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precision ag facts

SPAA115 *Communicating innovations in precision agriculture*

Nitrogen sensing

After soil moisture, available nitrogen is often the next limiting factor to crop production. Matching nitrogen application to crop needs during the growth cycle has the potential to improve profitability through improved average yield and reduced wastage. Research in Australia indicates that variable rate application (VRA) of nitrogen has the potential to reduce the cost of nitrogen inputs.

Actively growing 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 and areas where there is a constraint on production. Satellite, aerial and proximal sensor imagery can illustrate differences in plant growth, allowing farmers and their advisors to accurately scout and problem-solve, and also plan input applications that match the needs of the crop.

To benefit from the available technology there must be a foundation of good management in place. Using VRA to apply key nutrients such as nitrogen will make little difference to production if there are other constraints such as acidity, weed growth or disease pressure that are not being addressed.

These tools do not over-ride the need to look for anomalies in the field.

Making nitrogen application decisions

Nitrogen is an important macro-nutrient 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 temperature and soil organic matter (specifically the carbon:nitrogen ratio).

Nitrogen budgeting attempts to account for nitrogen available to the crop as it cycles between the organic and inorganic 'pools', with inputs from the soil, biological activity, the atmosphere and applied nitrogenous fertilisers. Farmers can use online tools such as N Calc and Yield Prophet to help make nitrogen management decisions using their own soil and crop sensing data.

Traditional soil nutrient analyses have long been used as the basis of 'best bet' prescriptions for fertiliser application rates across a paddock or management unit. Historical yield information, soil type maps and soil and crop sensing data can provide additional information for farmers to adjust their nutrient application rates according to likely crop needs. Some farmers have also used nitrogen test strips to measure crop response to different rates of nitrogen. This is the first step toward site-specific crop management.

With the increased availability of on-board yield monitors and commercially-available crop reflectance sensors, farmers can collect real-time data and use this information to make better-informed decisions in future seasons and within a growing season.

Steps toward site-specific nitrogen management

Nitrogen rich strip. Photo M Branson

The Normalised Difference Vegetation Index (NDVI) is a measure of the 'greenness of vegetation', and is derived from measuring the difference between visible light absorbed as part of photosynthesis and the solar energy reflected from the vegetation's surface. NDVI is unique to live vegetation and provides a way of measuring vegetation density and condition.

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

A strong relationship exists between NDVI and the nitrogen content of the plant biomass. However, there is a point at which the greenness and density of the crop biomass is saturated and NDVI ceases to distinguish incremental increases in the 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 closed, such as early in the season or on less fertile sites where saturation is unlikely to be a problem.

NDVI is sensitive to, and must be calibrated to, a specific crop, site and season. NDVI readings are influenced by a number of factors including:

- the variety and row spacing
- soil nutrition imbalances e.g. pH and nutrients other than N
- weed patches
- disease
- waterlogging.

Using the relationship between NDVI and the crop's nitrogen needs requires calibration of the sensor systems used to the field conditions, and should not be used in isolation to make nitrogen management decisions. Crop sensors are a useful tool to aid already-good crop management.

In-season satellite, aerial and ground-based sensor data

Hand-held, implement or vehicle-mounted and even aerial or satellite crop sensors all use NDVI to measure differences in crop canopy reflectance as an indication of variability in soil N mineralisation across a paddock.

NDVI data acquired remotely from satellites is available from a number of sources often with a revisit time of less than 7 days for the imagery, with a spatial resolution of 15 m or less. There are several private companies that can supply and interpret data from the National Oceanic and Atmospheric Administration (NOAA) series of satellites. NDVI is also available using light aircraft which provide data at a higher spatial resolution (up to 0.4 m) than the satellite platform.

There are currently five commercially available ground-based proximal crop sensors in Australia, all of which aim to determine changing nitrogen application requirements in-season and provide VRA prescriptions.

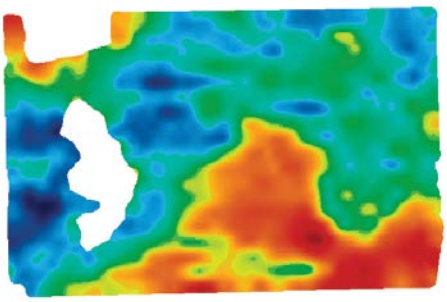
The commercial sensor units currently available are Crop Circle®, CropSpec™, GreenSeeker®, N-Sensor® (ALS) and OptRxTM. While they all operate slightly differently, they all emit light of a known wavelength, allowing operation any time of the day or night, and are either boom or implement-mounted. They all collect NDVI data from the crop canopy. There are differences in their operation and their compatibility with mapping and VRA software. These differences need to be investigated thoroughly to ensure the sensor is compatible with other equipment and technologies used on-farm.

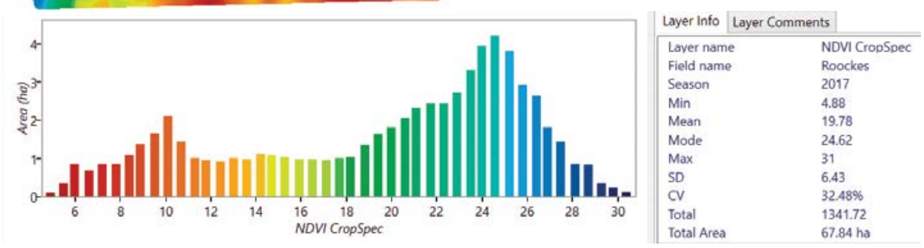
Due to the similarities in the reflectance technology used, farmers can be confident that data from these proximal sensors will be comparable to imagery collected remotely using camera systems mounted on aircraft or satellite platforms. This means farmers and their advisors can rely on historical research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

Nitrogen test strips (N-rich strips)

N-rich strips are a used to calibrate the crop sensor to enable more accurate use of crop reflectance (NDVI) data to calculate the varying N requirement across a paddock. An N-rich strip is usually one spreader width of nitrogen fertiliser applied early, across a representative part of the paddock at a non-limiting, but not excessive rate. This N-rich strip provides a comparison with the remaining area of the paddock to help show how much nitrogen is being supplied from the soil or fertiliser applied at planting, and whether the crop might respond to a later application of nitrogen fertiliser if sufficient soil moisture is available. The N-rich strip also demonstrates whether the difference in crop canopy NDVI is due to differences in nitrogen uptake or other potential limitations such as other nutrient deficiencies, disease, drought or waterlogging.

N-rich strips need only to be 50 m long. If there is known variability in soil properties across the field, multiple strips may be required, with at least one strip in each management zone. The placement of N-rich strips should vary from year to year. When conducting a reflectance survey of the field, re-scan the reference strip/s every two hours or so to account for changes in leaf orientation and environmental conditions during the survey period.





Variable rate application

Higher NDVI in sections of a paddock will often indicate a higher uptake of nitrogen into the crop canopy as a result of greater mineralisation of nitrogen in the soil. Areas of lower NDVI are more likely to respond to nitrogen fertiliser applications with improved crop biomass production.

Some sensor systems come with in-built algorithms that enable both sensing and variable rate fertiliser application in the same pass, in real time, but these should be treated with caution unless the algorithms have been shown to be appropriate to the local conditions.

Variable rate applications based on NDVI data is most likely to make an economic difference through reduced total nitrogen fertiliser use. In environments where soil moisture is usually not a limiting factor and yield is consistently over 2.5 t/ha, split applications can be beneficial. In these situations, a low rate of nitrogen fertiliser is applied at sowing – sufficient to establish the crop and support early growth. This is commonly less than 50 per cent of the expected crop requirement.

In lower yielding and lower rainfall situations, split nitrogen application is a riskier practice that is less likely to generate an economic benefit.

Yield monitoring

Yield monitoring data can be overlaid on NDVI variability maps to identify anomalies that may indicate other production constraints. For example, in an area where yield declines as NDVI rises, there may be significant weed pressure. Conversely, where yield rises as NDVI declines there may have been temporary waterlogging at the time of the survey.

Identifying these anomalies at the end of the season provides an opportunity to better understand the variability in crop yield potential within a field and to address problems ahead of the next cropping season. Site specific management tactics could be developed to manage problems such as high weed numbers and poor drainage, and possibly soil samples taken to provide useful information regarding other soil constraints that could be addressed to lift the yield potential of these areas.

Particular care is required with systems that collect sensing data in real-time and apply VRA nitrogen in the one pass, as there is no opportunity to assess the sensing data before making nitrogen application decisions.

Making N application decisions

Crop sensors can be used in conjunction with nitrogen budgets and online decision making tools such as N Calc and Yield Prophet (for wheat crops). These tools allow the user to input important information about the soil, crop and nitrogen status of the field to generate nitrogen recommendations.

Most nitrogen uptake 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 intended yield potential. Where possible, about 70–80 per cent of the nitrogen fertiliser should be applied in this period.

Crop sensing at the end of tillering and the start of stem elongation in cereals can guide nitrogen application rates to optimise yield and protein content to match expected yield potential for the season. Nitrogen fertiliser application should be complete by flag leaf emergence as nitrogen uptake and contribution to yield is minimal once flowering begins.

Nitrogen use efficiency drops when crop plants have access to 'luxury' levels of available nitrogen. Yield data can be used to calculate nitrogen use efficiency at the end of the season and this information can be factored into nitrogen application decisions in subsequent years.

Test strips of different nitrogen fertiliser rates established within a field or management zone can be used to establish the crop's response to nitrogen and this information can also assist in the development of prescriptive maps for future reference. This could be of use in lower yielding or lower rainfall situations to determine variable rate applications at sowing.

Case Study – *I'Anson Farms*

Kym and Katie I'Anson have been using crop biomass sensing as part of a suite of tools to reduce the variability in production across their farms at Marrabel, SA where they grow mainly oaten hay and canola, with a small amount of wheat.

Crop biomass sensing and variable rate in-crop nitrogen application has enabled the I'Ansons to make some of their low lying areas the most productive zones on the farm. These low lying areas are prone to early season waterlogging and denitrification, so crops respond well to in-crop applications of nitrogen. On the higher, shallower soils Kym applies much less nitrogen in-crop to reduce the risk of a dry finish that can result from excessive early growth taking up too much of the available soil moisture.

Canola yield previously ranged from 0.5 to 3 t/ha and now the crops produce 2.2 to 3.5 t/ha and average about 2.6 t/ha. Similarly, yield in the hay crops ranged from 3 to 12 t/ha, which had major implications on hay quality and harvestability. Hay production is now in the range of 7–8 t/ha, which optimises quality and profits. On the 10 per cent of the farm sown to wheat Kym has also evened out yield and uses crop N applications to manipulate wheat protein to suit either hard or soft wheat markets.

Overcoming the constraints on the lower lying areas of the farm meant the I'Ansons could minimise their frost risks while growing the most profitable crops for their business. Having more competitive crops growing across the farm has also drastically reduced annual ryegrass numbers.

For over 10 years the I'Ansons have been implementing soil and crop biomass sensing and variable rate technologies to better understand and manage their soils. Their current management system is underpinned by a Veris MSP soil survey that mapped pH and electro-conductivity (EC) across the farm in 2014. This survey helped identify different soil types and targeted soil sampling for further laboratory analysis to confirm the key constraints to production – primarily acidity and sodicity associated with waterlogging in low-lying areas.

Crop biomass sensing data overlaid on this soil map indicated that denitrification was preventing crops reaching their yield potential. They have recently re-surveyed the farm, collecting pH data to compare with the previous survey along with new optical data that provides indications of changes in soil colour and the mineralisation characteristics of the soil.

The second pH survey has shown that their liming program has been effective and that they can now cut back on their annual inputs of lime. Kym plans to re-survey the farm for pH every 5 years

Kym I'Anson. Photo E Lenoard.

CropSpec. Photo Topcon.

to ensure they are only liming when and where required.

There are currently no legumes in the I'Anson's cropping program so they are reliant on applied nitrogen and mineralisation in the soil to supply the crops' needs. Kym applies chicken manure at a rate of 2.5 t/ha to one-third of the farm each year, which provides the baseline phosphorus requirement, and then applies urea at seeding and in-crop.

Liming has improved P availability, which has led to the I'Ansons reducing the rate of P fertiliser applied at seeding from 16–20 units P/ha to just 4 units P/ha.

At the start of the season Kym determines a target yield for the hay and canola crops based on the stored soil moisture and expected rainfall for the cropping season. He then uses industry standard 'rules of thumb' for nutrient requirements to grow a tonne of grain to determine how much nitrogen is required to achieve the average yield target for each paddock that season (e.g. to achieve a 2 t/ha canola crop requires 140 units N/ha provided sufficient moisture is available, given 1 t canola requires 70 units N ha).

Kym applies 35 units of N at seeding to promote early growth in canola. He does not apply any nitrogen to the cereals at seeding so the crops are better able to conserve moisture for later in the season.

To guide the timing of his in-crop nitrogen applications Kym establishes N-rich strips of 0, 100 and 200 units of N and the total paddock rate estimated to achieve the target yield (e.g. 140 units of N/ha for a 2 t/ha canola crop). These strips are placed together in representative areas of the paddock based on their soil mapping.

Each time the tractor-mounted CropSpec sensors go through a paddock the crop biomass data is recorded and Kym looks for variability in crop growth compared to the N-rich strips. The N-rich strips provide a visual comparison, however the biomass sensors can detect changes in crop growth before the human eye can see symptoms of nitrogen deficiency. Kym is able to take corrective action before the crop begins to stress.

When nitrogen fertiliser is required Kym uses Bredal spreader to apply variable rates of urea across 36 m, based on the real-time data from the CropSpec sensors. He enters the paddock in the middle rather than on a border so the sensors can quickly calibrate with high and low biomass areas of the paddock. Kym picks a target rate of urea for the crop and then sets the spreader controller to apply fertiliser within a set range, say 0 kg/ha to 200 kg/ha, and the VRT system automatically applies the appropriate rate of urea, based on the likely crop response.

Up to 20 per cent of the farm area does not need any applied nitrogen, due to mineralisation throughout the season, however other areas require rates that would be uneconomic to apply across the whole farm. Several applications may be required to spread the full amount of nitrogen estimated at the beginning of the season to achieve yield potential. As the season unfolds Kym is able to update the yield potential and nitrogen requirements according to when and how much rain falls. In canola Kym aims to apply most of the nitrogen budget early in the season to maximise yield without compromising oil content at the end of the season. In contrast, applications in the wheat and hay crops are mostly applied mid-season to avoid excessive vegetative growth early in the crop cycle and conserve moisture for the end of the season.

Kym has found one of the greatest benefits to flow from using crop biomass sensors to manage nitrogen applications has been the ease of management and harvestability that results from having even crops.

Overall profitability has improved for the I'Anson's business as a result of consistently achieving the yield potential for each crop, each season while using the same or lesser amount of inputs.

Other resources

'Proximal Crop Reflectance Sensors – A guide to their capabilities and uses' by Brett Whelan, Precision Agriculture Laboratory, University of Sydney for the GRDC.

'Crop Sensing for Nitrogen Management' by Rob Craigie, FAR, Ian Yule, Massey University & Phillipa McVeagh, Massey University.

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