Precision agriculture: Using paddock information to make cropping systems internationally competitive

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Abstract

Precision agriculture was introduced to Australia in the early 1990s as a hi-tech crop management system that comprised on-the-go yield monitors, real-time GPS (Global Positioning Systems) and other information technologies. While the technology looks complex, its application can be remarkably simple, and summarised as improving crop management by reducing the level of uncontrolled variation which currently exists in farming systems. The potential benefits include greater profitability, more consistent product quality and reduced environmental risk. The ability to be informed about the performance of the system also increases the certainty during changes that are inevitable if agriculture is to maintain competitiveness in an increasingly tough international marketplace.

What is precision agriculture?

The term precision agriculture invokes images of satellites, electronic gadgetry, and computer controlled machinery. The technologies that are common to precision agriculture include one or more of the following:

- On-the-go monitors to measure crop yield and quality directly as it is being harvested;
- GPS, which references each measurement to a specific location. This is also central to the expanding use of vehicle guidance;
- Variable rate technology, which enables continuous control of inputs such as seed, fertiliser, spray or irrigation water;
- Remote sensing, which provides cheap information which may help explain or predict variations in crop behaviour; and
- GIS, which provides systems in which to assemble all the above information

While some aspects of the hi-tech image are true, such an image emphasises the technology rather than its use. This is a pity, because precision agriculture is really about improving management of the agricultural system. The definition provided by the U.S. National Research Council is a management strategy that uses information technologies to bear on decisions associated with crop production (NRC, 1997).

Precision agriculture offers information technologies to monitor, analyse and control crop production in the field. It informs farmers about the performance of the cropping system over a variable land surface, and provides control technology to respond to variations more precisely. By reading the system more accurately it also increases the
certainty with which farmers can introduce other innovations to the system. In short, precision agriculture merely enables field crop production to emulate the improvements many other industries have made, by using IT to improve production efficiency.

**How will precision agriculture technology drive agriculture?**

This new technology will enable agriculture to respond more effectively to the pressures exerted upon all export-dominated producers. Using Robertson (1998) as an example there will be:

- Strong growth in world demand for food and fibre;
- Global sourcing of food and fibre inputs;
- Progressive deregulation of international trade in agriculture, food and fibre products;
- Declining land area available for agriculture; and
- Pressure on agricultural land uses to control environmental impacts.

These drivers present an imperative to generate more product, of better quality, more efficiently, with fewer off-site impacts and on a reduced land area.

Precision agriculture technology provides the information and control technology to enable growers to manage the land resource more effectively. But how this actually occurs will vary depending on the problem facing individuals. The following examples illustrate the range of potential applications.

**Improving profitability:**

- Increasing the rate of return on investment by more accurate targeting of inputs such as fertilizer, seed or irrigation water;
- Improving product quality by fertilizing to demand, or more accurately segregating product at harvest.

**Controlling environmental impacts:**

- Reducing the risk of leaching of N or P to water quality by targeting fertilizer placement;
- Restricting application of pesticides to areas known to be at risk of infestation;
- Reducing the area of land under annual cropping to suitable areas.

**Improving manager skill:**
Accelerated development of management skill by detailed monitoring of crop system performance under change;

Exploration of changes in the system using participatory on-farm experimentation;

Detailed budgeting and certification of inputs and outputs.

**What is likely to be achieved by 2010?**

The vision for precision agriculture is of a technologically advanced plant production system that maximises the biological productivity of crops by controlling inputs exactly to the requirements of a given site and given season. In this vision, genotypes are selected for their ability to capture the resources available at a specific site, fertilizer and other inputs varied according to specific (known) demand; and product quality streamed to maximise the price it can command. In the same vision, the farmer spends more time in front of a computer, scanning images of crops like a surgeon diagnosing the need for medical treatment, consulting a specialist through the internet for a second opinion.

In reality, the process of adoption has hardly started. While substantial progress has been made in the development of basic technology, particularly in the US, the hard slog behind the myth paints a picture which can be paraphrased by the following statements: Now we can see what really happens I think I can see opportunities to improve it .if only I knew how. This paraphrases three stages of development:

- Defining the problem of poor control;
- Identifying the opportunities for change; and
- Developing the capacity to make change happen.

The U.S., with about 10 years experience in precision agriculture is already in the second phase — developing opportunities, and rapidly developing the third, even as it tackles the first. Precision agriculture there has reached the end of the early adopter stage with about 5 per cent adoption across all farm types. In Australia what development there is remains largely in the first phase.

**Defining the problem: Inadequate control of a variable cropping system**

Normally, the first reaction from a farmer to a yield map is surprise: I knew it varied, but not so much! This is a reasonable response- all good decision makers simplify their mental image of variation and ignore, as much as possible, deviations from the norm. But the comment reflects how little is known about the performance of agricultural land. For example, few, if any, farmers can quantify the effects of basic inputs such as fertilizer on specific paddocks, yet hundreds of millions of dollars are routinely invested in a general expectation of benefit. Few realise that while some parts of a paddock perform profitably, others may be losing money, year after year.
This first stage - defining the problem - is already being done. Yield maps and other spatial information reveal significant lack of control within the agricultural system — with consequent land degradation, low returns on investment and variable product quality. The next stage is to decide what can be done about it.

**Developing new opportunities: Describing how to control the cropping system more effectively**

If the problem is inadequate control of a variable system, the opportunity is to improve the control to meet objectives of profitability, reduced environmental risk or quality assurance. Uncontrolled variation becomes an opportunity for improvement when the linkage between control and outcome becomes certain enough to be acted upon.

The simplest example of improved control is spray guidance. In broadacre situations it can be difficult to avoid overlaps or spray misses, but guidance systems are increasingly used to increase the precision of tracking. Anecdotal evidence suggests that such systems pay for themselves very quickly.

The next level of prediction is the use of diagnostics to inform where, on the basis of spatial information, specific manageable limitations are likely to exist. An example is the crop vigour index offered by purveyors of remotely sensed imagery. Such information can be useful when interaction is possible after the event, but many agricultural decisions have to be made before such information is available. This requires representation within a predictive model. A range of models exists. Some have been trialled for Australian conditions (Adams et al., 2000). However, the ability of the current generation of models to represent complex cropping decisions seems inadequate. This has been the most active area of research in the U.S. A much smaller effort is supported in Australia and the methods available commercially to Australian growers appear mainly to be imported from the U.S.

If hard scientific methods seem unavailable an alternative approach is to enhance farmers' intuition by enabling them to use the technology to conduct full-scale experiments on their own farms. The principle is simple: Introduce deliberate variation in an input - such as fertiliser or seed rate - and measure the effect on crop yield (Bramley et al., 1999). If they are mapping crop yields anyway, this costs little and may provide valuable insight to facilitate change.

**Developing capacity: Delivering better methods to the farmer**

Precision agriculture provides complex numerical data about the crop, which requires new methods of interpretation and people to help implement them.

Very few methods have been written for Australian farmers to process yield maps. Imported methods are unlikely to be suitable in the long term.

The yield map interpreter will demonstrate a rare mixture of skills in biology, statistics and computing. These are rare in Australia and since there is, to my knowledge at least,
very limited training opportunities in this subject, such skills are likely to remain so for some time.

So what are the alternatives? Four come to mind:

1) **Developing the farmer skill base.** This has the advantage of developing a bottom-up skill-base. However, developing such specialist skills is time consuming and detracts from other management duties.

2) **Developing standard software to accompany technology:** It may be possible to provide basic analytical tools to the 1500 or so farmers in Australia with yield mapping technology. Many bugs would need to be ironed out and users may tire of basic methods that fail to address realistic management demands.

3) **Provision of specialist services by commercial suppliers:** Specialist mapping services could be bundled in with conventional advice delivered routinely by commercial suppliers of fertiliser, chemical or seed. An effective delivery option, but some farmers may prefer independent advice.

4) **Remote advisory services:** Increasing interest is being shown in the use of the Internet as a vehicle for providing the capacity to analyse and interpret information. With limitations on access reducing, this may develop into a valuable complement to conventional consulting services.

**What are the risks or returns to investors?**

The first risk is the investment in technology. These are relatively small. For moderately sized grains growers, the yield mapping technology represents less than 2 per cent of production costs. In higher value commodities, such as grapes, sugar or cotton, the figure is much smaller. Major investment can be staggered by incremental adoption, starting with the yield monitor and GPS; later on consider purchasing additional data such as airborne or satellite imagery. Detailed soil or tissue sampling may be useful, depending on the perceived limitations. Variable rate technology (VRT) is more expensive, but some growers are keen to start using it at an early stage. Guidance systems for sprayers are readily adopted. The problem seems to be less in acquiring the information but in acquiring value from it.

A much greater risk to adopters is that of information overload. This phenomenon is the scourge of many businesses. For example, in a survey of managers from a wide range of industries, information overload was perceived to create an amazing array of problems. Over 80 per cent of respondents felt they were being forced to collect information, 43 per cent felt that the information actually slowed down the decision-making process, and 40 per cent felt they wasted substantial amounts of time collecting it. Worse still, 50 per cent felt that the information was a distraction from their real work, 44 per cent felt it cost more than it was worth and a staggering 42 per cent felt they suffered from ill health simply as a result of information overload (Oppenheim, 1997). The problem has been summarised in the complaint (Koniger and Janowitz, 1995):
Drowning in information, thirsty for knowledge

This apparent paradox is caused by poor structuring of information, which is difficult to evaluate and consequently either ignored or forgotten. Precision agriculture provides information by the megabyte. A typical wheat paddock will generate perhaps 30,000 estimates of yield where previously there was one. Without help to structure the information and guide it towards an improved decision, the maps and images produced by the technology may merely distract a competent farmer from the right decision. The lack of capacity to process the information is a greater risk than the cost of gathering technology.

While the potential benefits from managing more of the spatial variation can be substantial, the actual benefit depends on the accuracy with which the variation can be predicted. Choosing an inappropriate method of prediction may actually increase the risk of more precise management. Lowenberg de Boer and Boehjle (1996) report experience from the US in which it appears that under the full burden of costs, the net returns of variable fertilizer management, using methods then available, can be mixed. But Swinton (1997) found that farmers perceived a range of benefits that extended beyond the simple placement of fertilizer.

Our experience suggests that returns to growers tend to be small but incremental and reflect a growth in their ability to manage increasingly more precisely. One year, N may be targeted, the next weeds. Further options include lime or gypsum treatments, weed control, crop varieties. The modest improvements reflect the fact that many improvements are received as better likelihood of gain rather than certainties. Nevertheless, on the field trials we have, improvements in profitability of $10-30/ha seem reasonable. These may take a range of forms:

- Reduced inputs over areas with low potential;
- Increased returns as other limitations are removed;
- Selective targeting of responsive areas; and
- De-selection of areas unsuitable for cropping.

Some of the benefits are operational. For example, farmers who have spray guidance systems report that the improved accuracy and night-time capability improve the window of spray opportunities substantially. Most believe their systems pay for themselves in the first year.

What regional or social factors are critical and what capacity is there to adopt precision agriculture?

An interesting observation from the U.S. is the patchiness in adoption of precision agriculture. This occurs even in the corn-soy belt of the mid-West, where precision agriculture originated. Verbal reports indicate that while most farmers in some areas have adopted yield mapping technology (and in some the figure is over 80 per cent), only a short drive away, there will be areas where the penetration of the technology is 10 per cent or less.
This seems to have less to do with the intensity of production or land capability than the shortage of skilled advisers. We note, for example, that adoption in Australia is more advanced in dryland grains, whereas adoption in the same sector in the U.S. is reported to be very slow. Conversely, precision agriculture there is practiced most intensively by corn growers, especially if they irrigate, whereas uptake by Australian maize growers has been slow. Even the wine industry, generally regarded to be highly progressive, started adoption of precision viticulture very late, and even now accounts for only a handful of grape yield monitors.

Patchy adoption in the U.S. seems to be related to the presence or absence of a local advocate, who is familiar enough with both the technology and the industry it aims to serve to overcome the problem of information overload. While remote solutions such as customised software and Web-based support, are being explored, most farmers are likely to use these to complement, rather than replace the local adviser.

The use of precision agriculture has implications for social organization within the industry. Organization of skills is the key to efficient flow of information. It has been described by Mintzberg (1994) as a hierarchy that progresses from the operating core (the doers) through tiers of managers with increasing specialisation to so-called visionaries at the top. Financial and technical services feed in to specialists within the industry, not at the core, and it is here that specialists need to be on hand to communicate with operators — which is the only place real change can occur. Such skills are too specialised to be supported on any but the largest farms, and this niche is where the conventional farm consultant is to be found. Adoption of precision agriculture technology in Australia now depends on the activity and development of specialist consultants. To date, very few exist.

Conclusions

Precision agriculture is a system of agricultural land management that uses spatial information technologies to identify and manage variation in the cropping system. An early product of the technology is a yield map, which almost invariably shows substantial opportunities for controlling variation. The second product is improved certainty about the effects of change. Both products enable a farmer to be a more skilled manager.

Given the current state of development of precision agriculture in Australia, few seem certain about methods of exploiting these opportunities, and fewer still capable of delivering them. Progress in the development of methods and applications has been much slower than expected. Nevertheless, it is difficult to imagine any industry that would reject the opportunity to control its production system better, if only it can be shown how to adopt.

Precision agriculture introduces a deep-seated change in agricultural land management that appears to require more effort than we originally realised to convert into management practice. More than 10 years were required for it to reach the end of the early adopter stage in the U.S. When it reaches the mainstream phase, changes in the
capacity to produce cheap, high quality and certifiable produce are likely to intensify the pressure for parallel changes in Australian agricultural exporters.

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References


