular care is required when using the in-built application decision system to control VRA nitrogen in the one pass. The algorithms need to be assessed for appropriateness for local conditions before use.

Further detail on the options for, and benefits from, using field-trials, crop reflectance and other data layers in nitrogen decision-making can be found in the article: *Better targeted, more precise fertiliser decisions as a counter to rising fertiliser prices – focussing on 3 of the 6 Rs,* published in Society of Precision Agriculture Australia (SPAA) *Precision Ag News*, Vol 18 (2).

CASE STUDY

Simple approach key to variable-rate success on 'Branson Farms'

As a founding member of SPAA, Mark Branson's journey with precision agriculture (PA) started with yield mapping the family's South Australian farm in 1997. Since then, he and his family have honed their overall approach and the technology used to manage variability across their farm, increase productivity and reduce costs.

On 'Branson Farms' in Stockport, SA, Mark Branson and son Sam use precision agriculture (PA) technology to apply variable rates of nutrients, seed and weed management.

Across the 1200ha farming operation, the soils range from red-brown earth to dark brown cracking clays. With these soil differences, plus undulation and creeks, the family could clearly see the variability in soil type and topography. Once they retrofitted a yield monitor to a new harvester in 1997, they could also see how that variability correlated with yield differences.

They tried to find out how to address that variability, and turn data into profit.

To address this knowledge gap, both for his own farm and for the wider industry, Mr Branson was a founding member of SPAA in 2002 and undertook a Nuffield Australia Farming Scholarship in 2005. He used the scholarship to research the use of precision and conservation agriculture to improve farm profits and environmental outcomes.

VARIABLE-RATE PHOSPHORUS AND NITROGEN

Inspired by his research findings, Mr Branson started to use large-scale variable-rate technology in 2006.

On-farm application started with introducing a variable rate for phosphorus. To do that, the Bransons take the previous year's yield map and apply a formula accounting for replacement rates for what was lost in yield, plus a factor of loss – or a buffer.

They expanded their use of variable-rate technology to nitrogen and started using N-rich strips. An N-rich strip is an area in the paddock that receives enough nitrogen fertiliser for the whole growing season, regardless of the environmental conditions. The rest of the paddock receives the standard pre-plant rate. Growers can then compare the N-rich strip to the rest of the paddock, to see if nitrogen is restricting growth.

For more accurate data on nitrogen levels, Mr Branson also uses a Trimble™ GreenSeeker handheld sensor, to determine mid-season nitrogen rates. The sensor uses brief bursts of red and infrared light to produce a normalised difference vegetation index (NDVI) reading to indicate the health of the crop.

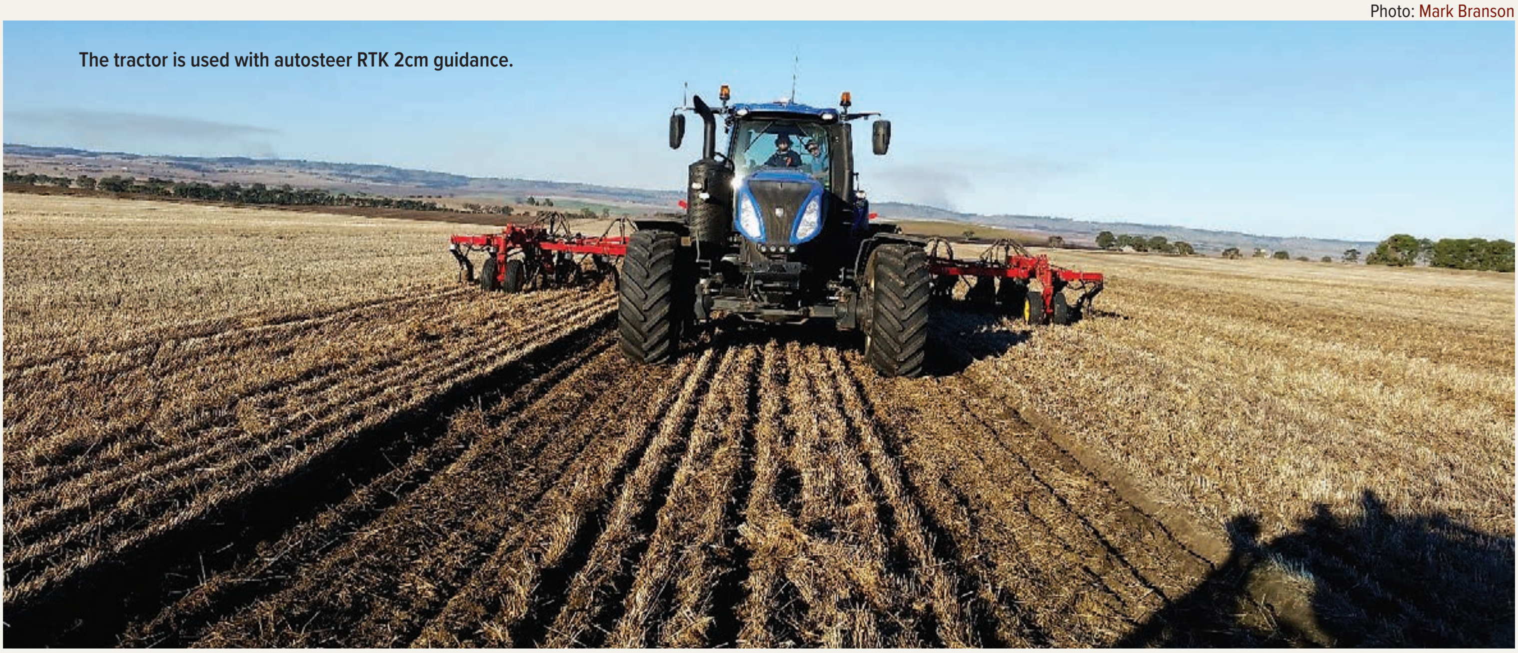
Mr Branson also uses Topcon CropSpec™ sensors mounted on his tractor. The crop canopy sensor measures plant reflectance to indicate chlorophyll content of the crop. This correlates to the nitrogen concentration in the leaf.

SNAPSHOT

Location: Stockport, South Australia
Farm size: 1200 hectares
Rainfall: 425 to 500 millimetres
Soil: Red-brown earth, dark brown cracking clays
Enterprises:
- Dryland cropping: Wheat, barley, field peas, faba beans, lentils, canola, oaten hay
- Livestock: 1000 Merino ewes (self-replacing flock), prime lambs, 20 cattle

Personnel: Mark Branson (general manager), son Sam (operations manager), one full-time and two casual workers

Photo: Mark Branson



The tractor is used with autosteer RTK 2cm guidance.

They use the data from the N-rich strips, GreenSeeker and CropSpec™ sensor to determine whether crops need nitrogen, and how much. They combine this data with visual observations of biomass, both from physically getting out into the paddock and imagery from a DJI Phantom 4 drone. This is fed into variable-rate nitrogen algorithms.

Although Mr Branson says precision agriculture has advanced in the past decades, there are still gaps.

"If I were to write a variable-rate wish list, it would include better algorithms for nitrogen. They've got these algorithms working nicely in the US and the UK, but there's still work to do in the Australian context," he said.

"You need a lot of data, and we got a lot of that through Dr Rob Bramley's project."

Dr Bramley is leading the Future Farm project, a GRDC-supported, multi-institutional project seeking to improve N fertiliser decision-making through automation and sensors.

"We were the strategic site in SA for the project. It showed nitrogen replacing is not easy. You need a lot of data to get it right, but I think I've got it more right than most others."

VARIABLE-RATE GYPSUM AND LIME

The 'Branson Farms' team uses a Veris® pH Manager to detect soil pH on-the-go. This machine can produce accurate maps for variable-rate lime application, providing sufficient measurements are made.

"Using a machine to detect soil pH gives us a higher density of data than, say, grid sampling. The reason why we don't go grid sampling is because the soil varies so much here. So, if you try, and unless you hit the exactly the sample site that you did 10 years earlier, then you're not guaranteed to get the same value."

They use this data to create variable-rate application maps for applying gypsum on areas with sodic soils (that is, those with more sodium than usual), and lime on acidic areas. They apply these at different levels depending on each area's needs.

VARIABLE-RATE WEED MANAGEMENT

Mr Branson explained that using a drone also helps with weed management. At 'Branson Farms' they use a drone to detect areas with extra biomass, which indicates where there are herbicide-resistant ryegrass, wild oats and wild radish. Mr Branson adds that detail to his variable management maps. He manages these areas differently, either cutting them for hay, spraying them or, where it is an ongoing problem, using variable-rate seeding to put out more seeds so the desired plants can outcompete the weeds.

REFINING THE PRECISION AGRICULTURE APPROACH

Mr Branson was an early adopter of yield maps.

"In 1997 our first yield map gave us a nice, coloured map, but so what? We didn't know how to make use of that data."

He said the family farming operation began to take a different approach, based on his research through the GRDC-sponsored Nuffield Scholarship program.

He has refined it further since then including through involvement with Grains Research and Development Corporation (GRDC) trials. Based on the principle of keeping things simple, Mr Branson has a five-stage approach to precision agriculture:

1. **Identify the problem.**
2. **Fix problems that can be permanently fixed.**
3. **Use variable rate in areas that cannot be permanently fixed.**
4. **Identify whether there is a PA tool to fix the problem and what it is.**
5. **Decide whether it is economical to implement that PA tool.**

It is important to start with a problem and look for a solution, rather than creating a reason to buy (or be sold) expensive equipment, machinery or services.

"PA is about solving agronomic problems, not buying trendy tools or services. But don't buy in a solution just for the sake that it is good technology and it looks fantastic and the sales have done a really good job on selling. It doesn't make any money," Mr Branson said.

"PA is profitable if you choose the right tools."

He gave the example of phosphorus management to demonstrate the approach.

"We have a problem in that our grain takes the phosphorus out of the paddock; we're essentially mining the phosphorus. So I ask, what's the best way to replace this phosphorus? One way is to use yield maps to refine the minimum replacement requirement and check to ensure soil phosphorus is not being depleted."

Despite their importance, Mr Branson said precision agriculture technologies were most effective when used with other tactics that reduce risks, such as pests and disease pressures, and promote productivity.

For example, the family rotates different crops and grazing pastures to help control weeds and diseases.

They also apply organic matter to the soils to boost organic carbon levels and overall soil health.

UNDERSTANDING THE ECONOMICS OF PRECISION AGRICULTURE

Mr Branson received help from University of Adelaide weed management expert Professor Christopher Preston, and others, to conduct an economic study of controlled-traffic farming (CTF) and PA tool use on the family farm. Professor Preston has presented the findings at conferences.

As of 2020, the economics of CTF and precision agriculture on the farm include:

- **yield gains averaging $5.95/ha/year;**
- **overlap savings (for seed, fertiliser and other chemicals) $7.24/ha/year; and**
- **nutrient savings (for phosphorus, nitrogen, gypsum, lime, weed control) $72.31/ha/year.**

These add up to total savings of $85.50/ha/year, and Mr Branson said that with the rising cost of fertiliser, those savings would be even bigger for 2022.

He acknowledges that CTF and precision agriculture incur equipment and other costs. 'Branson Farms' has spent approximately $110,000 on this specialised equipment in the past decade. Mr Branson calculated if you divided the cost over time and farmed area, it would come to $12.22/ha/year.

Since Mr Branson creates the maps himself, he calculates his time for managing CTF and precision agriculture as $2/ha/year. The other ongoing cost is the real-time kinematic (RTK, which is more accurate than devices like smartphones and wearables) GPS signal at 17c/ha/year.

These add up to expenses of $14.39/ha/year.

To work out the profits, a simple equation of total savings ($85.50/ha/year) minus total expenses ($14.39/ha/year) equals profits of $71.11/ha/year. This equates to $64,000/year

TOP PA TIPS

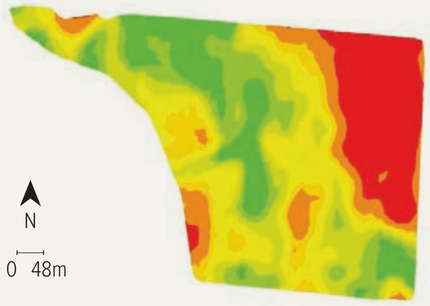
- PA is about solving an agronomic problem. Identify the problem before adopting a PA tool.
- PA is profitable if you use the right tool.
- The world needs to use PA to feed the growing population.

CASE STUDY (CONT.)

Figure 1 A and B below are examples of yield maps used by the Branson family to calculate phosphorus rates. C is a lime application map produced through the use of soil pH mapping on the Branson Farm.

A

Grain harvest 2008 – Top D paddock (canola)

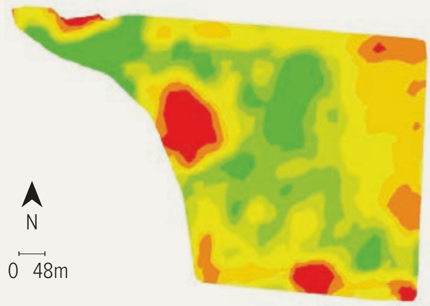


Yield mass (dry) (tonne/ha)

- 1.99 – 2.26 (3.01ha)
- 1.89 – 1.99 (3.22ha)
- 1.79 – 1.89 (3.60ha)
- 1.64 – 1.79 (4.52ha)
- 1.53 – 1.64 (2.11ha)
- 1.32 – 1.53 (2.11ha)
- 0.93 – 1.32 (4.14ha)

B

Grain harvest 2009 – Top D paddock (spring wheat)



Yield mass (dry) (tonne/ha)

- 6.03 – 7.24 (2.881ha)
- 5.86 – 6.03 (4.183ha)
- 5.69 – 5.86 (3.904ha)
- 5.38 – 5.69 (5.076ha)
- 5.16 – 5.38 (3.605ha)
- 4.84 – 5.16 (1.829ha)
- 3.43 – 4.84 (1.240ha)

C

Target rate (mass) (tonne/ha)

- 2500 (16.84t/ha)
- 1500 (19.45t/ha)
- 1000 (17.54t/ha)
- 0 (18.48t/ha)

across the 900ha area of cropped land.

Mr Branson said the benefits of precision agriculture go beyond economics.

"There are benefits such as using less chemicals and increasing soil health, and also when you increase your profits, it means you can employ more people on farm, so there are social benefits too.

"I'm not working as many hours in the machines as I used to – that's partly age, but also I had a farm accident five years ago and now I'm an amputee."

The accident has not dulled Mr Branson's passion for precision agriculture. Already, he and son Sam provide contracting services to create soil pH maps for variable-rate lime spreading on farms around the local area. Mr Branson is considering expanding these services by going into consulting.

He said precision agriculture is also key to sustainable farming.

"The only way we are going to feed the world's population with depleting resources is to adopt PA technologies."

GRDC CODE

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USEFUL RESOURCES

Society of Precision Agriculture Australia (SPAA), spaa.com.au

SPAA is Australasia's leading independent advocate and facilitator for increased research, extension and adoption of precision agriculture, delivering industry-wide value across different sectors.