Australian Centre for Precision Agriculture

SIDERE MENS EADEM MUTATO

The University of Sydney

The Australian Centre for Precision Agriculture Symposium on Precision Agriculture Research in Australasia

Proceeding of the 1998 Symposium

Universitas Sidneiensis

Programme of Presentation

Welcome and Introductory Remarks

Alex McBratney, Director of The Australian Centre for Precision Agriculture, The Univeristy of Sydney

Introduction

Brett Whelan and Alex McBratney, The Australian Centre for Precision Agriculture, The University of Sydney

Turning Spatial Data into Useful Information

Brendan Williams, Pathway

Crop Yield & Soil Attribute Monitoring Results

Nigel Bodinnar, Pivot Ltd.

Cotton Yield Mapping

Broughton Boydell, The Australian Centre for Precision Agriculture, The University of Sydney

Precision Agriculture in the Sugarcane Industry

Graeme Cox, The University of Southern Queensland

What Do We Know About the Spatial Distribution of Arable Weeds?

Lisa Rew, NSW Agriculture

Within-Paddock Variation in Wheat Quality: Measurement and Implications for Management

John Skerritt *et. Al.*, CSIRO

Examining Local Yield Response To Applied Nitrogen From On-Farm Experimentation In Western Australia

M. Pringle, S. Cook, M. Adams, & R. Corner, The Australian Centre for Precision Agriculture, The University of Sydney

Soil Sampling and GIS applications

Kim Bryceson, CSIRO Land and Water Science

Table of Contents

Welcome

Alexander McBratney, The Australian Centre for Precision Agriculture, The University of Sydney

Welcome to the 2nd Australian Symposium on Precision Agriculture Research. We are pleased to host participants who represent a broad cross section of agricultural industries. The symposium is attended by growers, representatives of information technology- and agri- businesses, research providers and researchers.

While Precision Agriculture continues to gain impetus internationally as a farm management philosophy, the public face of Precision Agriculture in Australia remains the monitoring and mapping of grain yield at the within-field scale. Yield mapping is only one component of a Precision Agriculture system and small-grains is not the only enterprise to embrace the ideas. Agricultural industries ranging from broadacre grain, cotton, sugar cane and potato farming through horticultural crops such as tomatoes to viticulture are in various stages of researching and implementing Precision Agriculture techniques.

At present the total number of grain yield monitors operating in the country is estimated at between 200 and 300 but the industry and end-user interest is extremely high. This interest suggests that the commitment to Precision Agriculture in Australia will follow the international trend. However, the heterogeneous nature of agriculture will ensure that operations and management techniques unique to Australian conditions will require development.

Relatively little is known about the extent of within-field variability in soil and crop attributes in Australia. Even less is understood regarding the response of crops to fine-scale soil variability. Australian conditions are unique and will dictate which variables are significant in this interaction. To this end the local research that is to be presented here by the Australian Centre for Precision Agriculture, CSIRO, State agricultural bodies and private companies should ensure the development and adoption of suitable and relevant technologies and systems.

Here it is important to emphasise that Precision Agriculture is a system for farm management. It is not just the application of new technologies. A combination of variability observation, examination and understanding must be followed by relevant decision making and useful actions at the within-field scale.

All these components are at different stages of development and implementation. It is true to say that the technology required to gather detailed data leads the agricultural science of deciphering and applying the information it contains. Australian research is attempting to infuse the system with a sound scientific basis.

We'd like to thank the University for its financial and academic support for our activities over the past four years. And we especially wish to thank the generous sponsors of this symposium

We do hope you enjoy to-day's activities.

Staff & Students

The Australian Centre for Precision Agriculture, The University of Sydney

Introduction

Brett Whelan and Alex McBratney, The Australian Centre for Precision Agriculture,
The University of Sydney

What is Precision Agriculture?

The following defintions are to be found in the 1997 US Farm Bill.

Precision agriculture

The term "precision agriculture" means an integrated information- and production-based farming system that is designed to increase long-term, site-specific and whole farm production efficiencies, productivity, and profitability while minimizing unintended impacts on wildlife and the environment by-

a) combining agricultural sciences, agricultural inputs and practices, agronomic production databases, and precision agriculture technologies to efficiently manage agronomic and livestock production systems;
b) gathering on-farm information pertaining to the variation and interaction of site-specific spatial and temporal factors affecting crop and livestock production;
c) integrating such information with appropriate data derived from field scouting, remote sensing, and other precision agriculture technologies in a timely manner in order to facilitate on-farm decisionmaking; or
d) using such information to prescribe and deliver site-specific application of agricultural inputs and management practices in agricultural production systems.

Precision agriculture technologies

a) The term "precision agriculture technologies" includes
b) instrumentation and techniques ranging from sophisticated sensors and software systems to manual sampling and data collection tools that measure, record, and manage spatial and temporal data;
c) technologies for searching out and assembling information necessary for sound agricultural production decision making;
d) open systems technologies for data networking and processing that produce valued systems for farm management decisionmaking; or
e) machines that deliver information based management practices.

It is clear from these definitions that Precision Agriculture is much much more than yield mapping or controlled trafficking using high resolution GPS technology or just a cheap way of doing on-farm experimentation. It is a nascent integrated farming system with the aims of improving production and environmental quality through the quantification and managment of uncertainty.The Bill authorizes an appropriation of US$40,000,000 for each of the fiscal years 1998 to 2002 inclusive. Proprtionally this suggests that government investment in precision agriculture research should be of the order of A$6M per annum for the next five years. The best guess at the moment is that funding is significantly less tham a$1M per annum.

The two major research prorities are

a) the 'cheap' collection of yield-related spatial data
b) the 'spatialialisation' of decission-suuport systems.

Reference

Lake, J.V., Bock, G.R., and Goode, J.A. (eds) 1997. Precision Agriculture: Spatial and Temporal Variability of Enviornmental Quality. Ciba Foundation Symposium 210. John Wiley, Chichester. 251pp.

Turning Spatial Data into Useful Information

Brendan Williams, Pathways

With a growing number of farmers having produced yield maps for a number of years attention is now being focused on manipulating this data to extract useful information. Many traditional agricultural researchers, like me, have not had the background and training in spatial statistics and this represents a major problem for the industry. Training and assistance is required in this area if the industry is to reap the full benefits of this technology.

We cannot continue to collect data indefinitely in the hope that in five years time some miraculous transformation will occur and "all will be revealed".

Spatial statistics it is a developing field and we are fortunate to have world leading expertise in this area in the Australian Centre for Precision Agriculture. The industry should look to the Centre in the future to provide leadership in this field. If the Proceedings from the First European Conference on Precision Agriculture is any indication then it seems that the Europeans are placing much greater emphasis on spatial statistical methods so in future it may be the Europeans that we need to look to. In more recent times in the US some greater attention is being shown to spatial data manipulation.

A US company called SST Development Group have developed a package called SSToolbox that combines our traditional statistics with spatial data. It is a package that I find very useful because it will be easily understood by agriculturalists. My presentation will demonstrate some of the features of this software.

Comparing successive yield maps and determining the level of correlation between yield maps. Normalising and adding yield maps to create a total yield map for 2 years. Producing EMI maps and calculating semi-variograms to determine the spatial dependence of data. Drawing correlations between yield maps and EMI maps. Perform regression analysis on EMI and yield maps. Investigating relationships between soil type and soil nutrients and the resulting correlation with yield maps.

Crop Yield and Soil Attribute Monitoring Results

Ian Boothey, Pivot Ltd.

The introduction of commercial grain yield monitors in the l996 season in South Australia brought with it expectations of yield variability, (but to what extent?) and the opportunity to maximise yields and returns with the application of variable rate technologies in seeding, fertilisers, herbicides and soil ameliorates. The innovative farmers who have taken on the technology went into it with their eyes open and the first season brought with it relatively large yield variability as some had expected but the keys to why that variability had occurred are certainly much more elusive.

The 1997 season brought with it variable seasonal conditions but for most farmers yields were better than average but still with significant yield variability. Some paddocks first monitored in 1996 showed similar yield patterns as they did in 1996 and others showed different patterns, some of the reasons for that variability were certainly different soil types within paddock and different crop types but other reasons are not obvious. This leads to another question, how many years will it take to obtain enough data to help provide answers, at this stage in the development of Site Specific Technology the questions are coming faster than the answers.

Crop nutrition is one of the first areas to be put under the microscope in the search for answers to yield variability. The relationship at this stage between yield variability and nutrition is poor. Soil type seems to have a better relationship but what are the parameters we should be testing for and how should we be doing the analysis, by sampling and laboratory tests or by remote sensing technology, one that currently exists or one that is under development?

The phosphorus relationship is one example, there is an inverse relationship between yield and phosphorus which a first glance seems strange, high yield, low soil phosphorus conversely low yield, high soil phosphorus but of course the higher phosphorus removal in the higher yielding areas is the reason for the differences. Does this mean we should try and find the reason for higher yield in these areas (other than phosphorus) or do we just match the removal with variable rate applications and maintain the status quo, this would probably mean redeploying phosphorus from the higher phosphorus areas to the lower phosphorus areas but the overall phosphorus use may not change.

The challenges of Site Specific Farming are not going to be overcome instantly as we all realise but do we need to know everything or can we act now with the information we already know, just like how you eat an elephant, one bite at a time.

Cotton Yield Mapping - Development of Precision Agriculture Techniques for Cotton Farming Systems

Broughton Boydell and Craig Stewart, The Australian Centre for Precision Agriculture, The University of Sydney

The emergence of new technologies is enabling farmers to gain a greater appreciation of the variability contained within field. In 1997, the CRC for Sustainable Cotton Production with funding support from the CRDC, initiated a project aimed at characterizing the spatial variability of cotton yield and investigating yield-influencing factors which may be managed in a PA farming system. Cotton yield monitors appear to be destined to fulfill a vital role in the determination of suitable management practices within a field, as well as on a field by field basis. Application of remote sensing techniques may generate useful indicator layers for interpreting data and determining the consequences of, and for justifying management decisions.

Test results from the 1997 and 1998 picking seasons indicate that there is substantial short-range variability in cotton yield. Calibration of yield monitors indicate that they are capable of achieving yields with estimates accurate to within 10% (1 s.d.). Spatial analysis of the yield from 15 fields yield mapped across three valleys revealed that on average for a 30 ha field, a grower can expect to see the yield at two sites separated by only 50 m to vary (either up or down) by as much as 1.5 bales/ha. From an economic viewpoint, this represents a gross return variation to the grower of $930/ha over the 50 m range. This spatial structure in yield variability suggests that there is considerable promise for site-specific management within the Australian cotton industry. As a consequence of these preliminary results, research aimed at characterizing within field nutrient levels has commenced, with a view to using variable-rate fertiliser application strategies to manage yield variability. This talk presents some of the research findings and discusses the relative accuracy that may be expected from various yield measurement and yield estimation systems.

Precision Agriculture in the Sugarcane Industry

Graeme Cox, The Unviersity of Southern Queensland

This paper focuses on the application of Precision Agriculture to sugar cane in an attempt to reduce spatial variability and improve production of a case study field. The first task was to undertake yield mapping and for this a unique yield mapping system was developed. The resultant yield map displayed yield variations from 70t/ha to 220t/ha. Next, a directed soil-sampling regime was implemented based on the yield map and other soil related maps. The results of the soil tests indicated a strong negative correlation of crop yield with the sodium and magnesium content of the soil. To overcome this yield-limiting factor, gypsum will be applied at variable rates over the field. A simple economic analysis is conducted based on the cost saving resulting from optimised gypsum input. The results show the viability of precision agriculture when applied to sugar cane in this situation.

What Do We Know About the Spatial Distribution of Arable Weeds?

Lisa Rew, NSW Agriculture

Weeds are not distributed evenly within fields, but until recently this issue has not been addressed. However, in the last few years two basic approaches to detecting and patch-spraying weeds have been taken. Target weeds may be detected and sprayed in one operation (real-time) or mapped in one operation and sprayed at a later data (mapping). The real-time option is most suited to fallow situations at present. Therefore, for in-crop herbicide application most studies have concentrated on mapping.

Several studies (in the USA and Europe) have mapped weed distribution using discrete sampling methods i.e. weeds are counted within a quadrat on a grid basis. A small number of studies have mapped weeds continuously, though at a less quantitative level. In order to create weed maps from data collected using the discrete method, geostatistical analysis is required to estimate the weed density between the sampling points. Kriging is the most regularly used technique, although the accuracy of this and other interpolation methods for estimating weed populations has not been fully evaluated.

Analysis of discrete sample data has generally fitted a negative binomial distribution i.e. the weeds are aggregated at the scale of the sampling unit. At the field scale the studies have also demonstrated the diverse range of infestation levels, and a few have found that the patches exhibited anistrophy. However, very few studies have addressed the size or pattern of weed patches, or whether species behave differently. We also have limited data on the population dynamics within patches, the importance of different dispersal agents to the development of new weed patches and the tail shape of the seed dispersal curve. If we are to realise the full potential of precision agriculture for weed management in the long term, more research is required on the numerous biotic and abiotic factors that affect weed distribution and dynamics; and models need to concentrate on predicting patterns and dynamics of existing distributions rather than new invasion foci.

Within-Paddock Variation in Wheat Quality: Measurement and Implications for Management

John H Skerritt, Simon Cook, Matthew Adams, Russell Heywood,, Greg Naglis, Denise de Paoli, Craig Stewart and Alex McBratney, CSIRO

The focus of wheatgrowers' interest in the use of precision agriculture has been mapping variation in yields in defined areas of individual paddocks. This information is then used to either attempt to remedy local deficiencies in soil fertility or weed control, or to decrease inputs to paddock areas that have major soil or other problems, so that yields and/ or gross margins can be maximised. Use of this information, together with soil maps and differential global positioning system equipment enables seeding, sprays, nitrogen and other fertiliser inputs to be made at a variable rate.

While the effects of any site-specific management strategies on yield can readily be measured at the time of harvest, effects on the protein content and processing quality of the grain could be more subtle. With premiums being paid for grain protein content and the various premium-paying wheat grades requiring a minimum and sometimes a maximum protein content specification to be satisfied, there is the risk that a focus on the use of site-specific management to solely enhance grain yield could result in the loss of grade premiums, if the protein content (and potentially grain quality) is not suitable.

In a GRDC-funded pilot project, we are investigating three issues at the single paddock level:

a) To what extent does protein content and grain quality vary within a paddock, especially for similar levels of fertiliser input ?
b) Within-paddocks, is there a relationship between grain yield, protein content and quality ?
c) How are these parameters affected by soil characteristics and plant nutritional status or variation in fertiliser and seed rate inputs?

In initial work, we have examined results from six paddocks, representing three Western Australian and one NSW location and four quality grades of wheat. The paddocks also differed significantly in fertility, management inputs and grain yield and protein profiles. Despite the differences between these paddocks, some consistent trends were observed:

a) Within-paddock variation in protein content and protein quality often is very significant and as large as between-paddock variation for the same wheat type/ cropping environment.
b) Areas of higher yield usually do not produce grain of lower protein content or protein quality.

Thus using precision agricultural methods to increase yield did not decrease protein content or quality.

Within-paddock variation in quality is often greater than within-paddock variation in protein content.

In 1997, soil characteristics (pH, organic carbon, nitrate) had a more significant effect on grain protein content and quality characteristics than did the variation of fertiliser application or seed rates.

In 1998 season we will obtain more data on other paddocks with variable fertiliser inputs, to establish whether the trends noted in 1997 are able to be generalised. Examination of the results of site-specific monitoring of yield, protein and grain quality for each paddock enables recommendations for the subsequent season to be made. For example, gross margins might be able to be increased by removing a very poorly performing part of the paddock from production, and the uniformity of protein content and quality may be improved by strategic variation in fertiliser application. In collaboration with local agronomists, future work will be needed to determine whether the adoption of suggested individual paddock management practices deduced from site-specific monitoring data does actually lead, in the subsequent season, to increased within-paddock uniformity and higher gross margins.

Examining Local Yield Response To Applied Nitrogen From On-Farm Experimentation In Western Australia

M. Pringle, S. Cook, M. Adams, & R. Corner, The Australian Centre for Precision Agriculture, The University of Sydney

Precision Agriculture offers a tool for growers to implement field-scale experimentation on their own land. With the aid of yield maps, variable-rate technology and some knowledge of basic statistical principles, trials can be set up to evaluate the site-specific crop response to an input. In Western Australia, field-scale experiments have been set up to examine the site-specific relationships between yield and applied nitrogen using strips, chequerboards and 2-dimensional sine waves as experimental designs.

The intensity of data gathered by these operations lends itself to a local examination of the yield response. Using a Mitscherlich equation, two methods were investigated to find the local yield response to applied nitrogen on a field with a chequerboard experimental design. The first was a 50 m search radius and the second was using the nearest 20 points in each treatment. It was found that approximately one-third of the field showed no response to the applied urea, while between 3-15% of the field exhibited a strong response (^{3} 0.3 Mg/ha) depending on the method used. It was thought that the 50 m search radius smoothed response peaks too much.

Analysis with the 50 m search radius was also conducted on a field with a 2-dimensional sine wave pattern of applied nitrogen. Over 50% of the field showed no response to the applied N and only about 8% responded strongly.

In conclusion, the methods used to look at local yield response to nitrogen are promising but further work must be done on their refining.

Soil Sampling and GIS Applications

Kim Bryceson, CSIRO Land and Water Science

After a year in which it seemed that Precision Agriculture was the phrase on everyone's lips, but also a year in which the coloured maps have generated more questions than answers and the vaguries of climate have created unrepeatable experimental results, the question of "value" keeps creeping into conversations.

a) From the primary producer "What value are these technologies to me?"
b) from agribusiness "What value is it to us?"
c) from R&D Corporations "What value is it to us and our stakeholders to get involved?"

Such questions tend inevitably to be focused on the dollar value rather than on any less quantifiable value associated with, for example, education.

This paper will look at a series of products that have been produced in the CRC for Soil & Land Management in the last year which have "dropped out" of Precision Agriculture/spatial variability research agriculture. In particular the development of Decision Support Systems based around geospatial modelling of acidity, sodicty and salinity, and an interactive computer game designed to enhance soil sampling skills. There is undoubtedly commercial value attached to these products but there are also educational issues that they address which have a much wider value in the long term for maintaining and improving agricultural production in this country.

Yield Maps for Management: Resolution and Uncertainty

Brett Whelan, The Australian Centre for Precision Agriculture, The University of Sydney

Producing meaningful information for management decisions from crop yield maps requires an understanding of the entire yield monitoring and prediction process. Errors in all aspects of the process contribute to uncertainty in the final product - the yield map. Yield maps are now being used to infer information for farm management. A brief journey into the world of map resolution and uncertainty will be provided.

We will concentrate on the final process in map production, the prediction of yield at unknown points. While point prediction techniques are mostly used, in the future it may be advantageous for cell or 'block' estimates to be determined so that yield values for minumum areas of interest (MAI) or management units can be represented. Prediction can be made onto `blocks' which represent these management areas, e.g., 10 x 10 metres using a number techniques. In the process of block kriging these blocks can overlap unlike the more crude operations that will be discussed. For example, a map on a 1 metre raster can then represent the average of a relevant quantity over the 10 x 10 metre block centred on the prediction point. Geostatistical methods appear the most advanced for such predictions, particularly for site-specific crop management (SSCM) where an estimate of prediction accuracy is required. This forms the basis for an estimate of uncertainty in the yield map.

In any form of cell-based estimation or block prediction method, the cell size and/or prediction block size will effect the smoothness of any subsequent map. Bigger cells/blocks, smoother maps. This also holds true for the neighbourhood size chosen in the point prediction methods . Smoothness can also be effected by the spatial dependence models underlying the prediction methods. These models control the weight attributed to observations. Only in the kriging procedures is the model (semivariogram) conditioned on the actual observation data set and not an arbitrary function of distance. The range parameter of the semivariogram (which estimates the distance of spatial correlation between observations) is therefore a tool for determining sensible neighbourhood or cell/block sizes.

Intertwined with the dilemma of appropriate neighbourhood size is the resolution at which the yield maps should be presented. Resolution should probably be governed by ensuring that the raster size is of a dimension that maintains a management determined uncertainty level within the map. Uncertainty in the individual yield estimates appears to be dominated by the harvester mechanical dynamics.

Finally, the most suitable mapping class size (e.g. 0.5, 1.0, 2.0 t/ha demarkations) remains unstandardised and basically unknown. This attribute also effects the degree of spatial variability presented in a map which will inturn influence the observers perception as well as management decisions based on the classified yield variability. As an example the variation in crop yield may be classified based on percentiles using +/- set percentages of the mean yield as the categories. Such an idea is quite plausible as the basis for standardisation because it would fix the maximum number of classes that can be displayed in yield maps. The determination of the most suitable percentile bands remains a project for research.

As an alternative, a useful approach would be to ensure that the uncertainty in crop yield data influenced the classification decision. For example, if the 95% confidence interval in crop yield estimates is ± 1.0 t/ha, classifying a field using classes less than 1.0 t ha^{-1} may be misleading. A classification system based on the uncertainty in the yield data may prove useful in the future.

Parrallel Swathing Guidance - Trimble Precision Agricultural Products Helping Agricultural Efficiency

Adrian Snow, Trimble Navigation, Ltd.

Agriculture is constantly striving toward greater efficiencies, whether it is via lowered input costs and/or via higher yields and returns. Trimble recognise the importance of this, evaluating their agricultural GPS-based products in the field and comparing these with traditional methods of farm management. Efficiency of agricultural application is one aspect of farm management efficiency that has been studied, comparing GPS-based guidance with a spray rig using a foam marker for guidance. The GPS guidance consisted of the AgGPS 132 Parallel Swathing System where a sub-meter accurate GPS receiver and lightbar are used for guidance. Application efficiency of the ground-based applications was compared in terms of several variables including ground speed, average distance off the swath line, as well as application overlap (double application) or application skip (i.e. missed areas).