

National Centre for Engineering in Agriculture



Final Report – SRDC Project NCA 009

Review, Analysis and Discussion of Precision Agriculture Technologies

By

R J Davis* and E J Schmidt

*** FSA Consulting**

*NCEA Publication 1002265/2
May 2007*

Contact:

Erik Schmidt
Director
NCEA
C/- University of Southern Queensland
West Street
Toowoomba Q 4350
Telephone: 07 4631 1347
Facsimile: 07 4631 1870
Email: schmidte@usq.edu.au



Australian Government
Sugar Research and
Development Corporation

The Research Organisation is not a partner, joint venturer, employee or agent of SRDC and has no authority to legally bind SRDC, in any publication of substantive details or results of this Project.

Disclaimer

While the National Centre for Engineering in Agriculture and the authors have prepared this document in good faith, consulting widely, exercising all due care and attention, no representation or warranty, express or implied, is made as to the accuracy, completeness or fitness of the document in respect of any user's circumstances. Users of the report should undertake their own quality controls, standards, safety procedures and seek appropriate expert advice where necessary in relation to their particular situation or equipment. Any representation, statement, opinion or advice, expressed or implied in this publication is made in good faith and on the basis that the National Centre for Engineering in Agriculture, its agents and employees, and the Sugar Research and Development Corporation (the commissioning Agency) are not liable (whether by reason of negligence, lack of care or otherwise) to any person for any damage or loss whatsoever which has occurred or may occur in relation to that person taking or not taking (as the case may be) action in respect of any representation, statement or advice referred to above.

TABLE OF CONTENTS

TABLE OF CONTENTS	3
EXECUTIVE SUMMARY	4
BACKGROUND	4
OBJECTIVES	5
METHODOLOGY	6
OUTPUTS	7
ENVIRONMENTAL AND SOCIAL IMPACTS	7
EXPECTED OUTCOMES	8
FUTURE RESEARCH NEEDS	9
RECOMMENDATIONS	10
LIST OF PUBLICATIONS	12

EXECUTIVE SUMMARY

The development of a range of new technologies has brought agriculture and agricultural equipment to a whole new level of sophistication. First hypothesised in the early 1990's, Precision Agriculture (PA) is a crop management philosophy, which utilises these technologies to produce crops in a more sustainable fashion.

The Australian sugar industry is faced with 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 PA a daunting prospect for cane growers, therefore the adoption of PA has been slow.

PA has gained a significant amount of publicity in recent years, especially in other farming systems such as cotton, grain growing and viticulture. There has been a flood of rapidly developing technologies and techniques (often very costly) that have confronted growers claiming to aid in all aspects of farm management. With a few notable exceptions, PA is still a relatively new concept in the sugar industry. However, it will happen in the sugar industry. PA technologies have the potential to improve the commercial viability and environmental sustainability of sugarcane production and harvesting.

To a degree, PA, within the sugar industry has been driven by the advent of various new technologies, particularly the coupling of real-time positioning using global positioning systems (GPS). 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.

There is thus an urgent need to increase knowledge of PA across the industry to ensure that adoption decisions are made on an informed basis that learns from other agricultural industries both domestically and internationally. Specifically, the industry needs to know how these technologies can:

- Reduce the breakeven cost of production.
- Improve the quality of life.
- Improve environmental sustainability.
- Boost associated research.
- Reduce production risks.
- Increase productivity and profitability.

Further, the limitations of the technologies need to be known.

Based on these requirements this project reviewed published and unpublished information on precision technologies that are being applied or could be applied to sugarcane production and harvesting in Australia. In addition, a brief review of applicable developments within international sugar industries was also undertaken.

A review and analysis report was prepared which describes how these technologies operate, their uses, opportunities, limitations, risks and costs with respect to precision farming in the sugar

industry. It describes how they can be integrated into a management system that will have both economic and environmental benefits for sugarcane production and harvesting.

An integral part of the project was the formation of regional industry consultative groups to ensure relevance of the review to the Australian sugar industry. A questionnaire was prepared to solicit the individual group member thoughts on the benefits, opportunities and limitations of PA technologies. The questions were: What precision farming technologies are being adopted within their respective regions? Where are they being adopted? What type of technologies are being adopted and the benefits, opportunities and limitations of current precision farming technologies. This questionnaire was distributed to the respective consultative group members. The questionnaire was aimed at capturing the consultative group members various perspectives on the benefits, limitations, opportunities for PA technologies, with the information used as a baseline by SRDC.

The review and analysis report was presented to the regional consultative groups in a series of regional consultation meetings in March 2007. .

The final phase of the project was the presentation of the outcomes at an Industry Workshop held after the 2007 ASSCT Conference in Cairns. The main objective of the workshop was to present the findings of the project and to facilitate further discussion that will deepen the understanding and knowledge of PA across the industry. The findings from the Industry Workshop were analysed and a final report presented to SRDC.

The project has led to a direct improvement in knowledge and understanding of PA within the industry via consultation and dissemination of outcomes with the industry.

Future directions for PA within the sugar industry will be dependent on external factors such as the continued development of technology, the conditions of world markets or the insistence of buyers on product standards - all of which are beyond the control of cane growers. In the end, the adoption of PA will depend on the economic benefits offered, which will, in turn, depend on the degree of variability present in the field, and the opportunity to manage that variability.

The opportunity for the sugar industry in adopting PA technologies is the associated benefits of improved environmental management and the increased knowledge for growers to better manage and control inputs/farming practices for specific areas across fields.

BACKGROUND

Cane growers are faced with a long term trend of reducing value of production and increasing input costs. Many growers now have access to high precision GPS technologies, yet there remains a wide range of uncertainties and conflicting opinions that make the next step for PA a daunting prospect for cane growers. Precision farming technologies have the potential to improve the commercial viability and environmental sustainability of sugarcane production and harvesting. The rapid adoption of tractor steering technology and the direct benefits of reduced overlap and increased productivity have made growers acutely aware of the potential benefits of new technologies. Specifically, the industry need to know how these technologies can:

- Reduce the breakeven cost of production.
- Improve the quality of life.
- Improve environmental sustainability.
- Boost associated research.
- Reduce production risks.
- Increase productivity & profitability.
- Further, the limitations of the technologies need to be known.

OBJECTIVES

The objective of the project is to:

- Review published and unpublished information on precision agriculture (PA) technologies that are applicable to sugarcane production and harvesting, including;
 - Currently used technologies, emerging technologies, technologies used in related industries and technologies used in sugar internationally that have not been adopted in Australia.
- Identify the opportunities, advantages, limitations, risks and costs of the range of technologies that would be applicable to implementation of PA in sugarcane.
- Ensure relevance to the Australian Sugar Industry through the involvement of Industry stakeholders in a series of regional consultative group meetings to identify:
 - Technology cost effectiveness.
 - Expertise required.
 - Industry understanding and perceptions.
 - Indirect benefits.
 - Environment benefits.
 - Ideas for mitigation of risks.
 - Priorities for precision agricultural research.
- Present the outcomes of the review and analysis at the 2007 ASSCT conference to be held at Cairns. In association with SRDC distribute the review, analysis and workshop discussion across the Australian Sugar Industry.

The project successfully completed all of the stated objectives. A report on the relevance and application of PA technologies in sugarcane was prepared. The limitations, opportunities, limitations, risks and costs were canvassed and documented in the report. Two regional consultative groups were formed and the outcomes of the review presented in a series of consultation meetings. The outcomes and opportunities of the review was presented at an industry workshop held in Cairns.

METHODOLOGY

The initial phase of the project included the formation of a consultative group in each of two regional centres in conjunction with SRDC. These groups ensured that the review and analysis of PA is relevant to the Australian sugar industry. The regional consultative groups comprised eight to ten industry stakeholders from the Bundaberg/ISIS/Maryborough and NSW regions. The makeup of these groups included industry representatives, growers and harvesting contractors and represented a typical cross section of the industry.

A review of unpublished and published information on precision technologies was undertaken along with an analysis of the opportunities, advantages, limitations, risks and costs of applicable technologies in sugarcane.

A review and analysis draft report was prepared and internally reviewed prior to presentation in meetings to the regional consultative groups. The draft report was refined with the outcomes of these meetings.

The final phase of the project included an Industry Workshop held after the ASSCT Conference in Cairns. The main objective of the workshop was to present the findings of the project and to facilitate further discussion that will deepen the understanding and knowledge of PA across the industry.

OUTPUTS

The project has led to a direct improvement in knowledge and understanding of PA within the industry via consultation and dissemination of outcomes with the industry. The outputs include analysis of:

- Capacity Building: Training and assistance required for effective implementation.
- Effect of associated research.
- Profiling of early precision agriculture adoption.
- Cross industry lessons for precision agriculture adoption.
- International experiences of precision agriculture in the sugar industry.
- Assessment of select precision agricultural technologies.
- Precision agriculture technology road map.
- Guidelines for successful introduction of precision agriculture.
- Identification of opportunities for precision agriculture.
- Understanding of the factors that limit or promote innovation.
- Recognition of the barriers to technology adoption.
- Insight into grower assessment of benefits of new in precision agricultural technologies.

ENVIRONMENTAL AND SOCIAL IMPACTS

Growers have continued to adopt more sustainable farming practices improving farm productivity while delivering improved environmental outcomes. While new cropping system programs may not be suitable on all farms, growers are adopting components of the system and are finding benefits which encourage them to progress with more changes that are in line with the base concepts of reduced cultivation, control traffic and break cropping. This has largely been due to the drop in price of technology, in particular GPS paved the way for growers to invest on a broad scale.

The opportunity for the sugar industry in adopting PA technologies is the associated benefits of improved environmental management and the increased knowledge for growers to better manage and control inputs/farming practices for specific areas across fields. However, environmental applications of PA may be of secondary importance when compared to management of production.

However, the location of the Australian sugar industry along the east coast of Queensland adjacent to the Great Barrier Reef places additional pressures on the industry to demonstrate that it is adopting best management practices that ensure that soil fertility is sustained and that any nutrient wastage is effectively eliminated. Therefore, PA may represent an important tool in the quest for improved environmental stewardship.

EXPECTED OUTCOMES

PA enabling technologies have been strengthened in recent years with accurate spatial referencing using RTK GPS, soil (moisture, nutrients) and crop monitoring capabilities, development of variable rate technology (VRT) for spatially variable application, harvester monitoring capabilities and GIS interface systems.

Many cane growers and harvesting operators will benefit from the use of some parts of the PA suite of technologies. For example implementation of new farming systems through GPS for machinery guidance, the testing of new varieties using yield data or harvester tracking and monitoring will be adopted.

However, PA may not be for everyone, at least not straight away. The first step is recognising that significant variability in yield and profit is occurring and at what scale within a paddock or across the farm, and determining whether the yield zones are stable or unstable between years (seasons) and different crops. This can generally be achieved from grower's own knowledge of blocks and from mill data from individual blocks.

The next step should be to identify the underlying causes of yield variability. These could include soil depth, soil type (water-holding capacity, nutrients), topography (elevation), acidity, subsurface salinity or compaction, presence of soil pests and diseases, or the influence of past management (old fencelines, previous crop type). This may require soil or disease testing, aerial photographs, or contour data. There is little point in trying to manage spatial variability in a block that suffers from waterlogging or compaction. Sorting out these more important problems, for example with laser leveling, controlled traffic or minimum tillage systems, will reduce the variability seen within the block.

Where there are several likely causes it is important to get a sense of their relative impact on yield and profit. By the end of this step, growers should know what the main underlying causes of yield variability are, and whether it is practical to do anything about them, either by direct amelioration (ripping, correcting nutrient deficiency, liming, gypsum) or by changing management (variety change, reducing fertiliser inputs on non-responsive areas and increasing them where there is a good yield response).

Dealing with spatial variability is not always a cane grower's first or immediate priority. Growers first need to make sure that they have addressed the basic components of their cropping system (crop type and varieties, rotations, nutrition, disease, weed and pest control) and have these working satisfactorily, before dealing with spatial variation. In other words, make sure the basics are right before considering PA.

The next step should ask the question "Does it matter?". In other words, knowing that variation exists and the scale of variation in yield (step 1) and the underlying causes and possible solutions (step 2), is it worth doing anything about it. In this step the cost of enabling technologies (GPS, remote sensing etc), grower/adviser experience or crop modelling can be evaluated to help assess the likely impact on yield under different management systems and seasonal conditions. The impediments to adoption of PA should also be assessed (i.e. current level of understanding and management, technology gaps or cost etc) Growers can then determine whether it is economically feasible or sensible to tackle yield variability using PA, and if so what its relative priority should be in the farm or cropping budget.

The next step is implementation and at what scale and monitoring the outcome. At present application of PA within the sugar industry is considered at a number of scales from regional level

through to block scale. Monitoring the outcome should occur as part of a continuous learning process of change.

Future directions for PA will be dependent on external factors such as the continued development of technology, the conditions of world markets or the insistence of buyers on product standards - all of which are beyond the control of cane growers. In the end, the adoption of PA will depend on the economic benefits offered, which will, in turn, depend on the degree of variability present in the field, and the opportunity to manage that variability.

FUTURE RESEARCH NEEDS

As the concept of PA is only embryonic in the sugarcane farming systems context, there are many potential areas of investigation that could significantly improve the profitability and long-term sustainability of the industry. Research needs to be undertaken to tackle some key technology gaps (eg yield monitoring), agronomic questions relating to site-specific yield variation, especially weed control and irrigation management; the area of harvester performance and building capacity with industry personnel in PA technology.

Finally, we urge the industry to consider the following research objectives to expand on the current understanding and management of spatial variability in Australian cane growing and harvesting systems:

- Investigations into the development of a robust, reliable, calibratable and accurate yield monitor and robust methodologies for the production of maps of yield.
- The provision of associated support services or tools for making use of the data collected by yield monitors to allow the development of accurate and reliable prescription maps.
- Investigations into the variable rate application of herbicides. This recommendation has significant environmental and economic considerations, demonstrating that best management practice is being employed for the coastal ecosystems in which the majority of sugarcane is grown. In addition, it may prolong the registered use life of key chemicals within the industry.
- An examination of variable-rate irrigation technology for the industry.
- An exploration of remote sensing technologies (satellite and/or airborne) to aid in site-specific cane management particularly for the early detection of pest or disease outbreaks or water stress.
- An examination of the EM, VERIS and other similar soil sensing systems for providing surrogate data for the creation of high-resolution maps of soil properties such as texture, cation-exchange capacity and soil moisture for PA .
- An examination of harvester performance data and the development of practical and meaningful real-time performance feedback measures for integration with PA programs.
- A program, possibly in combination with other industries, needs to be developed to rapidly up-skills personnel in new technology so that growers can obtain independent and up-to-date information.
- Pre-emptive evaluation of emerging technologies in other industries in Australia and overseas.
- Facilitate capacity building of PA skills viz data acquisition, management and analysis through appropriate training of committed industry research personnel.

Foster the development of industry PA user groups and facilitate the up-skilling of growers and consultants in PA skills. Allowing growers access to up-to-date independent information and to prevent other growers making the same mistakes as early adopters will be one of the keys to successful adoption of PA.

RECOMMENDATIONS

Precision farming is a systems approach to managing soils and crops to reduce decision uncertainty through better understanding and management of spatial and temporal variability.

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 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.

A review of the technologies associated with each component of this system suggests a range of skills are required for implementation of a successful PA system. Collectively, the sugar industry has the skill base required viz engineering technology, agronomic, soil science, GIS and information technology to facilitate adoption.

However, much of the research conducted to date has occurred across a number of scales to develop strategies for crop management within the sugar industry. Researchers and growers have collect huge amounts of information, but assessing the quality of this information, transforming it into meaningful management decisions, evaluating potential benefits and risks and coordination has proven to be a difficult task with respect to PA.

For example, many growers have shown an interest in GPS as they can see that it works in principle. Much of the development and adoption of GPS has been driven by growers who are motivated to adopt new farming system incorporating the principles of controlled traffic, minimum tillage and rotation crops. This has opened up a range of opportunities including reduced driver fatigue, precise tillage, planting and fertiliser placement, minimising overlaps, efficiency gains and staff management. Growers in most cases have individually purchased GPS systems incorporating base station and rovers. Networked RTK GPS is a completely different approach to calculating and communicating base station information to the mobile unit (i.e. tractor). This has approach offers an opportunity to the sugar industry with the potential to rapidly increase the number of users through a reduction in the cost of the technology. Community network based GPS are already being implemented within Queensland, with networks being established in the Maryborough, Isis, Bundaberg and Herbert River areas. This area along with developments in integrated communication technology and networking (i.e. wireless networks, broadband internet etc) should continue to be one area of focus for PA research and development.

For sugar cane farming, 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. An independent evaluation of the commercially available mass flow sensors should be undertaken. Depending on the outcome of this evaluation priority research may be needed into the development of a reliable and accurate mass flow sensor. 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, improved understanding of what factors are controlling yield, prescribing treatments and determining optimum management units. This should be a high priority for PA research.

A major opportunity for the sugar industry is to significantly increase industry profitability without increased capital investment through reducing field losses of cane and juice during mechanical

harvesting. Adoption of harvesting best practice with attention to extractor fan speed, pour rate, feed train and chopper speed synchronisation, base-cutter height control and field layout, not only increases the amount of cane delivered to mills but also reduces the potential for environmental impacts associated with sugar juice entering waterways causing de-oxygenation. Harvester performance monitoring systems are now available to the industry, however the priority for further research should be in the interrogation of the information collected and the development and interpretation of practical and meaningful real-time performance feedback indicators.

The APSIM-Sugarcane model has evolved and emerged as one of the more powerful modelling tools currently available to the sugar industry. It has been used in a number of studies for improving water and nitrogen management by more quantitative prediction of crop yield, water and nitrogen needs during the growing season. Climate forecasting has been shown to be a tool available to the industry to improve competitiveness and profitability, through enhanced decision making and forward planning. Further research should be aimed at building on social science and economic capacity to increase awareness about the capability of the technology and for the industry to understand the strengths, limitations and associated risks of the technologies so they can be better positioned to use the technology appropriately. Decision support tools which combine GIS and results derived from crop modelling and seasonal climate forecasting systems to provide objective assessments of management alternatives for specific crops and locations should also be developed.

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 at relatively low cost. Research has highlighted the potential for remote sensing in yield forecasting, improve crop production and in detecting outbreaks of disease. Continued research and development into higher resolution and hyperspectral sensors will open up many new possibilities for crop and farm management. The major opportunity is the need for further practical research in the sugar industry with lessons learnt from other industries (i.e. viticulture, grains, cotton etc). In addition, broader agronomic application of remote sensing with respect to pest and disease monitoring and integration with crop modeling activities should be investigated.

The technology to implement site-specific management is now available. Variable rates of inputs can be implemented by simple manually controlled systems to fully automated variable rate controllers. The technology will vary according to the situation and the type of VRT to be implemented. Technologies range in complexity and feature; most can be adapted to existing equipment and therefore do not require the expense of purchasing new equipment. It is possible to adapt machinery by adding different gearbox and clutch systems, but this will vary from one piece of equipment to another. It is necessary, with VRT capable machinery that the controllers have the correct “drivers”, software programs, necessary for that specific equipment. New equipment such as fertiliser applicators, sprayers can be purchased from several companies. Improving irrigation application uniformity may be one of the most important management improvements to come from PA. Variable irrigation control has been attempted using sprinklers on self-propelled irrigators, lateral move, centre pivot irrigators or trickle irrigation. Improved optimisation and management of furrow irrigation from a field rather than a furrow perspective should be investigated.

To date most emphasis has been on proving reliability of the hardware rather than actually using geo positioning to vary product rates. This is largely due to the lack of a sound basis for making site specific rate decisions. Therefore the question for site-specific management and implementation of VRT is what variables are controlling yield variation. This may range from soil water status due to variation in the degree of subsoil sodicity and subsequent impacts on irrigation efficiency, soil chemical parameters such as acidity, crop nutrition or a combination of these. The priority for the industry should be the development of accurate and reliable prescription maps. Therefore it is up to

soil and crop scientists along with agricultural engineers to develop simple and robust methodologies and technologies for growers so that the full potential of PA can be exploited. They must conduct rigorous evaluation studies at multiple sites and with standardised methodologies, including utilising PA technologies for gaining a better understanding of crop yield determinants.

Proof of economic and environmental benefits must be demonstrated. The widespread use of empirical rules and algorithms must gradually be replaced with more in-depth understanding of cause-effect relationships that determine crop productivity, soil and environmental quality at scales that are manageable through PA.

LIST OF PUBLICATIONS

A report on precision agriculture technologies and their relevance and application to sugarcane production was prepared. An electronic copy of this report is attached to this final report.

The report should be cited as follows:

Davis, RJ, Bartels, R & Schmidt, EJ 2007, Precision Agriculture Technologies Relevance and application to sugarcane production, National Centre for Engineering in Agriculture Publication 1002265/1, Toowoomba, Queensland.