# Sugar GPS Coordination Applications and Future Directions

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## ABSTRACT

During recent years there have been several changes both technologically and operationally in the way Mackay Sugar has undertaken harvest and transport management. From the introduction of remote sensing technologies in 2001 through to the continued development of GPS technologies, Mackay Sugar has been at the forefront of innovations and applications.

This paper discusses why these technologies have been introduced and will outline what further changes are intended to allow the development of an integrated farming, harvest and transport management system.

Some of the developments discussed in this paper include the introduction of GPS tracking devices onto harvesters, the development of a harvester yield monitor, the construction of a GPS base station network, development of Near Infrared Spectroscopy (NIR) technology and the development of GIS software to integrate the different spatial datasets.

## INTRODUCTION

The Mackay Sugar Co-operative owns and operates 4 raw sugar mills located throughout the Pioneer River Valley in the Mackay district of Queensland. The co-operative has approximately 900 grower shareholders growing sugar cane on approximately 88,000 hectares of land. The annual crop size (depending on conditions) can be 5 to 7 million tonnes of sugar cane and is harvested and processed annually between June and December. The crop would normally yield between 800,000 and 1,000,000 tonnes of raw sugar.

- Cane supply staff have the important task of keeping sugar cane supplied to the mill at an appropriate rate (up to 50,000 t/day). This task is complex owing to a number of factors, including:
- Sugar cane deteriorates quickly after harvesting, and it is preferable to process within 24 hours of harvest to maximise sugar production. This means that the control of the volume of cane being harvested on a daily basis is essential.
- Existing Cane Supply and Processing Contract requirements means that the proportion of cane being harvested is equal amongst the harvesting groups (a harvesting group is typically a group of growers using the same cane harvester to harvest the cane crops)
- A number of factors such as weather conditions, soil type/condition, disease, access to irrigation will change farm estimates during the harvest season and it is therefore necessary to perform a re-estimation of the remaining crop for all farms on a regular basis throughout the harvesting season.

To meet the challenges that have been raised above, Mackay Sugar regularly re-estimates the cane crop remaining on each farm during the harvest season. In its simplest form, the re-estimation process is the calculation of a ratio comparing the actual yield for an area of harvested cane against the original estimate for that same area and applying the calculated ratio to the remaining crop estimates for each farm. This in turn is used to calculate what percentage of the daily cane loading is required for each of the harvesting groups.

The two necessary inputs for re-estimation are, area harvested (to a point in time) and the tonnes of cane harvested from that area. The tonnes harvested for each farm is determined by the weight of the sugar cane delivered across the weighbridge at the sugar mill to which it is delivered.

In 2001 Mackay Sugar introduced remote sensing technology to tackle two major applications (Markley *et al*, 2003*)*. The first application developed was a crop estimation program and the second application was to develop a program that used remote sensing to determine area of harvested cane land at different times throughout the harvesting season. Unfortunately, obtaining regular cloud free imagery (especially following the demise of the image quality of the Landsat 7 satellite) has proved to be difficult at times and whilst remote sensing applications are still widely used by Mackay Sugar, a more reliable method of determining area harvested on a regular basis needed to be developed.
The introduction of GPS tracking devices onto harvesters was the first in a series of steps that Mackay Sugar has taken in what could commonly be described as a 'precision ag' route. This has included development of a harvester yield monitor, the construction of a GPS base station network, development of NIR technology to measure different sugar cane constituents that include nutrient components, the liaison with other GPS technology datasets such as Soil Electrical Conductivity (EC) mapping data and the development of GIS software to integrate the rapidly expanding spatial datasets.

## GPS ON HARVESTERS

Currently, Mackay Sugar has 164 harvesting groups harvesting 1480 cane farms with group sizes ranging from less than 5000 tonnes per harvester to in excess of 125,000 tonnes. In order to offer a more reliable estimate update, especially for the larger harvesting groups, Mackay Sugar introduced GPS tracking technology onto harvesters in 2005. One of the influencing factors for the introduction of GPS technologies onto harvesters was the relatively inexpensive cost coupled with an acceptable spatial accuracy for the applications proposed of the GPS receiver (between 2 and 3 metres).

Originally there were GPS units fitted to 43 harvesters in the Mackay Sugar area but this has since expanded to 51 harvesters that represents approximately 45% of the total sugar cane crop being harvested in the Mackay Sugar region. Mackay Sugar also fitted the same GPS tracking devices to its entire cane haulage locomotive fleet and track maintenance vehicles (another 64).

The original tracking units installed was a dats 3022 device manufactured by MT Data. The 3022 remote tracking unit consisted of a Trimble Lassen iq GPS receiver, a processing unit and a CDMA 1x modem used to transmit data from the remote vehicle to the Mackay Sugar data network. The first year of operations encountered numerous problems, mostly concerning the performance of the Telstra CDMA-1x network along with a few software bugs in the tracking device. Following considerable debate, Telstra proceeded to upgrade their CDMA network in the Mackay area at the start of 2006 and along with changes to the device software, an almost 100% reliability factor was obtained in the 2006 and 2007 cane harvest seasons for the data collected by the devices and the transmission of that data via the CDMA-1x network.

Unfortunately, the decision by Telstra to close the CDMA network in early 2008 has meant a complete re-development and re-installation of all tracking devices on harvesters and locomotive fleet. The units (dats 3026) were once again manufactured by MT Data and incorporates a ublox GPS receiver module, an on board processor and a Siemens NextG modem. Whilst the initial development and installation has progressed relatively smoothly, there are some concerns that NextG coverage in the Mackay area may be below that experienced with the CDMA network.

The primary reason for the installation of the GPS units was to track harvester location and to then convert those GPS positions into harvesting tracks and then finally into harvested area (Figure 1) (Crossley and Dines, 2004). The area is then used (in conjunction with the tonnage of cane supplied) to calculate a re-estimation of cane remaining on farms which is in turn used to re-calculate daily loading requirements.

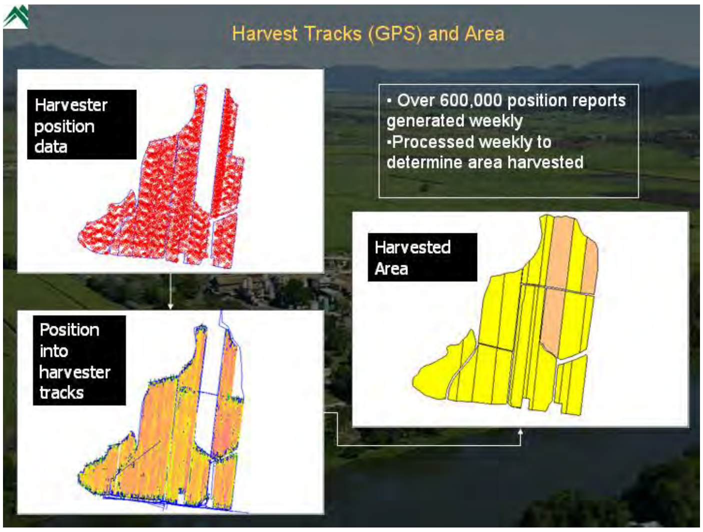



Figure 9

Knowing the position of the harvester is essential to create area maps, but knowing more about the characteristics of the harvester when position reports are generated would provide valuable information for assessment purposes. To achieve this there are digital inputs from the elevator switch and the ignition switch on the harvester into the tracking device. Another important feature is the ability to individually program when and how a position report is generated.

The configuration of the devices is performed at a central location with the configuration details transmitted to each device on start-up. The configuration of each device is individually programmed and is tailored to suit the differing circumstances of operations. A typical configuration program would be to generate a position report as follows:

- When a harvester has traveled *X* metres OR
- If the time between reports has exceeded *Y* seconds OR
- If the Elevator switch has changed state (on to off or visa versa) OR
- If the Ignition has changed state (off to on or visa versa) OR
- If the harvester has changed direction by greater than *Z* degrees

*N.B. - Factors X, Y and Z are programmable.*

From the interpretation of when and why a position report is generated, harvester efficiency reports (Figures 2 and 3) are compiled and distributed to harvester operators. These reports detail the time that harvesters remain in differing states (harvesting, turning or waiting) within each paddock for all farms harvested. When the tonnes of cane harvested from each paddock are added to the report, harvester throughput (pour rates) is calculated.

The examples shown in Figures 2 and 3 are from farms within two different harvesting groups and highlight the significant variation that can occur between harvesters. This report is the first step in highlighting to all parties the variability of the harvesting operation and is used as a catalyst to drive farm and harvesting improvements.

# Harvesting Efficiency Report

| 9998 JOE | | Start | End | Run | Harvest | Harvest | Turning | Turning | Waiting | Waiting | Consignment | | Pour Rates t/hr | | Av |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Block | Pdk | Date | Date | Time | Time | % | Time | % | Time | % | Tns | Bins | Harv | Elev | Speed |
| 1 | 2 | 8/11/2007 | 23/11/2007 | 3.5 | 2.36 | 67% | 0.65 | 19% | 0.49 | 14% | 253.89 | 45 | 72 | 107 | 5.75 |
| 2 | 1 | 28/07/2007 | 24/10/2007 | 3.75 | 2.44 | 65% | 0.8 | 21% | 0.51 | 14% | 157.12 | 27 | 41 | 64 | 6.04 |
| 3 | 1 | 2/09/2007 | 2/09/2007 | 1.92 | 0.72 | 38% | 0.87 | 45% | 0.34 | 17% | 74.95 | 12 | 38 | 104 | 5.2 |
| 4 | 1 | 28/07/2007 | 30/08/2007 | 1.37 | 0.56 | 41% | 0.57 | 42% | 0.24 | 18% | 110.82 | 20 | 80 | 197 | 5.31 |
| 5 | 1 | 28/07/2007 | 26/09/2007 | 2.04 | 1.15 | 56% | 0.37 | 18% | 0.52 | 25% | 46.31 | 8 | 22 | 40 | 6.72 |
| 6 | 1 | 30/08/2007 | 2/09/2007 | 3.36 | 1.69 | 50% | 1 | 30% | 0.67 | 20% | 202.36 | 34 | 60 | 119 | 6.67 |
| 7 | 1 | 27/09/2007 | 27/09/2007 | 1.39 | 0.69 | 50% | 0.5 | 36% | 0.2 | 14% | 68.63 | 12 | 49 | 98 | 6.27 |
| 8 | 1 | 27/09/2007 | 27/09/2007 | 2.76 | 1.86 | 67% | 0.46 | 17% | 0.44 | 16% | 187.77 | 31 | 67 | 100 | 6.29 |
| 9 | 1 | 25/10/2007 | 23/11/2007 | 5.15 | 3.34 | 65% | 1.05 | 20% | 0.76 | 15% | 250.41 | 46 | 48 | 74 | 6.06 |
| | **Whole of Farm** | | | **25.24** | **14.81** | **59%** | **6.27** | **25%** | **4.17** | **17%** | **1352** | **235** | **53** | **91** | **6.03** |

**Figure 10**

| 9998 GERRY | | Start | End | Run | Harvest | Harvest | Turning | Turning | Waiting | Waiting | Consignment | | Pour Rates t/hr | | Av |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Block | Pdk | Date | Date | Time | Time | % | Time | % | Time | % | Tns | Bins | Harv | Elev | Speed |
| 1 | 1 | 4/08/2007 | 3/09/2007 | 18.12 | 14.38 | 79% | 2.36 | 13% | 1.39 | 8% | 1946.5 | 319 | 107 | 135 | 7.23 |
| 2 | 1 | 2/09/2007 | 3/09/2007 | 7.61 | 5.08 | 67% | 1.63 | 21% | 0.89 | 12% | 766.93 | 125 | 100 | 150 | 6.27 |
| 3 | 1 | 3/08/2007 | 4/08/2007 | 9.97 | 8.17 | 82% | 1.38 | 14% | 0.41 | 4% | 961 | 155 | 96 | 117 | 6.08 |
| 4 | 2 | 4/08/2007 | 4/08/2007 | 2.96 | 2.38 | 80% | 0.39 | 13% | 0.2 | 6% | 279.75 | 46 | 94 | 117 | 6.14 |
| 4 | 3 | 4/08/2007 | 2/11/2007 | 11.29 | 8.95 | 79% | 1.24 | 11% | 1.1 | 10% | 847.89 | 158 | 75 | 94 | 6.24 |
| 4 | 6 | 2/11/2007 | 2/11/2007 | 2.87 | 1.99 | 69% | 0.52 | 18% | 0.36 | 13% | 300.76 | 51 | 104 | 151 | 7.96 |
| 4 | 7 | 2/11/2007 | 2/11/2007 | 1.55 | 1.12 | 72% | 0.34 | 22% | 0.09 | 6% | 92.85 | 16 | 59 | 82 | 7.37 |
| 5 | 2 | 5/08/2007 | 5/08/2007 | 5.03 | 3.71 | 74% | 0.81 | 16% | 0.5 | 10% | 432.25 | 65 | 85 | 116 | 7.09 |
| 6 | 1 | 5/08/2007 | 4/11/2007 | 14.8 | 10.77 | 73% | 2.42 | 16% | 1.61 | 11% | 1372.9 | 230 | 92 | 127 | 5.57 |
| 7 | 1 | 30/11/2007 | 30/11/2007 | 4.58 | 3 | 66% | 1.19 | 26% | 0.4 | 9% | 333.75 | 52 | 72 | 111 | 6.93 |
| **Whole Farm** | | | | **78.78** | **59.55** | **76%** | **12.28** | **16%** | **6.95** | **9%** | **7334.6** | **1217** | **93** | **123** | **6.69** |

**Figure 11**

## HARVESTER YIELD MONITOR DEVELOPMENTS

Yield monitors on sugar cane harvesters in Australia have had a stop/start development following the work by Cox in 1996 (Cox *et al*, 1997). It has been suggested that failure to make significant progress in yield monitor development has been linked to the cost of GPS devices and the reliability of the monitoring equipment.

Mackay Sugar started the development of a potential cane harvester yield monitor in 2005 with the installation of pressure sensors onto the chopper motor of a 1999 Austoft 7700 harvester. The sensors were installed onto the bottom chopper motor and measure the pressure of the hydraulic oil entering the motor and the pressure of the oil leaving the motor which in turn is the inlet to the roller train. The analog values from these sensors are inputs into the dats 3026 GPS tracking device. The pressure values are captured and transmitted as part of the location reports that are generated by the dats 3026 device.

Early analysis indicated that pressure variations recorded via the sensors appeared to have a direct correlation to variations in yield (Figure 4).

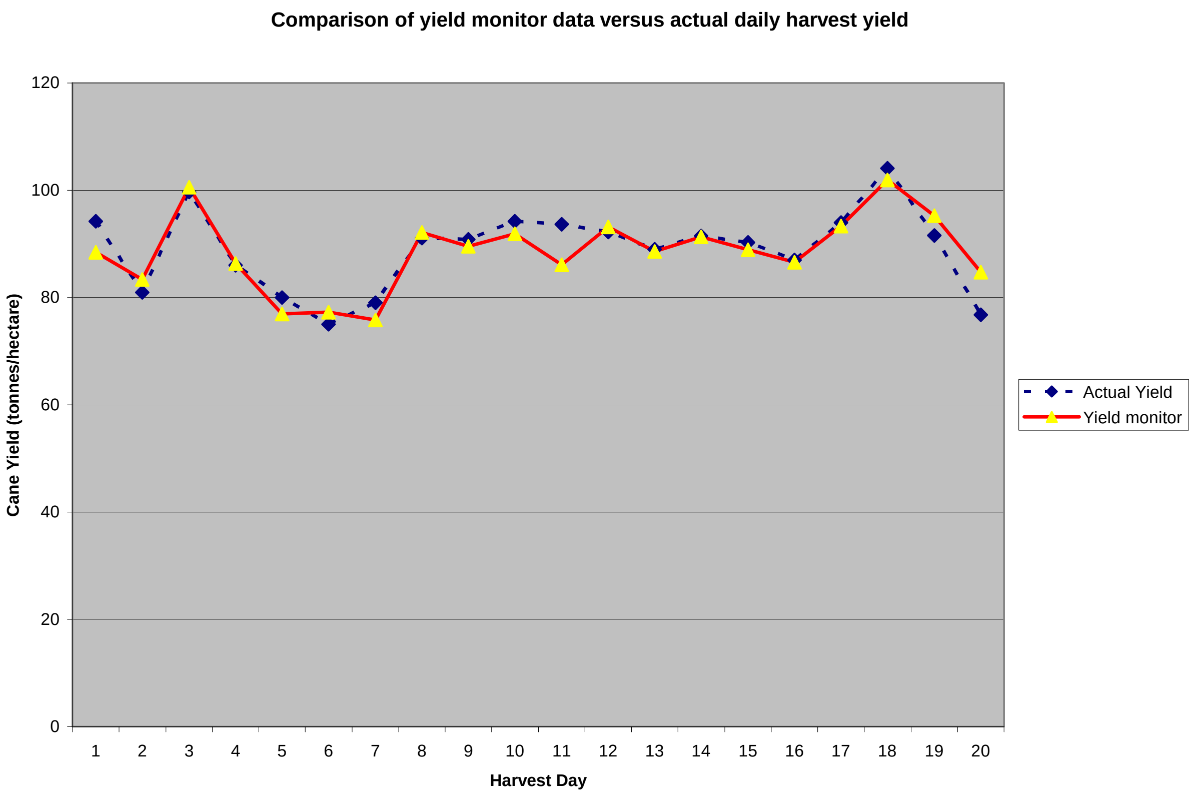



Figure 12

Progress has been made on the refinement of both the sensor positions and the algorithm development to convert pressure into yield with seven (7)harvesters now having yield monitor applications fitted.

## GPS BASE STATION NETWORK

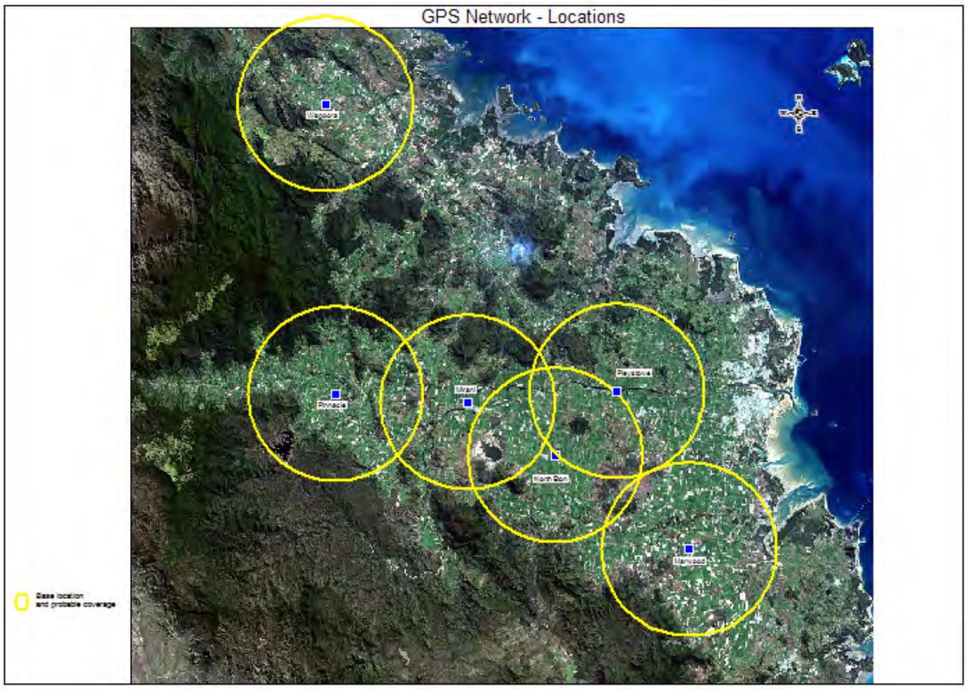
The number of growers migrating towards controlled traffic farming has been steadily increasing over the past few years. At the same time there appeared to be a proliferation of base stations within the region, many within a few kilometers of existing bases.

The Mackay Sugar Board of Directors recognized that these base stations were adding significant costs to growers wanting to adopt guidance technology. In early 2007 the Board of Mackay Sugar approved development of a series of Dual Frequency 2 cm RTK base stations throughout the Mackay Sugar cane growing region. The concept of a community network meant that the entry cost to individuals wishing to adopt the guidance technology would be decreased sufficiently to act as a driver for increased uptake.

The basic specifications for the supply of the base stations were as follows:

- Dual phase GPS receiver
  - Access to GPS and/or GLONASS with a capability of upgrade to Galileo
- GPS language – capable of transmitting CMR+
- Data transmission radios
  - 35 watt PacificCrest UHF
  - 900 MHz Spread Spectrum

Five of the six base stations were supplied by AgGuide and consisted of a Topcon GPS receiver and antenna plus and a radio component to match the original specifications. The bases were predominately located on masts attached to sheds within the region that gave the best value for coverage (See Map 1) and were completed by September 2007. To date the bases have operated satisfactorily with minimum downtime. The number of users has increased steadily over the last 12 months and it is now estimated that approximately 15% of the area is now utilizing controlled traffic practices.




Map 1

## INTEGRATION OF NIR AND GPS TECHNOLOGIES

Sugar cane is harvested into a series of containers (bins) that are linked together to form what is known as a 'rake' of cane. A rake would normally consist of between 6 and 30 uniquely numbered bins that are consigned to the sugar mill with details of the farm and the paddock from which they were harvested manually noted by the harvesting operator onto a paper consignment note.

On arrival at the factory the individual bins are weighed to gather the net weight of the cane. Juice from the rake of cane is sampled and analysed to determine information needed for cane payment. Cane payment is then calculated by using a formula that combines the weight of the cane supplied together with the analysis information of the cane.

Mackay Sugar has recently installed (Cane Analysis System) CAS-NIR into its factories to automatically measure the components in the cane supply needed for cane payment. The CAS-NIR performs analysis of the cane supply at frequent intervals with the results of those analysis averaged to determine the result for the rake of cane. One of the advantages of the CAR-NIR with the frequent analysis is the potential to provide analysis information at a resolution of an individual bin.

A trial project has found that CAS-NIR measurements can also provide information on the nutritional status of cane, especially for key nutrients of N, P, K and S. Understanding relationships between NIR measurements and field data, including application rates, crop response to nutrients, soils information and the linking of this data to a geographic position has the potential to provide valuable information to fine-tune nutrient management.

Unfortunately, inaccuracies in the current manual consignment system account for 30-40% of cane being assigned to incorrect paddocks from where it had been harvested thereby making the link between analysis information and paddock position of the cane inside the bin almost impossible.
The development of electronic cane consignment will reduce inaccuracies in the manual system by associating the cane bin being filled to the position of the harvester at the time of filling.

The benefit of electronic consignment is the ability to provide in-field mapping of cane constituents through the interfacing of the analysis data of each bin from the CAS-NIR to the position of the harvester at the time the bin was filled via the GPS tracking system.

## TURNING DATA INTO KNOWLEDGE

The sugar industry, like so many other agricultural industries has gathered a wealth of data regarding all facets of production, a process that seems to be gathering at an increasing pace. Unfortunately, providing applications to turn that data into useable knowledge have been slow in development. Turning data into knowledge is the aim of the AgDat project that has been established by a consortium of sugar industry participants.

The AgDat project has been envisaged to provide end to end data management, including capture, validation, reconciliation, sharing, security and publishing. The project builds on the extensive work undertaken in the sugar industry over the last decade whereby information technology has been utilised to enhance recording and reporting of on farm activities and extends this paradigm to further integrate work undertaken by other organisations.

AgDat is designed to provide a complete solution commencing with tools that enable and support ordinary users to capture complex spatial information, through the provision of web sites where this information can be collated and portrayed in conjunction with data from a number of sources.
The agricultural sector is being placed under increasing pressure to meet both regulatory requirements and community standards when it comes to the water quality runoff particularly in regards to the Great Barrier Reef catchment. The AgDat project will hopefully allow growers to meet those requirements in a timely, effective and cost efficient manner.

Whilst the initial AgDat development will be focussed on the Sugar Industry, the concept of AgDat is not sugar centric. Consideration of the needs of other agricultural sectors has been considered during the system design and functional specification stages and it is envisaged that the AgDat model will be configurable to suit the needs of these sectors.

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