PRECISION AG. – OZ STYLE

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Abstract

Precision Ag practitioners continue their pursuit of precision through "turning data into decisions." Economic studies are now beginning to show advantages of precision management. Precision agriculture terms are defined for Australia and elsewhere. We discuss a model for precision agriculture and review the management zone concept for site-specific crop management. The key areas of research for obtaining data layers and linkages, some of which is world-leading, are reviewed briefly. The principal industries involved are those cropping industries of highest value where yield monitors have become available, i.e., grains, cotton, sugar, viticulture and horticulture. Commercial activities include the provision of hardware for information gathering, software for information management and data generation and information management services. The future of precision agriculture in Australia requires the plugging of knowledge gaps, the development of new areas such as precision organic farming, and most importantly vigorous promotion and investment. The application of geospatial information technology to agriculture through precision agriculture is profitable, can create jobs in the bush, is environmentally friendly, and can give consumers a deserved confidence in the production process.

Introduction

Precision agriculture (PA) attempts to develop integrated information- and production-based agricultural systems designed to optimise long-term, site-specific and whole-farm productivity and minimise impacts on the environment. Achieving a viable PA management system, e.g., for cropping, requires the gathering and management of detailed geospatial information within fields.

Precision agriculture, has to a degree, been driven by the advent of various high technologies, particularly the coupling of real-time positioning using GPS, electronic yield monitors on harvesting machines, proximal soil and crop sensors, remote sensors, variable-rate controllers for fertiliser, pesticide and seed application and GIS (geographic information systems). The coupled technology provides the data to investigate opportunity and to manage inputs differentially and optimally.

In Australia, the technology has been taken up by hundreds, if not thousands, of growers in the grains and cotton industries, and to a lesser extent in others, as yield monitors and relatively cheap GPS receivers have become available. We are currently developing strategies for inserting the precision approach into whole-farm management systems. The idea of variable rate-applications (VRA) of fertilisers, ameliorants and pesticides

within fields (which is the principal management intervention of precision agriculture) still requires a deal of research. However, PA in general will develop as a more visionary approach to farm management. Besides deciding on the suitability for VRA in a paddock and for certain crops, the increased information provided by PA can be used for: - deciding suitability of individual crops for certain paddocks, deciding alternative uses for areas within paddocks, deciding on boundary changes to avoid VRA, monitoring chemical application accuracy, increasing personal interest in farm management, increasing personal knowledge in the farm landholding, improving property resale, improving financial dealings in town, and avoiding litigation.

Definitions of precision agriculture in Australia and elsewhere

Precision Agriculture may be defined as: - *Observation, impact assessment and timely strategic response to fine-scale variation in causative components of an agricultural production process.* Therefore PA may cover a range of agricultural enterprises, from dairy-herd management through horticulture to field-crop production. The philosophy can be also applied to pre- and post-production aspects of agricultural enterprises. Much of the current research and applications is focused on applying Precision Agriculture to field-crop production. The term Site-Specific Crop Management (SSCM) describes this facet of Precision Agriculture. SSCM may be defined as:- M*atching resource application and agronomic practices with soil attributes and crop requirements as they vary across a field.* Collectively these actions are referred to as the 'differential' treatment of field variation as opposed to the 'uniform' treatment that underlies traditional management systems.

Regional nuances of the terminology

In most of the world *precision farming* and *precision agriculture* are synonymous. In Australia (Oz) because farming refers only to cropping (unlike, e.g. Britain, where it refers to all kinds of agriculture) *precision farming* means *site-specific crop management* (Figure 1). There is one contentious and potentially confusing use of terminology however. *Precision farming* is **not** simply controlled-traffic using GPS technology – although the term is sometimes used with that very narrow meaning in northern New South Wales and Queensland – but nowhere else in the world - this very small subset of precision agriculture would be better termed *GPS- controlled trafficking.*
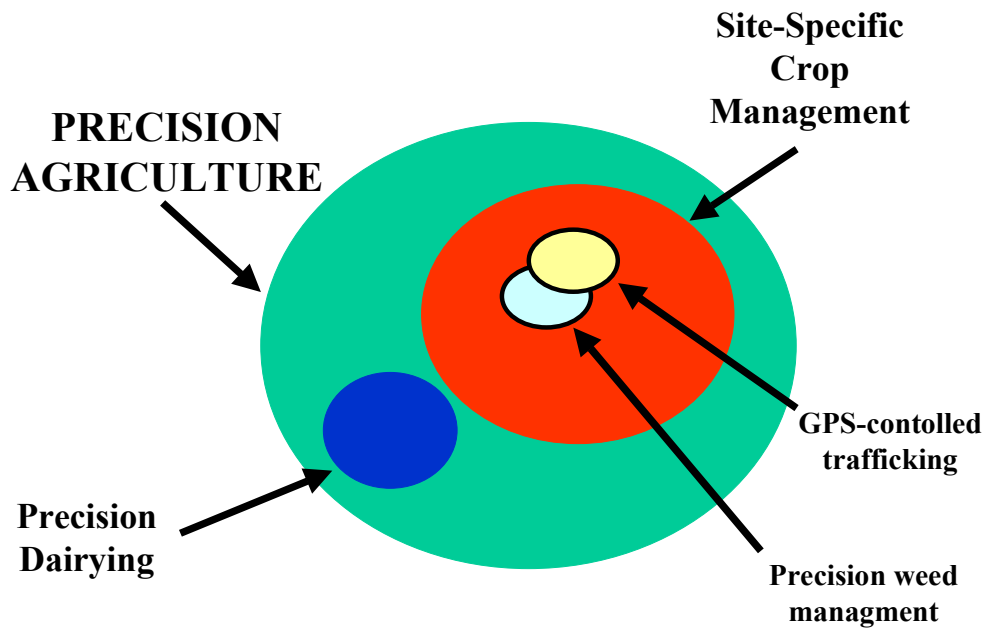
Figure 1. Diagrammatic representation of the relationships between various terms related to Precision Agriculture.
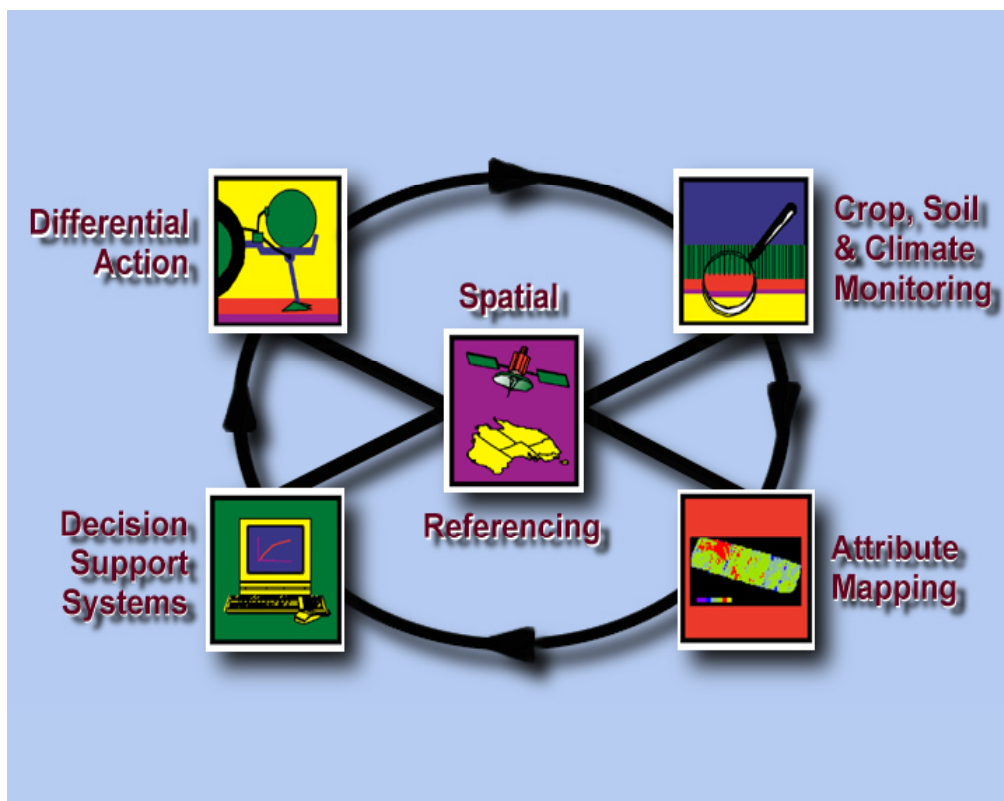

Figure 2. The precision agriculture wheel with GPS-based spatial referencing at its hub.

A Precision Agriculture Model

The SSCM Wheel

The SSCM wheel (Figure 2) depicts the general site-specific crop management system. The wheel would ideally turn once every growing season. There are 5 key components to consider in the development of a SSCM system. Because the complete process cannot yet be completed in a single pass of the paddock, the site-specificity is made possible by the Global Positioning System (GPS) which provides the ability to know accurately where you are during all facets of farming operations. The remaining components of the system operate in a cyclical fashion. Influential factors effecting crop yield, along with the crop yield itself, must be monitored within the paddock and maps made of the variation in these factors for an entire paddock.

The degree of variability across a paddock will determine whether different treatment is warranted in certain parts of the paddock. Linking the variation seen in crop yield with the measured factors influencing crop yield is done using suitable modelling procedures. Armed with this information it may then be possible to devise treatment strategies that are agronomically sensible. If these treatment strategies suggest that differential management is warranted, operations such as fertiliser, lime and pesticide application, tillage, sowing rate etc. may then be varied in real-time across a paddock using available technology.

Management Zones

PA began in the United States, prior to the advent of yield mapping, with the idea of variable-rate application of fertiliser based on the analytical testing (chemical analysis of nutrients) of topsoil samples collected on a 100-yard grid. This approach besides being expensive, is logically flawed. The idea presupposes that all areas in a field have the same yield potential and in order to reach that potential the optimum amount of fertiliser has to be applied at each point. Research in Europe and Australia (and only recently in the US) has suggested that it would be better to recognise areas within fields which have similar yield potentials and which can be managed relatively uniformly. These areas, which are called management zones (in essence, small fenceless paddocks within much bigger paddocks), are areas with different soil, slope position and microclimate – like the French idea of 'terroir' for grapes. They can be created from multiple-year yield mapping, proximal or remote sensed images, soil information from proximal and remote sensing and digital elevation models collected from high-resolution GPS.

Research for obtaining key data layers and linkages

There are several research groups researching PA in Australia, the principal ones being the Australian Centre for Precision Agriculture and CSIRO Land & Water. Work is focussing on developing the system shown in Figure 2 for various commodities. This involves obtaining key data layers and developing linkages to join them to make a seamless cycle. The other papers in this Symposium and those in previous symposia (see www.usyd.edu.au/su/agric/acpa) reflect the breadth of the work.

Key data layers

The key data layers are:- crop yield, quality of yield, soil physical and chemical attributes, terrain, weeds and diseases. In the Australian environment, soil moisture is often a yield limiting factor, so soil and landscape attributes that govern water flow and retention will be vital. The value and importance of these layers will be covered by the many speakers at this conference.

Linkages

The two key linkages required are GIS and DSS (Decision-support systems). GIS is required to overlay and spatially reference the data. DSS are required to process the data. DSS for precision agriculture are in their infancy. Crop simulation models seem to be the best way to translate soil and environmental information into production estimates. Such models are still not well 'spatialised' and it may be that simpler, spatial meta-models will have to be constructed in the meantime to supply decision support.

Measuring opportunity

According to McBratney et al. (2000) and Pringle et al. (submitted) the opportunity for SSCM can be regarded as a function of a Magnitude of yield variation component, an Area of management component, and Economic/environmental concerns. The SSCM Opportunity Index (OI) can be defined as:

$$OI = \sqrt{\left(\frac{auto\text{-}ARCOVAR_{1000}}{Median(auto\text{-}ARCOVAR_{1000})}\right) \times \left(\frac{pT \times A + (1 - pT) \times J_a}{MZEM}\right) \times E} \; . \qquad (1)$$

$$\underset{\text{Magnitude}}{\uparrow} \qquad\qquad\qquad \underset{\text{Area}}{\uparrow} \qquad \uparrow$$

Large values (OI >10) probably indicate an excellent opportunity for precision management – but we still have to establish a norm for the index. Evaluating E in equation (1) is still problematic.

On-farm experimentation

One of the key issues is to develop strategies for within-field management. This can be either through management zones or continuous moving-window management. Take the case for fertilisers, here we would like to know the response function for different management zones within the field or as a continuous moving window function of spatial coordinates. The variable-rate technology allows the setting down of sophisticated field experiments in farmers' fields to acquire this knowledge (Fig. 3) and the yield-monitoring technology allows the measurement of response. The spatial design of such 'on-farm' experiments are still in their infancy. Adams & Cook (2000) discuss some possibilities. For management zones, an efficient design would encompass "*flecks*" of different fertiliser rates within a paddock. Here, randomised block experimentation is done with spatial constraints and economic considerations. The economic consideration being that one does not want to penalise the grower by using sub-optimal rates over much of the field. Most of the field can have a uniform treatment

which the grower considers adequate. Data from all of the paddock can be used in the analysis. The proper objective function and design for these experiments have yet to be developed, but an approach homologous with the use of spatial simulated annealing (Van Groeinigen & Stein, 1998) for spatial sampling, seems the most obvious one.
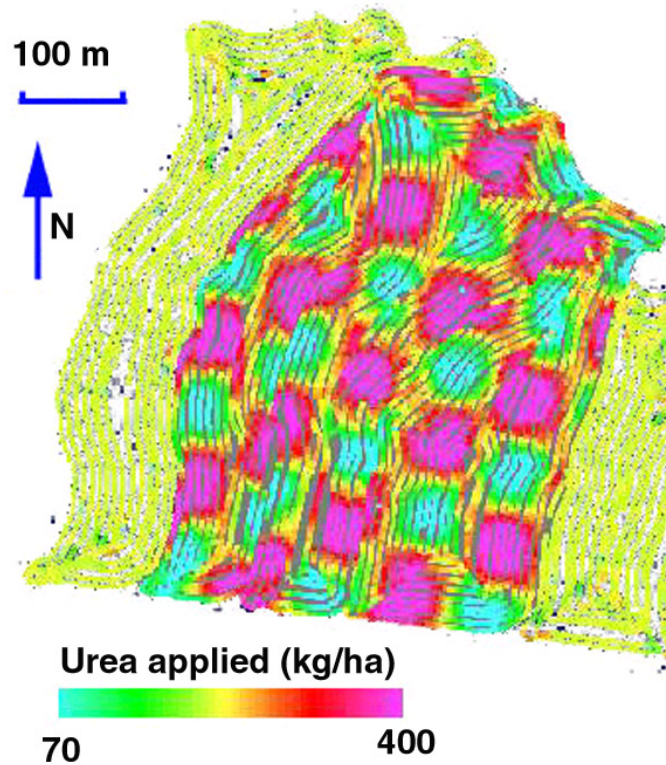

Figure 3. Spatial distribution of urea applied using a variable-rate controller in a field in northern new South Wales. The pattern approximates an egg-box design.

Where the object is to produce a local moving window response function, and one is not concerned about the grower's production from the experimental field, systematic designs such as a "draught *board*" with four levels or an "*egg-box*" design as shown in Fig. 3, sometimes called a two-dimensional sine wave (e.g., by Adams & Cook, 2000) can be used.

Principal industries

Monitoring and mapping the spatial variation in small-grain crop yields remains the dominant focus of PA in Australia. However, agricultural industries ranging from broad-acre cropping (grain, cotton, sugar cane and potato) through to horticultural crops such as tomatoes and the ever-expanding viticulture enterprises, are in various stages of researching and implementing PA techniques. In general, the principal industries involved are those cropping industries of highest value where yield monitors have become/are becoming available.

At present the total number of grain yield monitors operating with GPS is estimated at up to 500 and there would be approximately 20 cotton pickers fitted with GPS and commercial yield monitors. These numbers reflect the watchful eye of the Australian farmer as they wait for a fuller PA management system to be offered.

Commercial activities

Here we focus on the main activities and some of the key players.[*]

Hardware

The two major world agricultural machinery manufacturers, Case Corporation and John Deere, both actively support PA in Australia and offer hardware systems. Everyone is still keenly awaiting Case's protein sensor which will help to realise the total quality management aspirations of PA, and may well revolutionise the practices of the Australian grains industry. Many other hardware system components are available from third-party suppliers, most notably yield moniotrs and variable-rate controllers. GPS is also well supported by many brands of hardware and some are directed directly to the agricultural sector. Many of the large international equipment manufacturers also make use of our location in the southern hemisphere. The opportunity to test PA equipment on a summer/winter crop twice a year, along with the cooperation of Australian growers and researchers, makes an annual trip here quite enticing.

While most of the hardware is from the United States, it is pleasing to report that a number of Australian companies are now involved in producing or developing new grain, cotton, sugar cane and grape yield monitors for the world market. Australian research has also led to the development of technologies and implements for the detection and site-specific treatment of weeds in fallow fields, controlling chemical applications quantities and for the accurate guidance of tractors and chemical applicators. GPS-controlled traffic operations are now much discussed at field days.

Software

Case Corporation, John Deere and others provide software programs for processing data from yield monitors and basic interrogation of the data. There are several specially devised, commercially-available GIS for PA (PAGIS) such as SST, AgLink, AGIS, Red Hen etc. Some sit on top of other software such as MapInfo and ArcView. A key requirement of such software, besides ease of use, is the ability to handle yield-monitor data well and to write the appropriate files for variable-rate controllers. Unfortunately, at present many of the routines in these packages are relatively unsophisticated and none have a good decision-support system attached to them – these are the key challenges for PAGIS.

Information gathering, management & provision

Several companies offer information gathering, storage, processing and management-support services. We see this as a key way of implementing PA, with trained consultants having a group of grower clients. This leaves the grower free to make the key day-to-day decisions on the property. A key unresolved issue here is the ownership of data – if a consultant processes and stores data, then who has the right to access and use that data?

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[*] mention of a commercial name is intended for the free exchange of information and does not imply an endorsement

A reasonable principle would be that property owners have the right to data collected on their own property. Who else should have a right to the data?

Primary producers

Some of the larger producers, particularly in the cotton industry, have invested in hardware and software. Also a number of smaller, innovators with vision and computer and electronics skills, across all industries. It remains to be seen how the bulk of family-sized producers will implement PA but the commercial consultant model described above seems to be the most feasible one.

The future

We have only just begun with PA, it is probably too early to gauge its long-term impact in Australia. Where should we go from here?

Plugging knowledge gaps

The key gap in the PA knowledge, remains an efficient and definitive protocol for interpreting yield and crop quality maps. A protocol is emerging based on management zones, several years' yield mapping (the number of years required is still an open question), soil physical information from proximal sensing, terrain attributes from DEMs and on-farm experiments. The integration with crop-simulation models, such as APSIM etc., is still missing. Once the yield and crop quality maps can be properly and quantitatively interpreted, then appropriate differential actions can be taken. Optimal actions will only be possible when the environmental economics of the production process is fully understood – a second key knowledge gap. Thus far, the agricultural and environmental economists in Australia have not shown much interest, unlike Europe and the USA.

Precision quality assurance and organic farming

The whole world wants clean, green food. For conventional inorganic food production, PA provides the information to audit and track production. Commodities can be tracked from the part of the field they are grown (with all the associated input information) to the point of sale. Consumers can have the production-process information if they want it. They can know if a transgenic cultivar has been grown, how much insecticide has been applied etc. PA can have a large impact on quality assurance of the food supply. Achieving this is a challenge, but it is clearly possible. Growers will need to be paid premiums for the provision of this information.

If we go to the next step, where the consumer may demand no artificial fertilisers and pesticides, then production would be significantly tested. Such a production blueprint would require payment of a price premium, but the PA system should still be able to provide optimal solutions to this more difficult problem. Information-driven mechanical technology may well be able to solve the problems of weed control, which is one of the main problems of organic farming.

Promotion and investment

In Australia with its excellent communications and knowledge infrastructure and large variable fields, the opportunity for precision agriculture is enormous. But by world standard our investment in research and development is quite low. Germany has, for example, one 40 million DM ($A37 million) project and many other smaller ones.

Nevertheless, we are doing excellent research here in Australia. In some aspects we probably lead the world. Agricultural debate rages on the negative aspects of GMOs and biotechnology, the environment and land clearing, and deregulation. We, on the other hand, have a positive message. **The application of geospatial information technology to agriculture is profitable, can create jobs in the bush, is environmentally friendly, and can give consumers a deserved confidence in the production process.** We should sell this message vigorously. Because of its highly innovative nature, potential for improved quality of production, environmental management and the export of hardware and software, precision agriculture has the credentials to be a key candidate for a well-focused Co-operative Research Centre.

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