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Opportunities and constraints for managing within-field spatial variability in Western Australian grain production

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Abstract

Sensing, interpreting and acting upon within-field spatial variation in crop performance through precision agriculture (PA) techniques stands to benefit farmers economically and environmentally. The increases in crop gross margin required to offset the cost of purchasing and operating PA technology can be calculated to help growers make PA investment decisions. Economic modelling shows potential benefits of <\$5/ha to \$40/ha for variable rate management. This is supported by on-farm trials showing benefits of \$29–63/ha for zone management in the northern sandplain of Western Australia. The full benefits of zone management can only be realised by developing methods for defining management zones that are consistent in performance, and accounting for crop nutrient requirements within zones by allowing for seasonal effects on yield potential. Various methods can be used to define zones of consistent performance in fields that can be targeted for variable rate fertiliser inputs. In many situations yield variation can be related to variation in soil plant-available water capacity. Predictive systems using geophysical information will enable inexpensive extrapolation of valuable point-based soil characterisation. Constraints to adoption by farmers include lack of training and technical support, equipment incompatibility, perceived riskiness of economic returns, and barriers to use of "hi tech" elements. Future research, development and extension should target a wider farmer audience who are aware of spatial variability but are not currently using PA technologies.

Keywords: Precision agriculture; Soil variation; Yield maps; NDVI; EM38; Gamma-radiometry; Economics

1. Introduction

A major concept underpinning precision agriculture (PA) is the matching of nutrient supply to the spatial variability of grain yield over a farm, through the use of variable rate technology (VRT) (Dobermann et al., 2004). At the most refined level, this form of precision management requires the use of advanced technologies such as global positioning and guidance systems, grain yield monitors and variable rate applicators (Cook and Bramley, 1998). Emphasis in PA research to date has been placed on the use of VRT for nutrient management in different areas or zones in fields, hereafter called zone management (McBratney et al., 2005). Although the benefits of PA seem obvious, the adoption of spatially variable fertiliser management is not widespread, both internationally (Daberkow and McBride, 2003) and within Australia (Lowenberg-DeBoer, 2003). Although PA technology has been available in Australia for more than a decade, it has been estimated that only around 3% of Australian grain growers are using some form of the technology (Price, 2004).

We believe that the following conditions in Western Australia (WA) predispose PA to be advantageous relative to current practice (Dobermann et al., 2004). The large scale of farming operations means that the technology is affordable and increasing input costs are driving growers to improve farm efficiency to remain profitable. In addition, the approach of managing within-field or -farm production variability is well suited because of the consistency of patterns in crop

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performance, both in space and time, so that zones can be managed reliably from season-to-season (Adams and Maling, 2005). Finally, there is access to a strong communication network linking PA researchers, PA equipment and software manufacturers, consultants and leading-edge growers.

In this paper, we discuss current progress and future prospects in research and development for PA in WA and for grain production in large scale agriculture in other developed countries. The financial considerations of investing in PA are discussed and then evidence of economic benefits from zone management is described. A major technical component of PA is the definition of management zones through the use of various spatial information and current approaches and prospects for this are covered along with the use of such spatial information to diagnose yield constraints. Finally, brief consideration is given to the use of PA techniques at farm and landscape scale to address environmental issues, beyond the usual field scale to which PA is applied. Adoption of PA is like any other innovation in that it is influenced by a number of variables and we consider the role of industry development in constraining the wider adoption of PA among Australian grain growers.

2. Financial considerations of investing in precision agriculture

One of the reasons for low adoption of PA is the understandable reluctance of farmers to invest many thousands of dollars in PA for variable rate technology without knowing if the technology will return a profit (Dobermann et al., 2004; Jochinke et al., 2006). This problem is somewhat accentuated in PA as the early adopters are often moving into PA with systems based on high cost 2 cm accurate GPS auto-steer systems with capital costs ca. AUD $60 000 (Table 1) (note all financial figures given in this paper are in Australian dollars, AUD unless otherwise stated). To potential adopters this seems too expensive and they question the application of PA to their farming system. In WA the early adopters often crop large areas (above 3000 ha) which means highly accurate auto-steer 2 cm systems are a good investment based on 10% savings in inputs from less overlap (Stone, 2004). Highly accurate GPS systems are not an essential piece of the equipment for VRT and the cost can range from $800 to $60 000 depending on what accuracy is most appropriate for the operation (Table 1).

It is difficult for farmers to know if PA is profitable until something is known about the yield variability on the farm, which cannot be obtained without spending some money on PA equipment. We propose the decision can be tackled backwards by finding out by how much a gross margin needs to improve – using a simple investment analysis. A range of factors affect the investment value of PA including the current farm gross margin, cost of PA equipment, the area and number of years over which the equipment is used and the rate at which benefits from adoption start to occur (Stone, 2004). The investment analysis uses a 'discounting' process that recognises that a dollar received today is worth more than a dollar received next year. Rather than guessing how much benefit PA might provide, this analysis determines how much benefit the new technology needs to provide to make the investment in PA profitable. This value is presented as a 'break even' increase in gross margin, enabling the investor to reflect on how achievable could a break-even increase in gross margin be in practice. Table 2 illustrates the impact of variation in the amount invested in PA and area of cropping benefiting from PA on the required gross margin increase. Clearly, the increase in gross margin required depends on the size of the investment and will be lower if the benefits can be spread over a wider area.

Typical gross margin increases required to offset the PA technology costs can be calculated for different regions in WA according to statistics of cropped area on farms (Western Australia Department of Agriculture and Food, 2006). Grain growing properties in the northern agricultural areas of WA average 3600 ha, of which about 1700 ha is cropped each year. In the eastern agricultural area, average farm size is about 5000 ha with just over 1700 ha under crop each year. Given these farm sizes, the range of gross margin increases required to break even from investment in PA is less than $5/ha depending on the level of investment and assuming that benefits accrue

Table 1
Typical configurations and costs for investment in equipment and services for precision agriculture technology

Level of investment	Total cost	Equipment and services
Low	$7300	Variable rate controller – $3500 GPS – $800 Zone analysis – $3000 Existing seeder variable rate ready
Medium	$35 000	Yield monitoring and mapping – $7500 for Canlink Conversion of machinery to be variable rate capable – $10 000 to $30 000 Annual subscription – $2000
High	$90 000	Autosteer – $32 000 per vehicle 2 cm accuracy GPS – $18 000 to $22 000 Controllers for seeding, fertiliser spreading, pesticide spraying – $16 000 Zone analysis – $20 000

Table 2
Increase in gross margin ($/ha) required to cover the cost of investment in PA equipment

Investment in PA	Area benefiting (ha)	Increase in gross margin ($/ha)
$5 000	500	5
	1000	3
	2000	1
	4000	1
$20 000	500	11
	1000	6
	2000	3
	4000	1

Discount rate was 8% and annual operating costs for PA were $1000.