Department of **Agriculture, Fisheries and Forestry**

Queensland Government

Informing policy design for water quality improvements in the sugarcane industries adjacent to the Great Barrier Reef: a case study approach

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Contributed paper prepared for presentation at the
57th AARES Annual Conference, Sydney,
New South Wales, 5th-8th February, 2013

AARES
AUSTRALIAN AGRICULTURAL &
RESOURCE ECONOMICS SOCIETY

I would like to acknowledge the Plane Creek Sustainable Farmers Inc, the Sugar Research and Development Corporation, Project Catalyst and the Queensland Department of Agriculture, Fisheries and Forestry for their contributions to the development of this work and paper.

Informing policy design for water quality improvements in the sugarcane industries adjacent to the Great Barrier Reef: a case study approach

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Abstract

To achieve water quality targets, management practice change in the sugar cane industry has been a large focus for natural resource management initiatives such as Reef Plan and Reef Rescue. Considerable public funds have been targeted at landholders to change on-ground management practices. However, the economic implications for landholders are not well understood. To further inform future policy development of the upcoming Reef Water Quality Protection Plan 3 and Reef Rescue 2, the economic costs and benefits to landholders are required. This research used a case study approach to consider the economic implications of improved soil management through an extended fallow period in the Mackay-Whitsunday region. The results demonstrate the complexity of creating effective policy design for adoption of improved management practices for water quality in a semi-perennial farming system.

Keywords:
Water quality, sugar cane, Mackay Whitsunday, extended fallow.

1. Introduction

The Great Barrier Reef (GBR) Marine Park off the coast of Queensland, Australia is the largest coral reef in the world and a listed World Heritage Area. In 2008, The Reef Plan Scientific Consensus statement concluded that the quality of water entering the Great Barrier Reef (GBR) from adjacent coastal catchments continued to be of poor quality and is detrimental GBR health (Brodie *et al.*, 2012). The decline in water quality entering the GBR is the result of increased sediments, nutrients and pesticides since European settlement. These pollutants predominately travel into the GBR lagoon via surface runoff and subsurface water flows in large rainfall events detrimentally affecting the inshore coral and seagrass bed ecosystems (Fabricius and De'ath, 2004; McKergow *et al.*, 2005; Haynes *et al.*, 2007). Major land use change for the purposes of agricultural production in the adjacent catchments is understood to be the main source of these pollutants (Fabricius and De'ath, 2004; Haynes *et al.*, 2007;

Packett *et al.*, 2009) with approximately 80% of the GBR catchments used for some form of agricultural production, predominantly, grazing and sugarcane cultivation (Haynes *et al.*, 2007). This paper focuses on pollutant reductions from the sugarcane industry.

The Reef Water Quality Protection Plan (Reef Plan) was established in 2003 (and revised in 2009) with the objective to reduce non-point source pollutant loads entering the catchment waterways and GBR lagoon. Reef Plan targets intend that by 2013 a 50% reduction in nitrogen, phosphorous and pesticides loads and a 20% reduction in sediment load at the end of the catchment will be realised. Management practice targets in the agricultural industries adjacent to the GBR to reach these water quality targets include 80% of landholders adopting improved soil, nutrient and chemical management practices (Carroll *et al.,* 2012). In 2007, Reef Rescue, a voluntary-based incentives package for the adoption of on-ground improved management practices was launched by the Federal Government in conjunction with Reef Plan (Brodie *et al.*, 2012). The Reef Rescue policy initiative has to date been the most successful at promoting large-scale change of catchment land use (Waterhouse *et al.*, 2012). With the upcoming development of Reef Water Quality Protection Plan 3 and Reef Rescue 2 a better understanding of the economic costs and benefits to landholders of adopting improved management practices is needed.

Understanding the farm-level economics of new innovations and management practices for improved water quality is important to achieve broad-scale adoption (Pannell et al, 2006). New management practices are unlikely to be adopted unless they are perceived to be profitable or offer the landholder a 'relative advantage' (Pannell et al, 2006). This paper seeks to contribute to the economic literature concerning improved management practices for water quality by considering the economic implications of an extended (two year) sugarcane fallow case study in the Mackay-Whitsunday region. While an extended fallow production system is a relatively new concept initial data demonstrates that there are potential agronomic benefits of the lengthening fallow period (Garside *et al.*, 2000). Trial results from the Sugar Research Development Corporation (SRDC) Sustainable Farmers Plane Creek initiative were incorporated into a partial budget analysis to simulate two extended fallow production system scenarios. Firstly, the economic results and implications of the transition are considered, followed by the subsequent policy design implications for improved management practice adoption.

2. Background: sugar cane and extended fallows

Sugar cane is a semi-perennial, tropical crop grown predominately between Bundaberg and Port Douglas in Queensland. While only comprising one percent of the total GBR catchment area, it is a significant contributor to GBR water quality impacts given the industry's intensive use of land in high rainfall areas and close proximity to the coast (Rolfe *et al.*, 2008). In particular, the sugarcane industry is associated with exporting large quantities of dissolved inorganic nitrogen and PS-II[1] herbicides from the Wet Tropics, Burdekin, Mackay Whitsunday and Burnett Mary catchments (Waterhouse *et al.*, 2012).

In the Mackay Whitsunday region, an ABCD management practices framework for improved water quality was developed as part of the Mackay Whitsunday Water Quality Improvement Plan (Drewry *et al.*, 2008). The framework separates soil, nutrient and pesticide management practices from 'A' class cutting-edge practices to 'D' class superseded or unacceptable practices and thus, identifies and categorises sugarcane management practices according to recognised water quality improvements (Carroll *et al.*, 2012). One component of the ABCD soil management classification is the inclusion of rotational crops managed for green manure or grown to harvest – a 'B' or 'A' class management practice (Drewry *et al.*, 2008). Recognised benefits of including a fallow period in the sugarcane cropping cycle include improving soil biology, combating root diseases and acting as a source of fixed nitrogen for the following sugarcane crop (Garside *et al.*, 2000; Garside *et al.*, 2001).

Results from *Sugar Yield Decline Joint Venture* trials have indicated the potential of sugarcane fallows greater than one year (Garside *et al.*, 2000). Nine, eighteen and thirty month crop fallow trials were conducted in the Mackay Whitsunday region yielding improvements over plough-out/replant regimes between 37-56% in plant cane and 13-26% in the first ratoon. At this stage there has been no research beyond this trial (until the SRDC trial results used in this analysis) into the potential of extending sugar cane fallows and it is unknown how far the yield benefits of an extended fallow might extend throughout the crop cycle and whether the extended fallow will allow more ratoons to be grown, lengthening the crop cycle. Also unknown is the water quality impacts an extended fallow production system may have.

It is hypothesised that extended fallows with legume crops may further cumulate soil and yield benefits and further reduce the amount of nitrogen fertiliser required in the subsequent sugarcane crop. Other benefits include greater income diversity through selling the grain or seed of the multiple fallow crops and reducing the cane grower's exposure to the sugarcane price. Greater income diversity in the extended fallow production system is traded at the cost of less total hectares available for sugarcane production. In this case study the 175 hectare property conventionally has 145 hectares of sugar cane and 30 hectares of fallow in any given year. When operating in an extended fallow there the 175 hectares would become 125 hectares of sugar cane and 50 hectares of fallow. Additionally, the two production systems are not immediately interchangeable given the six or seven years it is likely to take a grower to transition a property into an extended fallow production system.

[1] Residual herbicides such as diuron, atrazine and hexazinone.

It is acknowledged that significant gaps in knowledge and understanding of both the agronomic and water quality aspects of an extended fallow production system exist. Despite this there is potential for an extended fallow production system to provide a more resilient and diversified farming system and improvements in water quality. This research considers the economic implications of operating an extended fallow production system and discusses the implications for policy to promote adoption should an extended fallow production system be included in the Mackay Whitsunday ABCD framework for improved water quality.

3.1 Economic methodology

To determine if transitioning to an extended fallow cropping system is economically viable a partial budget analysis and discounted cash flow analysis were used. Whole-of-farm gross margins (GM) were created using the Farm Economic Analysis Tool (FEAT), a sugarcane specific computer software program developed by QDPI&F Futurecane project (Stewart and Cameron, 2006). The marginal cash flow differences between the FEAT generated gross margins for the 'before' (Conventional fallow) and 'after' (Extended fallow) scenarios were then utilised in a discounted cash flow analysis to generate net present values (NPV). A ten year investment time period and a real discount rate of 7% were used in this analysis. The GMs of each scenario were then analysed for risk using a Monte Carlo simulation to generate cumulative frequency distribution curves based on the key variables of sugar cane and fallow crop price and yields.

3.2 Case study property

The trial data utilised is from the SRDC Grower Group Innovation project conducted by Plane Creek Sustainable Farmers Inc. (Sluggett, 2012). The trial site has nine different extended fallow cropping sequences including a control, each with differing combinations of bare fallow, chickpea, mungbean, sugarbeet, soybean and standover cane. At the time of writing, only plant cane and first ratoon trial yield data had been recorded.

Two sequences were selected for economic modelling; Jimbour Chickpea - Crystal Mungbean - Plant Cane (Sequence 1) and Sugarbeet - Leichhardt Soybean - Plant Cane (Sequence 2) based on the available trial data and realistic extended fallow potential of the sugarcane property in question.

The 175 hectare irrigated property where the trial is located and on which this case study is based is in the Sandy Creek Catchment in the Mackay-Whitsunday region with sugarcane processed by the Plane Creek mill. The property operates on 1.85 metre dual rows with green cane harvesting, usually grows plant cane and four ratoons in the crop cycle, operating with both minimum tillage and controlled traffic. The sugarcane grower provided detailed estimates of conventional sugar cane yields and farm operations (land preparation, machinery costs, chemical and fallow management). This information was used to calculate the 'before' property gross margin when the property is operating with a more conventional single soybean mulch fallow. The trial data from the two extended fallow sequences was utilised to calculate the 'after' whole of farm gross margins of the property should it hypothetically operate in either of the two extended fallow scenarios selected. Due to some weather and management problems during the trials some management and yield assumptions were required to complete the economic analysis.

3.3 Assumptions

Unseasonable wet conditions were experienced throughout the trial (2009-2011) resulting in some fallow crops becoming waterlogged and underperforming, in some cases not harvested at all. For this economic analysis, a 'typical' yield for the region was used instead. This allows the analysis to represent 'average' seasonal conditions. Despite the unseasonable conditions the trial plant cane yield results still recorded significant increases relative to the standard conventional fallow control sequence. A 38% increase in plant cane yield following the chickpea-mungbean fallow sequence (1) and a 19% increase for the sugarbeet-soybean sequence (2) were recorded and modelled in this analysis. These gains are similar to those reported in Garside *et al.* (2000). No yield increase was modelled for the ratoons as the trial results suggested a negligible increase.

A five year average (2007-2011) sugar price of $409 per tonne ($36.80 per tonne of cane) was used and all fertiliser and chemical prices were standardised using prices current as at May 2012. Labour was costed at $30 per hour. Table 1 presents the standardised prices and yields used in the analysis (current for 2012) for sugar cane and the fallow crops. These price estimates were sourced from local suppliers.

Table 1. Standardised sugarcane and fallow crop prices and yields

	Price ($/tonne)	Freight ($/tonne)	Harvest cost ($/tonne)	Yield (tonnes/hectare)
Sugarcane (KQ288)	36.80	N/A	10	85 (property average)
Jimbour Chickpea	500	20*	140	2
Crystal Mungbean	550	20*	140	1
Leichhardt Soybean	535	90**	140	3
Sugarbeet	36.80	N/A	450	70

** Freight to Mackay Port*

*** Freight to Dalby*

The analysis assumes that the above crops can readily be planted, harvested and freighted from the property at the costs in Table 1. It has also been assumed the Plane Creek sugar mill will accept the sugarbeet for processing, and the price for sugar from the sugarbeet achieves the same price as sugar derived from sugar cane.

No capital costs have been included in this analysis as the property in question has access to the required planting and harvesting contractors required for the fallow crops in question.

4. Results

4.1 Sequence 1 (Jimbour chickpea-Crystal mungbean- plant cane)

The conventional sequence (single soybean mulch fallow) property gross margin is $1,096 per hectare. Following a complete whole farm transition (six years) to Sequence 1 the gross margin improves to $1,101 (rounded) per hectare; an improvement of $4 per hectare.

Table 2. Discounted cash flow analysis (Sequence 1)

Year	0	1	2	3	4	5	6	7	8	9	10
Before GM (property)		191,886	191,886	191,886	191,886	191,886	191,886	191,886	191,886	191,886	191,886
After GM (property)*		191,996	192,105	192,214	192,323	192,432	192,541	192,650	192,650	192,650	192,650
Change in GM (property)		109	218	327	436	545	654	763	763	763	763
Before GM ($/ha)		1,096	1,096	1,096	1,096	1,096	1,096	1,096	1,096	1,096	1,096
After GM ($/ha)*		1,097	1,098	1,098	1,099	1,100	1,100	1,101	1,101	1,101	1,101
Change in GM ($/ha)		1	1	2	2	3	4	4	4	4	4
Change in property cash flow		109	218	327	436	545	654	763	763	763	763
Discounted property cash flow		102	190	267	333	389	436	475	444	415	388
Net Present Value	$3,440										
Net Present Value per hectare	$20										

** The after GM is a pro-rata composite of the before and after GMs for the first 6 years as the property transitions 1/7th of the total area into the extended fallow system each year.*

The marginal cash flow difference between the two scenarios is discounted at a rate of 7% over a ten year investment period. The resulting net present value is $3,440 or $20 per hectare. This indicates that the discounted net benefits of transitioning to a chickpea and mungbean extended fallow is marginally better than breakeven over a ten year period.

Table 3. Gross Margin results (Sequence 1)

	Conventional fallow (soy mulch)	Extended fallow (Sequence 1)	Net result
Property GM ($)	191,886	192,650	Increase
Property GM ($/ha)	1096	1101	Increase
Cane GM ($)	201,800	198,062	Decrease
Cane GM ($/ha)	1,391	1,584	Increase
Leichhardt Soybean GM ($)	-9,914	N/A	-
Jimbour Chickpea GM ($)	N/A	-5,703	
Crystal Mungbean GM ($)	N/A	291	Combined improvement relative to soybean mulch fallow

Table 3 presents the gross margin results by crop. There is a decrease in total cane gross margin from $201,800 to $198,062 and an increase in cane gross margin per hectare. Therefore, the marginal improvement in cane per hectare (the result of the 38% plant cane yield improvement) is not sufficient to compensate for the reduction in area available for cane production.

Despite this, the overall property gross margin improves with the chickpea – mungbean – plant cane extended fallow. The combined (negative) chickpea and (positive) mungbean gross margins exceeding the negative soy mulch crop GM in the conventional fallow resulting in the extended fallow crop system producing an overall slight improvement in the property gross margin.

A risk analysis for sugar cane, mungbean and chickpea prices and yields was conducted to determine their impact on the property gross margin. Figure 1 illustrates the cumulative probability of achieving different annual gross margins per hectare for the conventional fallow system and the extended fallow sequence. Cane, mungbean and chickpea prices were set to vary by up to 40% above and below the expected value. Cane yields were also set to vary by up to 40% above and below expected values. The legume fallow crop yields were set to vary by up to 20% above expected values and up to 100% below (no crop harvested) in an attempt to incorporate the greater risk associated with legume yields and ability to harvest.

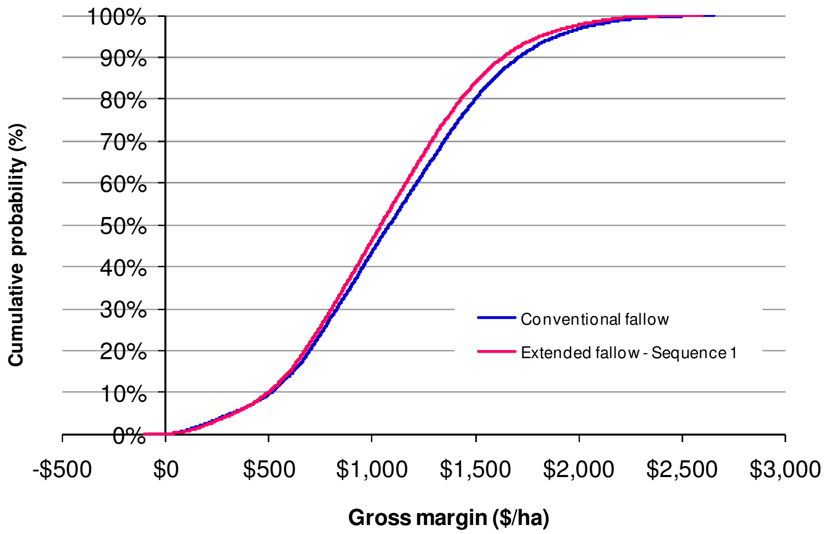

Figure 1. Risk analysis (Sequence 1)

The cumulative distribution illustrates that lower combinations of prices and yields there is little difference between the gross margins of either production system. However, at average and higher combinations of sugar cane prices and yields the conventional fallow system has a higher gross margin than the extended fallow system. This is attributed to the greater risk the extended fallow is exposed to and therefore reflected in the risk analysis.

4.2 Sequence 2 (Sugarbeet – Leichhardt Soybean – plant cane)

The conventional sequence (single soybean mulch fallow) property gross margin is $1,096 per hectare. Following a complete transition to Sequence 2 the gross margin improves to $1,350 per hectare, an improvement of $253 per hectare.

Table 4. Discounted cash flow analysis (Sequence 2)

Year	0	1	2	3	4	5	6	7	8	9	10
Before GM (property)		191,886	191,886	191,886	191,886	191,886	191,886	191,886	191,886	191,886	191,886
After GM (property)*		198,216	204,545	210,874	217,204	223,533	229,863	236,192	236,192	236,192	236,192
Change in GM (property)		6,329	12,659	18,988	25,317	31,647	37,976	44,305	44,305	44,305	44,305
Before GM ($/ha)		1,096	1,096	1,096	1,096	1,096	1,096	1,096	1,096	1,096	1,096
After GM ($/ha)*		1,133	1,169	1,205	1,241	1,277	1,314	1,350	1,350	1,350	1,350
Change in GM ($/ha)		36	72	109	145	181	217	253	253	253	253
Change in property cash flow		6,329	12,659	18,988	25,317	31,647	37,976	44,305	44,305	44,305	44,305
Discounted property cash flow		5915	11057	15500	19315	22564	25305	27591	25786	24099	22523
Net Present Value	$199,654										
Net Present Value per hectare	$1,141										

** The after GM is a pro-rata composite of the before and after GMs for the first 6 years as the property transitions 1/7th of the total area into the extended fallow system each year.*

The resulting whole farm net present value is $199,654 or $1,141 per hectare.

Table 5. Gross Margin results (Sequence 2)

	Conventional fallow (soy mulch)	Extended fallow (Sequence 2)	Net result
Property GM ($)	191,886	236,192	Increase
Property GM ($/ha)	1096	1101	Increase
Cane GM ($)	201,800	186,649	Decrease
Cane GM ($/ha)	1,391	1,439	Increase
Leichhardt Soybean GM ($)	-9,914	18,470	Combined improvement relative to soybean mulch fallow
Sugarbeet GM ($)	N/A	31,072	

The results demonstrate a decrease in total cane gross margin from $201,800 to $186,649 due to reduced cane area, but with an increase in cane gross margin per hectare (Table 5). Thus, the marginal improvement in cane per hectare (the result of the 19% plant cane yield improvement) is insufficient to compensate for the reduction in area available for cane production. The total property gross margin improves with the sugarbeet-soybean-plant cane extended fallow. This is the result of the combined sugarbeet and soybean gross margins exceeding the negative soy mulch crop GM of the conventional fallow.

Risk analysis was completed for sugar cane (and beet) and soybean prices and yields to determine the impact on the property gross margin. Figure 2 illustrates the cumulative probability of achieving different annual gross margins per hectare for the conventional fallow system and the extended fallow system.

Cane (and sugarbeet) and soybean prices were set to vary by up to 40% above and below the expected value. Cane yields were also set to vary by up to 40% above and below expected values. The soybean and sugarbeet crop yields were set to vary by up to 20% above expected values and up to 100% below (no crop harvested) in an attempt to incorporate the greater risk associated with legume yields and ability to harvest.

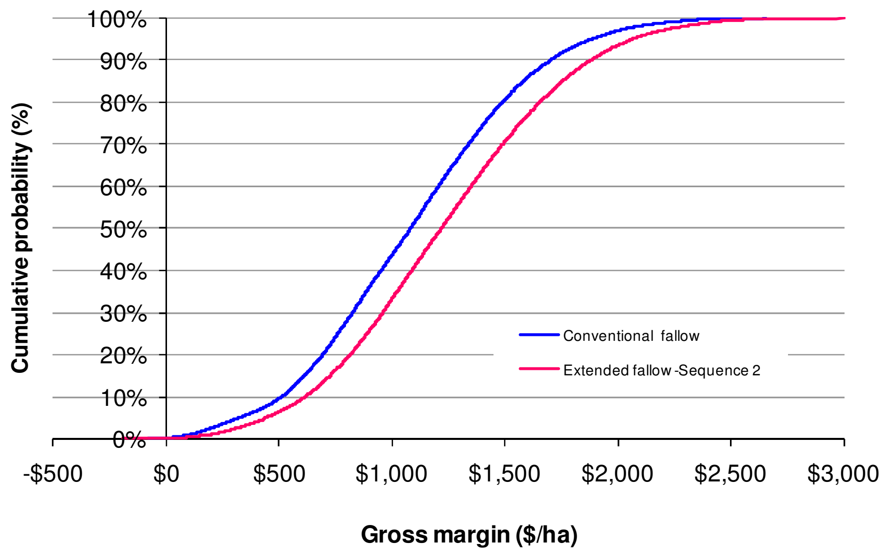

Figure 2. Risk analysis (Sequence 2)

The distribution illustrates that the majority of price and yield combinations the extended fallow Sequence 2 scenario produces higher gross margins. The extended fallow risk distribution also has a greater range of gross margins emphasising the increased exposure to low prices and poor yield. While Sequence 2 is likely to produce a gross margin higher than the conventional fallow in the majority of years, there also exists a slim possibility of receiving a lower gross margin.

There is a significant gross margin improvement for the property once fully transitioned to the sugarbeet - soybean extended fallow. As sugarbeet is modelled at the sugarcane price and assumed to be harvested at the mill alongside cane, the sugarcane grower has not increased income diversity by as much as Sequence 1 and is almost as equally reliant on the sugarcane price as in a conventional system. In addition, it is possible that the potential for commercial sugarbeet cultivation and processing has been overestimated and further verification of yield, harvest potential and processing capacity in the Mackay-Whitsunday region is required.

5. Discussion and policy implications

This case study contributes to the farm level economic implications of changing management practices by demonstrating the potential of an extended fallow to improve overall property gross margin whilst broadening their income diversity. However, it is apparent that this result relies heavily on the selection of an appropriate sequence of fallow crops that will return significantly positive gross margins without inviting significant extra risk in the production system. Pending further agronomic and water quality information, should an extended fallow production system become considered a best management practice for water quality there will be a number of issues that either enhance or impeded widespread adoption in the Mackay Whitsunday region.

The case study demonstrated that in instances (Sequence 1) where the property gross margin improvement is marginal, the added exposure to risk in the production system may present challenges adoption. In Sequence 1, the negative chickpea gross margin even in 'average' conditions compromises the economic viability of the system when a risk analysis is included. This emphasises the importance of considering the riskiness of alternate crops, and the associated variation in achievable yield across seasons with varying weather events. Even with expected price and yield for chickpeas, the chickpea gross margin is negative (Table 3). This indicates that chickpeas may not the best suited fallow crop for this property from an economic perspective. Further trials of the fallow crop yield performances and subsequent cane yields under different seasonal conditions are necessary. Verification of post extended fallow fertiliser management throughout the crop cycle, and alternate chickpea and mungbean markets in the region is also required.

Adoption of the new production system becomes a balancing act of reducing exposure to the sugar prices at the cost of increased fallow crop risk. In the current sugar cane market conditions of historically high prices it is hypothesised that for the majority of growers the transition would not be attractive. (Windle and Rolfe, 2005) found that even in 2003 during low sugarcane market conditions sugar cane was still the preferred crop and diversification was unlikely.

Practical implications for a grower considering an improved management practice of this kind are the capital costs to purchase or modify required equipment and/or availability of planting and harvesting contractors of the fallow crops. Additionally, the fallow crops may be unfamiliar to growers and require new management skills. Without a developed market in the region for the fallow crops and associated technical and market expertise diversifying into these crops may be prohibitively expensive and difficult. (Rolfe *et al.*, 2008) notes that best management practices that are large scale, complex and require investments in technical skills are likely to have low rates of adoption. This is likely to prove to be a barrier for the widespread adoption of extended fallow production system. Furthermore, trialability or the ability of the improved management practice to be tested by the grower to learn about its potential is an important component of adoption (Pannell *et al.*, 2006). Among other things small-scale, observable, shorter and less complex trials will lead to greater adoption. Unfortunately, an extended fallow production system is unlikely to meet these requirements. Significant heterogeneity between grower social circumstances, personal goals and culture will also influence the degree of likelihood of adoption (Pannell *et al.,* 2006), especially when such an extensive management practice change is being considered. Finally, should there be widespread adoption of a production system that reduces total cane production there may be repercussions imposed by the sugar cane mill for whom reduced total cane production is unfavourable. These broader industry scale factors will require consideration.

The nature of the semi-perennial sugar cane production system means that a grower is locked into the new production system; therefore adoption is a long-term management decision and similarly, does not present an option for trialability. Should an extended fallow production system be deemed a 'best management practice' for water quality, policy to promote adoption must consider the grower implications of balancing crop risk and the long term nature of changing the production system. One-off or short-term policy incentives are unlikely to induce a grower to switch into an extended fallow production system unless the net long term production benefits of the extended fallow production system become apparent.

This research highlights the importance of understanding the economic implications of best management practices when they promote largely untried innovations, technologies or management systems. Numerous complexities for the sugar cane grower and the broader industry must also be considered in conjunction with the economic implications. Agronomic research into the potential of extended fallow production systems is in the very early stages and many fundamental gaps in our understanding exist. Further trial data to improve knowledge of post extended fallow nutrient management will lead to improved understanding of the water quality impacts of an extended fallow. Better understanding of the performance of various fallow crop sequences, potential markets, root pathogen and disease behaviour and subsequent cane yield and productivity impacts will allow a more robust economic analysis to be conducted.

6. Conclusion

This economic case study has indicated that it may be economically viable to transition to an extended fallow production system, depending on the fallow crops chosen. However, an over-arching conclusion concerning the economic viability of extended fallows is not yet possible and it would be unwise to promote an extended fallow production system as best management practice for water quality without further in-depth consideration of the economic complexities the system would create for the grower and the region. If future research deems extended fallow production systems to be an improved management practice for water quality, adoption policy will need to address a number of barriers to adoption including long term risk, practical management issues of new fallow crops, the sugar cane mills role in the growers farming decisions and the difficulty in proving extended fallow viability through trials. It is suggested that the economic implications of best management practices for water quality be explored comprehensively before they are promoted by policy.

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