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PROFIT FROM PRECISION AGRICULTURE

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GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

Rural Directions Pty Ltd

Think Agri Agri Expertise

> A PROFIT FIRST APPROACH TO PA - A STEP BY STEP DECISION MAKING GUIDE FOR GROWERS AND ADVISERS

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ABOUT THIS RESOURCE

This resource is for grain growers and their advisers who are asking:

HOW DO I DECIDE TO INVEST IN PRECISION AGRICULTURE (PA) TO IMPROVE MY FARM PROFIT?

Here we explain **how to decide** to make an investment in a PA technology.

The document aims to raise growers and advisers awareness of situations where PA can help improve profits, how to navigate those options and how to make a considered decision.

The focus of this publication is on how to decide to invest in PA or not, and how to assess economic value and contribution to profit.

Our previous publication summarised the situations and technologies where PA has improved the profitability of cropping systems within GRDCs Southern Region (Tasmania, South Australia and Victoria). (GRDC 9176123 2018)

The term Precision Agriculture is often interlinked with other terms such as digital agriculture, decision agriculture, big data, and agtech. The Glossary of PA terms unpacks some of these definitions. In the context of this project PA is considered to be the actual change in practice, rather than the data associated with that change.

The section highlighting PA Technical information sources provides several technical reference materials for those needing a 'how to' manual for Precision Agriculture Tools.

Read on for PA investment decision making guidelines.

GLOSSARY OF PA TERMS

Derived from Whelan and Taylor (2010) and Leonard et al (2017).

TABLE 1. GLOSSARY OF PA TERMS	
TERM	DESCRIPTION
AgTech	Popular term in the investment community to describe the digital technologies used in agriculture.
Big data	Computerised analytics systems that interrogate extremely large databases of information in order to identify particular trends and correlations.
Coefficient of variation (CV)	A statistical measure of variability, involving the ratio of the standard deviation to the mean. Lower CV is less variable.
Controlled traffic farming (CTF)	A farming system in which most or all wheeled traffic runs on a set of permanent tracks to reduce overall soil compaction.
Decision agriculture	Conclusion or action resulting from the application of knowledge and/or information that may be derived from digital agriculture.
Digital agriculture	Collection and analysis of data to improve both on and off-farm decision making leading to better business outcomes.
EM38	A tool to measure electrical conductivity of water in the soil and the soil itself, which is influenced by the soil salt and water content, and the amount and type of clay in the soil. It can help to identify where important subsoil constraints may be present in paddocks and in assessing variation in the amount of soil water that can be available to plants.
GNSS	The standard generic term for satellite navigation systems that provide autonomous geo-spatial positioning with global coverage. GNSS allows small electronic receivers to determine their location (longitude, latitude, and altitude) using time signals transmitted along a line-of-sight by radio from satellites.
Gamma radiometry	The measurement of natural gamma ray emissions of radioactivity, primarily from the top 30 - 50cm of soil or rock. Often, this can provide information about the parent material of the soil that can be related to soil types across the region or paddock.
Normalised Difference Vegetation Index (NDVI)	A common method of analysing remotely sensed imagery for vegetation health, vigour and greenness. The index is created by subtracting the value of the red band of the imagery from that of the near infrared, and then dividing this by the sum of the red and near infrared bands. Red light is strongly absorbed for photosynthesis and near infrared light is strongly reflected in healthy plants, so a high index value relates to high health and greenness. The NDVI is the most commonly used vegetation index.
Optical spot sprayer	A spray system involving a sensor that detects the presence of a plant and automatically activates a valve to direct spray at the plant. Used in fallow situations.
PAWC (Plant Available Water Capacity)	Proportion of soil water that is available to plants within rootzone.
Precision Agriculture (PA)	Farming practices that involve precise spatial management using GPS technologies.
Resolution	The level of detail available for grain set of specified data.
Site specific crop management (SSCM)	A management system that considers the variability of crop and soil parameters to make decisions on the application of production inputs. Putting the right input in the right place.
Spatial variability	The variation found in soil and crop parameters (e.g. soil pH, crop yield) across an area at a given time.
Temporal variability	The variation found in soil and crop parameters within a given area at different measurement times.
Variable Rate (VR)	Applying an input at varying rates within a paddock.

PA TECHNICAL INFORMATION SOURCES

TABLE 2. INFORMATION SOURCES ON PA		
PA IN PRACTICE II	www.grdc.com.au/PAinPractice2	A seasonal guide to PA applications
APPLYING PA – A REFERENCE GUIDE FOR THE MODERN PRACTITIONER	https://grdc.com.au/resources-and-publications/all-publications/bookshop/2013/11/applyingpa	A practical guide to implementing PA
CALCULATING RETURN ON INVESTMENT FOR ON FARM TRIALS DIY PRECISION AGRICULTURE	https://grdc.com.au/__data/assets/pdf_file/0026/233945/diy-pa-calculating-roi-for-on-farm-trials.pdf.pdf	A guide to conducting on farm trials
UNIVERSITY OF SYDNEY PA MODULES	https://sydney.edu.au/agriculture/pal/publications_references/educational_resources.shtml	Technical reference material on the development and application of PA in the grains industry

FIVE QUESTIONS FOR PROFIT FIRST PA

Precision agriculture technologies can help make farming operations easier and contribute to profit via yield improvements or cost savings if implemented well.

The odds of PA adoption being profitable will improve if a 'profit search and rescue mission' is conducted, followed by considering where PA can help achieve that potential profit.

The five profit first PA questions provide a stepwise framework to firstly conduct a profit search (Question 1), consider if PA is part of the rescue mission in your region (Question 2) and suitable for your business (Question 3 and 4). Question 5 helps formulate an implementation plan.

TABLE 3. FIVE QUESTIONS FOR A PROFIT FIRST APPROACH TO PA

		EXAMPLE SCENARIO
QUESTION 1 (Page 8)	What profit gain opportunities exist for the farm business?	We have low pH soils limiting yield potential in some but not all areas on the farm.
QUESTION 2 2.1 LOW RAINFALL ZONE (Page 11) 2.2 MEDIUM RAINFALL ZONE (Page 12) 2.3 HIGH RAINFALL ZONE (Page 13)	Does PA have a role in addressing those opportunities?	Soil types are variable within paddocks so variable rate application of lime could be an option.
QUESTION 3 (Page 14)	Does the business have the capacity to usefully implement PA?	The PA profit ready check list is a good place to start.
QUESTION 4 (Page 15) 4.1 HOW MUCH SPATIAL VARIABILITY EXISTS? 4.2 CALCULATING THE LIKELY GAIN 4.3 WHAT ARE THE CAPITAL AND OPERATING COSTS? EXAMPLES OF AN ECONOMIC ANALYSIS FROM THE CASE STUDIES	Do the economics stack up and what else needs consideration?	A partial budget analysis compares using PA or not, (e.g VR lime v Uniform spreading) to address the issue. Lower liming costs will mean more paddocks can be amended in one season.
QUESTION 5 (Page 35)	How do we make it happen?	Considerations for effective implementation so that the profit gain opportunity is actually achieved.

QUESTION 1 - WHAT PROFIT GAIN OPPORTUNITIES EXIST FOR THE FARM BUSINESS

1.1 CHECK THE PROFIT DRIVERS FRAMEWORK

Previous GRDC funded research (GRDC RDP00013 2016) revealed that top 20% farm business performers had surpluses well above the average net surplus, sometime 2 to 3 times more. The good news is there are profit opportunities up for grabs for many farm businesses. These opportunities come from a combination of four key areas outlined below. Consider which opportunities may apply to your business.

TABLE 4. FOUR PROFIT DRIVERS OF FARM BUSINESSES AND THE CONSIDERATIONS THAT NEED TO BE MADE TO ADDRESS THEM

PROFIT OPPORTUNITY	KEY MANAGEMENT CONSIDERATIONS
Optimise the farm gross margin	Enterprise choice Crop rotation Timeliness of operations Sound agronomy driving high water use efficiency and yield Variable cost control Maximising quality
Understand and manage fixed costs	Overhead cost control Labour efficiency Machinery investment matched to business size Actively manage finance costs
Manage risks proactively	Strategies to withstand seasonal or other business shocks
Highly capable people	Getting things done in a timely manner and to a high standard Clear and balanced decision making Systems and processes to support work flow

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1.2 CONSIDER THE PA PROFIT PATHWAYS

We have divided the use of PA to improve profit into three pathways. Consider which pathways and examples apply to your farm business.

TABLE 5. THE THREE PA PROFIT PATHWAYS AND EXAMPLES OF THE PROFIT CONSTRAINTS/OPPORTUNITIES WITHIN EACH AREA		
STRATEGIC	EXAMPLES	PROFIT IMPACT POTENTIAL
Unlocking yield potential by cost effectively managing site specific soil constraints and/or enabling cost effective farming systems changes.	Sodicity Salinity Acidity Non-wetting sand Compaction Soil density Soil texture Waterlogging	This is usually where highest gain can be made. Yield potential is unlocked more quickly by using capital efficiently by targeting the areas that will have the highest response. Amelioration costs can also be saved by targeting to responsive areas.
TACTICAL		
Achieving water limited yield potential in a cost-effective manner while managing production risk.	Soil nutrition Matching yield potential to plant available water Crop monitoring Root disease management Fallow management of weeds In crop weed management	Can be high impact individually or incrementally. This relates directly to optimising your gross margin capturing the yield potential on offer as cost effectively as possible.
FLEXIBLE		
Optimising quality and price and therefore increasing revenue.	Frost Heat stress Harvest management Patchy weed infestations On farm trials	High impact but less frequently. This relates directly to proactive management of risk and making the most of every income opportunity.

QUESTION 2 - DOES PA HAVE A ROLE IN ADDRESSING THESE OPPORTUNITIES?

This section provides specific examples by rainfall zone and region.

2.1 LOW RAINFALL ZONE

Are you aware of which factors are *most likely* to influence grain yield in your region and on your farm?

TABLE 6. FACTORS THAT ARE LIKELY TO INFLUENCE GRAIN YIELD IN EACH LOW RAINFALL ZONE

LOW RAINFALL ZONE	PLANT AVAILABLE WATER	SANDY SOILS	ACID SOIL	SALINITY	SODICITY	WATER LOGGING	COMPACTION	NPKS NUTRITION	FALLOW MANAGEMENT	HERBICIDE RESISTANCE	FROST	HEAT STRESS
Upper EP	√	√			√		√	√	√	√	√	√
Western EP	√	√			√		√	√	√	√		√
Upper North	√	√	√	√	√		√	√	√	√	√	√
SAVIC N Mallee	√	√		√	√		√	√	√	√	√	√
SAVic S Mallee	√	√		√	√		√	√	√	√	√	√
Vic C Mallee	√	√		√	√		√	√	√	√	√	√

TABLE 7. THE LIKELY CONTRIBUTION OF VARIOUS PA APPLICATIONS TO PROFIT ACROSS THE LOW RAINFALL REGIONS BASED ON SUITABILITY AND AREA AFFECTED WITH GREEN BEING HIGHLY LIKELY, YELLOW SOMETIMES LIKELY AND ORANGE LESS LIKELY

LOW RAINFALL ZONE	STRATEGIC			TACTICAL									FLEXIBLE			
	Drainage mapping	Zoned claying/ delving	Zoned ripping/ spading	Zone management through variable rate application of:				Vehicle autosteer	Implement steering (Protrakker)	Compaction management with CTF	Inter-row or on-row sowing	Site specific weed detection and control	Decision support for soil & crop monitoring	Mapping weeds	Protein Mapping	On farm trials
				Lime	Gypsum	Seed	N, P, K, S									
Upper EP	Orange	Green	Green	Orange	Green	Yellow	Yellow	Green	Yellow	Yellow	Green	Green	Green	Green	Yellow	Green
Western EP	Orange	Green	Green	Orange	Green	Yellow	Yellow	Green	Yellow	Yellow	Green	Green	Green	Green	Yellow	Green
Upper North	Orange	Yellow	Yellow	Yellow	Green	Yellow	Yellow	Green	Yellow	Yellow	Green	Green	Green	Green	Yellow	Green
SAVIC N Mallee	Orange	Green	Green	Orange	Yellow	Green	Green	Green	Yellow	Yellow	Green	Green	Green	Green	Yellow	Green
SAVic S Mallee	Orange	Yellow	Yellow	Orange	Green	Green	Green	Green	Yellow	Yellow	Green	Green	Green	Green	Yellow	Green
Vic C Mallee	Orange	Yellow	Yellow	Orange	Green	Green	Green	Green	Yellow	Yellow	Green	Green	Green	Green	Yellow	Green

2.2 MEDIUM RAINFALL ZONE

Are you aware of which factors are *most likely* to influence grain yield in your region and on your farm?

TABLE 8. FACTORS THAT ARE LIKELY TO INFLUENCE GRAIN YIELD IN EACH MEDIUM RAINFALL ZONE

MEDIUM RAINFALL ZONE	PLANT AVAILABLE WATER	SANDY SOILS	ACID SOIL	SALINITY	SODICITY	WATER LOGGING	COMPACTION	NPKS NUTRITION	FALLOW MANAGEMENT	HERBICIDE RESISTANCE	FROST	HEAT STRESS
Lower EP	√	√	√	√	√	√	√	√	√	√	√	
Central YP	√	√					√	√	√	√		
Lower YP	√	√		√			√	√	√	√		
Northern YP - Mid North	√	√	√	√	√		√	√	√	√	√	√
Wimmera-Bordertown	√	√		√	√	√	√	√	√	√	√	√
SA Upper South East	√	√	√	√	√		√	√	√	√	√	√
Central Vic	√		√	√	√	√	√	√	√	√	√	√
Nth Central Vic	√		√	√	√		√	√	√	√	√	√

TABLE 9. THE LIKELY CONTRIBUTION OF VARIOUS PA APPLICATIONS TO PROFIT ACROSS THE MEDIUM RAINFALL REGIONS BASED ON SUITABILITY AND AREA AFFECTED WITH GREEN BEING HIGHLY LIKELY, YELLOW SOMETIMES LIKELY AND ORANGE LESS LIKELY

MEDIUM RAINFALL ZONE	STRATEGIC			TACTICAL									FLEXIBLE			
	Drainage mapping	Zoned claying/ delving	Zoned ripping/ spading	Zone management through variable rate application of: Lime	Gypsum	Seed	N, P, K, S	Vehicle autosteer	Implement steering (Protrakker)	Compaction management with CTF	Inter-row or on-row sowing	Site specific weed detection and control	Decision support for soil & crop monitoring	Mapping weeds	Protein Mapping	On farm trials
Lower EP	Green	Green	Green	Green	Green	Yellow	Yellow	Green	Yellow	Yellow	Green	Green	Green	Green	Yellow	Green
Central YP	Orange	Orange	Orange	Yellow	Orange	Yellow	Yellow	Green	Yellow	Yellow	Green	Green	Green	Green	Yellow	Green
Lower YP	Orange	Yellow	Orange	Orange	Orange	Yellow	Yellow	Green	Yellow	Yellow	Green	Green	Green	Green	Yellow	Green
Northern YP - Mid North	Orange	Yellow	Yellow	Green	Green	Yellow	Yellow	Green	Yellow	Yellow	Green	Green	Green	Green	Yellow	Green
Wimmera-Bordertown	Yellow	Yellow	Yellow	Yellow	Green	Yellow	Yellow	Green	Yellow	Yellow	Green	Green	Green	Green	Yellow	Green
SA Upper South East	Orange	Yellow	Yellow	Yellow	Green	Yellow	Yellow	Green	Yellow	Yellow	Green	Green	Green	Green	Yellow	Green
Central Vic	Green	Orange	Green	Green	Green	Yellow	Yellow	Green	Yellow	Yellow	Green	Green	Green	Green	Yellow	Green
Nth Central Vic	Yellow	Orange	Green	Green	Green	Yellow	Yellow	Green	Yellow	Yellow	Green	Green	Green	Green	Yellow	Green

2.3 HIGH RAINFALL ZONE

Are you aware of which factors are *most likely* to influence grain yield in your region and on your farm?

TABLE 10. FACTORS THAT ARE LIKELY TO INFLUENCE GRAIN YIELD IN EACH HIGH RAINFALL ZONE

HIGH RAINFALL ZONE	PLANT AVAILABLE WATER	SANDY SOILS	ACID SOIL	SALINITY	SODICITY	WATER LOGGING	COMPACTION	NPKS NUTRITION	FALLOW MANAGEMENT	HERBICIDE RESISTANCE	FROST	HEAT STRESS
SA Lower South East + Kangaroo Island	√	√	√	√	√	√	√	√	√	√		
Southern Vic	√		√	√	√	√	√	√	√	√	√	√
North East Vic slopes	√		√	√	√	√	√	√	√	√	√	√
Tas Grain	√		√		√	√	√	√	√	√	√	

TABLE 11. THE LIKELY CONTRIBUTION OF VARIOUS PA APPLICATIONS TO PROFIT ACROSS THE HIGH RAINFALL REGIONS BASED ON SUITABILITY AND AREA AFFECTED WITH GREEN BEING HIGHLY LIKELY, YELLOW SOMETIMES LIKELY AND ORANGE LESS LIKELY

HIGH RAINFALL ZONE	STRATEGIC			TACTICAL									FLEXIBLE			
	Drainage mapping	Zoned claying/ delving	Zoned ripping/ spading	Zone management through variable rate application of: Lime	Gypsum	Seed	N, P, K, S	Vehicle autosteer	Implement steering (Protrakker)	Compaction management with CTF	Inter-row or on-row sowing	Site specific weed detection and control	Decision support for soil & crop monitoring	Mapping weeds	Protein Mapping	On farm trials
SA Lower South East + Kangaroo Island	Green	Yellow	Yellow	Green	Green	Yellow	Yellow	Green	Yellow	Yellow	Green	Green	Green	Green	Yellow	Yellow
Southern Vic	Green	Orange	Green	Green	Green	Yellow	Yellow	Green	Yellow	Yellow	Green	Green	Green	Green	Yellow	Yellow
North East Vic slopes	Green	Orange	Green	Green	Green	Yellow	Yellow	Green	Yellow	Yellow	Green	Green	Green	Green	Yellow	Yellow
Tas Grain	Green	Orange	Green	Green	Green	Yellow	Yellow	Green	Yellow	Yellow	Green	Green	Green	Green	Yellow	Yellow

QUESTION 3 - IS PA APPROPRIATE FOR THE BUSINESS?

Once you are aware of the potential PA profit opportunity, it's advisable to check that your business is ready for PA or if there are other more pressing matters to attend to in the profit search.

TABLE 12. CHECKLIST FOR ASSESSING THE FEASIBILITY OF PA OPPORTUNITIES (ADAPTED FROM GRDC RDP00013 2015)

1	Is there room to improve water use efficiency and yield relative to climate limited potential via crop rotation, crop agronomy, and operational timeliness?	If yes, stop the PA path and explore these other profit pathways first.
2	How long has the PA product or application been around? Has it been robustly tested in a commercial environment?	More established PA products tend to be cheaper with greater capability and reliability.
3	Does the technology influence long term average crop yield?	Technologies which unlock yield potential and result in yield increases, with only a small to moderate increase in cost can deliver substantial net economic benefit.
4	Is the PA technology the most cost-effective mechanism to achieve the outcome that I am striving for?	Sometimes there are other ways to achieve the same outcome. Select the simplest and most cost-effective option to achieve a desired outcome wherever possible.
5	Have I undertaken a robust economic assessment? Did this analysis demonstrate a positive net benefit?	The range of net economic benefits can be substantial and is often very sensitive to the cost of purchasing the technology and the robustness of the assumptions made.
6	Do I understand how the benefit will be influenced by climatic variability between seasons? Do my assumptions accurately reflect the likely benefit or cost saving by taking a long term perspective which captures the influence of seasonal variability?	Some technologies have very different payoffs under different seasonal conditions. It is important that this difference is understood and captured in an economic analysis. Tools such as CliMate can be used to add rigour to assumptions around seasonality and the way in which it may influence the benefit.
7	Do I understand how my available level of scale impacts the commercial result?	A technology which is commercially feasible for one business may not pass the commercial feasibility test for a smaller scale business.
8	Have I used long term, decile 5 pricing rather than spot pricing when calculating the net economic benefit or a range of price scenarios?	Spot pricing influences the value of the possible benefit or cost saving and can be misleading if the price used is substantially different from the longer term average. This applies to both input cost prices and grain prices.
9	Can I access the skill set and capacity to manage the data capture and interpretation required for this PA application?	Most forms of PA require data capture, analysis, and preparation. The impact on labour demand is an important consideration.
10	Have I completed the economic assessment on the application of this technology without bias?	Personal bias can influence an economic assessment. A bias free analysis will be more robust.

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QUESTION 4 - DO THE ECONOMICS STACK UP AND WHAT ELSE SHOULD WE CONSIDER?

Once you know a profit opportunity exists (Q1,) that PA can actually help (Q2) and that your business is ready for PA (Q3), understanding the economic feasibility is the crucial next step.

The economic impact expressed as a net annual benefit ($/ha per year) will be a function of:

- The degree of *spatial variability* that in turn affects the case for spatial management.
- The *size of the financial gain* if a management practice becomes site specific compared to a uniform practice.
- The *capital and recurring costs* to implement the PA assisted site specific management practice.

The economics vary between farms so ***it is critical to do your own numbers***.

The steps to conduct economic analysis are similar regardless of the PA application you are testing, however the calculations will vary depending on how the gains occur and how the costs are incurred. This is explained in more detail below including examples from recent case studies. For more detail on the case studies please refer to tables 23, 24, 25 and 26.

1. Is spatial management warranted?
- Assess spatial variability
- Testing
- Sensing
- Existing info
- Ground truthing

→

2. Likely financial gain
- Yield
- Quality (grain price)
- Reduced variable costs

→

3. Likely PA capital and operating costs?
- Depreciation
- Finance
- Labour
- Contractors

=

4. Net benefit of PA (compared to uniform management)
- Annual benefit per ha
- Discounted annual benefit per ha
- Pay back period

4.1 HOW MUCH SPATIAL VARIABILITY EXISTS?

Considering spatial variability before investing in PA helps determine if:

- The variation is enough to justify the change in practice.
- Investing in data layers is likely to provide a return. The potential financial gain of managing variation can be eroded by the cost of measuring the variability if those costs get out of hand.

TABLE 13. DIFFERENT DATA CATEGORIES AND EXAMPLES OF THE DATA LAYERS USED TO BUILD THIS WITH A DESCRIPTION ON WHAT'S INVOLVED TO GET THAT DATA

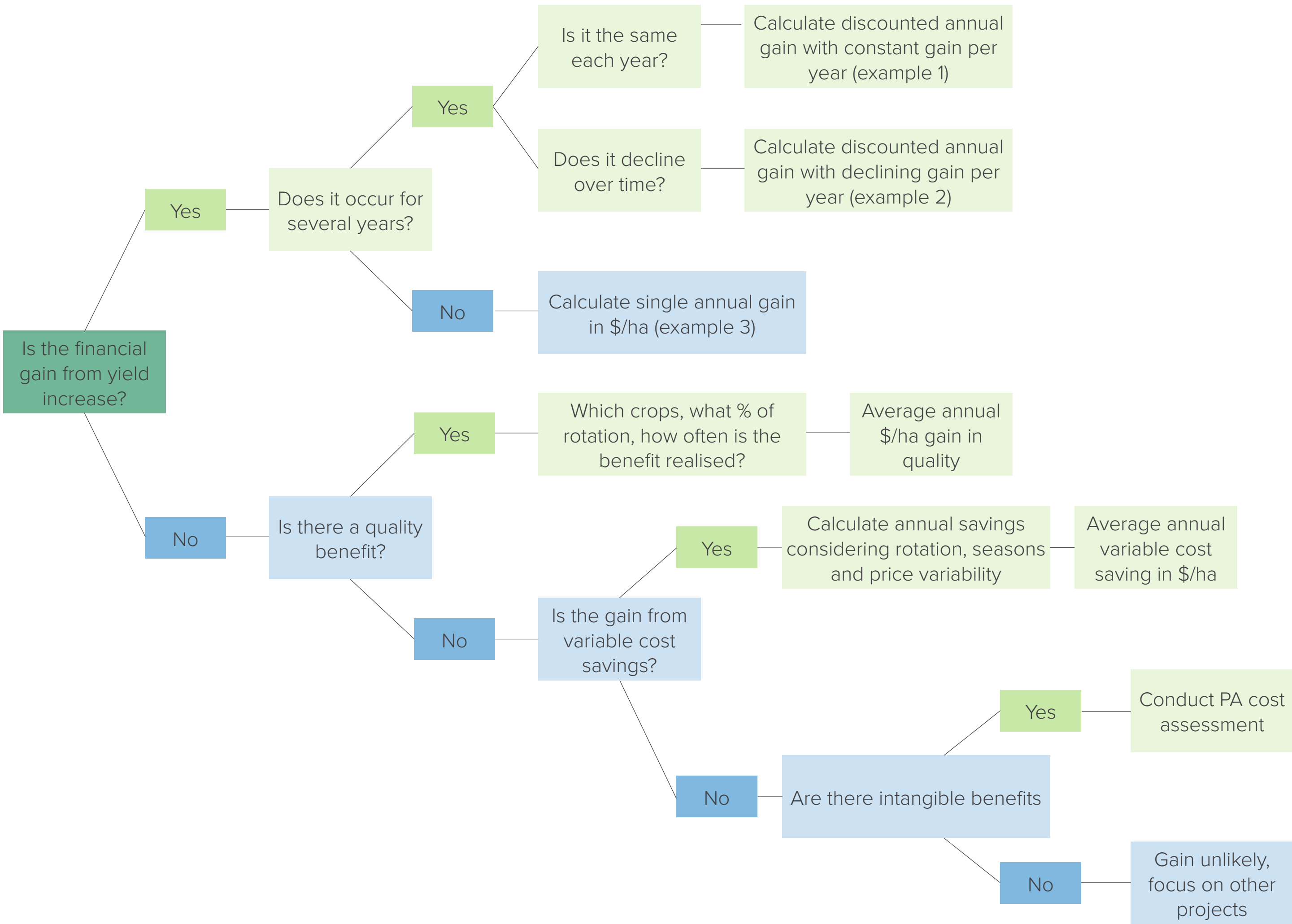
DATA CATEGORY	DATA LAYERS	COST INVOLVED
Manual information that can be georeferenced	Knowledge in your head Physical farm maps Historical soil test data Weed maps Digging holes in paddock	Time, PA consultant/ agronomist
Pre-existing georeferenced data low cost	Fuel use map Elevation Google earth imagery	Time/consultant to convert to data layers
Pre-existing georeferenced data medium cost	Yield maps Protein maps	Time/consultant to clean and collate
Purchased data-cost varies depending on data type and source	Biomass imagery	Purchase of data or drone time, consultant
Soil Survey data medium cost	EM38 Gamma radiometrics pH mapping	Contractor, consultant, own time
Soil test ground truthing-medium to high cost	Targeted soil sampling Zone sampling testing Soil pits	Contractor, consultant, agronomist, own time,
Data interpretation and sense making	Layer analysis Zone creation Ground truthing Interpolated data	Contractor, consultant, agronomist, own time

Tips to minimise costs and to account for them properly in the analysis include:

- Have a plan! (See question 5).
- Utilise existing or low cost data to get an initial indication of spatial variability before embarking on higher cost data collection.
- Gain a quote or estimate from providers before commencement.
- Consider the appropriate **resolution** needed to make a decision and gain benefit. More costly higher resolution data is not always required, but as the sampling resolution decreases so does the likelihood of interpolation errors.
- Consider data integration - are my map layers useful and in the best format for my machinery and software.
- Assign a realistic value to the time spent ground truthing and developing plans.
- Account for the total cost of sampling/testing/surveying.
- Bring the cost of data and mapping back to a $ per hectare cost where possible to make it easier to account for when determining final results.

4.2 CALCULATING THE LIKELY FINANCIAL GAIN

The decision tree below can be used to determine where the potential gain will come from and which type of calculation is appropriate.



4.2.1 GENERAL CONSIDERATIONS FOR CALCULATING FINANCIAL GAIN

There are some general principles to keep in mind when calculating yield gains:

- Allow for the overall impact of the practice on the rotation. If wheat is the only crop to benefit from the practice and it makes up 40% of the rotation, then the gain should be reduced in proportion to the rotation.
- Consider the time that a gain will be valid for. Different approaches are required for a single one-off gain vs a long-term repeatable gain.
- For longer term gains consider if the gain each year is the same or is it likely to gradually decline over time.
- Gains should reflect a range of seasonal conditions and be weighted using an averaging process or sensitivity analysis. This ensures that realistic assumptions are used.

4.2.2 CALCULATING A DISCOUNTED ANNUAL GAIN

Use this for strategic PA applications where gains accrue over time such as VR liming and VR gypsum, and PA assisted delving, claying or drainage.

When a gain is likely to occur in the future for several years, we need to be adjusting the gain to be had in future years into today's dollars (net present value). This is because a dollar today can buy more than a dollar tomorrow. The discount used is usually an interest rate to reflect the opportunity cost of not receiving that gain this year but in a future year when money is worth less.

If the practice change that unlocks yield potential would not occur without PA, then it is valid to claim the entire gain as a benefit from PA.

If the practice would occur without PA, gains attributed to PA are only any extra gain that comes from the PA component.

DISCOUNTED ANNUAL GAIN WITH CONSTANT GAIN PER ANNUM FROM A PERMANENT CHANGE

Use this technique for permanent or semi-permanent changes such as PA assisted claying, delving, draining.

Example 1 – PA assisted drainage

The calculated annual gain from implementing drainage was $130/ha. Using a discount rate of 6%, if this gain occurred every year for seven years the discounted annual average gain is $110 /ha.

TABLE 14. AN EXAMPLE OF THE DISCOUNTING METHOD WITH A CONSTANT BENEFIT FROM A PERMANENT CHANGE

		YEAR							DISCOUNTED AVERAGE
		1	2	3	4	5	6	7	$/ha/YEAR
Yield Gain	A	$130	$130	$130	$130	$130	$130	$130	-
Discounting factor at 6%	B	1	0.94	0.89	0.84	0.79	0.75	0.71	-
Net present value - Gains	C = A x B	$130	$123	$116	$109	$103	$97	$91	$110

DISCOUNTED ANNUAL GAIN WITH ANNUAL DECLINING GAIN PER ANNUM

Example 2 - Yield gain from applying lime

Some practices that provide a yield gain have a limited life span and the yield gain decreases over time. Eventually the practice needs to be repeated. Lime applications are a good example of this.

In this scenario, the initial gain after applying variable rate lime (from improved yield) was $24/ha but this declines over 7 years as the soil acidifies. (See Miller 2015 for yield assumptions). It is this declining yield gain that is then discounted to reflect the future value of money.

TABLE 15. AN EXAMPLE OF THE DISCOUNTING METHOD WITH A DECLINING BENEFIT FROM A TEMPORARY CHANGE

		YEAR							DISCOUNTED AVERAGE
		1	2	3	4	5	6	7	$/ha/YEAR
Yield gain	A	$24	$15	$10	$5	$2.5	$1.3	0	-
Discounting factor at 6%	B	1	0.94	0.89	0.84	0.79	0.75	0.71	-
Net present value - Gains	C = A x B	$24	$14	$9	$4	$2	$1	$0	$8

4.2.3 CALCULATING A SINGLE YEAR GAIN

Use this for Tactical PA applications that result in a yield gain in the year of application, for example, VR fertiliser application.

Example 3 – Annual yield gain associated with VR fertiliser

Tactical PA applications are more of a year on year decision, with lower upfront investment and gains attributed in a single year. This is the case for the VR fertiliser example below.

- P fertiliser was reallocated from poor performing zones to better performing zones without changing the total fertiliser used.
- This redistribution provided a 20% yield gain on all crop types on the flats which are 60% of arable farm area. The yield was an average that accounted for seasonal variability. There was no reduction to yield on the hills.
- Four crop types were grown with 25% of each crop type each year.
- The gain across the farm must account for the rotation by calculating a weighted average gain according to the crop percentages. Without this, there is a risk of over or underestimating the estimating the benefits.
- The gain must then be allocated only for the area impacted.

TABLE 16. AN EXAMPLE OF HOW TO DETERMINE THE WEIGHTED AVERAGED GAIN PER HECTARE

	WHEAT	BARLEY	CANOLA	LENTILS
AVERAGE YIELD T/HA	3.4	3.5	1.5	1.5
20% OF YIELD	0.68	0.7	0.3	0.3
DECILE 5 FARMGATE PRICE $/T	$255	$206	$430	$512
$/HA GAIN	$173	$144	$129	$154
ROTATION AVERAGE GAIN $/HA (1/4 EACH CROP)	$150			
WHOLE FARM GAIN (60% APPLICABLE) $/HA	$90			

4.2.4 CALCULATING GAINS OTHER THAN YIELD

FINANCIAL GAINS FROM QUALITY IMPROVEMENTS

Most financial benefits are attributed to yield gain or reduced input costs, but sometimes the gain can be attributed to price achievement through quality improvements. Gains from quality optimisation may become more common if on-the-go protein mapping in harvesters becomes more widely available.

When assessing a financial gain from quality improvement ensure that it accounts for seasonal fluctuation, is adjusted for the rotation, and is linked to an actual price change.

GAINS FROM REDUCING VARIABLE COSTS

Use this for optical spot spraying, any patching out exercise and fertiliser savings in VR.

The gain measured is the difference in costs of the previous practice, usually a blanket rate, and the PA application. (See example 4).

Example 4 – Variable cost savings from selective spot spraying

In this case there are still three passes but in the two passes with the optical spot sprayer there is a $14/ha chemical cost saving. It is important to note that the saving isn't $24/ha (2 passes of $15/ha with 80% saving), as this isn't comparing the optical spot sprayer technology to previous practices.

TABLE 17. AN EXAMPLE OF HOW TO CALCULATE VARIABLE COST SAVINGS WHEN THERE IS MULTIPLE PASSES AND DIFFERENT TREATMENTS

	PREVIOUS PRACTICE	PA PRACTICE	GAIN
PASS 1	Conventional Boom Spray 100% of area sprayed with $10/ha mix	Conventional Boom Spray Blanket coverage at $10/ha	0
PASS 2	As above $10/ha	Optical Spot spraying 20% of area sprayed with $15/ha mix = $3/ha cost	$7/ha
PASS 3	As above $10/ha	As above $3/ha	$7/ha
TOTAL COST	$30/ha	$16/ha	$14/ha

Input costs must represent your situation as they vary so much between years and districts. The impact of variation in cost of inputs delivered on farm is also important to recognise.

Example 5 - Impact of lime cost per tonne on financial gain from lime savings

For inputs where there is a freight component, the cost delivered on farm can vary greatly and impact on the economic feasibility. Lime price can differ substantially based on quality and freight as demonstrated below.

TABLE 18. NET GAIN PER HECTARE UNDER DIFFERENT LIME PRICES AND DIFFERENT LIME SAVINGS, AFTER $12/ha HAS BEEN TAKEN OFF FOR SOIL TESTING (ADAPTED FROM GRDC RDP00013 2016)

		COST APPLIED LIME (INC. FREIGHT AND SPREADING) ($/t)			
		$30	$40	$50	$60
REDUCTION IN APPLICATION RATE (t/ha)	1.5	$33	$48	$63	$78
	1.25	$26	$38	$51	$63
	1	$18	$28	$38	$48
	0.75	$11	$18	$26	$33
	0.5	$3	$8	$13	$18
	0.25	-$5	-$2	$1	$3

ACCOUNTING FOR LABOUR AND CONTRACTING SAVINGS

Reduced labour and contracting costs may contribute to the variable cost savings.

One VR lime case study saw the average lime rate decrease from 2.5 t/ha to 1.8t/ha which meant the contractor spreading fees were $9/ha less.

Remember that some PA applications require extra labour, which should also be accounted for in your calculations.

4.2.5 CONSIDERING INTANGIBLE BENEFITS

Intangible benefits are those that are hard to quantify in financial terms but can have substantial positive impact on the farm business. Except when health and safety or legal compliance is concerned, the intangible benefits alone are usually not enough to justify implementation without additional economic benefits.

Grower stories of intangible benefits include:

- Selective spot spraying technology:
    - Reduced operator exposure to chemicals by replacing manual spot spraying of weed patches. This improved employee safety and enjoyment.
    - Enabled the use of more expensive herbicide mixes which had greater efficacy than traditional mixes. Slowing down the development of herbicide resistant weed population through improved weed control and fewer survivors.
    - Prompted more timely spraying of summer weeds and improved soil moisture capture, by knowing that the cost was less and repeat applications would be economically viable.
- Data layers collected for one purpose (e.g EM mapping) reveal information that leads to other profit opportunities.
- Site specific management of seeding rate or fertiliser rate:
    - More even emergence resulting in a reduced number of weeds.
    - More even crop growth stages and harvest maturity simplifying the timing of in crop operations and harvest.
- PA assisted drainage reduced the number of bogging incidents and enabled better machinery efficiency and less operator frustration.

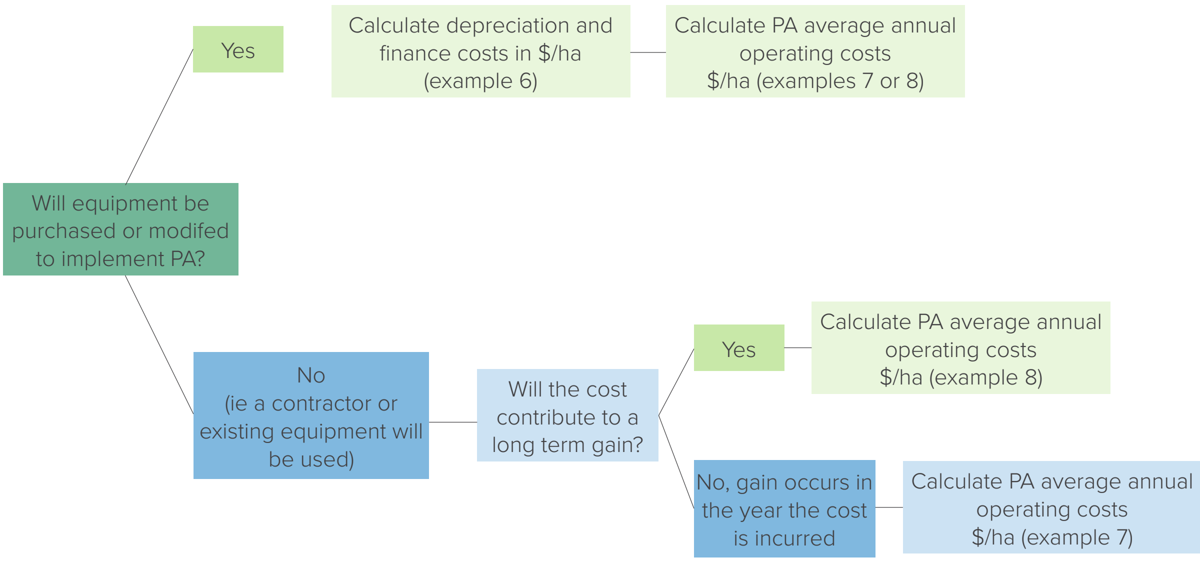
4.2.6 KEY POINTS FOR ROBUSTLY CALCULATING ECONOMIC GAIN

- Consider the economic impact across the whole rotation, not just the primary crop.
- Account for seasonal volatility by using high and low yield scenarios as well as average yield scenarios and consider the frequency of years where an economic response is likely.
- Use long term decile 5 grain pricing rather than seasonal spot prices.
- Accurately identify the hectares that will respond to the PA change rather than over ‘guesstimating’.
- Account for the financial gains from both income improvements and cost reductions (eg yield and variable cost savings).

4.3 WHAT ARE THE CAPITAL AND OPERATING COSTS?

These are the additional capital and operating costs associated with using PA technology for a particular task.

Use the decision tree below to identify those costs and the appropriate calculations to use.



4.3.1 CALCULATING ANNUAL DEPRECIATION AND FINANCE COSTS

Use this for PA applications that involve the purchase or modification of equipment such as a VR capable spreader or seeder or a WeedIT/Weedseeker unit.

Capital costs are single event purchases that have repeat use. Examples include land, infrastructure, plant and equipment. Capital costs attributed to PA are those single event purchases of plant or equipment necessary to undertake the PA action.

The annual costs of owning the capital item include the loss in value of the item (depreciation) and cost of finance (either interest payments or an opportunity cost).

Despite it not being a physical cash expense, allowing for depreciation accounts for the eventual cost associated with future machinery replacement. It is a commonly underestimated expense that erodes the return on investment from farming.

We recommend allocating an annual depreciation cost of 15% of the purchase amount. This factors in the possibility of the technology being superseded and becoming obsolete quicker than other machinery which may depreciate at 10%.

Allowing for finance costs ensures that the opportunity cost of spending money on equipment rather than something else is accounted for. This project used 5% of purchase cost as the opportunity cost.

Some equipment is used for both a PA assisted application and non PA operations. In this case it's the time in use for the PA operation that we account for or the difference between a PA capable machine and a non PA capable machine. For example, the cost difference between spreaders with and without VR capability, or the additional tractor hours used in a PA operation.

Example 6 – Accounting for machinery purchase or modification - depreciation and finance

These examples illustrate the cost impact of finance and depreciation on annual costs.

Table 19 highlights the adoption of optical spot spraying by two different growers and how a difference in purchase strategy influences capital cost.

Table 20 demonstrates how this difference in purchase price flows through to potential net benefit and payback period.

Table 21 models the interaction between different levels of cost saving (chemical saved and spray passes saved) and different fixed costs when adopting an optical spot sprayer. This shows that there are several different factors that ultimately influence the net benefit per hectare achieved.

TABLE 19. A BREAKDOWN OF ANNUAL COSTS AND THE IMPACTS OF DIFFERENT PURCHASE PRICES

	FARM 1 (SECOND HAND)	FARM 2 (NEW PURCHASE WITH ADDITIONAL CAPABILITY OF BLANKET SPRAY)
HECTARES	4,100	6,000
PURCHASE PRICE	$70,000	$350,000
ANNUAL DEPRECIATION (15%)	$10,500	$52,500
ANNUAL FINANCE (5%)	$3,500	$17,500
TOTAL ANNUAL CAPITAL COSTS	$15,000	$81,000
ANNUAL CAPITAL COSTS $/ha	$3.66	$13.50

TABLE 20. TWO DIFFERENT SCENARIOS WHERE AN OPTICAL SPOT SPRAYER (WEEDIT OR WEEDSEEKER) HAS BEEN PURCHASED. ONE IS NEW AND THE OTHER IS USED/SECOND HAND

FARM SIZE	CAPITAL INVESTMENT	TOTAL ANNUAL GAIN[1]	ANNUAL COST[2]	NET ANNUAL BENEFIT	PAYBACK PERIOD	ANNUAL MARGIN (NET BENEFIT/ TOTAL GAIN)	REQUIRED SCALE (BREAKEVEN AREA)
ha	TOTAL $ AND ($/ha)				YEARS	%	HA
4,100	70,000	118,900	15,000	103,900	0.6	87%	517
	(17.07)	(29.00)	(3.66)	(25.34)			
6,000	350,000	100,440	81,000	19,440	3.8	19%	4,839
	(58.33)	(16.74)	(13.50)	(3.24)			

[1] Savings in chemical, application and or labour costs (see Table 3)
[2] Depreciation (15% flat rate), finance, repairs and maintenance

TABLE 21. THE IMPACT ON NET BENEFIT PER HECTARE WITH DIFFERENT AMOUNTS OF CHEMICAL USAGE AND NUMBER OF PASSES				
NUMBER OF PASSES REPLACED BY OPTICAL SPOT SPRAYER	CHEMICAL USED (% OF FULL PADDOCK COVERAGE)	NET GAIN BEFORE FIXED COSTS	NET BENEFIT AFTER $4/ha FIXED COSTS	NET BENEFIT AFTER $12/ha FIXED COSTS
1	15%	$9	$5	-$3
	30%	$6	$2	-$6
	50%	$2	-$2	-$10
2	15%	$18	$14	$6
	30%	$12	$8	$0
	50%	$4	$0	-$8
3	15%	$27	$23	$15
	30%	$18	$14	$6
	50%	$6	$2	-$6

4.3.2 CALCULATING OPERATING COSTS

Use this for calculating operating costs with PA applications such as contractors, labour, repairs and maintenance.

There are two approaches to account for operating costs:

- Projects with gain over several years after the cost is incurred such as liming.
- Projects with gain occurring in the season when the cost is incurred. These costs are in addition to any capital costs already accounted for.

EXAMPLE 7 – CALCULATING OPERATING COSTS FOR A PA APPLICATION WITH SINGLE YEAR GAINS (GAINS OCCUR IN YEAR THE COSTS ARE INCURRED)

Operating costs for the PA operation should only account for the difference between the PA application and the standard practice.

- Additional labour required to implement PA.
- Additional input costs such as extra fertiliser or seed.
- Additional repairs and maintenance associated with PA technology or practice.
- Ongoing software maintenance or licencing costs.
- Service provider fees for PA related tasks.

EXAMPLE 8 – CALCULATING CONTRACTING COST FOR A SPADING OPERATION THAT HAS MULTIPLE YEAR GAINS

Engaging contractors for PA tasks can reduce the overall capital outlay. It also allows the trialling of a new practice before committing to large capital investment.

Spading is a capital-intensive amelioration technique. In this example, where targeted spading was undertaken, the first-year contract costs were averaged over seven years, as the executed lifespan of the benefit.

The expense occurs in the first year so a discounting procedure is not required in the calculations. The operation only occurred on 10% of the paddock but is expressed as a cost across the whole paddock.

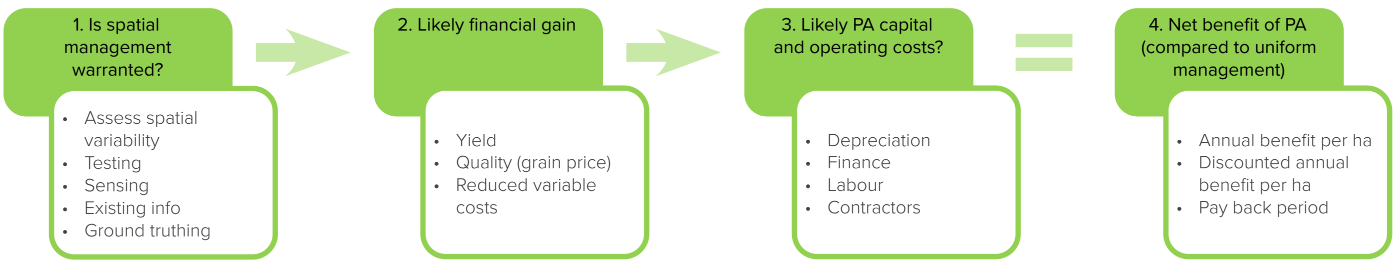
TABLE 22. A BREAKDOWN OF TOTAL SPADING COSTS TO A PER HECTARE COST PER YEAR

PADDOCK AREA (ha)	150
AREA TREATED (ha)	15
TOTAL COST OF SPADING	$2,700
LIFESPAN YEARS	7
AVERAGE COST/ha PER YEAR FOR PADDOCK	$2.57

4.3.3 KEY POINTS FOR CALCULATING ROBUST COSTS FOR CAPITAL AND OPERATING

- Consider the lifespan of the treatment and if upfront costs need to be averaged over the time of the project..
- Allow for some accelerated depreciation of technology focussed PA equipment.
- Ensure that costs are spread over the appropriate area to match up to the benefits that are calculated and keep ‘apples with apples’.
- Be clear on allocation of costs to the PA application compared to existing practice.
- Value extra labour required for the PA approach, including family labour.

4.4 THE BOTTOM LINE: WHAT IS THE NET ANNUAL BENEFIT AND WILL A PA APPROACH INCREASE PROFIT?



The net benefit is calculated as likely financial gain less the operating and capital costs and can be expressed in a number of ways.

This project used net benefit per ha per year and payback period as the two main metrics. A marginal benefit:cost ratio is also used to test the relative cost to attain a benefit.

A summary of the economic analyses conducted for case studies are listed per rainfall zone. Note that these are examples of how to do the numbers and what's possible, *not* a reflection of each agronomic strategy in itself. Remember - do your own numbers.

TABLE 23. A SUMMARY OF THE CASE STUDY RESULTS FOR THE LOW RAINFALL REGION

LOW RAINFALL ZONE	PROFIT OPPORTUNITY	PA PRACTICE	PREVIOUS PRACTICE	ANNUAL GAIN	ANNUAL COST	NET ANNUAL BENEFIT[1]	PAYBACK PERIOD	MARGINAL BENEFIT TO COST RATIO	MAIN GAIN COMPONENT AND % CONTRIBUTION	INITIAL CAPITAL OUTLAY $	MAIN COMPONENTS OF COST	COMMENTS
				$/HA/YEAR ON AREA TREATED			YEARS					
Mallee, Vic	Variable Cost reduction	Tactical Weedit optical spot sprayer	Blanket summer weed control	12	7	5	2.8	1.74	Variable cost savings (100%)	620,000	Depreciation (73%)	High capital structure counteracted economic gains from variable cost savings.
Upper North, SA	Variable Cost reduction	Tactical Weedseeker optical spot sprayer	Blanket summer weed control	29	4	25	0.6	7.93	Variable cost savings (100%)	70,000	Depreciation (70%)	Low capital investment driving higher retention of margin gained from chemical savings.
Southern Mallee, SA	Variable Cost reduction	Tactical Weedit optical spot sprayer	Blanket summer weed control	17	14	3	3.8	1.24	Variable cost savings (99%)	350,000	Depreciation (65%)	High capital structure reducing the economic gains from variable cost savings.
Upper EP, SA	Yield increase	Tactical Soil zones enabling VR P at seeding and driving more profitable fertiliser allocation	Blanket rate	54	2	52	0.1	30.8	Yield increase (100%)	24,800	Depreciation (49%)	High degree of variability between low and high yielding areas, with low capital costs due to existing equipment.

[1] Partial Budget Analysis was used to compare PA assisted practice to previous practice

TABLE 24. A SUMMARY OF THE CASE STUDY RESULTS FOR THE MEDIUM RAINFALL REGION

MEDIUM RAINFALL ZONE	PROFIT OPPORTUNITY	PA PRACTICE	PREVIOUS PRACTICE	ANNUAL GAIN	ANNUAL COST	NET ANNUAL BENEFIT	PAYBACK PERIOD YEARS	MARGINAL BENEFIT TO COST RATIO	MAIN GAIN COMPONENT AND % CONTRIBUTION	INITIAL CAPITAL OUTLAY $	MAIN COMPONENTS OF COST	COMMENTS
				$/HA/YEAR ON AREA TREATED								
Wimmera, Vic	Unlock yield potential in sodic clay soil prone to waterlogging on 200 of 1400 ha Strategic	Strategic Elevation maps from drone to plan drainage and deep ripping. GPS guided scraper	No drainage	227	21	206[1]	0.4	14.4	Yield increase (100%)	5,000	GPS assisted drainage work (87%)	The long term repeatable benefit across all crop types in the rotation provides a high lifetime value for the project.
Wimmera, Vic	Yield and quality increase	Tactical VR nitrogen for wheat and some canola	Blanket rate	56	1	55[3]	0.1	50.3	Yield increase (100%)	3,000	Additional labour (44%)	Specialised marketing program to capitalise on quality benefits, high input program with risk of haying off if overfed.
Upper SE, SA	Increase yield on poor sand and sodic clay	Strategic EM38 and yield maps used to plan targeted delving and VR gypsum application	Blanket rate gypsum, some delving	120	43	77[1]	1.9	2.8	Yield increase (86%)	1,500	Delving costs (98%)	Variable cost savings from gypsum application. Long term benefit of yield response provides a high lifetime value for project despite high initial investment.
Lower North, SA	Variable Cost reduction	Tactical Weedseeker optical spot sprayer	Blanket summer weed control and manual spot spray followup	16	9	7	2.8	1.8	Variable cost savings (93%)	160,000	Depreciation (74%)	Moderate capital investment, saved chemical costs as well as labour from manual spot spraying increasing economic gain.

[1] Gain calculated from seven year stable yield benefit with 6% discounted applied (see 4.2.2) followed by Partial Budget analysis

[2] Gain calculated from seven year declining yield benefit with 6% discounted applied (see 4.2.2) followed by Partial Budget analysis

[3] Gain calculated as single year benefit (see 4.2.2) followed by Partial Budget analysis

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TABLE 25. A SUMMARY OF THE CASE STUDY RESULTS FOR THE MEDIUM RAINFALL REGION, CONTINUED

MEDIUM RAINFALL ZONE	PROFIT OPPORTUNITY	PA PRACTICE	PREVIOUS PRACTICE	ANNUAL GAIN	ANNUAL COST	NET ANNUAL BENEFIT	PAYBACK PERIOD YEARS	MARGINAL BENEFIT TO COST RATIO	MAIN GAIN COMPONENT AND % CONTRIBUTION	INITIAL CAPITAL OUTLAY $	MAIN COMPONENTS OF COST	COMMENTS
				$/HA/YEAR ON AREA TREATED								
Upper YP, SA	Increase yield on non wetting sand rises	Strategic Drone mapping to identify variability and areas of highest response to spading and chicken litter	Blanket chicken litter, no previous spading	27	5	22[2]	1.0	5.6	Yield increase (100%)	Nil	Spading cost (53%)	Declining yield benefit over time- Cost savings from targeted spading. Yield increase accumulating over medium term on ameliorated area to offset high upfront costs of treatment.
Lower EP, SA	Increase yield by reduced runoff and waterlogging	Strategic EM38, Radiometrics, yield and elevation maps used to plan deep ripping, VR lime and gypsum spreading and drainage works	Blanket rate gypsum and lime, no drainage work or ripping	50	12	38[1]	0.9	4.3	Yield increase (100%)	43,000	Deep ripping and drainage costs (36%)	- Stable yield response over time. Variable cost savings from gypsum and lime. Long term benefit of yield response from drainage provides a high lifetime value for project despite high initial costs of surveying and mapping.
Lower EP, SA	Yield increase	Tactical Soil zones enabling VR P at seeding driving more profitable fertiliser allocation	Blanket rate	93	1	92[3]	0.02	84.2	Yield increase (100%)	5,000	Additional labour (40%)	Reliable area with high yield potential meant significant yield response on previously under fertilised areas, and low capital costs with existing equipment.

[1] Gain calculated from seven year stable yield benefit with 6% discounted applied (see 4.2.2) followed by Partial Budget analysis
[2] Gain calculated from seven year declining yield benefit with 6% discounted applied (see 4.2.2) followed by Partial Budget analysis
[3] Gain calculated as single year benefit (see 4.2.2) followed by Partial Budget analysis

TABLE 26. A SUMMARY OF THE CASE STUDY RESULTS FOR THE HIGH RAINFALL REGION

HIGH RAINFALL ZONE	PROFIT OPPORTUNITY	PA PRACTICE	PREVIOUS PRACTICE	ANNUAL GAIN	ANNUAL COST	NET ANNUAL BENEFIT	PAYBACK PERIOD YEARS	MARGINAL BENEFIT TO COST RATIO	MAIN GAIN COMPONENT AND % CONTRIBUTION	INITIAL CAPITAL OUTLAY $	MAIN COMPONENTS OF COST	COMMENTS
				$/HA/YEAR ON AREA TREATED								
North East Vic slopes	Unlock yield potential of acid soils on 500 of 3,500 Ha	Strategic Variable rate lime application	Lime applied uniformly	8	2	6[2]	0.5	4.6	Yield increase (95%)	5,000	Variable Costs of PA (83%)	Declining yield benefit over time. Yield benefit from reallocating lime to the most responsive zone.
Southern Vic	Reduce the variable cost of maintaining yield potential on acid soils 260 of 2,100 ha	Tactical Variable rate lime application	Lime applied uniformly	49	13	36[3]	0.3	3.8	Savings in lime and labour (80%)	Nil	Variable Costs of PA (100%)	Variable cost saving in saved lime and spreading and labour saving. Partial budget analysis.
Southern Vic	Unlock yield potential in sodic clay soil prone to waterlogging on 190 of 1960 ha Strategic	Strategic Elevation mapping to plan drainage	Ineffective drainage works	110	7	103[1]	0.4	14.8	Yield increase (100%)	Nil	GPS assisted drainage works (76%)	Yield benefit consistent for 7 years and was discounted at 6% to reflect real value. The long term repeatable benefit across all crop types in the rotation provides a high value for the project.
Tasmania	Reallocate fertiliser based on soil type (mainly red basalt clay loam) and increase yield and reduce fertilise cost on 165 of 400Ha property	Tactical Variable rate fertiliser at planting based on Spatial data layers including yield NDVI & soil surveys	Uniform rates of single super phosphate and potash	121	51	70[3]	1.4	2.4	Variable cost saving (100%)	16,000	Soil Testing (62%) Depreciation (28%)	High cost fertiliser regime on vegetable and pharmaceutical crops enabled scope for $20,000 fertiliser cost reduction.

[1] Gain calculated from seven year stable yield benefit with 6% discounted applied (see 4.2.2) followed by Partial Budget analysis
[2] Gain calculated from seven year declining yield benefit with 6% discounted applied using (see 4.2.2) followed by Partial Budget analysis
[3] Gain calculated as single year benefit (see 4.2.2) followed by Partial Budget analysis

4.5 FLEXIBLE PA PATHWAYS TO PROFIT

Regardless of geographic location, occasional short term specific situations occur where flexible PA can assist in providing a rapid response that can be highly profitable.

Stories of flexible or responsive PA pathways to profit told by growers are outlined below.

TABLE 27. EXAMPLES OF FLEXIBLE PA PATHWAYS THAT INCREASED PROFIT

PROFIT OPPORTUNITY	FLEXIBLE PA STORY
Salvaging income after late season frost	Selective harvesting of frosted peas to preserve grain quality and enable delivery: The frosted area of the paddock was identified by biomass imagery, not harvested and then later grazed by sheep. The unfrosted area was harvested and delivered for $8,000 without down grading or cleaning. Without PA intervention, the harvested peas would not have met delivery standards.
	Selective hay cutting of frosted wheat crops to maximise paddock value. Digital elevation maps were used to guide assessments of frost damage and inform the decision to cut for hay or leave for grain.
Matching crop type to soil type	Matching pulse choice to soil type. Seeding prescription maps based on soil type and variable rate seeding technology enabled lupins to be sown on light soil and beans sown on heavier soil in the same seeding pass.
Variable cost saving	Targeted application of expensive crop inputs. The return on investment from Plant Growth Regulator (PGR) use in barley was increased by applying PGR only to areas of high biomass to prevent lodging and improve harvest efficiency and grain yield. Satellite biomass imagery was used to identify the PGR responsive zones.
	Selective canopy closure fungicide spraying of lentil crops based on areas of highest biomass. Reduced fungicide application, and greater flexibility with fungicide choice by targeting timing of spray based on biomass by zone rather than as a whole paddock. In wet springs with higher fungicide requirements and multiple sprays this has the potential to make better use of different fungicides and keep within maximum residue limits for the grain.
Matching herbicide safety to soil type	Altering herbicide rates based on soil type to reduce risk of crop damage. This is common practice in lentils in dune/swale systems where the use of Group C herbicides can cause considerable crop damage on lighter soils. The variable cost savings are small but the benefits in crop establishment and subsequent yield can be high.
Increase price received	Using a protein monitor during harvest to manage within paddock quality variation and maximise value of grain delivered.

4.6 KEY POINTS FOR ROBUST ECONOMIC ASSESSMENT

- Allow for the impact of rotation and seasons when considering both costs and gains.
- Consider the time that a gain will be valid for – is it a one-off or will it be repeated?
- For longer term gains will the gain be consistent each year or is it likely to gradually decline over time?
- Spread costs and gains over the appropriate area and not just the responsive area.
- Allow for accelerated depreciation of technology focussed PA equipment.
- Account for any unintended costs such as a delay in timing of existing operations.
- Consider any risks or general reliability of the technology.

QUESTION 5 - HOW DO WE MAKE PROFIT FIRST PA HAPPEN?

Making a sound decision and being aware of the likelihood of a profitable outcome is only part of the PA journey.

The rewards of such a sound decision making process will only be reaped if the PA approach is well executed.

Successful implementation starts with a PA game plan at both the whole farm and individual application level and ends with an evaluation process to refine the plan each season. PA should not be a set and forget strategy, and each year is effectively a new decision. A checklist for implementation is shown in the following table.

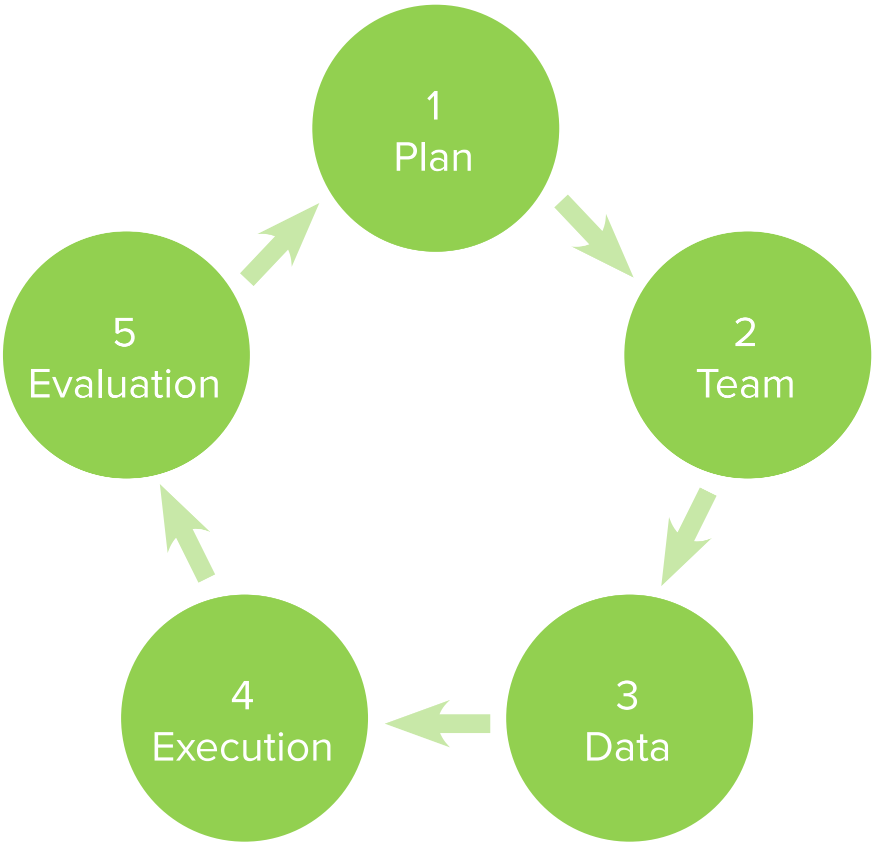

TABLE 28. CHECKLIST FOR PROFIT FIRST PA IMPLEMENTATION	
1. DEVELOP AN IMPLEMENTATION PLAN	• State clearly the profit opportunities you are trying to capture. • Step out some realistic timeframes to capture the opportunities. There may be multiple years required to achieve the goal and some opportunities may be higher priorities than others. • Prioritise tasks by identifying the critical steps in the process that if not done may jeopardise the outcome. • Document the plan.
2. CHOOSE YOUR PA TEAM (AND RESOURCES)	• Be realistic and recognise where you have internal capacity and where the gaps are. • Growers are often strong 'doers' and advisers strong 'planners' – use the strengths of each. • Form a team to implement the project, with clear roles for each member. • Some tips on getting the most out of the team is shown in table 30.
3. GATHERING THE DATA	A Profit from PA approach demands that data has a useful purpose. Consider the following when planning implementation: • What data do we need to make this happen? • Does this data actually provide insight into the opportunity? • Is the information showing me causation or just correlation? (Do your ground-truthing) • How much data is enough to capture the opportunity? • What is the most cost effective form of data collection? • Is there multi-purpose data applicable for several decisions? • Are the assumptions appropriate when converting data to management decisions?
4. EFFECTIVE EXECUTION	Implementation ultimately comes down to execution. The following execution tips were provided by growers and advisers using PA successfully: • Should we do a pilot or trial somewhere before committing to the whole farm or paddock? • Can I talk to someone with experience and learn from their mistakes? • Do I have key contacts in my phone ready for trouble shooting? • What could go wrong and what contingencies do we have in place?
5. EVALUATION	To evaluate the success of the project consider the following: • Did we capture the profit opportunity? • Do our trial results back up the approach? • Was the result consistent with our assumptions and plan? • What can we improve for next time? • Are there other opportunities we can apply this to in the future?

For ongoing PA applications that are implemented year on year such as variable rate fertiliser, the decision to continue with a PA approach should be re-tested each year. The economics may change with different fertiliser prices or changes in paddock variability. For example an amelioration approach to improve production on sandy soils may reduce the need for variable rate fertiliser, as the overall paddock variability may subsequently decline. An example of a PA implementation plan is shown below.

TABLE 29. PA PLAN FOR VARIABLE RATE FERTILISER AFTER PROFIT OPPORTUNITY HAS BEEN RECOGNISED

TIMEFRAME	ACTION 1	ACTION 2	ACTION 3
Year 1	+/- 2cm Integrated RTK autosteer.	Subscribe to Cloud based GIS platform for data storage, viewing and analysis.	Create digital farm map.
Year 2-5	GPS referenced soil and plant tissue testing with defined management zones.	Identify production zones from collected spatial data with input from agronomist and PA consultant.	Collect data- some or all of archived satellite images, yield data, elevation, fuel use soil surveys, EM38, etc.
Year 3-10	Conduct on farm strip trials and develop VR plan.	Execute VR on paddock basis and evaluate.	Roll out VR with annual review and adjustment.

Adapted from Torpy 2013.

Forming an effective PA team can be an important step in implementation. Table 30 has an outline of roles within a PA team and how it can be brought together.

5.1 THE PA TEAM

TABLE 30. DIFFERENT ROLES IN A PA TEAM AND THE VALUE THAT CAN BE CREATED BY EACH TEAM MEMBER

NAME	CAN ADD VALUE BY...	HOW TO EXTRACT THAT VALUE FROM YOUR TEAM MEMBER
Grower and Team Captain	• Driving the process and take ownership of it. • Sharing intimate farm knowledge. • Co-ordinating the various roles to get the best out of external providers along the PA journey. • Making final decision. • Depending on skills and the situation, managing the mapping and delivery of PA in house.	• Manage your own and others biases by involving all team members from the start.
Agronomist	• Providing input into opportunity identification and clarification. • Being the agronomic link between the current constraint and the future opportunity. • Eliminating errors and test assumptions when doing the economics. • Linking the practice change to the farming system as a whole. • Assisting with ground truthing.	• Use them to identify profit opportunities first up. • Involve them early to help identify issues before technology investment decision. • Use a team approach where agronomist and PA consultant each know their role and specific tasks and have access to the same information.
PA Consultant	• Recommending most appropriate method for understanding variability. • Collating and organise data. • Interpreting map information into meaningful zones and actions. • Trouble shooting issues with implementation as they arise. • Evaluating on farm trial information and ground truthing.	• Provide clear direction on the issues to be solved. • Use a team approach where agronomist and PA consultant each know their role and specific tasks and have access to the same information. • Allow plenty of time for appropriate data collection and ground truthing so the process is not rushed.
Machinery + technology support	• Ensuring equipment is capable of desired function. • Providing rapid in paddock support as needed to trouble shoot operational issues. • Seeking to understand the faming system and constraint before focusing on the technology.	• Provide a clear brief of what you want the equipment to achieve. • Specify existing equipment and the relative need for connectivity. • Seek evidence of others utilising the technology on their property in a similar situation to you. • Ask for contingency plans for when equipment is not working.
Contractor	• Providing expertise in doing the job. • Reducing the labour and capital required to implement PA.	• Remove barriers for them to do the job once on farm. • Have a backup plan that can be used if technology issues arise (eg paddock markers, physical maps). • Seek to make their job efficient by having a critical mass of work for them to undertake in the area (eg work in with neighbours).

5.2 COMMON ISSUES ENCOUNTERED THAT NEED TO BE PLANNED FOR

- If the satellites drop out what do we do?
- If the screens stop talking to each other can we keep seeding?
- What are the tech support numbers for the various items that could require help?
- How much downtime am I prepared to absorb before we proceed with a manual approach or a blanket rate application?
- Am I the only person who knows how to operate this or have I got clear instructions in place that can be followed by other operators?
- Can I work 'manually' in another area during technical down-time?

5.3 EVALUATION OF PA

On farm trials with PA are an excellent way to measure success and validate original assumptions on the economics. These need to be taken through to actual yield, and designed in a robust way to capture the variability across a paddock. An excellent resource for guiding on-farm trials was developed by SEPWA and GRDC, and can be found here https://grdc.com.au/ROI-OnFarmTrials

The use of 'as applied' maps also has a role to play in evaluating the success of a PA approach. This removes the assumption that everything was implemented according to the original plan, when in fact details and rates may have been changed at the time to suit operational needs.

5.4 WHEN CAN PA GO WRONG?

The adoption of PA does not always go smoothly and result in an improvement in profit. Example scenarios where there has been a disappointing result are mentioned below:

- "We found that not every input required a PA approach and even if it did, it was best that different zones were used for each input. Essentially we couldn't assume the zones were the same for N as they were for P."
- "Soil mapping showed that a blanket rate approach was still the best for our business. This was a considerable cost, however, we're still happy with the result as we now have confidence in applying our inputs in a cost-effective manner."
- "After adopting a PA approach, we found that we weren't as effective on timeliness due to a change in focus. This had an impact as the important drivers of production weren't optimised anymore."
- "We got some pH maps made which showed a large amount of variation in pH in the top 10cm of the soil. We then adopted a VR lime program to address this, but it didn't have the effects we were hoping for. After ground truthing further we found that the next 10cm of soil also had acidity problems that weren't consistent with the topsoil variation. Essentially, where it wasn't acidic on the surface it was at a sub soil level. We then went back to blanket rate applications of lime as that was more effective."
- "We knew we had some variation so when we realised the technology was available we jumped right in. We didn't realise how much time would be spent on making zones and we were out of our depth with the technology. We've now hired a PA consultant to create the maps each year so that we don't have to spend so much time on it."
- "Once we had the technology we started applying fertiliser with a variable rate however we didn't consult our agronomist when we made our zones which meant that we didn't achieve the best yield outcome."
- "Purchasing an optical spot sprayer saved a lot on chemical costs however they only just covered the depreciation and finance costs associated with owning the equipment. In hindsight we should have bought a second-hand sprayer as it would better suit our operating scale."
- "When the technology didn't work we spent too long trying to fix it which delayed other operations. We should have been better prepared so that normal operations could continue if the PA technology failed."
- "I've had to take on all of the PA work as other team members couldn't operate the technology. This wasn't accounted for initially and took some time to adjust to the change in roles amongst the team."
- "We tried to keep the costs down by keeping the soil sampling grid size pretty large, but in the end cheaper wasn't better, as we found it wasn't accurate enough as we have lots of variability. We might have got a better result by doing some targeted sampling first."

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SUMMARY

By following a 'Profit First' approach PA can improve returns across the southern region. It needs to be implemented in a disciplined manner for best results.

Answering the 5 question decision making process outlined in this management guideline will increase the chances of profitable PA adoption.

The most important step is to do your own numbers. Because the benefits of PA are situational, with variability between seasons, farms, and in the profit opportunity itself, each case for adoption is unique.

How will your PA Profit search end?

TABLE 33. FIVE QUESTIONS FOR A PROFIT FIRST APPROACH TO PA

		EXAMPLE SCENARIO
QUESTION 1 (Page 8)	What profit gain opportunities exist for the farm business?	We have low pH soils limiting yield potential in some but not all areas on the farm.
QUESTION 2 2.1 LOW RAINFALL ZONE (Page 11) 2.2 MEDIUM RAINFALL ZONE (Page 12) 2.3 HIGH RAINFALL ZONE (Page 13)	Does PA have a role in addressing those opportunities?	Soil types are variable within paddocks so variable rate application of lime could be an option.
QUESTION 3 (Page 14)	Does the business have the capacity to usefully implement PA?	The PA profit ready check list is a good place to start.
QUESTION 4 (Page 15) 4.1 HOW MUCH SPATIAL VARIABILITY EXISTS? 4.2 CALCULATING THE LIKELY GAIN 4.3 WHAT ARE THE CAPITAL AND OPERATING COSTS?	Do the economics stack up and what else needs consideration?	A partial budget analysis compares using PA or not, (e.g VR lime v Uniform spreading) to address the issue. Lower liming costs will mean more paddocks can be amended in one season.
QUESTION 5 (Page 16)	How do we make it happen?	Considerations for effective implementation so that the profit gain opportunity is actually achieved.

REFERENCES

Armstrong RD, Eagle C, Mattas V, Jarwal SD, (2007) Application of composted pig bedding on a vertosol and sodosol soil 1. Effect on crop growth and soil water. Australian Journal of experimental agriculture 47 689-699

Armstrong RD, Eagle C, Flood R, (2015) Improving grain yields on a sodic clay soil in a temperate medium rainfall cropping environment Crop and Pasture Science 66 492-505

Blackwell P, Hagan J, Davies S, Riethmuller G, Bakker D, Hall D, Knight Q, Lemon J, Yokwe S & Isbister B (2013) Pathways to more grain farming profit by CTF in WA https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2013/04/pathways-to-more-grain-farming-profit-by-ctf-in-wa

Barends E, Rousseau DM, Briner RB (2014) Evidence-Based Management, The Basic Principles, Amsterdam, Center for Evidence-Based Management, Amsterdam

Celestina C, Midwood J, Sherriff S, Trengove S, Hunt J, Tang C, Sale P and Franks A (2018) Crop yield responses to surface and subsoil applications of poultry litter and inorganic fertiliser in south-eastern Australia Crop and Pasture Science 69(3):303-316. 2018

Condon G and K (2016) Controlled traffic farming the costs and the benefits https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2016/02/controlled-traffic-farming-the-costs-and-benefits

GRDC (2009) How to put precision agriculture into practice. Precision Agriculture Factsheet Grains Research and Development Corporation, Canberra

GRDC RDP00013 (2016), Project Report for The integration of technical data and profit drivers for more informed decisions, authored by Rural Directions Pty Ltd, Macquarie Franklin, Meridian Agriculture, Agripath, and Corporate Agriculture Australia

GRDC RDP00013 (2015), Output 8 – Potential trade-offs between scale and precision use of inputs, authored by Rural Directions Pty Ltd, Macquarie Franklin, Meridian Agriculture, Agripath, and Corporate Agriculture Australia

GRDC (2017) Southern Regional Annual Report: Regional Cropping solutions network 2016-2017

GRDC (2006) Precision Agriculture Manual Part 1: Precision Agriculture Manual – http://www.grdc.com.au/Resources/Publications/2006/08/PA-Manual-2006

Hall D (2017) Economic analysis of the impacts and management of subsoil constraints report https://www.agric.wa.gov.au/managing-soils/economic-analysis-impacts-and-management-subsoil-constraints-report

Harding A, I'Anson K, Hughes B, Masters B, Herrmann T, (2018), Advancement of precision soil pH mapping in South Australia, 2018 SPAA symposium

Hochman Z, Gobbett D, Horan H, Garcia JN (2016). Data rich yield gap analysis of wheat in Australia. Field Crops Research 197, 97-106.1

Humpal J, McCarthy C, Thomassen JA, Percy C (2018). Machine vision learning for crop disease and quality parameters, 2018 SPAA Symposium

Inchbold A, Whelan B, Baines P (2009) Making Money out of Precision Agriculture Results from the Riverine Plains Inc project Improving Winter Cropping Systems in the Riverine Plains Project funded by GRDC In collaboration with ACPA https://riverineplains.org.au/wp-content/uploads/2015/05/RPI-Making-Money-out-of-Precision-Agriculture-2009.pdf

Kingwell R and Fuchsbichler A (2011) The whole farm benefits of controlled traffic farming: An Australian appraisal, Agricultural Systems, Volume 104 Issue 7

Lawes R, Chen C and Van Rees H (2018). The National Paddock Survey — what causes the yield gap across Australian paddocks? GRDC Update Perth WA February 2108 https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2018/02/the-national-paddock-survey-what-causes-the-yield-gap-across-australian-paddocks

Lawes RA and Kingwell RS (2012) A longitudinal examination of business performance indicators for drought-affected farms Agricultural Systems 106 94-101

Lawes RA and Robertson MJ (2011) Whole farm implications on the application of variable rate technology to every field, Field Crops Research 124 142-148

Leonard E (Ed), Rainbow R (Ed), Trindall J (Ed), Baker I, Barry S, Darragh L, Darnell R, George A, Heath R, Jakku E, Laurie A, Lamb D, Llewellyn R, Perrett E, Sanderson J, Skinner A, Stollery T, Wiseman L, Wood G and Zhang A (2017). Accelerating precision agriculture to decision agriculture: Enabling digital agriculture in Australia. Cotton Research and Development Corporation, Australia

Llewellyn RS and Ouzman J (2015) Adoption of precision agriculture related practices: status, opportunities and the role of farm advisers CSIRO www.csiro.au

GRDC

McCallum MH (2008) Farmer Case studies on the Economics of PA Technologies, Society of Precision Agriculture Australia www.spaa.com.au

Miller L (2015) Making better liming decisions https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2015/03/making-better-liming-decisions

Oliver YM, Robertson MJ, Wong MTF (2010) European Journal of Agronomy 32 (1) 40-50

Robertson M, Carberry P and Brennan L (2007) The economic benefits of precision agriculture: case studies from Australian grain farms, CSIRO for GRDC

Robertson M, Kirkegaard J, Rebetzke G, Llewellyn R and Wark T (2016). Prospects for yield improvement in the Australian wheat industry: a perspective Food and Energy Security 2016, 5(2):107–122

Sale P, Armstrong R, Wilhelm N, Davenport D, Tavvakoli E, Dean G, Desboiles J, O'Leary G, Malcom B, Celestina C (2016) Scoping Review for GRDC Project DAV00149 Understanding the amelioration processes of the subsoil application of amendments in the Southern Region

Sauer B, Wells T, Wells M, Neale T, Smart A, D'Emden, F (2013) Applying PA. A reference guide for the modern practitioner. Grains Research and Development Corporation, Canberra

Society of Precision Agriculture Australia (2008) PA in Practice, grain growers experience of using variable rate and other PA technologies. www.spaa.com.au

Society of Precision Agriculture Australia (2011) PA in Practice 2 Society of Precision Agriculture Australia. www.spaa.com.au

Torpy B (2013), Precision Ag News, Society of Precision Agriculture Australia Volume 9 Issue 2, www.spaa.com.au

Trengove S (2013), Potential for Site Specific Management of Lolium Rigidum (Annual Ryegrass) in Southern Australia, University of Adelaide

Trengove S (2016) – Users Guide for Site Specific Weed Management, SAGIT (unpublished)

Trengove S (2018) Where does PA fit in the Upper North?, presented at Upper North Farming Systems group August 2018

Umbers A (2017) GRDC Farm Practices Survey Report 2016. Grains Research and Development Corporation, Canberra

Whitlock A (2015) pH Mapping and Variable Rate Lime – 50,000 plus Hectares of Experience https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2015/08/ph-mapping-and-variable-rate-lime-50000-plus-hectares-of-experience

Whitlock A (2018) Utilising-spatial-data-for-within-paddock-soil-and-crop-management https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2018/03/utilising-spatial-data-for-within-paddock-soil-and-crop-management

Whitlock A and Torpey B (2017) Using precision agriculture technologies for drainage solutions https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2017/02/using-precision-agriculture-technologies-for-drainage-solutions

Whelan B and Taylor J (2010) PA Education and Training Modules for the Grains Industry. for the Australian Centre for Precision Agriculture, University of Sydney Grains Research and Development Corporation

Wong MTF, Asseng S, and Zhang H (2006), A flexible approach to managing variability in grain yield and nitrate leaching at within-field to farm scales Precision Agriculture Volume 7, Issue 6, pp 405–417 |

Wong MTF and Harper RJ (1999) Use of on-ground gamma-ray spectrometry to measure plant-available potassium and other topsoil attributes Soil Research, 37 (2) 267-278

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