Economic assessment of best management practices for banana growing

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

RP140B Adoption Innovation Profile Report 2018

Source: Kukulies, T, "Banana farm grassed inter-rows", 2015.

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Executive Summary

The main objective of this study is to report on identified key characteristics of best management practices as perceived by North Queensland banana producers. The aim is to gain a better appreciation of the opportunities and constraints banana growers face in adopting various best management practices. This information collected via a face-to-face survey in the Tully and Innisfail regions will assist in understanding the linkages between the types of banana growing enterprises, opportunities and constraints of shifting management practices and possible barriers to adoption.

A key mechanism to improve the water quality entering the Great Barrier Reef (GBR) is the adoption of best management practices by farmers in the GBR catchment area. Management practice adoption is a complex decision-making process motivated by many factors including growers' perceptions of a practice's impact on profitability. This survey will focus on how growers perceive the adoption of a selection of management practices with respect to some key characteristics around production and profitability. Other factors such as values and risk appetite are not explicitly considered and remain areas for future work.

The management practices included in the survey and subsequent analysis were taken from the Banana Best Management Practices Environmental Guidelines (King, 2008) and the Paddock to Reef Water Quality Risk Framework for Bananas (Queensland Government, 2015). King (2008) uses a 'best', 'okay' and 'improve' criteria while the Water Quality Risk Framework (Queensland Government 2015) uses 'high risk (superseded), 'moderate risk (minimum)' and 'moderate – low risk (best practice)' criteria.Seven practices were chosen at the 'best' level, which were most likely to improve water quality run-off from banana farms. The seven practices were: crop removal, fallow crop, tillage, ground cover, fertiliser rates, fertiliser application, and fertiliser application frequency.

The data analysed in this report is drawn from surveys completed by forty-six banana growers, from the two major banana growing areas in North Queensland, between May and July 2017. Each grower was asked 13 closed-ended questions (and 2 open-ended) over four separate sections (see Appendix 7.1). The duration of the interviews ranged from 30 minutes to 2 hours, depending largely on the extent of additional comments provided by growers regarding their specific farm practices or the level of detail provided in response to open ended questions. The questions were designed to identify grower attitudes towards best management practices, history of practice adoption, as well as a general description of grower characteristics and farm attributes characteristics.

Adoption rates for the seven practices included in the survey were all quite high, ranging from 72% - 87% of those growers surveyed. Each of these practices were analysed separately in terms of impacts on economic implications and the perceived barriers for adopting the practice. Overall, grower perceptions of practice adoption were that positive economic impacts encourage adoption. Barriers for adopting the practice were perceived to be low and therefore would not generally discourage adoption. Grower responses indicated, however, that there can be substantial differences between farming systems and the priorities of individual growers and that practice adoption will not always be desirable or compatible with a grower's farming system or business model. For example, organic banana growers would not be able to market their fruit as organic if they applied herbicides as part of the crop removal process.

The heat maps presented in Table 2 and Table 3 compare the (aggregated and averaged) grower perceptions on the best management practices surveyed and display their adoption rates. Overall, best practices were perceived to have impacts on economic outcomes that would be neutral or encourage adoption (production costs, production, profitability and variability of production). There was a similar result for the perceived characteristics (high capital investment needed, contractors needed to implement change, does not fit my farming system, not easy to trial, requires new skills and information and too much time required to look into) of adopting the practices. Only three were negative tending towards the 'constrains adoption' end of the scale and five neutral results. It is important to note, however, that for certain aggregated and averaged results there can be variation in the perceptions of individual growers, and the heat maps (table 2 and 3) indicate the instances where there was substantial variation.

Transaction costs were collected throughout the surveys and key insights were found. Those who invested low levels of resources before adopting may be benefitting from adopting practices that have been well trialled and proven for their farming system or are savvy in accessing resources through ABGC, Terrain or DAF to limit their personal transaction costs in the decision process to adopt. Those who have invested high levels of resources before adopting may be investigating innovative practices or adaption of practices to their particular farming system or conditions. Those growers who have invested high levels of resources before adopting may be investigating innovative practices or adaption of practices to their particular farming system or conditions, they may wish to conduct their own enquiries in addition to relying on external resources, or have high levels of risk aversion resulting in delays in the adoption process.

For each management practice, growers were classified as either adopters or non-adopters for a particular practice depending on which practices they indicated they had adopted in question nine of the survey. The perceptions of adopters and non-adopters were compared and contrasted which may assist in further identifying barriers to adoption.

The differences in perceptions between adopters and non-adopters on economic impacts were significant (at the 0.05 level) for enterprise profitability for the practices of fertiliser rate and method. In addition, production costs has a significant (at the 0.05 level) difference for the practice of fertiliser application frequency. It can be interpreted that fertiliser rate, method and frequency could be practices where there is a disconnect between adopters and non-adopters in terms of their perceived economic impacts.

It can be seen that the practice characteristic; doesn't fit in with current system, differs between adopters and non-adopters significantly (at the 0.01 level) for the practices; fertiliser rate and nutrient application method of fertigation, and significantly (at the 0.001 level) for the practice; crop removal using herbicide. This result may be self-confirming given that adopters have in fact already found a way of incorporating the practice into their system. However, it does underline that adoption is highly dependent on fitting with the broader farming system.

The practice characteristic; contractors needed to implement change, differs between adopters and non-adopters significantly (at the 0.05 level) for the practice of fertiliser rate. This can be interpreted that non-adopters perceive that contractors are needed for fertiliser rate change and slightly discourages adoption, but adopters believe that it is neutral and does not affect adoption.

When analysing farm attributes with adopters and non-adopters, a close relationship was identified (at a significance level of 0.053) for the farm attribute of gradients combined with the practice of fertiliser application frequency. This result suggests that the level of gradient on a farm could influence a grower to adopt the practice of fertiliser application frequency.

Three main recommendations came out of this study. Firstly, as there are significant variances between farming systems, further case study analyses of banana farms adopting or adapting practices to reduce their off farm water quality impacts would help increase understanding of the diversity and complexities driving adoption of practices. Such research could identify barriers to adoption in order of importance for a particular farming system or business model. Secondly, transaction costs are often hidden and can inhibit adoption of improved practices that are still being trialled and tested, such that policies directly targeted at reducing them could enhance the efforts of farmers looking into innovative practices. Lastly, given it has been ten years since the banana growing best management practices were published, a review of the best management framework could help identify and inform growers of more recent developments or innovations.

For each practice there are growers who (because of valid, underlying circumstances that are not explored in detail in this report), perceived the impacts of adopting particular practices to be unfavourable for their farming system. The variance in responses between growers and the additional reasons influencing growers' adoption decisions highlight the uniqueness and complexity of farming systems. This suggests that "one-size-fits-all" policy or extension approaches that fail to regard differences between farms and grower circumstances will be of limited effectiveness.

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1   Introduction

The health of the Great Barrier Reef (GBR) is an ongoing concern for industry, government and the broader community. A considerable body of scientific research indicates that links exist between the terrestrial runoff of nutrients, sediment and pesticides from farm lands and a decline in the health and resilience of coastal marine ecosystems (Schaffelke, B. et al. 2017; 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 identified by policy makers to improve the water quality entering the Great Barrier Reef (GBR) is for farmers in the GBR catchment area to adopt best management practices with water quality benefits. Adoption of practice change involves a complex decision-making process and can be influenced by grower perceptions of a particular practice's impact on production and profitability to a broad range of personal, social, cultural, environmental and situational factors (Pannell et al. 2006). Studies across a range of agricultural industries emphasise the importance of grower perceptions and how these affect the likelihood of adoption, however, limited research on these matters has been conducted with respect to the Australian banana industry.

1.1   Purpose of the study

This study forms part of the economic research project RP140B 'Economic Assessment of Banana Best Management Practices (BMP)'. The main objective of this study is to report on key characteristics of best management practices as perceived by banana producers in the Wet Tropics region to inform policy development and extension activities to achieve more rapid adoption and further research. Outcomes from this study may identify potential areas of inconsistencies between grower and academic perceptions, as well as providing a broader understanding of adoption trends.

The overall aims of this study are:

- To utilise survey data collected from banana growers in the Wet Tropics region to identify best management practice adoption trends.

- To identify the relative advantage and trialability of management practices as well as barriers to adoption as perceived by growers.

- To provide insights gained from this survey for further research in order to enhance the adoption of best management practices and assist extension officers in the tailoring of information to particular grower requirements.

1.2   Regions surveyed

The Australian banana industry is mainly focused in the Wet Tropics and Tablelands regions of North Queensland. This study is interested in banana production in the Wet Tropics region due to its proximity to the GBR, specifically the Tully and Innisfail districts. Figure 1 shows the key survey area of Tully and Innisfail which was mainly contained within the Cassowary Coast Local Statistical Area (indicated by the pink marker).

Figure 1: Local Statistical Area Map of the Cassowary Coast Region

Source: ABS, (2017). Data by Region, 2011-16 Catalogue No. 1410.0. ABS data used with permission from the Australian Bureau of Statistics. Licensed under Creative Commons Attribution 2.5 Australia (CC BY 2.5 AU).

1.3   Selection of practices surveyed

The management practices included in the survey and subsequent analysis were taken from the Banana Best Management Practices Environmental Guidelines (King, 2008) and the Paddock to Reef Water Quality Risk Framework for Bananas (Queensland Government, 2015). King (2008) uses a 'best', 'okay' and 'improve' criteria while the Water Quality Risk Framework (Queensland Government 2015) uses 'high risk (superseded), 'moderate risk (minimum)' and 'moderate – low risk (best practice)' criteria. The practices included in the Water Quality Risk Framework are similar to those in the industry guidelines, with the main difference being a greater level of technical specificity to provide for the modelling that is undertaken as part of the Paddock to Reef modelling program (see Appendix 7.2). Seven practices relevant to water quality and run-off from banana farms were included in the survey (see Table 1)[1]. Descriptions of practices detailed by King (2008) and Queensland Government (2015) were incorporated into the practices description for the purpose of the survey.

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[1] In Questions 11 and 12 of the survey, practice 3 (tillage) is defined in more detail as "Pre-formed beds using GPS and zonal tillage are used and the crop is planted into permanent beds. Row area only receives minimum tillage necessary for establishment" and practice 4 (ground cover) is defined in more detail as "At least 60% living ground cover is achieved in areas such as the inter-row space and headlands, greater than 60% inter-row ground cover is achieved by retention and mulching of banana waste."

Table 1: Management practices surveyed

Practice	Management Aspect
1. The banana crop is removed by treating with herbicide and plants are left to break down in the row area before cultivation.	Crop removal method
2. Either a grass or planted fallow crop is grown between banana crop cycles for at least 12 months.	Grass or planted fallow
3. The crop is planted into permanent beds. Row area only receives minimum tillage necessary for establishment when risk of erosion is low.	Crop planting and tillage
4. At least 60% of living ground cover is achieved in areas such as the inter-row space and headlands.	Living ground cover
5. The fertiliser program is based on recommended rates for nitrogen and phosphorus and is supported by leaf and soil testing on every block and yield monitoring. The program is revised annually and checked to ensure targets are updated and actually applied.	Fertiliser rates
6. All fertigation, or a combination of fertigation and banded surface applications is used depending on the weather conditions.	Fertiliser application method
7. Apply fertiliser fortnightly during high growth periods, and reduce this during low growth periods such as winter. Weather conditions may mean that this is not always possible.	Fertiliser application frequency

Source: King (2008), Queensland Government (2015).

1.4 Grower perceptions

Grower perceptions about the underlying characteristics associated with management practices play a fundamental role in the adoption process[2]. Pannell et al. (2006) posits, "Adoption is based on subjective perceptions or expectations rather than on objective truth". Moreover, each best management practice can be considered as having a bundle of characteristics that each grower values in differing proportions, which provides a description of that grower's particular preferences (Wossink et al., 1997). This study uses an approach based on these theoretical insights, eliciting responses to identify grower views toward best practice adoption.

Several studies have been undertaken that emphasise the importance of grower perceptions of management practices in determining the growers' adoption of them (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).

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[2] 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).

From his prominent work investigating the diffusion of innovations[3], Rogers (2003) identifies that the 'relative advantage' of a new practice to be a major motivator for adopting that practice, as well as complexity, observability, trialability and compatibility[4]. 'Relative advantage' is the perceived net benefit to be gained by adopting an innovation or new practice, relative to the practice it supersedes. Pannell et al. (2006) proposed that 'relative advantage' depends on a range of factors including perceptions of a practice's impact on short-term production costs and yields, on medium to long-term profitability, on the variability (riskiness) of production and the practice's required establishment costs. Practices are more likely to be adopted when they have a high relative advantage especially when it is characterised by an economic benefit (Hamilton, 2009).

Perceptions regarding practice characteristics are only one aspect influencing a grower's decision to adopt. Reimer, Weinkauf and Prokopy (2012) provide a framework (Figure 2) which models the adoption decision as a function of background factors, the perceived characteristics of a particular practice (Rogers 2003; Cary et al. 2001) and cognitive or behavioural aspects (Fishbein and Ajzen 2010)[5].
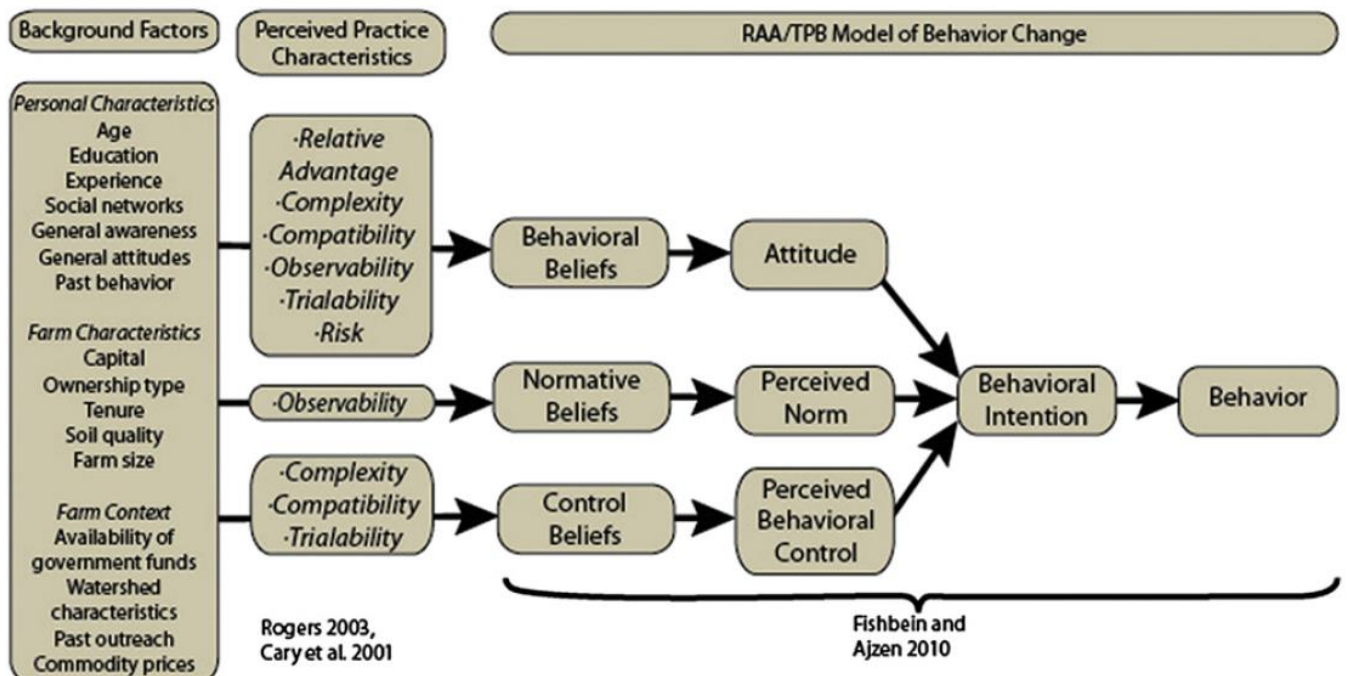
Figure 2: Conceptual framework of BMP adoption
Source: Reimer et al., 2012.

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[3] Diffusion is the process by which an innovation (or new practice) is communicated through certain channels over time among the members of a social system (Rogers, 2003).
[4] For the purposes of this report, adoption of "innovations" is, in essence, synonymous with adoption of "practices."
[5] A qualitative analysis of interviews with producers in two watersheds in Indiana, USA, was conducted to determine which characteristics make four common BMPs more or less acceptable to producers. Human behaviour is explained in the framework using the Reasoned Action Approach (Fishbein and Ajzen, 2010), an extension of the Theory of Planned Behaviour (Ajzen,1988).

1.5 Description of the perceived economic impacts and characteristics of management practice adoption

Throughout this report, the terms "economic impacts" or "economic aspects" are typically used to refer to the perceived impact of adopting a practice on the following matters (see Appendix 7.1, Question 11):

- Production costs;
- production of bananas;
- enterprise profitability; and
- variability of production.

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) affect the practice's probability or rate of adoption.

Production of bananas

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

Enterprise Profitability

A grower's perception of the profitability of a practice has been estimated to have a positive relationship with the adoption of best management practices (Norris & Batie, 1987; Pannell et al., 2006; Baumgart-Getz et al., 2012). If farm profitability from adopting a best management practice is perceived to be higher (lower) than the conventional practice, then it is estimated that it will positively (negatively) affect 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 a best management practice that made production more consistent from year to year, thereby reducing the production volatility that a grower might face or "smoothing" production outcomes between harvests. If the variability of production from adopting a practice is perceived to be less (greater) than the conventional practice, then it is estimated that it will positively (negatively) affect its probability or rate of adoption.

Throughout this report, the term "key characteristic" is typically used to refer to a practice being characterised by one of the following perceived barriers to adoption (see Appendix 7.1, Question 12):

- 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; and
- too much time required to look into.

High capital investment needed

The establishment costs, or the capital investment, required to implement a best 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) affect its probability or rate of adoption.

Contractors needed to implement change

Some growers may require the services of contractors in order to facilitate a practice adoption. 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) affect its probability or rate of adoption.

Does not fit with my current farming system

This 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). Examples in banana growing include whether best practices are compatible with an organic farming system or a variety of bananas other than Cavendish. If a practice is perceived to be compatible (incompatible) with the current farming system, then it is estimated that it will positively (negatively) affect its probability or rate of adoption.

Not easy to trial

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 practices and potential threats to the trial's outcome (Pannell et al., 2006). The divisibility of a practice refers to its ability to be trialled on a small scale. 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) affect its probability or rate of adoption.

Requires new skills and information and **too much time required to look into**

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 a management practice is perceived to be low (high), then it is estimated that it will positively (negatively) affect its probability or rate of adoption.

1.6 Conducting the Survey

The data analysed in this report is drawn from surveys completed face-to-face with 46 banana growers with farms in or around the two major banana growing areas of Tully and Innisfail in the Wet Tropics region.[6] More specifically, surveys were undertaken in the ABS level two statistical areas of Babinda, Innisfail, Johnstone and Tully. ABS 2015-16 survey data records 155 businesses producing bananas in those (level 2) statistical areas and 178 banana businesses for the total Wet Tropics NRM region, which extends from the Herbert River to the Daintree River catchments and includes additional level 2 statistical areas (ABS, 2017a). These numbers conservatively suggest that this survey accounted for approximately 30% of banana growers in the region.

The surveys were undertaken between May and July 2017. Initially growers were approached through cold calling to participate in the survey. Snowball sampling, asking respondents to refer other potential study participants, was subsequently used in order to identify additional participants.

The main limitation for snowball sampling is that it is not possible to determine the population distribution pattern and it can lead to bias in certain peer networks (Van Meter, 1990). However, this method was used because it is effective in increasing the survey size, it is simple and requires minimal planning.

Surveys were conducted with a primary farming decision-maker at the grower's home, workplace or somewhere local. It is believed that one-to-one interviews compared to group interviews increased response rates, reduced self-selection bias[7] and preserved the autonomy of responses. Higher response rates can lead to an increased sample size for the survey and can therefore capture more of the total population. Keeping responses free from external control or influence is important to avoid certain group mentalities or behaviours such as groupthink.[8] On the other hand, the main drawback for one-on-one interviews is that the participant can be influenced by the interviewer and may (either consciously or subconsciously) adjust their responses to suit what they think the interviewer wants to hear or to maintain a positive image of themselves (Nederhof, 1985).

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[6] The statistical boundaries mean that a separation of the Tully and Innisfail areas is not practical using ABS data, especially given that the Johnstone statistical area include some locations relatively close to Tully and other locations relatively close to Innisfail. Local opinions differ regarding which locations would typically be considered part of Tully or Innisfail.

[7] 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 best practice adoption being surveyed.

[8] Groupthink is when group members value conformity within the group over independent thinking, which can lead to an irrational decision-making outcome (Paulus, 1998).

The interview durations depended on the level of detail growers provided and ranged from 30 minutes to 2 hours with an average of one-hour duration. Each grower was asked 13 closed-ended and 2 open-ended questions over four separate sections (see Appendix 7.1). The questions were designed to identify grower perceptions towards best management practices, history of practice adoption, as well as a general description of grower characteristics and farm attributes.

The survey had four sections. In section one entitled "About You and Your Farm," grower characteristics and farm attributes were identified. In section two, entitled "Current Management Practices," current farming management practices were identified. In section three entitled "Usage of 'best practice,'" growers were asked to detail their use of and attitude to each practice. In section four entitled "Costs of Changing Practices," growers were asked to identify costs incurred in changing practices separate to the purchase of capital equipment or other physical inputs to production.

2 Grower perceptions of practice adoption

This section analyses and presents information about the seven best management practices included in the survey and how the growers surveyed perceive these practices with respect to the factors outlined in section 1.5, whether they have adopted them or not.

2.1 Adoption of best management practices in the survey

Within the survey, growers were asked whether they had adopted each of the management practices listed in Descriptions of practices detailed by King (2008) and Queensland Government (2015) were incorporated into the practices description for the purpose of the survey.

Table 1: Management practices surveyed The proportion of growers surveyed that indicated adoption of each management practice is presented in Figure 3.
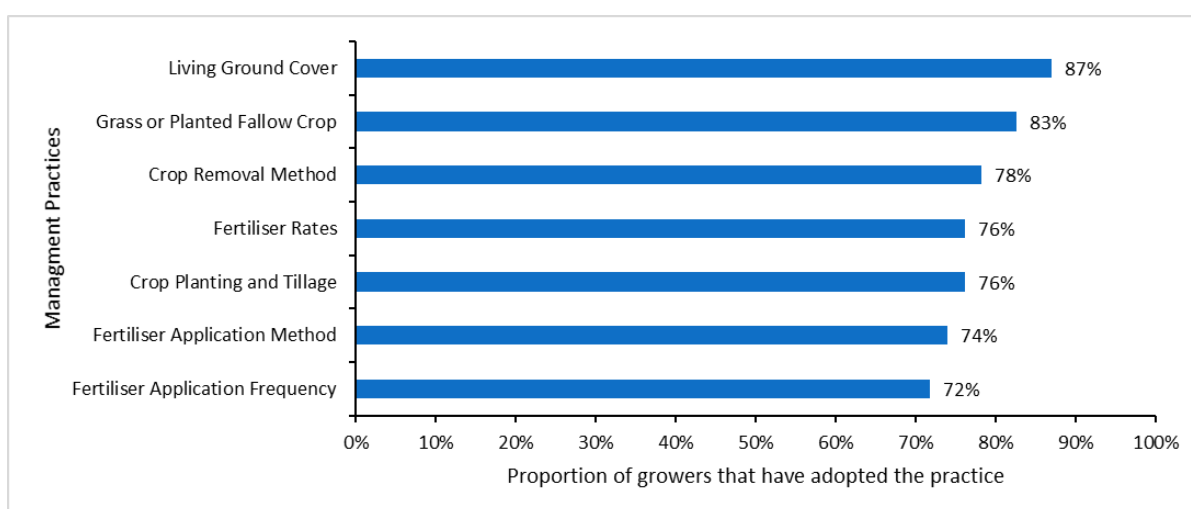
Figure 3: Proportion of growers that have adopted each practice

The 2016 GBR Reef Report Card found that 62% of the area in the Wet Tropics under banana production was managed under best management practice systems. More specifically 60% of the area was managed under best management practices for sediment and 63% was managed under best management practices for nutrients (Australian Government and Queensland Government 2017:19). While this is lower than we found in our survey, the GBR Reef Report Card covers all 250 growers managing 11,800 hectares of banana production in the Wet Tropics and reports on all growers, including those still using high risk practices (14% for soil and zero% nutrients) and moderate risk practices (25% for soil and 37% for nutrients). In a voluntary survey on adoption of best practices, you would expect some self-selection bias with growers who have adopted best management practices to be more willing to talk about their experiences. The 2016 GBR Reef Report card, however, does not break the management practices down further than by pollutant being addressed. Although our smaller survey may have some bias in the sample, there are still insights to be gained on the individual practices included.
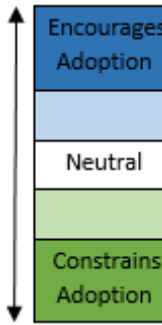
The perceptions of the likely economic impacts from practice adoption and other key characteristics of practice adoption are contrasted with the management practice adoption rates in order to demonstrate how perceptions may influence the adoption decision are presented in section 2.2.

2.2 Overview of grower perceptions of practice adoption

Table 2 uses the average grower response to provide a summary of the results presented in sections 2.3 to 2.9 for perceived economic impacts. For each of the management practices, the table uses colour-coding (heat map) to illustrate whether growers perceive the practice characteristic or economic impact to constrain (green) or encourage (blue) adoption. The heat map shows averages for each cell and therefore will not capture all data, however, this data is further broken down in the next sections. Adoption rates for each practice are indicated in the bottom row of the table.

*Table 2: Average perceptions of practice adoption for perceived economic impacts (heat map)^*

		Perceived Economic Impacts					
		Production costs	Production of bananas	Enterprise profitability	Variability of production	Adoption Rate	
Best Mgmt. Practices	Crop Removal Method	* 2.7	3.0	3.3	2.9	78%	
	Grass or Planted Fallow Crop	* 2.9	4.1	3.9	2.3	83%	
	Crop Planting and Tillage	2.6	3.6	* 3.9	2.5	76%	
	Living Ground Cover	* 3.0	3.5	3.7	2.3	87%	
	Fertiliser Rates	* 2.6	4.1	4.0	2.0	76%	
	Fertiliser Application Method	* 3.0	4.0	3.8	1.9	74%	
	Fertiliser Application Frequency	3.5	4.2	3.8	2.0	72%	

Encourages Adoption

Neutral

Constrains Adoption

^ The numbers represent a scale from 1 to 5 and should be read across practices for each economic impact. Adopting practices with perceived decreases to production costs and variability of production on average ranked below 3 are coloured blue – encouraging adoption while perceived decreases to production of bananas and enterprise profitability on average ranked below 3 are coloured green – constraining adoption. An asterisk (*) beside the figures indicates that there is notable variation within the average response. In these instances, 20% or more of the grower responses to the survey question were "small increase" or "large increase" and 20% or more of the responses were also "small decrease" or "large decrease."

Similarly, Table 3 uses the average grower response to provide a summary of the results presented in sections 2.3 to 2.9, but for perceived practice characteristics. The table works the same way as the previous table.

*Table 3: Average perceptions of practice adoption for perceived practice characteristics (heat map)^*

		Perceived Practice Characteristics						
		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	Too much time required to look into	Adoption Rate
Best Mgmt. Practices	Crop Removal Method	2.0	1.9	2.2	1.9	2.4	1.9	78%
	Grass or Planted Fallow Crop	* 2.3	2.0	2.0	1.9	* 2.5	1.8	83%
	Crop Planting and Tillage	3.9	* 3.0	* 2.5	* 2.6	3.6	* 2.5	76%
	Living Ground Cover	* 2.8	1.8	1.9	1.9	2.2	1.8	87%
	Fertiliser Rates	* 2.5	* 2.9	2.1	2.0	* 2.7	2.2	76%
	Fertiliser Application Method	4.0	* 2.8	2.3	* 2.6	* 3.2	* 2.4	74%
	Fertiliser Application Frequency	* 2.7	1.8	2.2	2.1	2.3	1.9	72%

Legend: Encourages Adoption / Neutral / Constrains Adoption

^ The numbers represent a scale from 1 to 5 and should be read across practices for each characteristic. Grower agreement with perceived characteristics on average ranked above 3 and are coloured green – constraining adoption. An asterisk (*) beside the figures indicates that there is notable variation within the average response. In these instances, 20% or more of the grower responses to the survey question were "agree" or "strongly agree" and 20% or more of the responses were also "disagree" or "strongly disagree."

Looking more closely at Table 2 and Table 3, it can be seen how each practice is perceived in terms of economic impacts or practice characteristics when grower responses to survey questions are aggregated and averaged. In addition, any notable variation in the average response is further explained in section 5. Overall, best practices were perceived to have neutral to positive impacts on economic outcomes (production costs, production, profitability and variability of production). There was a similar result for the perceived characteristics of adopting the practices with only three negative tending towards the 'constrains adoption' end of the scale and five neutral results.

An asterisk (*) beside the figures in Table 2 and Table 3 indicates that there is notable variation within the average response. For Table 2, an asterisk (*) indicates that 20% or more of the grower responses to the survey question were "agree" or "strongly agree" and 20% or more of the responses were also "disagree" or "strongly disagree." Similarly, for Table 3, an asterisk (*) indicates that for 20% or more of the grower responses to the survey question were "agree" or "strongly agree" and 20% or more of the responses were also "disagree" or "strongly disagree." There is notable variation for a number of practices. Some possible explanations for this variation in responses are discussed further in section 5, using the example of growers' perceptions of the impact on production costs of 60% living ground cover, where 37% of growers' perceived the practice would increase production costs, and the same amount perceived the practice would decrease production costs.

For the economic impact rows of Table 2 (Question 11 of the survey), growers were asked to rate the economic impact on their farm from best management practice adoption on a scale of 1-5   (1 = large decrease, 5 = large increase) against four criteria; Production Costs, Production of Bananas, Enterprise Profitability and Variability of Production. For the production costs and production variability, higher numbers mean that it is a constraint to adoption. For the other two criteria, production of bananas and enterprise profitability, higher numbers mean that it encourages adoption. Respondents were asked to provide an answer regardless of whether 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 the perceived practice characteristics rows of Table 3 (Question 12 of the survey), all participants were asked to identify the key characteristics of each practice on a scale of 1-5 (1 = strongly disagree, 5 = strongly agree) against six criteria; high capital investment needed, contractors needed to implement change, does not fit my farming system, not easy to trial, requires new skills and information and too much time required to look into. For all these criteria, higher numbers mean that these characteristics are perceived as a constraint or a barrier to adoption. Results for each practice are summarised below:

Crop removal method - the economic impacts are mainly perceived as neutral and the practice characteristics are perceived as slightly encouraging adoption.

Grass or planted fallow - the economic impacts are perceived as slightly positive apart from production costs being neutral. The practice characteristics are perceived to slightly encourage adoption.

Crop planting and tillage - the economic impacts are perceived as slightly encouraging adoption and the practice characteristics are mainly perceived as neutral. Two practice characteristics, high capital investment needed and requires new skills and information, are perceived as slightly constraining adoption. On the other hand, contractors being needed to implement change is perceived as neutral.

Living ground cover - the economic impacts are perceived as slightly encouraging adoption apart from production costs, which are perceived as being neutral. The practice characteristics are perceived as slightly encouraging adoption, except for contractors being needed to implement change, which is perceived as neutral.

Fertiliser rates - the economic impacts and practice characteristics are perceived as slightly encouraging adoption, except for the need for contractors to implement change, which is perceived as neutral.

Fertiliser application method - the economic impacts are perceived as slightly encouraging adoption apart from production costs being neutral. The practice characteristics are perceived as slightly encouraging adoption, except for high capital investment needed, which is perceived as slightly constraining adoption.

Fertiliser application frequency - the economic impacts are perceived as slightly encouraging adoption apart from production costs, which are perceived as slightly constraining adoption. Overall, the practice characteristics are perceived as slightly encouraging adoption.

Sections 2.3 to 2.9 go into more depth of surveyed growers' responses to the questions on perceived economic impacts and characteristics for each of the best management practices included in the survey.

Stacked bar charts were developed to provide a visual representation of the responses, with counts and percentages displayed for the 46 total surveys. Section 2.10 and 2.11 provide the responses to the two open ended questions around other barriers that were not included in question 12 and priority improvements for the next 5 years.

2.3 Crop Removal Method

Figure 4 illustrates the perceived economic implications for removing the banana crop by treating with herbicide and leaving plants to break down in the row area before cultivation. Of the growers surveyed, this practice had the third highest adoption rate (78%). Most growers surveyed perceived that adopting best practice crop removal method would not affect the variability of production (74%) and the production of bananas (78%). Half the growers surveyed (50%) perceived that the practice would have no impact on enterprise profitability and 37% of growers surveyed perceived the practice would increase enterprise profitability. In addition, most growers surveyed perceived that best practice crop removal method adoption would result in a decrease in production costs (48%) compared to an increase in production costs (24%) or no impact (28%).
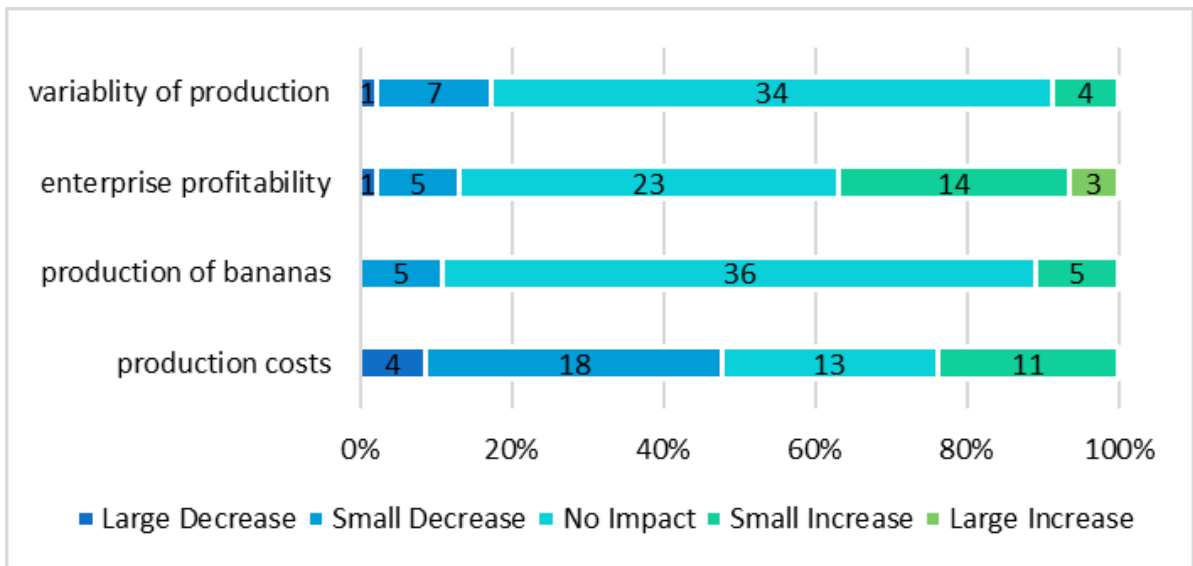
Figure 4: Perceptions of economic impacts for crop removal method

Grower survey responses to questions about specific characteristics for best practice crop removal method are illustrated in Figure 5. Most growers surveyed disagreed or strongly disagreed with the following statements with respect to removing the banana crop with herbicide: *too much time required to look into* (89%), *requires new skills and information* (72%), *not easy to trial* (89%), *does not fit with my current farming system* (80%), *contractors needed to implement change* (93%) and *high capital investment needed* (78%).
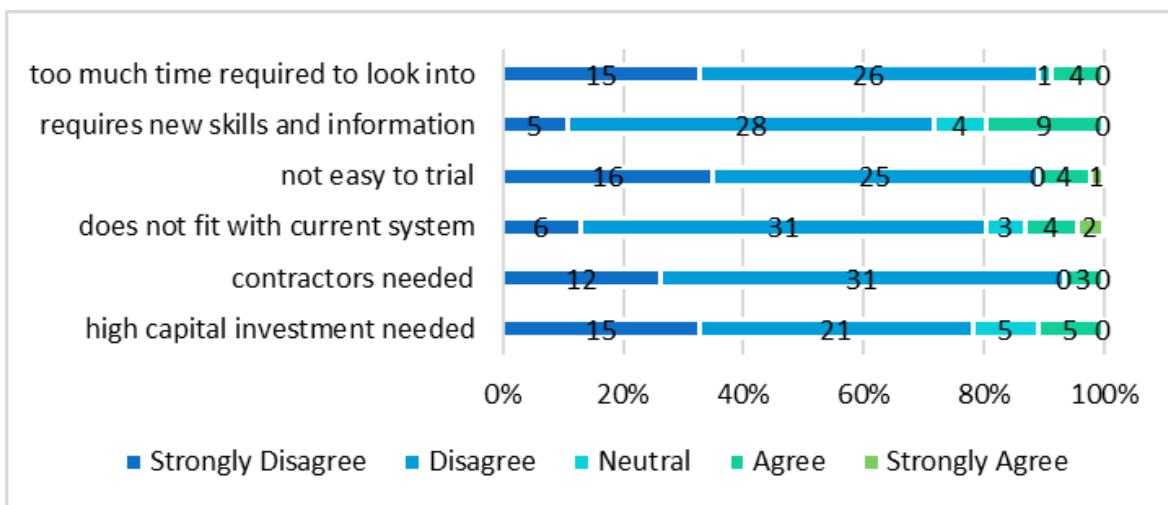
Figure 5: Perceptions of the practice characteristics of knockdowns and strategic residual use

2.4 Grass or Planted Fallow Crop

Figure 6 illustrates the perceived economic implications for having either a grass or planted fallow crop grown between banana crop cycles for at least 12 months. Of the growers surveyed, this practice had the second highest adoption rate (83%). Most growers surveyed perceived that fallow crop adoption would have a small decrease on the variability of production (72%). Growers perceived that fallow crop adoption had either a small decrease (35%), no impact (28%), or small increase (33%) in production costs. In contrast, most growers surveyed perceived that fallow crop adoption would have a small increase on the production of bananas (70%) and enterprise profitability (63%).

Figure 6: Perceptions of economic impacts for grass or planted fallow crop

How growers responded to questions about specific characteristics for fallow crop is illustrated in Figure 7. Most growers surveyed disagreed or strongly disagreed that any of the characteristics were barriers to adopting grass or planted fallow crops. There were two characteristics that had the highest responses as being barriers to adoption and these were *requires new skills and information* (30% agreed and strongly agreed) and *high capital investment needed* (28% agreed or strongly agreed).
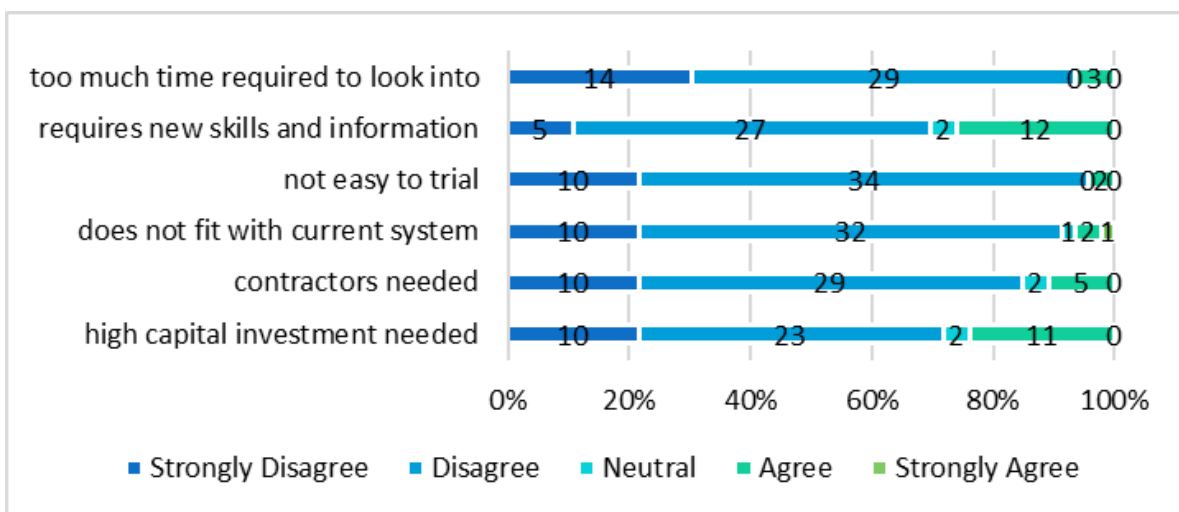
Figure 7: Perceptions of the practice characteristics for grass or planted fallow crop

2.5 Crop Planting and Tillage

Figure 8 illustrates the perceived economic implications for planting the crop into permanent beds with the row area only receiving minimum tillage to establish, when risk of erosion is low. Of the growers surveyed, permanent beds and minimum tillage had the third lowest adoption rate (76%). Half of the growers surveyed perceived that permanent beds and minimum tillage adoption would not affect the variability of production (48%). A majority of growers surveyed believed that permanent beds and minimum tillage adoption would result in an increase in enterprise profitability (77%) and a decrease in production costs (54%).

Almost all growers surveyed perceived that the production of bananas would not decrease (98%) from adopting permanent beds and minimum tillage, with most believing there would be no impact (46%) or a small increase in production of bananas (41%).
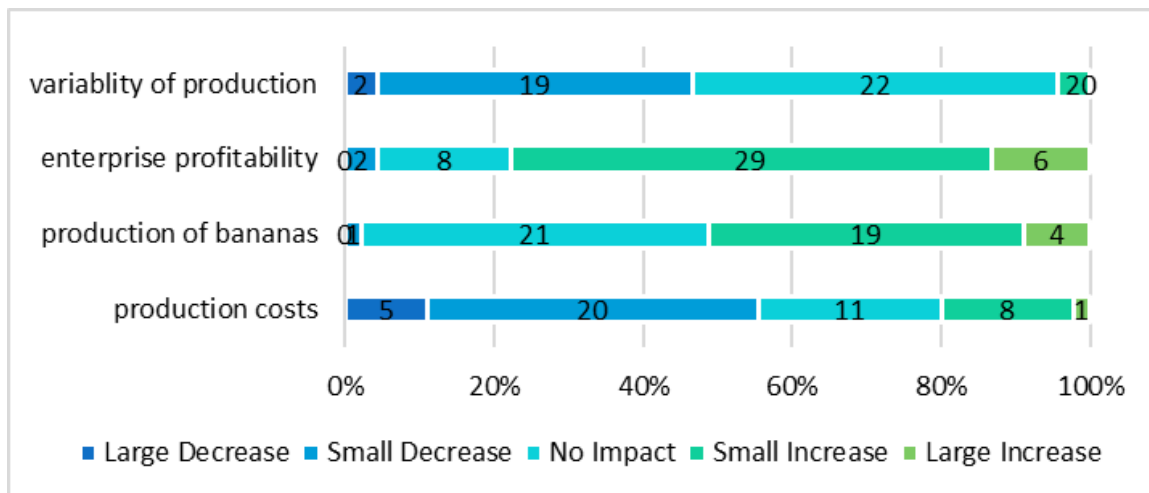
Figure 8: Perceptions of economic impacts for crop planting and tillage

Figure 9 illustrates how growers responded to questions about specific practice characteristics for permanent beds and minimum tillage. Most growers surveyed disagreed or strongly disagreed with the following statements with respect to permanent beds and minimum tillage: *too much time required to look into* (65%), *not easy to trial* (65%) and *does not fit with my current farming system* (67%). However, most growers surveyed agreed or strongly agreed that adopting permanent beds and minimum tillage would *require new skills and information* (67%), *contractors needed to implement change* (50%) and *high capital investment needed* (78%).
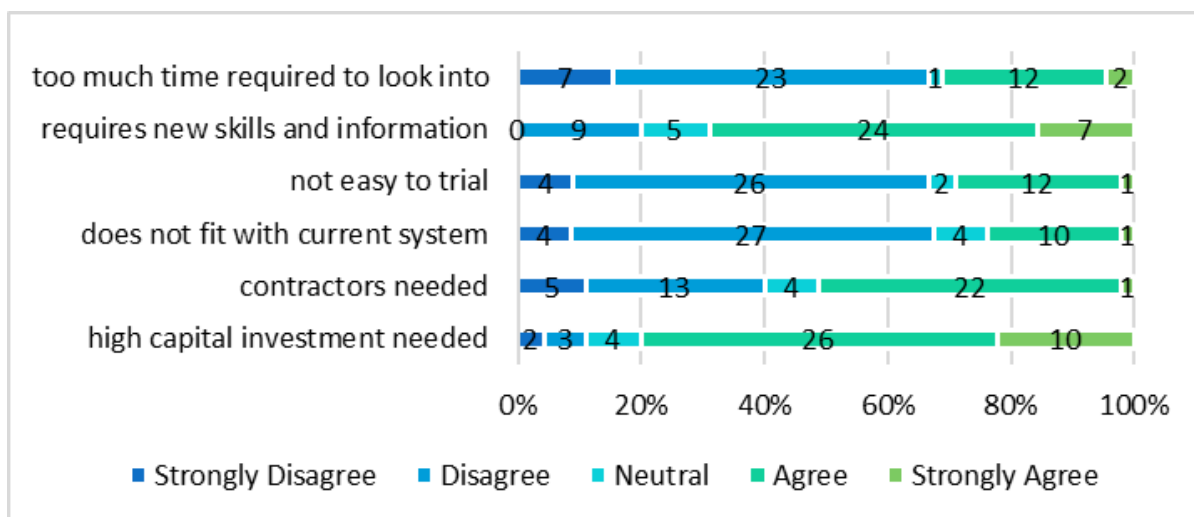
Figure 9: Perceptions of the practice characteristics for crop planting and tillage

2.6 Living Ground Cover

Figure 10 illustrates the perceived economic implications for having at least 60% of living ground cover achieved in areas such as the inter-row space and headlands. Of the growers surveyed, this practice had the highest adoption rate (87%). Most growers surveyed perceived that living ground cover adoption would result in a decrease in the variability of production (67%). Growers surveyed were generally in agreement in their perceptions that practice adoption would not result in a decrease in enterprise profitability (94%) or production of bananas (91%). Perceptions around production costs of living ground cover for the growers surveyed were evenly distributed.
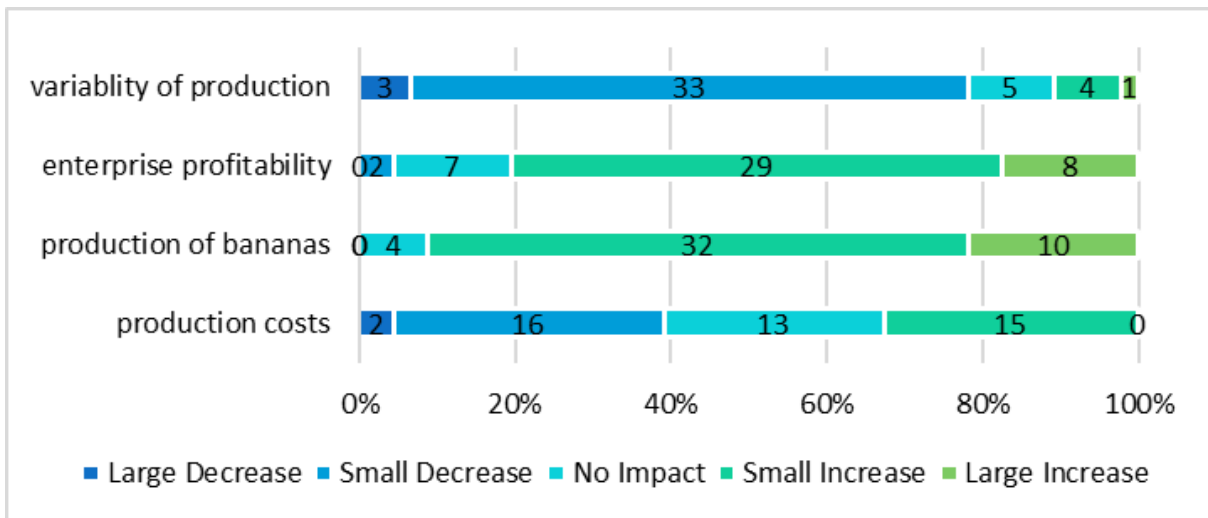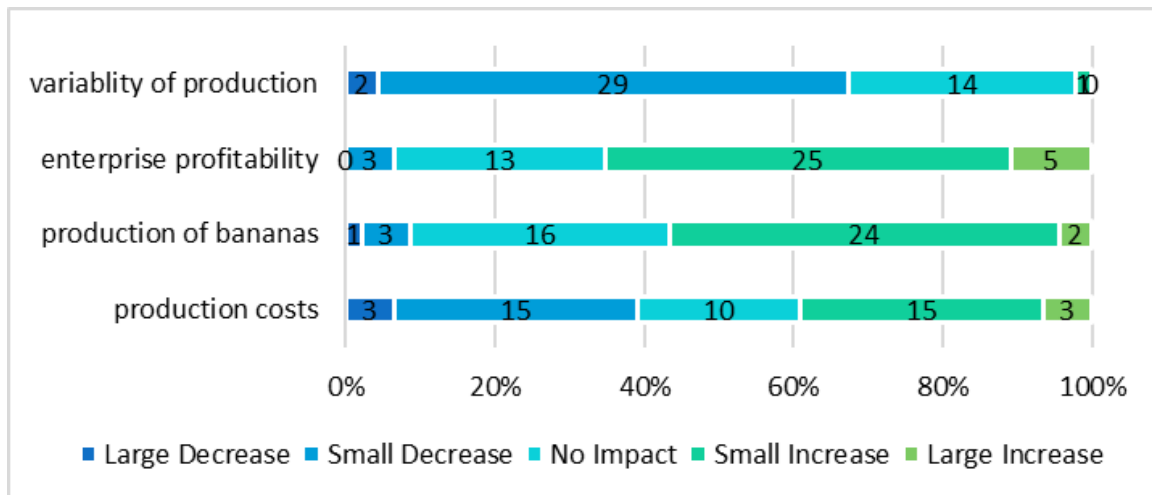

Figure 10: Perceptions of economic impacts for living ground cover

How growers responded to questions about specific characteristics for living ground cover is illustrated in Figure 11. Most growers surveyed disagreed or strongly disagreed with the following statements: *too much time required to look into* (96%), *requires new skills and information* (78%), *not easy to trial* (91%), *does not fit with current system* (94%) and *contractors needed* (94%). Perceptions around the levels of capital investment needed for living ground cover from the growers surveyed were that 33% agreed that *high capital investment was needed*, compared to 48% who disagreed that *high capital investment was needed*.
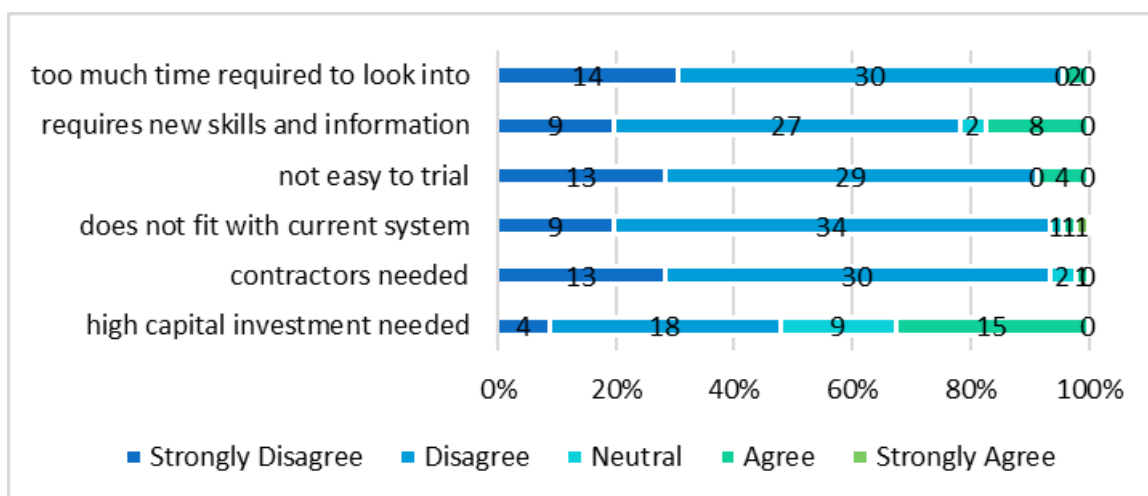
Figure 11: Perceptions of the practice characteristics for living ground cover

2.7 Fertiliser Rates

Figure 12 illustrates the perceived economic implications for basing the fertiliser program on recommended rates for nitrogen and phosphorus and is supported by leaf and soil testing on every block and yield monitoring. Of the growers surveyed, this practice had the fourth highest adoption rate (76%). Most growers surveyed perceived that recommended fertiliser rate adoption would cause a decrease in the variability of production (83%) and production costs (54%). Perceptions of growers surveyed who thought that adopting recommended fertiliser rates would cause an increase in the production of bananas (83%) and the enterprise profitability (85%) were high.
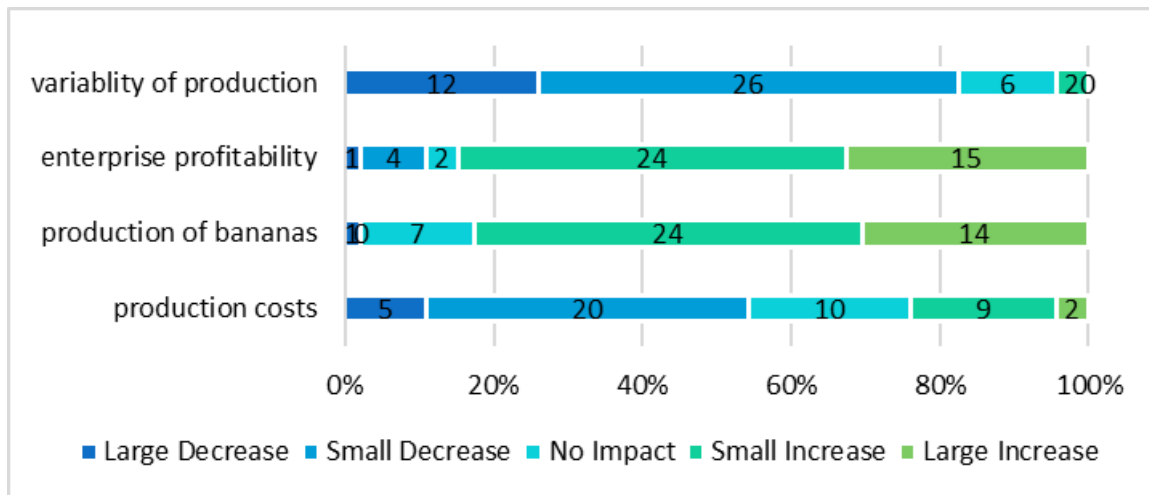
Figure 12: Perceptions of economic impacts for fertiliser rates

How growers responded to questions about specific characteristics for recommended fertiliser rates is illustrated in Figure 13. Most growers surveyed disagreed or strongly disagreed with the following statements: *too much time required to look into* (80%), *requires new skills and information* (59%), *not easy to trial* (85%), *does not fit with my current farming system* (87%) and *high capital investment needed* (65%). Most growers surveyed agreed that contractors were needed to implement recommended fertiliser rates (52%).
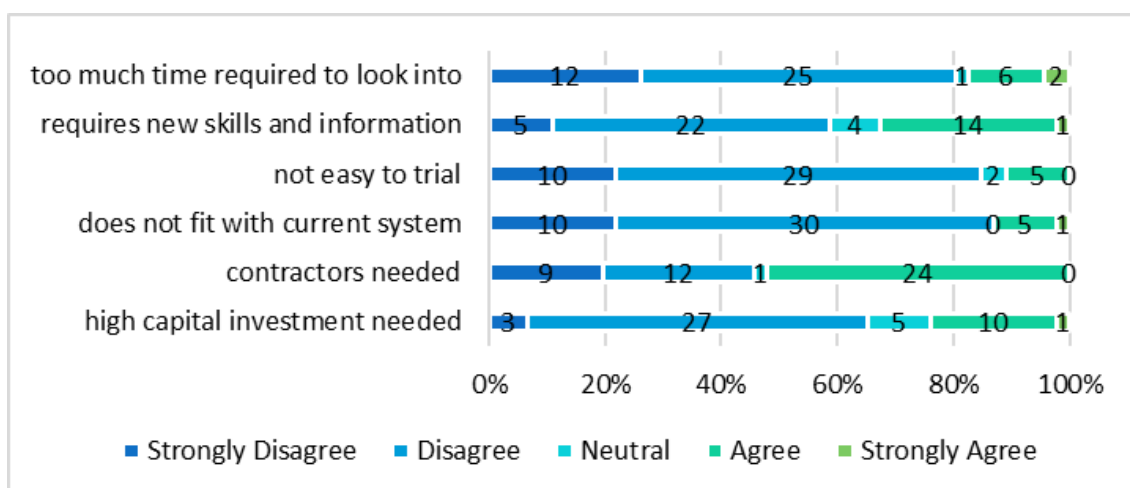
Figure 13: Perceptions of the practice characteristics for fertiliser rates

2.8 Fertiliser Application Method

Figure 14 illustrates the perceived economic implications for using all fertigation, or a combination of fertigation and banded surface applications depending on the weather conditions. Of the growers surveyed, fertiliser application method had the second lowest adoption rate (74%). Most growers surveyed perceived that fertiliser application method adoption would cause a decrease in the variability of production (83%). Most growers surveyed also perceived that fertiliser application method adoption would cause an increase in enterprise profitability (76%) and the production of bananas (80%). However, surveyed growers perceptions around production costs were evenly distributed around whether costs would increase (41%) or decrease (39%) from adopting best practice fertiliser application methods. The high production costs could be a possible barrier for growers adopting fertiliser application method.
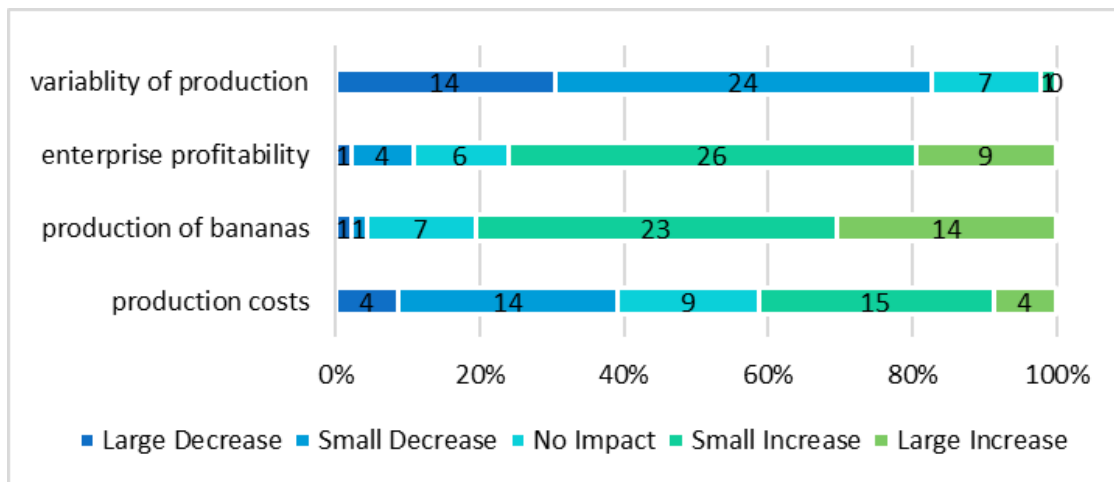
Figure 14: Perceptions of economic impacts for fertiliser application method

How growers responded to questions about specific characteristics for fertiliser application method is illustrated in Figure 15. Most growers surveyed disagreed or strongly disagreed with the following statements with respect to fertigation or a combination of fertigation and banded surface applications: too much time required to look into (70%), not easy to trial (63%), does not fit with current system (76%). Most growers surveyed agreed that new skills and information would be required (54%), however, they were mainly evenly split on whether contractors would be needed to adopt this practice. Only 15% of the growers' surveyed disagreed that *high capital investment* was *needed* for practice change.
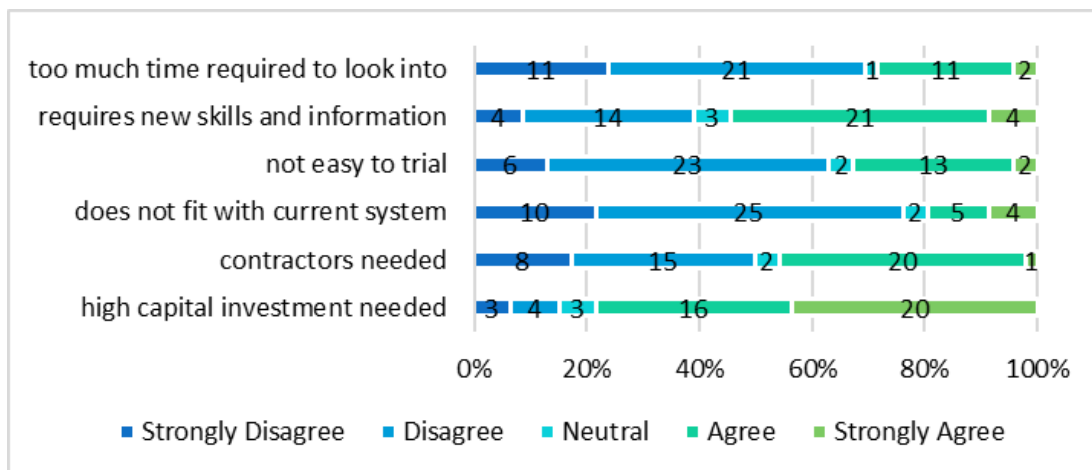
Figure 15: Perceptions of the practice characteristics for fertiliser application method

2.9 Fertiliser Application Frequency

Figure 16 illustrates the perceived economic implications for applying fertiliser fortnightly during high growth periods, and reduce this during low growth periods such as winter. Of the growers surveyed, this practice had the lowest adoption rate (72%), however this was still a quite high rate when compared to the 2016 GBR Reef Report Card results for area of banana production under best management practices for nutrient management was 63%. Only 2% of growers surveyed perceived that fertiliser application frequency adoption would increase the variability of production. Most growers surveyed perceived that adopting this practice would result in an increase in enterprise profitability (74%) and production of bananas (91%) even though they also believed production costs would increase with the adoption of adjusting fertiliser application to growth periods (63%).
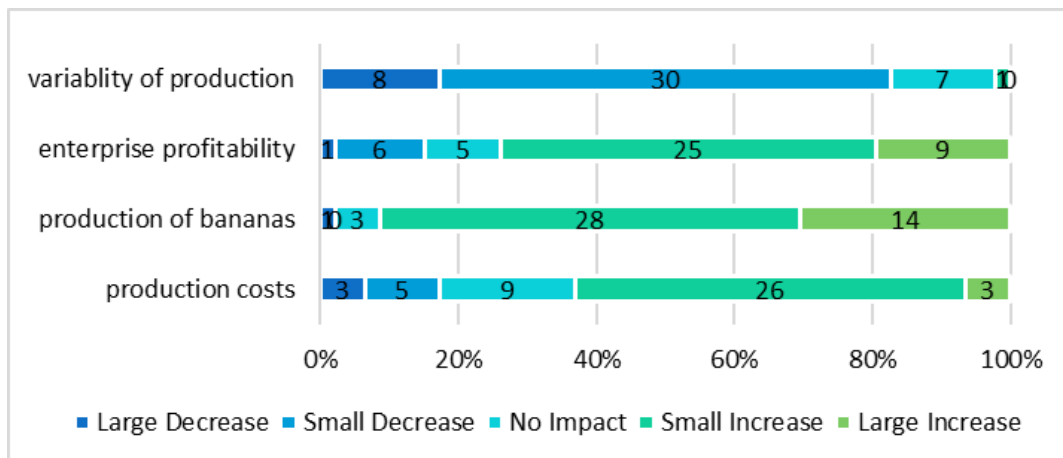
Figure 16: Perceptions of economic impacts for fortnightly fertiliser application frequency

How growers responded to questions about specific characteristics for fertiliser application frequency is illustrated in Figure 17. Most growers surveyed disagreed or strongly disagreed with the following statements: too much time required to look into (91%), requires new skills and information (70%), not easy to trial (87%), does not fit with my current farming system (80%) and contractors needed (93%). The survey found 36% of growers agreed or strongly agreed that high capital investment was needed for this practice, making it the largest perceived obstacle to adoption for fertiliser application frequency best practice. It is worth noting that frequency of application is influenced by the application method. For example, a grower that has installed a fertigation system will find it easier to apply nutrients more often than a grower that is applying granule nutrients by tractor. Investing in a fertigation system would support the reasoning behind high capital investments required for this practice, however, if a system was already in place it would not take much to adjust frequency of applications.
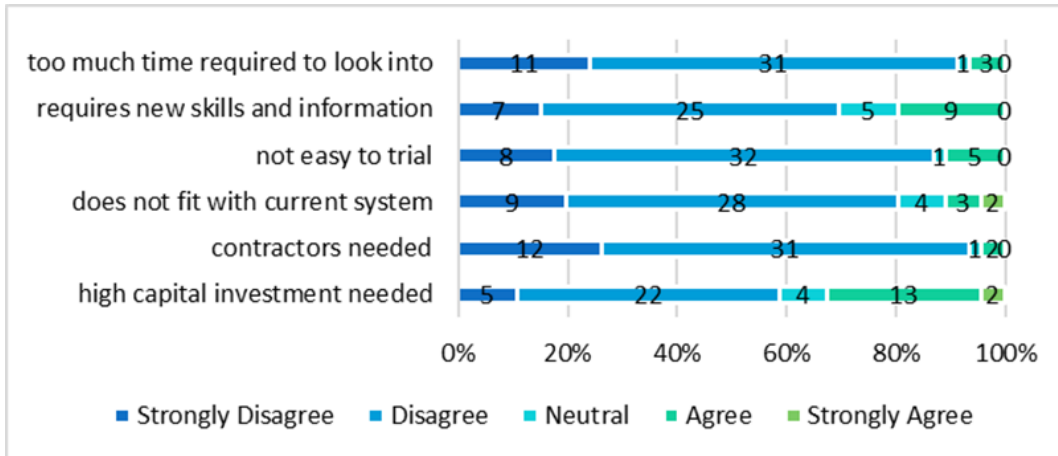
Figure 17: Perceptions of the practice characteristics for fertiliser application frequency

2.10 Other reasons influencing adoption

To capture other characteristics not included in the previous sections, growers were asked question 13 "Are there any other reasons not covered in the above tables that have influenced your decision to adopt/not adopt practices listed in question 12 above?" Some common characteristics identified from responses question 13 are listed below, in no particular order:

- Banana prices, profit, supply and marketability;
- Economic reasons;
- Labour issues;
- Funding and/or grants;
- Occupational Health and Safety;
- Pest management;
- Environmental concerns;
- Personal or family experience;
- Red tape and auditing;
- Panama Tropical Race 4 Disease;
- Weather, soil types, gradients and farm location;
- Resource accessibility, knowledge and business structure; and
- Access to finance.

The breadth of other reasons listed that were not included in the survey illustrate the complexity involved in the decision making process for changing management practices for many banana growers. For example, "labour issues" include problems such as high staff turnover, increasing minimum wage and training costs that all feed into the highest input cost of banana production – labour. Such issues can directly affect a grower's ability to consider adoption of best management practices.

2.11 Priority improvements for the next 5 years

Question 14, "What improvements, if any, are your top priority for your property in the next 5 years?" was used to capture growers priorities in terms of improvements in the medium term. A few growers answered that they would stay the same and keep with their current practices. The range of improvements that other growers answered as a priority are listed below, in no particular order:

- Update or install new fertigation system
- Upgrade fertiliser applicator
- Improve irrigation system
- Revegetate and stabilise riverbanks
- Level road and/or headlands
- Increase ground cover
- Improve water quality by reducing run-off
- Reconstruct wetlands
- Introduce a legume cover crop between crop cycles
- Improve packing shed efficiency, such as purchasing pallet stacker or improving wastewater system
- Upgrade tractor with GPS
- Increase profitability
- On-farm biosecurity improvements (Panama disease)
- Increase environmental awareness, for example being able to identify wildlife species.

The majority of the improvements listed come under one of the management practices included in the survey.

3 Costs of changing practices

The costs involved in changing management practices is often called a transaction cost and covers the costs (monetary and non-monetary) involved in learning about new practices, deciding whether to trial them, and gaining the skills required to trial and assess them. Many studies analysing the cost-effectiveness of changing management practices for improved environmental outcomes only estimate the production costs involved and do not explicitly account for transaction costs involved in making those changes (for example, Holligan et al. 2017; van Grieken et al. 2013; East, M, 2010). This is mainly due to transaction costs being highly variable between growers and determined by many factors such as involvement with industry or NRM groups, literacy and ability to access information and appropriate training.

One study into transaction costs of sugarcane growers participating in the Reef Rescue grant scheme in 2010/11 and 2011/12 estimated total transaction costs as ranging between $134 to $37,389 with an average of $8,389 (per farm) across the 110 sugarcane growers surveyed (Coggan et al. 2015). Many industry groups provide assistance to farmers looking to apply for funding to implement BMPs, such as in the Reef Rescue funding that Coggan et al (2015) analysed which can in a sense 'mask' or 'hide' the true transaction costs of the process had the farmer gone it alone.

To get a better understanding of the transaction costs faced by banana growers in changing to best management practices, the survey asked growers to identify costs they incurred separate to the purchase of capital equipment or other physical inputs to production with respect to a particular management practice they had adopted or considered adopting recently. Specifically, growers were asked 'what actions did you undertake to learn about changing management practice/equipment/machinery to enable successful implementation or help you decide not to go ahead with the change?' The different activities listed in the survey for growers to consider were; internet research, speaking to other growers, engaging an agronomist/consultant, engaging with DAF extension staff, field days or industry information sessions, training course or other training, small scale trial on farm, and scoping of different capital options. Growers were asked to try to quantify the resources spent on the change facilitating activity (hours, visits, dollars, etc.).

Out of the 46 growers surveyed, ten did not provide any answers for this question, four noted that they have been continually undertaking improvements so it would be difficult to quantify the transaction costs and two did not provide any estimates for the practices they had recently adopted. The results from the remaining 30 growers surveyed are presented in Table 4.

The main message from Table 3 is to convey the variability of transaction costs. Some growers will have done a lot of research and invested time and money in investigating adopting best practices while others will get assistance in applying for a grant to trial or others may just simply look over the fence and have a go at what their neighbour has done.

Table 4: Resources spent on change facilitating activity

Change facilitating activity	Resources spent on change facilitating activity								
	For all practices			Fertigation			Ground cover		
	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
Internet research (hours)	6	50	0	9	50	0	2	12	0
Speaking to other growers (visits/hours)	2 visits 7 hours	15 visits 50 hours	0	2 visits 7 hours	15 visits 50 hours	0	1 visit 5 hours	5 visits 25 hours	0
Engaging an agronomist/consultant (hours/visits)	15 hours 4 visits	120 hours 60 visits	0	30 hours 9 visits	120 hours 60 visits	0	1 hour	10 hours 2 visits	0
Engaging with DAF extension staff (visits/hours/trials)	1 visit 1 hour	4 visits 10 hours	0	1 visit 1 hour	3 visits 10 hours	0	1 visit 1 hour	4 visits 5 hours	0
field days or industry information sessions (days/hours)	3 hours 1 day	24 hours	0	4 hours	24 hours	0	2 hours	6 hours	0
Training course or other training (days)	0	12 days	0	1 day	5 days	0	2 days	12 days	0
Small scale trial on farm (trials/area/$)	2 ha	3 trials 20.2 ha $50 000	0	0.8 ha	3 trials 8.1 ha $50000	0	1 trial 4 ha	1 trial 20.2 ha	0
Scoping of different capital options (hours/visits)	2 hours	16 hours 2 visits	0	2 hours	16 hours 2 visits	0	1 hour	5 hours	0

Note: n= 30

Question 15 also asked growers to note down any other transaction costs they incurred that were not included in the table. These additional costs not covered in Table 4 that growers considered as transaction costs included:

- Using existing equipment to implement or converting existing equipment (up to 25 days of labour).
- Time spent on completing paperwork for reef rescue grants with and without help from industry representative (between 2 and 80 hours, average of 15 hours), including visits, emails and meetings to discuss trials.
- Time to implement changes and get working (approx. 5 weeks /100 hours) and then revising practice change and corresponding with provider (approx. 80 hours).
- Training staff how to work with new management practice (approx. 30 hours).
- Time spent thinking about how it would work with their system (approx. 200 hours).
- Minimal transaction costs, made the changes from what they had seen/heard in the region (e.g. ground cover).
- Engaging a contractor/agronomist and the time spent preparing to meet them or corresponding with them.
- Ongoing updates, trials and experiments (over decades of experience).

The question on transaction costs was included to get an idea of the main things that banana growers do in this space when considering changing to best management practices, a snapshot of activities and time and/or money invested in them. There are many other factors at play that would probably require a whole other survey to properly tease out, such as how to separate out these costs when a grower is constantly trialling and innovating on their farm over a number of years and the role of natural resource management and industry groups in reducing these costs or government grant schemes increasing them. Another reason for including this question is also to acknowledge that these costs are part of the decision-making process and may also play a role in the decision to adopt the timing.

4   Profiling adopters and non-adopters

In this section of the report data collected from the survey is analysed to see if there are any relationships between the key characteristics of adopters and non-adopters of a particular practice or perceptions of a particular practice. Comparing and contrasting the perceptions of adopters with non-adopters may assist in further identifying barriers to adopting a particular practice.

For each management practice, growers were classified as either adopters or non-adopters of the practice[9]. A Mann-Whitney test[10] was used to identify disparity in the perceptions of non-adopters and adopters with a level of significance of 0.05 and using a two-sided test. More specifically, it was used to test the null hypothesis that there is no difference between the perception ratings of non-adopters and adopters against the alternative hypothesis that there is a difference between the perception ratings of non-adopters and adopters.

4.1   Perceptions of Economic Impact

While section 2 presented the averaged perceptions of surveyed growers with respect to economic impacts and practice characteristics for each practice, we are interested to see if and how those perceptions differ depending upon whether the grower has already adopted that particular practice. Table 5 presents the averaged perceptions on the economic impact of adopting a best management practice by growers, separated into adopters and non-adopters (see Table 2 for aggregate results). The ranking of each economic impact is from 1 = large decrease, 2 = small decrease, 3 = no impact, 4 = small increase, 5 = large increase. For production costs and production variability a ranking close to 1 will encourage adoption but for production of bananas and enterprise profitability a ranking closer to 5 will encourage adoption.

For the hypothesis test that adopters have different perceptions of economic impacts compared to non-adopters, three instances of significant difference was found with the Mann Whitney test at a level of significance of 0.05 (which is highlighted in yellow). It can be seen that enterprise profitability has significant differences for the fertiliser rate and method. In addition, production costs has a significant difference for fertiliser application frequency..

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[9] Adopters are defined as those growers who responded positively to using a practice in question 9. Data from question 9 was checked against information obtained on current farm practice in Section 3 and any inconsistencies were removed from the analysis.
[10] 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.

Table 5: Economic Impact, Average Response of Adopters and Non-Adopters

Management Aspect	Production costs		Production of bananas		Enterprise profitability		Variability of production	
	Non-Adopter	**Adopter**	**Non-Adopter**	**Adopter**	**Non-Adopter**	**Adopter**	**Non-Adopter**	**Adopter**
Crop removal method	2.60 n= 10	2.69 n= 36	2.90 n= 10	3.03 n= 36	2.90 n= 10	3.39 n= 36	3.20 n= 10	2.81 n= 36
Grass or planted fallow crop	2.88 n= 8	2.89 n= 38	3.88 n= 8	4.18 n= 38	3.88 n= 8	3.95 n= 38	2.38 n= 8	2.26 n= 38
Crop planting and tillage	2.80 n= 11	2.49 n= 35	3.60 n= 11	3.57 n= 35	3.50 n= 11	3.97 n= 35	2.60 n= 11	2.51 n= 35
Living ground cover	3.17 n= 6	2.98 n= 40	3.50 n= 6	3.50 n= 40	3.83 n= 6	3.68 n= 40	2.50 n= 6	2.28 n= 40
Fertiliser rate	3.09 n= 11	2.49 n= 35	3.64 n= 11	4.23 n= 35	3.36* n= 11	4.26* n= 35	2.18 n= 11	1.89 n= 35
Fertiliser application method	3.58 n= 12	2.82 n= 34	3.58 n= 12	4.21 n= 34	3.33* n= 12	4.00* n= 34	2.25 n= 12	1.76 n= 34
Fertiliser application frequency	3.77* n= 13	3.33* n= 33	4.00 n= 13	4.24 n= 33	3.15 n= 13	4.00 n= 33	2.08 n= 13	2.00 n= 33

Scale: Production costs: 1= large decrease (encourages adoption), 2= decrease, 3= no impact, 4= increase, 5= large increase (discourages adoption). Production of bananas: 1= large decrease (discourages adoption), 2= decrease, 3= no impact, 4= increase, 5= large increase (encourages adoption). Enterprise profitability: 1= large decrease (discourages adoption), 2= decrease, 3= no impact, 4= increase, 5= large increase (encourages adoption). Variability of production: 1= large decrease (encourages adoption), 2= decrease, 3= no impact, 4= increase, 5= large increase (discourages adoption).

Note: For the hypothesis test that adopters have different perceptions of key characteristics compared to non-adopters, * and yellow highlighting indicates significant difference was found at a 0.05 level of significance.

4.2 Perceptions of Key Practice Characteristics

Table 6 presents the averaged perceptions of growers separated into non-adopters and adopters on the key characteristics of each best management practice (see Table 3 for aggregate results). The ranking of each key characteristic as a barrier to adoption is from 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree. For all characteristics ranking close to 1 will encourage adoption as they are not perceived as a barrier and a ranking closer to 5 will discourage adoption as these characteristics are perceived as barriers to adoption for a particular practice.

For the hypothesis test that adopters have different perceptions of key characteristics compared to non-adopters, one instance of significant difference was found with the Mann Whitney test at a level of significance of 0.05 (which is highlighted in yellow, two instances were found at a level of significance of 0.01 (which is highlighted in orange) and one instance was found at a level of significance of 0.001 (which is highlighted in red).

It can be seen that the practice characteristic; doesn't fit in with current system, differs between adopters and non-adopters significantly (at the 0.01 level) for the practices; fertiliser rate and nutrient application method of fertigation, and significantly (at the 0.001 level) for the practice; crop removal using herbicide. This result may be self-confirming given that adopters have in fact already found a way of incorporating the practice into their system. However, it does underline that adoption is highly dependent on fitting with the broader farming system. Much of the focus of BMP adoption programs has been to target particular practices (rather than broader farming system improvement) which is obviously limiting if that particular practice does not fit with a growers farming system (e.g. organic systems with best practice crop removal).

The practice characteristic; contractors needed to implement change, differs between adopters and non-adopters significantly (at the 0.05 level) for the practice of fertiliser rate. This can be interpreted that non-adopters perceive that contractors are needed for fertiliser rate change and slightly discourages adoption, but adopters believe that it is neutral and does not affect adoption.

Table 6: Key Characteristics, Average Response of Adopters vs. Non-Adopters

Best Management 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		Too much time required to look into	
	Non-Adopter	**Adopter**	**Non-Adopter**	**Adopter**	**Non-Adopter**	**Adopter**	**Non-Adopter**	**Adopter**	**Non-Adopter**	**Adopter**	**Non-Adopter**	**Adopter**
Crop Removal	2.40 n= 10	1.89 n= 36	2.30 n= 10	1.75 n= 36	3.40*** n= 10	1.92*** n= 36	2.50 n= 10	1.72 n= 36	2.60 n= 10	2.31 n= 36	2.10 n= 10	1.81 n= 36
Grass or planted fallow crop	2.63 n= 8	2.24 n= 38	2.25 n= 8	2.00 n= 38	2.13 n= 8	1.92 n= 38	2.00 n= 8	1.84 n= 38	2.38 n= 8	2.47 n= 38	1.75 n= 8	1.84 n= 38
Crop planting and tillage	3.80 n= 11	3.89 n= 35	2.90 n= 11	3.06 n= 35	2.91 n= 11	2.37 n= 35	2.60 n= 11	2.54 n= 35	3.10 n= 11	3.80 n= 35	2.30 n= 11	2.60 n= 35
Living ground cover	2.83 n= 6	2.75 n= 40	2.00 n= 6	1.78 n= 40	2.50 n= 6	1.85 n= 40	2.17 n= 6	1.85 n= 40	2.17 n= 6	2.20 n= 40	1.67 n= 6	1.80 n= 40
Fertiliser rate	2.18 n= 11	2.66 n= 35	3.64* n= 11	2.63* n= 35	2.82** n= 11	1.83** n= 35	2.00 n= 11	2.06 n= 35	2.55 n= 11	2.69 n= 35	1.82 n= 11	2.26 n= 35
Fertiliser application method	4.33 n= 12	3.88 n= 34	3.08 n=12	2.71 n= 34	3.33** n= 12	1.94** n= 34	2.75 n= 12	2.56 n= 34	3.25 n= 12	3.12 n= 34	2.50 n= 12	2.35 n= 34
Fertiliser application frequency	3.08 n= 13	2.52 n= 33	1.92 n= 13	1.82 n= 33	2.54 n= 13	2.00 n= 33	2.38 n= 13	1.94 n= 33	2.46 n= 13	2.30 n= 33	1.92 n= 13	1.91 n= 33

Scale: Key Characteristics. 1= strongly disagree (encourages adoption), 2= disagree, 3= neutral (no impact), 4= agree, 5= strongly agree (discourages adoption). **Note:** For the hypothesis test that adopters have different perceptions of key characteristics compared to non-adopters, * and yellow highlighting indicates significant difference was found at a 0.05 level of significance. ** and orange highlighting indicates significant difference was found at a 0.01 level of significance. *** and red highlighting indicates significant difference was found at a 0.001 level of significance.

4.3   Farm Attributes and Grower Characteristics: Adopters and Non-Adopters

Socioeconomic factors (including the grower's experience and education) as well as farm characteristics (including farm size and soil type) may affect the management practice adoption decision (Tey & Brindal, 2012). Results on this in the literature are inconclusive about which variables universally regularly explain adoption of conservation agricultural practices, however, depending upon the practices, farming system and region some farm attributes and grower characteristics may be significant (Knowler and Bradshaw 2007).

Section 1 (About You and Your Farm) of the survey generated mostly categorical and some ordinal data on socio-economic factors, which has all been converted to ordinal data using counts. For certain group combinations, low counts (<5) meant that certain statistical tests were not applicable, such as the Pearson Chi-Square test. The two statistical tests used to report statistical significance were the Pearson Chi-Square Permutation test and the Log Linear Model. The Pearson Chi-Square Permutation test uses a permutation test to calculate the significance probability for a chi-square test of the independence of rows and columns in a two-dimensional contingency table. The Log Linear Model tests the different factors that are used in the cross tabulation and their interactions for statistical significance. These two tests were used for the hypothesis test that states if you have a certain farm attribute or grower characteristic you are more likely to be an adopter compared to being a non-adopter.

Table 7 presents the key farm and grower characteristics for adopters and non-adopters. Some interesting points from the survey are as follows:

- The Log Linear Model found a close relationship (at a significance level of 0.053) for the farm attribute of gradients combined with the practice of fertiliser application frequency. While not quite statistically significant, it is very close by a margin of 0.003. This result suggests that the level of gradient on a farm could influence a grower to adopt the practice of fertiliser application frequency.

- There was a fairly even number of growers who were either in the industry for a short (<25 years) amount of time or a long (≥ 25 years) time.

- 72% of growers surveyed had education level beyond high school. This compares with 38% in 2011 for farmers as a whole in Australia with non-school qualifications (certificate, diploma or bachelor degree or above) (ABS 2012) and 49% of sugarcane growers surveyed in a similar study on adoption of best management practices in sugarcane (Thompson et al. 2014: 34).

- There were similar numbers of growers with either a small (<60 ha) farm or a large (≥60 ha) farm, which shows that there are many different sizes of farm in the area.

- For soil types, red soil was the most prevalent among those surveyed, but with many participants also choosing the 'other' option, the soil types provided may not have been sufficient.

- 72% of growers surveyed had farms on less than 3% gradient, which shows that the area surveyed has farms on mainly flat ground.

Table 7: Farm Attributes and Grower Characteristics, Adopters vs. Non-Adopters

		Crop Removal		Fallow Crop		Tillage		Ground Cover		Fertiliser Rates		Fertiliser App.		Fert. App. Freq.	
		Non-Adopter n= 10	Adopter n= 36	Non-Adopter n= 8	Adopter n= 38	Non-Adopter n= 11	Adopter n= 35	Non-Adopter n= 6	Adopter n= 40	Non-Adopter n= 11	Adopter n= 35	Non-Adopter n= 12	Adopter n= 34	Non-Adopter n= 13	Adopter n= 33
Adoption rate	-	78%		83%		76%		87%		76%		74%		72%	
Industry time (years)	Short (<25) n=27	28%	72%	18%	82%	25%	75%	15%	85%	26%	74%	29%	71%	32%	68%
	Long (≥25) n= 19	12%	88%	16%	84%	18%	82%	10%	90%	21%	79%	22%	78%	20%	80%
Education (level attained)	High School n= 13	23%	77%	20%	80%	32%	68%	17%	83%	26%	74%	30%	70%	20%	80%
	Diploma/Trade n= 24	18%	82%	22%	78%	20%	80%	8%	92%	17%	83%	9%	91%	31%	69%
	University n= 9	27%	73%	0%	100%	0%	100%	12%	88%	22%	78%	33%	67%	36%	64%
Farm size (ha)	Small (<60) n= 25	17%	83%	18%	82%	15%	85%	15%	85%	25%	75%	23%	77%	23%	77%
	Large (≥60) n= 21	26%	74%	15%	85%	32%	68%	10%	90%	23%	77%	29%	71%	33%	67%
Soil type	River flats n= 11	0%	100%	0%	100%	50%	50%	0%	100%	50%	50%	25%	75%	25%	75%
	Red soils n= 21	14%	86%	29%	71%	33%	67%	25%	75%	33%	67%	33%	67%	40%	60%
	Other n= 14	25%	75%	16%	84%	19%	81%	11%	89%	18%	82%	24%	76%	27%	73%
Gradient (%)	Small (<3%) n= 33	27%	73%	18%	82%	23%	77%	10%	90%	22%	78%	28%	72%	35%^	65%^
	Medium/Large (≥3%) n= 13	8%	92%	15%	85%	21%	79%	20%	80%	29%	71%	20%	80%	8%^	92%^

Note: For the hypothesis test that states if you have a certain farm attribute or grower characteristic you are more likely to be an adopter compared to being a non-adopters, no significant difference was found at a level of significance of 0.05, however ^ and light blue highlighting indicates that significance was found at a level of 0.053.

5 Discussion and policy implications

Understanding the factors influencing adoption is an essential part of increasing take up of best management practices to reduce the impact of banana farming on water quality in the Great Barrier Reef. This study examined the responses from forty-six banana growers surveyed across the Innisfail and Tully regions in order to develop a profile of management practices according to grower perceived characteristics of these practices. Statistical tests were also performed on available data to distinguish whether there is any significant difference between those that adopted best management practices and those that did not.

Adoption trends

Results indicated that adoption rates were quite high amongst the growers surveyed, ranging from 72% for fortnightly fertiliser application frequency to 87% for 60% living ground cover in the inter row and headland areas. These rates of adoption are higher than those reported by the 2016 Reef Report Cards (63% of area managed under best practice for nutrients and 60% of area managed under best practice for soil in the Wet Tropics) but there are key differences between the two. The 2016 Reef Report Card for bananas in the Wet Tropics includes all 250 banana growing businesses across 11800 hectares whereas our survey participants of 46 self-selected and no information was recorded on the proportion of their farms operating under the specified best management practices. However, our survey does provide a level of detail on individual practices that is not provided in the report cards. Future surveys similar to this one could be amended to include area of the specified best practices on the farm to enable better comparison with future Reef Report card results, although self-selecting approach is always likely to engage growers who are active in this space relative to those who aren't.

Profiling management practices

Each of these practices were profiled in the heat map presented in Table 2 and Table 3 and analysed separately in terms of impacts on economic outcomes and the perceived barriers for adopting the practice in sections 2.3 to 2.9. Interestingly, when aggregated and averaged across all survey respondents most of the practices had encouraging results in terms of economic impacts and key characteristics as barriers to adoption.

As all of the practices had relatively high adoption rates within the survey sample, it may be more insightful to pull out particular perceptions for individual practices that indicate a barrier to adoption. This is where policy may be able to improve uptake of best management practices as well as highlight the findings on the two most effective practices in terms of reducing soil and nutrient pollutants entering the GBR: living ground cover and fertiliser rates.

While best practice for crop planting and tillage was perceived to have slightly positive economic impacts, it was the only practice that had more than one characteristic that was perceived to be a barrier to adoption: high capital investment needed and requires new skills and information. This is likely to be directly tied to the definition of best practice used by industry as including permanent beds using GPS (Terrain include zonal tillage and pre-formed beds), which can be expensive to purchase and require uploading of property maps and programming skills for software growers have previously been unfamiliar with. In past government funding schemes for reef water quality improvements, GPS technology had been available as a technology that could receive funding. In 2015-16 under the Reef Programme water quality grants administered by Terrain saw four farms have GPS units funded (Australian Government and Queensland Government 2017: 19).

The other best practices that had perceived barriers to adoption were fertiliser application method (fertigation) needing high capital investment and fortnightly fertiliser application frequency with a perceived slight increase to production costs. These are evident, particularly for the installation of a fertigation system where the crop is currently rain fed. More frequent fertiliser applications (that meet plant requirements at a particular point in time) are often facilitated by a fertigation system that can easily deliver these nutrients relative to tractors in the field with a granular fertiliser. The perceived increase in production costs could come from liquid fertilisers being more expensive than traditional granular fertilisers, more fertiliser in general being applied if the rate is not adjusted appropriately or costs that may be associated with monitoring plant requirements and loading fertiliser into irrigation system.

Living ground cover and fertiliser rates best management practices did not reveal any perceived negative economic impacts from the surveyed growers (although production costs for best practice living ground cover were 'no impact') or perceived barriers to adoption with respect to practice characteristics (although best practice fertiliser rates was neutral for contractors needed to implement change). While this seems positive, why then have these practices not had a greater uptake more broadly. Also if this survey sample is biased the key characteristics and impacts that are 'neutral' and 'no impact' here may be negative for the broader industry and flag areas for further extension or policy intervention.

Division in grower responses

There is considerable division or variation in grower perceptions for some aspects of some practices, such as the impact on production costs of 60% living groundcover. Possible explanations for this variation may be attributed to factors such as farming systems, farm sizes or grower priorities.

For example, to maintain a 60% level of ground cover, some growers may have considered additional slashing costs to be substantial whilst others have not. Given a farm's biophysical characteristics and farm size, ground cover may become increasingly difficult to maintain at certain times of the year. Growers with farms on land with a potential for deep wheel ruts may also incur additional repairs and maintenance costs. On the other hand, in suitable areas, growers may be able to limit the slashing frequency by selecting a particular type of ground cover and any additional slashing costs may be perceived as negligible.

Further, the variations in responses may be due to growers having varying levels of experience with a particular practice. For growers who have adopted practices that are characterised as experimental, aspirational or above-BMP, shifting "back" to a particular "less-advanced" practice may actually result in reduced production costs.

In some instances "no impact" on economic outcomes may have been selected if a grower was reluctant to indicate "increase" or "decrease" without having further information at hand to evaluate the practice (e.g. trial results on the profitability implications of differences in slashing requirements for various levels of groundcover).

Transaction costs

Transaction costs are well acknowledged in the economic literature, however, trying to quantify them with growers unfamiliar with the concept is challenging and probably why it is often left out of studies like this one. Indeed, 30% of survey respondents could not provide information for this question. Like Coggan et al. (2015), we found substantial variance in the estimates given by growers for the types of transaction costs listed in the survey for them to consider for a recent change they had made. This

may be due to the variability between farming systems and the open-ended nature of the questions regarding transaction costs[11]. Banana growers are often involved in many aspects of the industry supply chain and some transaction costs may be difficult for growers to estimate if they are evaluating information that may inform their adoption decisions on an ongoing basis.

The inferences that can be drawn from the quantitative results in Table 3 may be limited. However, those growers who invested comparatively low levels of resources before adopting may be adopting at a later stage and benefitting from adopting practices that have been well trialled and proven in conditions similar to their farming system. Some growers may also be savvier than others in accessing resources through ABGC, Terrain or DAF to limit their personal transaction costs in evaluating whether or not to adopt a practice. Those growers who have invested high levels of resources before adopting may be investigating innovative practices or adaption of practices to their particular farming system or conditions, they may wish to conduct their own enquiries in addition to relying on external resources, or have high levels of risk aversion resulting in delays in the adoption process. These are more complex nuances that are likely to be more informative and warrant further research. There may be greater adoption potential if more funding is directed towards mitigating these transaction costs, particularly for innovative or adaptive practices.

Profiling adopters and non-adopters

Classifying growers surveyed into adopters and non-adopters provided further insights regarding which perceived characteristics of best management practices are most influential in the adoption decision (Tables 4 and 5). 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.

The differences in perceptions between adopters and non-adopters on economic impacts were significant for enterprise profitability for the fertiliser rate and method. This shows that adopters are aware of higher enterprise profitability for the practices of fertiliser rate and method compared to non-adopters. In addition, production costs has a significant difference for fertiliser application frequency. This shows that non-adopters perceive there to be higher production costs for the practice of fertiliser application frequency then there actually is.

There were also noticeable differences in practice characteristics. The characteristic; doesn't fit in with current system, differs between adopters and non-adopters significantly (at the 0.01 level) for the practices; fertiliser rate and nutrient application method of fertigation, and significantly (at the 0.001 level) for the practice; crop removal using herbicide. As highlighted earlier, these practices are likely to have been adopted because they do fit in with existing systems. Nevertheless, for those practices that do not fit in with existing systems, how can assistance be provided here? Should the focus be on net reduction of pollutions from a farm and growers left to decide the best way to achieve this rather than prescribing management practices that may not be appropriate for all banana growing enterprises? This might be an avenue explored as part of the Major Integrated Projects and is a tool that has been used in other areas of non-point source pollution management to achieve environmental objectives at least cost (e.g. nutrient trading scheme for Lake Rotorua in New Zealand). More case studies highlighting overall farming system adjustments emphasising impacts on business profitability overall as well as water quality benefits would also likely engage more growers

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[11] The questions regarding transaction costs were intended to capture costs incurred in changing practices separate to the purchase of capital equipment or other physical inputs to production. Some responses, however, incorporate such costs.

who could see how other growers have been able to adjust practices to both suit their individual circumstances and meet environmental obligations.

The practice characteristic; contractors needed to implement change, differs between adopters and non-adopters significantly (at the 0.05 level) for the practice of fertiliser rate. This can be interpreted that non-adopters perceive that contractors are needed for fertiliser rate change and slightly discourages adoption, but adopters believe that it is neutral and does not affect adoption.

When analysing farm attributes with adopters and non-adopters, a close relationship was identified (at a significance level of 0.053) for the farm attribute of gradients combined with the practice of fertiliser application frequency. This result suggests that the level of gradient on a farm could influence a grower to adopt the practice of fertiliser application frequency. There were no significant relationships (at a significance level of 0.05) between farm attributes and adoption rate. This may be the case because there were extremely low cell counts (<5) for many of the group combinations. With a higher sample of farmers taking part in the survey, it may be possible to identify stronger relationships between farm attributes and adoption rate.

Limitations, recommendations and further research

As outlined earlier, this survey sampling methodology is subject to self-selecting bias and growers who have engaged in adopting best management practices are more likely to want to participate, which may explain the high rates of adoption of the practices included in the survey. In addition, even though it was a face-to-face survey, the rate of participation was good. There were around 30% of growers in the areas covered, but this sample size is still likely to be too small to counter the self-selection bias. At the time, the project was trying to get growers interested in taking part in the survey there was a second incursion of Panama TR4, which would have affected growers availability to participate and interest in water quality impacts for the reef would have been a lower priority at that time.

Of course, like all surveys, there were only so many questions that could be asked to make it tractable and there will always be other questions that could have been included in hindsight. There will also be variability in how individual growers have interpreted questions. By conducting face-to-face surveys it was hoped to minimise this, however, most growers struggled to work through questions 11, 12 and 15 and the answers given may have been influenced by the project officer conducting the survey.

Whilst a detailed consideration of the question "other reasons influencing adoption" is beyond the scope of this report, grower responses indicated that there can be substantial differences between farming systems and the priorities of individual growers. Practice adoption will not always be desirable or compatible with a grower's farming system or business model. For example, organic banana growers would not be able to market their fruit as organic if they applied herbicides as part of the crop removal process.

It is worth noting that this is the first study focused on growers' perceptions of adopting best management practices for banana growing in the Wet Tropics region and it provides a starting point to move forward from. Three main recommendations from undertaking this study are as follows:

- More case study analyses of banana farming systems adopting or adapting practices to reduce their off farm water quality impacts would help increase understanding of the diversity and complexities driving adoption in banana farming systems (e.g. organic or varieties other than Cavendish, irrigation systems) and environmental factors (e.g. gradients > 6% or specific soil types or parasitic nematode presence). The emphasis should be on analysing the whole farming system and not on management practices in isolation, as many growers will adopt a number of practices over time and the importance of fitting with existing farming system was highlighted in section 4.2. Such research could identify barriers to adoption in order of importance for a particular farming system or business model.

- Transaction costs are often hidden and can inhibit adoption of improved practices that are still being trialled and tested, such that policies directly targeted at reducing them could enhance the efforts of farmers looking into innovative practices.

- It has been 10 years since the banana growing best management practices were published and a review of the best management framework could help identify and inform growers of more recent developments or innovations

Areas for further research include:

- How are growers adapting best practices to suit their farming system? This could be picked up in case studies and again highlighting innovative growers

- Are there differences between growers adopting all best management practices compared to one or two? What drives these different adoption processes (system vs individual practices) and is this something that can be aided through policy mechanisms?

- More in depth research into transaction costs – whilst variability between growers may limit the information gained from quantifying transaction costs, a greater understanding of grower's perceptions regarding such costs may provide insights to help increase (and speed up) the adoption of best management practices, especially for cutting edge innovative practices.

- How do growers' risk preferences influence their practice adoption decision process – such research could also be linked into transaction cost research.

- What role does membership in grower groups' play in the adoption decision process and how are these networks being affected by the presence of Panama TR4?

- Panama TR4 was not explicitly considered in this survey but it is worth explicitly investigating and estimating the economic impacts for growers where a future with Panama TR4 is uncertain. A current benchmarking project (BA16009) by Pinnacle Agribusiness is investigating some of the economic aspects of implementing biosecurity measures.

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7   Appendices
7.1   Survey

Queensland Government

Survey on adopting Best Management Practices for Banana Growing

This survey is being undertaken by economists from the Queensland Department of Agriculture and Fisheries as part of the *Economic Assessment of Banana Best Management Practice Project RP140B* funded by the Queensland Department of Environment and Heritage Protection's Reef Water Quality program. By undertaking this survey we hope to gain a better appreciation of the opportunities and risks banana growers face in adopting various best management practices and their associated characteristics. The information collected in this survey will assist in understanding the linkages between the types of banana growing enterprises, opportunities and risks of shifting management practices and possible barriers to adoption.

We would like to assure you that all data collected from this research will be kept strictly confidential. All data will be de-identified ensuring your participation is anonymous. All publicly available results will be reported in a summary manner to ensure no individual enterprise or person can be identified, for example "*X percentage of growers who have adopted practice (a) observed a decrease in production variability*". ***Your details will never be linked to any of the published information and you will not be identifiable from your answers***. The information from this survey will be used to write the final synthesis report to outline the research findings from the *Economic Assessment of Banana BMP Project RP140B* and will also be used to develop papers for academic publication. By participating in this survey, you agree to the use of the generated data in research project RP140B.

Participation is voluntary and you are able to withdraw at any time during the survey without explanation. The survey should take about 20 to 30 minutes to complete. We know your time is valuable, and by way of thanks we are offering all participants the chance to win one of three $200 vouchers to their local hardware store (terms and conditions apply and are available upon request).

Prizes will be drawn randomly after all surveys are completed and winners notified directly via the contact details provided on the consent form attached. In accordance with the Queensland Government Code of Conduct and directives for gifts and benefits, winners of the prizes may be published on the DAF website as per the "*Right to Information Act 2009*".

If you have any questions please contact:

- Mark Poggio, Project Manager, QLD DAF on (07) 4776 3907
- Sam Cook, Project Officer, QLD DAF on (07) 3330 4523

Section 1: About You and Your Farm

In this section we will ask you some questions about you and your banana farm.

This information will allow us to identify the diversity of operations and management practices across farms.

Q1. How long have you been working in the banana industry? _____ years

Q2. What education level have you completed? (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 _____

Q3. What is the total area of land that you (or your family) own or manage for banana production?

_____ Hectares   OR   _____ Acres

Q4. What proportion of the soil types below do you manage on your farm?

Medium alluvial soils (river flats): _____%

Basaltic krasnozem soils (undulating red soils):_____%

Other (please specify):_____%

Q5. What proportion of your farm has the following gradients? (please circle)

Gradient 0 - 3% (0-3 metre drop in 100 metres run): _____%

Gradient 3 - 6% (3-6 metre drop in 100 metres run): _____%

Gradient > 6% (more than 6m drop in 100m run): _____%

Q6. What is the typical number of ratoons you grow in a crop cycle across your farm? _____

Q7. For the last year please provide an estimate of your AVERAGE banana yield across your farm:

_____ Cartons per Acre   OR   _____ Cartons per Hectare

Q8. Do you contract out any operations? If yes, please indicate below

Operations	All the time	Some of the time
De-leafing		
Bell injection		
De-suckering		
Fungicide application		
Harvesting		
Other:		

Section 2: Current Management Practices

> In this section we will ask which of the 'best' management practices described in the Banana BMP Guidelines you are currently using.

Q9. Which of the following best management practices from *the Banana BMP Environmental Guidelines for the Australian Banana Industry* do you currently use?

Practice	Tick if using
1. The banana crop is removed by treating with herbicide and plants are left to break down in the row area before cultivation.	
2. Either a grass or planted fallow crop is grown between banana crop cycles for at least 12 months	
3. The crop is planted into permanent beds. Row area only receives minimum tillage necessary for establishment when risk of erosion is low	
4. At least 60% of living ground cover is achieved in areas such as the inter-row space and headlands	
5. The fertiliser program is based on recommended rates for Nitrogen and Phosphorus and is supported by leaf and soil testing on every block and yield monitoring. The program is revised annually and checked to ensure targets are updated and actually applied.	
6. All fertigation, or a combination of fertigation and banded surface applications is used depending on the weather conditions.	
7. Apply fertiliser fortnightly during high growth periods, and reduce this during low growth periods such as winter. Weather conditions may mean that this is not always possible.	

While 'best' rates are not specified in the Banana BMP guidelines due to the complexity around determining appropriate fertiliser use, we are interested in getting a snapshot of application rates.

Q10. What rate of Nutrients or product do you typically apply to your banana crop (kg/ha/year)?

Nitrogen (kg/ha/year):_____

Phosphorus (kg/ha/year): _____

Potassium (kg/ha/year): _____

Or Product (kg/ha/year):_____

Section 3: Usage of 'best practice'

> In this section we will ask you to identify factors that you have found in your experience, or believe to be present, that make it easier or harder to adopt the management practices identified in section 2 of this survey.

Q11. **For each of the practices listed below indicate on a scale from 1 to 5 whether you have found that Costs/Production/Profitability/Variability decrease (down to 1) or increase (up to 5) by moving to best practice. If you have not moved to best practice yet, rate on the scale what you believe would happen to Costs/Production/Profitability/Variability**

Large decrease	Small decrease	No impact	Small increase	Large increase
1	2	3	4	5

Practice	Production Costs	Production of bananas	Enterprise Profitability	VARIABILITY of production (more change in production between years)
1. The banana crop is removed by treating with herbicide and plants are left to break down in the row area before cultivation.				
2. Either a grass fallow or a planted fallow crop is grown between banana crop cycles on all fallow land (for at least 12 months).				
3. Pre-formed beds using GPS and zonal tillage are used and the crop is planted into permanent beds. Row area only receives minimum tillage necessary for establishment.				
4. At least 60% living ground cover is achieved in areas such as the inter-row space and headlands, greater than 60% inter-row ground cover is achieved by retention and mulching of banana waste				
5. The fertiliser program is based on recommended rates for Nitrogen and Phosphorus and is supported by leaf and pre-plant soil testing on every block and yield monitoring. The program is revised annually and checked to ensure targets are updated and actually applied.				
6. All fertigation, or a combination of fertigation and banded surface applications is used depending on the weather conditions.				
7. Apply fertiliser fortnightly during high growth periods, and reduce this during low growth periods such as winter. Weather conditions may mean that this is not always possible.				

Q12: What, in your opinion, are the key characteristics of best management practices? Rank the characteristics listed below on a scale of 1 (strongly disagree) to 5 (strongly agree) indicating which characteristics are least/most relevant to each 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	Too much time required to look into
1. The banana crop is removed by treating with herbicide and plants are left to break down in the row area before cultivation.						
2. Either a grass fallow or a planted fallow crop is grown between banana crop cycles on all fallow land (for at least 12 months).						
3. Pre-formed beds using GPS and zonal tillage are used and the crop is planted into permanent beds. Row area only receives minimum tillage necessary for establishment.						
4. At least 60% living ground cover is achieved in areas such as the inter-row space and headlands, greater than 60% inter-row ground cover is achieved by retention and mulching of banana waste						
5. The fertiliser program is based on recommended rates for Nitrogen and Phosphorus and is supported by leaf and pre-plant soil testing on every block and yield monitoring. The program is revised annually and checked to ensure targets are updated and actually applied.						
6. All fertigation, or a combination of fertigation and banded surface applications is used depending on the weather conditions.						
7. Apply fertiliser fortnightly during high growth periods, and reduce this during low growth periods such as winter. Weather conditions may mean that this is not always possible.						

Q13.   Are there any other reasons not covered in the above tables that have influenced your decision to adopt/not adopt practices listed in question 12 above?

_____
_____
_____
_____
_____
_____
_____
_____

Q14.   What improvements, if any, are your top priority for your property in the next 5 years?

_____
_____
_____
_____
_____
_____
_____
_____
_____

Section 4: Costs of changing practices

In this section we will ask you to identify costs incurred in changing practices separate to the purchase of capital equipment or other physical inputs to production.

Q15.   Thinking about a change you have made (identified in Q9) or considered making on your farm towards BMP, what actions did you undertake to learn about changing management practice / equipment / machinery to enable successful implementation or help you decide not to go ahead with the change?

Change recently made:

_____

Change facilitating activity	Resources spent on change facilitating activity (number of hours, visits, days, trials, area or $ spent)
Internet research (hours)	
Speaking to other growers (visits/hours)	
Engaging an agronomist/consultant (hours/visits/$)	
Engaging with DAF extension staff (visits/hours/trials)	
field days or industry information sessions (days/hours)	
Training course or other training (days/$)	
Small scale trial on farm (trials/area/$)	
Scoping of different capital options (hours/visits/$)	
Other (please describe):	

7.2 2015 Paddock to Reef Water Quality Risk Framework – Bananas

Management	Weighting (WQ Risk assessment)	High Risk Superseded	Moderate Risk Minimum	Moderate - Low Risk Best Practice
Runoff & Soil Loss				
Crop Removal	10%	Banana crop is removed through being knocked down and repeated disc ploughing	Banana crop is removed through mulching and/or light discing which minimises soil disturbance.	Banana crop is killed with herbicide and plants are left to break down in the row area before cultivation.
Fallow management	20%	Land is maintained bare between crop cycles, or there is no fallow period between crop cycles	Weedy fallow grows between banana crop cycles	Fallow crop is planted between banana crop cycles, or a volunteer grass fallow is maintained between crop cycles.
Tillage - plant crop	15%	Whole block is cultivated in preparation for planting	Minimum tillage of whole block area, with row area only subject to more cultivation necessary to establish row profile and plant.	Crop planted into permanent beds. Row area only receives minimum tillage necessary for establishment.
Ground cover	35%	Inter-rows and headlands are sprayed or cultivated bare.	Living or dead, at least 60% cover is maintained in inter-row space and headlands.	Living ground cover is maintained in the inter-row space and headlands.
Controlling runoff - contouring	10%	Production areas with gradient of 3% or more, but no control structures in place.	For gradient over 3%, MOST blocks planted on the contour and incorporating diversion banks and constructed waterways	For gradient over 3%, ALL blocks planted on the contour and incorporating diversion banks and constructed waterways
Controlling runoff - drains	5%	Constructed drains are mostly box drains with straight sides.	Most constructed drains are vegetated shallow spoon drains. Any box drains have a batter suited to the soil type to minimise erosion.	All constructed drains are vegetated shallow spoon drains
Sediment traps	5%	No sediment trapping structures in place.	Some sediment trapping structures. Insufficient capacity and/or design issues mean that significant amount of sediment can leave the farm in heavy events.	Expert advice informs design, construction and location of sediment traps that are effective across the entire production area.

Nutrients			
Soil testing	10%	No soil testing before planting	Soil testing before planting is infrequent and/or does not occur on all blocks being planted.	All blocks are soil tested pre-planting. Fertiliser rates for plant crop are adjusted based on soil test results.
Matching nutrient supply to crop demand	60%	N & P fertiliser rates are based on historical target rates with infrequent testing and/or no adjustment for yield potential	N & P fertiliser rates are supported by soil and leaf testing and yield monitoring.	Fertiliser program based on recommended rates for N & P and supported by leaf and soil testing and yield monitoring. Revised annually to ensure targets are achieved.
Fertiliser application frequency	15%	Fertiliser is applied less frequently than monthly.	Monthly fertiliser applications all year around	Aim to apply fortnightly during high growth periods and less frequently during low growth periods.
Fertiliser application method	15%	Fertiliser broadcast over rows and inter-row spaces.	Banded surface fertiliser application on row area only.	All fertigation. Banded surface application if wet weather rules out fertigation.
Water			
Irrigation method	35%	Some overhead irrigation	All irrigation is drip or micro sprinkler system, manually operated.	All irrigation is automated drip/micro sprinkler system underneath trees
Irrigation scheduling	65%	No soil moisture monitoring tools are used in scheduling irrigation.	Irrigation schedules are based on capacitance probes or tensiometers. Manually operated.	Irrigation schedules are based on capacitance probes and weather stations and are fully automated.

Source: Queensland Government (2015)