PRECISION AGRICULTURE TECHNOLOGIES – RELEVANCE AND APPLICATION TO SUGARCANE PRODUCTION

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ABSTRACT

The development of a range of new technologies has brought agriculture and associated equipment to a new level of sophistication. The Australian sugar industry is facing a long term trend of reducing value of production and increasing input costs. The industry has rapidly adopted GPS based guidance technology with many cane growers now having access to high precision GPS technologies. However, there remains a wide range of uncertainties and conflicting opinions that make the next step for precision agriculture (PA) a daunting prospect for cane growers, therefore the adoption of PA has been slow.

A recently completed project (Davis et al, 2007) reviewed published and unpublished information on precision agriculture technologies that are being applied or could be applied to sugarcane production and harvesting both in Australia and internationally. This paper summarises the application and opportunities for PA in the Australian Sugar Industry. It describes how PA technologies can be integrated into a management system that provides greater benefits to sugarcane production and harvesting.

Keywords: sugarcane, precision agriculture, GPS, technology

INTRODUCTION

The Australian sugar industry is situated along a narrow coastal strip which extends from Grafton in New South Wales to Mossman in north Queensland (Figure 1). Growing conditions vary significantly with annual rainfall ranging from 900 to 4000 mm / year. Approximately 35 million tonnes of sugar cane is crushed each year from an area of 370,000 hectares. This produces 4.5 to 5.0 million tonnes of raw sugar. Typical cane farming operations are 50 to 90 ha in size, while some are greater than 500 ha.

Apart from some notable exceptions (Cox et al, 1998; Bramley and Quabba 2001), Precision Agriculture (PA) is still a relatively new concept in the sugar industry. PA is defined here as the spatial and temporal management of agricultural production to improve farm profitability. Today PA is associated with newer technologies and management support systems that provide an increasingly better insight into what is happening in the field.

The rapid adoption of GPS guidance and tractor steering technology and the direct benefits of reduced overlap and increased productivity have made cane growers acutely aware of the potential benefits of new technologies. With the initial adoption of these technologies, cane growers are seeing the benefits of more efficient operations with some cane growers claiming that they have halved their labour requirements.

Figure 1 Australian Sugarcane Growing Areas

Within the Australian sugar industry, interest in PA has grown over the past decade and continues to grow across a range of scales. These include regional, mill, farm and field/block scale. This interest has been driven by the following factors:

- integration of technologies that allow the efficient collection of spatial information
- ability to address variables affecting crop performance through new technologies; research is developing PA tools to improve the management of disease, weeds, nutrition and the timeliness of operations
- the tools needed for PA (GPS for positioning and guidance, remote sensing technologies, maps of variation in soils and crops and variable-rate technology (VRT) and yield monitors to some extent) have become increasingly available and affordable.
- accessibility of state and federal government financial support for these technologies

Implementation of PA in the Sugar Industry

In all other industries, PA starts with yield maps and analysis of the yield variability. In the sugar industry, there are few accurate yield maps but other tools used in PA are increasingly common. This has lead to a situation where the sugar industry's perception of the term PA is very different to other agricultural industries that use yield maps as the starting point for precision agriculture. PA is currently being investigated by the sugar industry with many industry participants seeing this minimalist adoption as an end in itself. Integrating, these technologies offer much more as drivers of cultural and industry reform.

The extent to which PA technologies and methods are used in sugarcane production and harvesting depends on the purpose. PA within the industry are perceived to mean different things including, GPS technology, controlled traffic farming, zero/minimum tillage farming, tractor / harvester guidance, yield monitoring, variable rate fertilising, harvesting feedback etc.

Components of PA

The modern concept for PA focuses on managing and interpreting the information and knowledge gleaned through the agricultural cycle using the ever increasing array of new technologies available to growers. The PA management cycle has five key conceptual components (Figure 2) including production environmental monitoring, attribute/yield mapping, decision support (using models and GIS), differential actions based on the previous steps and spatial referencing at its centre. PA information can be used by growers and advisers to improve cropping decisions, crop agronomy and the efficiency of farming operations.

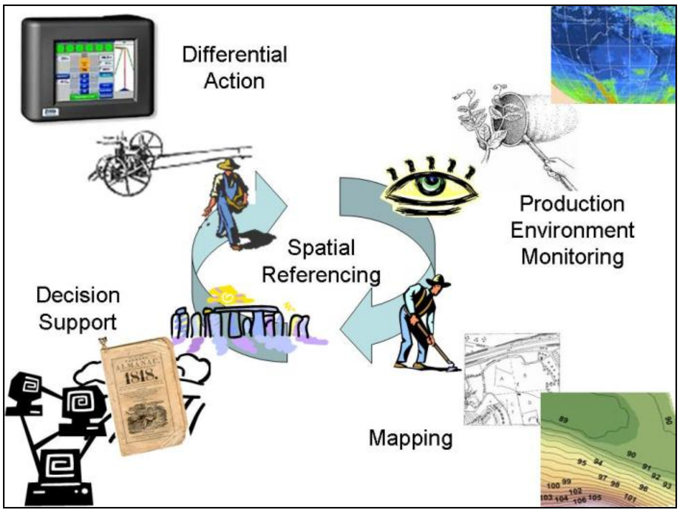

Figure 2 Precision Agriculture Components

SPATIAL REFERENCING

Spatial referencing is central to the PA management cycle. The main tool used for spatial referencing is global positioning system (GPS) but can also include the use of field maps and other surveying/positioning techniques such as remote sensing.

In-field Positioning

The sugar industry has seen the rapid adoption of positioning technologies particularly GPS in recent years. Within the Sugar Industry, GPS is predominantly used for guidance and auto-steering. This is mainly because of the more immediate benefits of precise machine control such as straight / even row spacing, reduced overlap, increased machine efficiency, maintenance of traffic zones, reduced driver fatigue and operating outside of daylight hours. Some of these benefits and early experiences were reported by Smith (2001). Other uses of GPS technology in the sugar industry include cane transport and logistics between the sugar mill and harvesting operations.

Growers in most cases have individually purchased GPS systems incorporating base station and rovers. However, community network based GPS have also been implemented with networks being established in the Northern New South Wales, Maryborough, Isis, Bundaberg and Herbert River areas.

Remote Sensing

Remote sensing provides a great deal of fundamental information relating spectral reflectance and thermal remittance properties of soils and crops to their agronomic and biophysical characteristics at scales that may range from small patches within a field to large regions.

Numerous studies in sugarcane in Australia and overseas (Lee-Lovick and Kirchner (1990, 1991), Noonan (1999) Schmidt et al. (2000, 2004), Gers (2003), Everingham et al. (2005)) have demonstrated associations between crop canopy reflectance, crop biomass, leaf area index and crop yield at different spatial scales. The strength of remote sensing is the opportunity to learn more about crop growth variability while the crop is still growing. In addition, remote sensing has been evaluated for delineation of harvested cane from unharvested cane (change detection).

Remote sensing has widespread potential application on a mill scale as early and accurate estimates of the size of the sugarcane crop can facilitate the planning of mill start dates, cane transport arrangements, harvest groups base daily loadings, harvesting schedules and assist marketers with forward selling sugar.

PRODUCTION ENVIRONMENT MONITORING

Factors affecting crop yield, along with the crop yield itself, must be monitored. At present, measurement of soil (texture, nutrient concentrations, pH etc) and crop (nutrient concentrations, disease etc) factors remains reliant on systematic manual sampling and analysis in the laboratory. Research is under way worldwide into real-time analytical sensors that will automate soil and crop sampling and analysis procedures in the field.

Real-time monitoring systems

For sugarcane production, the full benefits of PA are severely constrained by the lack of an accurate and reliable spatial yield monitoring solution. Within the industry a number of attempts have been made to monitor yield variation across a block, ranging from discrete yield monitoring systems based on mass measurement systems to the current focus of monitoring chopper pressure, feed train roller displacement and elevator power. Accurate yield monitoring will close the PA cycle to enable the use of precision farming tools and analysis that allow spatially based farming management and associated variable rate applications.

In addition to yield monitoring, there are studies aimed at developing a reliable in-field technique for measuring sugar juice on trash. Detailed research in Australia and overseas has shown sugar losses can, on occasion, exceed 20%. The potential of this technique, if proved to be reliable may be applicable for the monitoring of sugar yield in real-time.

Integrated harvester performance and monitoring systems also offers the Sugar Industry significant improvements over existing harvest and transport operations. Technologies have already been implemented in a number of mill areas such as Mackay Sugar and NSW Sugar milling co-operative to enhance operations and add value to harvest and transport management.

Proximal sensing systems

Ground-based sensors offer the opportunity to automate the collection of crop, soil and weed data at a spatial resolution that is not economically feasible with manual sampling methods. Increasing the intensity of sampling will result in a more accurate characterisation of the in-field variability. A number of sensors that provide real-time geo-referenced data have been developed or are in the progress of being developed for PA purposes.

Electromagnetic induction mapping quickly and accurately characterises soil differences within a cropping paddock. This equipment measures soil properties such as texture, cation exchange capacity, drainage conditions, organic matter, salinity and subsoil characteristics. The most common use of this equipment is the identification of soil sampling points for stratified soil sampling.

Figure 3 Verris 3100

Several commercial systems are available including the Veris 3100 (Figure 3) which is currently used within the sugar industry. It is used predominantly in the Prosperpine, Mackay and Sarina regions, however it can be towed behind a vehicle and has been used in the Bundaberg area. The generation of soil maps from these types of instruments (Figure 4) will facilitate the use of precision farming tools that allow spatially based farming management and associated variable rate applications.

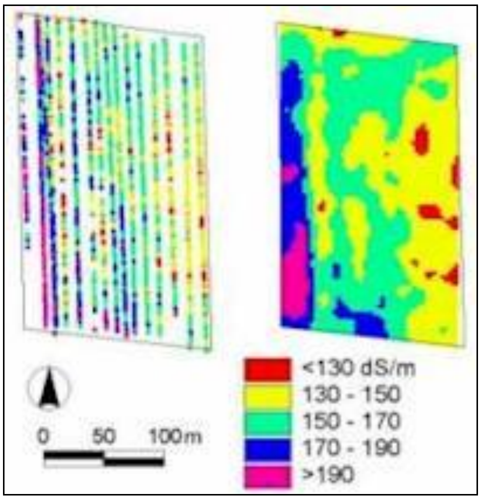

Figure 4 Veris 3100 Map of Soil EC (0-90cm)

Discrete soil and plant modelling
Discrete soil and plant sampling refers to the manual sampling of variables within a field using either a grid-based or statistically based random sampling strategy. In the sugar industry, this technique is predominately applied to the observation of soil and plant attributes and monitoring pest and disease levels.

Nutrient management and fertiliser inputs for sugarcane production in Australia is one example of a paradigm shift from a set of generalised recommendations across the industry towards sets of soil-specific nutrient management guidelines for use at district level and ultimately facilitating the use of nutrient management plans at block and farm scales. This includes the concept of 'whole-of-crop-cycle' fertiliser recommendations, using both soil and leaf analysis which is being promoted within the industry (Schroeder et al., 2006).

Soil-specific nutrient management offers a significant opportunity to the Sugar Industry. As such, the industry is well on its way to developing the capability to employ this approach to fertiliser management at a regional scale. The next challenge will be the extension of this framework to a farm/block scale.

Crop modelling
Crop simulation models are increasingly used in PA research, but their complexity has often hampered the use of modelling in making practical decisions. The key Australian sugarcane cropping systems model APSIM-Sugarcane has evolved and emerged as one of the more powerful modelling tools currently available to the Sugar Industry. Crop modeling has been used to improve water and nitrogen management by more quantitative prediction of crop yield, water and N needs during the growing season. Future opportunities could include the use of models to make quantitative N application decisions on-the-go, using actual weather data and crop reflectance characteristics.

Climate monitoring
The Sugar Industry operates under extreme variability in climate. Numerous research projects into seasonal climate forecasts have been undertaken for the Sugar Industry. Everingham et al. (2002b) examined the capability of the 'user-friendly' SOI phase system to target climate forecasts for the needs of the industry across different sectors of the value chain (farming, harvesting, milling and marketing) and demonstrated several ways in which climate forecasts can be used to plan activities for sectors of the industry. In particular they found that the SOI phase system offered potential to enhance irrigation management in the Bundaberg Region,

Investment Analysis
The key to making money from PA is for growers or harvesting contractors to choose an aspect of the technology that provides rapid and certain benefits across a wide area of their enterprise. Growers and harvesting contractors now have a good choice of programs at their disposal to assess risks to their business and to identify potential productivity and cost saving initiatives (Wrigley & Moore 2006). These can be utilised to assess whether or not investment in PA is feasible for their enterprise.

ATTRIBUTE MAPPING

Once data on spatial variability has been collected, it is necessary to capture, store (manage), integrate and analyse the data. The Sugar Industry is the only agricultural industry that, through its operational framework, collects large resources of base mapping data about the crop. Data is collected by mills for their business of crop estimation and harvest planning. This information is valuable for other purposes including research, optimisation studies and disease response. Hence a number of customised GIS are utilised in the sugar industry. These include:

- FarmMap which is designed to store attributes at the farm and block level such as owners, variety, class, estimates and area,
- CHOMP which is specifically designed to maintain harvested area and can source that data in several ways including satellite, web, GPS and manual inputs,
- FRANK – harvester tracking and productivity reporting (Figure 5),
- Land and water management plans,
- Farm productivity analysis.

The emerging technology in the sugar industry is spatial farm productivity information. This can lead to better environmental management and practice change from an understanding of pest and disease levels, plant and seed cane sources, time of planting and production inputs including location and amount of water and fertiliser.

Figure 5 FRANK Harvester Tracking System

DECISION SUPPORT

To ascertain whether differential treatment within the field is warranted, the spatial variability found needs to be quantified. Suitable treatment strategies can be formulated from the correlation between the variation in crop yield potential and the variability in factors influencing crop yield along with an economic analysis. Decision support systems need to be able to monitor the effects over time so as to remove seasonal variability from spatial data sets.

Decision support combines traditional management skills with PA tools to help growers make the best management choices or "prescriptions" for their crop production system. Their role is to integrate data sources with expert knowledge and decision models to aid in making strategic decisions for both the short- and long-term.

A number of sugar mills have, or are currently developing integrated cane harvest management systems to facilitate marketing and logistics, planning mill start dates, cane transport arrangements, harvest groups base daily loadings and harvesting schedules. These systems use modern computer and communication technologies to integrate data and systems and to develop tools that assist individual decision-making as well as support whole-of-industry management strategies.

DIFFERENTIAL ACTION

Much PA research is involved with monitoring and information gathering. However, it is important that the ultimate goal is to be able to implement site-specific management using variable rate application. Site-specific management is not a new concept. Many growers have been selectively managing certain areas within areas for many years.

Manufacturers have refined existing machinery and/or developed new machinery so that seed, fertiliser, agricultural chemicals, soil ameliorants, irrigation water and tillage can all now be applied variably within-field utilising more complex automated systems. The rate is changed either based on a preset map (determined by the user from the integration of yield, soil and plant data) or from information gathered by sensors as the machine moves through the field.

Variable-rate application of fertiliser at a block scale has generated a significant amount of interest among growers and service providers within the Sugar Industry. Examples include variable rates based on nitrogen replacement strategies (Thorburn et al., 2006a) or soil maps using a Veris 3100 to facilitate soil specific nutritional requirements.

Precision spray technology that targets specific weeds in crop is currently being developed and has the potential to revolutionise weed management. Spray the weeds, not the paddock technology offers the sugar industry potential reductions in herbicide usage in turn leading to a greater range of herbicide options. In addition, combined with GPS the technology will also be able to map weed infestation across a field.

CONCLUSION

Precision agriculture includes a wide array of site-specific technologies. These technologies provide a producer with site-specific information to aid in management decisions. Much research has been undertaken on the individual components of the PA management cycle. The challenge is for the industry to integrate these for whole of system gain. The application of PA within the sugar industry is occurring at a number of varying scales of management including:

- Regional Scale (development of soil-specific fertiliser recommendations)
- Mill Scale (logistical systems for cane harvest and transport)
- Farm Scale (yield estimation, productivity analysis, disease control).
- Block / Field Scale (yield mapping and variable rate application)

It is evident that PA enabling technologies are cost effective to Australian cane growers. The key to making money from PA is for growers or harvesting contractors to choose an aspect of the technology that provides rapid and certain benefits across a wide area of their enterprise. With the advent of cheaper GPS guidance systems, and growing evidence of the efficiency gains that can be made with them, more growers and harvesting contractors are investing in this part of the PA equipment suite.

In addition, cane growers have the benefit of being able to learn from a broader range of experiences of other industries (eg. cotton, grains and viticulture). Currently PA research is being progressed in the industry via a collaborative research initiative (NCEA, CSIRO and BSES) which will inform the implementation of PA across the sugar industry and focus on some of the opportunities described.

REFERENCES

Bramley, R.G.V. and Quabba, R.P. (2001). Opportunities for improving the management of sugarcane production through the adoption of precision agriculture – An Australian perspective, In *proceedings of the 24th Congress of the International Society of Sugar Cane Technologists*, 17-21 September, Brisbane. pp 38-46.

Cox, G., Harris, H., and Cox, D. (1998). Application of precision agriculture to sugar cane. In: *Proceedings of the 4th International Conference on Precision Agriculture*, edited by P. C. Robert, R. H. Rust, and W. E. Larson. pp. 753-765. ASA/CSSA/SSSA, St. Paul, USA.

Davis, R.J., Bartels, R. and Schmidt, E.J. (2007). Precision Agriculture Technologies Relevance and application to sugarcane production, *National Centre for Engineering in Agriculture Publication 1002265/1*, Toowoomba, Queensland

Everingham, Y.L., Inman-Bamber, N.G., Ticehurst, C., Barret, D., Lowe, K. and McNeill, T. (2005). Yield Forecasting for Marketers. *Proceedings of the Australian Society of Sugar Cane Technologists* **27**, (CDROM, 10pp).

Everingham, Y.L., Inman-Banber, N.G. and Smith, D.M. (2002b). Seasonal climate forecasts to enhance decision making across the sugar industry value chain. *Proceedings of the Australian Society of Sugar Cane Technologists* **24**, 67-74pp.

Gers, G.R. (2003). Relating remotely sensed multi-temporal Landsat 7 ETM+ Imagery to Sugarcane Characteristics *Proceedings of the South African. Sugar Technologists Association* **77,** 192-201.

Lee-Lovick, G. and Kirchner, L. (1990). The application of remotely sensed (Landsat TM) data to monitor growth and predict yields in sugarcane *Proceedings of the Australian Society of Sugar Cane Technologists* **12**, pp.65-71.

Noonan, M.J. (1999). Classification of Fallow and Yields using Landsat TM data in the Sugarcane Lands of the Herbert River Catchment, In: *Proceedings of 13th Annual Australian ESRI and ERDAS Users Conference*. Adelaide

Schmidt, E.J., Narciso, G., Frost P. and Gers, C. (2000). Application of remote sensing technology in the SA Sugar Industry. A review of recent research findings. *Proceedings of the South African. Sugar Technologists Association* **74**, 192–201.

Schmidt, E.J., Singels, A. and Gers, C.J. (2004). Sugar forecasting techniques in South Africa: Research and application *Proceedings of the Australian Society of Sugar Cane Technologists* **26**, (CDROM, 13 pp).

Schroeder, B.L., Wood, A.W., Moody, P.W., Panitz, J.H., Agnew, J.R., Sluggett, R.J., and Salter, B. (2006). Delivering Nutrient Management Guidelines to Growers in the Central Region of the Australian Sugar Industry *Proceedings of the Australian Society of Sugar Cane Technologists* **28**, (CD ROM, 13 pp).

Smith, M.A. (2001). The use of GPS guidance systems and controlled traffic in mechanised cane farming. *Proceedings of the International Society of Sugar Cane Technologists* **24**, 51–52.

Thorburn, P.J., Webster, A.J., Biggs, I.M., Biggs, J.S., Park, S.E. and Spillman MF. (2006a). Innovative management of nitrogen fertiliser: testing the replacement concept *Proceedings of the Australian Society of Sugar Cane Technologists* **28**, (CDROM) Poster Paper 1 p.