The Economic Benefits of Precision Agriculture: Case Studies from Australian Grain Farms

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INTRODUCTION

In commercial practice in Australia the implementation of precision agriculture (PA) has in common the use of spatially-aware technologies made possible through the use of global positioning systems (GPS). Most commonly this includes: the use of vehicle guidance to reduce overlap in application of agricultural chemicals, reduced traffic associated with tramlining to reduce compaction and operator fatigue, shielded spraying of pesticides in row crops, yield monitoring, variable rate technology (VRT) for application of agricultural chemicals, especially fertiliser, and within-paddock zone management for agricultural operations.

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. One of the chief reasons for low adoption of PA is the reluctance of farmers to invest many thousands of dollars in PA without knowing if the technology will return a profit. A number of studies have reported the economic benefits of tramline farming and guidance for chemical application. Few studies have examined the value of variable rate technology and zone management.

In this study we attempt to quantify the economic benefits of PA on six case study farms from the Australian wheatbelt. We did not confine our analysis to VRT alone but also considered benefits to guidance and reduced traffic. A more detailed report on this work can be found on the GRDC website.

THE ECONOMICS OF A PA INVESTMENT

One of the chief reasons for low adoption of PA is the reluctance of farmers to invest many thousands of dollars in PA without knowing if the technology will return a profit. Early PA adopters are often moving into systems based on high cost 2cm accurate GPS auto-steer systems with capital costs ca. $60,000 (Table 1). To potential adopters this seems too expensive and they question the application of PA to their farming system. In Australia the early adopters often crop large areas (above 3000 ha) which means highly accurate auto-steer 2cm systems are a good investment based on 10% savings in inputs from less overlap. GPS costs can range from $800 to $22,000 depending on what accuracy is most appropriate for the operation (Table 1). Highly accurate GPS systems are not an essential piece of the equipment for VRT.

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 (Jennings, 2005). An investment analysis using a ‘discounting’ process has been used to calculate a required ‘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.

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	$17,300	Variable rate controller - $3,500 GPS - $800 Zone analysis (using NDVI) - $3,000 Existing seeder variable rate ready 10 cm accuracy auto-steer - $10,000
Medium	$45,000	Yield monitoring and mapping - $7,500 Conversion of machinery to be variable rate capable - $10,000 to $30,000 10 cm accuracy auto-steer - $10,000 Annual subscription - $2,000
High	$75,000	Auto-steer - $32,000 per vehicle 2 cm accuracy GPS - $18,000 to $22,000 Controllers for seeding, fertiliser spreading, pesticide spraying - $16,000 Zone analysis (using NDVI, yield maps, soil testing) - $20,000

Typical gross margin increases required to offset the PA technology costs can be calculated for different regions in the wheatbelt according to statistics of cropped area on farms. For example, grain growing properties in the northern agricultural areas of WA average 3600 ha, of which about 1700 ha is cropped 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 over the *entire* cropping program on the farm starting at year 2 after equipment purchase and persist through a 10 year period. Average farm size in the central agricultural area and southern cropping areas of WA is similar at about 2300–2600 ha. About 1000 ha of this land is cropped each year. For these areas, the break-even increase in gross margin will be $3-6/ha depending upon the size of the investment

Table 2: Increase in gross margin ($/ha) required over 10 years to cover the cost of investment in PA equipment. Discount rate was 8% and annual operating costs for PA were $1000

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

METHODOLOGY

Farm case studies

The farm case studies covered a range of agro-climatic regions (Mediterranean, uniform and summer dominant rainfall patterns), cropping systems (wheat-lupin, wheat-canola, and winter and summer crops), farm sizes (1,250 to 5,800 ha cropping program), soil types (shallow gravels to deep cracking clays), and production levels (average wheat yields from 1.8 to 3.5 t/ha) (Table 3). The farmers had been involved in PA from 2 to 10 years and covered the range of PA technologies that are commonly used by Australian grain farmers. Among the six farmers, all had invested in guidance and were practising some form of variable rate management of fertiliser. However, only some were using auto-steer and tramlining. One was using NDVI and another, the GreenSeeker technology for in-season nitrogen management. As such, the data set covered the range of likely situations confronting practitioners of PA in the Australian wheatbelt.

Table 3: Summary details of the six case studies used for this analysis.

Farming family	*Location*	*Cropping program*	*Years experience in PA*	*PA technologies used*
David and Christine Forester	Casuarinas, WA	2,600 ha of wheat, barley, lupins	9	Guidance Variable rate fertiliser
David and Jo Fulwood	Cunderdin, WA	5,800 ha of wheat, barley, lupins	2	Auto-steer Tramlining Shield spraying Guidance Variable rate fertiliser
Stuart and Leanne McAlpine	Buntine, WA	3,400 ha of wheat, barley, canola, lupins	6	Auto-steer Tramlining Guidance Variable rate fertiliser
Michael and Bev Smith	Moree, NSW	1250 ha of wheat, barley, sorghum, chickpeas, canola, sunflower	7	Auto-steer Tramlining Guidance Variable rate fertiliser and pesticides
Richard and Tammy Heath	Gunnedah, NSW	3430 ha of wheat, barley, fababean, canola, sorghum, maize, sunflower	8	Auto-steer Tramlining Guidance Variable rate fertiliser In-season NDVI
Rupert and Claire McLaren	Barmedman, NSW	4000 ha of wheat and canola	10	Guidance Variable rate fertiliser In-season NDVI

Data collected and analysis

Each grower was interviewed and information was collected on: area of cropping program, crops grown, area of the cropping program to which PA technologies are applicable, average cropping gross margin, PA equipment purchased, included date and cost, management actions associated with PA technology implementation, the estimated reduction in overlap for tramlining / guidance, the rates of fertiliser applied in each zone for zone management, areas of management zones in each paddock, rates of fertiliser applied for uniform zone management, yield in each management zone, and growers' opinion of non-monetary benefits of PA.

Standard economic analyses were applied including gross margin calculations and discounted cash flow analysis. We used an investment analysis to estimate when the initial investment in PA would have been paid off. Annual benefits and costs attributable to PA were listed in time order when they occurred, adjusted for inflation using the Consumer price Index and accumulated from the time of entry into PA. The experience of Western Australia Department of Agriculture and Food staff, encapsulated in a spreadsheet calculator (Blackwell and Webb 2003), was used in this study to quantify benefits of tramlining and guidance gained through reduction in fuel, fertiliser and chemical use and more efficient use of labour. In each case study, the benefits were checked against what the grower thought the benefits had been.

Estimating the benefits of variable rate fertiliser

In order to calculate the benefit of variable rate fertiliser application, some estimate had to be made of yield on each zone if uniform management had been applied rather than variable rate. Two approaches, arrived at after discussion with the farmer, were taken depending upon the circumstances of each case study. In one type of case, total fertiliser use was unchanged between uniform and variable rate situations (Table 4a). In the other type of situation, all zones were assumed to be nutrient non-limited under uniform management due to high soil fertility status (Table 4b).

Table 4a: Example of assumed yield and fertiliser rates under uniform management when yields and fertiliser rates in management zones under variable rate management are known. In this case the high zone yield potential is assumed to be nutrient-limited and hence increases in yield under variable rate, while the low potential zone is nutrient non-limited and yield increases by 5% due to less "haying off". The medium zone remains unchanged.

Zone yield potential	*Under variable rate management*		*Under uniform management*	
	Grain yield (t/ha)	Fertiliser rate (kg/ha)	Grain yield (t/ha)	Fertiliser rate (kg/ha)
High	3.0	75	2.75	50
Medium	2.5	50	2.5	50
Low	2.0	35	1.9	50

Table 4b: Example of assumed yield and fertiliser rates under uniform management when yields and fertiliser rates in management zones under variable rate management are known. In this case all zones are assumed to be nutrient non-limited under uniform management and hence do not increase in yield under variable rate, with the exception of the low potential zone where yield increases by 5% due to less “haying off”

Zone yield potential	*Under variable rate management*		*Under uniform management*	
	Grain yield (t/ha)	Fertiliser rate (kg/ha)	Grain yield (t/ha)	Fertiliser rate (kg/ha)
High	3.0	75	3.0	75
Medium	2.5	50	2.5	75
Low	2.0	35	1.9	75

RESULTS AND DISCUSSION

Investment in PA

The level of capital investment in PA varied from $55,000 to $189,000 (Table 5), which is typically at the medium to high end of investment for Australian grain growers. When expressed as capital investment per hectare cropped it varied by a factor of three from $14 to $44/ha. The estimated annual benefits from PA ranged from $14 to $30/ha and consequently the investment analysis showed that the initial capital outlay was recovered within 2-5 years of the outlay, and in four out of the six cases within 2-3 years.

Table 5: Summary across six farmer case studies of capital investment in precision agriculture technologies, estimated annual benefits and year when initial investment is recovered.

Farmer	Size of cropping program (ha)	Capital Investment in PA		Annual estimated benefits to PA*	Years to break even
		total $	$/ha	($/ha)	
Forrester	2,600	90,000	35	21	4
Fulwood	5,800	189,000	33	22	2
McAlpine	3,400	65,000	19	21	2
Smith	1,250	55,000	44	30	2
Heath	3,430	95,000	28	24	3
McLaren	4,000	56,000	14	14	5

** EXCLUDING CAPITAL COSTS*

Benefits to variable rate fertiliser

For all farmers we were able to quantify benefits to variable rate fertiliser management, ranging from $1 to $22/ha across the six farms (Table 6). On a per paddock basis, benefits ranged from -$28 to +$57/ha/year. This wide range can be explained in part by two factors. Most farmers varied starter fertiliser as well as nitrogen topdressing, however one farmer (McAlpine) only varies topdressing and the benefits to VRT were lower for him than the other case studies. The degree of within-paddock yield variation also contributed to differences among farms in the benefits to VRT (Robertson et al 2006). The degree of within-paddock variation was noticeably less in the case of McLaren where VRT benefits were on average $7/ha, compared with Smith or Forrester where benefits were >$20/ha. The difference between the average yield of the pre-determined high and low zones was always positive and substantial, suggesting that growers were successful in identifying zones of that perform differentially across seasons.

Table 6: Summary across six farmer case studies of benefits ($/ha) to precision agriculture technologies, in total and separated into categories.

Farmer	Total	Reduced overlap	Fertiliser management	Less soil compaction	Fuel savings	Other
Forrester	21	5	16			
Fulwood	22	13	7			2
McAlpine	21	12	1		4	4
Smith	30	8	22			
Heath	24		20	4		
McLaren	14	7	7			

McLaren was the only farmer who had a deliberate strategy of reducing fertiliser inputs overall upon moving to a VRT situation, whereas others either maintained or increased fertiliser use. In the case of McLaren the reduction of fertiliser P rates was due to a history of P build-up before the adoption of VRT and this necessitated lower rates of P especially on medium and low yield potential zones of his paddocks.

Where VRT benefits were able to be estimated across a run of seasons for a given paddock, it was noticeable that benefits, albeit diminished, still accrued in below average years, such as the 2002 drought. This suggests that, once zones have been defined, benefits from VRT will occur in most seasons.

There were no clear trends for differences in benefit due to crop type, with canola and wheat (McLaren), wheat and lupins (Forrester) performing similarly. In the case of Smith, chickpea gave lower returns to VRT than wheat because of less nitrogen applied on the former.

The methodology for estimating the benefits of VRT requires further testing on paddock-scale data where yields and fertiliser rates are recorded for uniform and VRT-managed strips. Where such studies have been conducted (e.g. Isbister *et al*., 2005) the benefits recorded are in line with what we have estimated from farmer records.

Other benefits

Benefits due to reduced overlap of spraying were typically in the order of 10% savings on spraying costs. Other benefits nominated by farmers and estimated by us were less fuel use, soil compaction, and hired labour, and timelier sowing (Table 6). Intangible benefits listed by farmers were: the ability to conduct on-farm trials, increased knowledge of paddock variability, increased confidence in varying fertiliser rates, and better in-crop weed control due to shielded spraying. It was noted that no farmer nominated pest management, grain marketing or nutrient budgeting as benefits from the use of PA.

Characteristics of adopters

A clear impression gained through interviewing each farmer is that they were all highly literate in the use of computers, GPS technology, and variable rate controllers, routinely soil tested and kept good farm records. All invested considerable time in setting up their system in the beginning (with considerable teething problems in some cases), but on-going labour demands were minimal. Some did not use a consultant, while others placed heavy reliance on consultants for zone definition, yield map processing and variable rate map production. We also found that, while a number of farmers are trialling VRT in test strips within paddocks, it seems that very few have taken the jump into full commercial implementation of VRT on their farms.

CONCLUSIONS

This study is the first of its kind to estimate the economic benefits of precision agriculture in a commercial context. It demonstrates that Australian grain growers have adopted systems that are profitable, are able to recover the initial capital outlay within a few years, and also see intangible benefits from the use of the technology. While the results here will go some way towards informing the debate about the profitability of PA, it also illustrates that the use of, and benefits from, PA technology varies from farm to farm, in line with farmer preferences and circumstances.

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