



Adoption of precision agriculture-related practices: status, opportunities and the role of farm advisers

Rick Llewellyn, CSIRO
Jackie Ouzman, CSIRO

December 2014

Report for Grains Research and Development Corporation

[CSIRO

Agriculture Flagship]

Copyright and disclaimer

© 2015 CSIRO To the extent permitted by law, all rights are reserved and no part of this publication covered by copyright may be reproduced or copied in any form or by any means except with the written permission of CSIRO.

Important disclaimer

CSIRO advises that the information contained in this publication comprises general statements based on scientific research. The reader is advised and needs to be aware that such information may be incomplete or unable to be used in any specific situation. No reliance or actions must therefore be made on that information without seeking prior expert professional, scientific and technical advice. To the extent permitted by law, CSIRO (including its employees and consultants) excludes all liability to any person for any consequences, including but not limited to all losses, damages, costs, expenses and any other compensation, arising directly or indirectly from using this publication (in part or in whole) and any information or material contained in it.

Contents

Contents	3
Acknowledgments	7
Executive summary.....	8
1 Introduction	11
2 Method.....	12
2.1 Data.....	12
2.2 Analysis	15
3 Results	16
3.1 Farm and grower characteristics	16
3.2 Adoption of cropping practices.....	17
3.3 Awareness and perceptions of adopters and non-adopters	24
3.4 Skills, education and agronomic advisers	29
3.5 Grower to grower and adviser to grower recommendations	35
3.6 Identifying factors associated with adoption	41
4 Conclusions	44
5 Appendix	45
5.1 Grower and farm characteristics	45
5.2 Adoption of precision agriculture practices.....	51
5.3 Regression analysis – factors associated with adoption.....	59
5.4 Survey script.....	63
References.....	74

Figures

Figure 1 Regions included in grower survey.....	12
Figure 2 Distribution of respondents per statistical local area.....	13
Figure 3 Adoption of precision agriculture practices over time.....	19
Figure 4 Proportion of growers using auto steer over time by region.....	20
Figure 5 Proportion of growers over time who have collected yield map data by region.....	20
Figure 6 Proportion of growers varying fertiliser on identified paddock zones over time by region.....	21
Figure 7 Proportion of growers with variable rate capable seeding equipment over time by region.....	21
Figure 8 Expected extra cost to become equipped for using variable rate technology for growers with a range of existing equipment.....	24
Figure 9 Expected percentage increase in profitability of their average wheat crop if they were (or do) apply different fertilizer rates on different soils within paddocks instead of using a uniform rate (mean % gain).....	28
Figure 10 Proportion of growers expecting gains of greater than 15% in profitability of their average wheat crop if they were (or do) apply different fertilizer rates on different soils within paddocks instead of using a uniform rate (% all growers).....	28
Figure 11 Proportion of growers paying for agronomic advice over time.....	31
Figure 12 Major sources of agronomic advice for growers including paid, unpaid, retail and state government.....	33
Figure 13 Percentage of growers with a major source of agronomic advice that offers precision agricultural related services such as mapping, prescription maps, paddock zoning maps; managing spatial data from your paddocks; technical services for PA equipment.....	33
Figure 14 Proportion of growers rating the skills of their major source of agronomic advice as ‘strong’ ² for precision agriculture skills (dark blue) and crop nutrition (light blue).....	34
Figure 15 Proportion of growers using autosteer that would recommend autosteer to other interested growers in their district.....	36
Figure 16 Proportion of growers yield mapping that would recommend yield mapping to other interested growers in their district.....	36
Figure 17 Proportion of growers varying fertiliser rates within paddock (VR) that would recommend it to other interested growers in their district.....	37
Figure 18 Input from agronomy advisers relating to grower consideration of varying fertiliser rates on different soils within paddocks.....	38
Figure 19 Input from agronomy advisers relating to grower consideration of yield mapping.....	38
Figure 20 Input from agronomy advisers relating to grower consideration of paddock mapping such as NDVI, EM or Gamma.....	39
Figure 21 Input from agronomy advisers relating to grower consideration of variable rate technology.....	39
Figure 22 Input from agronomy advisers relating to grower consideration of soil sampling for nutrient testing.....	40
Figure 23 Range of farm sizes of respondents by region.....	46
Figure 24 Proportion of growers who have used no-till over time.....	47
Figure 25 Age group of respondents.....	48

Figure 26 Expectation that the farm business will continue to be run by a family member after retirement of respondent.....	48
Figure 27 Percentage of growers that have ever joined a PA group or association with a focus on precision agriculture. Values on top of the bars indicate the % of farmers still associated with such a group.	50
Figure 28 Proportion of growers who have auto steer over time by region.....	52
Figure 29 Proportion of growers collecting yield map data over time by region.	54
Figure 30 Proportion of growers using different fertilizer rates on different soils within paddocks (VR) over time by region.	56
Figure 31 Proportion of growers with seed machinery equipped with VRT over time by region.	57

Tables

Table 1 Regions represented in this study and example districts with distribution of 573 respondents.....	14
Table 2 Summary statistics for respondents (n=573).....	16
Table 3 Adoption of yield mapping, use of variable fertiliser rates on identified zones and use of variable rate technology (% growers who have used practice).	18
Table 4 Adoption of autosteer, soil testing and no-till cropping (% growers who have used practice).	18
Table 5 Stated expectations as to whether the practice is expected to be used in 5 year time (% of all respondents including current adopters).....	22
Table 6 Proportion of growers with electromagnetic or gamma soil maps of their paddocks (soil maps) and normalised difference vegetation index (NDVI) based (including satellite vegetation; crop circle; greenseeker). The proportion of VRT adopters with the maps is also shown in parentheses.	23
Table 7 Perceptions relating to precision agriculture and variable rate costs and benefits showing proportion agreeing with statement (% of growers who agree or strongly agree).	26
Table 8 Percentage of growers paying for advice, and expect to be paying in the future. For farmers using advisors number of visits per year and amount spent.	30
Table 9 Perceptions of growers relating to management skills and preferences showing proportion agreeing with statement (% of growers who agree or strongly agree).	32
Table 10 Factors associated with yield mapping – showing significant factors from regression analysis. Factors having negative influence shown in red.	41
Table 11 Factors associated with adoption of autosteer – showing significant factors from regression analysis. Factors having negative influence shown in red.	42
Table 12 Factors associated with adoption of varying fertiliser rates within paddocks (VR) and use of variable rate technology (VRT) – showing significant factors from regression analysis. Factors having negative influence shown in red.	43
Table 13 Classification of farm type and relative importance of cropping compared to sheep, including stated respondent preference for cropping or sheep if forced to choose one.	45
Table 14 Age of existing seeding and harvesting machinery and use of no till.....	46
Table 15 Age of youngest person managing the farm, education and number of years expected to be farming into the future.....	49

Table 16 Percentage of autosteer adopters, stated adoption in 5 years time and average year of awareness of a grower in district using autosteer and adoption of auto steer per region.	51
Table 17 Percentage of yield map adopter, future adopters and average year of awareness of a grower with yield maps in district and adoption of yield map per region.	53
Table 18 Percentage of adopters, expected adopters in 5 years time (as stated by growers) and percentage of crop area treated with varying fertiliser rates on different soils within a paddock (VR), use of variable rate technology to apply varying fertiliser rates on different soils within a paddock and those with VRT-equipped seeding machinery.....	55
Table 19 Use of soils sampling for nutrient testing.	58
Table 20 Factors associated with yield mapping – regression analysis.....	60
Table 21 Factors associated with adoption of autosteer – regression analysis.....	61
Table 22 Factors associated with adoption of varying fertiliser rates within paddocks (VR) and use of variable rate technology (VRT) – regression analysis.....	62

Acknowledgments

The authors would like to thank the grain growers who contributed data to this project and the cooperation and input of a large number of agronomists, consultants and growers throughout Australia, including the SPAA-Precision Agriculture Australia through Nicole Dimos and Sam Trengove. Geoff Kuehne, Brendan Lynch, Marit Kragt, and David Gobbett contributed significantly to associated components of this project, including collaborations involving the University of Western Australia and University of Adelaide. Feedback from Rob Bramley is also gratefully acknowledged.

Executive summary

It can take many years before new farming practices are adopted by all of the farmers who will potentially benefit from them. In many cases it can be difficult to learn whether there is or will be benefit at all, and to whom. The need to consider the benefits for a diverse and constantly evolving population of potential adopters from innovations with uncertain and evolving characteristics makes the development of strategies to promote more rapid adoption of beneficial practices particularly challenging. Studies such as this one are aimed at better understanding the adoption process for particular innovations so that efforts to accelerate and increase the benefits from practice change can be better informed.

Precision agriculture-related practices but have been the subject of considerable effort aimed at understanding and increasing its application in Australian cropping. Practices involving spatial management such as variable rate technology are still at the relatively early stage when information, learning and extension can be at its most influential. This can provide opportunities for effectively targeted adoption strategies.

The study examines trends in adoption of practices such as variable rate fertiliser applications, yield mapping, EM, Gamma and NDVI mapping, autosteer and soil testing together with the use of agronomy advisers. Using data from interviews conducted in 2012 with 573 grain growers from 12 regions of the Australian cropping belt in Western Australia, South Australia, Victoria and southern New South Wales, perceived characteristics of the practices are identified along with future adoption intentions. The factors with the strongest influence on adoption are identified using regression analysis and opportunities to target particular characteristics to accelerate adoption are identified.

Key findings:

The adoption and local learning process for variable rate technology is still relatively young. For example, 52% of all respondents were unaware of a grower in their district using variable rate technology (VRT) before 2006.

The adoption of autosteer is approaching what appears to be peak levels of around 90% of growers in many districts after particularly rapid uptake since 2004. Relative to the other innovations, autosteer is a relatively simple innovation which is not information intensive and not highly influenced by farm characteristics. Its readily apparent benefits are a reason for its rapid adoption. This is demonstrated by 94% of users stating that they would recommend its use to other local growers. This compares to 77% of those with yield maps; 80% of those varying fertiliser rates and less than 60% of those with NDVI, EM or Gamma maps being willing to recommend the practices to other local farmers.

The proportion of growers who collect crop yield maps varies greatly between regions, ranging from around 20% to over 40%. Use of yield mapping is increasing but only about half of growers with a yield monitor collect yield map data. This suggests that acquisition of yield monitoring equipment is occurring as rapidly as grower capacity or motivation to collect and process yield data.

Overall, 35% of growers are equipped with VRT equipment but only 15% use VRT with only a few regional exceptions above 20% adoption such as in the Vic Mallee. A higher proportion of growers vary fertiliser rates within paddocks according to soil type (49%) and this exceeds 65% in Vic Mallee, Upper Eyre Peninsula and WA North Central, but does not necessarily involve precision agriculture technology.

The cost that growers expect to incur to make VRT seeding equipment operational is typically \$20,000 for those with the VRT seeding equipment and approximately \$100,000 for growers with no seeding equipment or yield mapping capacity. Cost expectations vary greatly between growers suggesting that this may be worth exploring as an opportunity where shared information may be effective.

Soil (e.g. EM and Gamma) and vegetation maps (NDVI) remain uncommon overall, but are far more common among VRT users with a majority of VRT users having an EM or gamma map in several regions.

While increases are evident and expected in all regions, extensive adoption of spatial management practices should not be expected to result across all regions. Adoption of variable rate technology for fertiliser management is likely to remain far more variable between regions than other technologies such as autosteer or no-till. Overall, over 40% of growers believe they don't have sufficient variability to justify variable rate, indicating a substantial existing 'cap' on current potential for this particular practice. In some regions such as Vic Wimmera this is as high as 60%. In other regions there appears to be substantial potential for greater adoption of VRT in the short-medium term future as 'lags' relative to regions with similar land types are overcome (e.g. SA Mallee compared to Vic Mallee).

Both adopters and non-adopters generally have modest expectations of the percentage increase in profitability of their average wheat crop if they apply different fertilizer rates on different soils within paddocks instead of using a uniform rate (typically 10%). SA Mallee and SA Upper EP have a substantial proportion of growers expecting wheat profitability gains of at least 15% as a result of varying fertiliser use.

Only 33% agree that there is insufficient technical support available for precision agriculture technology, although some regions such as WA Sth Central (45%) have far more growers perceiving a lack of support than its neighbouring region of WA Southern (22%). Rather than being an obvious factor influencing the decision to adopt, adopters of VRT (49%) are more likely to perceive a lack of support for PA technology than non-adopters (31%). Overall 64% of growers rate the precision agriculture skills of their major source(s) of agronomic advice as strong (compared to 90% of growers rating the crop nutrition skills of their major sources of agronomic advice as strong).

Overall, 46% had a major source of agronomic advice that offered precision agriculture-related services such as mapping, prescription maps, paddock zoning maps; managing spatial data and/or technical services for PA equipment. Vic Mallee (63%) and Nth Central WA (63%) had the highest proportion. Together with use of a paid consultant, having a major source of agronomy advice was very strongly associated with the likelihood of adopting VRT in the next 5 years.

A major finding of this study relates to the very strong association between use of agronomy advisers and adoption. To explore the relationship further, the level of recommendation coming from growers' major source(s) of agronomic advice were explored. Advisers were rarely found to recommend against a practice and in many cases it is most common for precision agriculture practices not to be discussed at all. Adviser input into discussion around mapping is not common overall, but is more frequent in NSW Riverine Plains, SA and Vic Mallee and WA Southern. An adviser suggesting a practice be considered by a grower is common enough to suggest it helps to explain the significant influence of advisers on adoption. Yield mapping has been suggested frequently to growers by advisers in WA Nth Central and VR has been commonly suggested for consideration by growers in SA and Vic Mallee. Varying fertiliser rates within paddocks (VR) is more commonly discussed than use of VRT. Where there is potential for profitable adoption but a low level of advisory support with PA capacity, lags in adoption of yield mapping and VR/VRT can be expected.

Factors relating to computer data management and maintaining simplicity were commonly found to significantly influence the likelihood of adoption of spatial management practices. Having a younger person involved on the farm was only found to significantly increase the likelihood of adoption in the case of autosteer.

Growers with a relatively strong preference for keeping their farming operations simple are significantly less likely to have adopted yield mapping, VR or VRT, or expect to adopt VRT in the next 5 years. Farm businesses that have someone with strong computer skills and motivation for data analysis are more likely to be adopters. The influence of the perceived ability to readily zone paddocks is also shown to be important.

In summary, adoption of all practices is increasing but unlike autosteer, adoption of spatial management practices cannot be expected to be similarly rapid or extensive across all regions. Regional differences are highly significant and not all have been captured by the variables identified in this study. Many influential

factors are associated with information, learning and management demands. This includes the role of agronomy advisers and support for precision agriculture in assisting growers to achieve the common goal of maintaining simplicity in farming operations. While benefits are commonly expected, growers are generally not expecting a major step gain in profitability from adoption of current precision agriculture practices and considerable information processing and learning is likely to be involved. This means that rapid adoption of spatial management practices has not occurred and should not be expected, even in regions where the role of spatial management is most obvious. However, the results do demonstrate potential for accelerated adoption where advisory support with is present and in alignment with adoption potential and relevant on-farm skills. More generally, large differences in use of agronomy advisory support exist between regions. This study reinforces the conclusions of previous studies of adoption in the Australian grains industry that use of agronomy advisory support is strongly associated with more rapid adoption of cropping practices.

1 Introduction

Many involved in research and extension become frustrated about the slow or low rate of uptake of a new technology by farmers. More often than not there are a number of understandable reasons why adoption by farmers does not always take the shape that the R&D community might have initially expected (Pannell et al 2006).

By understanding more about the farmer perspective R, D & E can be better targeted to lead to better outcomes. Further, farm advisors are playing an increasing role in decisions to change farm practice and have been shown to be strongly associated with more rapid adoption of some farming systems practices (e.g. D'Emden et al 2008). This study also examines the role and influence of agronomy advisers.

Using practices associated with precision agriculture as a case study, the trends in uptake of new technologies as well as advisory support are captured. The precision agriculture practices involve a range of characteristics from the relatively simple to the information intensive, with the latter being the main focus of the study (Bramley 2009, Robertson et al 2012). The survey does not attempt to represent all grain growing regions of Australia but instead focuses on 12 selected regions from southern New South Wales, Victoria, South Australia and Western Australia. These provide contrasts between agro-ecological characteristics as well as the opportunity to compare differences between neighbouring regions.

The study aims to:

1. Increase knowledge and understanding of levels and trends in adoption of key practices in cropping regions, in this case precision agriculture-related practices, through the analysis of socio-economic and practice use data collected from Australian grain growers.
2. Identify key factors influencing capacity and decisions to adopt or not adopt key practices and approaches, including the role of advisers.
3. Recognise attitudes and perceptions that are both influential in the adoption decision and can potentially be influenced by targeted R, D & E activities.
4. Inform strategies for increasing the capacity of growers to adopt new practices and achieve more rapid farming systems improvement.

Adoption status and trends are presented along with characteristics and perceptions relating to adoption of precision agriculture practices in particular. Differences between adopters and non-adopters are shown. To better explore factors likely to be associated with and possibly influence adoption, regression analysis is included with models able to predict the likelihood of adoption of precision agriculture practices. This allows a range of factors to be considered together and those that are most strongly associated with adoption to be identified.

Using the examples of precision agriculture practices, several insights into the potential for improving the rate of adoption of profitable practices by grain growers are generated, including the current and potential role of agronomy advisers.

2 Method

2.1 Data

A telephone survey was conducted in August-October 2012 with the primary cropping decision maker from broadacre grain farms across 12 southern and western grain growing regions in Australia (Figures 1 & 2 and Table 1). Farmers in each region were randomly selected from a comprehensive data base of grain growers until the target number of respondents for each region was reached. Only those growing more than 500ha of grain were selected.

The 573 respondents represent 24% of all farm businesses contacted. 45% of farm businesses contacted elected not to take part and 31% agreed to take part but the primary cropping decision maker was not available to complete the questionnaire at the time of the initial call and the regional respondent quota had been filled before a call back was made.

The survey collected data on respondents' adoption of a range of farming practices including precision agriculture, no-till, soil testing and use of farm advisers, as well as general data about farm size and enterprise mix, and farmer demographics, attitudes and perceptions (see appendix).

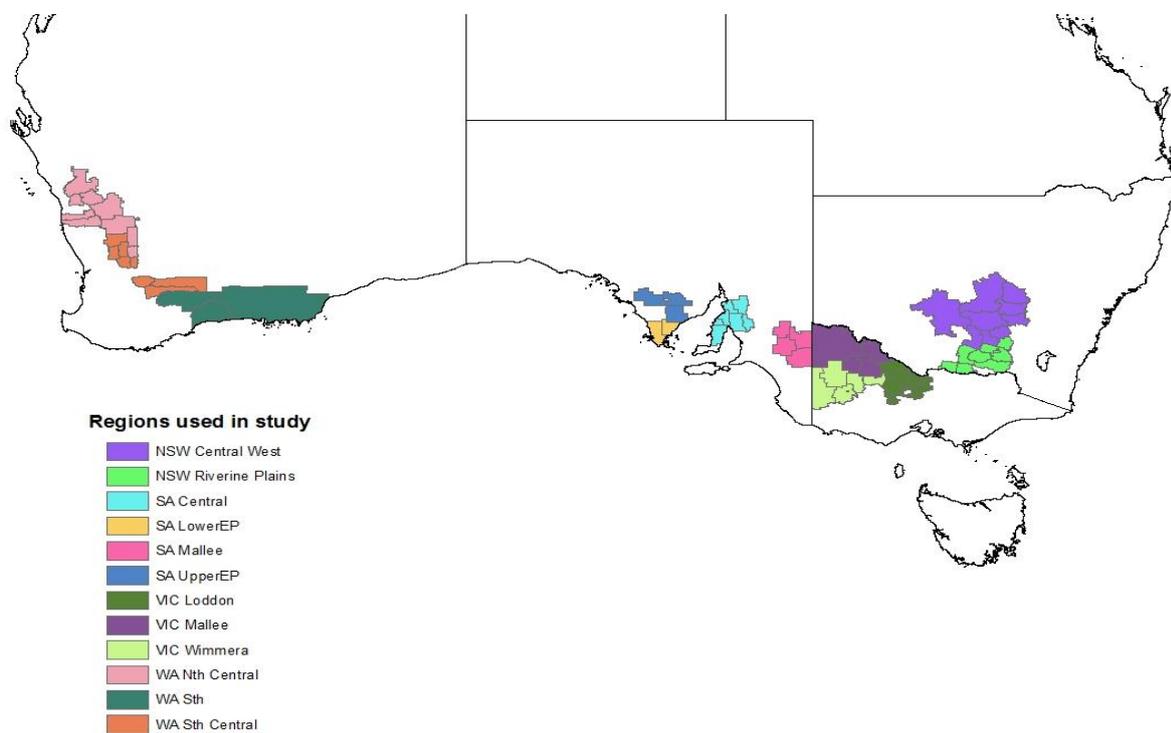


Figure 1 Regions included in grower survey

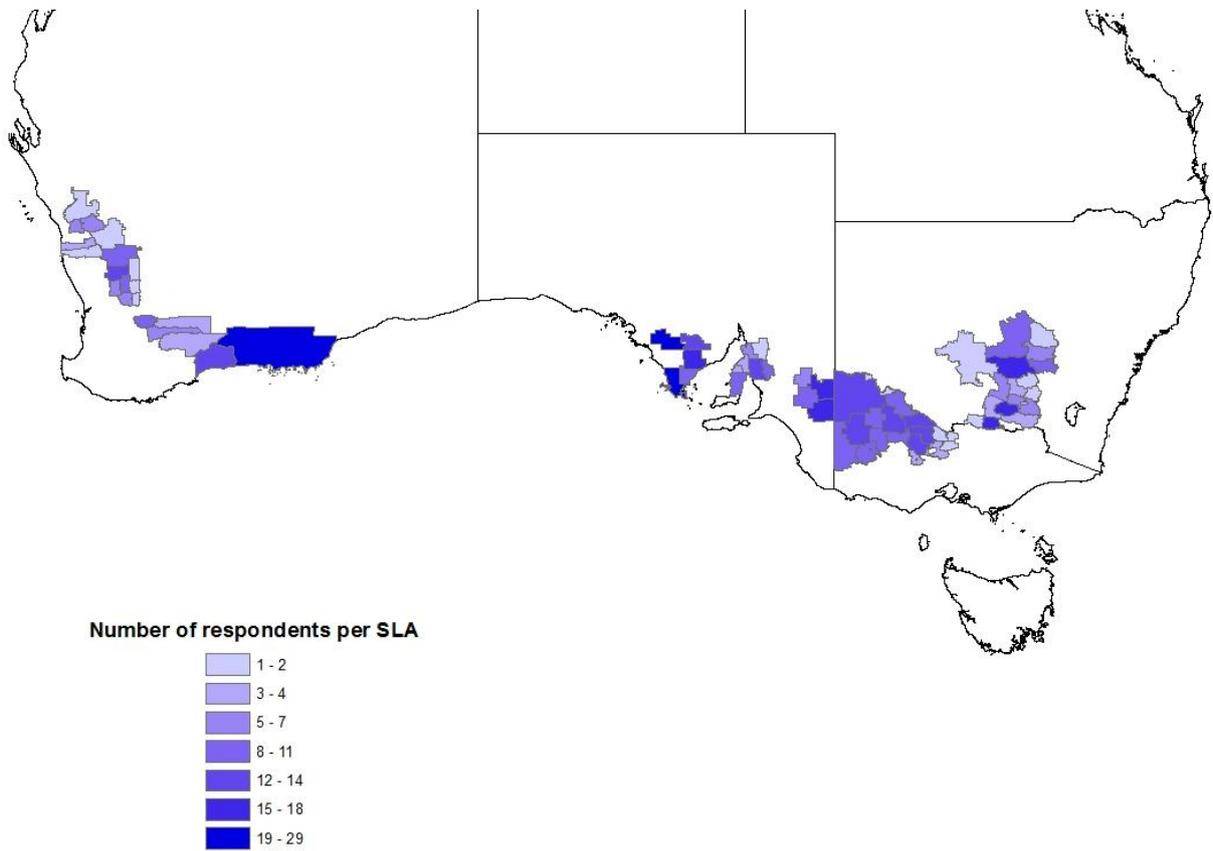


Figure 2 Distribution of respondents per statistical local area.

Table 1 Regions represented in this study and example districts with distribution of 573 respondents

Region	Respondents	ABS Statistical Local Areas
NSW Central West	53	Bland ; Forbes ; Lachlan ; Parkes ; Weddin ; Coolamon ; Narrandera ; Temora ; Carrathool
NSW Riverine Plains	50	Wagga Wagga - Pt A ; Junee ; Lockhart ; Wagga Wagga - Pt B ; Corowa Shire ; Greater Hume Shire - Pt B ; Urana ; Berrigan
NSW	103	
VIC Mallee	52	Yarriambiack - North; Mildura - Pt A; Buloke - North; Mildura - Pt B; Swan Hill - Robinvale; Swan Hill Bal
VIC Wimmera	51	Horsham Bal ; West Wimmera ; Hindmarsh ; Yarriambiack - South ; Bulok - South
VIC Loddon	50	Gannawarra ; C. Goldfields Bal ; Gr. Bendigo- Pt B ; Loddon - North ; Loddon - South ; Campaspe - Echuca ; Campaspe - Kyabram ; Campaspe - Rochester ; Campaspe - South
VIC	153	
SA Mallee	50	Loxton Waikerie - East ; Loxton Waikerie - West ; Karoonda East Murray ; Southern Mallee
SA Central	52	Barunga West ; Copper Coast ; Yorke Peninsula - North ; Clare and Gilbert Valleys ; Wakefield ; Northern Areas ; Port Pirie
SA UpperEP	51	Cleve ; Kimba ; Wudinna
SA LowerEP	36	Lower Eyre Peninsula ; Tumby Bay
SA	189	
WA Nth Central	36	Dalwallinu ; Koorda ; Wyalkatchem ; Carnamah ; Coorow ; Mingenew ; Morawa ; Mullewa ; Perenjori
WA Sth Central	47	Wongan-Ballidu ; Corrigin ; Kondinin ; Kulin ; Cunderdin ; Dowerin ; Goomalling ; Tammin
WA Sth	45	Lake Grace ; Esperance ; Ravensthorpe
WA	128	

2.2 Analysis

The data collection involved a range of formats including continuous, binary, categorical and ordinal variables so a range of statistical tests were required to test for significant differences. Where possible t-tests were used. However, some of the continuous data did not meet criteria for normal distribution so non-parametric tests based on differences in medians are specified. Pearson chi-square tests were used for most binary and categorical data.

To allow data to be presented consistently and succinctly for ease of interpretation, means have generally been presented. Therefore in some cases means are presented where the statistical test used a median-based method. For binary and other categorical data, not all categorical response proportions are always shown.

Where differences between adopters and non-adopters at the regional level were statistically significant, these were reported in the text indicated by * $P < 0.1$; ** $P < 0.05$ and *** $P < 0.01$.

In many cases the ability to statistically test differences at the regional level was limited by the low number of users or non-users and some care should be taken in interpreting results. A low number of observations in a region may be the reason why a difference was not found to be significant and therefore not presented in the tables.

Diffusion curves (cumulative adoption over time) were generated using the growers' stated year of first use of a particular practice on their farm. As they are based on recall they should be considered approximate. Particularly for early times of adoption it should be noted that the figures represent the time of first use of some no-till by the current farming population. For example, the total farming population a decade ago was different to the farming population now so the percentage of respondents shown to be using a practice in the figures may not reflect the percentage of growers who were farming during that period using the practice. The adoption curves also do not take into account potential disadoption or extent of use once adopted. Extent of use is addressed in other tables.

Regression analysis to identify factors significantly associated with the likelihood of adoption was performed using logit models with binary adoption variables.

3 Results

3.1 Farm and grower characteristics

The summary statistics for the respondents suggests that a representative sample of commercial grain growers has been achieved, including substantial representation of mixed farmers (Table 2). More summary statistics characterising respondents by region and the large variation between regions are included in the Appendix.

Table 2 Summary statistics for respondents (n=573)

Variable	Mean	Std. Dev.
Total arable area(ha)	2541	2111
Crop area (ha)	1805	1605
Proportion arable area cropped (%)	64.01	25.41
Age (3= 35-44; 4=45-54; 5=55-64)	4.39	1.05
Income from crop (% of total)	73.7	22.73
Income from sheep (% of total)	22.1	19.78

3.2 Adoption of cropping practices

3.2.1 YIELD MAPPING, VARIABLE RATE AND AUTOSTEER

Figure 3 shows the differences in time of adoption for several PA technologies and practices across all regions and demonstrates the exceptional rate of adoption of autosteer (Figures 3-4). The proportion of growers with who collect crop yield maps varies greatly between region, ranging from around 20% in NSW Central West, SA Mallee and Vic Loddon to over 40% in SA Lower EP, Vic Mallee and two WA regions (Table 3). Adoption is still steadily increasing and has more than doubled over the past 10 years (Figure 3), including much more rapid increases in some regions (Figure 5). While the capacity to spatially monitor crop yields steadily increases, only about half of growers with a yield monitor collect yield map data. This gap does not appear to be closing, indicating that acquisition of yield mapping equipment (e.g. through new harvester purchase) is occurring as rapidly, or possibly more rapidly, than grower capacity or motivation to collect and process yield data.

The number of farmers varying fertiliser rates based on soil type within paddocks is substantial in several regions, particularly in lower rainfall regions such as Vic Mallee, SA Upper EP, SA Mallee and WA Nth (Table 3 and Figure 6). However, it is not necessarily always being done using variable rate technology (such as controllers, prescription maps etc) (Table 3). Figure 6 shows that there was substantial use of soil-specific fertiliser management prior to most precision agriculture technology becoming available and indicates that 'low-tech' variable rate fertiliser application continues.

Overall, 35% of growers overall are equipped with VRT seeding equipment capable of varying fertiliser rates (Figure 7), but only 15% use VRT. There are only a few regions with VRT use above 20% such as Vic Mallee (Table 4). Both of these indicators of precision agriculture adoption and soil-specific management do still show steadily increasing adoption over time in almost all regions (Figures 5 and 6). However, Figure 7 suggests that 'two-paced' adoption rates may be emerging between regions such as between the neighbouring regions of Vic Mallee, where there is clearer in-paddock variability to be managed, and Vic Wimmera, where growers find variability less apparent.

Table 3 Adoption of yield mapping, use of variable fertiliser rates on identified zones and use of variable rate technology (% growers who have used practice).

State	Region	Yield Mapping	Vary Fertiliser Rates	Variable Rate Technology
NSW	All	26	34	11
	NSW Central West	21	34	8
	NSW Riverine Plains	32	34	14
SA	All	30	52	15
	SA Central	27	42	12
	SA LowerEP	44	39	11
	SA Mallee	20	56	20
	SA UpperEP	31	67	18
VIC	All	33	50	16
	VIC Loddon	22	42	4
	VIC Mallee	50	75	37
	VIC Wimmera	27	33	6
WA	All	43	55	17
	WA Nth Central	53	67	25
	WA Sth	49	53	22
	WA Sth Central	30	49	6
All respondents		33	49	15

Table 4 Adoption of autosteer, soil testing and no-till cropping (% growers who have used practice).

State	Region	Autosteer	Soil testing	No-till
NSW	All	76	88	82
	NSW Central West	70	85	77
	NSW Riverine Plains	82	92	86
SA	All	79	71	84
	SA Central	92	87	87
	SA LowerEP	78	75	89
	SA Mallee	70	54	80
	SA UpperEP	75	71	82
VIC	All	74	81	86
	VIC Loddon	56	90	88
	VIC Mallee	88	75	77
	VIC Wimmera	76	78	92
WA	All	79	90	89
	WA Nth Central	89	89	89
	WA Sth	80	82	82
	WA Sth Central	70	98	96
All respondents		77	81	85

The surge in use experienced for GPS-based autosteer in the past 5-10 years is yet to be experienced for other practices (Figure 3). With the notable exception of Vic Loddon, autosteer also shows a much more consistent and high adoption pattern across regions (Figure 4) than other practices that are likely to be dependent on characteristics of in-paddock variability (Figure 6 & 7).

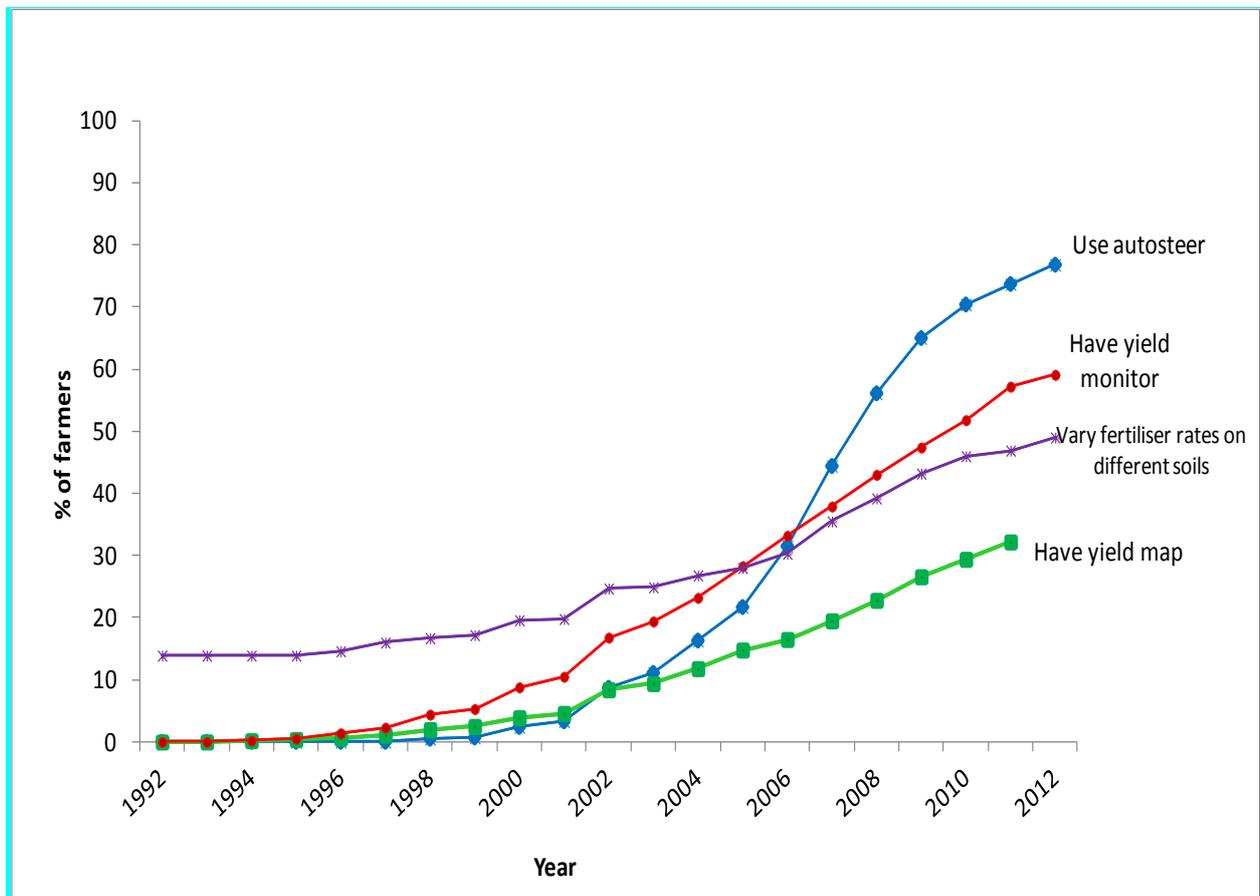


Figure 3 Adoption of precision agriculture practices over time

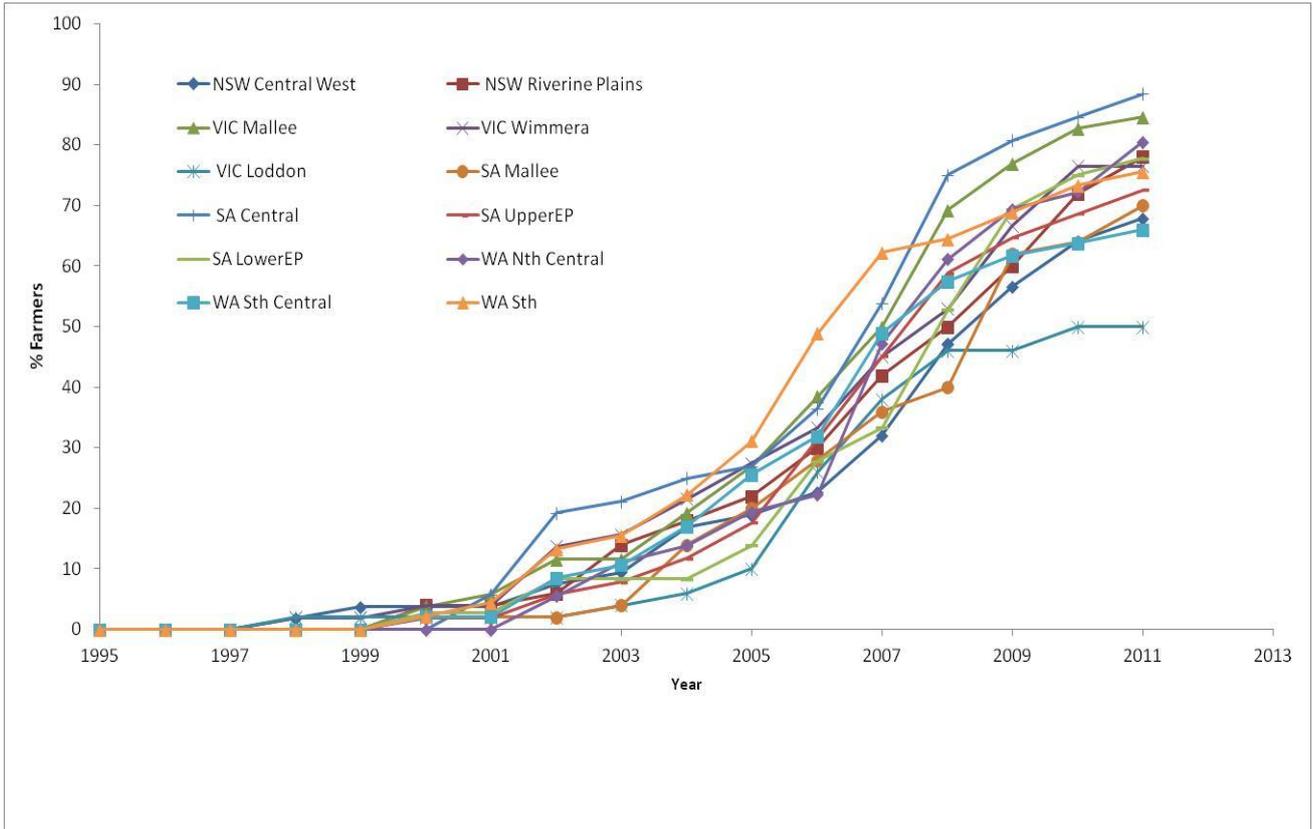


Figure 4 Proportion of growers using auto steer over time by region

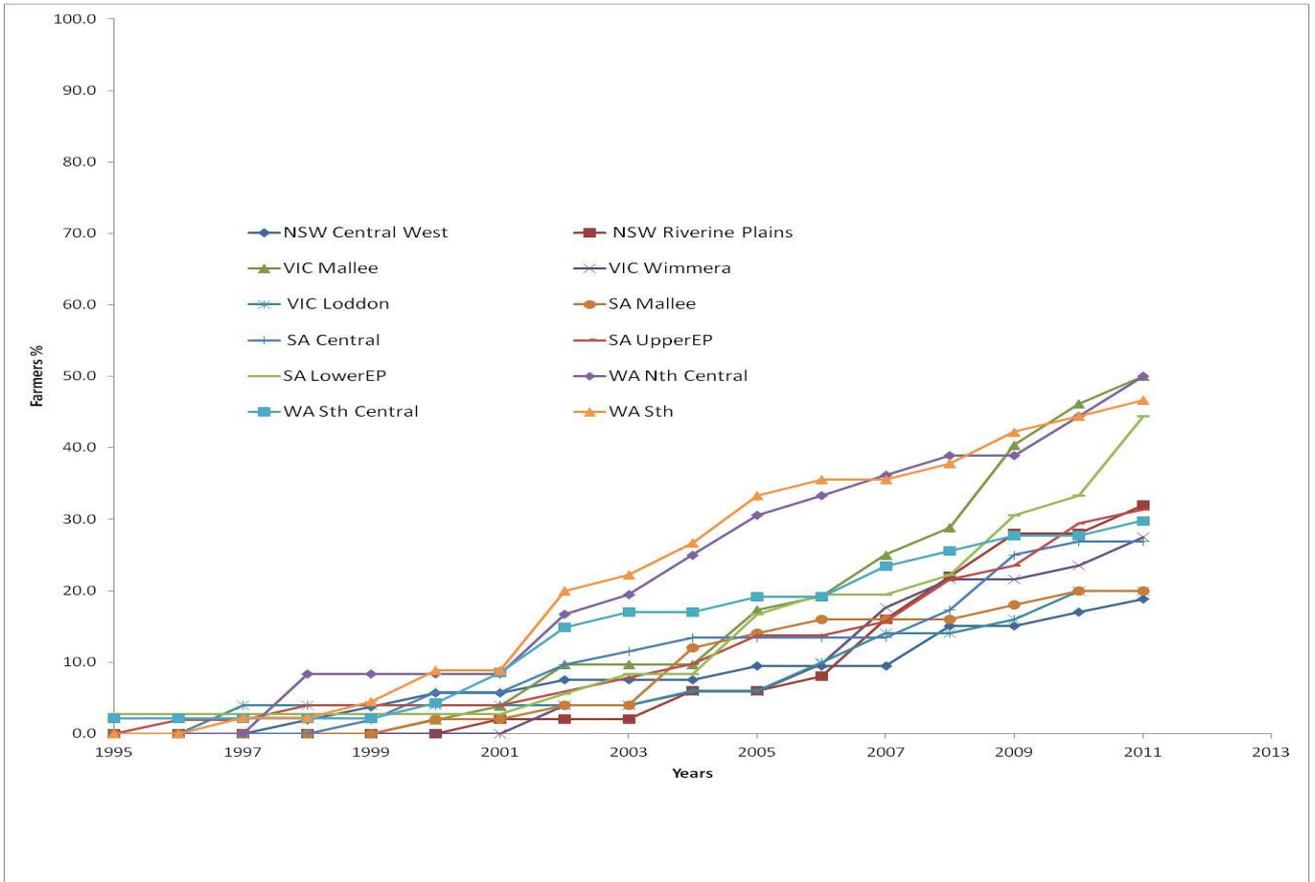


Figure 5 Proportion of growers over time who have collected yield map data by region

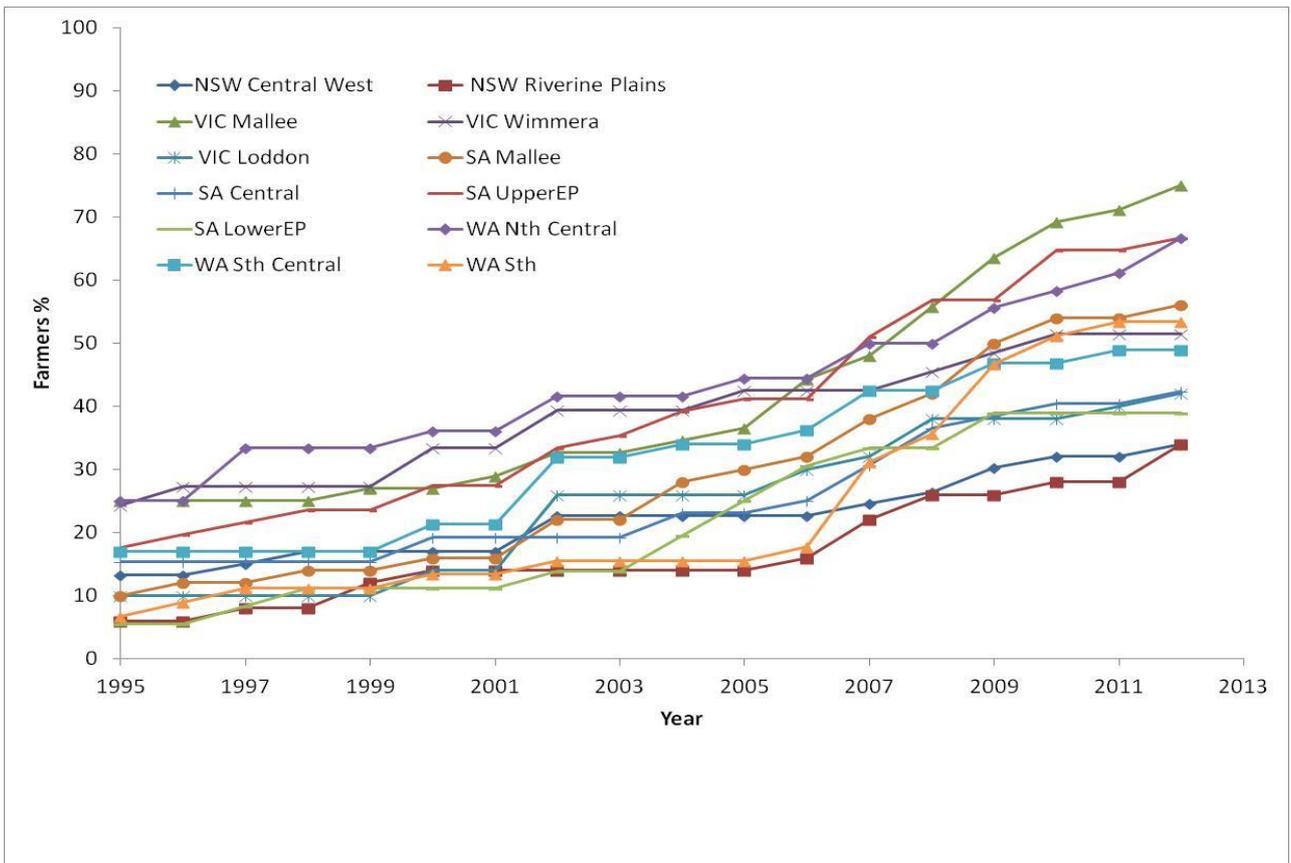


Figure 6 Proportion of growers varying fertiliser on identified paddock zones over time by region

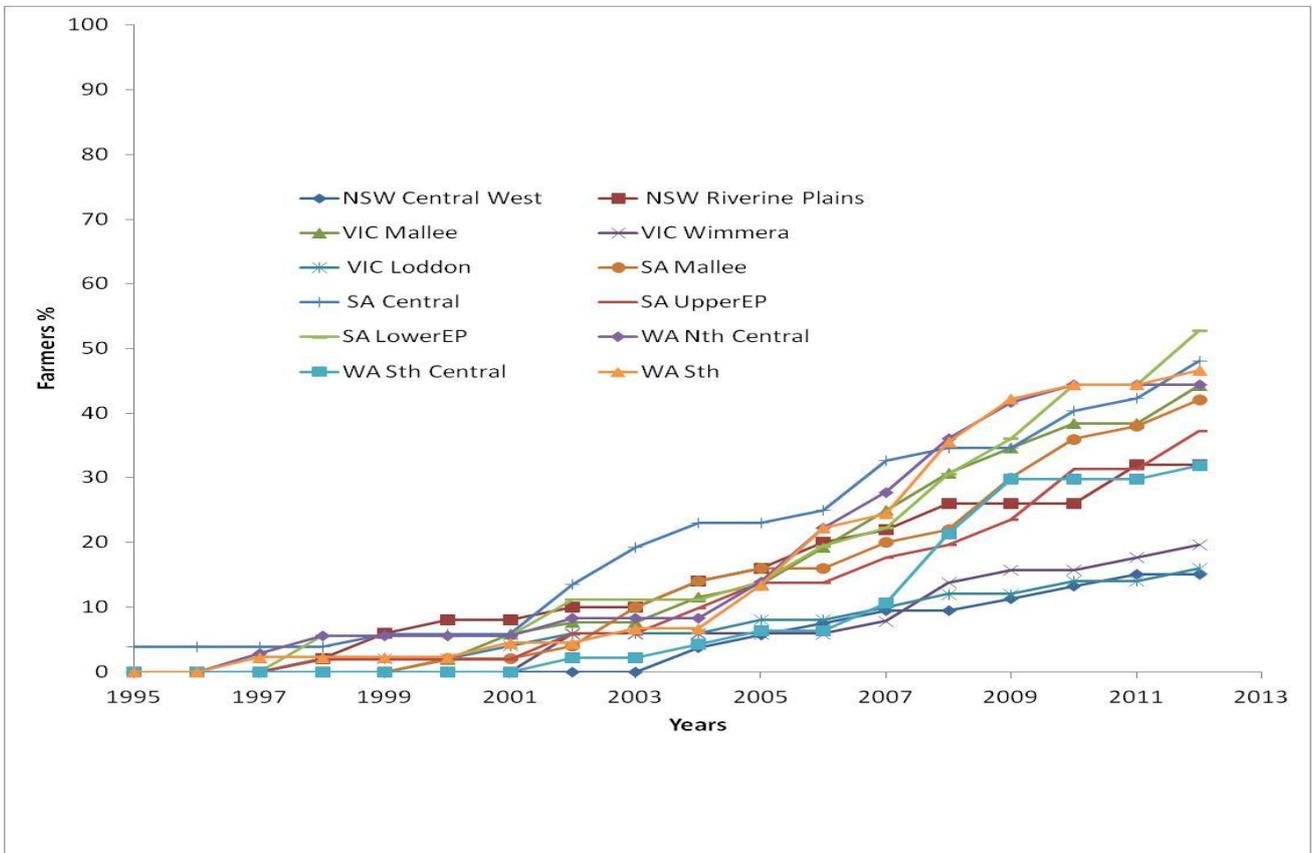


Figure 7 Proportion of growers with variable rate capable seeding equipment over time by region

Future adoption intentions

An indication of future adoption intentions was gained by asking growers if they expected to be using a practice in 5-years time. While this method is prone to ‘yeah-saying’ and inflates expected adoption figures, it does provide indications of relative differences between practices and regions. Overall, results shown in Tables 5 support the ongoing upward adoption trends for yield mapping and variable rate practices suggested by recent adoption patterns (Figures 3-7).

As indicated by current adoption trends, autosteer is already approaching peak adoption of close to 90%. Autosteer adoption in Vic Loddon is expected to increase but remain the lowest of the regions (Table 5).

Substantial increases in yield mapping are expected over the next 5 years (Table 5). Vic Wimmera, Vic Loddon and NSW Central West are expected to remain among the lowest users of variable fertiliser rates and variable rate technology over this period.

Table 5 Stated expectations as to whether the practice is expected to be used in 5 year time (% of all respondents including current adopters)

State	Region	Autosteer	Yield mapping	Varying fertiliser rates	Variable rate technology
NSW	All	88	65	65	51
	NSW Central West	85	66	55	40
	NSW Riverine Plains	92	64	76	64
SA	All	88	69	72	61
	SA Central	96	77	65	54
	SA Lower EP	86	81	72	67
	SA Mallee	82	54	72	66
	SA Upper EP	88	67	78	59
VIC	All	87	65	62	50
	VIC Loddon	78	60	50	44
	VIC Mallee	94	75	83	65
	VIC Wimmera	88	61	53	41
WA	All	89	73	75	57
	WA Nth Central	89	75	72	56
	WA Sth	89	76	73	60
	WA Sth Central	89	68	79	55
All respondents		88	68	69	55

3.2.2 SOIL AND NDVI MAPPING

The proportion of growers with soil maps from electromagnetic or gamma data or crop vegetation maps (NDVI-based) remains relatively low and very variable between regions (Table 6). Both are relatively high in the Vic Mallee where use of variable fertiliser rates on paddock zones is most common. Highest use of soil mapping is in the NSW Riverine Plains and WA Southern where the majority of VRT adopters also have EM and/or gamma soil maps.

A substantial proportion of VRT users have acquired soil and vegetation maps with up to 70% of VRT users having an EM or gamma map in several regions (Table 6). As well as reflecting the differences in soil and landscape characteristics, the results may indicate varying degrees of regional access to associated services and extension activities related to the mapping e.g. high soil map rates in WA Southern, NSW Riverine Plains and Mallee regions. The extent to which the maps have been used in paddocks zoning by growers was not confirmed by the study.

When asked if they expect to have these maps in 5 years time, respondents suggested that the overall proportion of growers with at least some EM or gamma maps will rise to 33% and 34% for NDVI based maps.

Table 6 Proportion of growers with electromagnetic or gamma soil maps of their paddocks (soil maps) and normalised difference vegetation index (NDVI) based (including satellite vegetation; crop circle; greenseeker). The proportion of VRT adopters with the maps is also shown in parentheses.

State	Region	Soil maps	NDVI maps
NSW	All	15 (45***)	8 (27**)
	NSW Central West	9 (0)	2 (0)
	NSW Riverine Plains	20 (71***)	14 (43*)
SA	All	13 (38***)	6 (10)
	SA Central	17 (33)	10 (17)
	SA LowerEP	14 (50**)	11 (50**)
	SA Mallee	14 (50***)	4 (0)
	SA UpperEP	6 (22*)	2 (0)
VIC	All	16 (29)	20 (38*)
	VIC Loddon	16 (0)	8 (0)
	VIC Mallee	25 (37)	29 (42)
	VIC Wimmera	6 (0)	24 (33)
WA	All	19 (41**)	16 (41***)
	WA Nth Central	14 (22)	19 (44**)
	WA Sth	33 (70***)	16 (40**)
	WA Sth Central	9 (0)	15 (33)
All respondents		15 (37***)	13 (28***)

Asterisks indicate significant difference in proportion of growers with maps between VRT adopters and non-adopters.

3.3 Awareness and perceptions of adopters and non-adopters

The adoption and local learning process for variable rate technology is still relatively young. For example, 52% of all respondents were unaware of a grower in their district using VRT before 2006. Only 18% were aware of local use prior to 2001. More data on time of awareness can be found in the Appendix.

3.3.1 PERCEIVED COSTS AND SUPPORT NEEDS

Growers currently without yield mapping or autosteer typically expected that over \$100,000 would need to be spent to become equipped to use variable rate technology with their seeding equipment (Figure 8).

Those with VRT equipment but not employing it typically expect that \$20,000 would be needed to make it operational (Figure 8). This is likely to partly explain the observed lag between having VRT seeding equipment and operationalising it. An additional technical investment in is usually required rather than just time, skills and motivation. A similar situation is also likely to exist for many to become equipped to collect yield map data after first acquiring a yield monitor.

The high means relative to medians suggest that a number of growers have far higher expectations of cost of achieving VRT capability than the median farmer. If some of these represent cost expectations higher than actual, this may highlight a potential constraint to adoption that could be influenced by information and awareness.

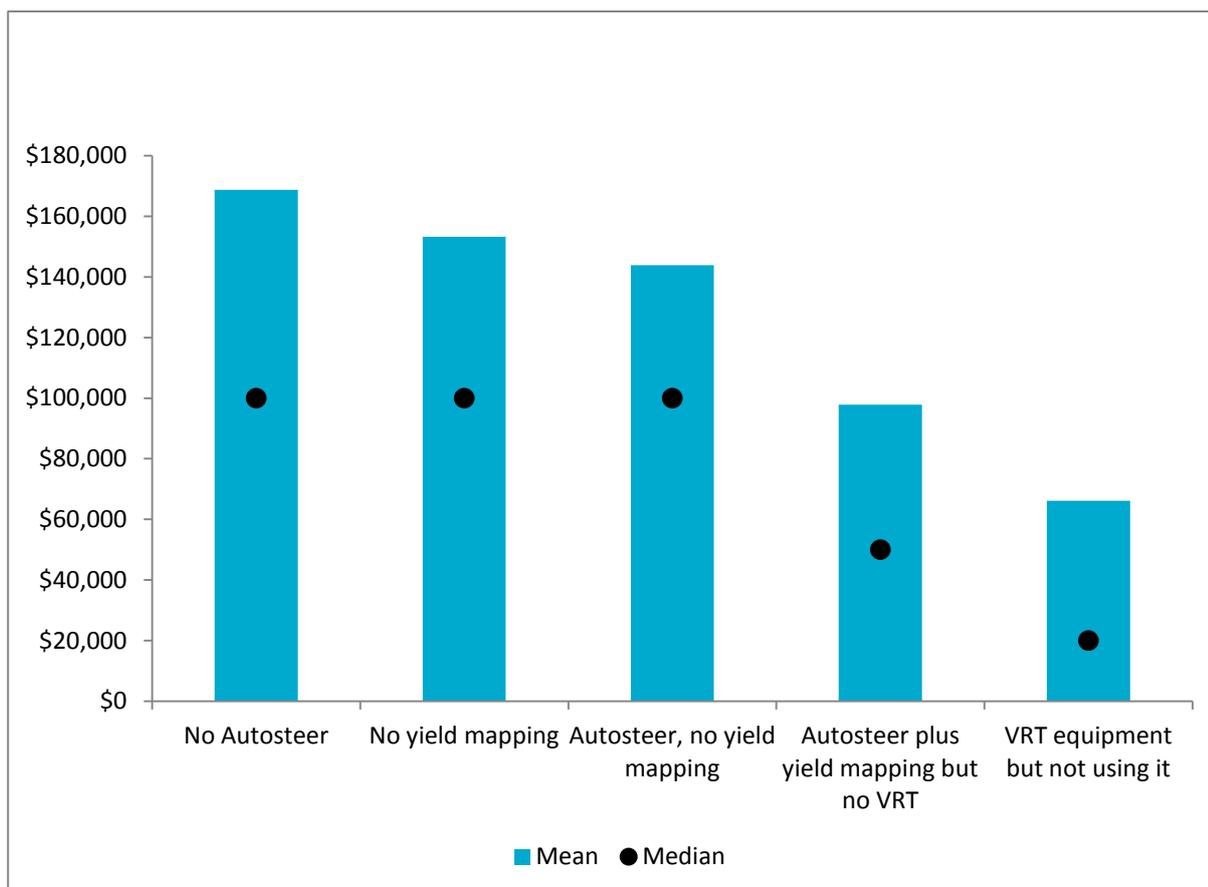


Figure 8 Expected extra cost to become equipped for using variable rate technology for growers with a range of existing equipment.

In a series of questions, respondents revealed perceptions and attitudes relating to the practices and their approach to farming. Several of these reveal expectations relating to costs of precision agriculture. Sixty percent of growers (adopters and non-adopters) agreed with the statement that managing precision agriculture data is (or would be) time consuming (Table 7). Only 28% expect that they would be able to fix most of their PA technology problems themselves.

Only 33% agree that there is insufficient technical support available for precision agriculture technology, although some regions such as WA Sth Central (45%) have far more growers perceiving a lack of support than its neighbouring region of WA Southern (22%) (Table 7). Overall, adopters of VRT (49%) are significantly more likely ($P < 0.01$) to perceive a lack of support for PA technology than non-adopters (31%).

Over 40% of growers believe they don't have sufficient variability to justify variable rate, indicating a substantial existing 'cap' on adoption potential for this particular practice (Table 7). Growers in the Wimmera are most likely to believe that there is insufficient variability to justify variable rate (61%) compared to 37% and 28% of growers in the neighbouring Mallee regions. SA Mallee, Upper EP and Vic Mallee growers are most likely to agree that their paddocks have a wide range of soil types. Overall, only 47% believe mapping paddocks is time consuming but reaches 60% in WA Southern.

Table 7 Perceptions relating to precision agriculture and variable rate costs and benefits showing proportion agreeing with statement (% of growers who agree or strongly agree).

	All	NSW Central West	NSW Riv. Plains	VIC Mallee	VIC Wimm.	VIC Lodd.	SA Mallee	SA Central	SA Upper EP	SA Lower EP	WA Nth Cent.	WA Sth Central	WA Sth
A major benefit of using different fertilizer rates on different soils within paddocks is reduced input costs	63	62	82	65	61	74	60	58	51	58	69	62	58
A major benefit of using different fertilizer rates on different soils within paddocks is more profitable cropping	72	60	78	87	59	70	78	65	86	72	78	64	64
A major benefit of using different fertilizer rates on different soils within paddocks is increased crop production.	67	68	70	79	57	56	74	60	78	61	75	66	56
A major benefit of using different fertilizer rates on different soils within a paddock is making investment in applying fertiliser less risky	66	55	72	77	53	64	72	56	73	72	67	68	71
Managing precision agriculture data is very time consuming	60	66	68	52	51	54	60	62	63	47	69	66	60
Treating paddocks with gypsum or lime is a major cost to my farm business	42	49	60	25	47	60	18	23	12	36	53	68	56
Using variable rate technology is very complicated	35	38	48	29	33	42	26	40	24	33	44	36	33
Mapping paddock zones is very time consuming	47	43	58	42	39	40	46	35	49	39	58	53	60
It is not obvious how to identify paddock zones on my farm	28	34	40	15	22	38	34	23	31	25	28	21	27
There isn't enough variability within my paddocks to justify using different fertilizer rates on different soils within paddocks	41	58	56	37	61	54	28	37	33	36	25	26	36
There is a lack of technical support available for precision agriculture technology	33	32	36	38	39	22	40	31	35	28	28	45	22
I'd be able to fix most problems with precision agriculture technology myself	28	26	26	23	25	38	26	27	39	22	28	28	22
Most of my cropping paddocks contain a wide range of different soil types.	61	42	34	73	43	42	92	63	80	69	64	68	62
Using variable rate technology is very complicated	35	38	48	29	33	42	26	40	24	33	44	36	33

3.3.2 PERCEIVED BENEFITS

Growers generally have modest expectations of the percentage increase in profitability of their average wheat crop if they were (or do) apply different fertilizer rates on different soils within paddocks instead of using a uniform rate (Figure 9). Only NSW Riverine Plains, Vic Mallee, SA Mallee and SA Upper EP have average expectations above 8%. Few growers expect gains of over 15%, although SA Mallee and SA Upper EP have a substantial proportion of growers expecting wheat profitability gains of at least 15% as a result of varying fertiliser use (Figure 10).

Overall, existing users of variable fertiliser rates expect a mean profitability gain of 14% compared to non-users (10%) but there was no significant difference in the median or any differences in median expectations of users and non-users of VRT (median 10%).

Over 60% of growers agree that one of the major benefits of variable rate fertiliser is reduced input costs (Table 7). More growers in the Riverine Plains believe that reduced costs are a major benefit than in any other region. Over 70% of growers believe that increased profitability from variable rate fertiliser within paddocks is a major benefit with the most widespread agreement in Vic Mallee and Upper EP.

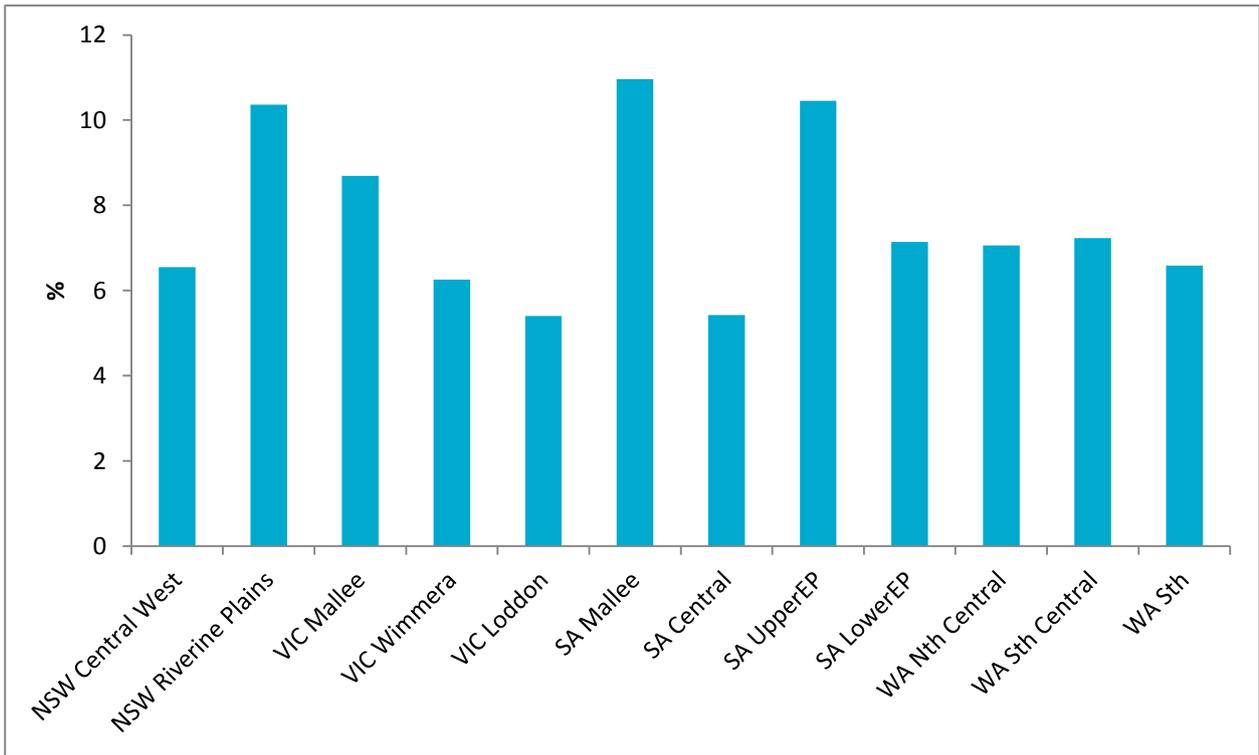


Figure 9 Expected percentage increase in profitability of their average wheat crop if they were (or do) apply different fertilizer rates on different soils within paddocks instead of using a uniform rate (mean % gain)

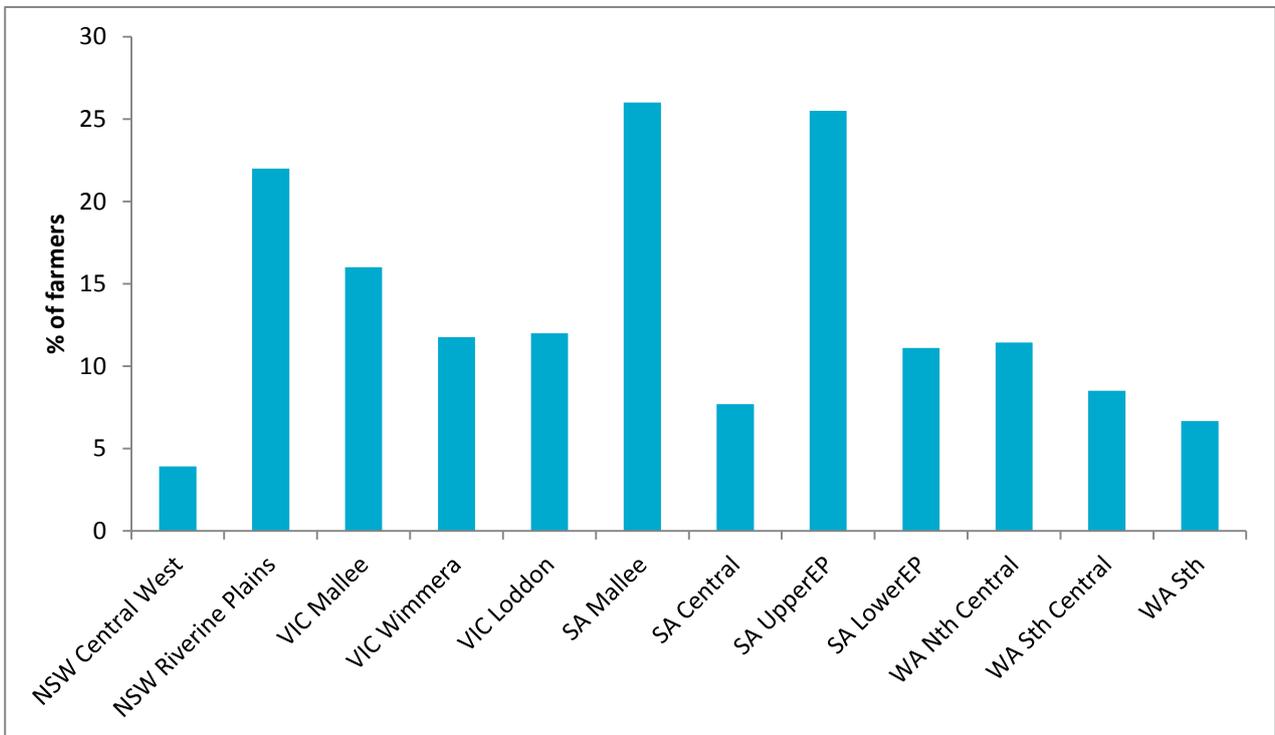


Figure 10 Proportion of growers expecting gains of greater than 15% in profitability of their average wheat crop if they were (or do) apply different fertilizer rates on different soils within paddocks instead of using a uniform rate (% all growers)

3.4 Skills, education and agronomic advisers

A majority of growers state that there is someone involved with the farm business that has strong computer skills (Table 9). NSW Central West and Vic Loddon have the highest proportion of growers who say that they are not confident in developing new computer skills when required. Half of growers state that there is someone involved in the farm that enjoys data analysis, with Lower EP appearing to have a relatively high proportion of farms with computer and data analysis capacity. A lack of skilled labour is stated as a major constraint on 46% of farms, with NSW Central West & SA Upper EP being the most widely affected and SA Central the least.

A vast majority (82%) of growers prefer to keep their farming operations very simple (Table 9). Adopters of VRT (66%) were significantly less likely than non-adopters (85%) to state a preference for keeping their farming operations very simple ($P<0.01$).

Thirty two percent have someone in the farm business that has completed a university degree. This ranged from 16% in Upper EP and 18% in the SA Mallee to 44% in Riverine Plains (Table 9).

Overall 25% of growers have been members of a group focusing on precision agriculture, including 49% of those using VRT and 37% of those with a yield map ($P<0.001$). Overall, 55% of respondents were members of a group that discusses cropping issues.

3.4.1 AGRONOMY ADVISERS

Overall, 52% of growers pay for agronomic advice. There is wide variation in use of paid agronomic advice between regions, reaching 69% in WA North Central and as low as 32% in NSW Central West (Table 8 and Figure 11).

The general trend remains upward and the proportion of growers expecting to use paid cropping advisers in 5 years time is 63% (Table 8). This includes substantial gains in the regions currently with the lowest use such as NSW Central West (32% to 60%); Vic Loddon (36% to 56%); SA Mallee (38%-50%) and Upper EP (45%-61%).

There appears to be a slowing of the rate of increase once paid cropping adviser use approaches approximately 70%, with only Riverine Plains (74%) and WA North Central (75%) expecting to have greater than 70% use of paid advisers, consultants and agronomists for cropping advice in 5 years time.

On average growers with paid advisers receive 8 on-farm visits and spend \$4500 for agronomic advice (Table 8).

A higher proportion of VRT users use a paid adviser (73%) than non-users (49%) ($P<0.001$). Overall, VRT adopters spent \$1500 more on advisory support ($P<0.001$) than non adopters but there was no significant difference between the number of visits received by adopters.

Table 8 Percentage of growers paying for advice, and expect to be paying in the future. For farmers using advisors number of visits per year and amount spent.

State	Region	Growers paying a consultant, advisor or agronomist for cropping advice (%)	Growers expect to be paying a consultant, advisor or agronomist for cropping advice in 5 years time (%)	Median number of adviser visits to farms with a paid adviser ¹	Median annual spend (\$) per year for paid agronomic advice by those with paying for some advisers ¹
NSW	All	48	67	9	5000
	NSW Central West	32	60	6	5000
	NSW Riverine Plains	64	74	10	5000
SA	All	50	62	6	3500
	SA Central	58	71	8	3500
	SA LowerEP	64	67	17	4125
	SA Mallee	38	50	4	3000
	SA UpperEP	45	61	5	3000
VIC	All	53	61	6	5000
	VIC Loddon	36	56	9	3500
	VIC Mallee	62	62	6	8000
	VIC Wimmera	61	65	6	5000
WA	All	59	66	5	4500
	WA Nth Central	69	75	6	5000
	WA Sth	56	60	8	4500
	WA Sth Central	53	64	5	3750
All respondents		52	63	6	4500

¹median used due to a small number of extremely high figures

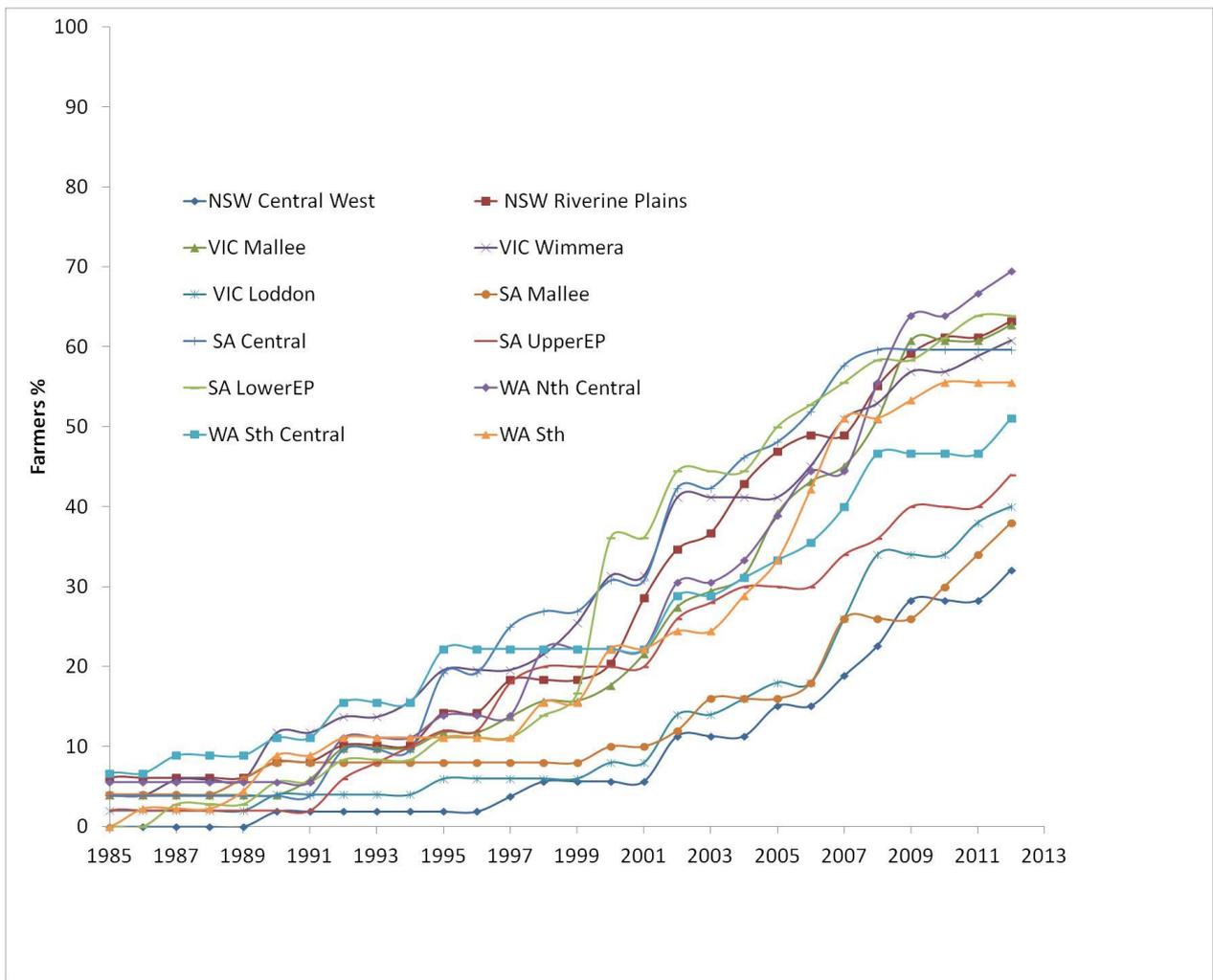


Figure 11 Proportion of growers paying for agronomic advice over time.

Table 9 Perceptions of growers relating to management skills and preferences showing proportion agreeing with statement (% of growers who agree or strongly agree).

	All	NSW Central West	NSW Riv. Plains	VIC Mallee	VIC Wimm.	VIC Lodd.	SA Mallee	SA Central	SA Upper EP	SA Lower EP	WA Nth Cent.	WA Sth Central	WA Sth
I am not confident in developing new computer skills when I need to	38	51	36	42	24	52	44	38	33	33	36	30	33
There is someone involved in the farm business who has strong computer technology skills	61	57	56	58	67	68	58	54	53	78	64	57	67
I enjoy analysing data from the crops and/or farm business	55	36	54	65	53	54	56	56	55	64	58	62	58
There is someone involved in the farm business that enjoys analysing data from the crops and/or farm business	50	38	48	56	43	46	50	44	57	64	58	55	53
I prefer to keep my farming operations very simple	82	85	80	77	75	84	84	81	90	78	86	79	84
A lack of skilled labour is one of the biggest constraint to my farm operations	46	58	40	37	51	48	46	31	57	39	44	45	53

As well as paid agronomy advisers, the proportion of growers classifying unpaid and state government providers as major sources of agronomic advice for their farm is shown in Figure 12. Use of unpaid advisers from retail outlets (distributor representatives) as a major source is particularly high in some regions such as NSW Central West, Vic Loddon and SA Upper EP. NSW Central West, where use of paid agronomists is among the lowest, is the only region where state government agronomists are rated as a major source by more than 20% of growers.

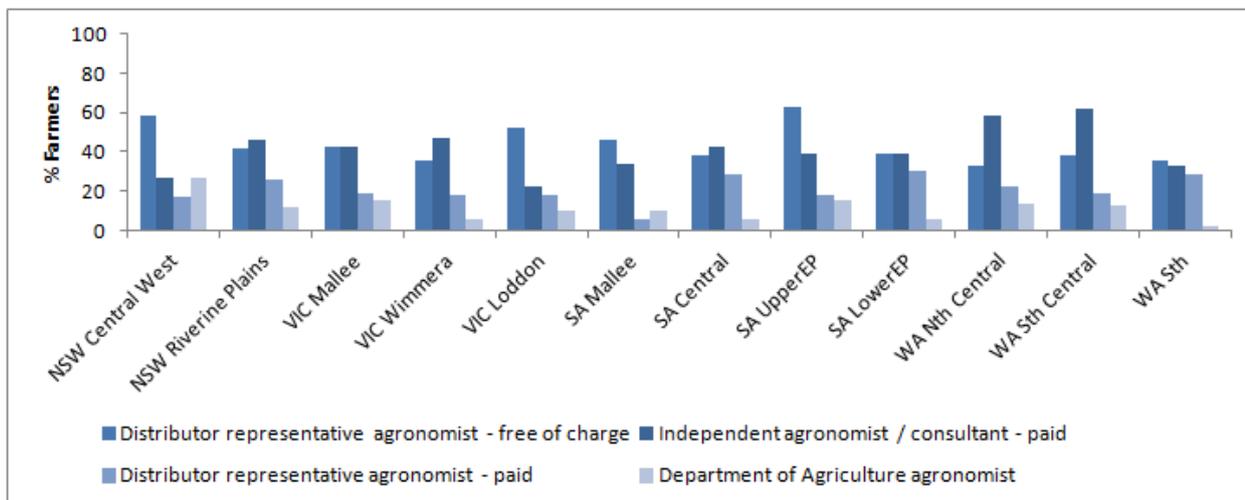


Figure 12 Major sources of agronomic advice for growers including paid, unpaid, retail and state government

Overall, 46% had a major source of agronomic advice that offered precision agriculture-related services such as mapping, prescription maps, paddock zoning maps; managing spatial data from your paddocks and/or technical services for PA equipment (Figure 13). The high adopting regions of Vic Mallee (63%) and Nth Central WA (63%) had the highest proportion, but SA Mallee was among the lowest (38%) with other low adopting of Central West (32%) and Wimmera (36%).

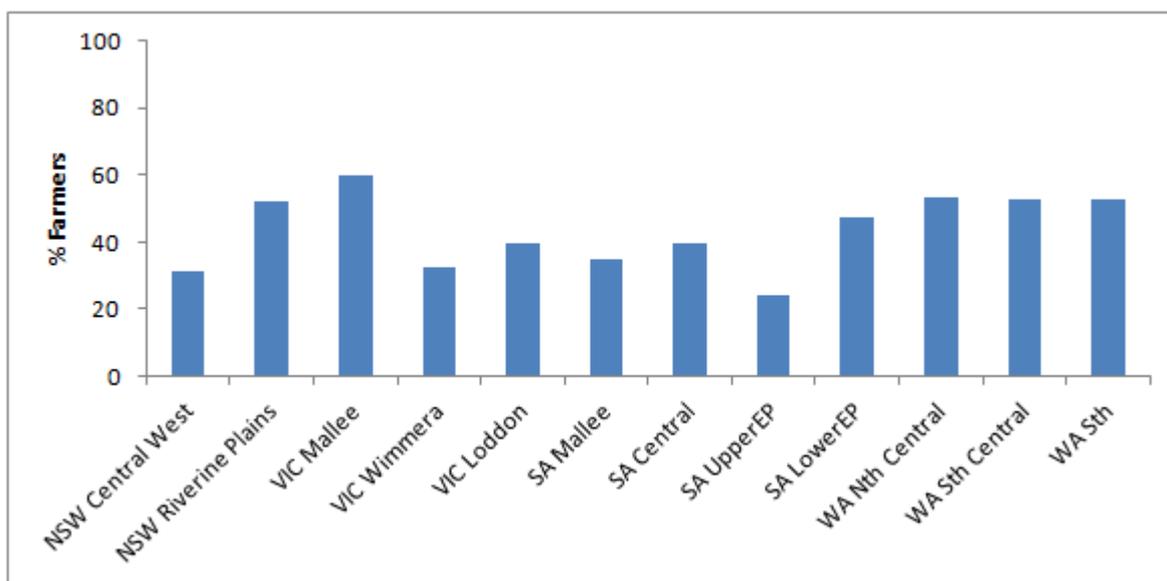


Figure 13 Percentage of growers with a major source of agronomic advice that offers precision agricultural related services such as mapping, prescription maps, paddock zoning maps; managing spatial data from your paddocks; technical services for PA equipment.

Across all regions, VRT users (68%) were significantly more likely ($P < 0.01$) to have a major source of agronomic advice offering PA services than non users (41%). A similarly large difference exists for yield mapping (63% vs 36% $P < 0.001$). Although the statistical analysis is limited by sample size, some notable regional differences exist. There was no significant relationship between yield map use and growers with agronomy advisers offering PA services in SA Central (46% vs 41%), but large differences in SA Lower EP (69% vs 29% $P < 0.05$) and Vic Mallee (85% vs 36% $P < 0.001$) and WA Southern (80% vs 24% ($P < 0.001$)).

When considering their major sources of agronomic advice, 90% of growers rate the crop nutrition skills of their adviser(s) as strong. This compares to 64% for precision agriculture skills (Figure 14). Growers in SA Upper EP are least likely to rate the precision agriculture skills of major sources of agronomy advice as strong, in contrast to Lower EP.

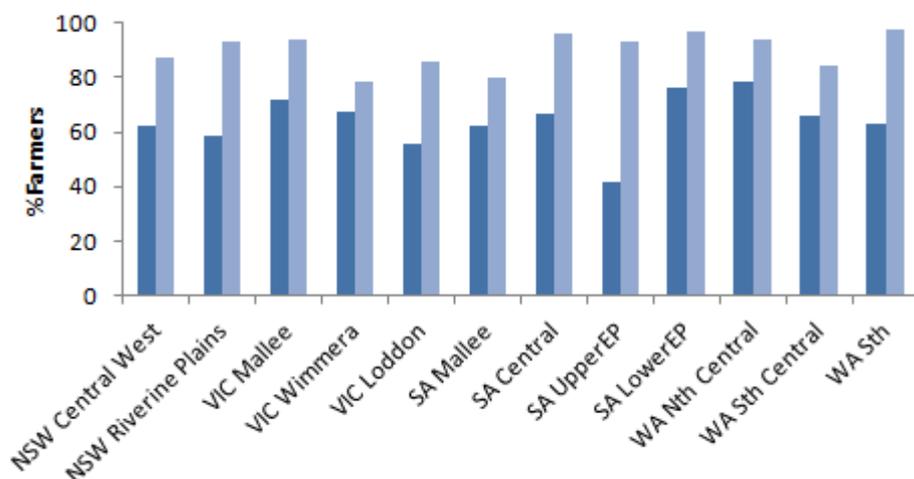


Figure 14 Proportion of growers rating the skills of their major source of agronomic advice as ‘strong’² for precision agriculture skills (dark blue) and crop nutrition (light blue).

² Results show percent of growers rating skills of major source of agronomic advice as ‘yes’ strong. Other response options were ‘no’ and ‘don’t know’.

3.5 Grower to grower and adviser to grower recommendations

3.5.1 GROWER RECOMMENDATION OF PRACTICES

Users of practices were asked if they would recommend the practice to interested farmers in their district. The results give a guide to whether local grower to grower communication is likely to lead to rapid widespread diffusion of a practice.

Autosteer is the most highly recommended practice with 94% of all farmers that use autosteer stating they would recommend it to others and very few still unsure (Figure 15).

Farmers collecting yield maps were mostly positive about their experience. Overall, 77% of these farmers would recommend it to other farmers in their district (Figure 16). Vic Wimmera and Vic Loddon have the highest proportion of growers with yield maps who would not recommend yield maps to others in their district.

On average 80% of farmers varying fertilisers rates within paddocks (VR) and 86% of those using VRT would recommend using it to other farmers in their district (Figure 17). Users in higher adopting regions of SA Mallee, Vic Mallee, Upper EP, SA Central and NSW Riverine Plains are highly positive. Only 60% of VR users in NSW Central West would recommend it to other growers in their district.

Only a small minority of growers use VRT in most districts so a full regional breakdown is shown only for VR and not VRT.

The mapping technologies are least likely to gain recommendation from those with at least one of the maps but substantial proportions remain unsure (19% unsure for EM or Gamma and 18% for NDVI). Of the 15% of growers overall who have EM or Gamma maps, 46 % would recommend them to an interested grower in the district. Of the 13% that have NDVI maps, 57% would recommend them.

Only a small proportion has any soil or vegetation maps so a full regional breakdown is not presented. It should also be noted that because of the low level of current map users many growers may only have gained maps for 'trial' purposes or via extension programs rather than through a decision to invest.

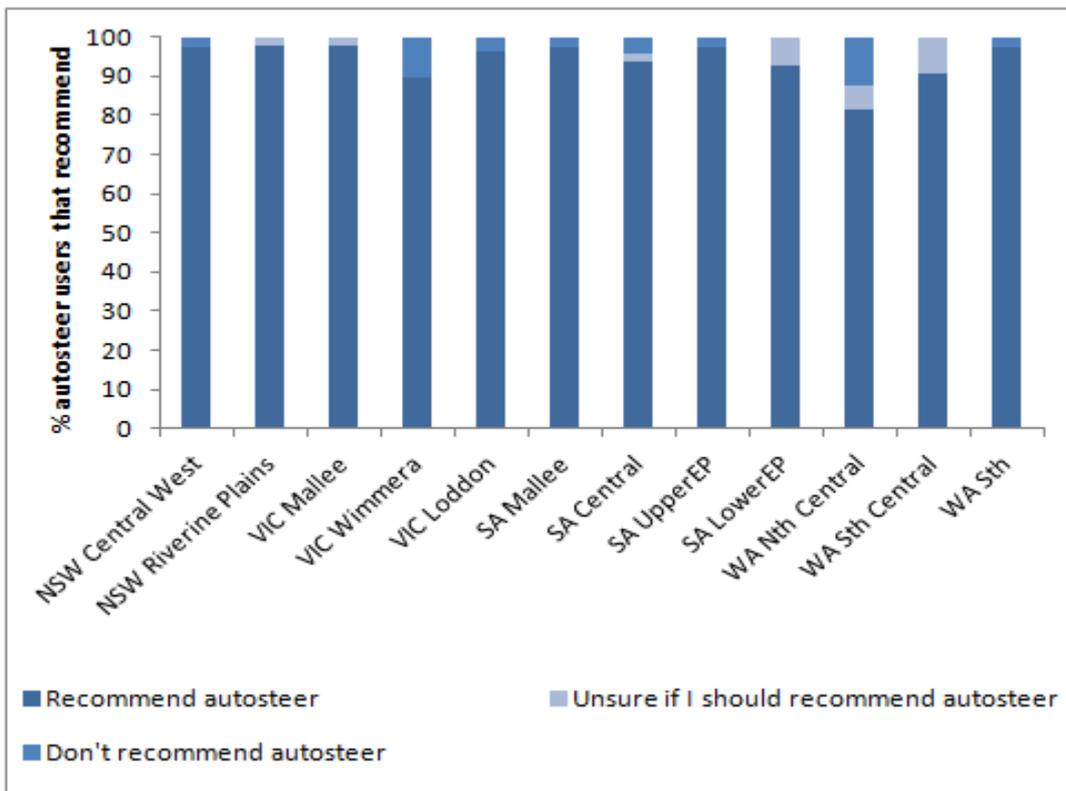


Figure 15 Proportion of growers using autosteer that would recommend autosteer to other interested growers in their district

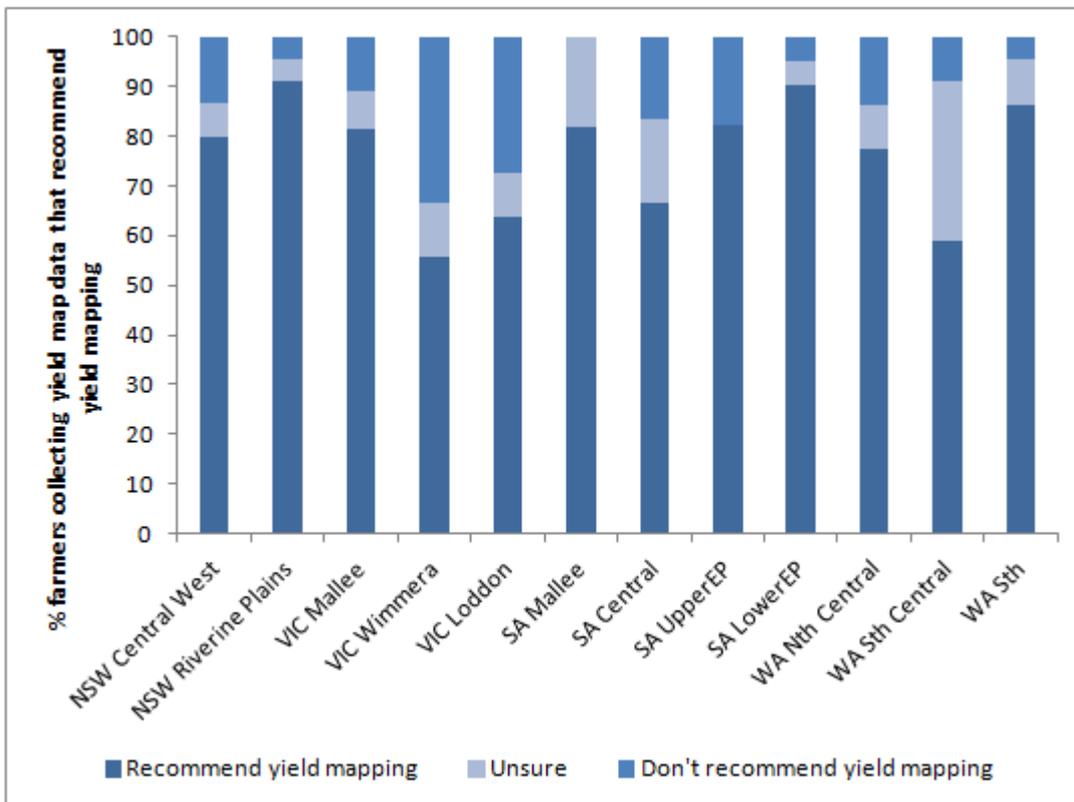


Figure 16 Proportion of growers yield mapping that would recommend yield mapping to other interested growers in their district

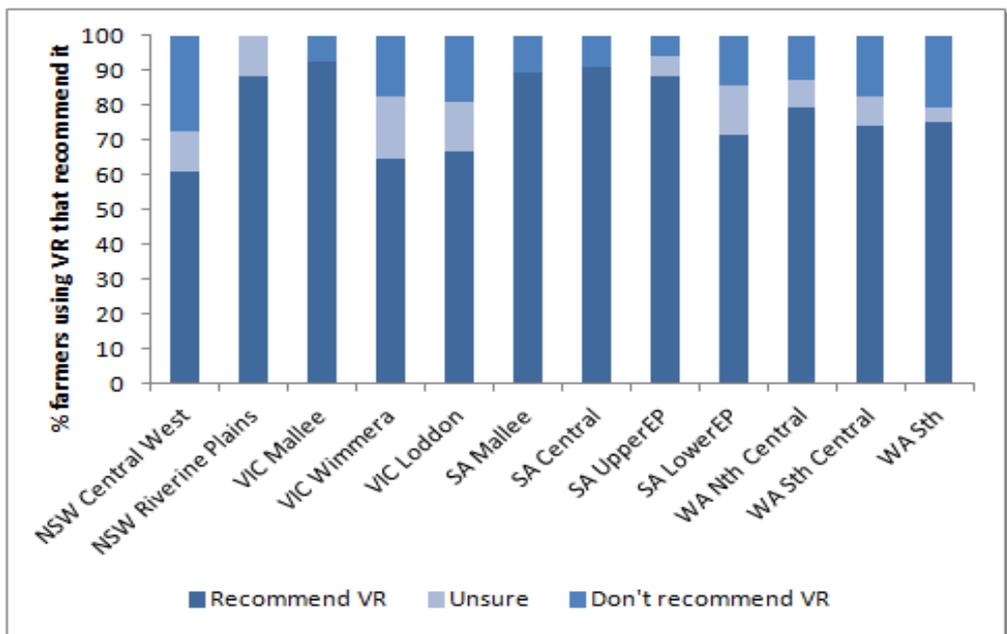


Figure 17 Proportion of growers varying fertiliser rates within paddock (VR) that would recommend it to other interested growers in their district.

3.5.2 ADVISER RECOMMENDATION OF PRACTICES

Growers were asked whether any of their major sources of agronomic advice had suggested a practice be considered, recommended against it or offered support to the grower's decision to consider it. Agronomy advisers were shown to rarely recommend against practices (Figures 18-21) and commonly suggest a practice be considered. Soil testing is included for comparison in Figure 22.

It is more common for advisers to suggest that growers consider a practice than just support the growers' idea to consider a practice. For example yield mapping has been suggested frequently to growers by advisers in WA Nth Central and VR has been commonly suggested for consideration by growers in SA and Vic Mallee (Figure 19). Varying fertiliser rates within paddocks (VR) (Figure 18) is more commonly discussed than use of VRT (Figure 21). VRT is most commonly suggested by advisers in the SA Mallee (Figure 21).

Orange bars are often higher than the green bars for mapping practices such as EM, Gamma or NDVI indicating that they are more commonly not discussed than the subject of any suggestion, recommendation or discussion (Figure 20). Adviser input into discussion around mapping is most common in NSW Riverine Plains, SA and Vic Mallee and WA Southern.

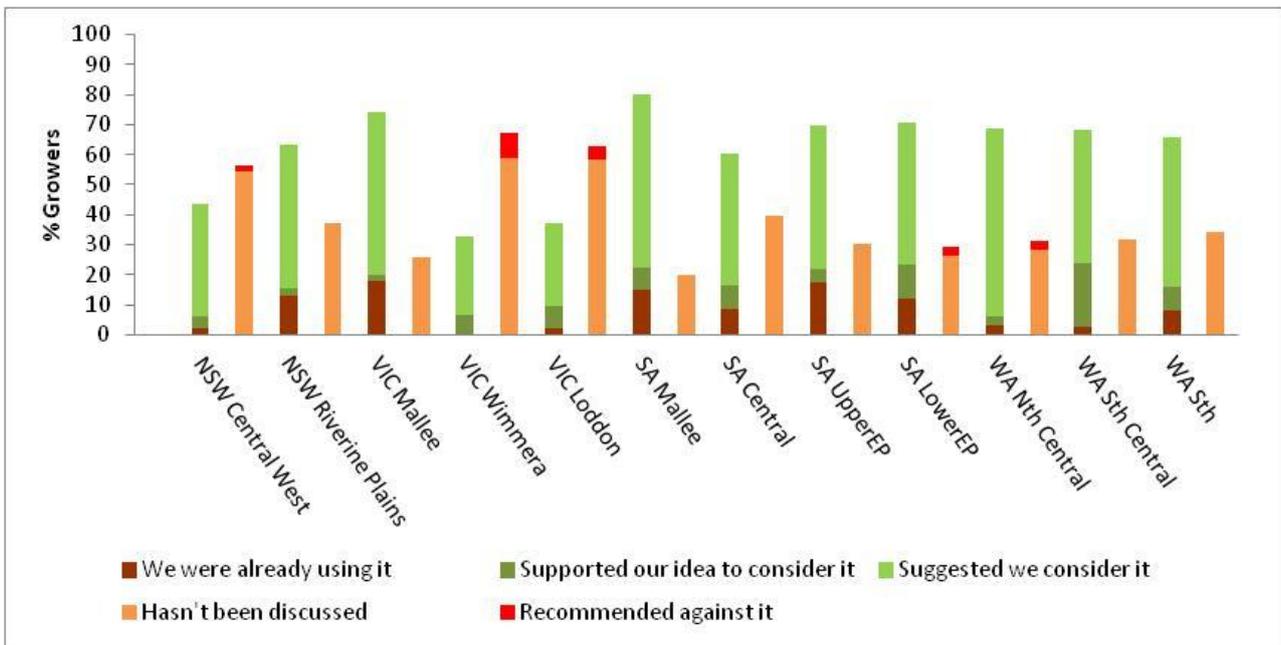


Figure 18 Input from agronomy advisers relating to grower consideration of varying fertiliser rates on different soils within paddocks

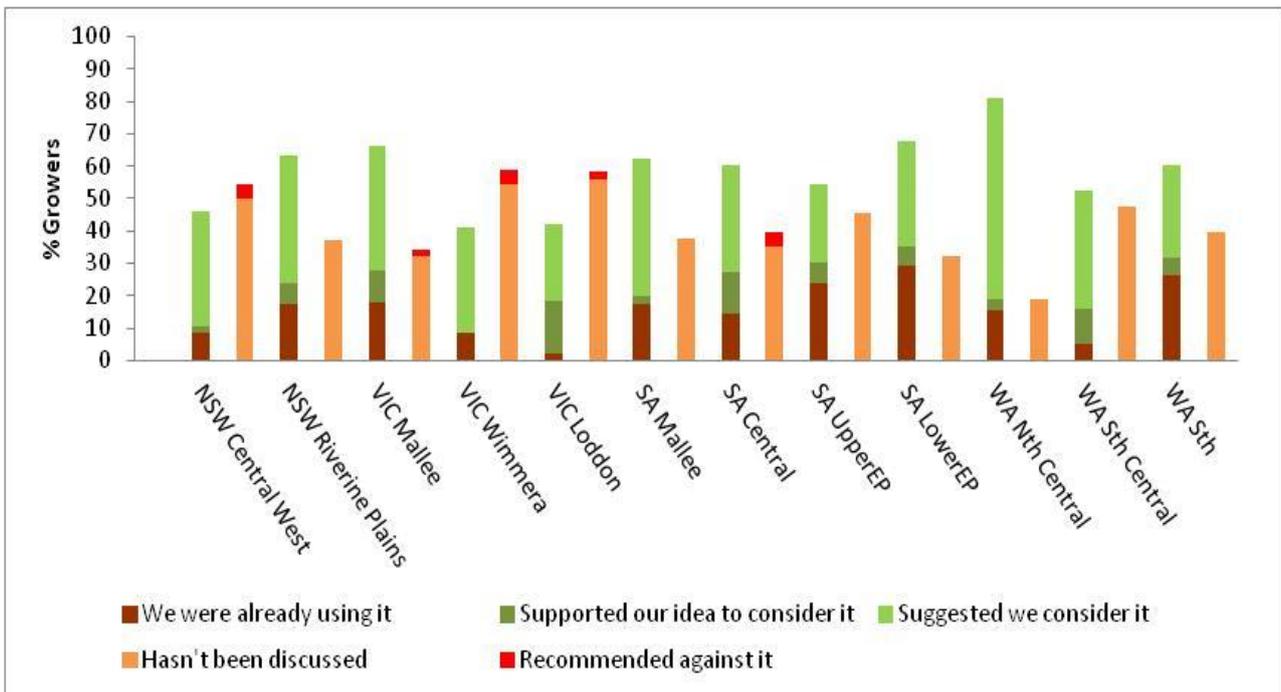


Figure 19 Input from agronomy advisers relating to grower consideration of yield mapping

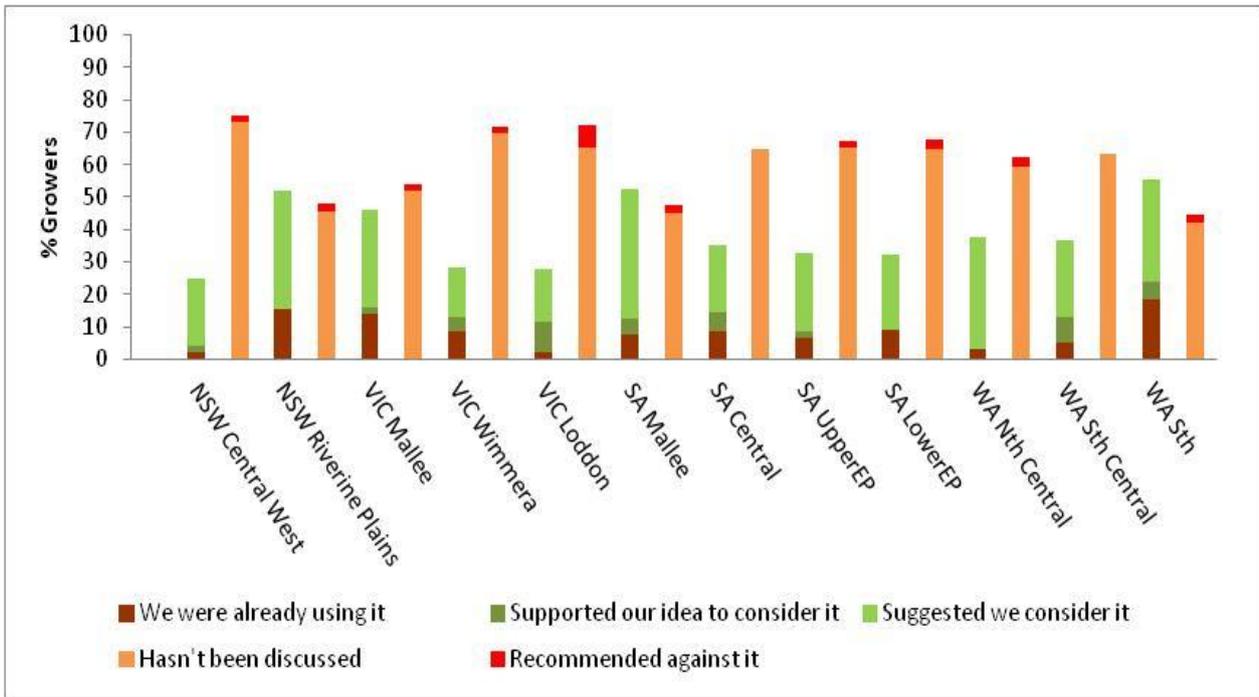


Figure 20 Input from agronomy advisers relating to grower consideration of paddock mapping such as NDVI, EM or Gamma

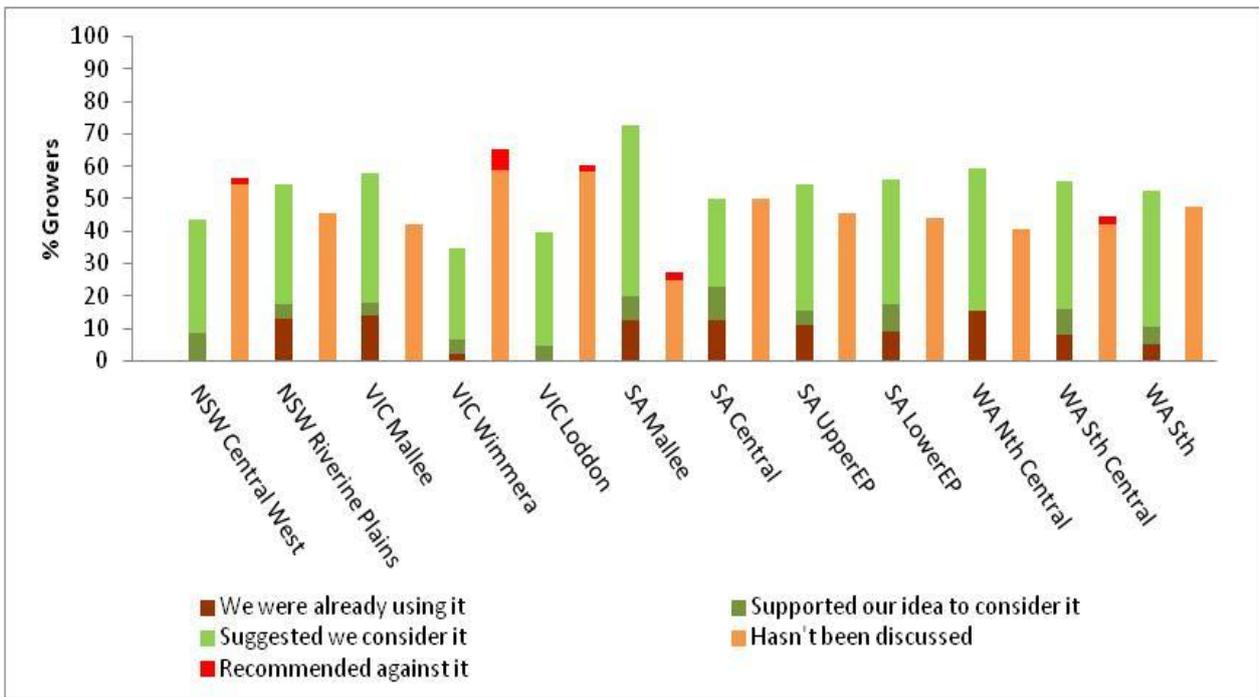


Figure 21 Input from agronomy advisers relating to grower consideration of variable rate technology

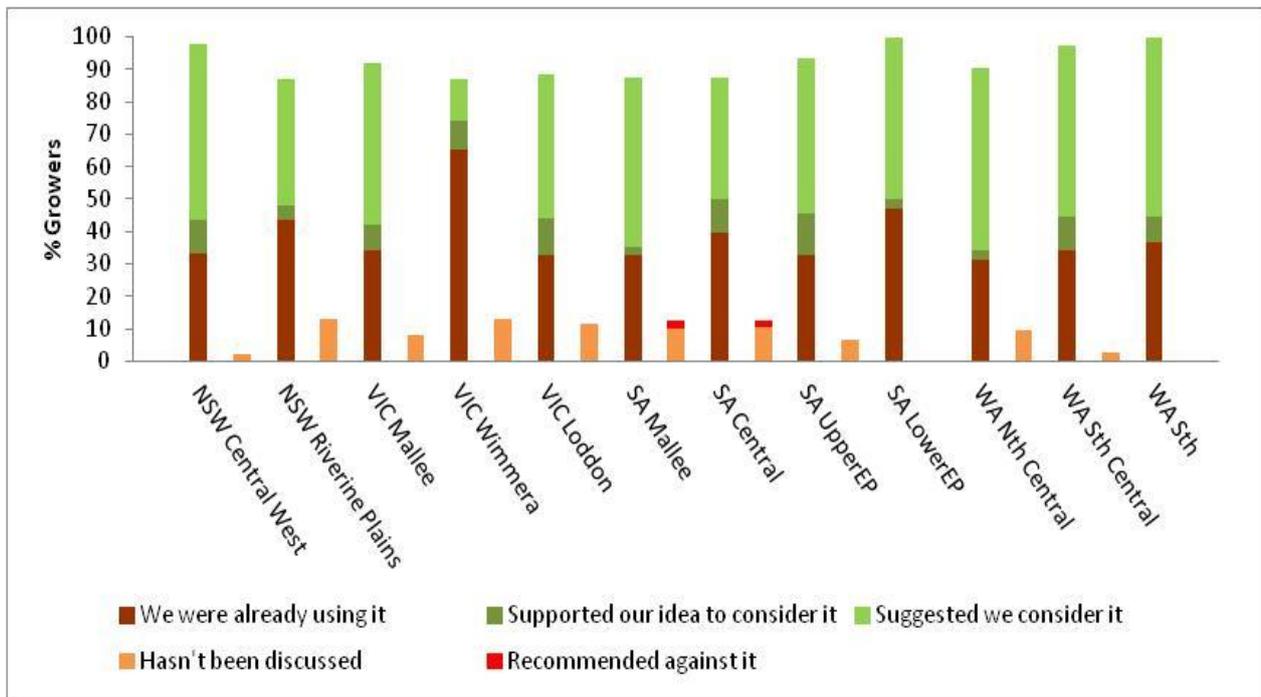


Figure 22 Input from agronomy advisers relating to grower consideration of soil sampling for nutrient testing

3.6 Identifying factors associated with adoption

Selected farm, grower characteristics, grower perceptions and regional identifiers were used in logit regression analysis to successfully generate models predicting adoption of yield mapping, autosteer, VR and VRT. All models presented were successful in predicting between 71% and 90% of decisions to adopt or not adopt (Tables 10-12). Odds ratios are shown which indicate the marginal level of influence of a change in the variable on the probability of adoption. Using the example of yield mapping and a binary variable such as possession of a University degree, having someone involved with the farm with a degree or diploma increases the probability of the grower being an adopter by 58% (Table 10). The influence of region when all other factors are also taken into account is estimated by using Vic Mallee as a benchmark. For example, a grower from the Vic Wimmera is 33% less likely to be a yield map adopter if all other factors remain equal (Table 10). In the case of a variable such as the age of the youngest person involved in managing the farm (Table 11), each additional year of age is associated with the probability of autosteer adoption falling by 3%. Statistically significant variables are shown here and the full range of variables and model details are included in the Appendix.

The likelihood of a grower being a yield map adopter is strongly associated with information and learning-related factors such as the grower using a paid adviser and having an adviser that offers precision agriculture-related services (Table 10). Education is shown to be influential along with orientation towards data analysis. Being a grower that strongly prefers to keep farming operations simple significantly reduces the probability of yield map adoption. Vic Wimmera, Vic Loddon, SA Mallee and SA Central are regions that have characteristics not captured by the other variables that reduce the likelihood of yield map adoption (relative to Vic Mallee).

Table 10 Factors associated with yield mapping – showing significant factors from regression analysis. Factors having negative influence shown in red.

Factor	Odds Ratio
Arable land cropped (%)	1.00**
Age of main seeding machine (years)	0.94***
University degree or diploma	1.58*
Pay a consultant, advisor or agronomist for cropping advice	2.15***
Strong computer technology skills	1.41**
Enjoys analysing data	1.26*
Agronomic adviser(s) offer precision agriculture-related services	2.05***
Year first became aware of someone in your district using VRT (year)	0.92***
Prefer to keep farming operations very simple	0.75**
Believes mapping paddock zones is very time consuming	0.70**
<i>Regions relative to VIC Mallee:</i>	
VIC Wimmera	0.33*
VIC Loddon	0.29**
SA Mallee	0.34*
SA Central	0.26**
WA Sth Central	0.32*

Prob > chi² 0.00; Correct predictions 80% (82% non-adoption; 75% adoption)

Autosteer adoption is also well-predicted by the regression model (Table 11). Being a large grain producer (income from cropping) increases the likelihood of adoption while having only older managers involved in the farm reduces the likelihood of adoption. Being a member of a local cropping group is strongly associated with adoption as is paying an agronomy adviser. Vic Loddon and WA Sth Central have additional characteristics that greatly reduce the likelihood of autosteer adoption.

Table 11 Factors associated with adoption of autosteer – showing significant factors from regression analysis. Factors having negative influence shown in red.

Factor	Odds Ratio
Income from broadacre cropping (\$)	1.03***
Age of main seeding machine (years)	0.92***
Age of the youngest person involved in managing the farm (years)	0.97**
Member of a local farmer group that looks at cropping issues	4.79***
Pay a consultant, advisor or agronomist for cropping advice	1.78*
<i>Regions relative to VIC Mallee:</i>	
VIC Loddon	0.21***
WA Sth Central	0.11***

Correct predictions 86% (71% non-adoption; 89% adoption) Prob > χ^2 0.00;

The adoption of variable rate fertiliser practices either through precision agriculture technologies such as GPS and controllers etc (VRT) and/or through low-technology methods (VR) highlights the importance of variability and complexity of management far more so than autosteer adoption (Table 12). The perceived ease and simplicity of the zoning process is indicated to be very important. In the case of VRT, growers' stated likely use in five years time is also predicted.

Expected benefits of production gains (for VR and VRT) and allowing better management of risk in investment in fertiliser (VRT Future) demonstrate the importance of perceived economic value of spatial management. A key question is whether the results reflect actual levels of economic gain that should be expected or whether there is the potential for further observation and learning to increase expectations of economic benefit.

A perceived lack of technical support for PA is significant for VRT but not for the commonly low-technology VR (Table 12). It should be noted that stating a lack of available support for PA is more likely to come from adopters of VRT, presumably because non-adopters are less exposed to lack of support than adopters. This is one variable where non-adopters may become less likely to adopt if adopters' experience with lack of support services is shared. Expected future adoption of VRT is much higher among growers using a paid adviser and growers with an adviser that offers precision agriculture-related services. Growers with an agronomy adviser also offering precision agriculture-related services is more than twice as likely to expect to be using VRT in 5 years time.

Growers with a relatively strong preference for keeping their farming operations simple are significantly less likely to have adopted yield mapping, VR or VRT, or expect to adopt VRT in the next 5 years.

Vic Mallee along with SA Upper EP, WA North Central, WA Southern and SA Mallee have additional characteristics not captured by other factors that leads to significantly higher adoption of VR or VRT than other regions (Table 12). SA Mallee has generally lagged behind its neighbour Vic Mallee for adoption but is expected to have significantly higher likelihoods of VRT adoption over the next 5 years.

Table 12 Factors associated with adoption of varying fertiliser rates within paddocks (VR) and use of variable rate technology (VRT) – showing significant factors from regression analysis. Factors having negative influence shown in red.

	VR Odds Ratio	VRT Odd Ratio	Future VRT Odds Ratio
Arable land cropped (%)	ns	1.00**	1.00*
Age of main seeding machine (years)	ns	0.91***	0.96**
University degree or diploma	1.53*	ns	ns
Pay a consultant, advisor or agronomist for cropping advice	ns	ns	1.92**
Enjoys analysing data	1.35**	1.84***	ns
Agronomist offering precision agriculture-related services	ns	ns	2.45***
Prefer to keep farming operations very simple	ns	0.65**	0.56***
Lack of skilled labour a major constraint	0.83*	ns	1.25**
Lack of technical support available for precision agriculture technology	ns	1.49***	1.44***
Mapping paddock zones is very time consuming	ns	ns	0.65***
It is not obvious how to identify paddock zones on my farm	0.77**	0.75*	ns
Not enough variability within my paddocks	0.76**	0.64***	0.70***
Major benefit of different fertilizer rates on different soils within paddocks is increased crop production	2.04***	ns	ns
Major benefit of using different fertilizer rates on different soils within a paddock is making investment in applying fertiliser less risky	ns	ns	1.60***
Expected increase in wheat profitability by using different fertilizer rates on different soils within paddocks (%)	1.04***	ns	ns
<i>Regions relative to VIC Mallee</i>			
NSW Riverine Plains	0.19***	ns	ns
NSW Central West	0.26**	ns	ns
VIC Wimmera	0.27**	0.08**	ns
VIC Loddon	0.37*	0.16*	ns
SA Mallee	ns	ns	3.15*
SA Central	ns	0.29*	ns
SA LowerEP	0.24**	0.24*	ns
WA Sth Central	0.21***	0.09***	ns

VR: Correct predictions 72% (72% non-adoption; 72% adoption)

Prob > chi² 0.00

VRT: Correct predictions 89% (90% non-adoption; 77% adoption)

Prob > chi² 0.00

Future VRT: Correct predictions 79% (75% non-adoption; 81% adoption)

Prob > chi² 0.00

4 Conclusions

The adoption of spatial management and mapping practices is far from mature in the Australian cropping industry. Use of all practices studied is increasing but unlike autosteer, adoption of spatial management practices cannot be expected to be similarly rapid or extensive across all regions. The results highlight the potential for substantial increases in adoption of precision agriculture-related cropping practices and use of spatial information. Regional differences are highly significant, including some that have not been captured by the variables identified in this study. Many influential factors are associated with information, learning and management demands and these present opportunities for effective intervention. This includes the role of agronomy advisers and support for precision agriculture in assisting growers to achieve the common goal of maintaining simplicity in farming operations. A major step gain in annual profitability is not typically expected from adoption of precision agriculture and considerable information processing and learning is expected to be involved. This means that rapid adoption of spatial management practices has not occurred and should not be expected, even in regions where the role of spatial management is most obvious. However, the results do demonstrate potential for accelerated adoption where advisory support is present and in alignment with adoption potential and relevant on-farm skills. More generally, large differences in use of agronomy advisory support still exist between regions. This study clearly reinforces the conclusions of previous studies of adoption in the Australian grains industry that use of agronomy advisory support is strongly associated with more rapid adoption of cropping practices.

5 Appendix

5.1 Grower and farm characteristics

Table 13 Classification of farm type and relative importance of cropping compared to sheep, including stated respondent preference for cropping or sheep if forced to choose one.

State	Region	Percentage of farmers that are:		Percentage of gross property income is from:		Percentage of farmers with preference for:	
		Grains farmers	Grain and Livestock	Broadacre cropping	Sheep	Cropping only	Livestock only
NSW	All	31	63	63	30	55	45
	NSW Central West	23	68	59	33	49	51
	NSW Riverine Plains	40	58	68	26	62	38
SA	All	61	36	76	20	69	31
	SA Central	77	21	85	12	79	21
	SA LowerEP	75	22	81	19	83	17
	SA Mallee	42	52	68	27	52	48
	SA UpperEP	53	45	71	23	67	33
VIC	All	62	33	75	22	75	25
	VIC Loddon	46	42	62	33	62	38
	VIC Mallee	81	17	84	14	83	17
	VIC Wimmera	59	41	78	20	78	22
WA	All	64	33	77	18	84	16
	WA Nth Central	78	19	83	12	83	17
	WA Sth	56	40	72	21	76	24
	WA Sth Central	62	36	78	21	91	9
All respondents		57	39	74	22	71	29

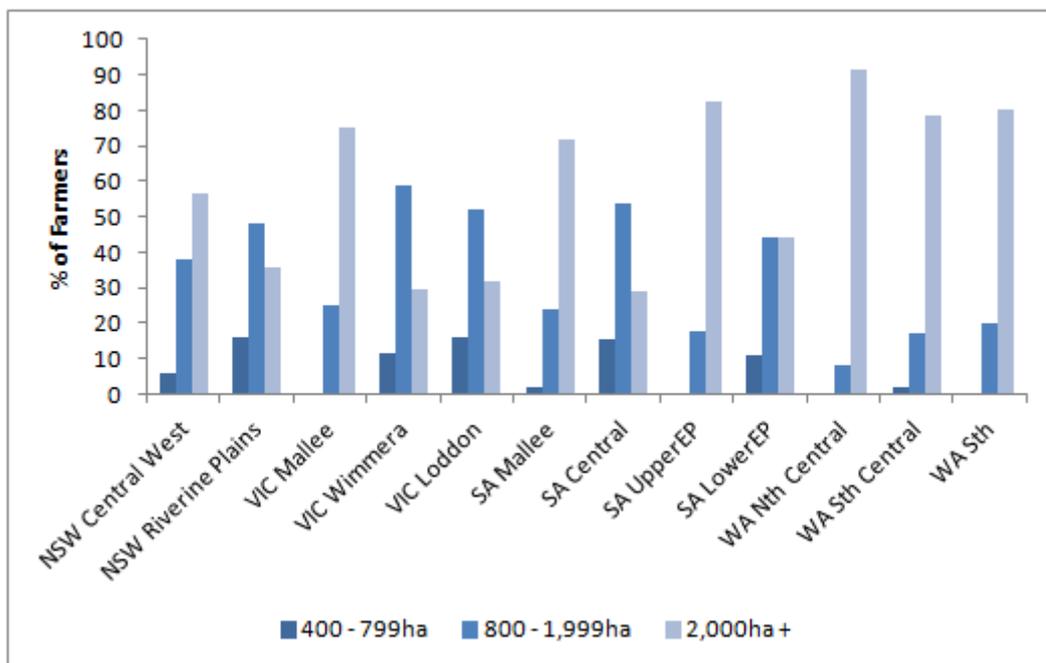


Figure 23 Range of farm sizes of respondents by region

Table 14 Age of existing seeding and harvesting machinery and use of no till.

State	Region	% farmers who have used no till	Average age of main seeder	Average age of main header
NSW	All	82	12	10
	NSW Central West	77	12	11
	NSW Riverine Plains	86	12	8
SA	All	84	12	11
	SA Central	87	10	7
	SA LowerEP	89	13	9
	SA Mallee	80	12	13
	SA UpperEP	82	13	14
VIC	All	86	12	10
	VIC Loddon	88	13	12
	VIC Mallee	77	11	8
	VIC Wimmera	92	12	10
WA	All	89	9	8
	WA Nth Central	89	9	9
	WA Sth	82	9	8
	WA Sth Central	96	9	8
All respondents		85	11	10

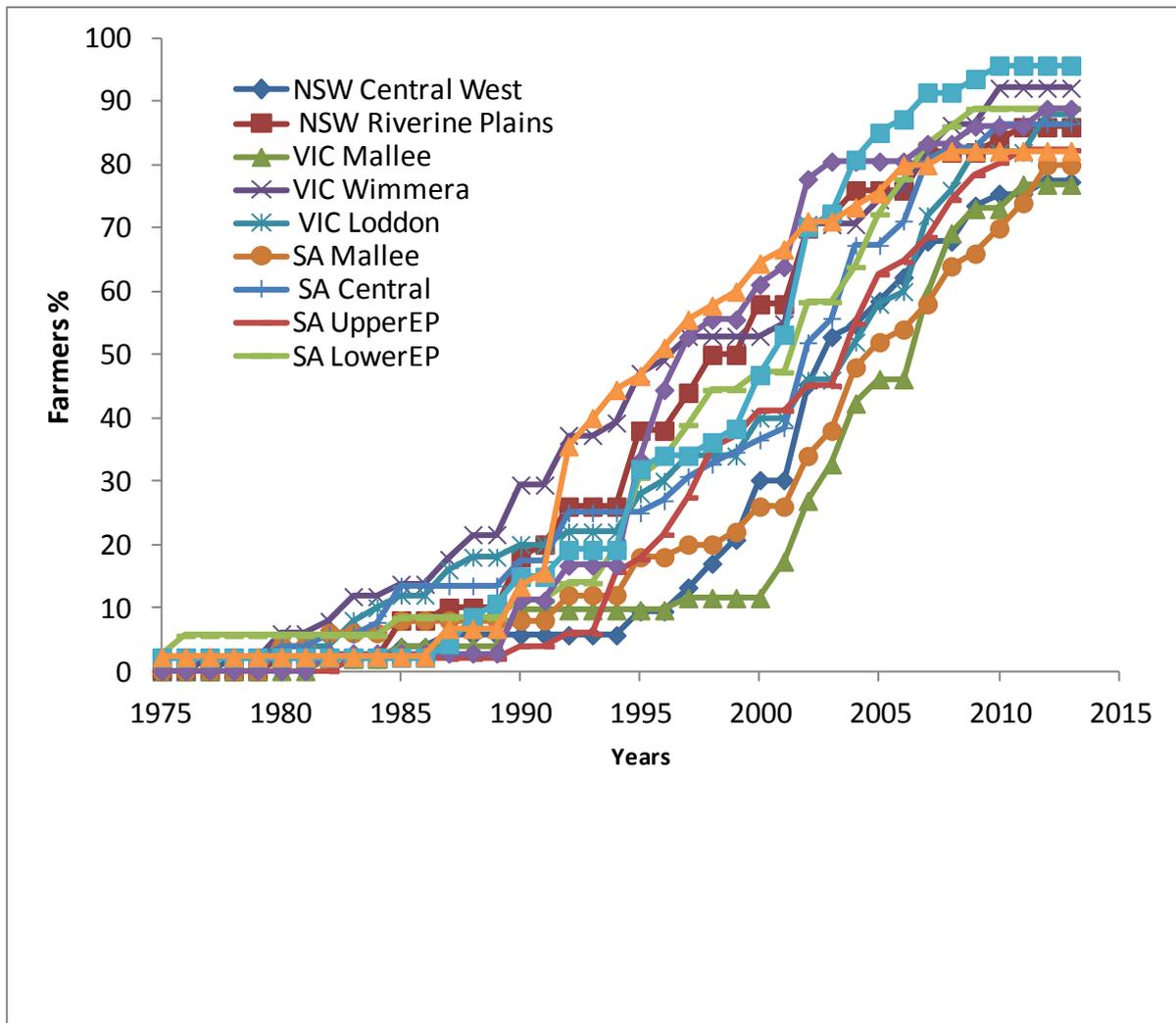


Figure 24 Proportion of growers who have used no-till over time.

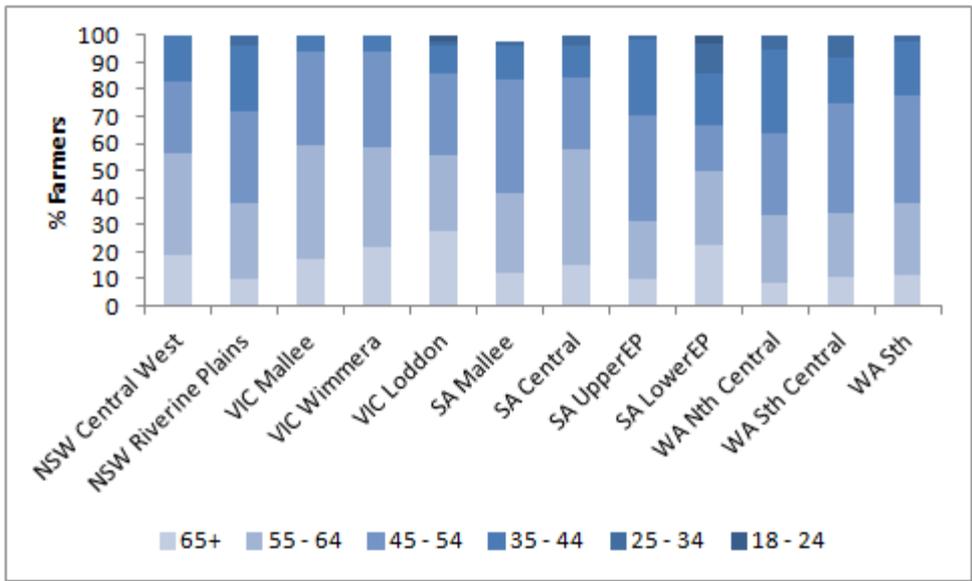


Figure 25 Age group of respondents

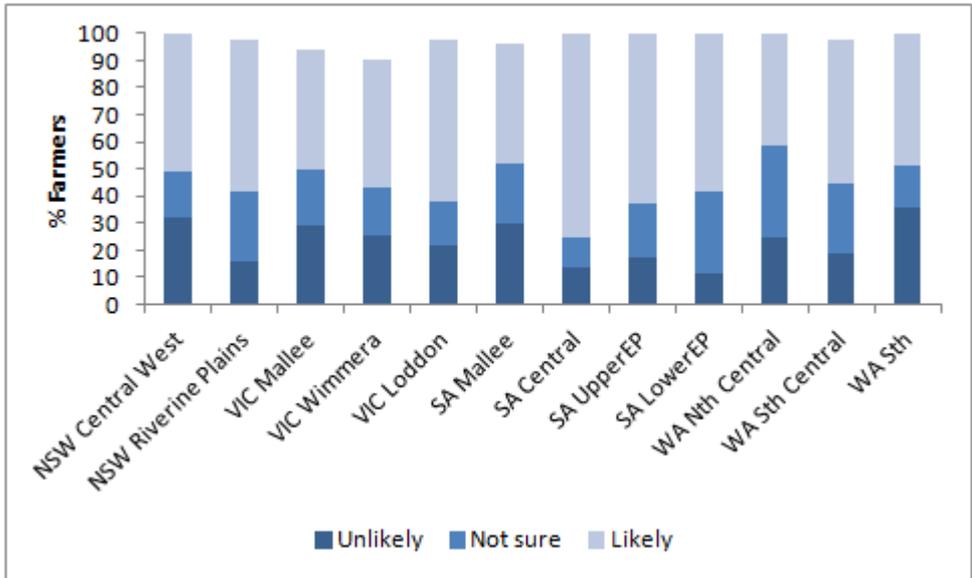


Figure 26 Expectation that the farm business will continue to be run by a family member after retirement of respondent.

Table 15 Age of youngest person managing the farm, education and number of years expected to be farming into the future

State	Region	Average age of youngest person managing the farm	Percentage with a person involved in management of farm with university degree or diploma	Number of years that respondent intends to be farming into the future
NSW	All	41	38	15
	NSW Central West	43	32	13
	NSW Riverine Plains	39	44	17
SA	All	40	23	13
	SA Central	38	27	13
	SA LowerEP	36	36	15
	SA Mallee	44	18	12
	SA UpperEP	40	16	13
VIC	All	42	37	11
	VIC Loddon	39	28	14
	VIC Mallee	44	40	10
	VIC Wimmera	44	41	10
WA	All	39	33	14
	WA Nth Central	37	28	15
	WA Sth	39	33	12
	WA Sth Central	41	37	14
All respondents		40	32	13

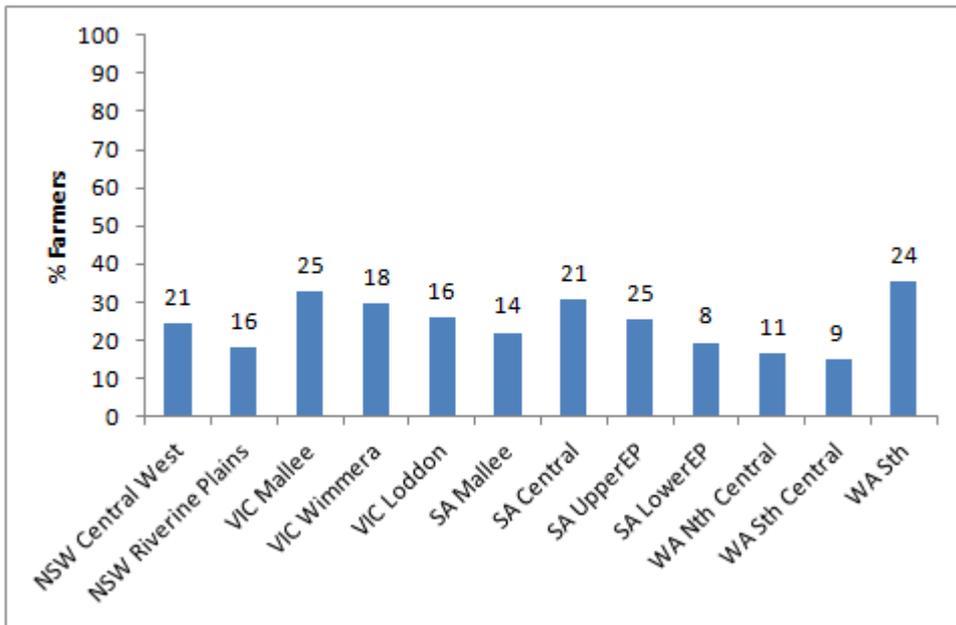


Figure 27 Percentage of growers that have ever joined a PA group or association with a focus on precision agriculture. Values on top of the bars indicate the % of farmers still associated with such a group.

5.2 Adoption of precision agriculture practices

Table 16 Percentage of autosteer adopters, stated adoption in 5 years time and average year of awareness of a grower in district using autosteer and adoption of auto steer per region.

State	Region	Percentage of autosteer adopters	Percentage of autosteer adopters in 5 years (as stated by growers)	Average of years between becoming aware and adopting	Average year farmer first became aware of auto steer use in district	Average year adopted auto steer
NSW	All	76	88	4.5	2004	2007
	NSW Central West	70	85	4.5	2004	2007
	NSW Riverine Plains	82	92	4.5	2004	2007
SA	All	79	88	3.3	2004	2007
	SA Central	92	96	3.1	2004	2006
	SA LowerEP	78	86	3.5	2004	2007
	SA Mallee	70	82	3.2	2005	2007
	SA UpperEP	75	88	3.5	2004	2007
VIC	All	74	87	3.0	2004	2007
	VIC Loddon	56	78	2.8	2005	2007
	VIC Mallee	88	94	3.5	2004	2007
	VIC Wimmera	76	88	2.6	2004	2006
WA	All	79	89	2.8	2004	2007
	WA Nth Central	89	89	3.3	2004	2007
	WA Sth	80	89	2.5	2004	2006
	WA Sth Central	70	89	2.4	2005	2006
All respondents		77	88	2.9	2004	2007

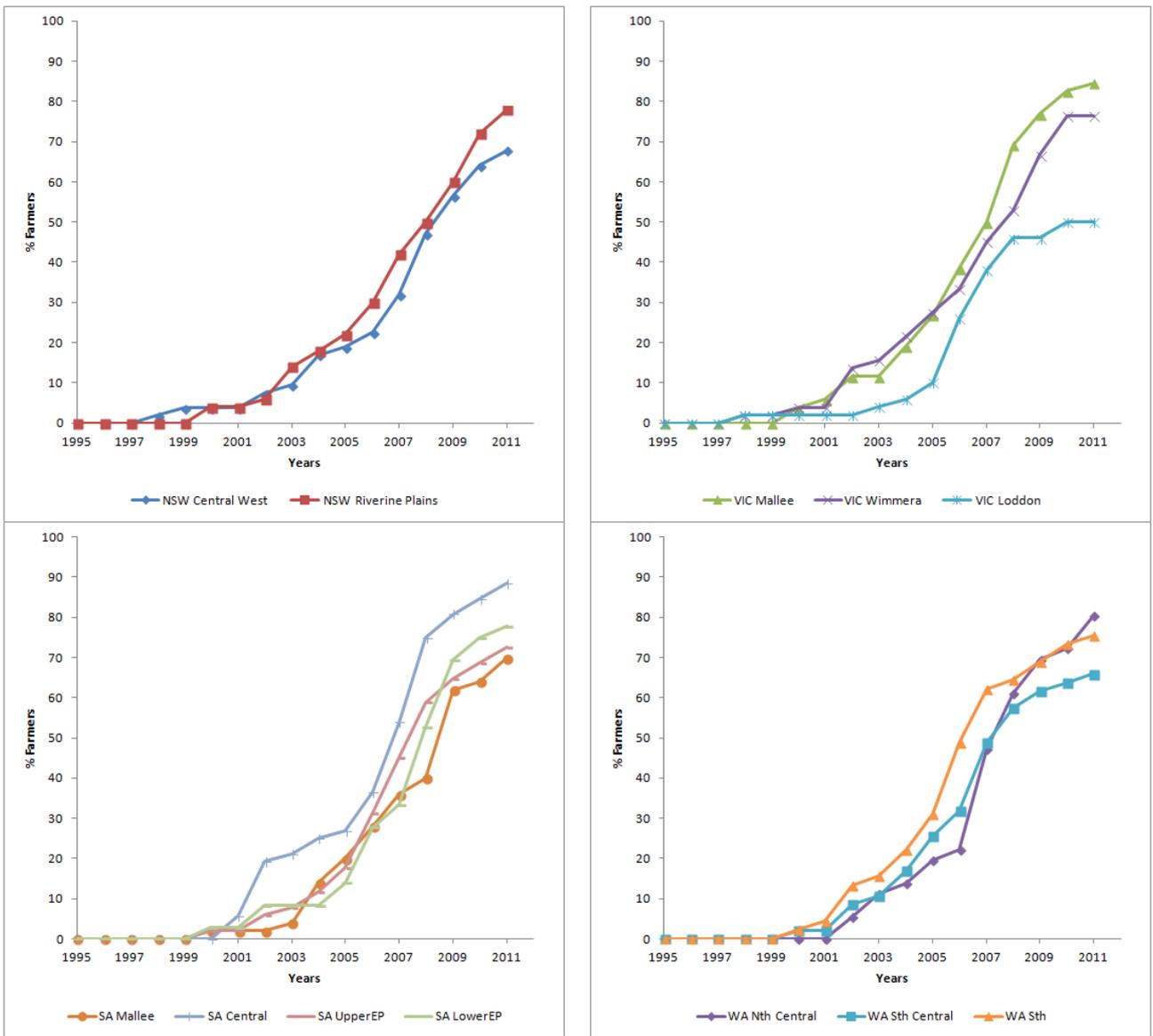


Figure 28 Proportion of growers who have auto steer over time by region

Table 17 Percentage of yield map adopter, future adopters and average year of awareness of a grower with yield maps in district and adoption of yield map per region.

State	Region	Percentage of yield map adopters	Percentage of yield map adopters in 5 years (as stated by growers)	Average of years between becoming aware of someone with yield maps in district and adopting	Average year farmer first became aware of yield map use in district	Average year adopted yield map
NSW	All	26	65	3.3	2005	2006
	NSW Central West	21	66	2.2	2005	2005
	NSW Riverine Plains	32	64	4.0	2005	2007
SA	All	30	69	3.3	2005	2006
	SA Central	27	77	4.7	2003	2005
	SA LowerEP	44	81	3.5	2004	2007
	SA Mallee	20	54	2.0	2006	2005
	SA UpperEP	31	67	2.8	2005	2006
VIC	All	33	65	2.8	2005	2007
	VIC Loddon	22	60	1.4	2006	2006
	VIC Mallee	50	75	2.8	2005	2007
	VIC Wimmera	27	61	3.8	2005	2007
WA	All	43	73	2.5	2003	2004
	WA Nth Central	53	75	3.0	2002	2005
	WA Sth	49	76	2.0	2004	2004
	WA Sth Central	30	68	2.4	2004	2004
All respondents		33	68	2.9	2005	2006

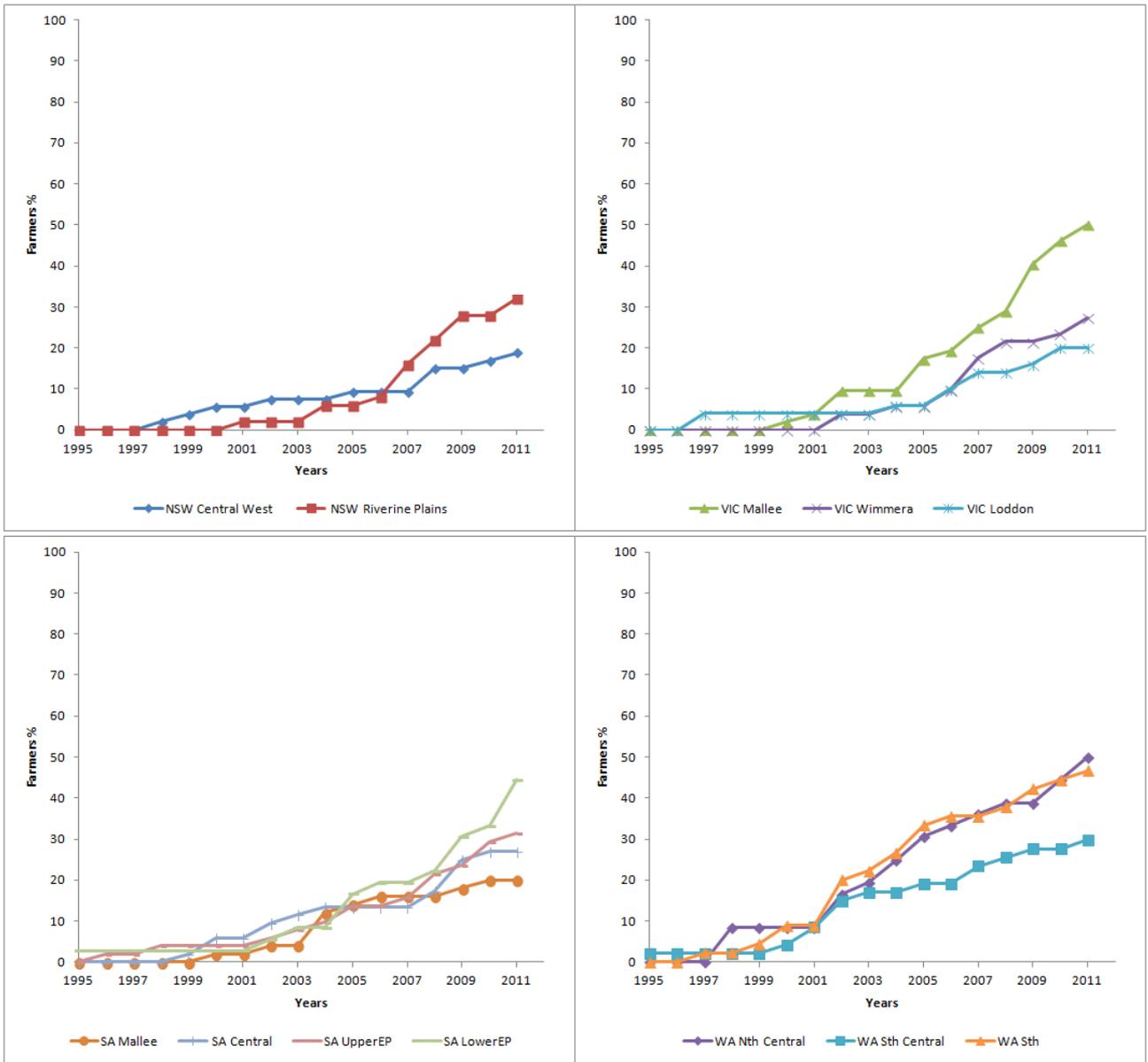


Figure 29 Proportion of growers collecting yield map data over time by region.

Table 18 Percentage of adopters, expected adopters in 5 years time (as stated by growers) and percentage of crop area treated with varying fertiliser rates on different soils within a paddock (VR), use of variable rate technology to apply varying fertiliser rates on different soils within a paddock and those with VRT-equipped seeding machinery

State	Region	Percentage applying different fertilizer rates on different soil within paddocks	Percentage expected to be applying different fertilizer rates on different soil within paddocks	Percentage of cropping land treated with different fertilizer rates on different soil within paddocks (by adopters)	Percentage of VRT adopters (varying fertiliser rates within paddocks with VRT seeding equipment)	Percentage of future VRT adopters (varying fertiliser rates within paddocks with VRT seeding equipment)	Percentage with VRT seeding equipment	Percentage expecting to have VRT seeding equipment in 5 years time
NSW	All	34	65	43	11	51	23	54
	NSW Central West	34	55	43	8	40	15	45
	NSW Riverine Plains	34	76	42	14	64	32	64
SA	All	52	72	51	15	61	44	68
	SA Central	42	65	42	12	54	48	65
	SA LowerEP	39	72	68	11	67	53	72
	SA Mallee	56	72	57	20	66	42	64
	SA UpperEP	67	78	44	18	59	37	73
VIC	All	50	62	60	16	50	27	54
	VIC Loddon	42	50	57	4	44	16	42
	VIC Mallee	75	83	64	37	65	44	67
	VIC Wimmera	33	53	53	6	41	20	51
WA	All	55	75	38	17	57	41	63
	WA Nth Central	67	72	41	25	56	44	64
	WA Sth	53	73	38	22	60	47	67
	WA Sth Central	49	79	35	6	55	32	57
All respondents		49	69	49	15	55	35	61

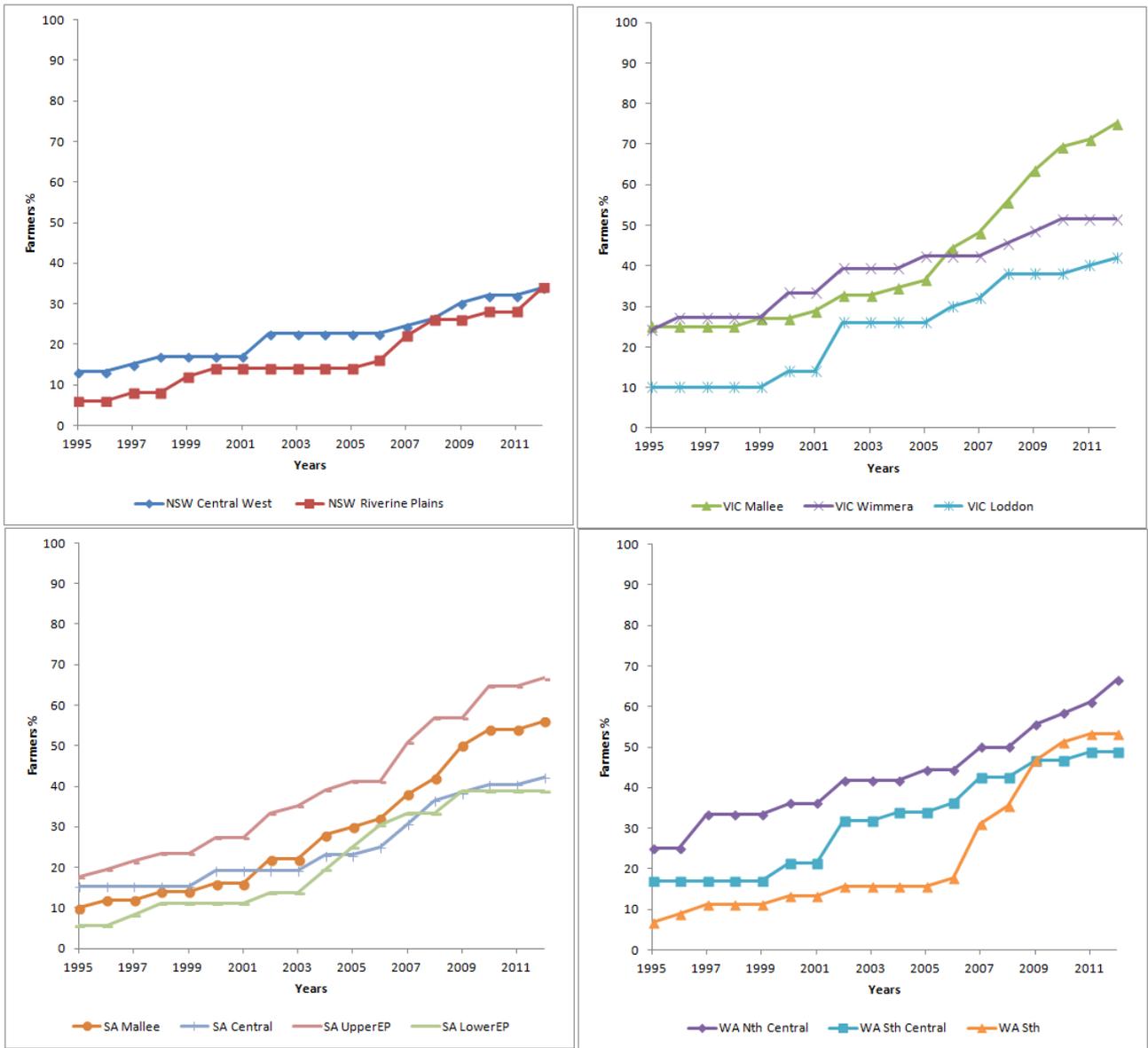


Figure 30 Proportion of growers using different fertilizer rates on different soils within paddocks (VR) over time by region.

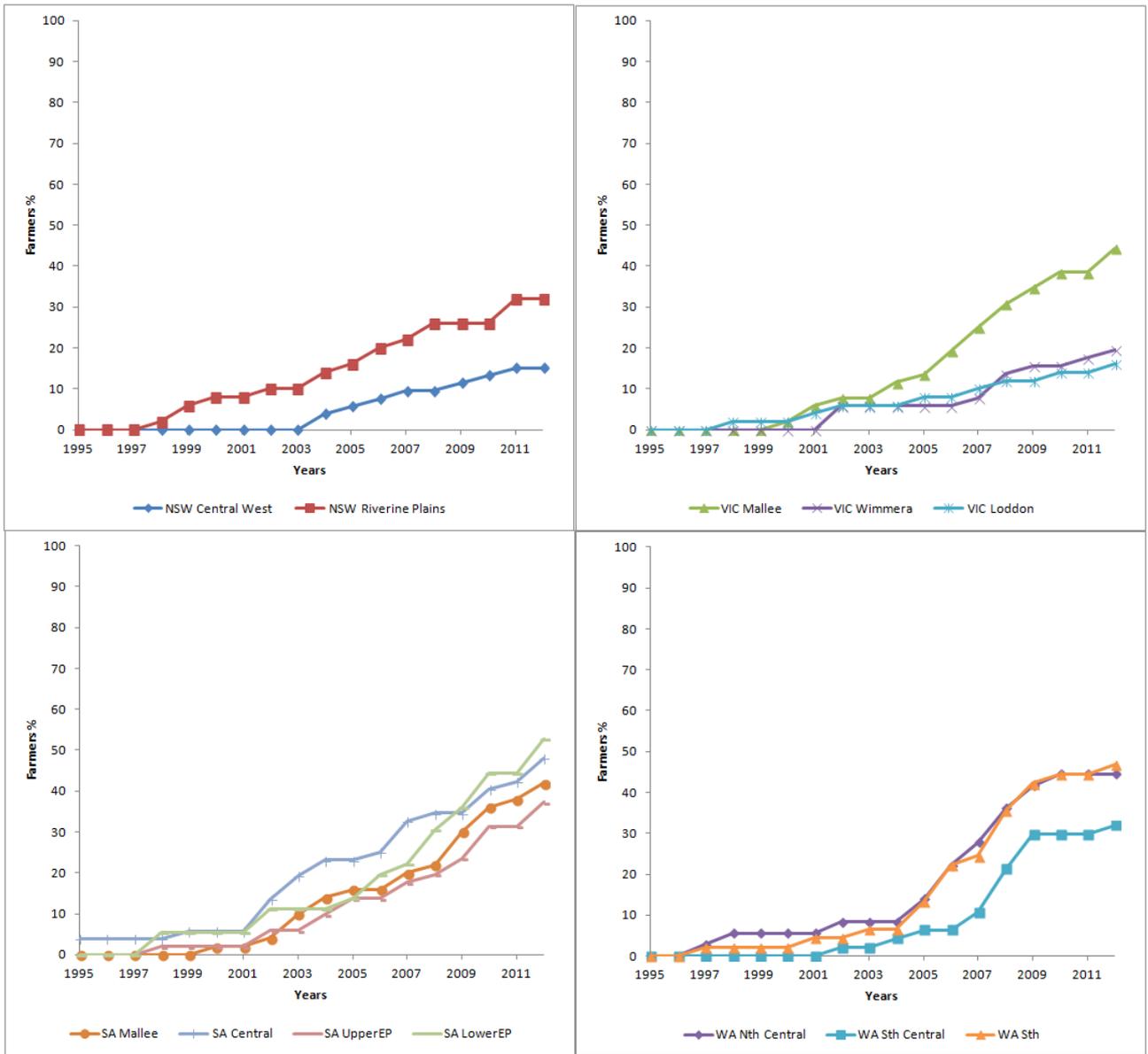


Figure 31 Proportion of growers with seed machinery equipped with VRT over time by region.

Table 19 Use of soils sampling for nutrient testing.

State	Region	Percentage of growers that had soil test in last 3 years	Average percentage of paddock that has had soil testing in last 3 years	Expect to use more than currently in 5 years	Expect to use less than currently in 5 years	Expect to use the same in 5 years
NSW	All	88	61	43	3	54
	NSW Central West	85	59	42	4	55
	NSW Riverine Plains	92	63	44	2	54
SA	All	71	36	47	6	47
	SA Central	87	33	33	4	63
	SA LowerEP	75	41	61	3	36
	SA Mallee	54	46	52	10	38
	SA UpperEP	71	30	47	6	47
VIC	All	81	55	36	7	57
	VIC Loddon	90	58	38	8	54
	VIC Mallee	75	56	40	4	56
	VIC Wimmera	78	50	29	10	61
WA	All	90	68	33	2	65
	WA Nth Central	89	68	31	0	69
	WA Sth	82	74	31	7	62
	WA Sth Central	98	62	36	0	64
All respondents		81	54	40	5	55

5.3 Regression analysis – factors associated with adoption

Table 20 Factors associated with yield mapping – regression analysis

		Yield Map		Future Yield Map	
Prob > chi2		0		0	
Sensitivity		66.08%		92.49%	
Specificity		87.75%		51.97%	
Positive		75.33%		83.99%	
Negative		82.04%		71.74%	
Correctly		79.92%		81.61%	
Questions		Odds Ratio	z	Odds Ratio	z
Farm	Gross property income Broadacre cropping	1.01	1.36	1.01	1.61
	What is the total area of arable land that you currently manage (ha)	1.00	-1.20	1.00	-1.17
	As an average over the past 3 years, approximately what proportion of your arable land do you crop each year?	1.00	2.03**	1.00	2.24**
Farmer	How old is your current main seeding machine?	0.94	-3.32***	0.96	-2.7***
	What is the age of the youngest person involved in managing the farm? Has anyone involved with managing the farm completed a university degree or diploma?	0.99	-1.00	0.97	-2.42**
Information sources	Are you a member of any local farmer group that looks at cropping issues in your district?	1.58	1.73*	1.02	0.07
	Do you pay a consultant, advisor or agronomist for cropping advice?	1.22	0.76	0.91	-0.36
	There is someone involved in the farm business who has strong computer technology skills	2.15	2.73***	1.95	2.35**
	There is someone involved in the farm business that enjoys analysing data from the crops and/or farm business	1.41	2.32**	1.23	1.50
	Do any of your major sources of agronomic advice offer precision agriculture-related services?	1.26	1.78*	1.26	1.72*
	Thinking back, in what year did you first become aware of someone in your district using variable rate technology? (That is seeding with GPS, variable rate machinery and prescription maps etc)	2.05	2.83***	1.37	1.12
	I prefer to keep my farming operations very simple	0.92	-2.88***	1.04	1.25
Perception	A lack of skilled labour is one of the biggest constraint to my farm operations	0.75	-2**	0.59	-2.77***
	There is a lack of technical support available for precision agriculture technology	1.16	1.36	1.31	2.25**
	Managing precision agriculture data is very time consuming	1.10	0.75	1.21	1.39
	Mapping paddock zones is very time consuming	1.05	0.29	0.90	-0.55
	It is not obvious how to identify paddock zones on my farm	0.70	-2.37**	0.77	-1.39
	There isn't enough variability within my paddocks to justify using different fertilizer rates on different soils within paddocks	0.97	-0.26	1.08	0.56
	A major benefit of using different fertilizer rates on different soils within paddocks is increased crop production.	0.86	-1.26	0.92	-0.67
	A major benefit of using different fertilizer rates on different soils within paddocks is reduced input costs	0.83	-1.08	1.01	0.06
	A major benefit of using different fertilizer rates on different soils within a paddock is making investment in applying fertiliser less risky	1.04	0.27	0.94	-0.40
	By using different fertilizer rates on different soils within paddocks instead of using a uniform rate I could increase my average wheat crop profitability by what %?	1.28	1.54	1.85	3.62***
	By using different fertilizer rates on different soils within paddocks instead of using a uniform rate I could increase my average wheat crop profitability by what %?	0.98	-1.33	0.98	-1.37
	Regions	Region compared to VIC Mallee			
NSW Riverine Plains		0.63	-0.81	1.19	0.28
NSW Central West		0.58	-0.88	2.28	1.32
VIC Wimmera		0.33	-1.84*	0.84	-0.27
VIC Loddon		0.29	-1.97**	0.98	-0.02
SA Mallee		0.34	-1.69*	0.86	-0.24
SA Central		0.26	-2.28**	1.82	0.89
SA UpperEP		0.74	-0.52	1.14	0.21
SA LowerEP		0.82	-0.31	2.35	1.10
WA Nth Central		0.55	-0.91	0.93	-0.08
WA Sth Central		0.32	-1.92*	0.57	-0.88
WA Sth		0.73	-0.50	1.66	0.70
_cons	4.03E+68	2.85***	5.06E-31	-1.25	

Table 21 Factors associated with adoption of autosteer – regression analysis

		Autosteer	
		0.0	
Prob > chi2		94%	
Sensitivity		57%	
Specificity		89%	
Positive		71%	
Negative		86%	
Correctly			
		Odds Ratio	z
Gross property income from broadacre cropping (\$)		1.03	3.19***
Farm	What is the total area of arable land that you currently manage (ha)	1.00	1.17
	As an average over the past 3 years, approximately what proportion of your arable land do you crop each year?	1.00	1.13
Farmer	How old is your current main seeding machine?	0.92	-4.51***
	What is the age of the youngest person involved in managing the farm?	0.97	-2.55**
Information sources	Has anyone involved with managing the farm completed a university degree or diploma?	0.79	-0.64
	Are you a member of any local farmer group that looks at cropping issues in your district?	4.79	4.56***
	Do you pay a consultant, advisor or agronomist for cropping advice?	1.78	1.69*
	There is someone involved in the farm business who has strong computer technology skills	1.10	0.61
	There is someone involved in the farm business that enjoys analysing data from the crops and/or farm business	0.98	-0.12
Perception	Do any of your major sources of agronomic advice offer precision agriculture-related services?	1.01	0.02
	Thinking back, in what year did you first become aware of someone in your district using variable rate technology? (That is seeding with GPS, variable rate machinery and prescription maps etc) I prefer to keep my farming operations very simple	0.83	-0.89
	A lack of skilled labour is one of the biggest constraint to my farm operations	1.01	0.03
	There is a lack of technical support available for precision agriculture technology	1.05	0.29
		0.88	-0.63
Regions	Region compared to VIC Mallee	2.36	1.03
	NSW Riverine Plains	0.53	-0.88
	NSW Central West	0.90	-0.14
	VIC Wimmera	0.21	-2.14**
	VIC Loddon	0.38	-1.25
	SA Mallee	1.80	0.65
	SA Central	0.41	-1.17
	SA UpperEP	0.28	-1.56
	SA LowerEP	0.48	-0.58
	WA Nth Central	0.11	-2.92***
WA Sth Central	0.40	-1.04	
WA Sth	4.17	0.8	
_cons			

Table 22 Factors associated with adoption of varying fertiliser rates within paddocks (VR) and use of variable rate technology (VRT) – regression analysis

		VR		VRT		Future VRT	
Prob > chi2		0		0		0	
Sensitivity		70.51%		49.40%		83.69%	
Specificity		73.22%		96.92%		71.20%	
Positive		72.05%		77.36%		81.10%	
Negative		71.72%		90.00%		74.73%	
Correctly		71.88%		88.58%		78.65%	
		Odds Ratio	z	Odds Ratio	z	Odds Ratio	z
Farmer Characteristics	Gross property income Broadacre cropping	0.99	-1.20	1.00	-0.09	1.00	-0.14
	What is the total area of arable land that you currently manage (ha)	1.00	0.06	1.00	-1.62	1.00	0.33
	As an average over the past 3 years, approximately what proportion of your arable land do you crop each year?	1.00	0.89	1.00	2.39**	1.00	1.75*
	How old is your current main seeding machine?	0.99	-0.45	0.91	3.16***	0.96	-2.57**
	What is the age of the youngest person involved in managing the farm?	1.00	0.06	0.99	-0.46	0.99	-1.25
	Has anyone involved with managing the farm completed a university degree or diploma?	1.53	1.71*	1.50	1.17	0.75	-1.08
	Are you a member of any local farmer group that looks at cropping issues in your district?	1.03	0.13	0.92	-0.23	0.71	-1.29
	Do you pay a consultant, advisor or agronomist for cropping advice?	1.27	0.95	1.72	1.37	1.92	2.40**
	There is someone involved in the farm business who has strong computer technology skills	0.93	-0.56	1.02	0.09	1.24	1.58
	There is someone involved in the farm business that enjoys analysing data from the crops and/or farm business	1.35	2.49**	1.84	2.99***	1.02	0.13
Information sources	Do any of your major sources of agronomic advice offer precision agriculture-related services?	1.15	0.59	1.62	1.41	2.45	3.43***
	Thinking back, in what year did you first become aware of someone in your district using variable rate technology? (That is seeding with GPS, variable rate machinerand prescription maps etc)	1.00	-0.15	0.95	-1.23	1.00	-0.12
	I prefer to keep my farming operations very simple	1.02	0.17	0.65	-2.47**	0.56	-3.65***
	A lack of skilled labour is one of the biggest constraint to my farm operations	0.83	-1.83*	0.79	-1.58	1.25	1.98**
	There is a lack of technical support available for precision agriculture technology	1.13	1.13	1.49	2.59***	1.44	2.81***
	Managing precision agriculture data is very time consuming	1.06	0.38	1.01	0.02	0.96	-0.25
	Mapping paddock zones is very time consuming	1.22	1.35	1.22	1.03	0.65	-2.61***
	It is not obvious how to identify paddock zones on my farm	0.77	-2.18**	0.75	-1.69*	1.12	0.87
	There isn't enough variability within my paddocks to justify using different fertilizer rates on different soils within paddocks	0.76	-2.52**	0.64	2.83***	0.70	-3.00***
	A major benefit of using different fertilizer rates on different soils within paddocks is increased crop production.	2.04	4.33***	1.45	1.57	1.24	1.20
Perception	A major benefit of using different fertilizer rates on different soils within paddocks is reduced input costs	1.03	0.22	1.12	0.61	1.17	1.07
	A major benefit of using different fertilizer rates on different soils within a paddock is making investment in applying fertiliser less risky	1.01	0.04	0.84	-0.83	1.60	2.94***
	By using different fertilizer rates on different soils within paddocks instead of using a uniform rate I could increase my average wheat crop profitability by what %?	1.04	2.89***	1.03	1.37	1.01	0.90
	Region compared to VIC Mallee						
	NSW Riverine Plains	0.19	-3.1***	0.47	-1.08	2.14	1.26
	NSW Central West	0.26	-2.49**	0.82	-0.24	0.86	-0.25
	VIC Wimmera	0.27	-2.36**	0.08	-2.55**	0.56	-0.98
	VIC Loddon	0.37	-1.8*	0.16	-1.96*	0.71	-0.58
	SA Mallee	0.59	-0.95	0.89	-0.16	3.15	1.74*
	SA Central	0.43	-1.56	0.29	-1.83*	1.17	0.26
SA UpperEP	0.68	-0.67	0.72	-0.49	1.80	0.95	
Regions	SA LowerEP	0.24	-2.48**	0.24	-1.75*	2.05	1.11
	WA Nth Central	0.91	-0.14	0.36	-1.32	0.34	-1.43
	WA Sth Central	0.21	-2.87***	0.09	2.94***	0.49	-1.15
	WA Sth	0.49	-1.24	0.52	-0.95	0.77	-0.38
	_cons	140.2	0.1	3.52E+42	1.2	280.878	0.11

5.4 Survey script

Q1. Introduction/permission

Q2. Are you a main cropping decision maker on the farm?

Re-introduce yourself to the relevant person if needed

Yes	1	
No	2	End

Q2

Q3. Dummy question - LGA

Q4. Thanks for your help; your time is greatly appreciated. Please note that this call may be recorded for quality assurance and training purposes So that we can be sure we are interviewing a cross section of rural producers, over the last three financial years, roughly what percentage of your gross property income, that is, only income from your property, came from the following activities?

Q5. Dummy Farm Type Question Q3x1: [Q3x1] Q3x2: [Q3x2]Q3x3: [Q3x3]Q3x4: [Q3x4]Q3x5: [Q3x5]Q3x6: [Q3x6]Q3x7: [Q3x7]Q3x8: [Q3x8]Q3x9: [Q3x9] Q3x10: [Q3x10] Q3x11: [Q3x11] Q3x12: [Q3x12] Crops: [xCrops] Livestock: [xLivestock]

Do not show If true

Grains	1
Grain/Livestock	2
Beef and Sheep	4
Beef	5
Sheep	6
Dairy	7
Sugar Cane	8
Cotton	50
Horticulture	70
QNA	99

Q5

Q6. And what is the total area of your property, including all leased land and any unused land?

CHECK WHETHER THE SHOW IS HECTARES OR ACRES & RECORD

Hectares	1
Acres	2

Q6_1

Q7. Farm Size Groups

Do not show If true

Under 400ha	1
400 - 799ha	2
800 - 1,999ha	3
2,000ha +	4

Q7

Q8. In a normal season, how many hectares would you crop on average?

CHECK WHETHER THE SHOW IS HECTARES OR ACRES & RECORD

Hectares	1
Acres	2

Q8_1

If ([Q8_1] = 1 AND [Q8_2] >= 200) OR ([Q8_1] = 2 AND [Q8_2] >= 500) go to Q10

Q9. Thank you for your time but we are actually looking for different types of producers for this survey. We appreciate your offer to provide input and are sorry to have taken your time. Best of luck with the rest of the season.

End

Q10. Thinking of your personal lifestyle and management preference, if you had to choose between cropping only or livestock only, what would you choose?

Cropping only	1
Livestock only	2

Q10

Q11. What is the total area of arable land that you currently manage?

CHECK WHETHER THE SHOW IS HECTARES OR ACRES & RECORD

Hectares	1
Acres	2

Q11_1

Q12. Do you think the total area of arable land that you or a family member will be managing in 5 years time will be

READ OUT AND RECORD - SINGLE RESPONSE ONLY

Less	1
Same	2
More	3
Will not be farming in 5 years	4

Q12

Q13. What was the total area of arable land that you managed 10 years ago?

CHECK WHETHER THE SHOW IS HECTARES OR ACRES & RECORD

Hectares	1
Acres	2

Q13_1

Q14. Approximately what proportion or percent of your land did you crop back then?

If can't estimate percentage, ask area of land (hectares or acres)

Percent	1
Hectares	2
Acres	3
Don't know	999

Q14_1

Q15. As an average over the past 3 years, approximately what proportion of your arable land do you crop each year?

If can't estimate percentage, ask area of land (hectares or acres)

Percent	1
Hectares	2
Acres	3
Don't know	999

Q15_1

Q16. What do you expect this figure to be in 4 or 5 years time?

If can't estimate percentage, ask area of land (hectares or acres)

Percent	1
Hectares	2
Acres	3
Don't know	999

Q16_1

Q17. How old is your current main seeding machine?

Months	1
Years	2
Don't know	999

Q17_1

- Q18. How old is your current main harvester / header?**
- | | | |
|------------|-----|-------|
| Months | 1 | |
| Years | 2 | Q18_1 |
| Don't know | 999 | |
- Q19. Have you ever used no-till for cropping?**
- THAT IS SEEDING WITH NO PRIOR CULTIVATION AND INCLUDES KNIFEPOINTS, ZERO-TILL WITH DISC MACHINES, SUPER-SEEDER, INVERTED-T I.E. NOT FULL-CUT SEEDING*
- | | | |
|-----|---|---------------|
| Yes | 1 | |
| No | 2 | Go to Q22 Q19 |
- Q20. In what year did you first try no-till for cropping?**
- Q21. For the crop area that you have sown this year, what percentage was sown using No Till?**
- ie seeding with discs or knife points, including super seeder or inverted T, with no prior cultivation*
- Q22. Thinking back, in what year did you first become aware of someone in your district using different fertiliser rates on different soils within paddocks?**
- Q23. Thinking back, in what year did you first become aware of someone in your district using variable rate technology? (That is seeding with GPS, variable rate machinerand prescription maps etc)**
- THAT IS SEEDING WITH GPS AND PRES*
- Q24. Thinking back, in what year did you first become aware of someone in your district using auto steer?**
- Q25. Thinking back, in what year did you first become aware of someone in your district using yield mapping?**
- Q26. Have you ever been a member of a precision agriculture association or a group with a strong focus on PA?**
- | | | |
|-----|---|-----|
| Yes | 1 | |
| No | 2 | Q26 |
- Q28. Are you still a member?**
- Show If Attribute "Yes" from Q26 is SELECTED*
- | | | |
|-----|---|-----|
| Yes | 1 | |
| No | 2 | Q28 |
- Q29. What is the name of the group?**
- Show If Attribute "Yes" from Q26 is SELECTED*
-
-
- Q30. Are you a member of any local farmer group that looks at cropping issues in your district?**
- | | | |
|-----|---|--|
| Yes | 1 | |
|-----|---|--|

	No	2								Q30
Q31.	AGRONOMISTS Do you pay a consultant, advisor or agronomist for cropping advice?									
	Yes	1								
	No	2								Q31
Q32.	Do you expect to be paying a consultant, advisor or agronomist for cropping advice in 5 years time?									
	Yes	1								
	No	2								Q32
Q33.	In a year, how many visits do they typically make to your farm?									
	<i>Show If Attribute "Yes" from Q31 is SELECTED</i>									
Q34.	In what year did you start paying for agronomic advice?									
	<i>Show If Attribute "Yes" from Q31 is SELECTED</i>									
Q35.	How much do you spend each year for your paid agronomic advice?									
	<i>Show If Attribute "Yes" from Q31 is SELECTED</i>									
	\$	1								
	Refused	888								Q35_1
Q36.	Which of the following are major sources of agronomic advice for your farm?									
	READ OUT - MULTIPLE RESPONSE OK									
	Independent agronomist / consultant - paid	1								Q36_1
	Distributor representative agronomist - free of charge	2								Q36_2
	Distributor representative agronomist - paid	3								Q36_3
	Department of Agriculture agronomist	4								Q36_4
	None of the above	555								Q36_5
	<i>If [Q36_5] = 555 go to Q45</i>									
Q37.	Do any of your major sources of agronomic advice have strong.....?									
	READ OUT AND RECORD									
		Yes	No	Don't know						
	precision agriculture skills	1	2	999						Q37_1
	crop nutrition skills	1	2	999						Q37_2
Q38.	Have any of your major sources of agronomic advice ever suggested that you should consider using (READ OUT) on your farm?									
	READ OUT - SINGLE RESPONSE ONLY									
		Yes, suggested we consider it	Yes, supported our idea to consider it	Recommended against it	Hasn't been discussed	We were already using it				
	varying fertilizer rates on different soils within paddocks	1	2	3	4	5				Q38_1
	yield mapping	1	2	3	4	5				Q38_2
	other types of paddock mapping data eg EM, NDVI , Gamma etc	1	2	3	4	5				Q38_3
	variable rate technology	1	2	3	4	5				Q38_4
	soil nutrient testing	1	2	3	4	5				Q38_5

Q39.	Do any of your major sources of agronomic advice offer precision agriculture-related services? (if asked: eg soil mapping, prescription maps, paddock zoning maps; managing spatial data from your paddocks; technical services for PA equipment)		
	Yes	1	
	No	2	Q39
	Don't know	999	
Q41.	How many do you think use different fertilizer rates on different soils within paddocks REMOVED POST PILOT		
	<i>Do not show If true</i>		
Q45.	AUTOSTEER I now want to ask you some questions about your adoption of PA. Do you use auto steer using GPS (on any of your machinery)?		
	Yes	1	
	No	2	Q45
Q46.	When did you first get auto steer using GPS?		
	<i>Show If Attribute "Yes" from Q45 is SELECTED</i>		
Q47.	Do you expect to be using auto steer in 5 years time?		
	Yes	1	
	No	2	Q47
Q48.	YIELD MAPPING Do you have a yield monitor on a harvester?		
	Yes	1	
	No	2	Q48
Q49.	In what year did you first get a yield monitor?		
	<i>Show If Attribute "Yes" from Q48 is SELECTED</i>		
Q50.	Do you have a crop yield map from any of your paddocks?		
	Yes	1	
	No	2	Q50
Q51.	Will you be collecting yield maps from crops this year?		
	Yes	1	
	No	2	Q51
Q52.	What are YOUR reasons for not collecting yield map data?		
	<i>Show If Attribute "No" from Q51 is SELECTED</i>		
	RECORD VERBATIM		
	Reason 1	1	Q52_1_1
	Reason 2	2	Q52_1_2
	Reason 3	3	Q52_1_3
Q54.	In what year did you start collecting crop yield map data from any of your paddocks?		
	<i>Show If Attribute "Yes" from Q50 is SELECTED</i>		
Q55.	Do you expect to be collecting yield map data from crops in 5 years time?		
	Yes	1	

	No	2	Q55
Q56.	EM MAPS Do you have any EM (electromagnetic) or gamma maps of any of your paddocks?		
	Yes	1	
	No	2	Q56
	Don't know what they are	3	
Q57.	Do you expect to have EM or gamma maps of any of your paddocks in 5 years time?		
	<i>Show If Attribute "No" from Q56 is SELECTED</i>		
	Yes	1	
	No	2	Q57
	Don't know what they are	3	
Q58.	NDVI MAPS Do you have any NDVI-based (including satellite vegetation; crop circle ; greenseeker) maps of any of your paddocks?		
	Yes	1	
	No	2	Q58
	Don't know what they are	3	
Q59.	Do you expect to have NDVI-based maps in 5 years time?		
	<i>Show If Attribute "No" from Q58 is SELECTED</i>		
	Yes	1	
	No	2	Q59
	Don't know what they are	3	
Q60.	FERTILISER VRT Do you use different fertilizer rates on different soils within paddocks?		
	CAN INCLUDE EITHER MANUAL EG NO GPS/VRT OR VR TECHNOLOGY		
	Yes	1	
	No	2	Q60
Q61.	What are the reasons for not using different fertilizer rates on different soils within paddocks		
	<i>Show If Attribute "No" from Q60 is SELECTED</i>		
	RECORD VERBATIMS IN FULL		
	Reason 1	1	Q61_1_1
	Reason 2	2	Q61_1_2
	Reason 3	3	Q61_1_3
Q62.	What are the reasons for using different fertilizer rates on different soils within paddocks? REMOVED POST PILOT		
	<i>Do not show If true</i>		
	RECORD VERBATIMS IN FULL		
	Reason 1	1	Q62_1_1
	Reason 2	2	Q62_1_2
	Reason 3	3	Q62_1_3
Q63.	In what year did you start using different fertilizer rates on different soils within paddocks?		
	<i>Show If Attribute "Yes" from Q60 is SELECTED</i>		
Q64.	On average, on what percentage of your cropping paddocks each year do you use different fertilizer rates on different soils within paddocks?		
	<i>Show If Attribute "Yes" from Q60 is SELECTED</i>		

Q65.	Do you expect to be using different fertilizer rates on different soils within paddocks in 5 years time?		
	Yes	1	
	No	2	Q65

Q66.	SEEDINGVRT Do you have seeding machinery that is equipped with variable rate technology?		
	Yes	1	
	No	2	Q66

Q67. When did you first get seeding machinery that was equipped with variable rate technology?
Show If Attribute "Yes" from Q66 is SELECTED

Q68.	Do you expect to have seeding machinery that is equipped with variable rate technology in 5 years time?		
	Yes	1	
	No	2	Q68

If [Q60] = 2 go to Q73

Q69.	Do you use variable rate technology e.g. using prescription maps to apply variable fertiliser rates to identified zones within any of your cropping paddocks?		
	Yes	1	
	No	2	Q69

Q70. What are YOUR reasons for not using variable rate technology?

Show If Attribute "No" from Q69 is SELECTED

RECORD VERBATIMS IN FULL

Reason 1	1	Q70_1_1
Reason 2	2	Q70_1_2
Reason 3	3	Q70_1_3

Q72. In what year did you first start using variable rate technology?

Do not show if true

Q73. Do you expect to use variable rate technology in 5 years time?

	Yes	1	
	No	2	Q73

Q74. SOIL TESTING What proportion of your cropping paddocks have had soil samples taken for nutrient testing in the last 3 years?

Q75. In what year did you start taking soil samples for nutrient testing?

Show If [Q74] > 0

Q76. What are YOUR reasons for not doing more soil nutrient testing?

Show If [Q74] < 50

RECORD VERBATIMS IN FULL

Reason 1	1	Q76_1_1
Reason 2	2	Q76_1_2
Reason 3	3	Q76_1_3

Q78.	In 5 years time do you expect to be doing more/less/the same amount of soil sampling for nutrient testing?				
	More than currently	1			
	Less than currently	2			Q78
	Same as currently	3			

Q79. RECOMMENDATIONS Would you recommend (READ OUT) to other interested farmers in your district? Would you say....

Do not show If [Q45] = 2 AND [Q51] = 2 AND [Q56] = 2 AND [Q58] = 2 AND [Q60] = 2 AND [Q69] = 2 AND [Q74] = 0

READ OUT AND RECORD

	Yes	No	Unsure	
<i>Show If Attribute "Yes" from Q45 is SELECTED</i>				
Autosteer	1	555	666	Q79_1
<i>Show If Attribute "Yes" from Q51 is SELECTED</i>				
Yield mapping or yield data files from crop	1	555	666	Q79_2
<i>Show If Attribute "Yes" from Q56 is SELECTED</i>				
EM or gamma mapping	1	555	666	Q79_3
<i>Show If Attribute "Yes" from Q58 is SELECTED</i>				
NDVI-based mapping	1	555	666	Q79_4
<i>Show If Attribute "Yes" from Q60 is SELECTED</i>				
Using different fertilizer rates on different soils within a paddock	1	555	666	Q79_5
<i>Show If Attribute "Yes" from Q69 is SELECTED</i>				
Variable rate seed technology	1	555	666	Q79_6
<i>Show If [Q14003d] > 0</i>				
Soil sampling for nutrient testing	1	555	666	Q79_7

Q80. STATEMENTS For the following statements, please indicate whether you: strongly disagree; disagree; neither disagree nor agree; agree; or strongly agree with them?

READ OUT AND RECORD

	Strongly disagree	Disagree	Neither	Agree	Strongly agree	
I am not confident in developing new computer skills when I need to	1	2	3	4	5	Q80_1
There is someone involved in the farm business who has strong computer technology skills	1	2	3	4	5	Q80_2
I enjoy analysing data from the crops and/or farm business	1	2	3	4	5	Q80_3
There is someone involved in the farm business that enjoys analysing data from the crops and/or farm business	1	2	3	4	5	Q80_4
I prefer to keep my farming operations very simple	1	2	3	4	5	Q80_5
A lack of skilled labour is one of the biggest constraint to my farm operations	1	2	3	4	5	Q80_6
A major benefit of using different fertilizer rates on different soils within paddocks is reduced input costs	1	2	3	4	5	Q80_7
A major benefit of using different fertilizer rates on different soils within paddocks is more profitable cropping	1	2	3	4	5	Q80_8
Most of my cropping paddocks contain a wide range of different soil types.	1	2	3	4	5	Q80_9
Managing precision agriculture data is very time	1	2	3	4	5	Q80_10

consuming						
A major benefit of using different fertilizer rates on different soils within a paddock is making investment in applying fertiliser less risky	1	2	3	4	5	Q80_11
Treating paddocks with gypsum or lime is a major cost to my farm business	1	2	3	4	5	Q80_12
Using variable rate technology is very complicated	1	2	3	4	5	Q80_13
Mapping paddock zones is very time consuming	1	2	3	4	5	Q80_14
It is not obvious how to identify paddock zones on my farm	1	2	3	4	5	Q80_15
There isn't enough variability within my paddocks to justify using different fertilizer rates on different soils within paddocks	1	2	3	4	5	Q80_16
There is a lack of technical support available for precision agriculture technology	1	2	3	4	5	Q80_17
I'd be able to fix most problems with precision agriculture technology myself	1	2	3	4	5	Q80_18
A major benefit of using different fertilizer rates on different soils within paddocks is increased crop production.	1	2	3	4	5	Q80_19

Q81. GENERAL PA QUESTIONS By using different fertilizer rates on different soils within paddocks instead of using a uniform rate I could increase my average wheat crop profitability by what %?

ENCOURAGE ESTIMATE

%	1
DK	999

Q81_1

Q82. From what you have now, how much extra do you think that it would cost you to become equipped to use variable rate technology if you chose to do so (eg seeding machinery; gps; software; yield monitoring)?

ENCOURAGE ESTIMATE.

\$	1
DK	999

Q82_1

Q83. What are the 2 main changes that you expect to make to improve your farm productivity in the next 5 years?

RECORD VERBATIM IN FULL

Q83

Q84. What do you think is the biggest potential benefit from precision agriculture technology on YOUR farm in the future?

RECORD VERBATIM IN FULL

Q84

Q85. If technology became available that could control where livestock grazed using electronic collars or ear tags, often called virtual fencing, how beneficial do you think it would be to your farm? Would you say...

READ OUT AND RECORD

Very beneficial	1
Moderately beneficial	2
Slightly beneficial	3
Not beneficial	4

Q85

Q86. Would you consider forming a joint venture arrangement with another farm business that involves putting land or major cropping machinery into a company arrangement?

Yes	1
Maybe	2
No	3
Already in one	4

Q86

Q87a. What is your main reason for considering a joint venture arrangement?

*Show If Attribute "Yes" from Q86 is SELECTED OR
Show If Attribute "Maybe" from Q86 is SELECTED OR
Show If Attribute "Already in one" from Q86 is SELECTED*

RECORD VERBATIM IN FULL

Q87a

Q87. Are you likely to consider forming a joint venture arrangement with another farm business in the next 5 years or are you already in one?

Do not show If true

DO NOT READ OUT

Looking to form one	1
Already in one	2
Not interested in forming one	3
Don't know	999

Q87

Q88. USE OF CONTRACTORS Do you currently use contractors for:

READ OUT AND RECORD

	Always	Sometimes	Never
Seeding / Planting	1	2	3
Fertiliser Spreading	1	2	3
Harvesting	1	2	3

Q88_1

Q88_2

Q88_3

Q89. DEMOGRAPHICS Finally, just a few demographic questions to make sure we have interviewed a representative sample of producers: Could I ask you into which of the following age groups you fall?

READ OUT AND RECORD

18 - 24	1
25 - 34	2
35 - 44	3
45 - 54	4
55 - 64	5
65+	6
REFUSED (DO NOT READ OUT)	888

Q89

Q91. What is the age of the [LQ90] person involved in managing the farm?

*Loop by Q90 for the following attributes:
youngest*

Q92. Has anyone involved with managing the farm completed a university degree or diploma?

Yes	1
No	2

Q92

Don't know

999

Q93. How many more years do you expect to be actively farming?

Q94. Will any of your family members continue your farm business after you retire?

READ OUT AND RECORD

Very unlikely	1
Unlikely	2
Not sure	3
Likely	4
Very likely	5
Not applicable	6

Q94

Q95. Thank you for your time and we appreciate your input and views. As part of our quality control, my supervisor will be re-contacting a percentage of respondents to verify the interview was conducted. For this purpose may I ask your first and last name?

First	1
Last	2

Q95_1_1

Q95_1_2

Q96. Thank you for your time and we appreciate your input and views. Best of luck with the rest of the season.

GENDER - DO NOT ASK

Male	1
Female	2

Q96

References

Bramley R.G.V. 2009. Lessons from nearly 20 years of precision agriculture research, development and adoption as a guide to its appropriate application. *Crop and Pasture Science*, 60:197–217.

D’Emden FH, Llewellyn RS, Burton MP. 2008. Factors influencing adoption of conservation tillage in Australian cropping regions. *Australian Journal of Agriculture and Resource Economics*, 52:169-182.

Pannell D, Marshall G, Barr N, Curtis A, Vanclay F, Wilkinson R. 2006. Understanding and promoting adoption of conservation technologies by rural landholders. *Australian Journal of Experimental Agriculture*, 46:1407-1424.

Robertson MJ, Llewellyn RS, Mandel R, Lawes R, Bramley RGV, Swift L, Metz N, O’Callaghan C. 2012. Adoption of variable rate technology in the Australian grains industry: status, issues and prospects. *Precision Agriculture* 13:181-199.

CONTACT US

t 1300 363 400
+61 3 9545 2176
e enquiries@csiro.au
w www.csiro.au

YOUR CSIRO

Australia is founding its future on science and innovation. Its national science agency, CSIRO, is a powerhouse of ideas, technologies and skills for building prosperity, growth, health and sustainability. It serves governments, industries, business and communities across the nation.