Farmer Trials and Experience Prove the Adoption of Precision Agriculture Technologies is Profitable in Western Australia (WA)

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ABSTRACT

The marked increase during the last two years, in costs of fuel (30%) and fertiliser (18%) has contributed to increasing uptake of precision agriculture (PA) technologies in Western Australia. The on-farm trials and farmer observations reported in this paper indicate, in most cases, that the contributing farmers are obtaining a return on investment in the order of 300% over three years. Payback generally occurs within the first year, except at the upper end of investment (A$120,000). Their results are supported by economic modelling. For those farmers yet to take up this technology, cost, lack of compatibility of equipment, data collation and analysis are still perceived as barriers to adoption.

Keywords: profitability, adoption, Western Australia, farm results

INTRODUCTION

The South-West of Western Australia has a total agricultural area of 16 million hectares, of which 6.7million hectares is cropped in any year. The landscape is ancient, hundreds of millions of years old, highly weathered, leached and in its natural state, very infertile. The soils are predominantly acidic sands and sandy loams of granitic origin, (many of our pasture species have been selected from the acid soils of the Greek islands). The climate encountered by the contributing farmers is Mediterranean with between 200mm – 400mm of average annual growing season rainfall, falling between April and October each year (i.e. during winter).

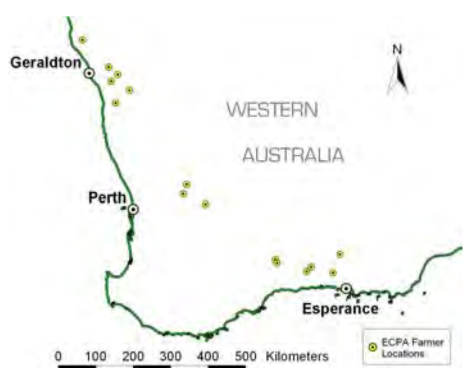

Figure 1. Location of contributing farming families in Western Australia

The 14 farming families contributing data to the paper, located as in Figure 1, farm a total of 70,700 hectares (174,500 acres) or about 1% of the cropping area in South-West of WA. The working unit is often a father and son with one or two staff, working an average farm size of 5,000 ha with about 4,000 ha in crop. Field sizes are typically 100 ha. Tractors are commonly 450 hp with triple wheel 4wd or track systems. Boom widths are approximately 45 m. Seeders are approximately 15m wide, and are generally attached to 3 bins or 2 bins plus a liquid cart. The principal crops they grow are wheat, barley, oats, lupins, canola and peas. Typically they use a minimal tillage or a one pass approach to sowing, with a resulting increase in reliance on chemicals for weed control and an increase in herbicide resistance. The marked increase in costs in the last two years of fuel (30%) and fertiliser (18%) has contributed to the increasing uptake of precision agriculture (PA) technologies. Urea prices for 2007 have risen from A$450/t I 2006 to A$550/t.

Investment in PA equipment by the growers ranges from A$15,000 to A$120,000 (approximately €9,000-72,000) with accuracy in the GPS signal being the main contributor to increased cost (typically 2-10 cm precision at the top end). Returns to PA investment come from two main areas. Firstly, the reduction in underlap and overlap in application of insecticides/herbicides and fertiliser, enabled by GPS auto steer and auto boom and secondly, from the redistribution of fertiliser based on zones of crop performance (variable rate fertiliser application). Variable rate controllers used by this group of farmers include the Western Australian manufactured range of Farmscan (http://www.farmscan.net) products (6 farmers), the KEE/Zynx (http://www.kee.com.au) products (6 farmers) manufactured in South Australia and one John Deere (http://www.deere.com) and one Flexicoil controller (http://www.flexicoil.com).

This paper will present practical farming examples of the application of PA and its benefits, supported by on farm research results where available and highlight some survey results on factors still limiting adoption of the technology.

INCREASES IN MACHINERY EFFICIENCY AND OTHER BENEFITS AND OPPORTUNITIES FROM USING GPS

The farmers represented in this paper typically reported efficiency gains of 8-10% in chemical usage through the adoption of auto steer and the associated auto boom technology (solenoids on each jet or a segment of the boom can be switched off when the controller senses that the segment of the boom is passing over a previously sprayed area). This equates to a saving of at least A$8/ha or A$32,000/annum for the average sized cropped area noted above. Further fuel efficiencies of about 20% (A$3.60/ha) can be made if they are using a tramline system (all vehicles with the same wheel spacing, generally 3 m) which confines compaction to dedicated wheel tracks that become firm over time requiring less traction and reducing fuel use. Further benefits of 3-15% come from reduced compaction and crop damage on the rest of the paddock (Webb et al. 2004). The efficiency benefits from using GPS technology of varying accuracy, including auto steer/auto boom technology, are widely accepted in WA (There are about 2000 farmers with the property size that warrants this technology at present in WA. The sales manager for Farmscan estimates 400 hydraulic steerage units have been sold in WA and a further 200 visual steerage units in the last three years).

Our reduced tillage systems have lead to an increased use of selective herbicides for weed control and a resulting increase in the herbicide resistance of weeds. Options for controlling multiple herbicide resistant ryegrass are limited and expensive. They include switching to more expensive herbicides, catching the residue coming out of the back of the harvester and dumping it in piles to be burnt, cutting a crop for hay, returning to pasture and grazing and using spray topping to control the grass in the pasture phase. This latter option results in a net loss of A$8-42/ha/annum (Monjardino et al, 2004). On David Fulwood's farm, a 2 cm GPS is used so that he can inter-row spray lupins using a shielded boom with a non selective herbicide (Figure 2). Lupin row spacing is taken out to 75 cm with no yield penalty to the crop. This gives him another tool to fight against ryegrass herbicide resistance whilst maintaining fields in crop. The net result is about A$15/ha more return than the standard management strategy of using more costly selective herbicides. However, it is slow work with the sprayer only moving at between 9-13 km/h compared to 25-35 km/h for traditional broad acre spraying, depending on the water rate required and the terrain.

Figure 2. Wide spaced lupins at 75 cm centres, and shielded boom spraying the crop, 2 cm accuracy guidance (David and Malcolm Fulwood).

VARIABLE FERTILISER RATES

Slow adoption

Variable rate technology (VRT) has been slower in adoption than the auto steer and auto boom. VRT is not purely mechanical in its nature as are auto boom and auto steer. Once management of performance zones are determined and the rates set, then the programming and application are mechanical. However the precursor to the rate map involves understanding the agronomics of a crop and its interaction with its environment over time. Farmers understand how variable seasonal/agronomy interactions can be and the resulting risks they face. Variable rate includes these seasonal and other agronomic risks. Additional reasons for the slower adoption of VRT will be reported in the outcome of two surveys later in this paper.

Forming a performance zone

The approach to performance zoning uses a statistical analysis to reduce the inherent agronomic risk of defining a performance zone (Adams and Maling 2004). Although this analysis can use yield monitor data, NDVI derived from Landsat data has been used by my clients. The NDVI from different seasons is analysed temporally as described in Adams and Maling 2004). A performance zone map is generated which defines three zones: above average, average, and below average with 60% of the area occupying the average zone. Further, each pixel is identified as being consistently high or consistently low performing through time based on a threshold value on the standard deviation of a normalized pixel through time. If a pixel has been highly consistent through time, it is very likely that the pixel will behave the same way next year. Therefore the risk in defining a zone in a field as good, or poor performing is markedly reduced. In practice we have found that if over 60% of a field has performed in a consistent manner through time (either high or low) we can effectively identify the zones; that is, if we classify a zone as high performing, the yield in this zone is nearly always higher than other parts of the same field.

These zones have been verified as accurate in the following season's yield and trial data. Table 1 shows typical results of that approach with the historical mid season NDVI derived zones effectively picking the yield zones. Field characterisations of soils in different performance zones and modelling point to plant available water as the main factor affecting the crop performance between zones in our rain limited environment (Oliver *et al.*, 2006).

Table 1. Yield monitor yields (2005) for barley (fields) and wheat (fields) obtained from zones derived from a historical analysis of NDVI at David Fulwood's farm. The percentage of the field performing consistently (C) i.e a pixel falls within the same performance zone for all the years analysed.

Zone	Field 4, C=75%	Field 5, C=79%	Field 10, C=80%
	Yield t/ha	Yield t/ha	Yield t/ha
Good	3.25	2.60	3.13
Average	2.91	2.10	2.78
Poor	2.11	1.95	2.07
	Field 11, C=74%	Field 18, C=69%	Field 23, C=83%
	Yield t/ha	Yield t/ha	Yield t/ha
Good	3.27	2.87	3.03
Average	2.90	2.48	2.70
Poor	2.37	1.71	1.77

Turning a performance zone into a fertiliser rate

Forecasting the performance of a zone defines the crop demand for nutrients which must be matched with what the soil and fertiliser can supply. Underestimate the nutrient requirement and the crop performance will be limited. Overestimate nutrient requirement and an excessive amount of fertiliser will be applied. In the Western Australian environment the Department of Agriculture has developed sound relationships between soil tests for N, P and K and the fertiliser needed to meet a target yield (Adams *et al* 2000, Bowden and Bennett 1974, Bowden and Diggle 1996, Bowden and Scanlan 2006).

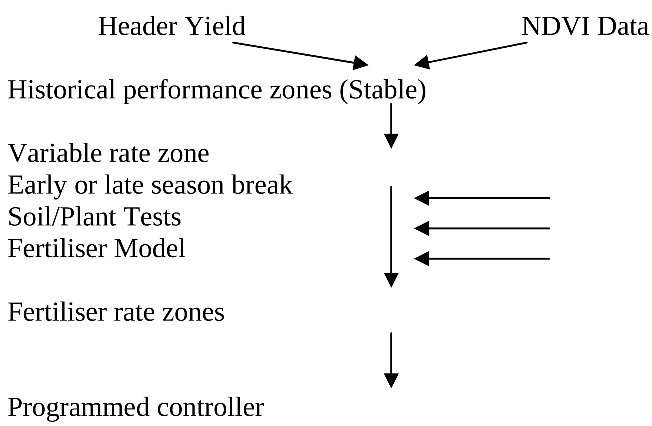

Figure 3. Diagram of the process of taking historical header yield or NDVI data to variable fertiliser rates in Western Australia

Therefore, by estimating the anticipated yield from the performance zones and linking it with a soil test, we can derive the fertiliser rate for that zone. A simplified flow diagram of the process is presented in Figure 3.

In practice, the potential yield zones are further modified up or down based on the timing of the seasonal break (the first large falls of rain in autumn after the hot, dry summer) which in turn provides an indication of likely growing season rainfall. In the wheat belt area we are representing the average break is considered to occur on or about the 15th of May. In an early seasonal break, e.g. about three weeks earlier than average, the productive potential of all zones is raised and the nutrient demand increased. In a late seasonal break, e.g. three weeks later than normal, the productive potential of all zones is depressed and hence, nutrient demand is less than normal. In extreme cases farmers don't sow. Equally, if the season starts average, but performs well early, nitrogen top up fertiliser is applied because of an increased potential for each zone.

Does variable rate fertiliser pay?

David Forrester, who farms in the Geraldton area of WA, has been using zones to apply his variable rates of fertiliser for the last 8 years. He tests the efficacy of his rates and zones by applying low, average and high fertiliser rates in strips across all zones. The Department of Agriculture and Food Western Australia (DAFWA) became involved in 2002 in formalising this process and analysing the data. In 2002 the high rate of fertiliser for "Dam" field was 145 kg/ha of DAPSZC (DAPSZC is the trade name of a compound fertiliser sold in WA containing 16.9% N, 18.2% P, 0.15% Zn and 0.05% Cu based on DAP – diammonium phosphate) plus 220 kg/ha of urea. The average rate was 80 kg DAPSZC with 120kg/ha urea, and the low rate was 20 kg DAPSZC with 0 kg/ha urea. David's target grain quality measures were a grain protein of at least 10.5% and screenings of less than 5%. Tables 2a and 2b show that in 2002 the low fertiliser input gave the best return on the poor performing zone, the average rate the best return on the medium performance zone, and the high rate the best return and grain quality on the good performance zone.

Table 2a. Yield t/ha and A$ Gross Margin/ha by zone and fertiliser input for David Forrester's 'Dam' field in 2002. Same letter following yield indicates no significant difference.
Analysis by DAFWA and adapted from Blake et al. (2003).

Crop Potential/Zone	Poor		Medium		Good	
	t/ha	$GM/ha	t/ha	$GM/ha	t/ha	$GM/ha
Low Fertiliser	1.54 a	105	2.10 b	248	2.45 b	254
Average Fertiliser	1.68 a	38	3.56 c	303	3.62 c	320
High Fertiliser	1.67 a	-26	3.69 c	238	4.26 d	398

Table 2b. Protein % and screenings% by zone and fertiliser input for David Forrester's 'Dam' field in 2002. Adapted from Blake et al. (2003).

Crop Potential/Zone	Poor		Medium		Good	
	Prot %	Scree %	Prot %	Scree %	Prot %	Scree %
Low Fertiliser	9.3	2.3	8.3	1.9	9.2	1.6
Average Fertiliser	9.6	6.1	11.1	3.1	9.8	2.5
High Fertiliser	12.7	9.0	11.3	5.7	12.3	3.4

In 2004 David applied a high rate of fertiliser 145 kg of DAPSZC with 180 kg/ha of urea, an average rate of 80 kg DAPSZC with 120 kg/ha urea, and a low rate of 20 kg DAPSZC with 60 kg/ha urea. The areas associated with each zone in 2004 were 21% poor, 28% medium and 51% good. The results in 2004 showed an average $63/ha benefit by using zoned rates rather than an average rate across the field.

Table 3a. Yield t/ha and $GM/ha by zone and fertiliser input for David Forrester's 'Dam' field in 2004. Same letter following yield indicates no significant difference.

Crop Potential/Zone	Poor		Medium		Good	
	t/ha	$GM/ha	t/ha	$GM/ha	t/ha	$GM/ha
Low Fertiliser	2.20 a	188	2.30 a	209	2.45 b	242
Average Fertiliser	1.95 a	88	2.70 b	223	3.00 c	275
High Fertiliser	2.15 a	60	3.35 c	285	3.80 d	357

Table 3b. Protein % and screenings% by zone and fertiliser input for David Forrester's 'Dam' field in 2004.

Crop Potential/Zone	Poor		Medium		Good	
	Prot %	Scree %	Prot %	Scree %	Prot %	Scree %
Low Fertiliser	10.6	1.3	11.4	1.2	12.3	1.3
Average Fertiliser	11.8	1.5	12.7	1.1	12.9	1.5
High Fertiliser	12.9	1.1	13.5	0.8	13.5	1.5

Given the similarity in outcomes between 2002 and 2004 matching fertiliser rate to productive potential should hold across seasons and this conclusion supports David's experience on farm, however the years had similar growing season rainfall at 328 mm in 2002 and 308 mm in 2004. Unanalysed data from the 2006 drought year indicate a 300 kg/ha response to the higher fertiliser rate on the "good" performing areas of the paddock and a depression in yield on the "poor" areas of 140 and 290 kg for the average and high rates respectively. Average yield on the paddock for 2006 was in general 1 t/ha less than the reported yields in the above table from 160 mm growing season rain. David believes he is getting a $30-$60/ha benefit to the zoned application of fertiliser across the farm which agrees with the measured and analysed results by DAFWA on his 'Dam' field and modelled estimates from nutrient response curves. Farmer observations, field trial results, and economic modelling are in general agreement; variable rate applied over stable performance zones, using fundamental agronomic understanding *is* profitable. This approach is also clearly more environmentally responsible with fertiliser being placed where it is needed and not where it is superfluous.

There is always an exception

The following results (Table 4.) come from typical non replicated farmer trial strips, placed across performance zones which were derived by Silverfox Solutions. The rates were applied by Murray Carson, the owner, using commercial equipment on a farm located approximately 60kms north of Geraldton near Ajana. The rates were recommended by Shane Turner, Summit Fertiliser's local area manager. The yields were measured from a John Deere harvester equipped with a John Deere yield monitor.

The results indicate clearly the interaction that can occur between zone and soil test. In this case there is still a response to the high fertiliser rate above the average trial rate in the poor performing zone due to the soil's inability to match the plant's nutrient demand, even at the lower yield level. The result emphasises the importance of the soil test and modelling input steps indicated in figure 2. The units/ha of N, P, and K applied were 24, 7 ,10 (low); 48, 14, 21 (average); 71, 21, 32 (high) kg/ha fertiliser rates, respectively.

Table 4. Yield (t/ha) and soil test data by zone and fertiliser input for Murray Carson's field number 26 in 2005.

Crop Zone	Poor t/ha wheat	Medium t/ha wheat	Good t/ha wheat
Low Fertiliser	1.29	1.50	2.21
Average Fertiliser	1.67	2.19	2.71
High Fertiliser	2.10	2.21	3.00
Soil P (ideal 20 ppm +)	10 ppm	16 ppm	15 ppm
Soil K (ideal 60 ppm +)	15 ppm	24 ppm	48 ppm
Organic C	0.45 %	0.82 %	0.93 %

Survey results show perceived impediments to Precision Agriculture adoption

Surveys carried out by the WA Department of Agriculture and Food (DAFWA) (Webb,xxx) and the Grains Research and Development Corporation (GRDC) (Price, 2004) have identified a number of factors that remain as hindrances to widespread adoption of PA by Australian grain growers. The nationwide GRDC survey (n=145) indicated key factors such as lack of confidence about cost, cost/benefit, setting up equipment, matching and understanding data sets and collecting and collating required data. The DAFWA survey of three grower groups (n=45) indicated cost of equipment as the biggest barrier to adoption. Other barriers included the knowledge and skills required in collecting and collating data, poor compatibility of equipment, and time taken to set up equipment to make it fully operational. Cost of the equipment is reducing as the scale of adoption increases. The on farm research contributing to the results noted above is addressing the cost/benefit issue. Setting up equipment remains a problem as a number of the contributing farmers would attest to (even within one make/brand). Private consultants specialising in PA are moving into the area as the volume of farmer's participating in PA provides sufficient income for them to assist in data manipulation and interpretation.

CONCLUSION

Precision Agriculture as practised by the 14 farmers contributing to this paper is profitable and in some cases highly profitable. Returns per hectare range from A$11.60/ha for those using purely mechanical efficiencies to obtain a benefit to over A$60/ha for those using variable rate technologies. Less tangible benefits are obtained from reduced stress and increased working life of some family members. However for those still to take up this technology, cost, lack of compatibility of equipment, and the complexities of data collation and analysis, are still perceived as barriers to widespread adoption of PA.

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REFERENCES

Adams, M.L., Cook, S. and Bowden, J.W. (2000). Using yield maps and intensive soil sampling to improve nitrogen fertiliser recommendations from a deterministic model in the Western Australian wheat belt. *Australian Journal of Experimental Agriculture* 40, 959-968.

Adams, M.L. and Maling, I.R. (2004). Simplifying management zones – A pragmatic approach to the development and interpretation of management zones in Australia. In: *Proceedings of the 7th International Conference*. Rust, R.H. and Larson, W.E. (Eds), ASA/SSSA/CSSA, Madison, W.I., USA (CD-ROM).

Blake, J., Forrester, D., Knell, G., McConnell, G., Patabendige, D., Rosser, T., Shepherd, D., Burt, E. (2003). Evaluating the impact of farming systems change using precision agriculture within innovative farmer groups. In: *Proceedings of the 2003 Australian Farming Systems Association Conference* (online). http://afsa.asn.au/pdfs/blakejohn.pdf (accessed 14 Feb 2007)

Bowden, J.W. and Bennett, D.L. (1974). The "Decide" model for predicting superphosphate requirements. Reprinted from *Proceedings of Phosphorus in Agriculture symposium Australian Institute of Agricultural Science (Victorian Branch*) p.36.

Bowden, W.J. and Diggle, A.J. (1996). *The TopCrop West Nitrogen Calculator*. Department of Agriculture, South Perth, Western Australia. 2p.

Bowden, W.J. and Scanlan, C. (2006). KASM, the potassium in Agricultural Systems Model. In: *Agribusiness Crop Updates 2006*. Department of Agriculture, South Perth, Western Australia. (online). http://www.agric.wa.gov.au/pls/portal30/docs/FOLDER/IKMP/FCP/FarmingSystems2006_1.pdf (accessed 14 Feb 2007)

Monjardino, M., Pannell, D.J. and Powles, S.B. (2004). The economic value of pasture phases in the integrated management of annual ryegrass and wild radish in a Western Australian farming system. *Australian Journal of Experimental Agriculture*, 44, 265-271.

Monjardino, M, Pannell, D.J. and Powles, S.B. (2004). The economic value of haying and green manuring in the integrated management of annual ryegrass and wild radish in a Western Australian farming system. *Australian Journal of Experimental Agriculture*, 44, 1195-1203.

Oliver Y., Wong, M.T.F., Robertson, M.J. and Wittwer, K. (2006). PAWC determines spatial variability in grain yield on northern WA sandplain. In: *Proceedings of the 13th Australian Society of Agronomy Conference*, 10-14 September 2006, Perth WA. Australian Society of Agronomy, The Regional Institute, Melbourne. (online) http://www.regional.org.au/au/asa/2006/concurrent/water/4570_oliver.htm (accessed 14 Feb 2007)

Price, P. (2004). Spreading the PA message. *Ground Cover*, Issue 51, August 2004. Grains Research and Development Corporation, Canberra.

Webb, B., Blackwell, P., Riethmuller, G. and Lemon, J. (2004). *Tramline Farming Systems: Technical Manual*, Bulletin 4607, Department of Agriculture, South Perth, Western Australia. 89p.