Project Catalyst Trial Report

Variable Rate Maps from Haulout Sensors

Grower Information	
Grower Name:	Steve and Marguarite Young
Entity Name:	Casey Zarb Pty Ltd
Trial Farm No/Name:	4202A
Mill Area:	Mackay Sugar
Total Farm Area ha:	240
No. Years Farming:	20
Trial Subdistrict:	Sandy Creek/Homebush/Bakers Creek
Area under Cane ha:	200

Trial Status

Completed

Author: John Markley (Farmacist). For further information contact John on Mb. 0408 185 083.

Background Information

Aim: To improve the availability and accuracy of variable rate (VR) maps to growers by using low-cost sensors on haul-out vehicles to produce cane yield maps.

Background:

Using known yield data would greatly improve the accuracy, and provide added confidence, for growers to apply variable rate nutrients. While newer model harvesters have advanced in improving the accuracy of factory fitted harvester yield monitors, the reality is most harvesters used in the industry to not have this technology. Unfortunately, it is grower experience that market harvester yield monitors have their issues and are expensive. This has impacted adoption.

Steve (Figure 1) and Maguarite Young farm more than 240 hectares in the Homebush/Sandy Creek and Bakers Creek area in the Mackay region. Steve also operates a harvesting contract business. Steve's harvester had one of the first GPS tracking devices fitted when introduced by Mackay Sugar in the early 2000's, and he has taken a keen interest in understanding yield variations that exist within a farming operation.

This project sought to explore opportunities to develop low-cost and reliable yield data using a combination of GPS and satellite technologies. Data was collated and analysed to produce effective yield maps that growers can utilise to develop VR nutrient maps.

Figure 1 - Steve Young

Potential Water Quality Benefit:
The application of VR nutrients that reflect yield variability has shown to significantly improve Nitrogen Use Efficiency (NUE), without impact to yield. The improved NUE results from improved synergy between Nitrogen (N) application and plant uptake potential, therefore reducing the amount of N that remains unused in the soil and exposed to loss pathways.

Expected Outcome of Trial:
This project will provide data from GPS tracking devices and satellite imagery that can be converted to show accurate yield variability within cane paddocks.

Service provider contact: Farmacist Pty Ltd

Where did this idea come from: Farmacist and Steve Young

Plan - Project Activities		
	Dates:	**Activities:**
Stage 1	Dec 2016	• Install logger and electronics onto selected haul-out vehicle • Gather data, assess calibration of sensors, develop protocols for algorithm development to calculate cane yield • Assess suitability of device, make suggested changes
Stage 2	June 2017	• Install required hardware onto all haul-out vehicles in harvesting group
Stage 3	Nov 2017	• Analyse collected data, create yield variation maps • Develop Variable rate nutrient maps • Select trial site location • Instigate trial to compare VR application against standard practice
Stage 4	Nov 2018	• Harvest trial location, compare cane yields • Collect yield monitor data • Develop Variable rate nutrient maps • Select trial site location/s • Instigate trial comparing VR to grower standard
Stage 5	June 2019	• Install updated GPS monitoring equipment into harvester • Test software development
Stage 6	December 2019	• Report Progress
Stage 7	August 2020	• Updated GPS and software trials • Variable rate fertiliser map production and implementation into controller

Project Trial site details

Trial Crop:	N/A
Variety: **Rat/Plt:**	N/A
Trial Block No/Name:	N/A
Trial Block Size Ha:	N/A
Trial Block Position (GPS):	N/A
Soil Type:	N/A

PROJECT CATALYST

Block History, Trial Design

Sensors and Tracking Device

Air bags are often fitted as an alternative to conventional steel spring suspensions, especially on trucks and trailers that travel over rough terrain. Air is pumped in to reinforced rubber bellows that raise the trailer chassis from the axle. Tests indicated that there is a direct correlation between air bag pressure and weight of product in the trailer to which the air bag is fitted.

The sensors fitted to the haul-out vehicle are 0-10 bar pressure transducers with a 4-20mA output (Figure 1), installed onto the airbags in September 2016. The output of the pressure transducers feed into a GPS tracking device that integrates GPS signals, GSM modem and data logger (Figure 2).

Figure 1 - 0-10 bar pressure transducer

Figure 2 - GPS tracker and Data Logger

The date from the loggers is sent via the mobile phone network to a purpose-built database. An example of the type of data sent is shown in Table 1.

Table 1 - Example of transmitted data from data logger

Report Time	Latitude	Longitude	Direction	Input 1	Input 2
4:04:30 AM	21.26269	149.092093	333	171	304
4:04:32 AM	21.26268	149.09208	335	171	304
4:04:43 AM	21.26238	149.0919958	240	171	316
4:05:33 AM	21.26237	149.091958	240	175	317
4:05:44 AM	21.26251	149.0916928	61	175	317
4:06:34 AM	21.26251	149.0916928	61	175	318
4:06:45 AM	21.26251	149.0916928	61	174	318
4:07:34 AM	21.26251	149.0916928	61	173	318
4:07:45 AM	21.26251	149.0916928	61	173	318
4:08:35 AM	21.26251	149.0916928	61	232	310
4:08:44 AM	21.26251	149.0916928	61	249	295
4:09:34 AM	21.26251	149.0916928	61	279	310
4:09:44 AM	21.26251	149.0916928	61	266	311
4:11:35 AM	21.2619	149.09046	302	205	350
4:11:46 AM	21.26178	149.089988	274	205	350
4:11:55 AM	21.26174	149.089413	274	203	350

Results

A plot of air bag pressure versus time (Figure 3) clearly shows the pressure within the airbags increases as the haul-out bins are being filled during harvest operations. It then rapidly declines when the haul-out empties the load into cane bins on the mill rail system.

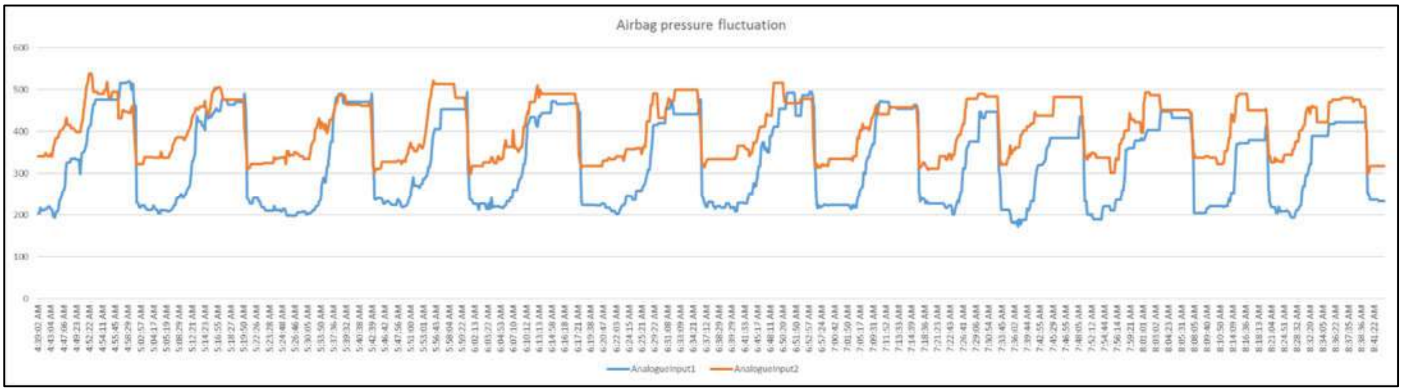

Figure 3 Fluctuation in airbag pressure over time

Upon closer inspection, there is considerable fluctuation in the sensor values as the bin is being filled. This can be attributed to a variety of reasons but predominately the rough terrain inside a cane paddock causes highly variable pressures in the air bags. The cause of fluctuation is very difficult to assess as weight increase of cane in the bin or air bags being pressurised from the travel over rough terrain.

Evaluation refocuses trial

In 2018, rather than monitoring the haul-out vehicles and airbag sensors, the trial monitored harvest position on a daily basis. GPS tracking devices fitted to the harvester record the positional location of the harvester at regular intervals. This data was then transmitted from the GPS device into a dedicated database. Here the position reports were analysed and processed to produce maps of the locations where cane has been harvested.

The calculated harvest area for each harvest day was then matched to the weight of cane, as measured by the mill weighbridge, for each harvest date to create a daily area yield map (Figure 4). Without further processing, these maps alone demonstrate the often extreme variability in cane yield across a farm.

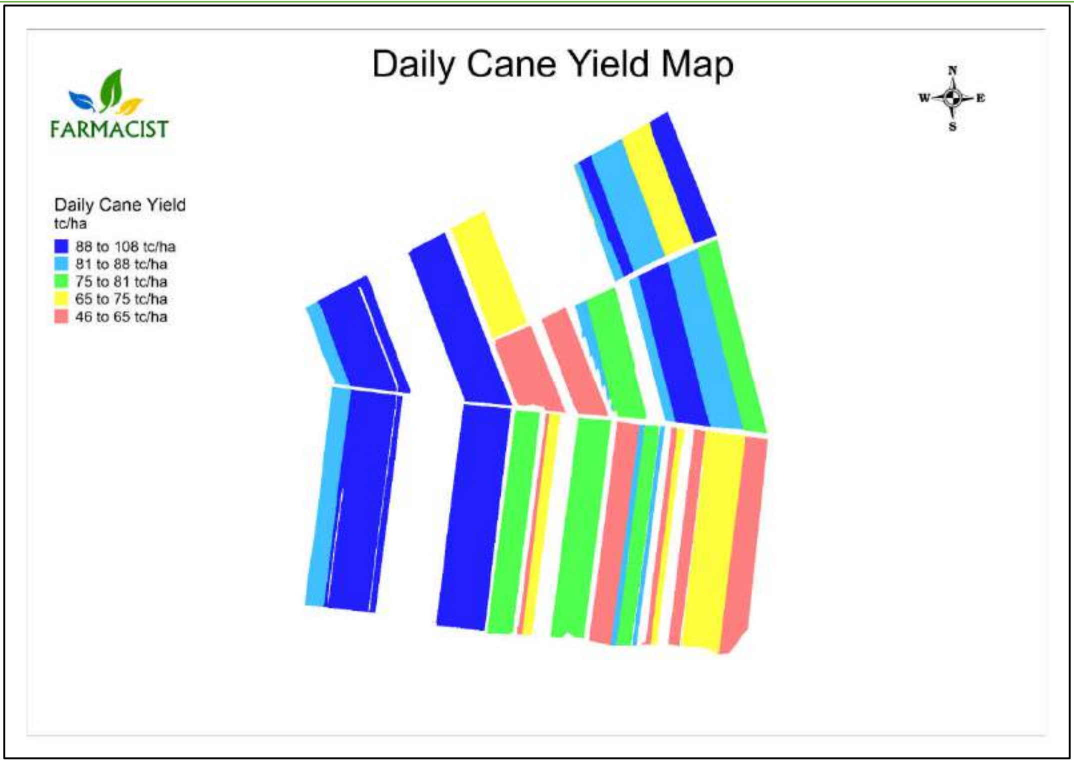

Figure 4 - Daily harvest yield map

The use of satellite imagery

Multi-spectral satellite imagery has been used for several years to assess the health, vigour and yield potential of many agricultural crops, with Farmacist being one of the pioneers in developing techniques and algorithms to process satellite data into cane yield. Assessment of crop yields usually requires the conversion of the satellite data into vegetation indices such as Normalised Difference Vegetation Index (NDVI) or Green Normalised Difference Vegetation Index (GNDVI). Once converted, calibration algorithms are used to convert the indices into cane yields. However, one of the lingering doubts as to the level of accuracy of calculated cane yields is the lack of detailed calibration data to assess the validity of the algorithms when converting from the vegetation index.

This project has produced a method whereby the daily yields, as calculated from the harvester and weighbridge date, can be used to accurately calibrate satellite data to show actual and detailed cane yield variability.

Prior to the commencement of the 2018 harvest season, a 10-metre spot multispectral satellite image was acquired and analysed to indicate the variability in vigour using NDVI. The satellite data was overlayed onto the daily harvest map (Figure 4) where daily harvest yields were used to convert the variations in NDVI values from the satellite image into a yield variation map (Figure 5).

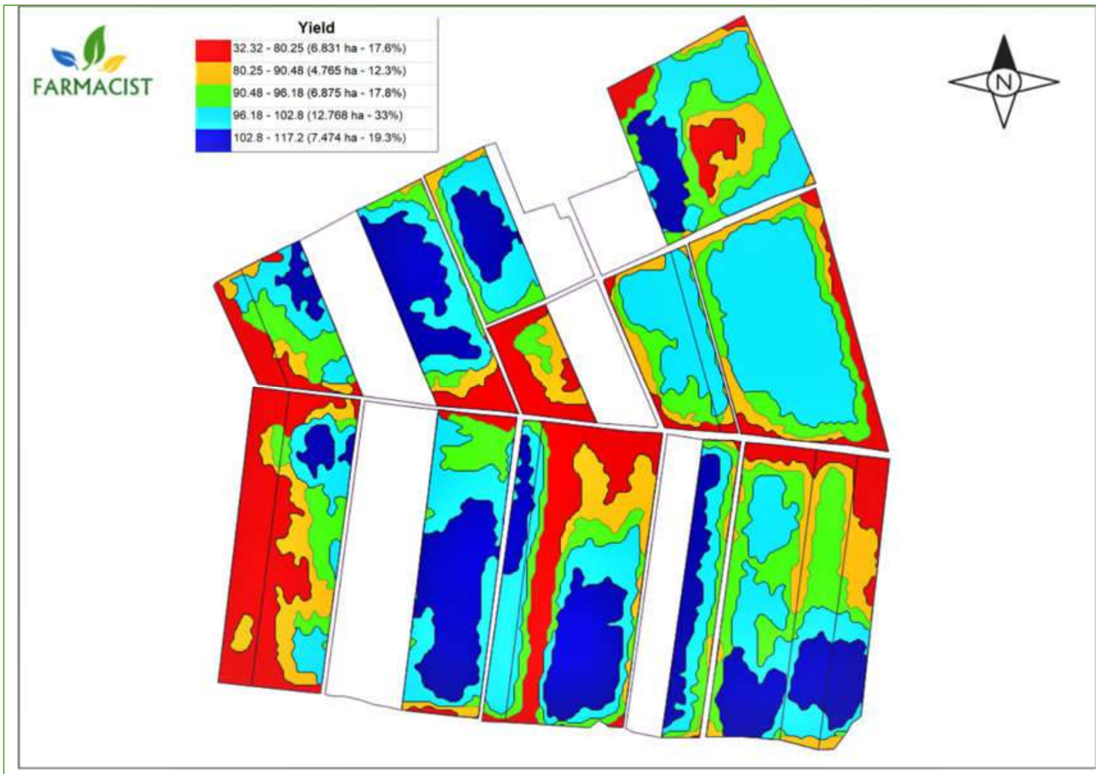

Figure 5 - Yield variation map

2019 Data

Harvester position reports from early in the 2019 harvest season, combined with daily delivery data from the farm, were used to create a daily harvest yield map (Figure 6). This shows a wide variation in average cane yields for each harvested area within the 16 hectare block, ranging from less than 82 to more than 111 tonnes per hectare (tc/ha).

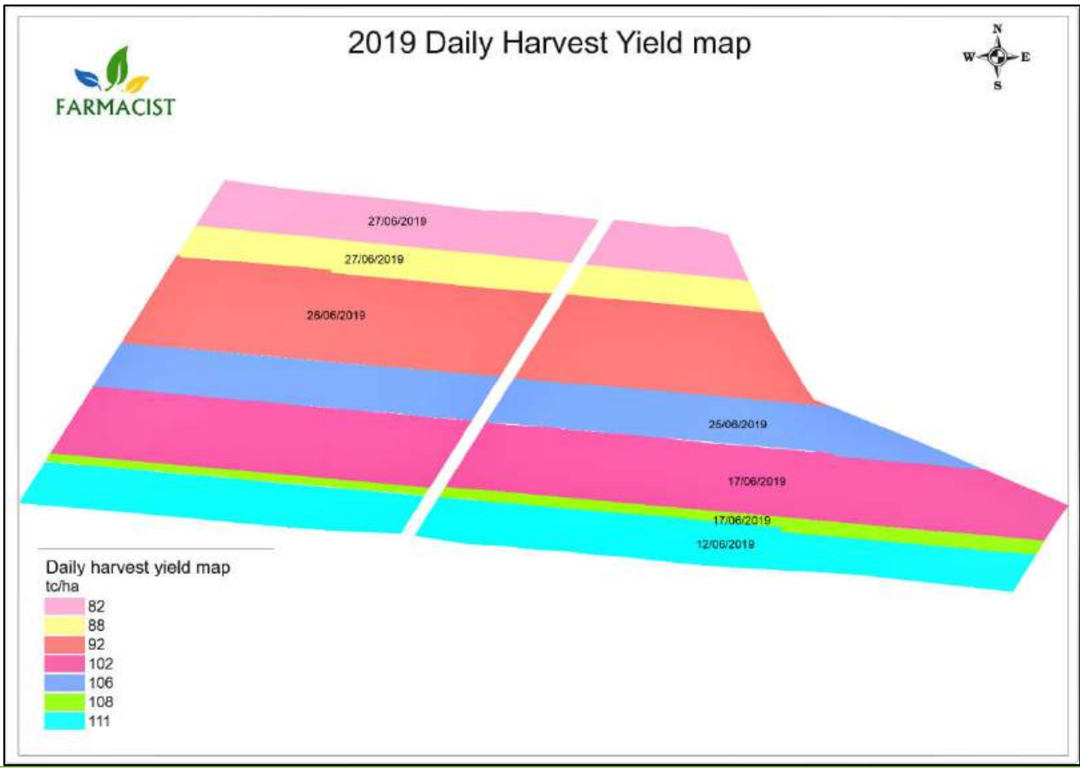

Figure 6 - 2019 harvested area daily yield map

A satellite image captured in April 2019 was converted to GNDVI and overlayed onto the daily yield map. The variability within the GNDVI values from the satellite imagery were calibrated using the daily yield data, producing a detailed yield variation map (Figure 7). The map shows large variation exist in yields within this block, ranging from a low of 47 tc/ha to a high of 131 tc/ha. Overall , the block averaged 100 tc/ha.

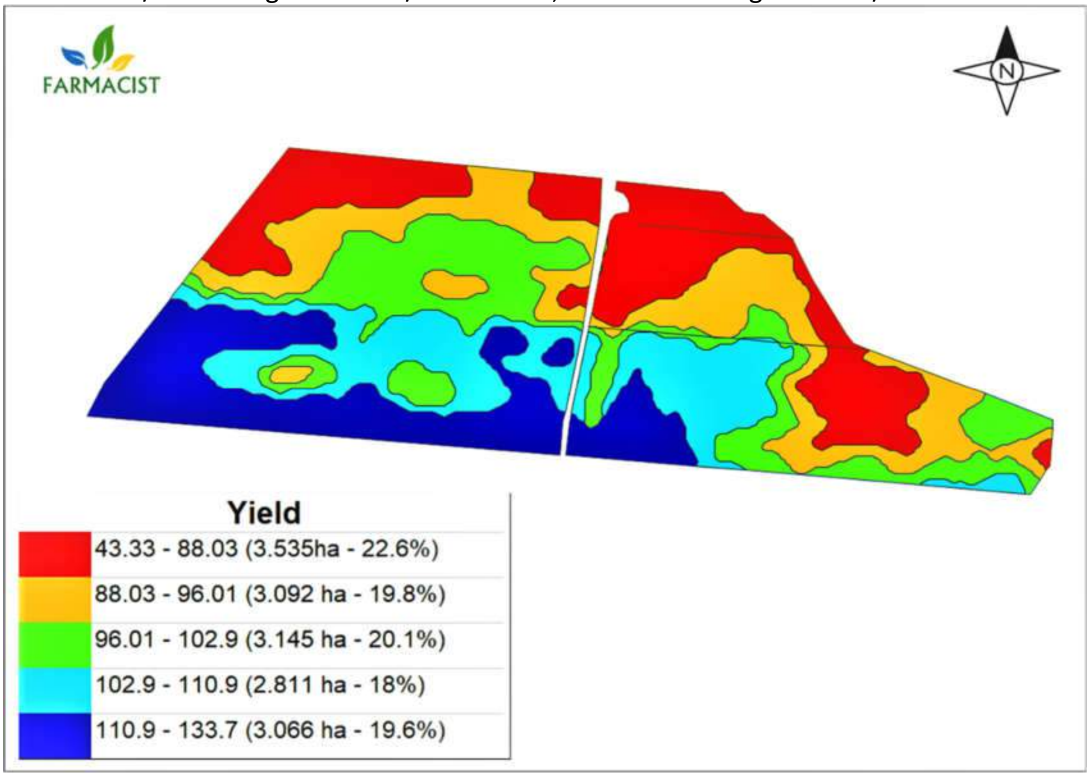

Figure 7 - 2019 yield variation map generated from combination of harvester position and satellite image analysis

In July 2019, an upgraded GPS tracking device was fitted to the harvester (Figure 8) which provided similar positional accuracy to the previous device, however, the upgraded device improved installation efficiency by more than 50%. This is because they do not require external antennas to be mounted to the harvester.

Upgrades also included changes to processing software that allowed for the automated processing of daily harvesting reports, matching cane harvested for the day to the area harvested for the same day.

Figure 8 - Upgraded GPS monitor fitted to the harvester for the 2019 harvest season.

Validation of image calibrations

In November 2019, a cane block within the Young's farm was used to validate the accuracy of the calibrated satellite image. Using the Farmacist weigh truck, plots of 3 rows wide (row width 1.83m) by 30 metres long were harvested and weighed to calculate actual cane yields within each plot (Figure 9).

Figure 9 - Validation plot layout

A comparison of the actual cane yield, as derived from the weigh truck, to the calibrated yield from the satellite image showed a high degree of correlation achieving an R^2 of more the 0.85 (Figure 1).

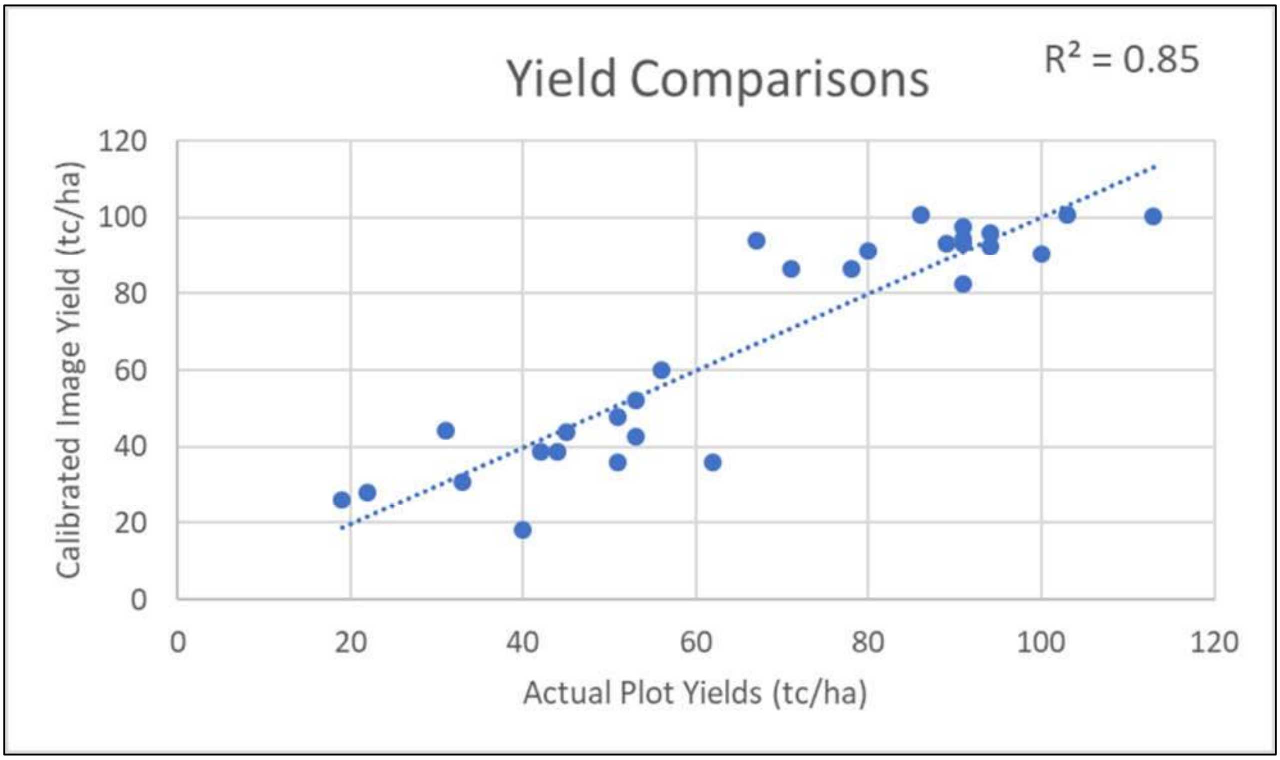

Figure 10 - Comparisons from plot actual cane yields against calibrated satellite image derived cane yields

A yield variability, map generated from the calibrated satellite image for the block, also showed extreme variability of cane yield (Figure 11) ranging from a low of 26 tc/ha to more than 100 tc/ha.

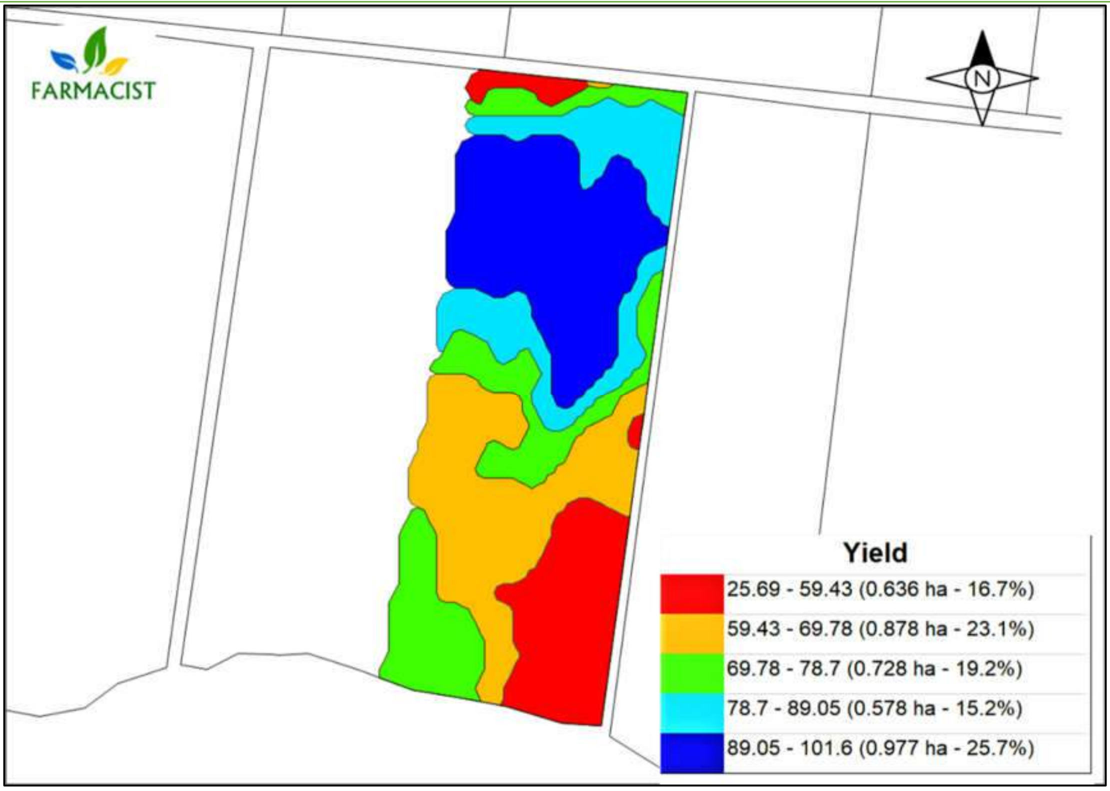

Figure 11 - Within paddock yield variability

Variability within whole of farm

The Young's Baker's creek farm was harvested in mid-October 2019 with average daily harvest yields ranging from 65 to 85 tc/ha (Figure 12).

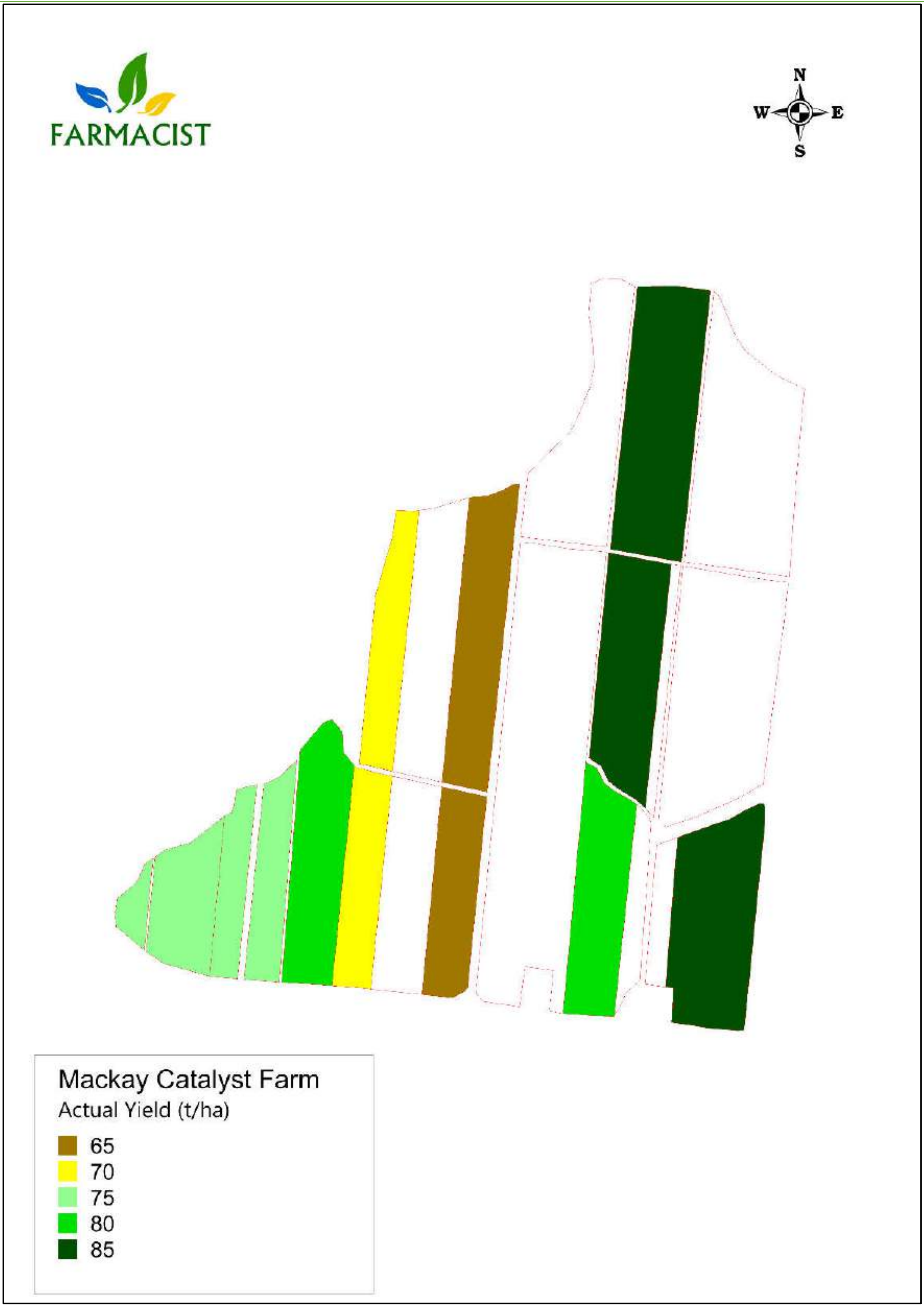

Figure 12 - Daily harvester yield map

The development of the calibrated satellite yield variation map again highlighted significant variability of more than 54 tc/ha across the farm, and within paddocks (Figure 13).

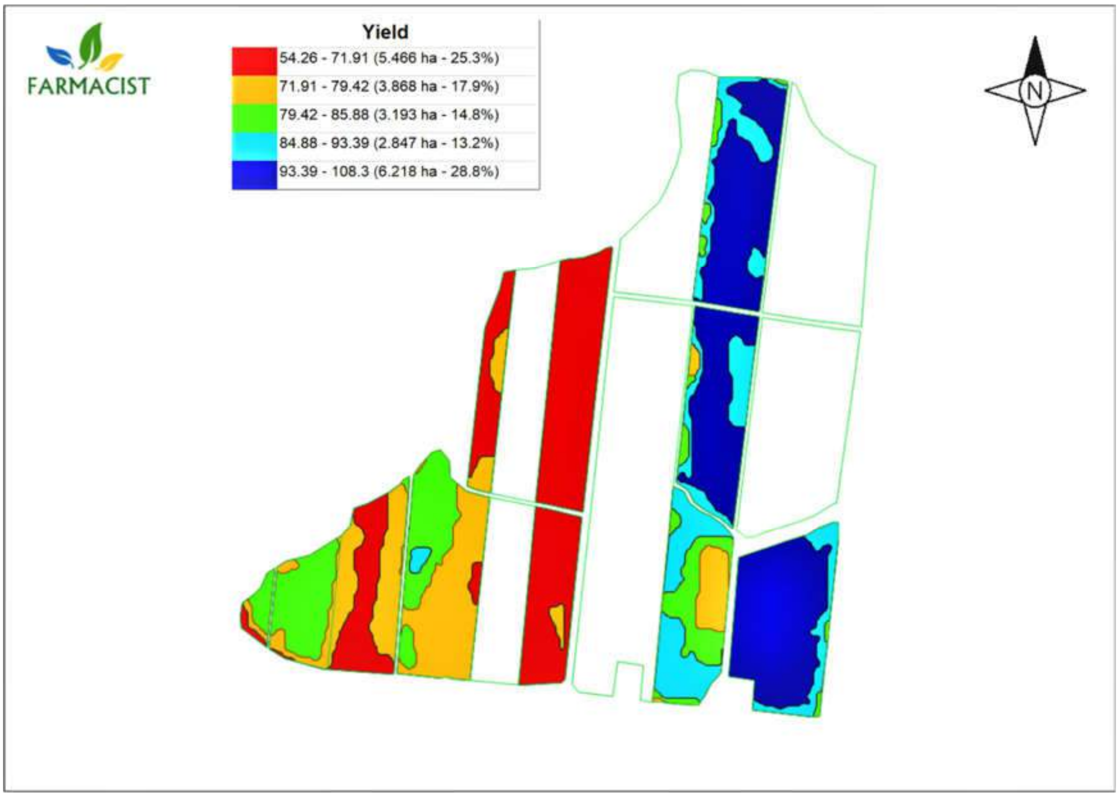

Figure 13 - Farm yield variability map

2020 Data

GPS position reports received from the harvester were used to create daily harvest areas. The tonnes of cane delivered from the harvested farm for the day was allocated to the harvested areas to create a paddock-by-paddock yield variation map (Figure 14).

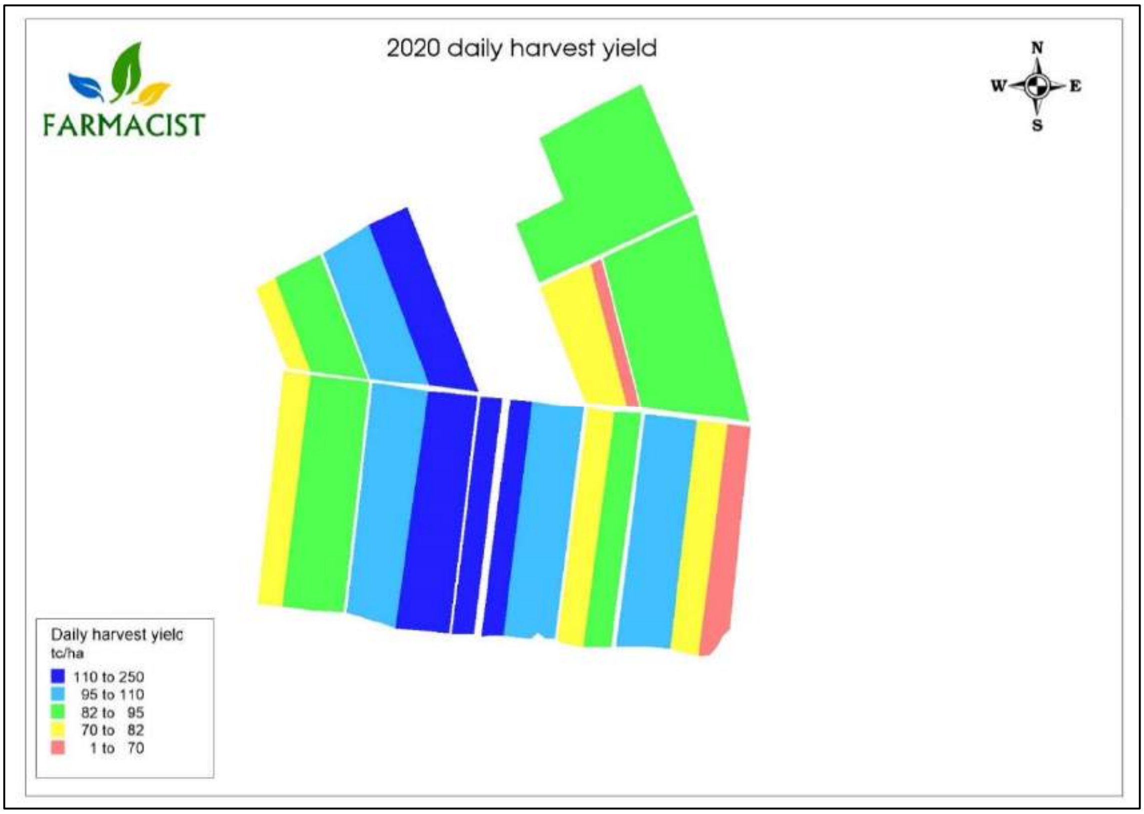

Figure 14 - 2020 daily harvest yield map

The yield variability for this farm is significant, from below 70 to >110 tc/ha.

Satellite Imagery and yield calibrations

An image from the Sentinel-2 satellite was captured in May 2020. The imagery has a pixel resolution of 10 metres and captures multi-spectral data in the visible, near infrared and shortwave infrared spectral zones. Vegetation indices, such as NDVI, have been used to detect changes in vegetation status of sugar cane crops (Markley & Fitzpatrick, 2004. Markley & Hughes, 2013). Data from the Sentinel-2 imagery was converted to NDVI and subsequently calibrated to cane yield using the daily harvested yield data (Figure 15). The calibrated satellite data highlights the significant within-paddock yield variation across the farm ranging from 20 tc/ha to >148 tc/ha.

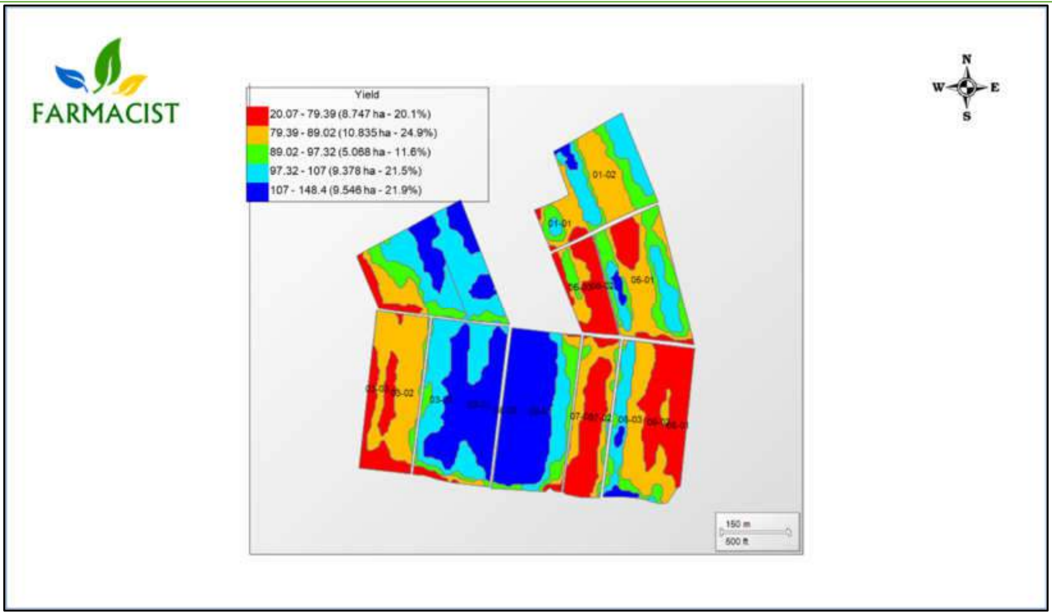

Figure 15 - Within Paddock cane yield variability (2020)

The yield legend box within Figure 15 also indicates the percentage of the farm that is within each yield category. The average cane yield for this farm in 2020 was 93 tc/ha. Interestingly, 45% of the farm is below the average yield category and 43% of the farm is above the average yield category with only 12% classified as being average yield. This result further highlights the significance of the yield variations within the farm.

Validation of image calibrations

In November 2020, data from individual plots was used to validate the accuracy of the calibrated satellite image using the same methodology used in the 2019 validation process. The 2020 validation saw a slightly improved degree of correlation with the R^2 improving from 0.85 in 2019 to 0.86 (Figure 16).

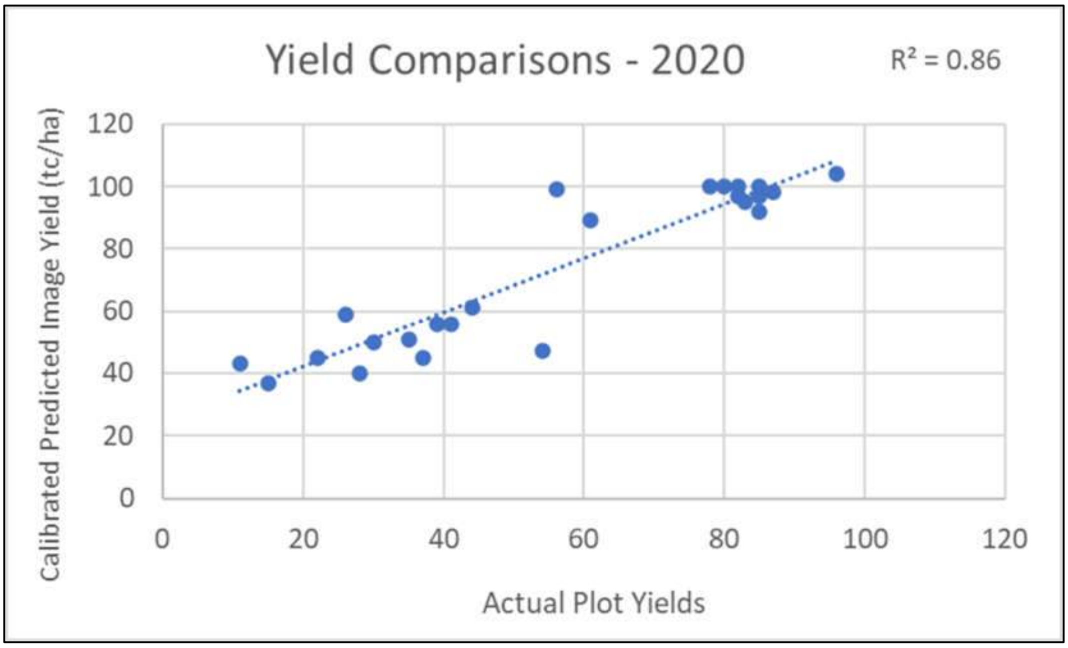

Figure 16 - Comparisons from plot actual cane yields against calibrated satellite image derived cane yields (2020)

Conclusions and comments

Trials to evaluate whether measuring airbag pressure in a haul-out vehicle would provide data to determine yield variation within a cane paddock were proven unsuccessful due to the extreme fluctuations in pressure caused from travelling over rough terrain. The fluctuations created excessive 'noise' in the data signals, making it difficult to process with any great confidence.

A change in focus in 2018 saw harvester GPS position reports used to create area harvested polygons that can be directly matched to daily farm delivery information. These can then be used to create daily yield maps and, when overlayed with satellite data acquired in the pre-season, yield variability maps with a high degree of accuracy.

The development of the satellite calibration process, based on daily harvest yields, has proven to be reliable and repeatable with an acceptable degree of accuracy. The level of accuracy achieved has given the grower confidence to use the data as the basis for implementing a variable rate fertiliser application program within locations that exhibit high yield variability.

Advantages of this Practice Change:
A reliable and repeatable method of creating cane yield variability within a farm. There is a need to have a GPS tracking unit installed on the harvester. The older versions required significant purchase and installation costs totalling approximately $650, however, the new GPS tracking unit offers significant cost reduction with purchase and installation costs of approximately $200. This method negates the need to purchase and maintain costly harvester yield monitors.

Disadvantages of this Practice Change:
To produce within paddock yield variation maps, a cloud free satellite image is required to be captured during April or May of each year. Sugar cane growing regions can have excessive cloud coverage during these months that may prevent a capture of a suitable image. If this is not available, within paddock variation maps may not be produced, however, an alternative is to use daily harvest areas matched to tc/ha harvested to produce accurate yield maps on a day to day basis.

Will you be using this practice in the future:
Yes, the provision of accurate yield information is important to the decision-making process, not only for nutrients but also crop rotations, weed, pest and disease information and early detection of issues where crop yields maybe in decline.

% of farm you would be confident to use this practice: 100%
Steve has two farms that the family owns and manages. He intends to use yield information for both farms.