Adoption Innovation Profile Report: Survey Analysis

Report to the Department of Environment and Heritage Protection through funding from the Reef Water Quality Science Program

2014

Acknowledgments:

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Summary

- A key mechanism to improve water quality entering the Great Barrier Reef (GBR) catchment area is the efficient and extensive adoption of improved agricultural management practices.

- This report seeks to identify the key characteristics of improved management practices as perceived by North Queensland sugarcane farmers and to determine the main factors influencing a sugarcane farmer's adoption decision.

- Sixty-one surveys were conducted with cane growers from three of the major cane growing districts (Ayr, Ingham and Tully) in North Queensland. Growers were asked to state which management practices they had adopted and to identify the key characteristics of each management practice.

- The management practices with the lowest adoption rates were *variable nutrient rates within blocks* (7 per cent), *knockdowns and strategic residual use* (23 per cent) and *electronic records* (36 per cent). Potential constraints to adoption identified for these practices included: a high capital investment and new skills requirement; and a negative impact on farm profitability.

- The management practices with the highest adoption rates were *sub-surface application of nutrients* (98 per cent), *variable herbicide rate between blocks* (95 per cent), *directed herbicide application* (93 per cent) and *variable nutrient rates between blocks* (91 per cent). These practices had perceived characteristics that encourage adoption such as: high compatibility with existing farming systems; easy to trial; limited new skill and capital investment requirement. Additionally, these practices were perceived by growers to have a positive impact on profitability.

- Farmer perceptions of improved management practices were found to play a fundamental role in the adoption decision. Perceptions of the impact on farm profitability and compatibility with existing farming practices were critical factors impacting on the adoption decision.

- The perceptions of farmers who had/had not adopted a management practice were compared. On average, adopters believed more positively in the economic benefits of adoption compared to non-adopters.

- Socioeconomic factors as well farm characteristics were generally found to be insignificant in determining an adoption decision. However, a proportionally higher amount of younger farmers (aged 45 or less) were found to have adopted *precision and directed herbicide application* and *electronic records*.

- In the cases where improved management practices were perceived to be unprofitable by farmers and the results from RPP Economic research indicates otherwise, further work leading to a greater understanding of the true costs/benefits of improved management practices may increase adoption rates.

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1 Introduction

Industry, government and the broader community are increasingly concerned about the impact of land management practices on the Great Barrier Reef (GBR). The sugarcane industry is of important interest in this regard owing to its relative size and proximity to the GBR. A study by De'ath, Fabricius, Sweatman and Puotinen (2012) reports that over the period 1985 to 2012 there has been a decline in coral cover across the GBR from 28 per cent to 13.8 per cent. Moreover, a considerable body of research indicates that scientific links exist between the terrestrial runoff of nutrients, sediment and pesticides from farm land and a decline in the health and resilience of coastal marine ecosystems (Thorburn, Biggs, Attard & Kemei, 2011; Haapkyla, Unsworth, Flavell, Bourne & Schaffelke, 2011; Brodie, Kroon, Schaffelke, Wolanski, Lewis, Devlin, Bohnet, Bainbridge, Waterhouse & Davis, 2012; Brodie, Fabricius, De'ath & Okaji, 2005; Cook, Knight, Silburn, Kookana & Thorburn, 2011).

A key mechanism to improve water quality entering the GBR catchment area is the efficient and extensive adoption of improved agricultural management practices. Management practice adoption is a complex decision-making process motivated by perceptions of a practice's impact on profitability and other characteristics. Several studies across a range of agricultural industries emphasise the importance of perceptions and how these affect the likelihood of adoption. To date, limited research has been conducted within the sugarcane industry on these perceptions in the context of improved practice adoption.

1.1 Purpose of the Study

This study forms part of the Reef Water Quality Protection Program (RPP) economic research project, titled 'The Economics of Pesticide Management Practices on Sugarcane Farms'. RPP is an integral part of Reef Plan 2009, which is aimed at improving the quality of water entering the GBR. The main objective of this study is to report on the key characteristics of improved management practices as perceived by North Queensland cane producers. In line with this objective, this study examines factors influencing the adoption of management practices and aims to inform targeted research, policy development and extension activities to achieve more rapid adoption. Outcomes from this study may be compared with results from related RPP economic research in order to identify potential areas of grower and/or academic misconception, as well as providing a broader understanding of adoption trends.

1.2 Intended Outcomes

The overall aims of this study are:

- To utilise survey data collected from North Queensland cane farmers to identify improved management practice adoption trends.
- To analyse the key characteristics of improved management practices as well as the impact of improved practices on farm profitability as perceived by growers.
- To provide recommendations for further research, policy and extension in order to enhance the adoption of improved management practices.

1.3 Report Outline

The data presented in this report is compiled from surveys of cane farmers in North Queensland. The report is structured as follows:

Section 2: Background provides an overview of the regions in which the survey was conducted, a description of the management practices of interest to the study and a description of survey methods;

Section 3: Grower Perceptions of Practice Adoption reports on the results of the survey and provides an analysis of the key characteristics of management practices as perceived by growers;

Section 4: Profiling Adopters and Non Adopters compares and contrasts the perceptions of growers adopting and not adopting management practices;

Section 5: Discussion and Policy Implications concludes the report.

2 Background

2.1 Regions

The North Queensland cane industry comprises three major growing regions: the Wet Tropics (WT); Burdekin Dry Tropics (BDT); and Mackay Whitsundays (MW). Land management practices across these regions are of significant environmental concern owing to their proximity to the GBR. The growers surveyed for the purpose of this research reside in core cane-growing centres including Tully in the WT, Ingham in the WT, and Ayr in the BDT. The selection of these centres aligns this course of study with broader RRP economic research. Incidentally, data for MW was not obtained due to practical limitations relating to its proximity and the survey method of face-to-face interviews.

2.2 Management Practice Selection

The management practices included in the survey and subsequent analysis were developed with consideration of the following; the RPP regulatory requirements; the Reef Rescue ABCD framework; and alignment with practices evaluated in the 'The Economics of Pesticide Management Practices on Sugarcane Farms' report. Both of the RPP and Reef Rescue programs identify a number of management practices that are likely to improve water quality run-off from sugarcane farms.

The reef regulations provide a set of standards for all sugarcane growers in the WT, BDT and MW regions, including restrictions on the use of certain nutrients and pesticides. The ABCD framework, formulated in 2008/09 as part of the development of Water Quality Improvement Plans, defines a continuum of management practices from out-dated (D practices) to cutting-edge (A practices). ABCD guidelines have been developed for nutrient management, pesticide management, soil and water management in consultation with growers and industry experts. More recently, the cane industry is in the process of implementing a new Best Management Practice program, with the aim of advocating profitable and sustainable farming systems.

The majority of the improved management practices analysed in this report are considered best management or B-Class practices. The improved management practices; *variable nutrient rate within blocks*; and *precision and directed herbicide application* are considered A-Class. The management practice, *knockdowns and strategic residual use (excluding Diuron, Atrazine, Hexazinone and Ametryn)*, was included to align with the RPP economic research project. A list of the management practices surveyed is presented in Table 1 with more detailed definitions provided in Appendix 1 (A1).

Table 1: Management practices surveyed

	Management Aspect
1. Variable nutrient rates within blocks (based on EC mapping, yield mapping and soil tests)	Nutrients
2. Variable nutrient rates between blocks (based on Six-Easy-Steps principles)	Nutrients
3. Cover legume crop	Soil
4. Sub-surface application of nutrients	Nutrients
5. Low tillage (e.g. zonal tillage)	Soil
6. Knockdowns and strategic residual use (only where needed; excluding Diuron, Atrazine, Hexazinone and Ametryn).	Pesticides
7. Herbicide rate varies between blocks with consideration of weed type and pressure	Pesticides
8. Use of precision and directed herbicide application equipment with appropriate nozzles (e.g. Two Tanks, Electronic Rate Controller, banded spraying and Air	Pesticides

Inducted nozzles).	
9. Use of directed herbicide application equipment and appropriate nozzles (e.g. Air Inducted Nozzles).	Pesticides
10. Electronic records (nutrients and herbicides)	Nutrients, Pesticides
11. Nutrient and weed management plans developed by an agronomist.	Nutrients, Pesticides

Much research, including RPP economic research, has sought to quantify the economic and environmental benefits of adopting new management practices. This report differs in its approach by considering the adoption of each management practice independently. This will allow greater articulation of the key characteristics as well as a more comprehensive understanding of the adoption decision.

2.3 Grower Perceptions

Behavioural economics emphasises the importance of psychological variables such as perceptions that influence economic behaviour. In this strand of economics, perceptions of the characteristics of practices are afforded the same consideration as objective characteristics (Kaish, Gilad, Frantz, Singh, & Gerber, 1991; Wossink, De Buck, Van Niejenhuis, & Haverkamp, 1997). Pannell et al. (2006) posits that "adoption is based on subjective perceptions or expectations rather than on objective truth". Within this context, grower perceptions about the underlying characteristics associated with management practices play a fundamental role in the adoption process. Moreover, each improved management practice can be considered a bundle of characteristics that each grower values in differing proportions, which provides a description of that farmer's particular preferences (Wossink et al., 1997). This study uses an approach based on these theoretical insights, which elicits responses from growers to develop a profile of grower views toward improved practice adoption.

Several studies emphasise the importance of grower perceptions toward the characteristics of management practices in determining adoption (Adesina & Baidu-Forson, 1995; Adesina & Zinnah, 1993; D'Emden, Llewellyn, & Burton, 2008; Gould et al., 1989; Pannell et al., 2006; Van der Meulen, De Snoo, & Wossink, 1996; Wossink et al., 1997). For instance, Adesina and Zinnah's (1993) study into the adoption of rice varieties found that perceptions of the technology-specific characteristics of varieties were the major factors that determine adoption and suggest that the omission of perceptions may bias the results of other factors that affect the adoption decision. Similarly, work from a later study by Adesina & Baidu-Forson (1995) lends support to those findings. Wossink et al. (1997) found that perceptions of the characteristics of new weed control techniques were critical determinants of adoption behaviour.

From his prominent work investigating the diffusion of innovations, Rogers (2003) specifies that relative advantage, complexity, observability, trialability and compatibility are perceived characteristics of an innovation that, after extensive investigation, have been found to explain about fifty percent of the variance in the rate of innovation adoption. Rogers (2003) identified the relative advantage of adopting a new practice as a key motivator of adoption. Relative advantage is the perceived net benefit to be gained by adopting an innovation relative to the practice it supersedes. Building on Rogers' (2003) work, Pannell et al. (2006) postulates that relative advantage is a function of several perceived attributes including a practice's impact on short-term production costs and yields, medium to long-term profitability, the variability (or riskiness) of production and the required establishment costs. It is therefore unsurprising that the greater a practice's relative advantage (especially in economic terms), and the easier it is to trial, the greater the likelihood of adoption (Pannell et al, 2006).

Each of these perceived characteristics are expanded upon in Appendix 2 & 3 (A.2 & A.3) in the context of sugarcane farming and management practice adoption. Characteristics of practices

may be interpreted differently by each farmer and the adoption decision will be a product of each practice's perceived advantages and disadvantages.

2.4 Conducting the Survey

The data analysed in this report is drawn from surveys completed by sixty-one cane farmers from three of the major cane growing areas in North Queensland between March and May 2013. Table 2 lists the sample sizes for each area where surveys were conducted.

Table 2: Location of Growers Surveyed

Area	Growers Surveyed
Ayr	30
Ingham	26
Tully	5
Total	*61*

A list of 25 growers, known to the researchers through past engagement, were contacted by telephone and asked to participate in the survey. The majority (over 90 per cent) of growers agreed to participate in a face-to-face interview.

Snowball sampling, asking respondents to refer other potential study participants, was subsequently used in order to identify additional participants. All surveys were conducted with a primary farming decision-maker in person at the farmer's home or workplace. One-to-one interviews were used in favour of a group-based method in order to increase response rates, reduce the likelihood of self-selection bias[1] and to preserve the autonomy of responses.

Interviews ranged from 30 minutes to 3 hours with an average duration of 1 hour. Each grower was asked a set of 41 closed-ended questions that were categorised into four separate sections in order to identify farmer attitudes towards improved management practices, history of practice adoption, as well as a general description of grower and farm characteristics.

In *Section 1: About You* and *Section 2: Your Farm*, farmer and farm characteristics were identified. In *Section 3: Nutrient and Herbicide Management*, current farming management practices were identified. In *Section 4: Usage of Best Practice*, growers were asked to detail their use of and attitude to each improved practice. Growers were asked whether or not they used a particular practice, in what year they commenced use of the practice and whether or not they received Reef Rescue funding to implement the practice.

For Question 40, growers were asked to rate the impact on their farm from improved practice adoption on a scale of 1-5 (1 = large decrease, 5 = large increase) against four criteria; *Production Costs*, *Production of Sugar*, *Enterprise Profitability* and *Variability of Production*. Respondents were asked to complete question 40 regardless of whether or not they had adopted the practice. Growers who had not adopted the practice were asked to hypothesise about what the impact on their farm might be.

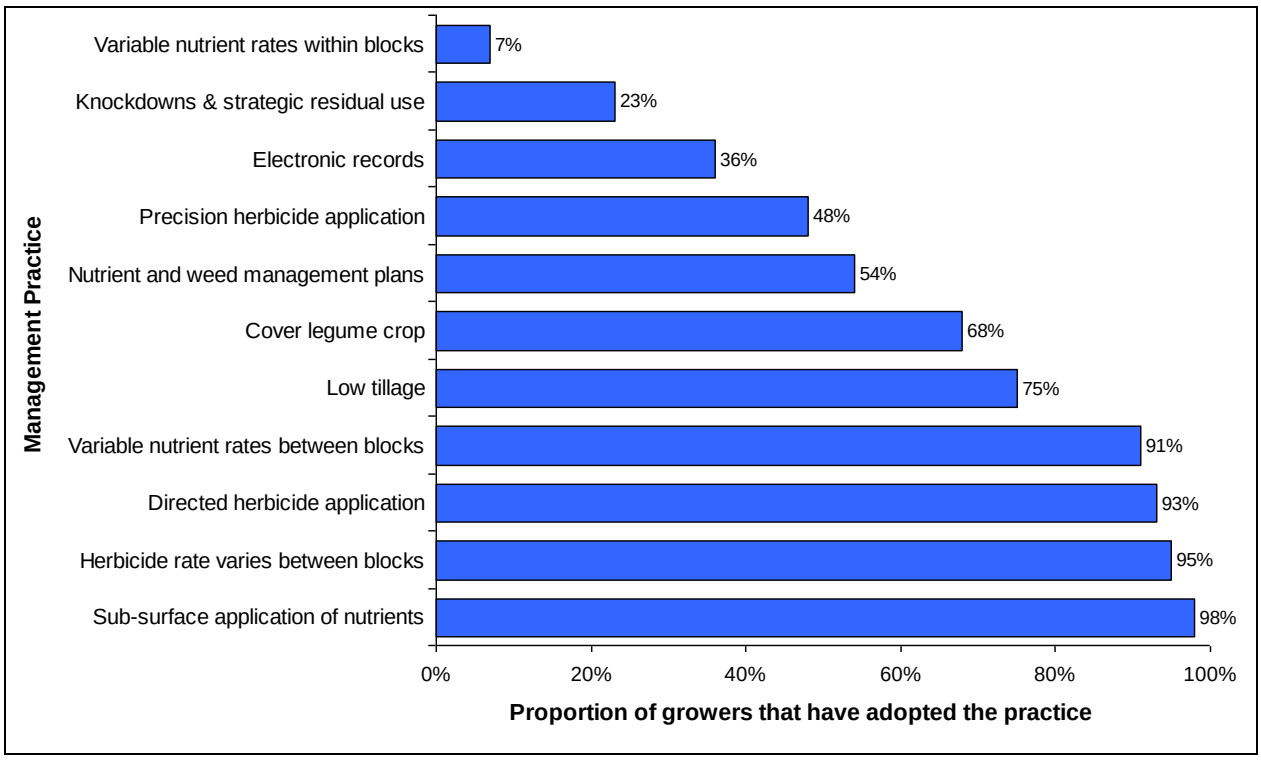
For Question 41, all participants (those who had adopted the practice and those who had not adopted the practice) were asked to identify the key characteristics of each practice on a scale of 1-5 (1= strongly disagree, 5= strongly agree) against four criteria: *High Capital Investment Needed*; *Contractors Needed to Implement Change*; *Does not Fit my Farming System*; *Not Easy to Trial;* and *Requires New Skills and Information*.

[1] For example, an open invitation to attend a group-based interview may increase the likelihood of those with an interest in the subject attending. This may increase the likelihood of a perverse outcome resulting in only those with positive attitudes toward improved practice adoption being surveyed.

2.5 Management Practice Adoption

Within the survey, growers were asked whether they had adopted each of the management practices listed in Table 1. The proportion of growers that indicated adoption of each management practice is presented in Figure 1.

Figure 1 Proportion of growers that have adopted each practice



3 Grower Perceptions of Practice Adoption

This section investigates how growers perceive improved management practices. In particular, it aims to profile perceptions of the likely economic impacts from practice adoption and the key management practice traits identified within the adoption literature (see Rogers, 2003; Pannell et al. 2006). These perceptions are contrasted with management practice adoption rates in order to demonstrate how perceptions may influence the adoption decision.

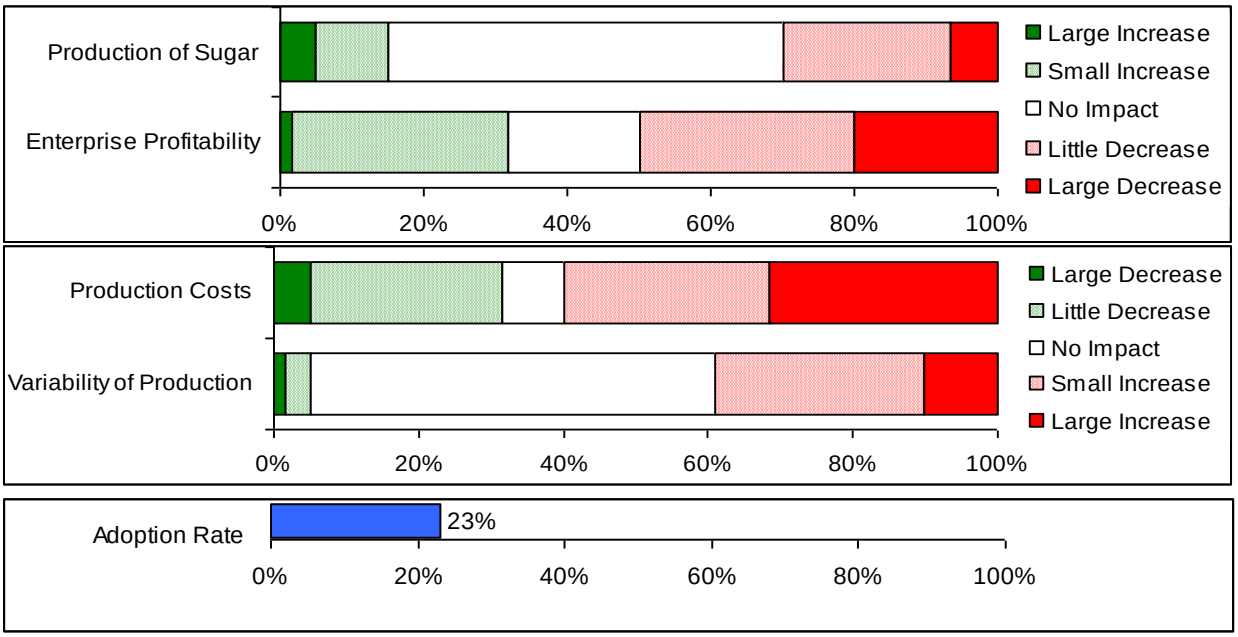
Given the survey responses to the questions outlined in the previous section, frequency distributions were formulated in order to statistically analyse the data (Appendix A.4 provides a summary of the data used in this section). Stacked bar charts were then developed to provide a visual representation of the responses across each distribution. Green sections were coded to represent the proportion of growers that perceive the practice as being beneficial once adopted, while the red sections represent the proportion of responses that suggest the contrary. Incidentally, the proportion of each coloured region (i.e. red or green) is indicative of a more generalised view of whether this particular trait presents as a potential barrier or driver toward adoption.

3.1 Pesticide Practices

3.1.1 Knockdowns and strategic residual use (ex. Diuron, etc)

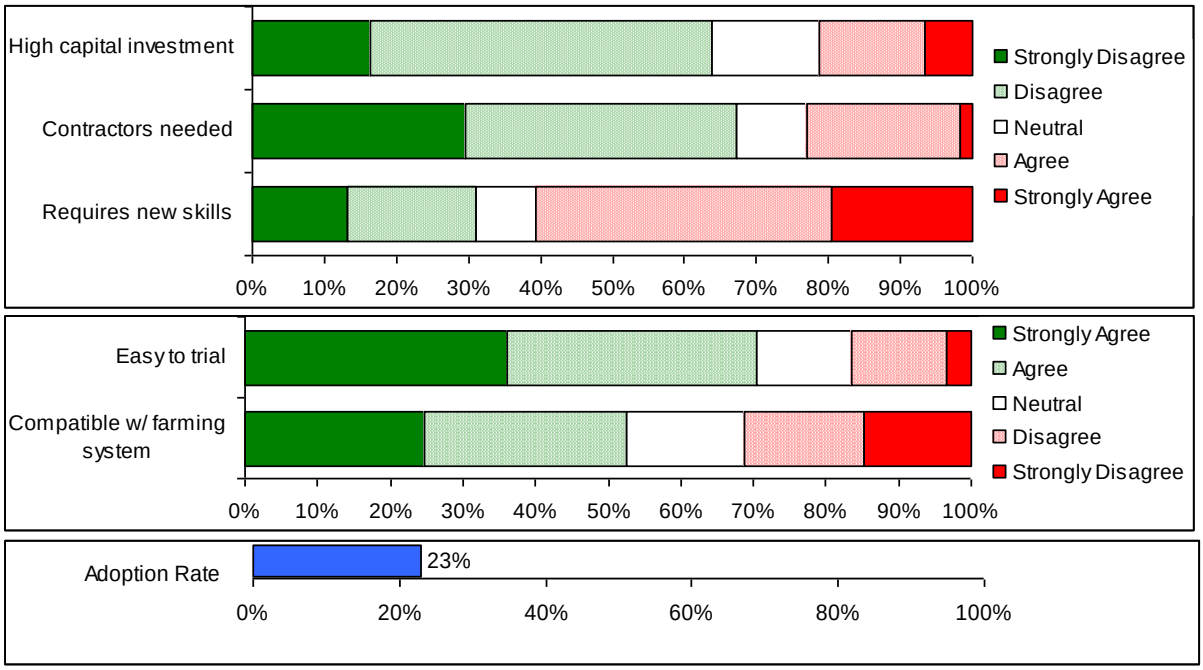
Figure 2 illustrates the perceived economic implications for using knockdowns in conjunction with strategically applied residuals (excluding Diuron, Atrazine, Hexazinone and Ametryn). Of the growers surveyed, this practice had the second lowest adoption rate (23 per cent). The majority of growers surveyed perceived that practice adoption would not impact the production of sugar (55 per cent) nor affect the variability of production (56 per cent). On the other hand, most growers believed practice adoption would increase production costs (60 per cent) and lead to a decrease in profitability (50 per cent). These results suggest that the low adoption rate for knockdowns and strategic residual use may be related to the perception that adoption of the practice will increase production costs and, in turn, decrease profitability.

Figure 2 Perceptions of economic impacts for knockdowns and strategic residual use



How growers responded to questions about specific characteristics of this practice is illustrated in Figure 3. The majority of growers agreed that the practice is easy to trial (70 per cent) and is compatible with existing farming systems (53 per cent). Furthermore, the majority disagreed with notions that practice adoption requires a high capital investment (64 per cent) and contractors (68 per cent). On the contrary, most growers hold an affirmative view that the practice requires new skills and information (61 per cent). Results here clearly indicate that growers perceive the requirement of new skills and information to be a potential issue of concern when considering adoption.

Figure 3 Perceptions of the characteristics of knockdowns and strategic residual use



3.1.2 Herbicide rate varies between blocks

Figure 4 presents the perceived economic implications for varying the rate of herbicide use between blocks. Of the growers surveyed, this practice had the second highest adoption rate (95 per cent). Accordingly, most growers perceived that this practice would not impact the production of sugar (64 per cent) nor affect the variability of production (75 per cent). Similarly, a significant proportion of growers believed that practice adoption would result in a decrease in production costs (73 per cent) and an increase in profitability (75 per cent).

Figure 4 Perceptions of economic impacts for varying herbicide rates between blocks

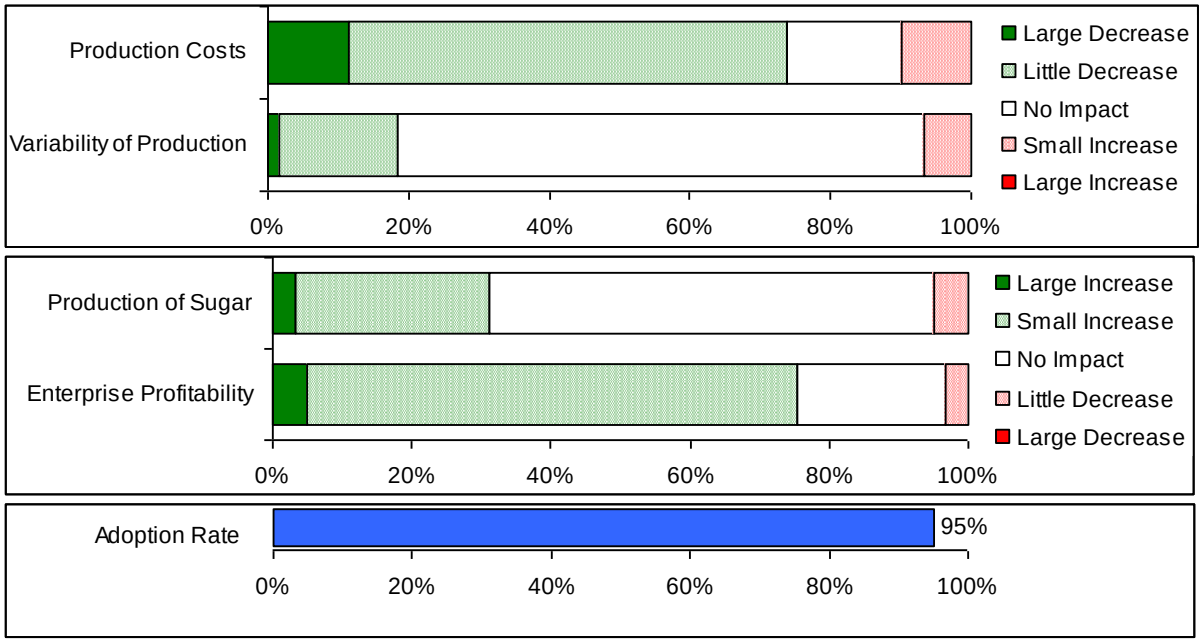
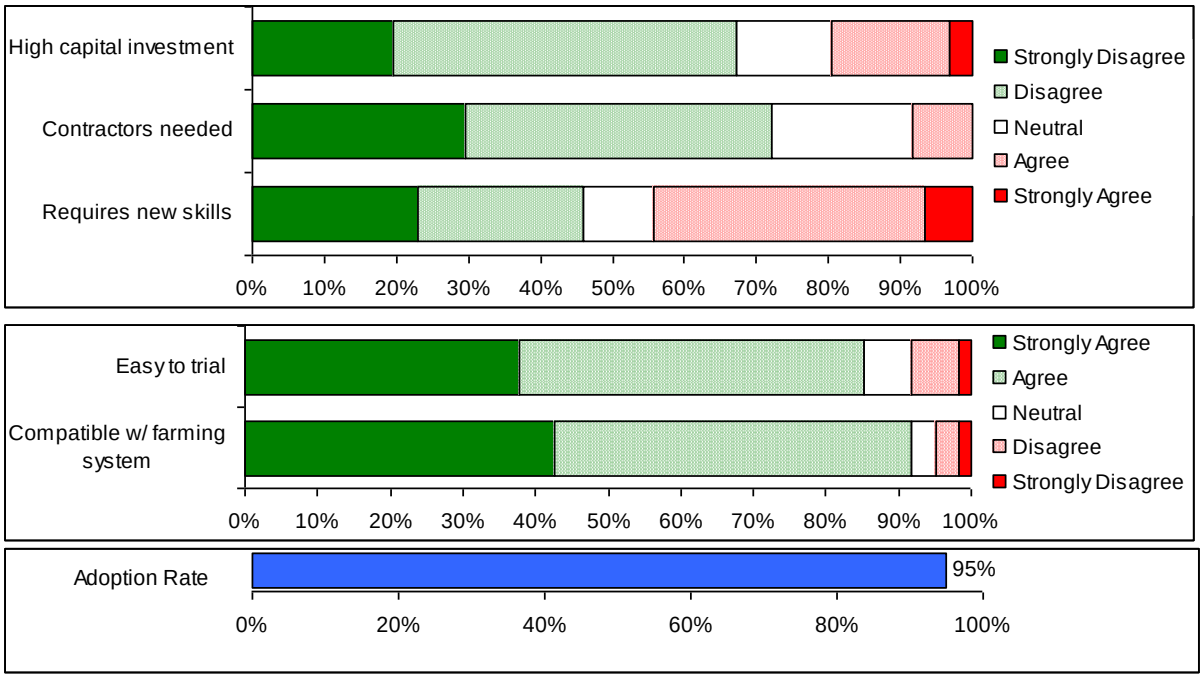


Figure 5 shows that growers agreed quite emphatically that varying herbicide rates between blocks is compatible with existing farming systems (92 per cent) and is easy to trial (86 per cent). In addition, growers disagreed that contractors (73 per cent) and a high capital investment (68 per cent) were required in order to adopt the practice. Results were less decisive, on the other hand, regarding the issue of whether or not the practice requires new skills and information. In particular, a similar proportion of growers agreed (45 per cent) as did those that disagreed (46 per cent). This indicates that the requirement of new skills was perceived to be one practicality that may potentially impede adoption.

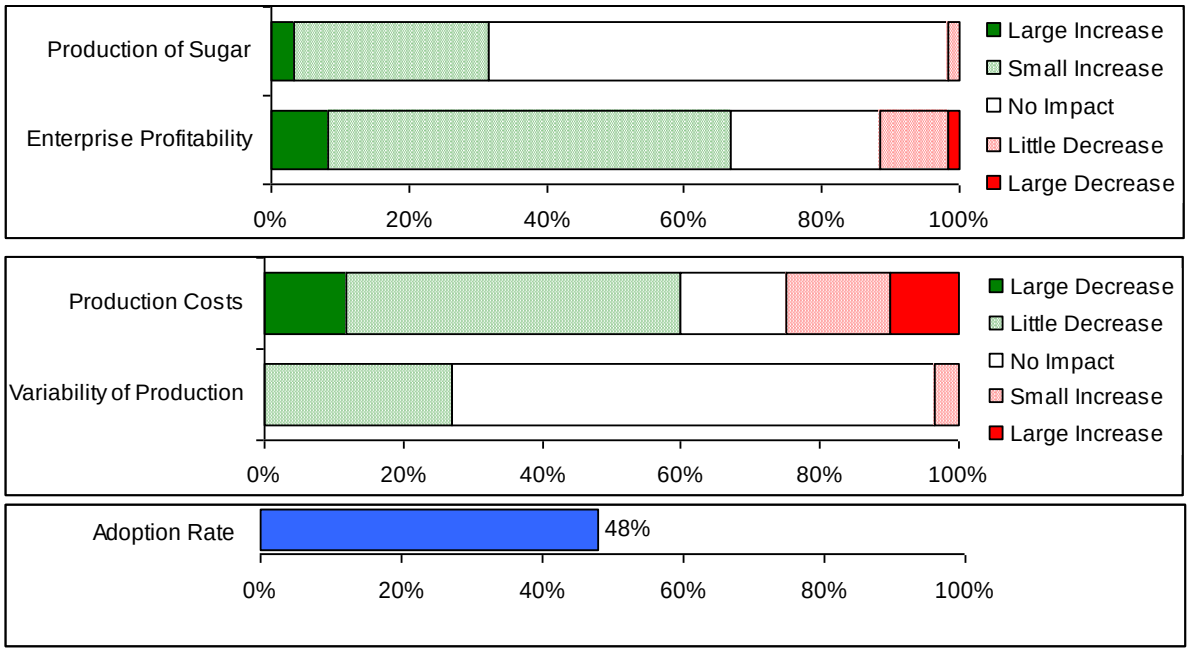
Figure 5 Perceptions of the characteristics of varying herbicide rates between blocks



3.1.3 Precision and directed herbicide application

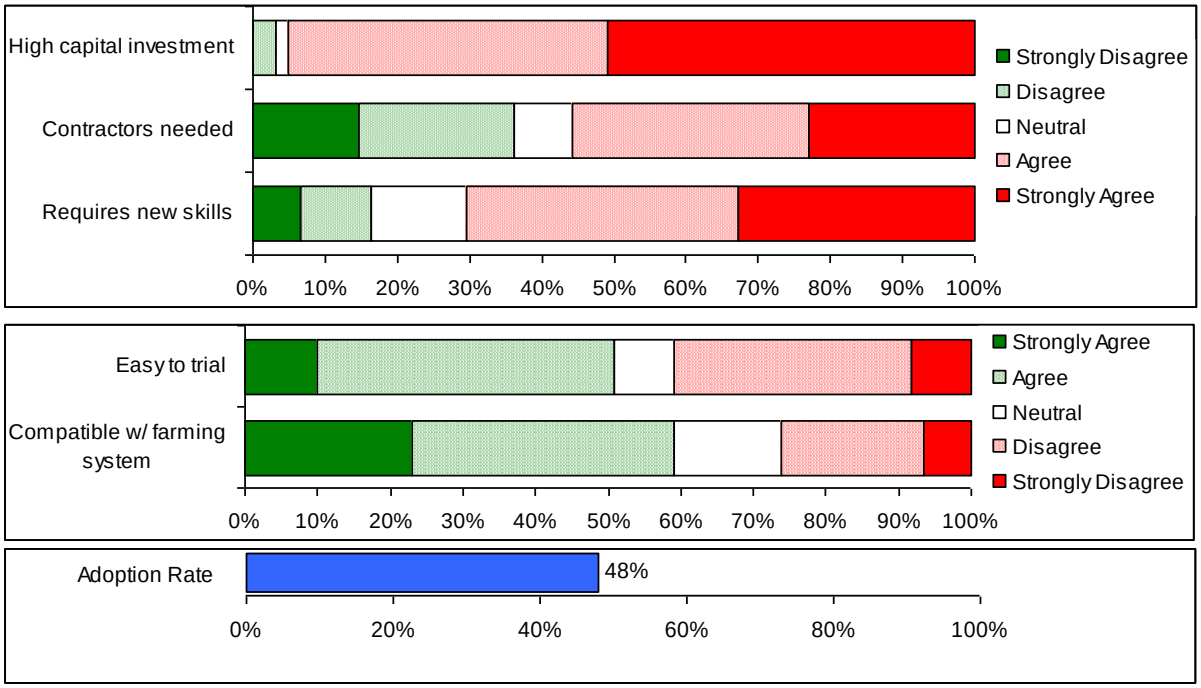
A substantial proportion of growers believed adopting precision and directed herbicide application would have no impact on the production of sugar (67 per cent) nor any affect on the variability of production (69 per cent), see Figure 6. While at the same time, a majority of growers expect that practice adoption would decrease production costs (60 per cent) and increase profitability (66 per cent). Of growers surveyed, 47.5 per cent had adopted precision and directed herbicide application.

Figure 6 Perceptions of the economic impacts for precision and directed herbicide application



As shown in Figure 7, growers were close to absolute agreement that adoption would require a high capital investment (95 per cent) and, to a lesser extent, new skills and information (71 per cent) and contractors (56 per cent). On the contrary, the majority of growers agree that the practice is compatible with existing farming systems (59 per cent). Whether or not growers view the practice as easy to trial is less decisive, with a comparable proportion of growers agreeing (41 per cent) and disagreeing (51 per cent). These results suggest that whilst growers perceive the practice to make sense economically, their views towards the practical aspects of adoption are far more discouraging. Adoption will likely require new capital purchases of farming equipment such as a GPS, rate controller and hoods, as well as training to use the equipment with efficacy. Consequently, capital poor growers may require contractors. However, those with limited or no access to contractors may find it difficult to adopt or even trial. Additionally, the new skill requirement may deter adoption. These barriers to adoption provide an explanation as to the cause of this practice's relatively low adoption rate; the fourth lowest out of the eleven management practices considered in this report.

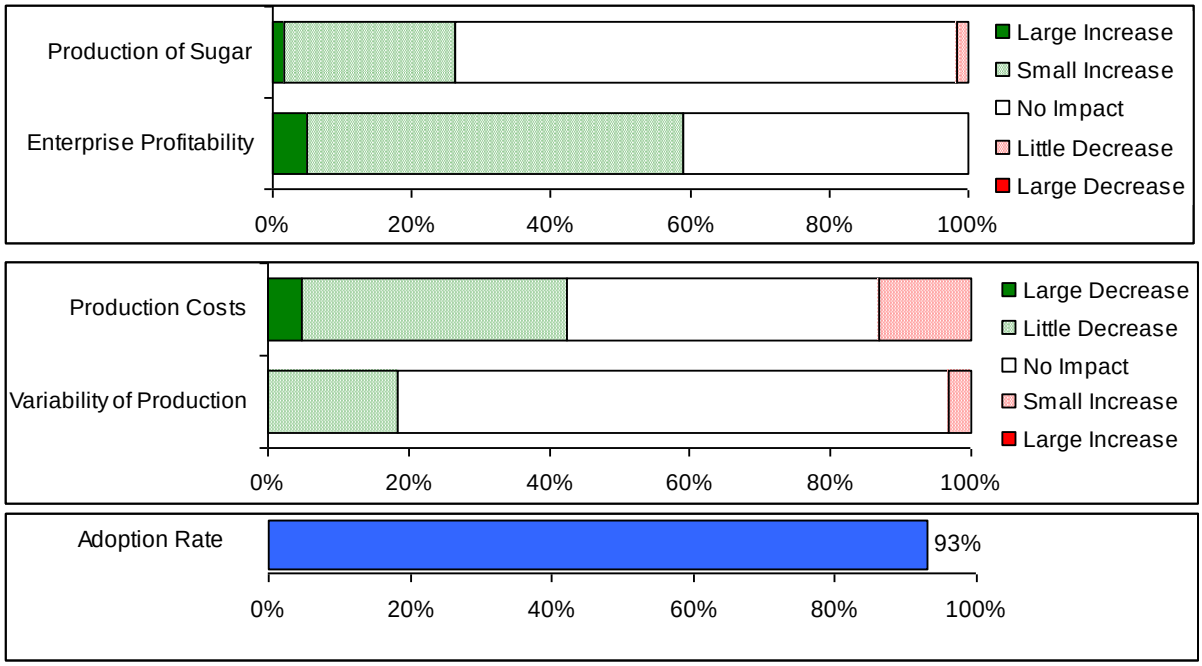
Figure 7 Perceptions of the characteristics of precision and directed herbicide application



3.1.4 Directed herbicide application with appropriate nozzles

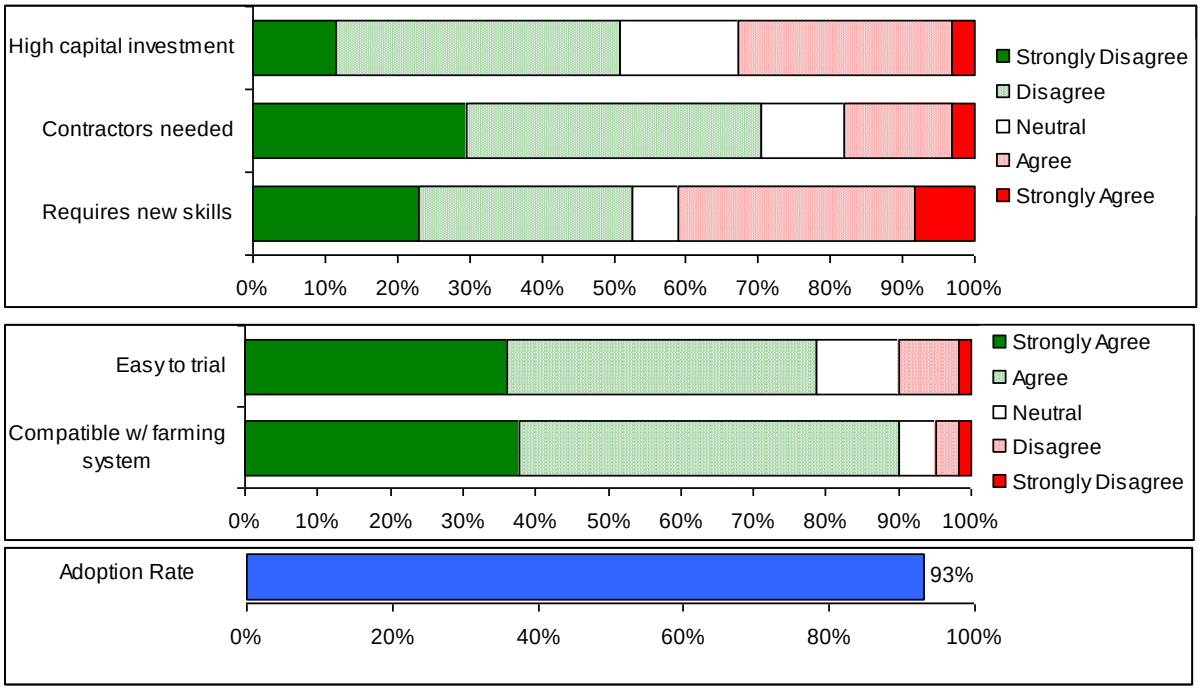
Of the growers surveyed, 93.4 per cent had adopted directed herbicide application. Most growers perceived that adopting directed herbicide application with appropriate nozzles is unlikely to impact on the production of sugar (72 per cent) or affect the variability of production (78 per cent), see Figure 8. Responses were less decisive regarding the impact on production costs; albeit, the majority of growers perceive that this practice will lead to an increase in profitability (59 per cent).

Figure 8 Perceptions of the economic impacts for directed herbicide application



Most growers perceived the adoption of directed herbicide application as being compatible with current farming systems (90 per cent) and easy to trial (79 per cent), see Figure 9. Moreover, a greater number disagreed that adoption required the use of contractors (71 per cent). Responses were less clear regarding whether the practice required a high capital investment or new skills; however, the majority disagreed. On the whole, these results are consistent with the high adoption rate for this practice; the third most adopted among the eleven.

Figure 9 Perceptions of the characteristics of directed herbicide application



3.1.5 Electronic records

The majority of growers (see Figure 10) perceived that adoption would have no impact on the production of sugar (86 per cent). They also tended to believe that maintaining electronic records has no affect on their profitability (71 per cent), production costs (61 per cent) or variability in production (86 per cent). Only 36 per cent of growers surveyed had adopted electronic records; placing it as the third least adopted practice.

Figure 10 Perceptions of the economic impacts of using electronic records

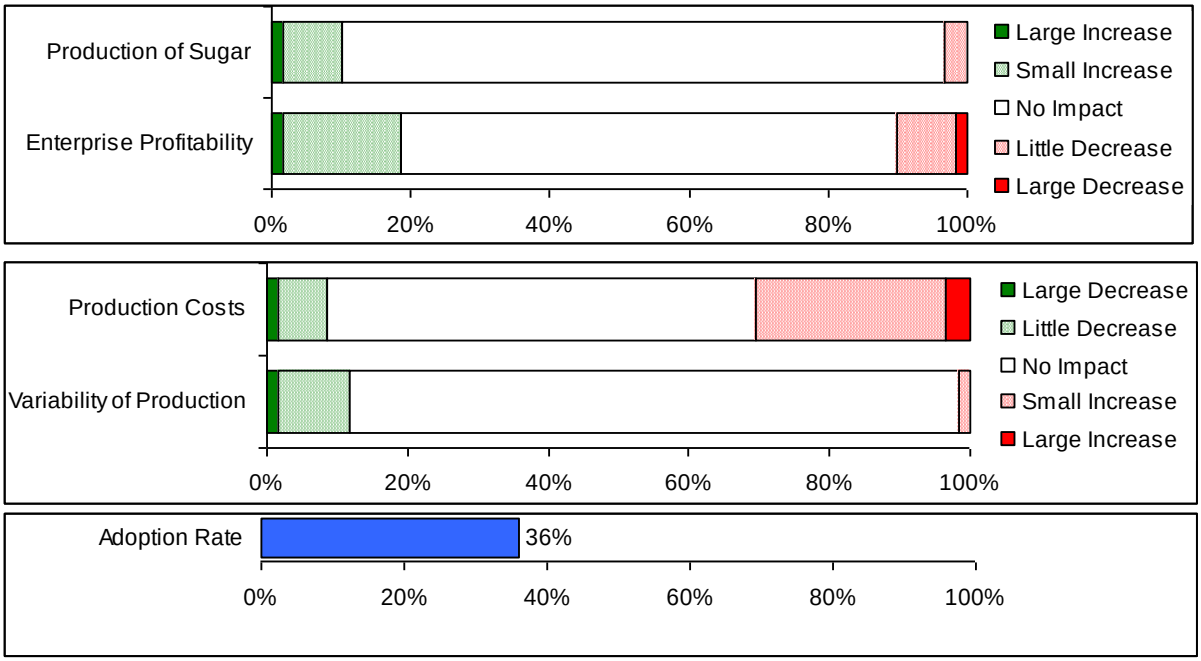
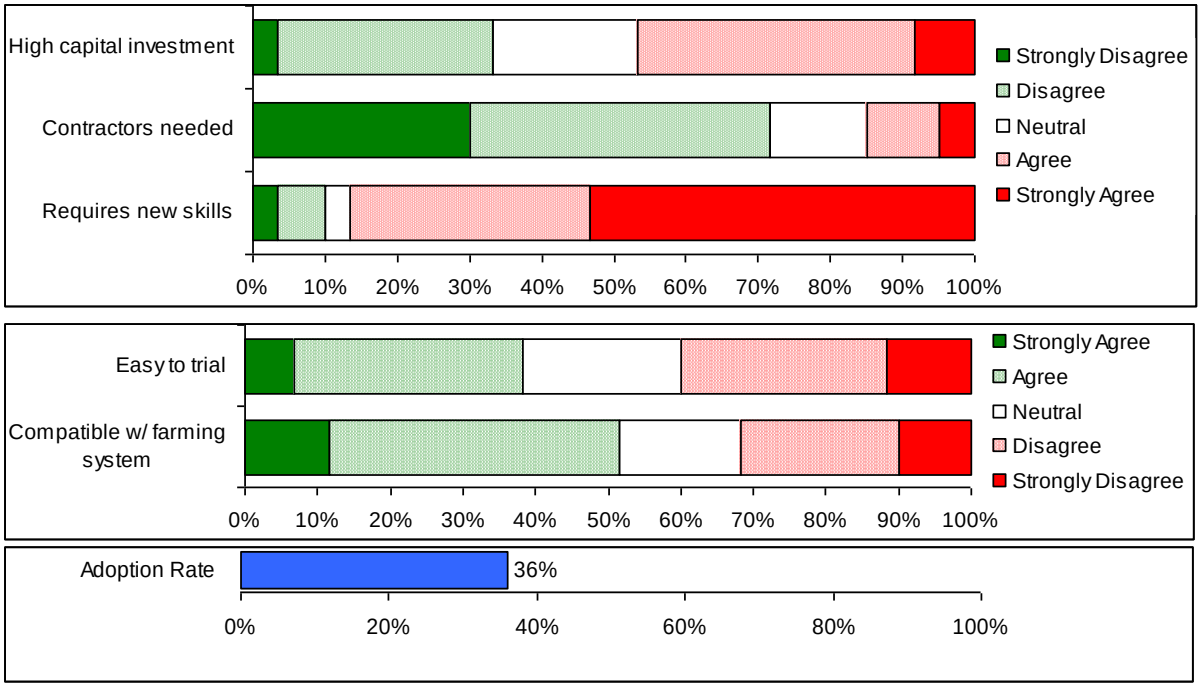


Figure 11 reveals grower perceptions of the characteristics of adopting electronic records. Growers were divided in their perceptions of several characteristics. Similar proportions of growers both agreed and disagreed that the practice requires a high capital investment (46 per cent and 33 per cent, respectively) and was easy to trial (39 per cent and 40 per cent, respectively). Moreover, a considerable proportion of growers disagreed that contractors (i.e. agribusiness consultants etc) were needed to implement adoption (72 per cent), while the majority agreed the practice was compatible with their current farming system (52 per cent). Importantly, the majority of growers strongly agreed that the practice requires new skills and information (53 per cent). This result may exemplify the difficulty some growers face in using computers.

While there were negligible perceived economic constraints to adopting electronic records, growers perceived the requisite new skills and information as the primary limiting factor. To a lesser extent, some growers may be deterred by the necessary capital investment and poor trialability.

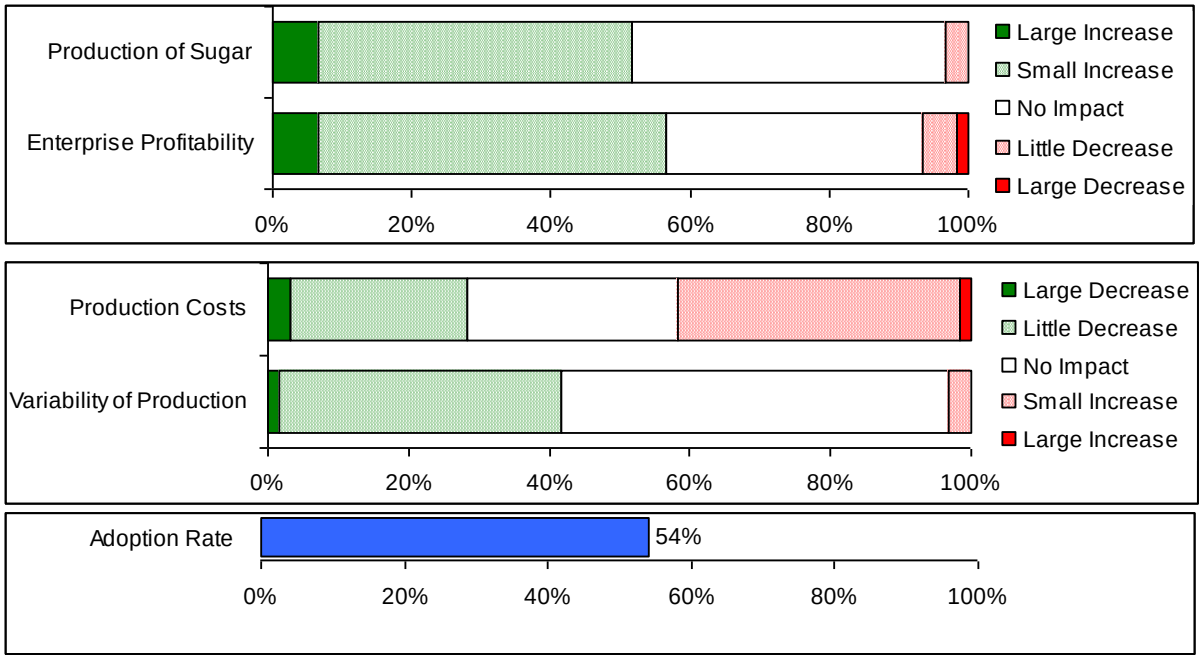
Figure 11 Perceptions of the characteristics of using electronic records



3.1.6 Nutrient and weed management plans

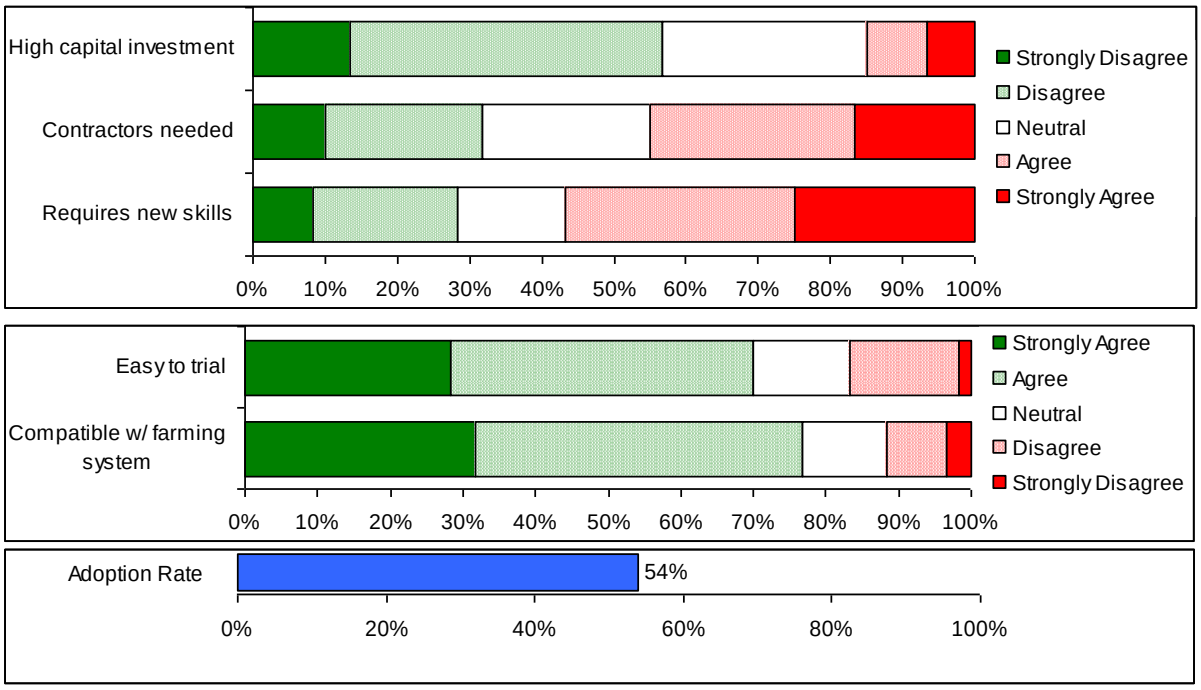
Figure 12 highlights the perceived economic impacts from adopting nutrient and weed management plans developed by an agronomist. Of the growers surveyed, 54 per cent had adopted this practice. The greatest number of growers perceived that adoption would increase production costs (42 per cent). However, on balance the majority perceived an increase in the production of sugar (52 per cent) and profitability (57 per cent). In addition, the bulk of grower perceptions ranged between no impact (55 per cent) and a decrease (40 per cent) to production variability. These results indicate that many growers perceive the adoption of nutrient and weed management plans to be economically beneficial, as higher production costs are outweighed by increased sugar production.

Figure 12 Perceptions of the economic impacts of using nutrient and weed management plans



Most growers disagreed that practice adoption required a high capital investment (56 per cent) and agreed the practice was easy to trial (70 per cent) and compatible with existing farming systems (77 per cent) see Figure 13. On the other hand, the majority of growers agreed that practice adoption requires new skills and information (57 per cent) and a contractor to implement (45 per cent). Importantly, growers may have access to local extension services; in which case, this may reduce their demand for contractors. However, if growers have access to neither, then practice adoption may be limited. All things considered, the need for contractors and new skills and information may potentially constrain adoption which is consistent with the average adoption rate for this practice; the seventh most adopted among the eleven.

Figure 13 Perceptions of the characteristics of using nutrient and weed management plans

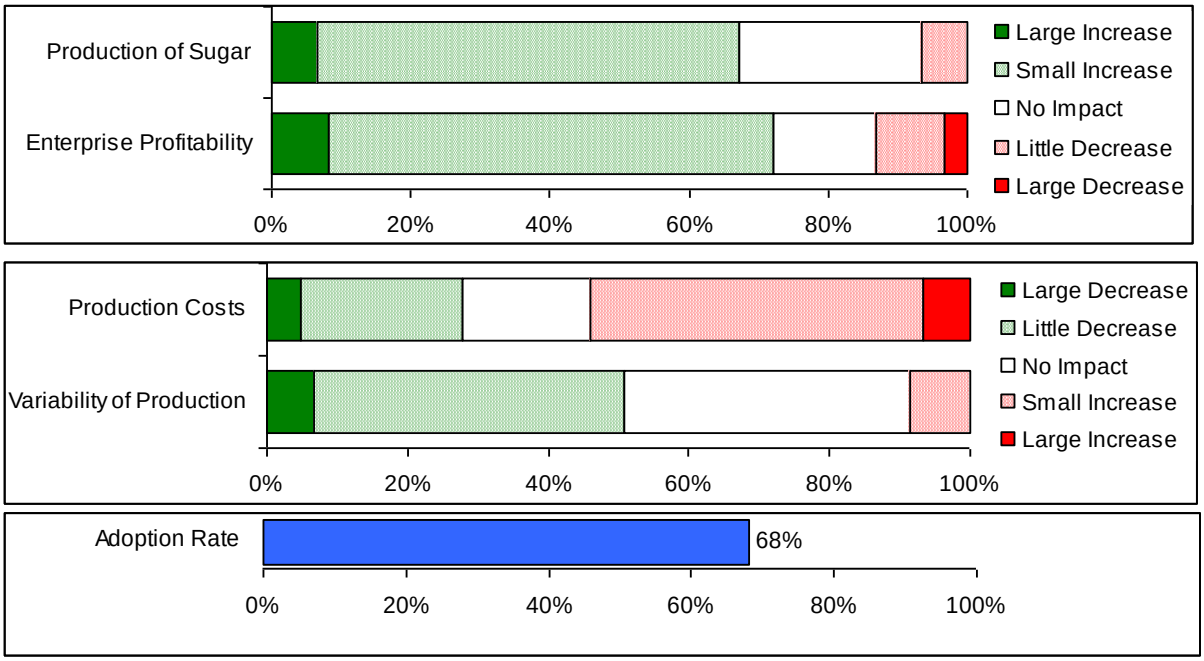


3.2 Soil Practices

3.2.1 Cover legume crop

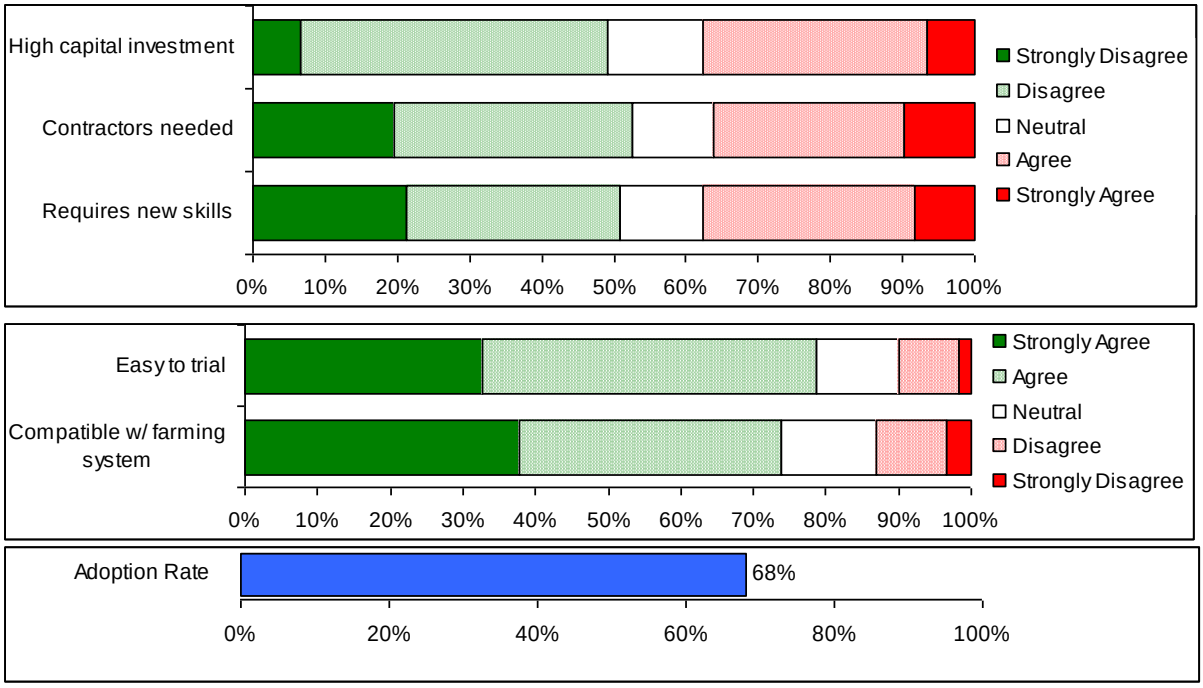
Most growers perceived that using a cover legume crop would be beneficial to their farming business (see Figure 14). In particular, the majority of growers perceived that adoption would increase the production of sugar (68 per cent) and profitability (72 per cent) while reducing production variability (44 per cent). There was some division among growers in regards to the perceived impact on production costs, with 55 per cent indicating an increase and 28 per cent a decrease. This may be because production costs are influenced by the success of the legume crop as well as the adjustment of nitrogen rates in subsequent plant cane crops. Technically, the capital investments associated with production (legume planter, etc) are considered fixed costs and should not be included in an analysis of variable/production costs. However, some growers may not have differentiated between fixed and variable costs and as such may have perceived the inclusion of capital investments.

Figure 14 Perceptions of the economic impacts of a cover legume crop



Most growers agreed that a cover legume crop is compatible with existing farming systems (74 per cent) and is easy to trial (79 per cent), see Figure 15. Growers were divided, however, in their perceptions toward several characteristics. For instance, responses were split on the notion that a legume fallow requires a high capital investment (38 per cent agreed and 50 per cent disagreed), contractors to implement (36 per cent agreed and 53 per cent disagreed) and new skills and information (38 per cent agreed and 51 per cent disagreed). These results may indicate that some growers view these characteristics as potential obstacles to adoption while others do not. Growers with smaller farms may see the capital investments associated with a cover legume crop as relatively higher and consequently more of a potential barrier. Furthermore, some growers may exploit less expensive methods to plant legume crops. These results are consistent with the above average adoption rate for this practice (68 per cent); ranking it as the sixth most adopted out of the eleven management practices examined.

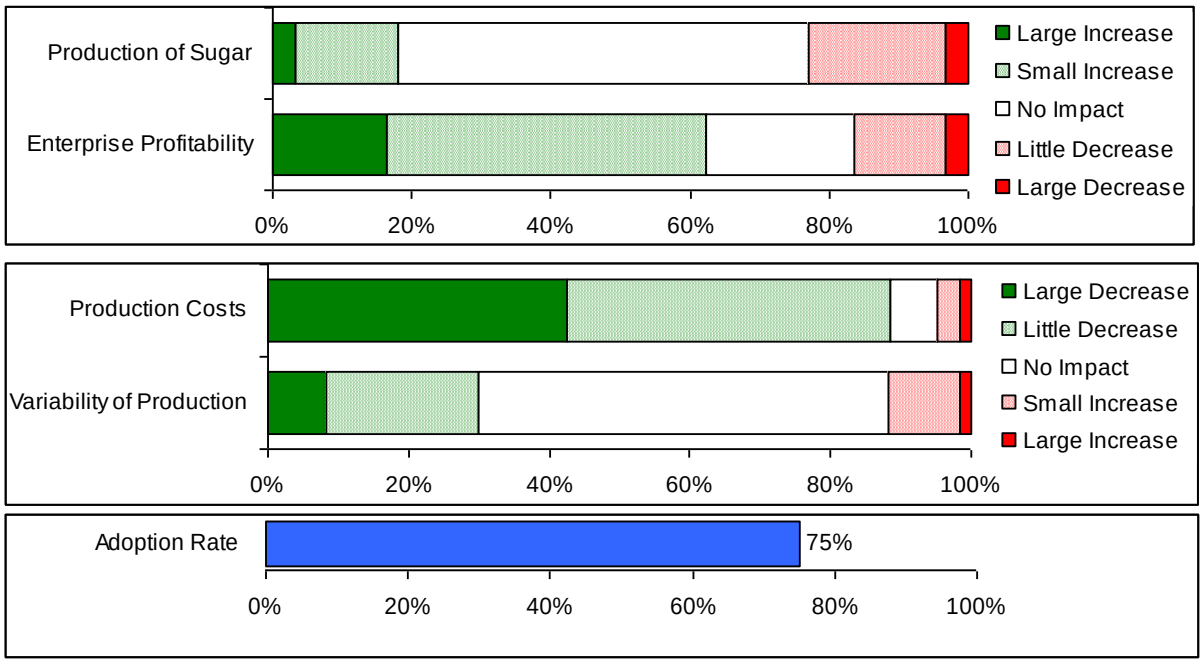
Figure 15 Perceptions of the characteristics of a cover legume crop



3.2.2 Low Tillage

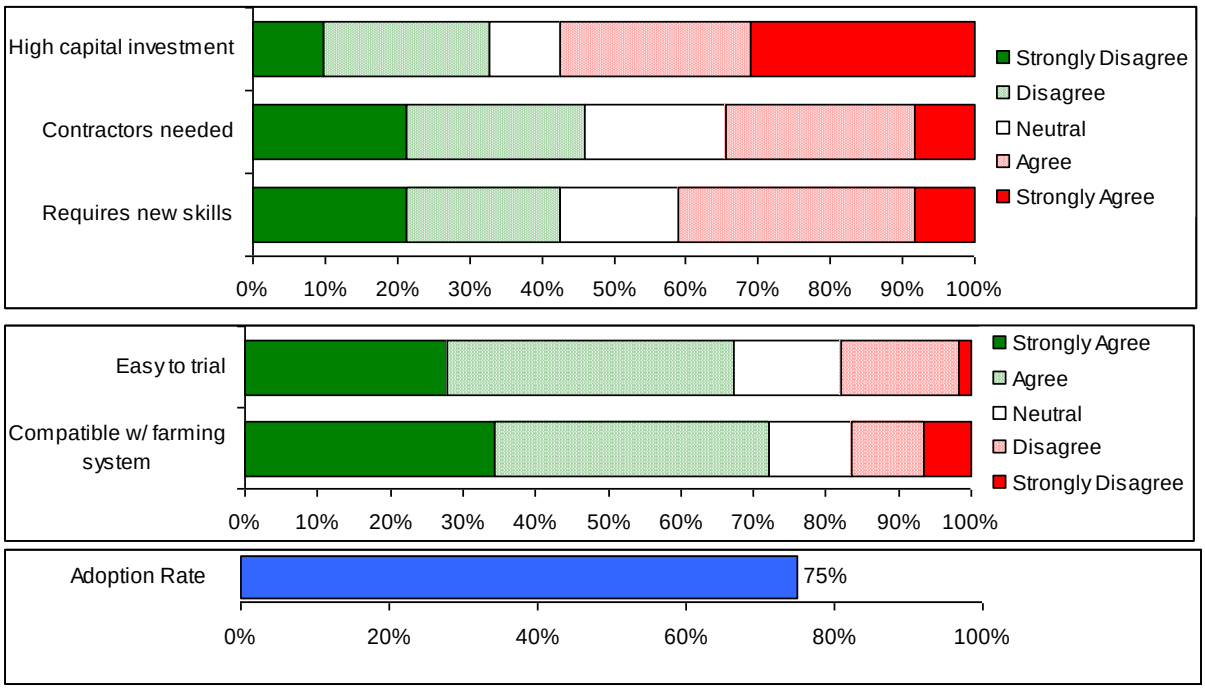
Figure 16 shows that the majority of growers indicated they did not believe that low tillage would have an adverse affect on their production of sugar (59 per cent) or variability of production (58 per cent). Rather, most growers perceived that adoption would decrease their production costs (89 per cent) and increase their profitability (62 per cent). Overall, no potential economic barriers to adoption were identified. Of the growers surveyed, 75 per cent indicated they had adopted low tillage.

Figure 16 Perceptions of the economic impacts of low tillage



Most growers agreed (57 per cent) that using low tillage requires a high capital investment, see Figure 17. Conversely, the majority of growers agreed that the practice is compatible with existing farming systems (72 per cent) and is easy to trial (67 per cent). Perceptions were divided amongst growers regarding whether or not adopting low tillage requires new skills and information (41 per cent agreed and 42 per cent disagreed) and contractors to implement (34 per cent agreed and 46 per cent disagreed). On the whole, growers perceived a high capital investment and, to a lesser extent, the requirement of new skills and information as well as contractors to implement as potential barriers to adoption. Low tillage had the fifth highest adoption rate relative to the other practices analysed.

Figure 17 Perceptions of the characteristics of low tillage

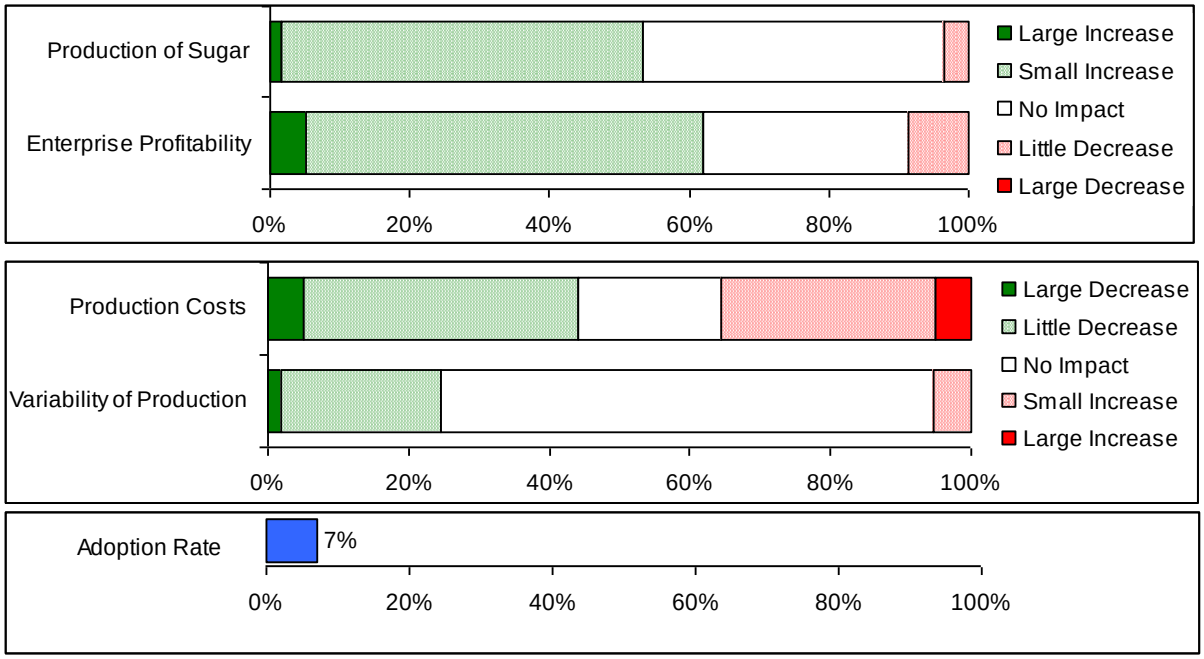


3.3 Nutrient Practices

3.3.1 Variable nutrient rates within blocks

Figure 18 illustrates the perceived economic impacts from adopting the improved management practice 'variable nutrient rates within blocks'. Growers were split in their perceptions toward production costs; a similar proportion of growers expected adoption to lead to both an increase (36 per cent) and decrease (45 per cent) in costs. While most growers expect variable rates to have no impact on the variability of production (70 per cent), the majority believed the practice would provide an increase in the production of sugar (54 per cent) and profitability (62 per cent). These results indicate that many growers perceive adoption to be economically beneficial as higher production costs are likely outweighed by other economic factors (e.g. increased sugar). Of the growers surveyed, this practice had the lowest adoption rate (7 per cent).

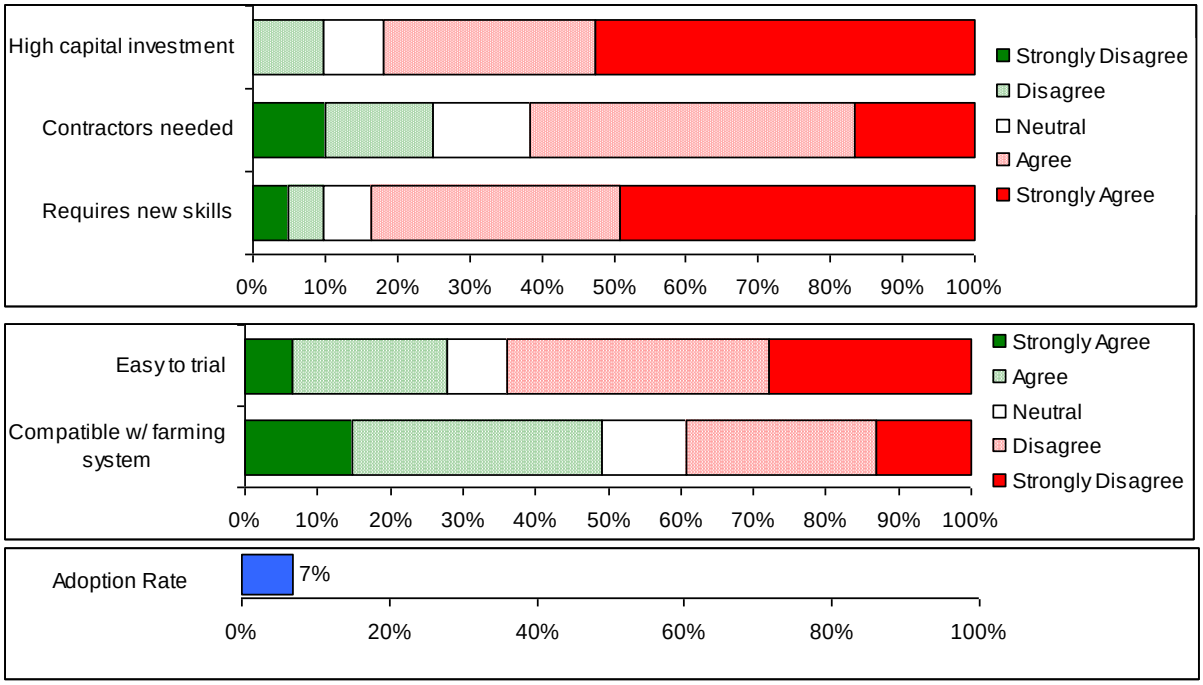
Figure 18 Perceptions of the economic impacts of variable nutrient rates within blocks



The majority of growers strongly agreed that varying nutrient rates within blocks requires a high capital investment (82 per cent agreed) and new skills and information (83 per cent agreed). Moreover, most growers agreed to a lesser extent that the practice requires contractors to implement (62 per cent) and disagreed that it was easy to trial (64 per cent). Interestingly, Figure 19 reveals that 39 per cent of growers regard the practice as incompatible with their farming system. Of course, growers that have limited variation in soils across their paddocks may gain little benefit from adoption and as such may perceive the practice as being incompatible for this reason.

Overall, while growers perceive the adoption of ‘variable nutrient rates within blocks’ to be economically acceptable, many potential constraints to adoption were revealed thus providing an explanation for the relatively poor adoption rate. Most significant were the requirements of a high capital investment as well as new skills and information. To a lesser extent, was the practice’s difficulty to trial and the need for contractors to implement the practice. Importantly, growers may only find the practice compatible if they have variable soils.

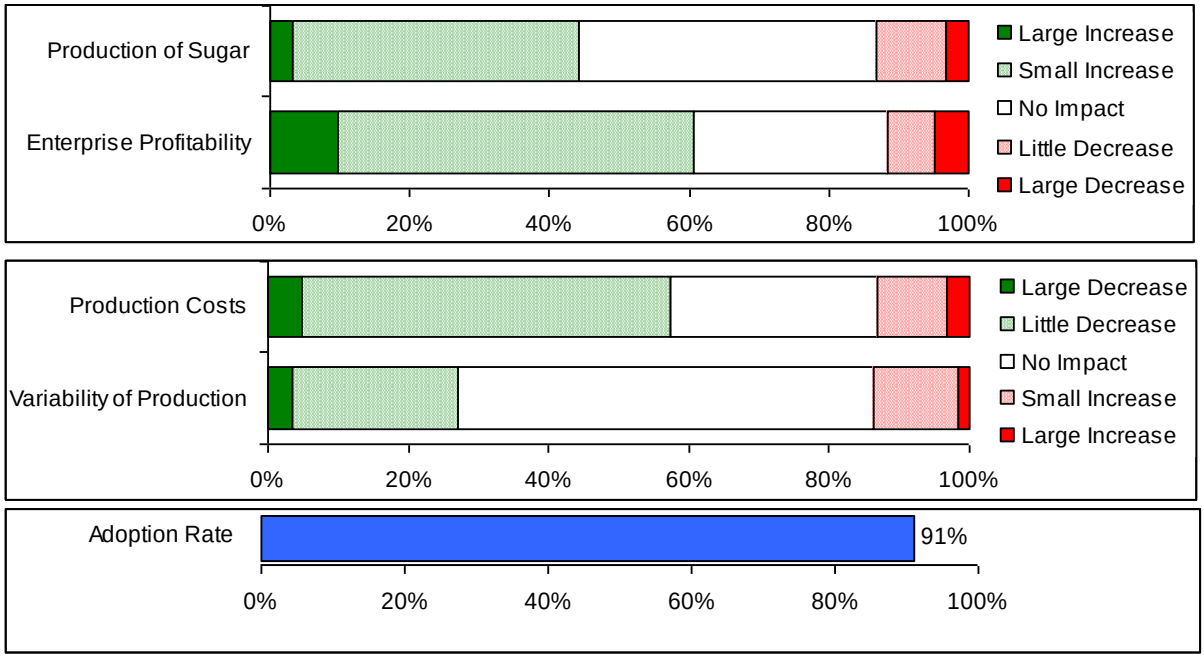
Figure 19 Perceptions of the characteristics of variable nutrient rates within blocks



3.3.2 Variable nutrient rates between blocks

Figure 20 indicates a larger number of growers perceived that varying nutrient rates between blocks would decrease production costs (57 per cent) and increase both sugar production (44 per cent) and profitability (61 per cent). Responses indicate that adoption would not impact production variability. The adoption rate for this practice was 91 per cent.

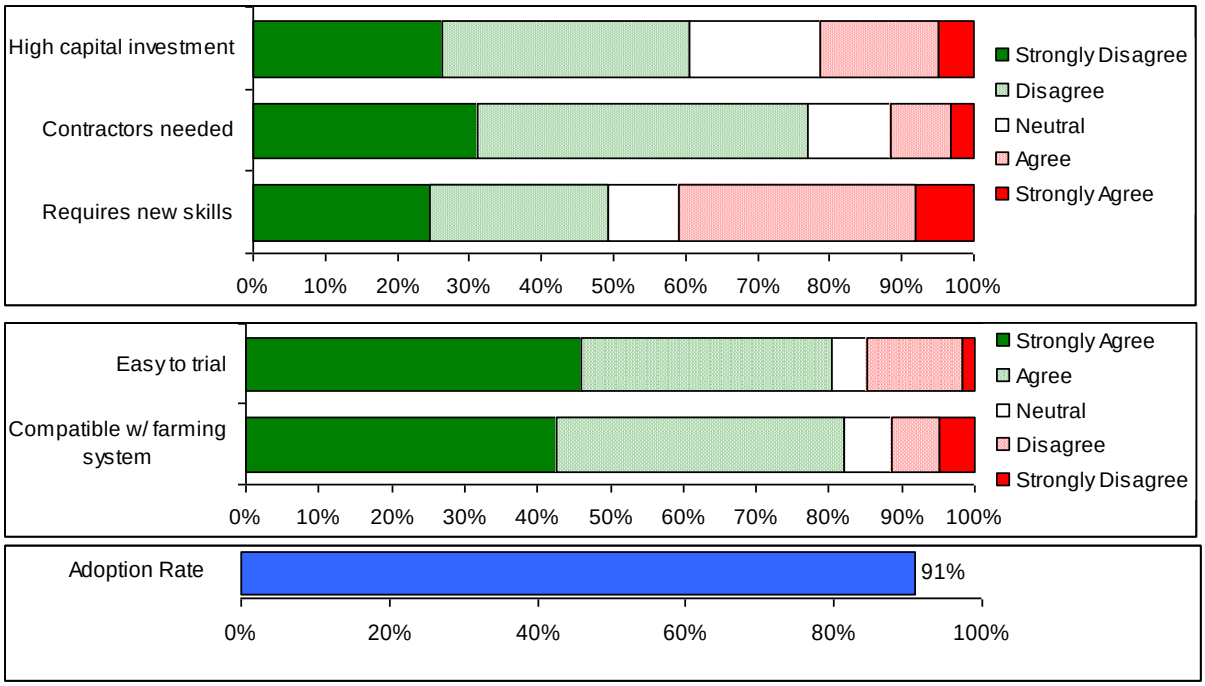
Figure 20 Perceptions of the economic impacts of variable nutrient rates between blocks



As shown in Figure 21, the majority of growers agreed that varying nutrient rates between blocks was compatible with their farming system (83 per cent) and easy to trial (80 per cent). In addition, most growers disagreed that practice adoption requires a high capital investment (60

per cent) and contractors to implement (77 per cent). However, 41 per cent of growers perceived that practice adoption requires new skills and information. Overall, only the need for new skills and information was revealed as a hurdle to adoption. The results are consistent with the practice's relatively high adoption rate; the fourth highest among the eleven analysed.

Figure 21 Perceptions of the characteristics of variable nutrient rates between blocks



3.3.3 Sub-surface application of nutrients

While slightly more growers perceived that practice adoption would increase their production costs (45 per cent compared to 28 per cent), the majority perceived a decrease in production variability (55 per cent) as well as both an increase in sugar production (60 per cent) and profitability (68 per cent), see Figure 22. These results indicate that the practice is economically acceptable as the majority of growers see the practice as profitable taken as a whole. This result corresponds to the very high adoption rate for this practice (98 per cent).

Figure 22 Perceptions of the economic impacts from sub-surface application of nutrients

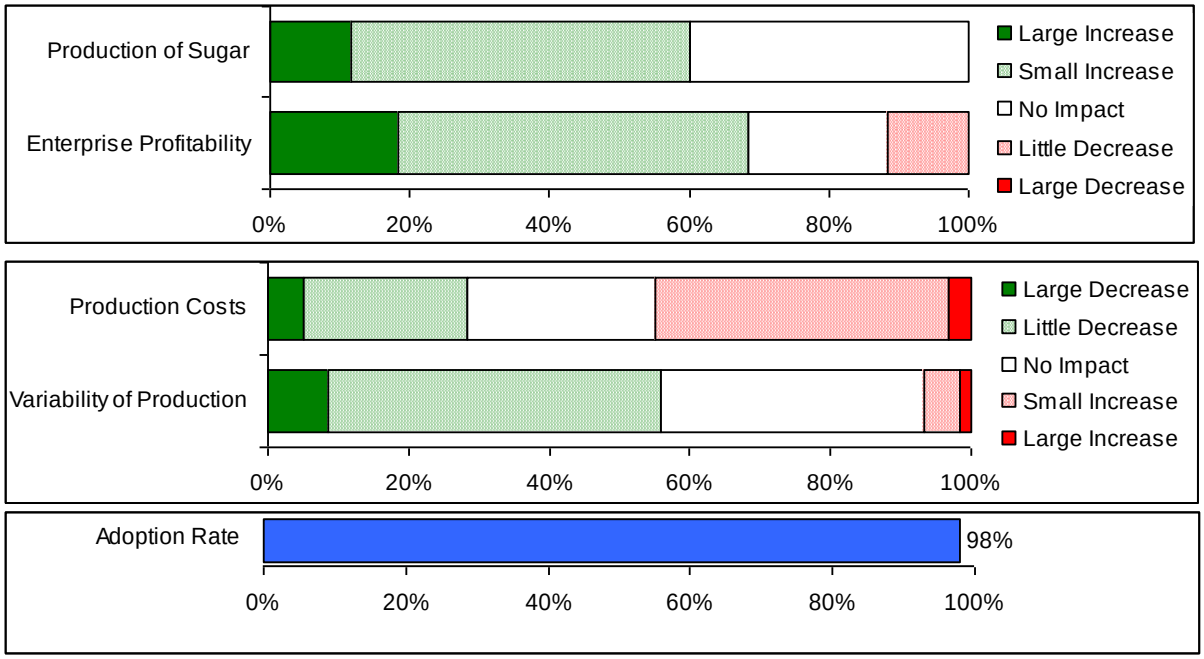
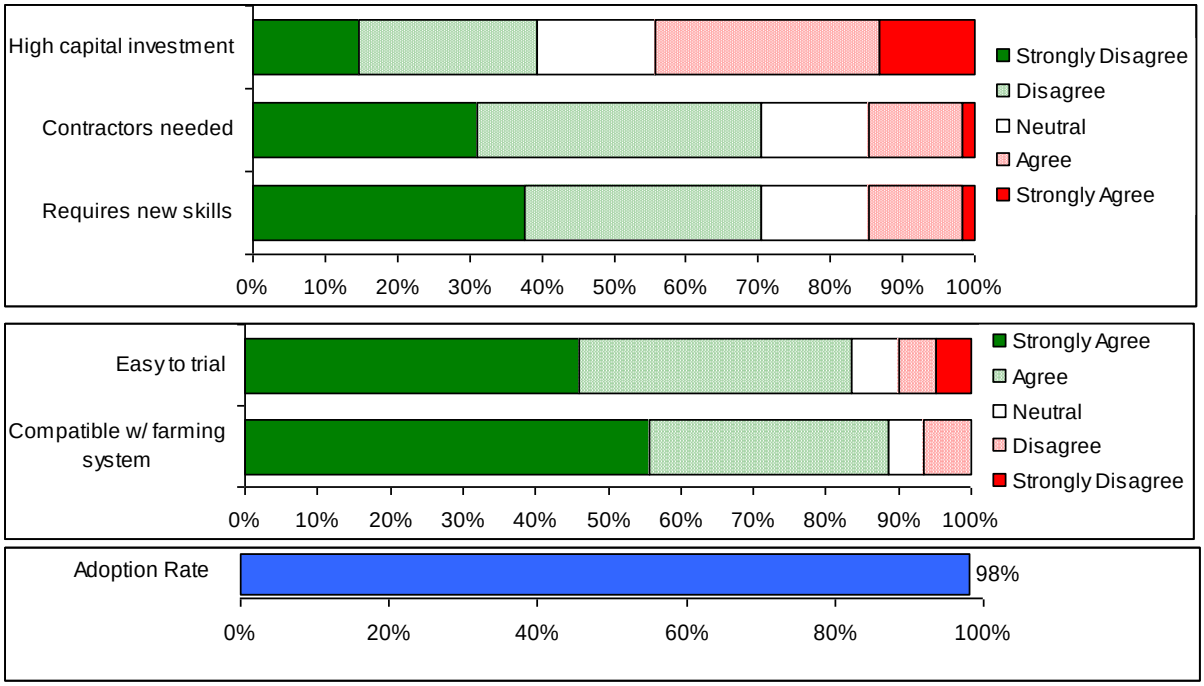


Figure 23 illustrates that the majority of growers strongly agreed that the sub-surface application of nutrients was compatible with farming systems (89 per cent agreed) and easy to trial (84 per cent agreed). Accordingly, most growers disagreed that the practice requires new skills and information (71 per cent) nor contractors to implement (70 per cent). Importantly, 44 per cent of growers perceived that practice adoption requires a high capital investment.

Taken as a whole, a high capital investment was detected as the only potential barrier to adoption, which is commensurate to the practice having the highest adoption rate relative to the other practices examined in this report.

Figure 23 Perceptions of the characteristics of sub-surface application of nutrients



3.4 Summary

The following heat map uses the average grower response to provide a summary of the results presented in section 3.1 to 3.3. For each of the management practices, the heat map uses colour-coding to illustrate whether growers believe the characteristic or impact constrains (red) or encourages (green) adoption. Asterisks indicate that some growers agreed it was a constraint while others disagreed. Adoption rates for each practice are indicated at the bottom of the table.

Figure 24 Average perceptions of practice adoption (heat map)

		PRACTICES										
		Pesticide				Pesticide & Nutrient		Soil		Nutrient		
		Knockdowns & Strategic Residual Use (ex. Diuron, etc)	Vary Herbicide Rate Between Blocks	Precision & Directed Herbicide Application Equipment	Directed Herbicide Application Equipment	Electronic Records	Nutrient & Weed Management Plans (agronomist)	Cover Legume Crop	Low Tillage	Variable Nutrient Rates Within Blocks	Variable Nutrient Rates Between Blocks	Sub-surface Application of Nutrients
IMPACTS	Production Costs						*			*		*
	Production of Sugar											
	Enterprise Profitability	*										
	Production Variability											
CHARACTERISTICS	Level of Capital Investment					*		*				*
	Need for Contractors						*	*	*			
	Compatibility									*		
	Trialability			*		*						
	New Skill Requirement		*		*			*	*		*	
ADOPTION RATE		23%	95%	48%	93%	36%	54%	68%	75%	7%	91%	98%

SCALE

- Constraint to adoption
- No impact
- Encourages adoption

*Growers perceptions were divided (some growers agreed whilst others disagreed that it was a constraint to adoption)

4 Profiling adopters and non-adopters

This section discusses the characteristics of adopters and non-adopters. Comparing and contrasting the perceptions of adopters with non-adopters may assist in further identifying barriers to adoption. For each management practice, growers were classified as either adopters or non-adopters of the practice[2]. A Mann-Whitney test[3] was used to identify disparity in the perceptions of non-adopters and adopters. More specifically, it was used to test the null hypothesis that there is no difference between the perceptions of non-adopters and adopters against the alternative hypothesis that there is a difference between the perceptions of non-adopters and adopters.

Where differences between adopters and non-adopters were statistically significant, this is reported in Table 3, 4 and 5 as * (where the p-value from the test is less than 0.05 indicating significance at the 5% level) and ** (p-value is less than 0.01; significant at the 1% level). Where perceptions of non-adopters and adopters were found to be statistically significant, some discussion has been provided. Intuitively, the differences in perception may be a function of learning-by-doing; where a grower's understanding of the practice has been increased due to the adoption process.

Not all management practices surveyed are included in this section. For some practices, the ability to test for statistical differences in these data was limited by the low number of either adopters or non-adopters. Accordingly, these practices have been excluded from the analysis.

4.1 Perceptions of Economic Impact

Table 3 presents the average perceptions of adopters and non-adopters on the economic impact of adopting an improved management practice. Each average perception is scaled from 1 to 5. An average of 3 indicates that the average adopter/non-adopter perceives that practice adoption will not impact the variable being considered (production costs, etc). Moreover, an average of less than 3 signifies that adoption is perceived to decrease the variable with an average of 1 representing the largest decrease. Alternatively, an average above 3 indicates an increase with 5 representing the largest increase.

Results suggest that perceptions of the impact on enterprise profitability were significantly different for four of the six practices analysed (no statistical difference in perceptions was observed for knockdowns and strategic residual use and electronic records). On average, adopters believed more positively in the economic benefits of adoption compared to non-adopters.

On average, non-adopters believed that adopting knockdowns and strategic residual use and nutrient and weed management plans would increase production costs. This compares to adopters who, on average, believe production costs would decrease by adopting the practices. Both adopters and non-adopters believed production costs would decrease by adopting precision and directed herbicide application, with adopters believing that production costs would decrease more substantially compared to non-adopters.

[2] Adopters are defined as those growers who responded positively to using a practice in question 39. Data from question 39 was checked against information obtained on current farm practice in Section 3 and any inconsistencies were removed from the analysis.

[3] The Mann-Whitney test is a non-parametric (no assumption of normal distribution) test of the null hypothesis that two independent populations are the same.

Perceptions about the impact of low tillage on sugar production were found to be significantly different between adopters and non-adopters. In particular, non-adopters believed low tillage would decrease sugar production, while, on the other hand, adopters believed the production of sugar would increase. Perceptions of the impact on the variability in production for nutrient and weed management plans were also found to be significantly different, whereby adopters believed more strongly that variability in production would decrease.

Perceptions of improved management practice profitability that are distinctly different between adopters and non-adopters may lead to the conclusion that the economic impact of management practice adoption is a key factor in the adoption decision. Reasons why all growers do not hold the same perceptions of management practice profitability are vast, but may be influenced by grower's misconceptions and/or preconceived ideas about the practice. Also growers who have adopted the practice may be more likely to speak positively about its benefits.

Farmer and farm characteristics are also likely to impact on perceptions. Some practices may indeed be more profitable depending on farm size, soil type and climatic conditions. Each individual farmer's perception of what constitutes a 'high' capital investment is also likely to be different.

Table 3: Economic Impact: Average Response of Adopters vs. Non Adopters

	Production Cost†		Production of Sugar†		Enterprise Profitability†		Variability†	
	Non-Adopter	Adopter	Non-Adopter	Adopter	Non-Adopter	Adopter	Non-Adopter	Adopter
Legume Fallow	3.42	3.15	3.58	3.72	3.26*	3.87	2.58	2.46
Low Tillage	2.00	1.67	2.4**	3.13	2.93**	3.82	2.93	2.69
Knockdowns and Strategic Residuals (excl. Diuron, etc)	3.74*	2.85	2.69	3.00	2.48	3.00	3.52	3.23
Precision and Directed Herbicide Application	2.90*	2.36	3.23	3.50	3.35**	3.96	2.84	2.68
Electronic Records	3.32	3.09	2.97	3.27	3.03	3.18	2.89	2.86
Nutrient and Weed Management Plans	3.48**	2.82	3.44	3.64	3.30*	3.76	2.74*	2.48

†Scale: 1= large decrease, 2= little decrease, 3= no impact, 4= small increase, 5= large increase
*P<0.05 and **P<0.01

4.2 Perceptions of Key Characteristics

Table 4 presents the average perceptions of adopters and non-adopters on the key characteristics of each improved management practice. Compatibility was identified by Pannell (2006) as a key factor determining practice adoption. For all of the management practices analysed a significant difference between adopters and non-adopters perceptions of compatibility was observed, with adopters believing more strongly that practices are compatible. It is not possible to determine from the results what the drivers of incompatibility/compatibility for non-adopters/adopters are. That is, for each management practice a factor of the practice's characteristics as well as the farmers and farm characteristics are likely to impact compatibility.

Similarly, significant differences were observed with regards to high capital investment in precision and directed herbicide application as well as knockdowns and strategic residuals

use. On average, non-adopters believed more strongly than adopters that high capital investment was a characteristic of these practices.

On average, non-adopters believed that contractors were required for adoption of precision and directed herbicide application whereas adopters tended towards a neutral opinion. It may be the case that adopters have the skills and or equipment necessary to conduct this practice themselves whereas non-adopters do not; however, preconceptions and misconceptions may also be at play.

There was little difference in the perception of trialability between adopters and non-adopters with the exception of nutrient and weed management plans, with adopters believing the practice is slightly easier to trial than non-adopters. For the characteristic, 'Requires new skills and information', there was no significant difference between adopters and non-adopters. This would suggest that both growers who have and growers who have not adopted nutrient and weed management plans are equally aware of what additional learning is required in order to implement the practice

Table 4: Key Characteristics: Average Response of Adopters vs. Non Adopters

	High Capital Investment^		Contractors Needed^		Does not fit farming system^		Not easy to trial^		Requires new skills^	
	Non Adopter	Adopter	Non Adopter	Adopter	Non Adopter	Adopter	Non Adopter	Adopter	Non Adopter	Adopter
Legume Fallow	2.68	3.00	2.42	2.82	3.26**	1.49	2.11	1.87	2.63	2.69
Low Tillage	3.87	3.38	3.13	2.58	3.33**	1.80	2.40	2.20	2.80	2.82
Knockdowns and Strategic Residuals (excl. Diuron, etc)	2.69*	1.92	2.45*	1.77	3.00*	2.15	2.31	1.92	3.52	3.00
Precision and Directed Herbicide Application	4.58*	4.25	3.68*	2.89	3.10**	1.82	2.97	2.68	3.74	3.82
Electronic Records	3.35	3.00	2.19	2.23	3.16**	2.23	3.16	2.86	4.24	4.27
Nutrient and Weed Management Plans	2.78	2.30	3.48	2.97	2.44*	1.76	2.48*	1.97	3.41	3.48

^ Scale: 1= strongly disagree, 2= disagree, 3= neutral, 4= agree, 5= strongly agree
*P<0.05 and **P<0.01

4.3 Farm and Farmer Characteristics: Adopters and Non Adopters

Socioeconomic factors (including the farmer's age, experience and education) as well as farm characteristics (including land tenure, farm size, soil quality, farm ownership, farm specialisation, off-farm employment, yield and percentage of cropped land to total farmland) are all factors which may affect the management practice adoption decision (Tey & Brindal, 2012).

Section 1 (About Your Farm) generated mostly categorical and some ordinal data. Categorical variables were combined to create binary (two) groups to allow statistical analysis where sample sizes were otherwise too small. Table 5 presents the key farm and farmer characteristics for adopters and non-adopters. Binary data has been analysed using

the Pearson Chi-Square test[4]. As before, statistical significant is represented as *P<0.05 and **P<0.01.

Younger farmers (45 or less) were significantly more likely to have adopted precision and directed herbicide application and electronic records. 71.4 per cent of farmers aged 45 or less indicated they had adopted precision and directed herbicide application, as compared to an adoption rate of 35 per cent for farmers aged over 45. 57.1 per cent of farmers aged 45 or less indicated adoption of electronic records as compared to an adoption rate of 25 per cent for farmers aged over 45.

Farmers managing larger farms (more than 200ha) were significantly more likely to adopt precision and directed herbicide application. 62.1 per cent of farmers on large farms indicated adoption of precision and directed herbicide application, as compared to 34.4 per cent of farmers on small farms (200 ha or less).

There were no other statistical differences in adoption rates identified at the specified level of significance. This result indicates that the farm and farmer characteristics identified are unlikely to be determining factors in the adoption decision. Furthermore, other farm and farm characteristics not included in this analysis, such as soil type, field variability and climatic differences, may be more deterministic. The tests may also be impacted by the small sample size and the combining of categorical variables, which may be impacting on results.

Table 5: Farm and Farmer Characteristics: Adopters vs. Non Adopters

		Legume Fallow	Low Tillage	Knockdowns & Strategic Residual Use (ex. Diuron etc)	Precision & Directed Herbicide Application	Electronic Records	Nutrient & Weed Management Plans
	Percent of Sample	Percentage of group that have adopted the practice					
Full Sample		68.3%	75.4%	22.8%	47.5%	36.1%	54.1%
Age of farmer:							
-45 or less	34%	76.2%	76.2%	33.3%	71.4%**	57.1%*	57.1%
-Over 45	66%	64.1%	75.0%	17.9%	35.0%	25.0%	52.5%
Time In Industry:							
-30 years or less	51%	70.0%	67.7%	24.1%	45.2%	32.3%	45.2%
-More than 30 years	49%	66.7%	83.3%	21.4%	50.0%	40.0%	63.3%
Income Earned Off-Farm:							
-20 % or less	64%	69.2%	74.4%	18.9%	51.3%	38.5%	53.8%
-More than 20 %	36%	66.7%	77.3%	30.0%	40.9%	31.8%	54.5%
Education:							
-High School Only	51%	56.7%	74.2%	13.8%	48.4%	29.0%	48.4%
-Post-High School	49%	80.0%	76.7%	32.1%	46.7%	43.3%	60.0%
Farm Size:							
-200ha or less	52%	61.3%	65.6%	30.0%	34.4%*	31.3%	43.8%
-More than 200ha	48%	75.9%	86.2%	14.8%	62.1%	41.4%	65.5%

*P<0.05 and **P<0.01

[4] The Pearson Chi-Square test assesses whether paired observations on two variables are independent of each other (i.e. comparing the adoption/non adoption decision of two people from different age groups to see if age is related to the response).

Discussion and Policy Implications

Understanding the drivers of management practice adoption is an essential part of increasing adoption of improved management practices focussed upon reducing the impact of sugarcane farming on water quality in the GBR. This study examines responses involving sixty-one cane growers surveyed across the BDT and WT cane growing regions in order to develop a profile of management practices according to their key characteristics. Statistical tests were also performed on available data to distinguish whether there is any significant difference between those that had adopted improved management practices and those that had not.

Results indicated that adoption rates varied widely for each of the management practices that were analysed in this study. In particular, *sub-surface application of nutrients* were found to have the highest adoption rate (98 per cent), while *variable nutrient rates within blocks* had the lowest adoption rate (7 per cent). Notably, the practice with the second lowest adoption rate (23 per cent - *knockdowns and strategic residuals use excluding Diuron, etc*) was perceived by growers to have the greatest negative impact on profitability; while practices with the highest adoption rates were perceived to have a positive impact on profitability (see Figure 25).

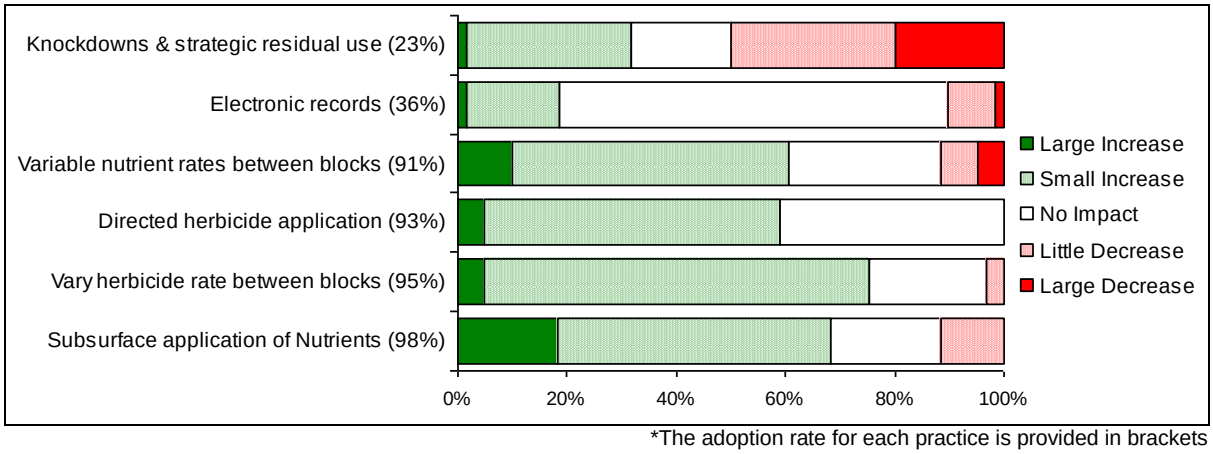
The study also identified characteristics of practices that tend to provide reasonable explanations as to why growers have been slow in adoption. For instance, despite being perceived as profitable, *variable nutrient rates within blocks* had reportedly the lowest adoption rate (7 per cent). This is unsurprising, however, given that the majority of growers strongly agreed that this practice requires a high capital investment and new skills and information. Moreover, most growers agreed that it required contractors to implement and disagreed that it was easy to trial (see Figure 19).

Similarly, the majority of growers perceived that adopting *precision and directed herbicide application* would increase profitability. However, growers specified several characteristics as potential constraints to adoption. Most growers strongly agreed that practice adoption would require a high capital investment. Additionally, the new skill and information requirement was found to be a limiting factor. These barriers explain the relatively low adoption rate (48 per cent); fourth lowest out of the eleven management practices considered.

The relatively poorly adopted practice *electronic records* (36 per cent adoption rate) is also a case in point. Given that it is perceived to have no impact on profitability (see Figure 25), there is little financial incentive for adoption. Furthermore, most growers strongly agree that the practice requires new skills and information (see Figure 11).

Intuitively, management practices with high adoption rates had perceived characteristics that encourage adoption. In these cases, the majority of growers generally agreed that the practices were compatible with existing farming systems and easy to trial, while they disagreed that the practice requires a high capital investment, new skills and contractors to implement (see Figures 5, 9, 21 and 23).

Figure 25 A comparison of the perceived impact to profitability from practice adoption



*The adoption rate for each practice is provided in brackets

Classifying growers into adopters and non-adopters may provide further information regarding which characteristics of improved management practices are most influential in the adoption decision. Perceptions of the impact on enterprise profitability between adopters and non-adopters were found to be significantly different for four of the six practices analysed. No statistical difference in perceptions was observed for *knockdowns and strategic residual use (excluding Diuron, etc)* or *electronic records*.

On average, adopters believed more positively in the economic benefits of adoption compared to non-adopters. For all of the management practices analysed, a significant difference between adopters and non-adopters perceptions of compatibility was observed; adopters believe more strongly that improved management practices are compatible with their existing farming techniques.

This study found that farm as well as farmer characteristics themselves were relatively insignificant in determining an adoption decision. On the other hand, the perceptions of the impact on profitability and compatibility with existing farming practices were found to be critical factors most likely to affect the adoption decision of farmers. High capital investment requirements were also factored into some decisions, such as the decision to adopt *precision and directed herbicide application* practices. Other perception-based variables, including the perception of low profitability of *electronic records* and *knockdowns and strategic residual use*, may further indicate that many non-users have preconceived ideas that improved management practices are not effective.

In the cases where management practices were perceived not to be profitable by growers, the results from RPP Economic research indicating the contrary suggests there is opportunity for extension work in this area. For example, educating farmers about the costs and benefits of improved management practices, as well as further economic assessment of the profitability of improved practices on specific farming enterprises, may be appropriate. Further research is also required to investigate reasons why growers who have not adopted management practices perceive that those practices are not compatible with their farming system.

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Appendices

A.1 Description of Management Practices

Variable Nutrient Rate within Blocks

Within block variable application of fertiliser based on spatial within-block data

Variable Nutrient Rate between Blocks

Match fertiliser application rate to crop requirements at the block level

Legume Fallow

Plant legumes at the end of a cropping cycle

Low Tillage

Apply minimum ploughing passes when preparing a block for planting

Knockdowns and Strategic Residuals (excluding Diuron, etc)

Knockdown herbicides replace residuals where practical. Residual herbicides used only where weed species and pressure demands it. The residual herbicides Diuron, Atrazine, Hexazinone and Ametryn are not used.

Herbicide Rate Varies Between Blocks

Herbicide strategy is determined by weed type and pressure and adjusted between blocks where difference is identified

Precision and Directed Herbicide Application

Herbicide is applied only where needed and at the minimal effective rate. Directed herbicide application delivers herbicide directly to a targeted zone. Precision application methods includes the use of Global Positioning System (GPS) guidence, electronic rate controller, two spray tanks and banded spraying. Spray drift is reduced through the use of Air Inducted nozzles.

Directed Herbicide Application

Herbicide is applied only where needed and at the minimal effective rate. Directed spraying delivers the herbicide directly to a targeted zone. Spray drift is reduced through the use of Air Inducted nozzles.

Electronic Records

Nutrient and herbicide records are kept in electronic form.

Nutrient and Weed Management Plans

An agronomist prepares nutrient and weed management plans to be implemented by the farmer.

Sub-Surface Application of Nutrients

Fertiliser is applied below the soil surface.

A.2 Description of the Perceived Economic Impacts from Practice Adoption

Production costs

The adoption of new practices can potentially affect the usage of inputs such as nutrients, pesticides or diesel and subsequently impact production costs. If the production costs from adopting a practice are perceived to be relatively lower (higher) than the conventional practice, then it is estimated that it will positively (negatively) impact the practice's probability (or rate) of adoption.

Production of sugar

The adoption of some practices may impact a farm's ability to produce sugar by affecting sugar yields or commercial cane sugar levels. If the production of sugar from adopting an improved management practice is perceived to be higher (lower) than the conventional practice, then it is estimated that it will positively (negatively) impact its probability (or rate) of adoption.

Farm Profitability

A grower's perception of the profitability of a practice reflects their belief of the economic impact that would likely occur as a consequence of that practice's adoption (Baumgart-Getz et al., 2012). It has been estimated to have a positive relationship with the adoption of improved management practices (Norris & Batie, 1987; Pannell et al., 2006). In addition, perception of profitability has been found to be a significant predictor of the decision to adopt conservtion practices and legume crops (Cary & Wilkinson, 1997; Ghadim, Pannell, & Burton, 2005). If farm profitability from adopting an improved management practice is perceived to be higher (lower) than the conventional practice, then it is estimated that it will positively (negatively) impact its probability (or rate) of adoption.

Variability of production

The variability of a farm's production could potentially decrease if a grower was to adopt an improved management practice that made production more constant from year to year and thereby reducing the risk that the grower faces. For example, research has found that the use of a legume crop in fallow, to combat the effects of yield decline caused by cane monoculture, has the potential to significantly increase the yield of the following cane crop (Pankhurst et al., 2003). If the variability of production from adopting a practice is perceived to be less (greater) than the conventonal practice, then it is estimated that it will positively (negatively) impact its probability (or rate) of adoption.

A.3 Description of the Perceived Characteristics of Practices

Establishment costs

The establishment costs, or the capital investment, required to implement an improved management practice can be a barrier to adoption. Some practices can be characterised by large up-front costs and accumulate interest while benefits accrue over a long period. If the capital investment required to adopt a practice is perceived to be low (high), then it is estimated that it will positively (negatively) impact its probability (or rate) of adoption.

Trialability

The trialability of a management practice consists of several traits. These include the divisibility of a practice, the observability of the practice's benefits, the similarity of a practice to current pratices and potential threats to the trial's outcome (Pannell et al., 2006). The

divisibility of a practice refers to it's ability to be trialed on a small scale. This factor is a function of the requisite initial investment, a high sunk costs reduces the practice's divisibility, and access to contractors, which may eliminate the trial's need for an initial capital investment. Greater observability indicates that the practice's impact is more noticeable in a shorter period of time thus enabling more rapid adoption decisions. In addition, it enhances district-wide diffusion as neighbours can assess the trial's performance by peering into a neighbour's fields (Pannell et al., 2006). The similarity of a practice's behaviour to a familiar practice can aid the adoption process because, given initial trial results, a grower may believe that they can more reliably forecast the practice's long-run efficacy. Perceived potential threats existing during the planning stages of the trial, such as disease or pests, may boost the risk of failure and reduce trialability. If the trialability of a management practice is perceived to be easy (difficult), then it is estimated that it will positively (negatively) impact its probability (or rate) of adoption.

Compatibility

Compatibility refers to whether the grower believes the adoption of the management practice fits with their current farming system. This may include such things as the grower's existing machinery, soil types, beliefs and management practices (Pannell et al., 2006). If a practice is perceived to be compatible (incompatible) with the current farming system, then it is estimated that it will positively (negatively) impact its probability (or rate) of adoption.

Complexity

The complexity of a practice refers to the perceived degree of difficulty to understand and use. This can be measured by asking a grower how much new information and skills are required for the practice to be successfully adopted on the farm. Practices that are more complex can potentially increase the requisite management effort and the possibility of failure (Rogers, 2003). If the complexity of the practice is perceived to be low (high), then it is estimated that it will positively (negatively) impact its probability (or rate) of adoption.

Contractor requirement

Some growers may require the services of contractors in order to facilitate a practice adoption. This requirement is particularly relevant when a grower requires specialised services including EC mapping, yield mapping or agronomy services. If a contractor is perceived to be not required (required) in order to adopt a practice, then it is estimated that it will positively (negatively) impact its probability (or rate) of adoption.

A.4 Summary of Results: Section 3: Grower Perceptions of Practice Adoption

Table 6: Adoption Rate of Management Practices

Best Management Practice	Adoption Rate
Cover Legume Crop	68%
Low Tillage	75%
Knockdowns & strategic residual use (excluding Diuron, etc)	23%
Vary herbicide rate between blocks	95%
Precision herbicide application equipment	48%
Directed herbicide application equipment (w/ AI nozzles)	93%
Electronic records	36%
Nutrient & weed management plans (agronomist)	54%
Variable Nutrient Rate within blocks	7%
Variable Nutrient Rate between blocks	91%

Sub-surface application of nutrients	98%

Table 7: Farmer Perception of Farm Economic Impact

	Variability of Production	Enterprise Profitability	Production of Sugar	Production Costs
Cover Legume Crop				
Decrease	51%	13%	7%	28%
No Impact	41%	15%	26%	18%
Increase	8%	72%	67%	54%
Low Tillage				
Decrease	30%	17%	23%	88%
No Impact	58%	21%	59%	7%
Increase	12%	62%	18%	5%
Knockdowns & strategic residual use (excluding Diuron, etc)				
Decrease	5%	50%	30%	32%
No Impact	56%	18%	55%	8%
Increase	39%	32%	15%	60%
Vary herbicide rate between blocks				
Decrease	18%	3%	5%	74%
No Impact	75%	21%	64%	16%
Increase	7%	75%	31%	10%
Precision herbicide application equipment				
Decrease	27%	12%	2%	60%
No Impact	70%	21%	67%	15%
Increase	3%	67%	32%	25%
Directed herbicide application equipment (w/ AI nozzles)				
Decrease	18%	0%	2%	43%
No Impact	79%	41%	72%	44%
Increase	3%	59%	26%	13%
Electronic records				
Decrease	12%	10%	3%	8%
No Impact	86%	71%	87%	61%
Increase	2%	19%	10%	31%
Nutrient & weed management plans (agronomist)				
Decrease	42%	7%	3%	28%
No Impact	55%	36%	45%	30%
Increase	3%	57%	52%	42%
Variable nutrient rate within blocks				
Decrease	25%	9%	3%	44%
No Impact	70%	29%	43%	20%
Increase	5%	62%	54%	36%
Variable nutrient rate between blocks				
Decrease	27%	11%	13%	57%
No Impact	59%	28%	43%	30%
Increase	14%	61%	44%	13%
Sub-surface application of nutrients				
Decrease	56%	12%	0%	28%
No Impact	37%	20%	40%	27%
Increase	7%	68%	60%	45%

Table 8: Farmer Perceptions of Management Practice Key Characteristics

	Requires new skills	Not easy to trial	Incompatible w/ farming system	Contractors needed	High capital investment
Cover Legume Crop					
Disagree	38%	10%	13%	36%	38%
Neutral	11%	11%	13%	11%	13%
Agree	51%	79%	74%	53%	49%
Low Tillage					
Disagree	43%	67%	72%	46%	33%
Neutral	16%	15%	12%	20%	10%
Agree	41%	18%	16%	34%	57%
Knockdowns & strategic residual use (excluding Diuron, etc)					
Disagree	31%	71%	53%	67%	64%
Neutral	8%	13%	16%	10%	15%
Agree	61%	16%	31%	23%	21%
Vary herbicide rate between blocks					
Disagree	46%	85%	92%	72%	67%
Neutral	10%	7%	3%	20%	13%
Agree	44%	8%	5%	8%	20%
Precision herbicide application equipment					
Disagree	16%	51%	59%	36%	3%
Neutral	13%	8%	15%	8%	2%
Agree	71%	41%	26%	56%	95%
Directed herbicide application equipment (w/ AI nozzles)					
Disagree	52%	79%	90%	71%	51%
Neutral	7%	11%	5%	11%	16%
Agree	41%	10%	5%	18%	33%
Electronic records					
Disagree	10%	38%	52%	72%	33%
Neutral	3%	22%	16%	13%	20%
Agree	87%	40%	32%	15%	47%
Nutrient & weed management plans (agronomist)					
Disagree	28%	70%	77%	32%	57%
Neutral	15%	13%	11%	23%	28%
Agree	57%	17%	12%	45%	15%
Variable nutrient rate within blocks					
Disagree	10%	28%	49%	25%	10%
Neutral	6%	8%	12%	13%	8%
Agree	84%	64%	39%	62%	82%
Variable nutrient rate between blocks					
Disagree	49%	80%	82%	77%	61%
Neutral	10%	5%	7%	11%	18%
Agree	41%	15%	11%	12%	21%
Sub-surface application of nutrients					
Disagree	70%	84%	88%	70%	40%
Neutral	15%	6%	5%	15%	16%
Agree	15%	10%	7%	15%	44%

A.5 Survey

Survey of Management Practice Characteristics

This survey is being undertaken by researchers from the Queensland Department of Agriculture, Fisheries and Forestry and CSIRO. It is supported by funding from the Queensland Government and Australian Government Reef Rescue program. The survey aims to shed light on grower's perceived risks of adopting various best management practices and the associated characteristics of these practices. The information collected in this survey will assist in understanding the linkages between the types of sugarcane enterprise, risks of management practices and possible barriers to adoption. The survey information will be used to write a general report to outline the research findings and will also be used to develop papers for academic publication.

All data from this research will be completely confidential. All publicly available results will be reported in a summary manner to ensure no individual enterprises or persons can be identified. No contact details or other identifying details will be released as a result of this research.

By participating in this research you agree to the use of the generated data in research. All data will be unidentified ensuring your participation is anonymous. Participation in this survey is voluntary and you are able to withdraw from the study up until the 30th of April, at which time the data will be aggregated and analysed for research purposes.

The survey should take about 1 hour to complete.

To verify your agreement for participation in this survey please provide your signature

_____

(Signature of participant)

Section 1: About You

In this section we will ask you some questions about you and your experience in sugar cane farming.

Q1. What age group do you belong to? (please circle)

a. Under 30 years
b. 30 - 45 years
c. 46 – 55 years
d. 56 – 65 years
e. Over 65 years

Q2. How long have you been working in the sugarcane industry?

You _____ years **Your partner** _____ years

Q3. How many children (dependent) do you have? _____

Q4. If you have children, do you expect any of them to continue on with your farm business? (please circle)

Yes No N/A

Q5. To what extent have you planned for business succession? (please circle one number)

Not at all	=>	Partially	=>	Completely
1	2	3	4	5

Q6. What education do you/your partner have? (please circle, multiple responses accepted)

a. Grade 10 certificate
b. Grade 12 certificate
c. Diploma or Trade
d. Undergraduate tertiary degree
e. Post-graduate tertiary degree
f. Other _____

Q7. Do you or your partner earn off-farm income? _____ % of total income

Section 2: Your farm

In this section we will ask you some questions about your farm operation.
This information will allow us to identify the diversity of operations and management practices across farms.

Q8. What kind of enterprise do you have?

Sugarcane
Sugarcane/Horticulture
Sugarcane/Grazing
Sugarcane/Other

Q9. What is the total area of land that you (or your family) own or manage for sugarcane production?

_____ Hectares or **_____ Acres**

Q10. What proportion does this represent of the total property? _____ % of total FARMED area

Q11. Do you have ownership of the farming land?

a. Yes
b. No (lease/rent/manage)
c. Split (own/lease or share arrangement)

Q12. If you are a tenant or manager, does the landlord have a significant role in farm decision-making?

a. Yes
b. No
c. Partly
d. NA

Q13. What BEST describes your role in the farming business?

a. Owner (not manager)
b. Owner/manager
c. Manager
d. Employee
e. Other (please specify ……)

Q14. How much labour support did you have on your property in 2011/12 counting yourself (count part-time labour as a fraction – e.g. 0.5 people)

Unpaid _____people (use this one for any not paid a wage or salary)
Family paid _____people (for family paid a wage or salary)
Paid staff _____people (for non-family employed staff)

Q15. Do you contract out the following operations? :

Fertiliser operations	Yes	No	Sometimes
Herbicide operations	Yes	No	Sometimes
Harvesting operation	Yes	No	Sometimes
Tillage operations (excluding laser levelling)	Yes	No	Sometimes

Q16. Is your farm on controlled traffic (row spacing matches machinery width, including harvesting machinery) ?

a. Yes
b. No
c. Partly _____% of farm

Q17. Do you burn the crop prior to harvest?

a. Yes
b. No
c. Partly _____% of farm

Q18. What is the percentage of different soil textures on your farm?

a. Light: _____%
b. Medium_____%
c. Heavy: _____%

Q19. What proportion of your farm has the following gradients?

Gradient 0 - 3% (0-3 metre drop in 100 metres run): _____%
Gradient 4 - 9% (4-9 metre drop in 100 metres run): _____%
Gradient > 10% (more than 10m drop in 100m run): _____%

Q20. What is the typical number of ratoons you grow in a crop cycle? _____

Q21. How is your farm affected by flooding?

(flooding which affects your production or production decisions)

	Percent of farm
Never	
Occasionally	
Sometimes	
Every year	
TOTAL:	**100%**

Q22. Please describe the types of fallow that you used in 2011/12:

	Type of Fallow	Percent of Fallow
Type 1		
Type 2		
Type 3		
Type 4		
Type 5		
	TOTAL:	**100%**

Q23. For the last 10 years please provide an estimate of your LOWEST, AVERAGE and HIGHEST cane yield (in Tonnes/acre or Tonnes/ha)

	Tonnes	Year	Per?
Lowest			Hectare / Acre
Average			Hectare / Acre
Highest			Hectare / Acre

Q24. For the last 10 years please provide an estimate of your LOWEST, AVERAGE and HIGHEST CCS:

	AVERAGE CCS	
	Amount	Year
Minimum		
Average		
Maximum		

Section 5: Nutrient and Herbicide management

In this section we will ask you some questions about your nutrient and herbicide management.

Q25. What type of nutrient budgeting do you use?

a. N-replacement (based on crop yield)
b. Variable rate within blocks where the basis of variability is identified (e.g. EC mapping, yield mapping and soil tests) and taking into account other sources of nutrients
c. Variable rate between blocks based on soil tests in plant/ratoon and taking into account other sources of nutrients (e.g. six easy steps)
d. One rate for plant and another for ratoons based on soil tests/soil type
e. One fixed rate for plant and one for ratoons based on historical use/experience

Q26. Do you currently split fertiliser applications? I.e. more than two applications in plant cane and more than one in ratoon cane. (Please circle one)

Yes No

Q27. How do you currently apply fertiliser in your plant cane crop? (you may select more than one)

Sub-surface within the stool or fertigation
Sub-surface beside the stool
Surface banded
Surface broadcast
Liquid surface
Liquid sub-surface

Q28. Do you usually grow a legume break crop in your fallow when seasonal and/or field conditions permit?

a. Yes
b. No

Q29. If you grow legume break crops, do you adjust the nitrogen rate in subsequent plant cane crop?

a. Yes
b. No
c. N/A

Q30. How often do you calibrate your fertiliser applicator?

a. Use of electronic rate controller with calibrations undertaken frequently
b. Calibrate for each fertiliser product and batch
c. Calibrate once per season for each fertiliser product
d. Calibration less than once per season

Q31. Do you have a nutrient management plan which is documented and implemented, taking the crop age, soil type, block history and timing into account?

a. Yes
b. No

Q32. Do you keep records of nutrient management on your farm and in what form?

a. No records
b. Paper based records only
c. Electronic records only
d. Electronic records and paper based records

Q33. What type of herbicides (knockdown and/or residual) and strategy do you currently use for effective weed management?

a. No chemicals used
b. Knockdowns only
c. Knockdowns and residuals used at spike rates (e.g. <0.5kg/ha)
d. Knockdowns and strategic residual use (only where needed; <u>excluding</u> diuron, atrazine, hexazinone and ametryn)
e. Knockdowns and strategic residual use (only where needed; <u>including</u> diuron, atrazine, hexazinone and ametryn)
f. Knockdowns and non-strategic residual use i.e. residuals used across all plant and ratoon cane blocks

Q34. What methods do you use for spraying? (Circle more than one if needed)

Use of precision and directed application equipment with appropriate nozzles (e.g. GPS, two tanks, banded spraying and AI nozzles). Equipment matches situation.

Use directed application equipment with appropriate nozzles (e.g. AI nozzles)

Use directed sprays with non-specific nozzles

Use broadcast applications (non-targeted)

Q35. Is your current rate of herbicide application: (please tick whichever apply)

	PLANT	RATOON
The maximum recommended label rate applied across the farm		
Varied between blocks with consideration of weed type and pressure		
Varied within blocks with consideration of weed type and pressure		
A standard rate based on experience		

Q36. With regard to timing, what do you usually account for when deciding when and how to apply herbicides?

a. Crop stage, weed size and type, environmental conditions, irrigation (if irrigating), climate forecasting
b. Crop stage, weed size and type, environmental conditions and irrigation (if irrigating)
c. Crop stage and weed size and type
d. Timing by convenience or experience

Q37. How often do you calibrate your spray equipment?

a. Use of electronic rate controller with calibrations undertaken frequently
b. Calibrate during application of each block
c. Several times per year
d. Once per year

Q38. Do you have an Integrated Weed Management Plan which is documented and implemented taking the crop cycle, weed type, pressure and timing into account?

a. Yes
b. No

Q39. Do you keep records of herbicide use and monitoring on your farm and in what form?

a. No records
b. Paper based records
c. Electronic records
d. Electronic records and paper based records

Section 6: Usage of 'best practice'

In this section we will ask you to identify factors that make it easier or harder to adopt a number of key management practices.

Q40: What herbicide/nutrient management practices do you use? Please indicate your history of adoption and usage of nutrient and herbicide management practices in the table below. If you don't use the practice please leave the row blank.

Practice	Year used (or N/A)	NRM or Reef Rescue funding used to adopt? (Yes/No)
1. Variable nutrient rates within blocks (based on EC mapping, yield mapping and soil tests)		
2. Variable nutrient rates between blocks (based on Six-Easy-Steps principles)		
3. Cover legume crop		
4. Sub-surface application of nutrients		
5. Low tillage (e.g. zonal tillage)		
6. Knockdowns and strategic residual use (only where needed; excluding diuron, atrazine, hexazinone and ametryn).		
7. Herbicide rate varies between blocks with consideration of weed type and pressure		
8. Use of precision and directed herbicide application equipment with appropriate nozzles (e.g. Two tanks, Electronic Rate Controller, banded spraying and Air Inducted nozzles)		
9. Use of directed herbicide application equipment and appropriate nozzles (e.g. Air Inducted nozzles).		
10. Electronic records (nutrients and herbicides)		
11. Nutrient and Weed Management Plans developed by an agronomist.		

Q41. How do new management practices impact your farm? For each of the practices listed below indicate on a scale from 1 to 5 whether you believe Costs/Production/Profitability/Variability are decreased (1) or increased (5) by using the new practice.

Large Decrease	Little Decrease	No Impact	Small Increase	Large Increase
1	2	3	4	5

Practice	Production Costs	Production of sugar	Enterprise Profitability	VARIABILITY of production (more change in sugar production between years)
1. Variable nutrient rates within blocks (based on EC mapping, yield mapping and soil tests)				
2. Variable nutrient rates between blocks (based on Six-Easy-Steps principles)				
3. Cover legume crop				
4. Sub-surface application of nutrients				
5. Low tillage (e.g. zonal tillage)				
6. Knockdowns and strategic residual use (only where needed; excluding diuron, atrazine, hexazinone and ametryn).				
7. Herbicide rate varies between blocks with consideration of weed type and pressure				
8. Use of precision and directed herbicide application equipment with appropriate nozzles (e.g. Two tanks, Electronic Rate Controller, banded spraying and Air Inducted nozzles)				
9. Use of directed herbicide application equipment and appropriate nozzles (e.g. Air Inducted nozzles).				
10. Electronic records (nutrients and herbicides)				
11. Nutrient and Weed Management Plans developed by an agronomist.				

Q42: What, in your opinion, are the key characteristics of these management practices? Rank the following on a scale of 1 (strongly disagree) to 5 (strongly agree) indicating which characteristics are least/most relevant to each new management practice.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

Practice	High Capital Investment Needed	Contractors needed to implement change	Does not fit with my current farming system	Not easy to trial	Requires new skills and information
1. Variable nutrient rates within blocks (based on EC mapping, yield mapping and soil tests)					
2. Variable nutrient rates between blocks (based on Six-Easy-Steps principles)					
3. Cover legume crop					
4. Sub-surface application of nutrients					
5. Low tillage (e.g. zonal tillage)					
6. Knockdowns and strategic residual use (only where needed; excluding diuron, atrazine, hexazinone and ametryn).					
7. Herbicide rate varies between blocks with consideration of weed type and pressure					
8. Use of precision and directed herbicide application equipment with appropriate nozzles (e.g. Two tanks, Electronic Rate Controller, banded spraying and Air Inducted nozzles)					
9. Use of directed herbicide application equipment and appropriate nozzles (e.g. Air Inducted nozzles).					
10. Electronic records (nutrients and herbicides)					
11. Nutrient and Weed Management Plans developed by an agronomist.					

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