Using Crop Sensors as an aid for nitrogen decisions

Funded by Caring For Our Country and GRDC (SFS 00017).

Key findings

- Crop sensors are a useful tool for measuring and mapping the growth of crops, however their limitations need to be recognised.
- Poorer crop growth and lower sensor NDVI values can indicate lower N availability within a paddock, but this should be ground truthed, rather than assumed as there are many potential constraints to crop growth that could also be the cause.
- The use of an N-rich strip in conjunction with crop sensors can provide an indication of the likely grain yield response to N.
- The N rate calculation still requires a yield prediction – a potential fit with APSIM / Yield Prophet.
- Utilising predefined paddock zones created from historical yield and/or soil data may help to refine the use of crop sensors for variable rate applications.

Background

There has been a movement away from applying all crop N requirements at sowing to now apply most of the crop's needs in crop during stem elongation (GS30 – 39). This change in application timing allows N input to be better matched to seasonal conditions and may allow greater use of crop sensor technology to aid in N rate decisions. Crop sensors include Greenseeker, Crop Spec, Crop Circle, N-Sensor and may also include imagery from aeroplanes and satellites.

While each of these sensors differs in specifications and features, their current outputs are largely responsive to the green leaf area of the crop, which is often related to crop biomass and N uptake (kg N/ha). The normalised difference vegetative index (NDVI) is an index that is output most commonly from the hand held sensors Greenseeker and Crop Circle, however investigations into improved indices are continuing.

Where variability in crop growth is influenced by N availability these sensors can be utilised to identify the areas in a paddock of higher and lower N availability. Figure 1 demonstrates how a difference in crop growth due to different levels of N availability can be detected by the Greenseeker NDVI sensor at various growth stages. However, the NDVI measurements don't reflect the accumulation of N during the season (Figure 2). This is because the NDVI measurement has a limited range (~ 0.13-0.18 for bare ground to ~ 0.9 for full canopy closure) and "saturates" at high leaf area index, or in this case N uptake (Figure 3).

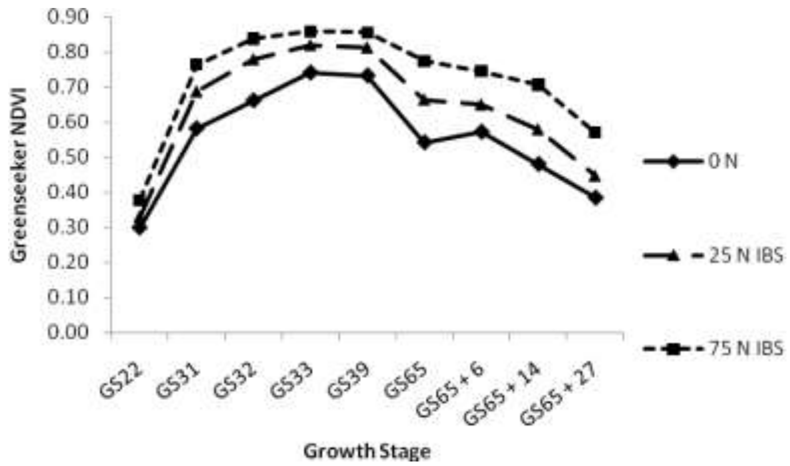

Figure 1: Greenseeker NDVI response to N applied at seeding at a range of crop growth stages. Tarlee 2010, cv Mace.

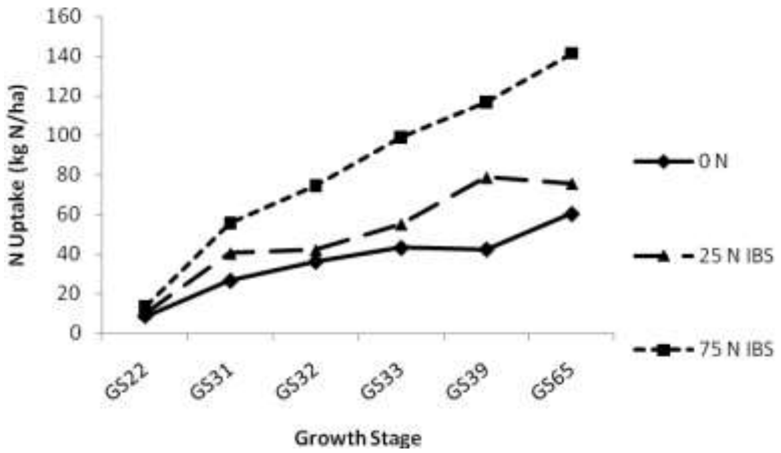

Figure 2: Nitrogen uptake response to N applied at seeding at a range of crop growth stages. Tarlee 2010, cv Mace.

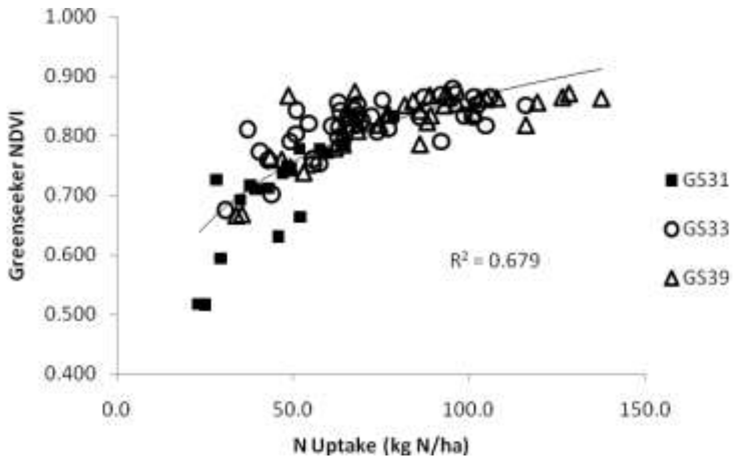

Figure 3: Greenseeker NDVI relationship with N uptake at three growth stages. Tarlee 2010, cv Mace.

Predicting a nitrogen response: N-rich strips
It is possible to implement an automated variable rate system, whereby crop sensing technology is linked directly to a variable rate spreader or boom sprayer, and the rate of N is manipulated according to crop growth. In most circumstances for N application during stem elongation these sensors are calibrated such that N rates are increased where the sensor identifies poorer crop and reduced where the sensor identifies more vigorous crop. This is based on the assumption that N is limiting crop growth and that variable N availability is the cause of variability in crop growth. Where this assumption holds true it is a valid use of the crop sensors.

To validate the assumption that N is limiting crop growth and is the cause of variability in the field N-rich strips can be applied to act as an in-field reference. An N-Rich strip is a high N reference strip that the farmer managed crop can be referenced against. Crop sensor measurements of both the N-rich strip and the farmer managed crop can be recorded and a response index (RI) calculated, that is indicative of the likely final yield response to N, where
RI = NDVI fertilised reference strip/ NDVI unfertilised crop
To establish the relationship between the in season RI and the final yield response trials have been setup in five paddocks across the Mid North in 2009 and 2010. N-Rich strips have been applied to wheat and barley across a range of soil types (Figure 4). NDVI of the N-rich strip and the adjacent unfertilised crop were measured during the growing season to determine the RI. A range of RI's were established in each paddock and at each of these sites a replicated small plot trial was put in place with N treatments ranging from 0 to 100 kg N/ha (Figure 4).

These were applied during stem elongation. Grain yield and protein were measured at each site in each paddock, an example of the yield responses observed in a paddock at Kybunga is shown in Figure 5. Grain yield N response at each site was calculated and correlated with the RI measured during the season (Figure 6 & 7).

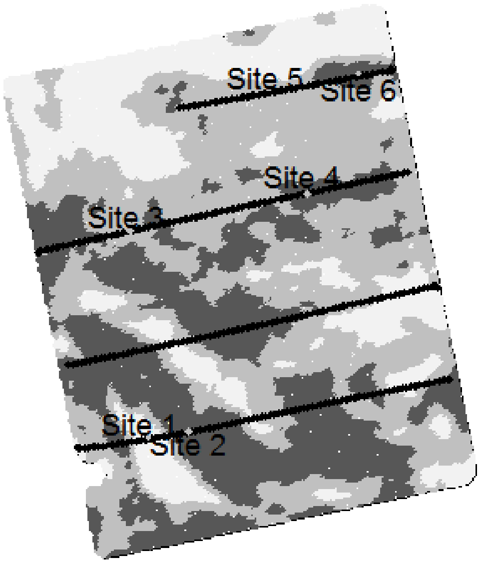

Figure 4: Location of N-rich strips (black lines) and trial sites in relation to the paddocks productive zones in a paddock at Kybunga, 2010. Similar designs were utilised in the other four paddocks.

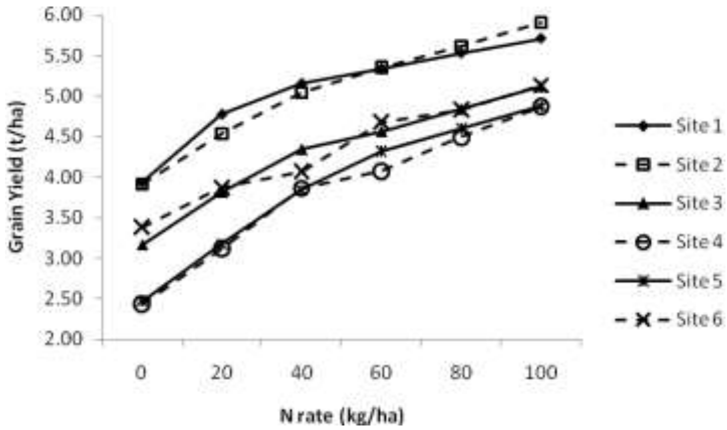

Figure 5: Grain yield response to applied N at six sites in a paddock at Kybunga, 2010.

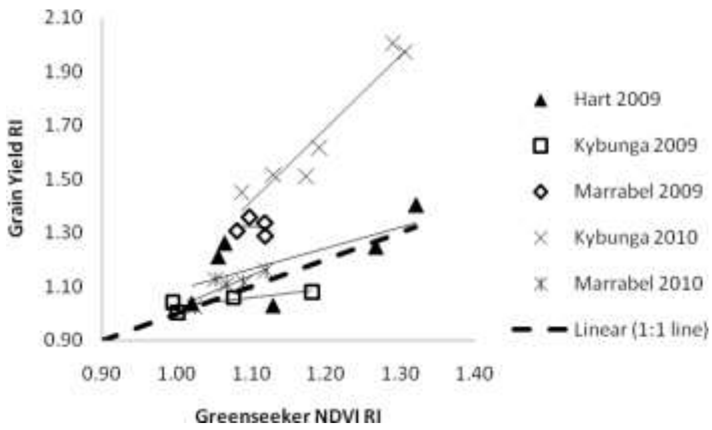

Figure 6: Relationship between in season response index and final grain yield response index for five paddocks. Growth stage is indicated in brackets. Hart 2009 (GS32, R2 = 0.44), Kybunga 2009 (GS22 R2 = 0.71), Marrabel 2009 (GS32 R2 = 0.009), Kybunga 2010 (GS32, R2 = 0.92), Marrabel 2010 (GS37, R2 = 0.71).

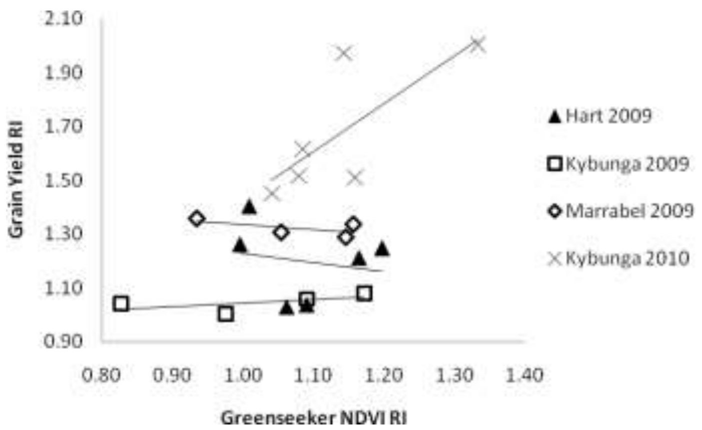

Figure 7: Relationship between in season response index and final grain yield response index for four paddocks. Growth stage is indicated in brackets. Hart 2009 (GS14, R2 = 0.04), Kybunga 2009 (GS13 R2 = 0.36), Marrabel 2009 (GS15 R2 = 0.38), Kybunga 2010 (GS30, R2 = 0.57).

The relationship between in season growth response measured by NDVI and the final yield response was found to have a correlation coefficient (R^2) of 0.44 or greater in 4 of 5 paddocks (Figure 6). The Marrabel 2009 data had a poor within paddock correlation, this can be related to the very narrow range of both in season NDVI RI and grain yield RI. However, the points still fall within the range of the other paddock data sets. The in season NDVI RI never exceeded 1.32, while the grain yield RI reached a maximum of 2. The limited range of the NDVI RI can be attributed to the limited range of the NDVI itself.

The growth stage when the in season NDVI RI is calculated appears to have a significant impact on the relationship with final grain yield response. The in season NDVI RI's measured at earlier growth stages (GS13 to GS30) in Figure 7 tend to have a poorer relationship with final grain yield response compared to the in season NDVI RI's measured at later growth stages (GS22 to GS37) in Figure 6. It might be possible in the future to establish a relationship between the timing that a significant in season NDVI RI can be measured and the final grain yield response. Increasing the period before the in-season measurements are recorded increases the time for the crop to "display" (in crop canopy greenness and biomass) how much N is available to it at that time.

In the five trial paddocks, calculating an in season NDVI RI improved the prediction of a grain yield N response compared with using the NDVI of the unfertilised crop only in some cases (Figure 8). At the Hart paddock in 2009 utilising N rich strips across the range of soil types improved the prediction of a grain yield response significantly, where the correlation coefficient increased from 0.04 when relying on the NDVI of the unfertilised crop only to 0.44 when incorporating the in season RI (Figure 6 & 8). In this paddock one of the six sites had a low NDVI suggesting a large N response would be expected, however it also had a low in season response to applied N, and this was due to other soil constraints limiting the crops ability to respond to N. It subsequently had a low grain yield response to N.

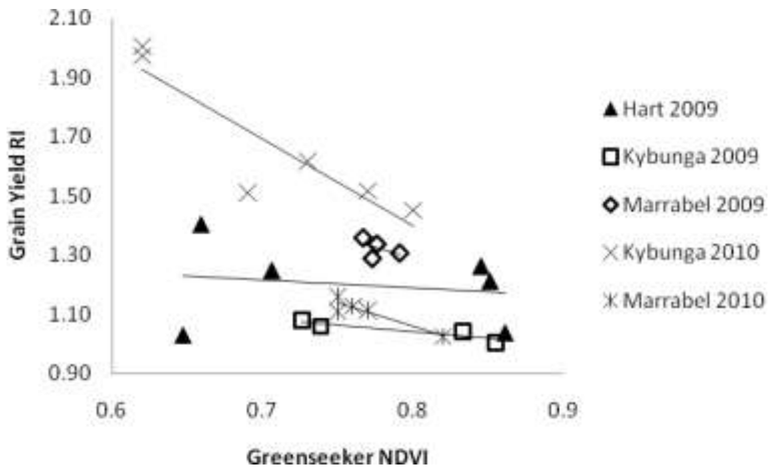

Figure 8: Relationship between NDVI of unfertilised crop and final grain yield response index for five paddocks. Growth stage is indicated in brackets. Hart 2009 (GS32, R^2 = 0.04), Kybunga 2009 (GS22 R^2 = 0.83), Marrabel 2009 (GS32 R^2 = 0.23), Kybunga 2010 (GS32, R^2 = 0.81), Marrabel 2010 (GS37, R^2 = 0.86).

Fine tuning the N rate calculation

The crop sensors in conjunction with an N-rich reference strip provide an indication of N supply to the crop at that point in time and a relative indication of the likely final yield response to N. However, in isolation it does not provide a recommended N rate. Oklahoma State University use the following methodology to calculate an N rate based on the sensor readings –

1. Estimate of grain yield without additional N, based on NDVI measured at GS30 and the growing degree days (GDD) > 0 (INSEY based on numerous trials)
2. In season response index (RI) = NDVI N-rich/NDVI unfertilised paddock
3. Estimation of yield with N = RI x Yield with no N applied
4. N rate to be applied = [Grain N content of fertilised crop (from step 3) – Grain N content of unfertilised crop (from step 1)] / Nitrogen use efficiency (usually 40-50% under Australian conditions)

The methodology has merit for use in Australia, however it is expected that the grain yield estimate could be improved by incorporating soil moisture and historical climate data into the calculation, i.e. in the form of APSIM. The relationship between in season crop growth and final crop yield can be highly variable between seasons under Australian conditions due to the variable spring conditions that are encountered, and the potential for haying off, so higher NDVI measured at GS30 does not necessarily imply higher yield as it does in the above methodology.

Also, step 3 assumes a 1:1 relationship between final grain yield response and in season N response measured by NDVI. This assumption is not always valid. Figure 6 shows that the grain yield N response ratio with in season N response ranged from 0.9 to 1.55:1. This too may be influenced by variable climatic conditions following the collection of in season measurements. It may also be an artefact of the limited range of the NDVI, and therefore also the in season NDVI RI.

To incorporate an improved yield prediction that utilises soil water holding parameters on a spatial basis requires the use of additional data layers, including historical yield data and soil sensing data such as EM38 and Gamma radiometrics, an example is shown in Figure 4. Combining the use of historical data and in season imagery recognises that there can be zones of significantly different yield potential within a paddock, however there can still be significant variability within those zones that the crop sensors can identify.