Journal of Rural Studies 54 (2017) 276–287

Contents lists available at ScienceDirect

Journal of Rural Studies

journal homepage: www.elsevier.com/locate/jrurstud

Heterogeneity in practice adoption to reduce water quality impacts from sugarcane production in Queensland

John Rolfe [a,*], Sally Harvey [b]

[a] CQUniversity, Rockhampton, Qld 4702, Australia
[b] Queensland Department of Agriculture and Fisheries, Australia

ARTICLE INFO

Article history:
Received 23 November 2016
Received in revised form
14 May 2017
Accepted 29 June 2017

ABSTRACT

A key strategy in reducing water quality impacts into the Great Barrier Reef is to change farm management practices to limit the creation of pollutants or their transmission off farm. However, designing programs to improve adoption in agriculture of Better Management Practices (BMPs) can be challenging because of heterogeneity among landholders and between farms and farming systems. This is relevant to broader issues in the adoption literature where a focus on identifying factors influencing and heterogeneity in adoption have rarely transferred through to analysis and prediction models suitable for policy purposes. In this case study these issues have been tested with sugarcane farmers in Queensland, where the current policy settings are targeting increases in adoption of better management practices from 34% in 2011 to 90% by 2018. The main goals of the study were to identify how rates of adoption for different practices might be explained by (a) the motivations of farmers (b) potential barriers to adoption (c) farm characteristics and (d) financial drivers. The results confirm that measures to improve BMP adoption are complicated by heterogeneity in adoption drivers between practices and across groups of landholders, creating challenges to find effective strategies to encourage adoption.

1. Introduction

There is substantial interest in Australia in reducing environmental impacts from agriculture by improving management practices (Pannell et al., 2006; Whitten et al., 2013). A key challenge is to understand the factors driving adoption of new practices, including the social dimensions of practice change (e.g. Cary et al., 2002; Pannell et al., 2006; Cary and Roberts, 2011). While most reviews of adoption practice highlight the importance of net private returns as a core driver (e.g. Pannell et al., 2006), the relevant literature is notable in the extent of different different influencing factors that have been identified. For example, Australian studies have noted that factors such as farm characteristics, practice types, trialability, management values, attitudes and norms, and socio-economic characteristics can be just as important as expected profitability in explaining adoption (Pannell et al., 2006; Morrison et al., 2012; Price and Leviston, 2014; Greiner, 2016).

The focus of much of the agricultural adoption literature to date has been on the identification problem, where the challenge has been to determine which factors influence farmer decisions to improve productivity (e.g. Prokopy et al., 2008; Baumgart-Getz et al., 2012) or adopt conservation practices (e.g. Pannell et al., 2006), as well as to identify the heterogeneity in landholder choices and drivers (Cary et al., 2002; Morrison et al., 2012). The more difficult task is to move from identification to analysis and prediction, as it is the relative importance of factors influencing adoption that is the more critical information for designing policy interventions. While there has been some developments of conceptual frameworks to underpin analysis (e.g. Price and Leviston, 2014), practical applications remain limited.

The case study of interest for this paper are agricultural land uses in Queensland, Australia that contribute pollutants to the Great Barrier Reef (GBR), with sugarcane production the dominant source of nutrients and pesticides (Brodie et al., 2013; GBRWST, 2016). A key strategy in reducing water quality impacts from agricultural production is to change farm management practices to limit the creation of pollutants or their transmission off farm (GBRWST, 2016). There are a number of different mechanisms available to help farmers adopt Best or Better Management Practices (BMPs), including mechanisms that change attitudes (e.g. education programs), mechanisms that improve information (e.g. extension programs), mechanisms that improve technology (e.g.

* Corresponding author.
E-mail addresses: j.rolfe@cqu.edu.au (J. Rolfe), Sally.Harvey@daf.qld.gov.au (S. Harvey).

http://dx.doi.org/10.1016/j.jrurstud.2017.06.021

research programs), mechanisms that provide incentives to change behaviour, and regulatory programs (GBRWST, 2016).

The sugarcane industry within catchments to the GBR involves around 3777 growers farming 400,000 ha of land (State of Queensland, 2015). Given the importance of voluntary adoption and participation to achieving pollution reduction, the Australian and Queensland Governments now explicitly target rates of adoption of BMPs by landholders as key program outputs (State of Queensland, 2014; GBRWST, 2016). The approach taken is to classify by farmers (or farms) by broad level of adoption of BMPs in an A,B,C,D framework that groups practices from Aspirational Best Practice/Lowest Risk (A) to Traditional Practices/High Risk (D) (State of Queensland, 2014). Under this approach the area of land under different levels of management practice are assessed and tracked over time to measure adoption change.

Heterogeneity in drivers means that farmers may be at a certain practice level for very different reasons; i.e. farmers might use traditional practices because of habit and customs, a lack of capital to change, or poor information about alternatives. In this example, very different policy mechanisms would be needed to change behavior (e.g. education, access to capital, extension). Policy solutions may be even more complex for heterogeneity within farming systems where each farmer has varying mixes of poor to excellent practices. In this case programs might need to be more atomistic and tailored to different elements of each farming system rather than being standardized across a farming district.

These issues are explored in this paper with an application to the adoption of BMPs in the sugar industry in Queensland. Substantial public funds have been allocated through the Reef Rescue program to improving landholder adoption of BMPs in efforts to reduce pollutants to the GBR. The sugarcane industry is a key focus of attention because high transmissions of nutrients (from fertilizer applications) and agricultural chemicals are impacting on water quality, exacerbated by the close proximity of farming along the coast to the inshore reef (Brodie et al., 2013; GBRWST, 2016). The targets for adoption change are ambitious, with the expectation that 90% of sugarcane will be using BMPs by 2018, up from 34% in 2011.

Currently the literature on quantifying adoption drivers for improved land management practices in GBR catchments is very limited. Greiner and Gregg (2011) provide some empirical evidence about how farmer motivations are linked to practice adoption and potential policy instruments, while Emtage and Herbohn use a market segmentation approach to categorise farmers in the Wet Tropics region. Greiner (2016) reports the use of a choice experiment to understand how cattle producers in northern Australia might be involved in biodiversity conservation contracts, while Rolfe and Gregg (2015) used factor analysis on survey responses from graziers in GBR catchments to classify them into different adoption groups.

The research reported in this paper explored the relative importance of different drivers of BMP adoption across landholders and practices to identify the extent of hetegeneity in drivers and implications for policy mechanisms. The contribution to the literature is the assessment of heterogeneity in adoption drivers between and within farms, as distinct from the more standard approach of identifying factors that limit or enhance adoption in particular systems. The paper is structured as follows. Relevant BMPs and literature relating to BMP adoption are outlined in the next two sections, followed by the case study and results in section four, and conclusions in section five.

2. Better management practices in the Great Barrier Reef catchments

There have been a number of investments in Reef Programs and Reef Initiatives funded by the Australian and Queensland Governments since 2003, with nearly $1billion committed between 2009 and 2018 (GBRWST, 2016). Most have been specifically designed to reduce agricultural pollutants damaging the GBR from a number of catchments and industries (Fig. 1), as well as to increase landholder adoption of BMPs.

Examples of BMPs relevant to the sugarcane industry in GBR catchments include controlled traffic permanent beds, zero till rations, legume fallow, soil testing each cycle, nutrient rates block specific, sub-surface nutrient application, and herbicide application based on pressure and timed for stage of growth and rainfall. Dated practices include cultivation of block prior to planting and for weed control in plant cane, applying nutrients at the same rate across all blocks in a single surface application and having one pesticide strategy for whole farm based on historic rates. The categorisation of practices is dynamic and has been adjusted over time to take into account innovation and changes in industry standards and legislation.

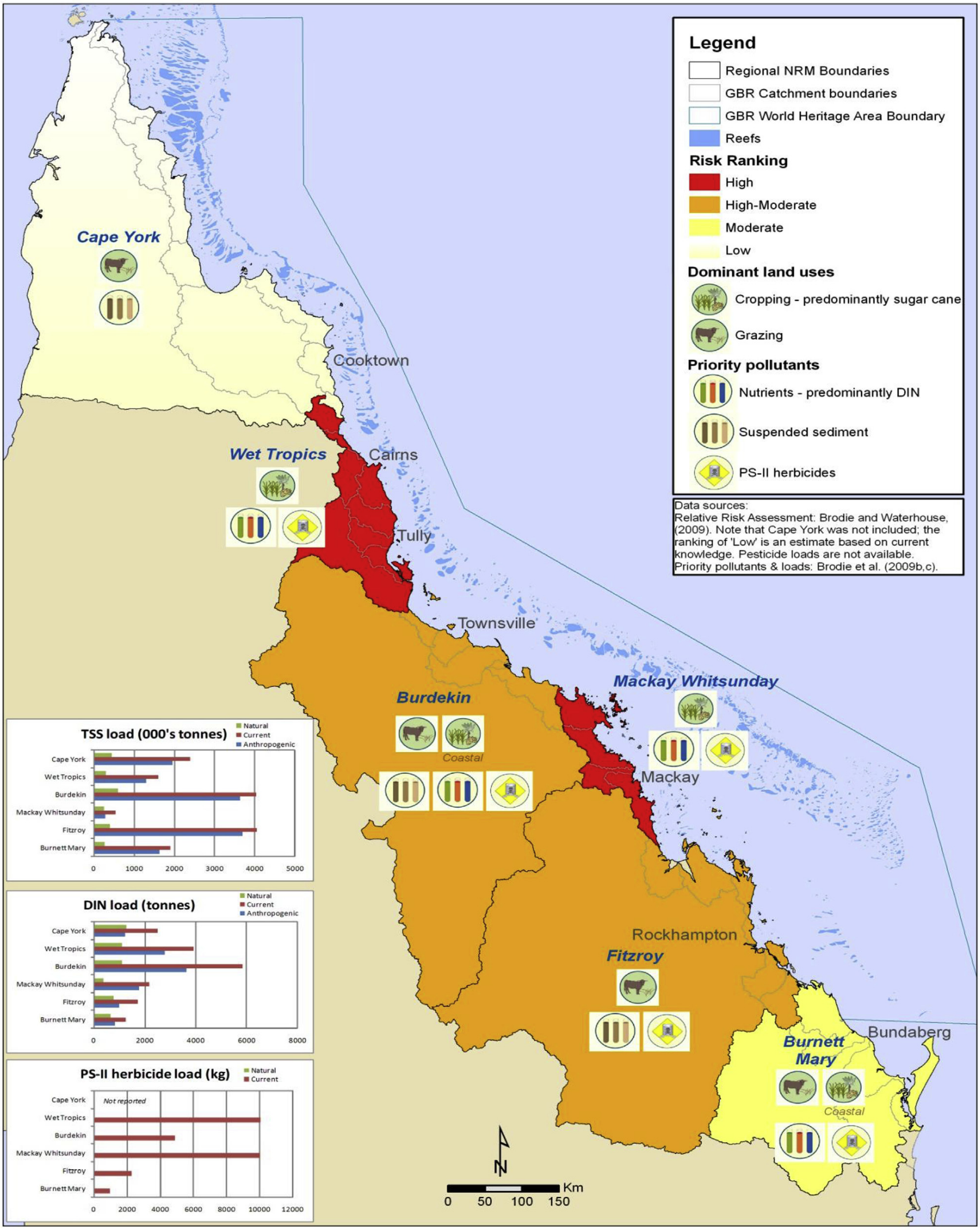
There have been several reports and studies over the years that have focused on the adoption of BMPs in the GBR catchments (e.g. Lockie and Rockloff, 2005; Greiner et al., 2007). From 2009 the assessment of adoption rates has been incorporated into Report Cards for the GBR prepared by the Queensland and Australian governments. The first Report Card (State of Queensland, 2011) set the 2009 baseline, and identified that BMPs involving cutting edge (A class) or best management (B Class) were used by 36% of sugarcane growers for nutrient practices, 7% for pesticides and 19% for soil management. This had risen to 40%, 23% and 15% respectively by 2010 (State of Queensland, 2013a), and to 45%, 28% and 20% respectively by 2011 (State of Queensland, 2013b).

From 2009 the focus of reporting changed from the number of farmers adopting BMPS to the area of sugarcane land that was managed under BMP conditions. In the 2014 Report Card (State of Queensland, 2014) it was estimated that 13%, 30% and 23% of sugarcane lands involved BMPs for nutrients, pesticides and soil respectively, increasing to 15%, 32% and 23% in the 2015 Report Card (State of Queensland, 2015). Overall 23% of sugarcane lands were under BMPs in 2015, compared to the target of 90% by 2018. GBRWST (2016) noted that on current trends transformational change in adoption rates will be needed to meet various targets for water quality improvements.

3. Identifying factors that are relevant to adoption

Triggering widespread adoption of BMPs is often challenging, and substantial research effort has been applied to understand what factors underpin farmers' choices to adopt BMPs or participate in agri-environmental schemes that promote BMPs (Cary et al., 2002; Pannell et al., 2006; Knowler and Bradshaw, 2007; Prokopy et al., 2008; Baumgart-Getz et al., 2012). Pannell et al. (2006) classified the drivers into two broad groups: those relating to social, cultural and personal factors, and those relating to the practices themselves. Much of this work has its roots in an older literature on farmer adoption of practices to improve production, given the commonality of factors and motivations.

There have been a number of studies that have examined adoption of BMPs in the GBR catchments. These include studies that identify factors by region (Greiner et al., 2009; Greiner and Gregg, 2011), landholder characteristics, goals and attitudes (Productivity Commission, 2003; Lockie and Rockloff, 2005; Marshall et al., 2011; Emtage and Herbohn, 2012; Rolfe and Gregg, 2015) and financial drivers and premiums required (Roebeling et al., 2009; Rolfe and Gregg, 2015). Factors that have been identified to explain slow adoption in GBR catchments include:



Note: TSS = Total Suspended Sediments, DIN = Dissolved Inorganic Nitrogen, PS-II = Photosystem II inhibiting herbicides.

Fig. 1. Industries and pollutants in Great Barrier Reef catchments.
Note: TSS = Total Suspended Sediments, DIN = Dissolved Inorganic Nitrogen, PS-II = Photosystem II inhibiting herbicides.

- Financial returns or incentives are not sufficient
- BMPs may not align with farmer objectives and outlooks or stage of life
- There are information gaps or farmers may not trust the information provided
- Attitudes to risk may limit trials and adoption of new practices
- Farmers may not have all the skills required for some BMPs
- Innovations and programs may require farmers to invest considerable time and effort
- There may not be peer group support for adoption of practices.

A challenge for policy makers who want to increase adoption of BMPs to generate net public benefits is to select appropriate policy mechanisms. The conceptual framework of Pannell (2008) helps to illustrate the issue (Fig. 2). He recommended that the choice of policy instruments be linked to the mix of public and private net benefits. As improvements in water quality will generate public benefits, and as most farming changes are expected to have positive to slightly negative effects on profitability, the relevant areas are the upper right hand quadrant extending across into the upper left hand quadrant. This matches public policy to date, where various information, extension, incentive and regulatory approaches have been used (GBRWST, 2016).

Heterogeneity in the private benefits of changing management practices may be an important explanation of small improvements in adoption rates. The oval shape in Fig. 2 illustrates the two types of heterogeneity of interest. Large variation in the mix of private and public benefits across farms mean that individual farmers might be at different locations in the oval; this would explain why a particular poicy instrument might only attract a small subset of farmers. As well, variation within a farming system might mean that there is a mix of public and private benefits at the practice level; this implies that for each farmer a particular policy instrument might only be relevant to specific practices. To set policy mechanisms effectively, information about the variability of factors across landholders and practices may be just as important as identification of key factors. These issues are tested in this study.

4. Case study

The research involved a survey of sugarcane growers conducted at 10 workshops held in the priority catchments of Wet Tropics, Burdekin and Mackay Whitsundays in March and May 2013. Sugarcane growers were invited to the workshops through contact lists provided by the Queensland Department of Agriculture, Forestry and Fisheries (QDAFF) and Reef Catchments (the latter only in the Mackay-Whitsunday region). Farmers self-selected attendance at the workshops, so the final sample is better characterized as non-random and biased towards growers who are adopters. A total of 55 surveys were completed during the workshops, 38 from the Mackay-Whitsunday region, 8 from Ayr and 9 from Tully.

The main goals of the study were to identify how rates of adoption for different practices might be explained by (a) the motivations of farmers (b) potential barriers to adoption (c) farm characteristics and (d) financial drivers. Growers were asked in the survey to rate the importance of a series of statements in each category from 1 (least important) to 10 (most important), as well as providing information about their farm and management practices. The questions related to 11 specific management practices identified as strategic BMPs by van Grieken et al. (2013a,b), as summarized in Table 1.

4.1. Rates of adoption

An initial focus of the survey was to identify levels of practice adoption. This was important to establish the key variables of interest for the subsequent analysis.

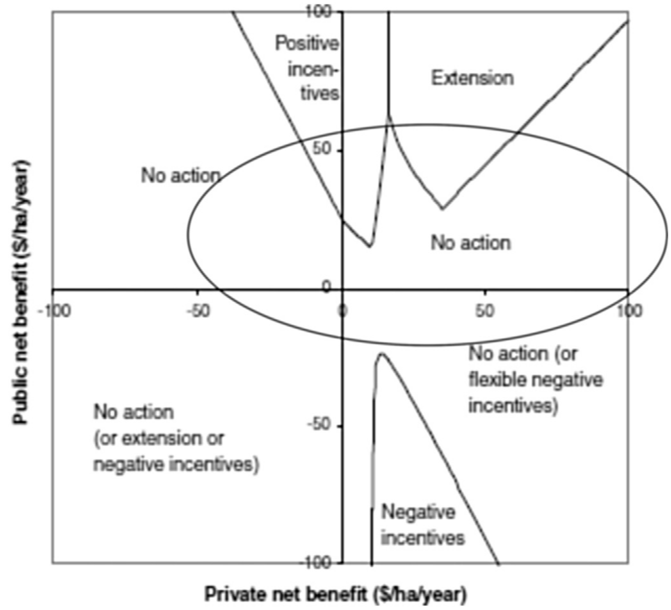


Fig. 2. Public and private benefit decision framework (adapted from Pannell, 2008).

Table 2 displays adoption rates of surveyed BMPs as a proportion of landholders surveyed. Across all regions, sub-surface application of nutrients (89%), use of directed herbicide application equipment and appropriate nozzles (85%) and herbicide rate varies between blocks with consideration of weed pressure (80%) had the highest rates of adoption. The BMPs with the lowest rates of adoption were variable nutrient rates within blocks (31%) and use of precision and directed herbicide application equipment (35%). The rates of adoption from this survey sample are higher than those in the third Reef Rescue report card (Table 2), which may be a reflection of the non-random and self-selecting bias in the sample.

4.2. Goals and motivations of canegrowers

The literature suggests that the goals of farmers have a large

Table 1
Key BMPs included in the study.

Key principle	Practice
Application rate management	Variable nutrient rates within blocks (e.g. EM mapping)
	Variable nutrient rates between blocks (based on Six Easy Steps)
	Herbicide rate varies between blocks with consideration of weed type and pressure
Application method	Sub-surface application of nutrients
	Use of precision and directed herbicide application equipment (two tanks, electronic rate controller and GPS)
	Use of directed herbicide application equipment and appropriate nozzles (e.g. air inducted nozzles)
Fallow management	Cover legume crop
Tillage managment	Low tillage (e.g. zonal)
Herbicide selection and use	Knockdowns & strategic residual use (only where needed; excluding diuron, atrazine, hexazinone & ametryn)
Record keeping	Electronic records (nutrients and herbicides)
	Management plans (e.g. nutrient and weed management plans developed by an agronomist)

Table 2
Adoption of best management practice as a proportion of workshop participants.

		This study 2013	This study 2013 average	GBR report card 2010-11[a]
Nutrient BMPs	Variable nutrient rates within blocks	31%	67%	45%
	Variable nutrient rates between blocks	75%		
	Cover legume crop	73%		
	Sub-surface application of nutrients	89%		
Soil BMPs	Controlled traffic and low (reduced) tillage	75%	75%	20%
Herbicide BMPs	Knockdowns & strategic residual use (excluding diuron, atrazine, hexazinone & ametryn)	58%	64.5%	28%
	Herbicide rate varies between blocks with consideration of weed type and pressure	80%		
	Use of precision and directed herbicide application equipment	35%		
	Use of directed herbicide application equipment and appropriate nozzles	85%		
Management	Electronic records (nutrients and herbicides)	44%		
	Management plans (Nutrient and Weed Management Plans developed by an agronomist)	56%		

Note: **a** = Queensland Government (2013b).

influence on adoption (e,g. Emtage and Herbohn, 2012; Greiner and Gregg, 2011; Moon and Cocklin, 2011). In their survey of the Wet Tropics, Emtage and Herbohn (2012) used management objectives (business, environment, lifestyle) and the primary purpose of land ownership (agriculture, conservation, hobby/lifestyle, residential) to identify landholder types with respect to BMP adoption and engagement with NRM programs. They found the strength of a farmers business focus as a management goal to be positively related to the adoption of agricultural industry BMPs and those with a focus on the environment tend to have the highest adoption of vegetation management BMPs (Emtage and Herbohn, 2012).

Two questions in this study were used to explore the goals and motivations of landholders, where farmers were asked to rate a series of statements. The first were about the relevance of different management goals, while the second were about key barriers to adoption. Factor analysis was used with each group to condense the responses into smaller number of underlying factors, using a cluster analysis process similar to that used by Emtage and Herbohn (2012). Although the sample size is relatively small for a factor analysis at 55 respondents, the K-M-O statistic for each analysis was adequate (above .5), and the Barlett's Test was significant at the 1% level, indicating that a factor analysis was appropriate. The approaches are then compared to identify if categorization of landholders into groups is consistent. If membership of particular groups is relatively stable, it will facilitate more specific adoption strategies to particular groups.

The responses to the question about the relevance of different management criteria are shown in Fig. 3.

Maximizing sugar production was the most highly rated management criteria on average in the survey. Across all landholders, 60% rated it at maximum importance (10) and 90% rated it 8 or higher. This was followed by *maximizing profit* with just below 50% of landholders rating it 10 and just below 85% rating it 8 or higher. The Factor Analysis was used to identify four groups of management focus (see Appendix One), with significant groupings summarized as follows:

Managing resources — these are the landholders who place importance on taking into account weather and soil conditions when making management decisions for efficient fertilizer and herbicide use, maintaining the natural resources on the property and keeping good records. Seven percent of growers identified most strongly with this group.

Lifestyle and leisure — these landholders place importance on doing well enough in the business to stay on the land, maximizing leisure time and being respected by other growers. Only four percent of growers identified most strongly with this group.

Profit and production — these landholders place importance on maximizing the production of sugarcane in the current year, maximising profit and minimising the chance of making a loss.

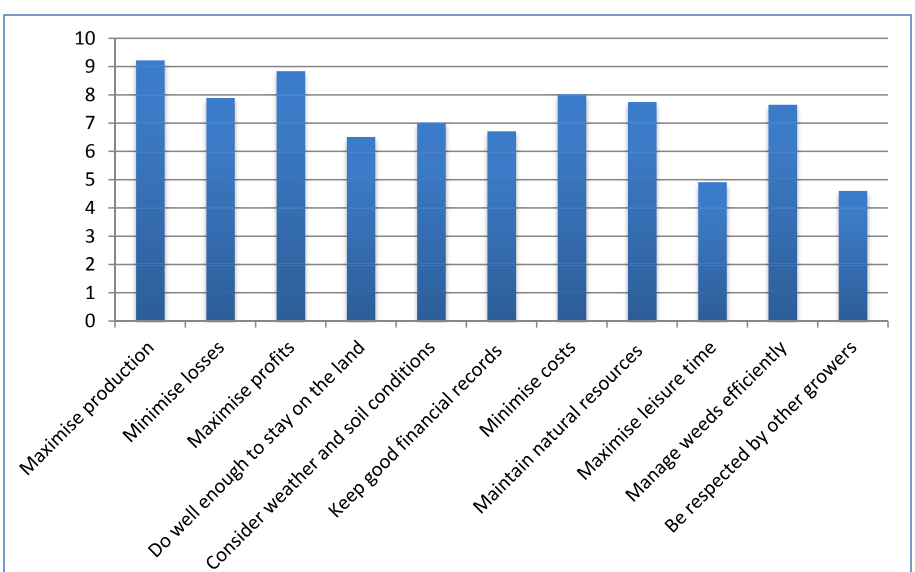


Fig. 3. Relevance of management criteria (average of score 1 (lowest) to 10 (highest)).

This is the largest group identified, accounting for 71% of the growers surveyed.

Minimise costs – these landholders are focused on minimising costs and keeping good financial records, indicating that they are more cautious operators. The second largest number of growers identified most strongly with this group at 18%.

The second approach to categorising landholders focused on barriers to management. The results are summarised as average weightings in Fig. 4, and show that financial factors were the most important barriers. *High costs for capital investments* had 40% of growers rating it at the maximum level of barrier (10) and over 75% rating it 8 or higher. The next most important factor rated a 10, was *cash flow* at just over half the proportion of *high costs for capital investments*. The least important factor was *peer pressure to manage your farm in a conventional manner*, with 40% of growers rating it 1 and over 65% rating it 3 or lower. *Business management decisions are difficult* and *difficult to acquire more land* were the next lowest rated limiting factors respectively.

As with motivations, four different factors were identified from the Principal Components Analysis (Appendix Two), as follows:

Non-business - these landholders place importance on barriers external to the running of the farming enterprise such as environmental regulation, business management decisions are difficult to make, concern over meeting environmental goals, family commitments, lack of information for minimizing environmental impacts in sugar farming and peer pressure to manage their farm in a conventional manner. Only five percent of growers identified with this group.

Uncertainty – these landholders are focused on barriers which are a source of uncertainty in managing their business such as climate in both the long and near term and in selling markets. This was the second largest grouping with 27% of growers identifying with this group.

Finance and markets – these landholders placed importance on the financial barriers of concern over meeting financial commitments and cash flow. Uncertainty over selling markets also had a loading of over .5 for this grouping. The majority of growers (60%) identified most strongly with this category.

Capital, Scale and Information – these landholders placed importance on the difficulty in identifying appropriate fertilizer and herbicide application, difficulty in acquiring more land, high costs for capital and lack of information for minimizing environmental impacts in sugar farming. Seven percent of growers identified most strongly with this group.

To identify any relationships or overlaps between the groups identified in each factor analysis, correlations of famer's scores in each factor grouping were correlated (Table 3).

The results show that the group focused on profits and production were quite distinctive, with little correlation against any of the other factor groupings. In contrast, the other groupings for key motivations tended to be correlated with each other, suggesting that at a simpler level, the growers surveyed can be categorized into two groups: those who are primarily focused on profits and production, and those who have other key focuses. Correlations between the different factors for barriers were generally high, indicating that there is limited difference between growers surveyed in terms of barriers to adoption.

Correlations were also calculated for the factor groupings against information collected from the farmers about their years of experience, number of children, and off farm income. There was only one significant relationship at the .05 level and that was between experience and the motivation factor of *minimising costs* (.321). Older farmers tend to be less likely to invest in BMPs that require large amounts of upfront capital.

Other relationships that were positive and significant at the .10 level were between experience and motivation factors of *managing resources* (correlation coefficient = .234), *lifestyle and leisure*

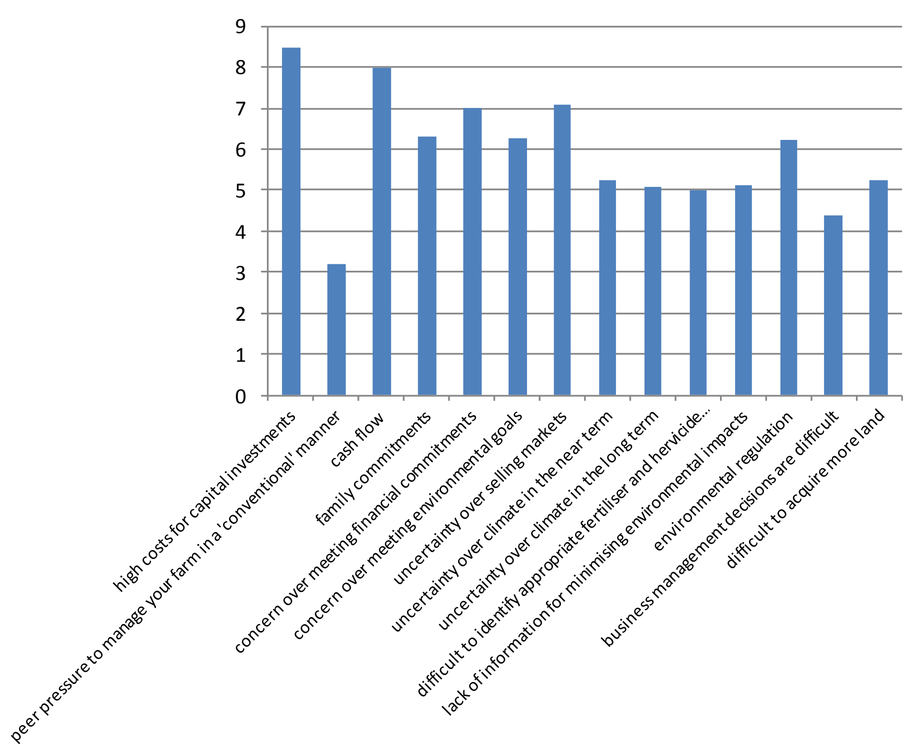


Fig. 4. Importance of factors limiting farmers' ability to manage their property.

Table 3
Correlation matrix of respondent ratings for 8 factors.

Factor % identifying	DRIVER Managing resources 7%	DRIVER Lifestyle and Leisure 4%	DRIVER Profit and production 71%	DRIVER Minimise costs 18%	BARRIER Non-business 5%	BARRIER Uncertainty 27%	BARRIER Finance and markets 60%	BARRIER Capital, scale and information 7%
DRIVER Managing resources								
DRIVER Lifestyle and Leisure	0.489**							
DRIVER Profit & production	0.224	0.169						
DRIVER Minimise costs	0.449**	0.292*	0.106					
BARRIER Non- business	0.587**	0.486**	0.103	0.349**				
BARRIER Uncertainty	0.314*	0.360**	0.242	0.120	0.419**			
BARRIER Finance & markets	0.327*	0.147	0.117	0.199	0.356**	0.408**		
BARRIER Capital, scale & information	0.34	0.156	0.338*	0.154	0.360**	0.193	0.291*	

Note: medium and light shaded cells and **, * represent significance at the 1% and 5% levels.
Pearson correlation with 2 tailed significance used.

Table 4
Tests for relationships between factor groupings and BMPs.

	Factor % identifying							
	DRIVER Managing resources 7%	DRIVER Lifestyle & Leisure 4%	DRIVER Profit & production 71%	DRIVER Minimise costs 18%	BARRIER Non-business 5%	BARRIER Uncert. 27%	BARRIER Finance & markets 60%	BARRIER Capital, scale & info. 7%
Variable nutrient rates within blocks	0.802	0.624	0.564	0.337	0.539	0.281	0.373	0.233
Variable nutrient rates between blocks	0.733	0.833	0.689	0.592	0.294	0.017	0.336	0.221
Cover legume crop	0.074	0.829	0.267	0.318	0.072	0.127	0.032	0.726
Sub-surface application of nutrients	0.879	0.986	0.119	0.365	0.473	0.556	0.21	0.715
Low tillage	0.437	0.022	0.142	0.274	0.588	0.3	0.993	0.345
Knock-downs and strategic residual	0.617	0.736	0.2	0.916	0.67	0.607	0.266	0.988
Herbicide rate varies between blocks	0.298	0.45	0.135	0.392	0.027	0.978	0.229	0.647
Use of precision and directed herbicide equipment	0.226	0.389	0.249	0.247	0.234	0.013	0.201	0.954
Use of precision and directed herbicide nozzles	0.577	0.664	0.979	0.687	0.591	0.278	0.72	0.107
Electronic records	0.957	0.808	0.055	0.969	0.067	0.022	0.529	0.635
Management plans	0.94	0.474	0.18	0.453	0.114	0.997	0.448	0.335

Note: Values are probability values from independent sample t-tests about whether a relationship exists..
Note: Dark and light shadings indicate positive and negative relationships between the practice and the factor respectively, with significance up to 20%.

(correlation coefficient = .254) and the barrier grouping of *non-business* (correlation coefficient = .243). There was a negative correlation between off-farm income and experience at the .10 level of significance. This is consistent with younger farmers and their families being more likely to be involved in outside employment and business enterprises.

A key question is whether the categorization of landholders by different drivers (as measured by Factor scores) helps to explain rates of adoption. Tests for relationships between underlying factors on motivation and barrier factors against whether or not farmers had adopted different BMPs are shown in Table 4. The cells that are shaded are significant (at a .20 level). Darker shaded cells show a positive relationship where landholders who score higher on a particular factor are more likely to adopt. Lighter shaded cells show a negative relationship where landholders who score higher on these factors are less likely to adopt. For example, growers who are identified under the uncertainty factor grouping are less likely to adopt variable nutrients rates between blocks, cover legume crops, precision and directed herbicide equipment and electronic records. Growers who are identified under the profit and production factor grouping are more likely to adopt low tillage, variable herbicide rate between blocks, electronic records and management plans.

The results show that there are limited relationships between the factor scores and the rates of takeup for different management practices. Most relationships are negative (light shaded cells). However the farmers who were identified as focusing on profit and production were more likely to be adopting four of the better management practices, suggesting that this group is engaged with proposals to reduce environmental impacts.

Farmers who were identified as perceiving that there were non-business barriers to management, or who perceived that uncertainty of outcomes was a key barrier, were more likely to not adopt better management practices (four significant non-adoption practices for each group).

4.3. Characteristics of the enterprise

Theory about economies of scale suggests that the larger an enterprise is, the more efficient (cost savings in buying in bulk and owning equipment) and consequently, the more money available to invest in new technologies. In Hooper et al. (2007) this only applies convincingly to the gross margins of growers in the Burdekin region, and modestly to growers in the Mackay region. The gross margins in 2005-06 for growers producing between 15 and 30 kilotonnes in Far North Queensland were almost half that of growers producing both under 15 kilotonnes and over 30 kilotonnes. In line with this existing literature, our survey results identified a weak and insignificant positive correlation between size of property and the number of BMPs adopted. This is consistent with the findings from Knowler and Bradshaw (2007) that the overall impact of farm size on adoption is inconclusive.

Significance tests were conducted between key farm and individual characteristics on the one hand and whether or not landholders were adopting BMPs surveyed on the other. The results are shown in Table 5 as probability values from independent sample t tests. Medium shaded cells show a positive relationship between growers who answered higher on these questions and adoption rate of the corresponding BMPs and lighter shaded cells show a negative relationship between growers who answered lower on these questions and adoption rate of the corresponding BMPs. Growers who use a high proportion of their property for growing cane, have higher yields and higher commercial cane sugar (CCS) are more likely to adopt electronic records. Growers with high levels of succession planning are more likely to adopt variable nutrient rates within blocks and use knockdowns and strategic residual use for weed management. Growers with lower years of experience, lower yields and lower CCS are less likely to adopt management plans.

The results show that there are only limited relationships between enterprise characteristics and adoption drivers, similar to

Table 5
Significance tests between farm characteristics and adoption of BMPs.

BMP	Years experience	% off farm income	Ha of land to sugar	% of property to sugar	Min cane yield	Max cane yield	Average cane yield	Min Cane CCS	Max cane CCS	Average cane CCS
Variable nutrient rates within blocks	0.536	0.113	0.757	0.001	0.178	0.535	0.313	0.05	0.627	0.05
Variable nutrient rates between blocks	0.827	0.24	0.628	0.449	0.55	0.655	0.504	0.626	0.61	0.933
Cover legume crop	.873	0.307	0.402	0.863	0.982	0.906	0.834	0.803	0.293	0.193
Sub-surface application of nutrients	0.504	0.954	0.476	0.064	0.365	0.201	0.168	0.295	0.524	0.055
Low tillage	0.016	0.447	0.597	0.815	0.354	0.203	0.183	0.062	0.691	0.426
Knock-downs and strategic residual	0.093	0.042	0.258	0.533	0.878	0.878	0.817	0.717	0.684	0.901
Herbicide rate varies between blocks	0.792	0.74	0.264	0.668	0.844	0.902	0.686	0.438	0.841	0.16
Use of precision and directed herbicide equipment	0.554	0.338	0.623	0.968	0.84	0.457	0.589	0.361	0.346	0.125
Use of precision and directed herbicide nozzles	0.193	0.546	0.253	0.987	0.335	0.729	0.656	0.088	0.929	0.591
Electronic records	0.209	0.803	0.549	0.031	0.036	0.175	0.028	0.117	0.102	0.357
Management plans	0.028	0.035	0.775	0.65	0.106	0.853	0.579	0.071	0.737	0.099

Note: Values are probability values from independent sample t-tests.
Note: Darker shaded cells mean that group adopting the practice have a higher score on the relevant issue, lighter shaded cells mean that group adopting practice have a lower score on the relevant issue.

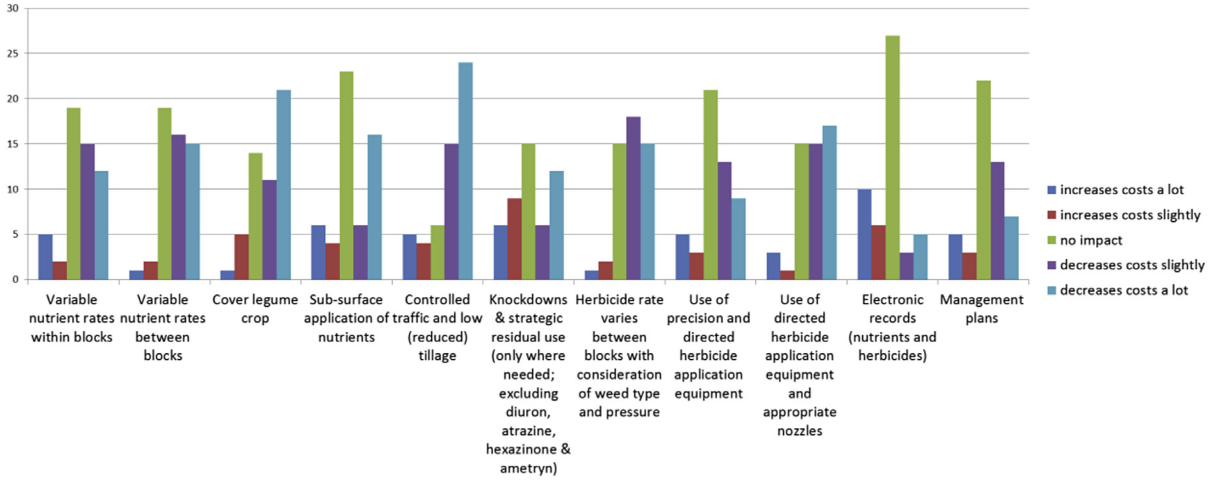


Fig. 5. Landholder perceptions of change to costs of production from adopting BMPs.

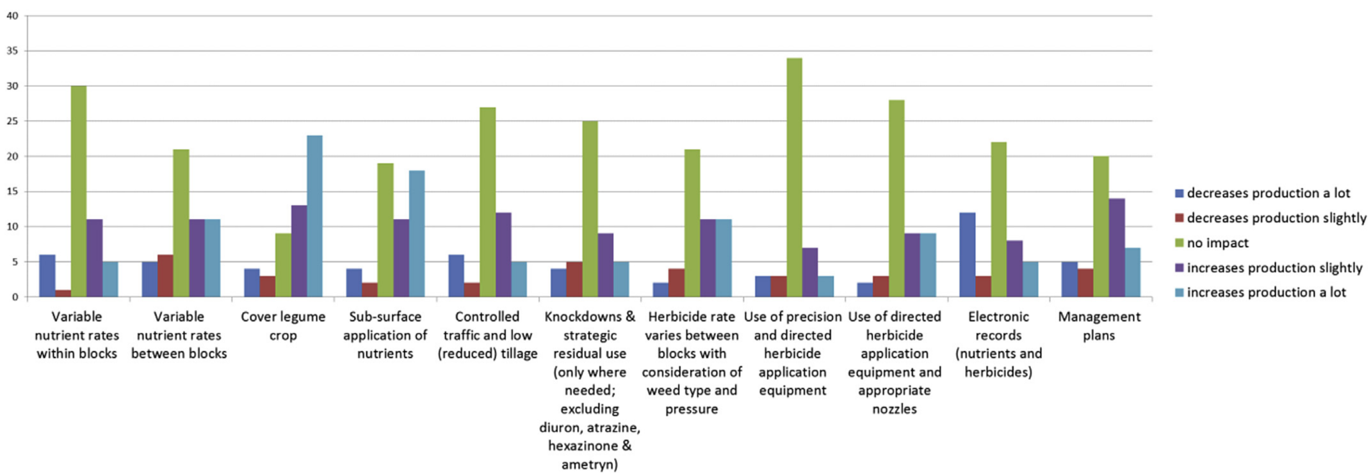


Fig. 6. Landholder perceptions of change to production from adopting BMPs.

the results between personal characteristics and adoption drivers. Practices that had positive relationships to some enterprise characteristics included *electronic records, variable nutrient rates* and *low tillage*. Practices where more than one negative relationship was identified were *sub-surface application of nutrients* and *management plans*.

4.4. Net private returns

Farmers were asked specifically if different costs of practice change had large impacts on adoption (Fig. 5). Averaged across all landholders, most growers identified that the nominated BMPs in the survey had no impact on operational costs, while some identified that costs were reduced. Only one BMP was identified as

Table 6
Constraints identified as having an impact on the decision to adopt BMPs as a percentage of landholders surveyed.[a]

	High fixed costs	Contractors need to implement	Does not fit with farming system	Not easy to trial	Requires new skills and information
Variable nutrient rates within blocks	56	40	15	20	38
Use of precision and directed herbicide application equipment	80	5	13	4	16
Controlled traffic and low tillage	49	5	20	11	7
Electronic records (nutrients and herbicides)	25	2	13	0	45
Variable nutrient rates between blocks	24	9	15	4	31
Cover legume crop	24	11	16	4	16
Nutrient and Weed Management Plans	20	13	5	0	33
Sub-surface application of nutrients	40	11	11	4	4
Knockdowns & strategic residual use (with some exclusions)	18	4	7	7	13
Use of directed herbicide application equipment and appropriate nozzles	27	4	4	0	4
Herbicide rate varies between blocks	18	2	2	4	11

[a] 55 landholders surveyed.

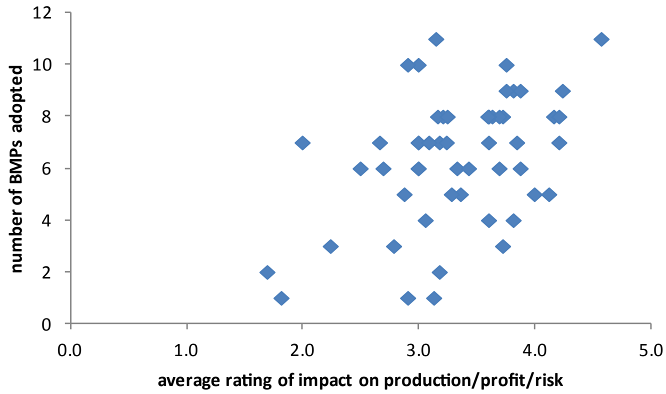


Fig. 7. Relationship between average rating of BMP and number of BMPs adopted.

increasing production costs (electronic records).

The rating of 'No impact' was even more pronounced for growers' perception or experience with BMPs on production/yields (Fig. 6). The main exception was for cover legume crops which had the highest rating for increases in production.

Table 6 shows which constraints to adoption listed in the survey were most identified by landholders for each BMP. The BMPs are arranged in order of the total number of total constraints identified for each, with *Variable nutrient rates within blocks*, *Use of precision and directed herbicide application equipment, Controlled traffic and low (reduced tillage)* and *Electronic records* accounting for 19, 13, 11 and 10% of constraints identified respectively. 'High fixed costs' accounted for 43% of identified barriers in the survey. The next most identified constraint at 25% was 'Requires new skills and information'. 'Does not fit with my current farming system', 'Contractor needs to implement' and 'Not easy to trial' accounted for 14, 12 and 6% of constraints identified respectively.

5. Discussion and conclusions

The focus of the research reported here was to go beyond the standard identification approach to adoption drivers and demonstrate how the relative influence of factors influencing adoption could be measured in a case study setting. The results of this study identify limited heterogeneity around decisions to adopt BMPs. Consistent with the wider literature, a number of financial, attitudinal, personal and enterprise factors appear to be important in explaining whether or not growers have been adopting various best management practices. Three major conclusions are noted.

First, landholders can be categorized into different groups according to motivations and perceptions of barriers, and those groupings help to explain adoption decisions. The most distinctive grouping in our survey were farmers focused on profits and production, with little correlation against any of the other factor groupings. This group of farmers, which accounted for approximately two thirds of the sample, were more likely to adopt specific BMPs. For this group, it is likely that further adoption can be encouraged by demonstrating the production and financial benefits of particular practices. In contrast, the other groupings for key

Table 7
Summary of adoption, rating and number of barriers for particular management practices.

		average rating for impact on production/costs/variability[a]		average number of other barriers identified		Barriers with greatest influence on adoption decision (% of growers identifying)
	% adopted	adopt	non-adopt	adopt	non-adopt	
Variable nutrient rates within blocks	30.9	3.15	3.14	1.76	1.66	High fixed costs (58) Involves contractor (47) Requires new skills (45)
Variable nutrient rates between blocks	74.6	3.55	3.30	0.73	1.07	Requires new skills (42) High fixed costs (31)
Cover legume crop	69.1	3.78	3.45	0.62	1.00	High fixed costs (38) Requires new skills 31)
Sub-surface application of nutrients	87.3	3.65	3.33	0.64	1.14	High fixed costs (47)
Controlled traffic and low (reduced) tillage	76.4	3.48	3.46	0.83	1.42	High fixed costs (51) Does not fit (31)
Knockdowns & strategic residual use (excluding diuron, atrazine, hexazinone & ametryn)	58.2	3.12	3.10	0.61	0.58	High fixed costs (25)
Herbicide rate varies between blocks with consideration of weed type and pressure	80.0	3.71	3.46	0.40	0.38	High fixed costs (29)
Use of precision and directed herbicide application equipment	34.6	3.60	2.85	1.05	1.32	High fixed costs (84
Use of directed herbicide application equipment and appropriate nozzles	85.5	3.57	2.50	0.35	0.67	High fixed costs (35)
Electronic records (nutrients and herbicides)	41.8	2.80	2.60	0.65	1.10	Requires new skills (47) High fixed costs (33)
Management plans	56.4	3.36	2.70	0.63	0.91	Requires new skills (42) High fixed costs (31)

Note A: scale used 1= strongly agree; 3 = neutral; 5 = strongly disagree with the statements that it increases production costs, it decreases production of sugar and it makes production more variable.
Note B: Shaded cells show significant differences between adopters and non-adopters.

motivations tended to be correlated with each other, suggesting they could be treated as a relatively homogeneous group (but different to the 'profits and production' group). These growers were more likely to perceive barriers to adoption (such as capital costs, higher risks, new skills required, contractors need to change), and to have adopted fewer better management practices. For this group, addressing particular barriers to adoption may be required.

Second, financial factors are important drivers of adoption decisions, in part because these align with key motivations for the bulk of growers surveyed. The broad positive relationship between perceptions of the impact on productivity and profits against the number of better management practices adopted is shown in the Figure below (see Fig. 7).

None of the BMPs tested in this study were identified as having a major impact on production or costs (apart from using electronic records, where 10% of growers considered that it would increase production costs). This is consistent with growers not identifying short-term impacts on profit as a barrier to adoption. However high fixed costs and the costs of capital investment were identified as important for some practices, while there were limited impacts on capital costs, production costs or production outputs identified for other BMPs.

Third, there is large variation in the drivers and barriers to adoption for different practices, as demonstrated in the summary in Table 7. There was a significant difference between adoptors and non-adoptors for three practices in terms of expected economic returns (shaded in blue), and for eight practices for other barriers (shaded in red), with the relative importance of economic versus other barriers varying across practices. However, the most important barriers identified were similar across practices, including *High fixed costs* and *Requires new skills* the most important.

These results confirm that measures to improve BMP adoption are complicated by heterogeneity in adoption drivers between practices and across groups of landholders, creating challenges to find effective strategies to encourage adoption. Future monitoring and research is warranted in two key areas. The first is to plan and detail how adoption strategies can be tailored by practice and region to address particular needs and barriers. The second is to trial, record and evaluate different approaches to adoption, so that innovative practices can be found and assessed. Continued effort is likely to be required to achieve ongoing adoption of better management practices, particularly as attention moves from earlier adopters and farmers interested in practice change to those who may have different motivations and prefer to maintain current farming systems.

Acknowledgements

The research has been funded by the Australian Government and partners through the Reef Rescue R&D Project 39 in the Caring for Our Country's Reef Rescue Program. The contributions of Stuart Whitten, Daniel Gregg, Bruce Taylor, Martijn van Grieken, Mark Poggio, Rob Milla and John Hughes in the design and conduct of the grower workshops and Andy Wallace for review is gratefully acknowledged.

APPENDIX 1. Factor analysis of grower motivations

	Factor 1	Factor 2	Factor 3	Factor 4
	Managing resources	Lifestyle & Leisure	Profit & Productn.	Minimise costs
Maximise production of sugarcane for the current year	.154	-.121	.813	-.163
Minimise the chance of making a loss	.089	.265	.663	.098
Maximise Profit	-.134	.062	.673	.495
Do 'well enough' in the business to stay on the land	.015	.727	.234	.010
Consider expected weather and soil conditions for targeted fertiliser use	.871	.041	.124	.014
Keep good financial records	.574	-.179	.076	.677
Minimise costs	-.040	.360	.007	.759
Maintain the natural resources (e.g. wetlands, soil health) on the property	.591	.490	-.193	.033
Maximise leisure time	.257	.657	.041	.239
Manage weeds for efficient use of herbicides	.702	.324	.230	.014
Be respected by other growers	-.493	.549	-.152	.117
Percentage of landholders identifying most strongly	7%	4%	71%	18%
Sample size	55			
Method	Principal Component Analysis, Varimax rotation			
Barlett's Test of Sphericity	Approx. Chi-Square 153.521 with 55 DoF, Sign. = 0.000			
Kaiser-Meyer-Olkin Measure of Sampling Adequacy	0.584			
Total variance explained by factors	66.21%			

Note: dark shaded cells have loading on factors >0.5.

APPENDIX 2. Factor analysis of barriers to management

	Factor 1	Factor 2	Factor 3	Factor 4
	Non-business environ.	Uncertainty	Finance & markets	Capital, Scale & Inform.
High costs for capital investments (e.g. machinery and equipment)	-.384	.113	.494	.578
Peer pressure to manage your farm in a 'conventional' manner	.565	.139	-.159	.484
Cash flow	.187	-.184	.728	.067
Family commitments	.674	-.023	.315	.042

(*continued*)

	Factor 1	Factor 2	Factor 3	Factor 4
	Non-business environ.	Uncertainty	Finance & markets	Capital, Scale & Inform.
Concern over meeting financial commitments (e.g. loans)	.037	.214	.783	.005
Concern over meeting environmental goals	.678	.208	.330	.170
Uncertainty over selling markets (world price for sugar)	.198	.555	.556	.031
Uncertainty over climate in the near term	.090	.869	.005	.090
Uncertainty over climate in the long term	.239	.872	.077	.047
Difficult to identify appropriate fertiliser and herbicide applications	.192	.361	.-.079	.702
Lack of information for minimising environmental impacts in sugar farming	.617	.119	.131	.549
Environmental regulation	.748	.099	.012	-.117
Business management decisions are difficult to make (i.e. more than one owner)	.730	.319	-.081	.134
Difficult to acquire more land (e.g. purchase, lease)	.038	-.122	.094	.682
Proportion identifying most strongly	5%	27%	60%	7%
Sample size	55			
Method	Principal Component Analysis, Varimax rotation			
Barlett's Test of Sphericity	Approx. Chi-Square 264.71 with 91 DoF, Sign. = 0.000			
Kaiser-Meyer-Olkin Measure of Sampling Adequacy	0.682			
Total variance explained by factors	65.44%			

Note: dark shaded cells have loading on factors >0.5.

References

Baumgart-Getz, A., Prokopy, L.S., Floress, K., 2012. Why farmers adopt best management practice in the United States: a meta-analysis of the adoption literature. J. Environ. Manag. 96, 17–25.

Brodie, J., Waterhouse, J., Schaffelke, B., Kroon, F., Thorburn, P., Rolfe, J., Johnson, J., Fabricius, K., Lewis, S., Devlin, M., Warne, M., McKenzie, L., 2013. 2013 Scientific Consensus Statement: Land Use Impacts on Great Barrier Reef Water Quality and Ecosystem Condition. State of Queensland, Brisbane.

Cary, J., Roberts, A., 2011. The limitations of environmental management systems in Australian agriculture. J. Environ. Manag. 92 (3), 878–885.

Cary, J., Webb, T., Barr, N., 2002. Understanding Landholders' Capacity to Change to Sustainable Practices: Insights about Practice Adoption and Social Capacity for Change. Bureau of Rural Sciences, Canberra.

Emtage, N., Herbohn, J., 2012. Assessing rural landholders diversity in the Wet Tropics region of Queensland Australia in relation to natural resource management programs: a market segmentation approach. Agric. Syst. 10, 107–118.

Great Barrier Reef Water Science Taskforce (GBRWST), 2016. Clean Water for a Healthy Reef. Final Report. State of Queensland, Brisbane.

Greiner, R., 2016. Factors influencing farmers' participation in contractual biodiversity conservation: a choice experiment with northern Australian pastoralists. Aust. J. Agric. Resour. Econ. 60, 1–21.

Greiner, R., Gregg, D., 2011. Farmers' intrinsic motivations, barriers to the adoption of conservation practices and effectiveness of policy instruments: empirical evidence from northern Australia. Land Use Policy 28, 257–265.

Greiner, R., Lankester, A., Patterson, L., 2007. Incentives to Enhance the Adoption of 'best Management Practices' by Landholders: Achieving Water Quality Improvements in the Burdekin River Catchment. Report for the Burdekin Dry Tropics NRM and the Coastal Catchment Initiative (Burdekin). River Consulting, Townsville.

Greiner, R., Patterson, L., Miller, O., 2009. Motivations, risk perceptions and adoption of conservation practices by farmers. Agric. Syst. 99, 86–104.

Hooper, S., Henry, C., Ashton, D., Lubulwa, M., 2007. Australian Sugar Cane Growers: Financial Performance 2005-06. ABARE Research Report 07.18, Prepared for Sugar Research Australia.

Knowler, D., Bradshaw, B., 2007. In: Farmers' Adoption of Conservation Agriculture: a Review and Synthesis of Recent Research Food Policy, vol. 32, pp. 25–48.

Lockie, S., Rockloff, S., 2005. Landholder Attitudes to Wetlands and Wetland Conservation Programs and Incentives, CRC for Coastal Zone. Estuary and Waterway Management, Brisbane, 2005.

Marshall, N.A., Gordon, I.J., Ash, A.J., 2011. The reluctance of resource-users to adopt seasonal climate forecasts to enhance resilience to climate variability on the rangelands. Clim. Change 107, 511–529.

Moon, K., Cocklin, C., 2011. Participation in a biodiversity conservation: motivations and barriers of Australian landholders. J. Rural Stud. 27, 331–342.

Morrison, M., Durante, J., Greig, J., Ward, J., Oczkowski, E., 2012. Segmenting landholders for improving the targeting of natural resource management expenditures. J. Environ. Plan. Manag. 55, 17–37.

Pannell, D.J., 2008. Public benefits, private benefits, and policy intervention for land-use change for environmental benefits. Land Econ. 84, 225–240.

Pannell, D.J., Marshall, G.R., Barr, N., Curtis, A., Vanclay, F., Wilkinson, R., 2006. Understanding and promoting adoption of conservation practices by rural landholders. Aust. J. Exp. Agric. 46, 1407–1424.

Price, J., Leviston, Z., 2014. Predicting pro-environmental agricultural practices: the social, psychological and contextual influences on land management. J. Rural Stud. 34, 65–78.

Productivity Commission, 2003. Industries, Land Use and Water Quality in the Great Barrier Reef Catchment. Research Report 02/2003. Productivity Commission, Canberra. http://www.pc.gov.au/shody/gbr/finalreport/index.html.

Prokopy, L.S., Floress, K., Klotthor-Weinkauf, D., Baumgart-Getz, A., 2008. Determinants of agricultural best management practice adoption: evidence from the literature. J. Soil Water Conservation 63, 300–311.

Roebeling, P.C., van Grieken, M.E., Webster, A.J., Biggs, J., Thorburn, P.J., 2009. Cost-effective water quality improvement in linked terrestrial and marine ecosystems: a spatial environmental-economic modeling approach. Mar. Freshw. Res. 60, 1150–1158.

Rolfe, J., Gregg, D., 2015. Factors affecting the adoption of improved management practices in the pastoral industry in Great Barrier Reef catchments. J. Environ. Manag. 157, 182–193.

The State of Queensland, 2011. Great Barrier Reef First Report Card 2009 Baseline: Reef Water Quality Protection Plan. Published by the Reef Water Quality Protection Plan Secretariat, Brisbane.

The State of Queensland, 2013a. Great Barrier Reef Second Report Card 2010: Reef Water Quality Protection Plan. Published by the Reef Water Quality Protection Plan Secretariat, Brisbane.

The State of Queensland, 2013b. Great Barrier Reef Report Card 2011: Reef Water Quality Protection Plan. Published by the Reef Water Quality Protection Plan Secretariat, Brisbane.

The State of Queensland, 2014. Great Barrier Reef Report Card 2014: Reef Water Quality Protection Plan. Published by the Reef Water Quality Protection Plan Secretariat, Brisbane.

The State of Queensland, 2015. Great Barrier Reef Report Card 2015: Reef Water Quality Protection Plan. Published by the Reef Water Quality Protection Plan Secretariat, Brisbane.

van Grieken, M., Poggio, M., Smith, M., Taylor, B., Faure, C., Boullier, A., Whitten, S., 2013a. Cost-effectiveness of Management Activities for Water Quality Improvement in Sugarcane Farming. Report to the Reef Rescue Water Quality Research & Development Program. Reef and Rainforest Research Centre Limited, Cairns, 71pp.

van Grieken, M., Thomas, C.R., Roebling, P.C., Thorburn, P.J., 2013b. Integrating economics drivers of social change into agricultural water quality improvement strategies. Agric. Ecosyst. Environ. 180, 166–175.

Whitten, S., Reeson, A., Windle, J., Rolfe, J., 2013. Designing conservation tenders to support landholder participation: a framework and case study assessment. Ecosyst. Serv. 6, 82–92.