Department of Agriculture, Fisheries and Forestry

The Economics of Pesticide Management Practices on Sugarcane Farms

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

2014

Final synthesis report

Great state. Great opportunity.

Queensland Government

Acknowledgements:

We would like to acknowledge the Department of Environment and Heritage Protection for funding this research through the Reef Protection Science Program. The authors would like to thank the anonymous reviewers for their invaluable comments and suggestions on both the content and structure of this report. Last we would like to thank the many people and organisations who have contributed to the report and for commenting on earlier versions.

Cover photo supplied by Lawrence DiBella.

Citation:

Smith, M., Poggio, M. J., Thompson, M. & Collier, A. (2014). *The Economics of Pesticide Management Practices on Sugarcane Farms: Final Synthesis Report*. Department of Agriculture, Fisheries and Forestry (DAFF), Queensland.

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1. Introduction

Sugarcane production has been the predominant agricultural industry for coastal Queensland since the middle of the 19th century. Today, sugar remains the economic backbone of many coastal communities (Garside, 2003). The Queensland sugar industry provides vital socio-economic benefits within many coastal towns in Queensland, creating employment opportunities for those directly associated with farm enterprises as well as flow-on effects for community organisations and local businesses that service those enterprises. The flow-on effects from local household expenditures into recreational activities and domestic holiday/leisure tourism provides a substantial contribution to the economic value of the Great Barrier Reef (GBR) (see Deloitte Access Economics, 2013).

Over eighty-five per cent of sugarcane production in Queensland is concentrated in the Wet Tropics, Burdekin Dry Tropics and Mackay Whitsunday regions (BSES Limited, 2012). These regions extend along the north-east coast of Queensland adjacent to the GBR catchment area. Sugarcane production in these coastal regions involves a relatively intensive production system, with potential losses of inorganic nutrients, pesticides and sediments from cane land. The potential for adverse environmental impacts occurring from traditional cane production practices has been identified as an emergent risk factor affecting water quality in the GBR catchment area, with waters within twenty kilometres of the shore at highest risk of water quality degradation (The State of Queensland, 2011a).

The Reef Water Quality Protection Plan (Reef Plan) formalises a joint commitment by government, industry and regional bodies to act to reduce the contribution of total contaminants entering coastal waterways from agricultural land located in the GBR catchment area. The Reef Plan initiative consists of a range of major programs covering monitoring, modelling and reporting of water quality outcomes, research programs focused upon improving knowledge about the economic and environmental impacts of different farm management practices, and increasing the adoption of management practices that improve water quality.

This synthesis report provides an overview of key research relevant to the economics of pesticide and nutrient management practices in the northern sugarcane industry (in particular, the Wet Tropics, Burdekin Dry Tropics and Mackay Whitsunday regions). The report details the impetus behind the Reef Plan and a resultant focus on management practices leading to water quality improvement. An overview of the cane growing business is outlined to provide a better understanding of the farm business environment and its impact on profitability and business management. Pesticide and nutrient management practices are then reviewed, along with a critical analysis of the economic information available and identified gaps. The report highlights the regional and enterprise diversity in sugarcane growing regions and its influence on management practices, adoption and profitability. Lastly, potential areas of future research are outlined focusing upon enhancing the delivery mechanisms for greater adoption of improved management practices.

1.1 Reef Water Quality Protection Plan

The long term goal of Reef Plan is to ensure that “by 2020 the quality of water entering the reef from broad scale land use has no detrimental impact on the health and resilience of the Great Barrier Reef” (The State of Queensland, 2013a). In order to monitor and assess Reef Plan’s progress, a set of water quality targets as well as land and catchment management targets have been developed.

Water quality targets for 2018 include (The State of Queensland, 2013a):

- “At least a 50 per cent reduction in anthropogenic end-of-catchment dissolved inorganic nitrogen loads in priority areas.
- At least a 20 per cent reduction in anthropogenic end-of-catchment loads of sediment and particulate nutrients in priority areas.
- At least a 60 per cent reduction in end-of catchment pesticide loads in priority areas.”

Land and catchment management targets for 2018 include (The State of Queensland, 2013a):

- “90 per cent of sugarcane, horticulture, cropping and grazing lands are managed using best management practice systems (soil, nutrient and pesticides) in priority areas.
- Minimum 70 per cent late dry season groundcover on grazing lands.
- The extent of riparian vegetation is increased.
- There is no net loss of the extent, and an improvement in the ecological processes and environmental values, of natural wetlands.”

As an integral part of Reef Plan, the Reef Water Quality Program (RWQ) is tasked with reducing current levels of pollution runoff from agricultural land to the reef, specifically from cane growing and cattle grazing, through improved understanding, extension and policy development. The most important reef pollutants coming from sugarcane farming are nutrients (especially nitrogen and phosphorus) and PSII pesticides (herbicides designed to inhibit photosynthesis in plants). Sediment-related water quality decline is also a concern to RWQ; however, wide-spread adoption of practices such as green cane trash blanketing and reduced tillage has helped address this issue in the cane industry. The main aim of the RWQ in sugarcane production is to minimise the loss of nitrogen, phosphorus and PSII pesticides by increasing the adoption of management practices that facilitate improvements to water quality while maintaining or improving business profitability.

1.2 RWQ Cane Science sub-program

The cane science sub-program aims to fund projects to identify sources of pollution and develop management solutions that can be adopted effectively by cane growers. The RWQ economic research project, funded by the cane science sub-program, aims to give cane farmers greater confidence in the likely economic and water quality outcomes of the various management options. RWQ will bring together all available information about the economics of management practice improvement and extend knowledge about improved pesticide and nutrient management. Further research will be undertaken to examine various options for pesticide management, in particular, and produce extension materials that are relevant to growers within each of the three targeted regions. The project will focus on identifying profitable pesticide management practices that satisfy the guiding principles of Best Management Practices (BMPs) and minimum industry standards (regulatory requirements) such as Reef Protection. A priority will be given to practices that can be implemented cost-effectively and that are likely to achieve the greatest water quality improvement at a property scale. Efficient adoption of the identified management practices will be achieved by exploring barriers to adoption and a landholder's motivations for change.

1.3 Report objectives

This report has been written to provide an overview of the currently available literature relating to the economics of pesticide and nutrient management in the northern cane industry. The information compiled in this synthesis report specifically aims to:

- Outline the current status of the Australian sugar industry.
- Capture the current state of knowledge about the impact of management practices on water quality and determine how to best monitor this impact and management changes required.
- Communicate the work being undertaken to fill knowledge gaps.
- Provide an opportunity to assess and refine methodological approaches to be used in projects to address reef water quality issues.
- Re-evaluate the focus of RWQ initiatives in relation to species of pollutants, geographic location, land use, property configuration and associated management practices.

1.4 Information sources and scope

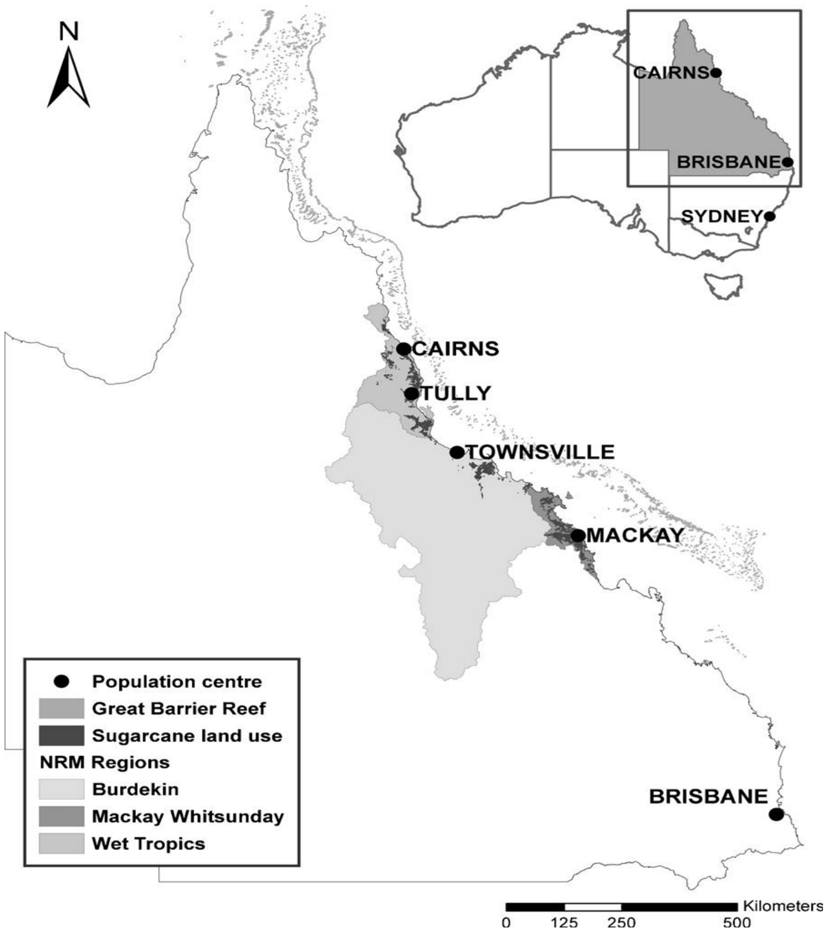
The authors have endeavoured to synthesise the available literature and have drawn on a diverse range of published information sources. In some instances valid work may have been overlooked and the reference list is by no means exhaustive.

2. Background to understanding the cane growing business

2.1 Farm business environment

The Queensland sugar industry produces approximately 95 percent of Australia's total raw sugar which is typically worth around 1.5 – 2.5 billion dollars to the Australian economy (Department of Agriculture, Fisheries and Forestry, 2012; CANEGROWERS, 2012). Sugarcane production in Queensland is most concentrated in the north of the state where three key growing regions make up the northern cane industry – the Wet Tropics, the Burdekin Dry Tropics, and Mackay Whitsunday. A visual profile of these natural resource management regions including major coastal towns/cities, cane production areas, and their relative proximity to the GBR is presented in Figure 1.

Figure 1: The Wet Tropics, Burdekin Dry Tropics, and Mackay Whitsunday regions



Source: van Grieken et al., 2011.

In the last twenty years the sugar industry has come under increasing economic pressure from a range of factors including increased international competition, industry deregulation, increasing input costs, pest and disease outbreaks, extreme weather events and relatively weak world sugar prices for a prolonged period. Along with these difficult operating conditions, the industry is facing increased expectations from community and government regarding its environmental responsibilities due to the close proximity of these particular cane growing regions to the GBR.

Finding tractable solutions that will minimise nutrients and pesticides eventually entering the GBR catchment has become the primary concern for policy-makers and industry alike. The sugar industry now finds itself operating in a social and commercial environment that is concerned with negative consequences arising from its operating activities, especially when they have the potential to adversely affect the health of the GBR. Long-term production issues associated with traditional intensive cropping systems have also pressed the industry to adopt improved management practices to become sustainable.

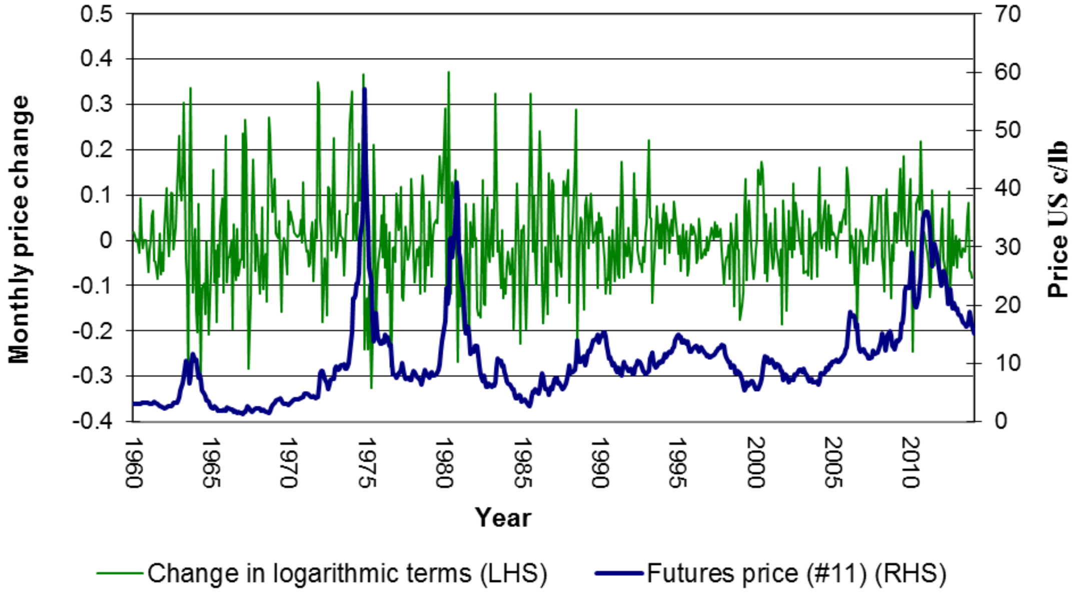
Sugarcane production in North Queensland has traditionally been carried out in an intensive monoculture cropping system. The combination of monoculture, intensive tillage and burning for harvesting gradually degraded the soil resource, until the associated yield decline of the 1980s and 1990s threatened the viability of the industry (Garside, 2003). This led to improved farming practices being developed to improve production and profitability. While adopting these practices has helped the cane industry to improve environmental sustainability, meeting Reef Plan water quality targets remains a challenge.

To understand the cane farming business one needs to first gain an appreciation of the economic environment in which it operates. Cane farmers are price-takers and Australian sugar prices are highly exposed to volatility in residual world market prices since eighty percent of its product is exported and export price parity is applied to the domestic market (Sugar Industry Oversight Group, 2006). More than eighty-five per cent of Australia's total raw sugar exports are managed by Queensland Sugar Limited (QSL) whose marketing system offers growers and suppliers (millers) a broad range of options over the sale of their sugar (Queensland Sugar Limited, 2012).

The Intercontinental Exchange No. 11 (ICE No 11) futures market is one of the most commonly used mechanisms to derive the Australian sugar price and is considered the world benchmark for determining the value of raw sugar (Queensland Sugar Limited, 2012). Other mechanisms include various over-the-counter contract pools where the future delivery price is negotiated directly with customers and the United States (US) Quota Pool. In contrast to the deregulated market in Australia, the US market has a quota system in place and price is derived from the ICE No 16 futures market; sugar sold to this market is usually at a higher price because of the regulated market conditions.

Participants in the futures market include producers and consumers of sugar endeavouring to hedge their underlying exposures to price risk, as well as speculators looking to potentially capitalise on price movements. Price discovery for sugar in the futures market is influenced by the complex interactions between buyers and sellers of futures contracts. Depending on the volume of trades, these complex interactions occur instantaneously within the futures market to produce the commodity price cycle of world sugar prices and determine its relative volatility. Figure 2 shows monthly world sugar prices and the volatility in these prices over the period January 1960 to January 2014.

Figure 2: World average monthly raw sugar prices, January 1960 – January 2014



Source: United States Department of Agriculture, 2014. (Original sourced from New York Board of Trade; Contract No. 11-f.o.b. stowed Caribbean port, including Brazil, bulk spot price, plus freight to Far East.)

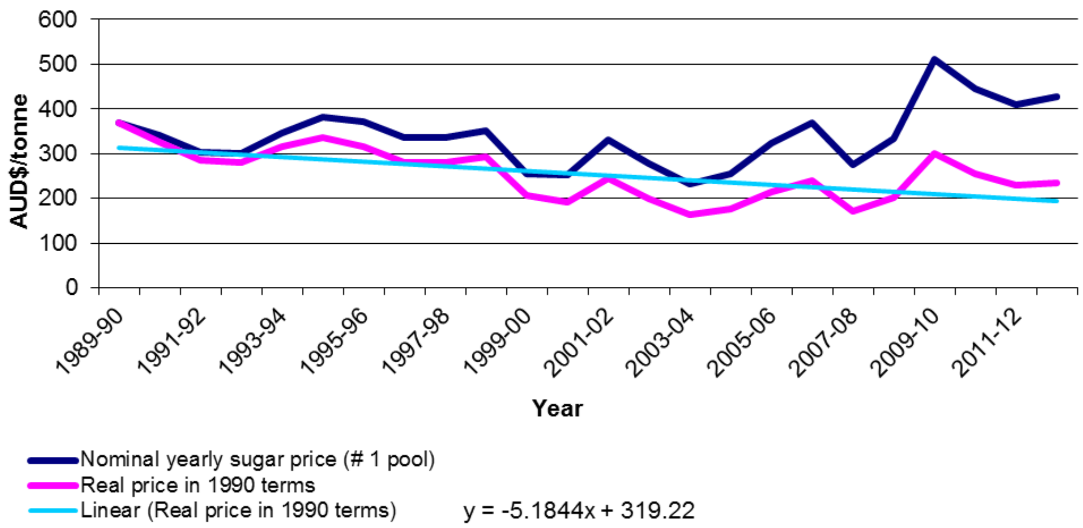
The world sugar price (Figure 2, RHS) has receded from a recent period of strengthening in which it peaked at 36.11 US cents per pound in early 2011. The changes to the world price (Figure 2, LHS) also illustrates that the price for sugar in the futures market is historically quite volatile[1]. While the futures market provides a global benchmark for pricing sugar, other factors affect the domestic price that growers receive for their sugar; this includes the Australian exchange rate, as well as local marketing arrangements.

Despite the nominal sugar price received by Australian growers recently rising to its highest point over the past two decades (i.e. between 1989-90 and 2011-12), prices have on average fallen in real terms over this period (see Figure 3). Analysing the sugar price in real terms gives a more meaningful measure of the economic situation for cane growers as it reflects the ability of the nominal price to maintain its local

[1] The price of an homogenous commodity traded on futures markets can be expressed as an exponential function of the current spot price $F_0 = S_0e^{(r-q)T}$ (see Hull, 2012; Smith, 2012). Calculating the statistic $dt = \ln(F_0 / S_0)$, and annualising by multiplying by 12, gives a mean of 3.01% and volatility (i.e. the annualised standard deviation of the continuously compounding change in sugar prices) of 35.51% per annum from January 1960 to January 2014. To put this into perspective, it is common to observe annual variations of between 25 to 50 per cent in output prices for natural resource industries (Brennan & Schwartz, 1985).

purchasing power of domestic goods and services. As can be seen in Figure 3, a tonne of sugar at a nominal price of $428 in 2012-13 dollar terms is equivalent to the relative purchasing power of $235 worth of the same basket of goods and services in 1989-90.

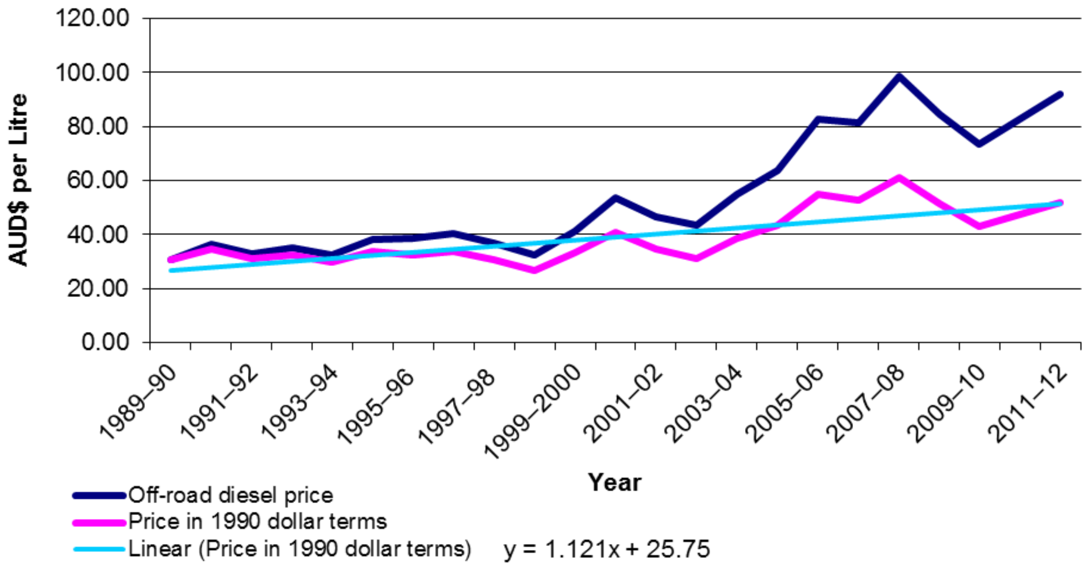
Figure 3: Australian sugar prices in real terms 1990-91 to 2012-13



Source: Australian sugar prices sourced from ABARES, 2011 and QSL (2011-13). Prices deflated using Consumer Price Inflation (CPI) measures sourced from ABS, 2013 (base year=100=2012).

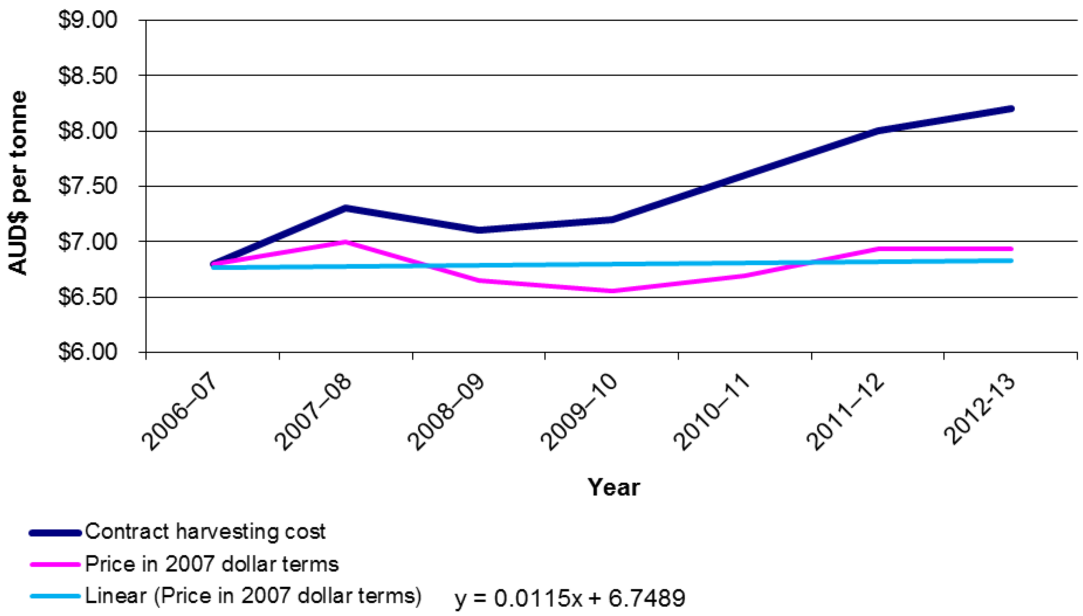
At the same time that real output prices were declining during the last two decades, the cost of diesel fuel, which is a key input for growing and harvesting, tended to trend upwards in real terms (see Figure 4). In other words, the nominal price of diesel increased on average at a greater rate than consumer price inflation over this period. On the other hand, over the period 2006-7 to 2012-13 the costs of harvesting have grown broadly in line with inflation (see Figure 5).

Figure 4: Diesel prices 1990-91 to 2011-12



Source: Input prices sourced from ABARES, 2013. Prices deflated using CPI measures sourced from ABS, 2013 (base year=100=2012).

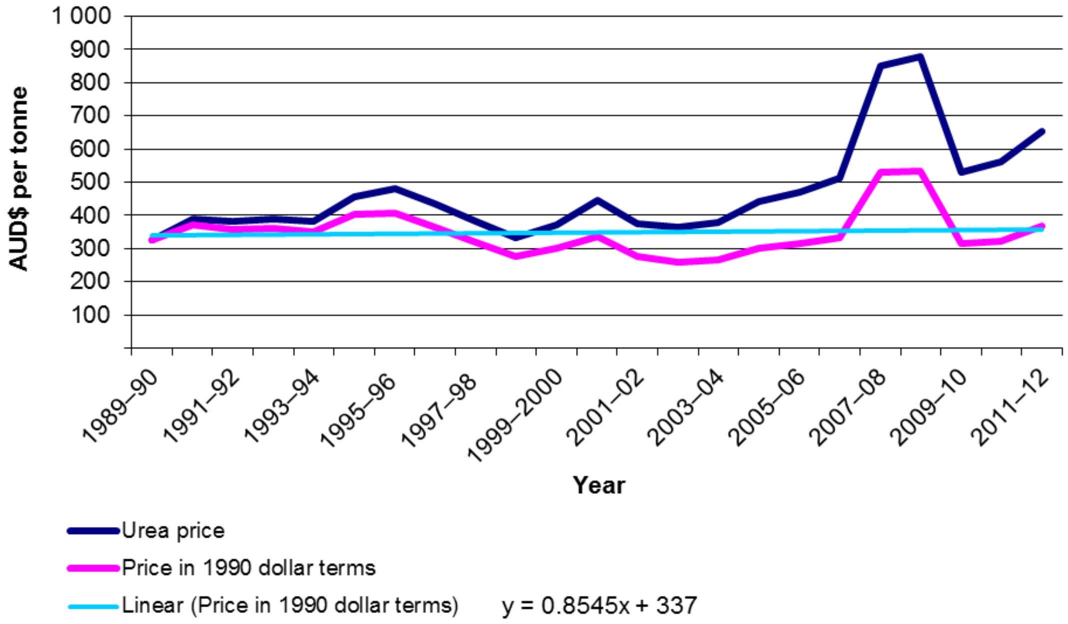
Figure 5: Contract harvesting prices (Herbert region), 2006-7 to 2012-13



Source: Contract prices sourced from private communication. Prices deflated using CPI measures sourced from ABS, 2013 (base year=100=2012).

Similarly, the cost of urea in real terms (indicative of fertiliser costs) appears to be relatively flat. This implies that these prices have on average grown in line with consumer price inflation (see Figure 6). Interestingly, a large shock occurring in 2007-08 and 2008-09 increased the cost of urea significantly during this period, before recently returning to trend.

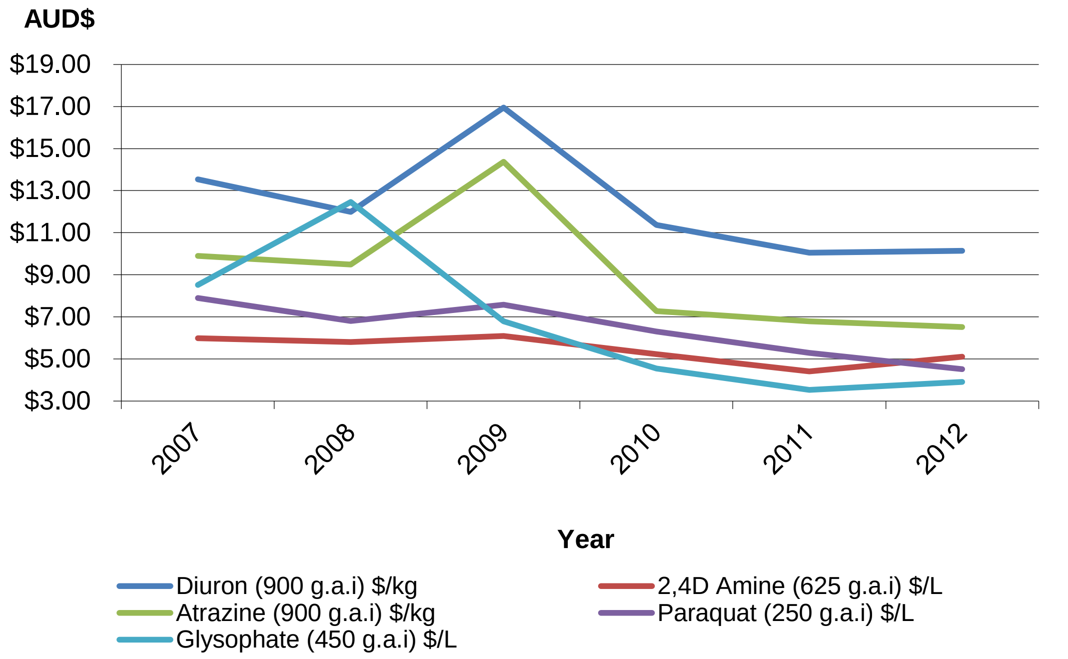
Figure 6: Urea prices, 1990-91 to 2011-12



Source: Input prices sourced from ABARES, 2013b. Prices deflated using CPI measures sourced from ABS, 2013 (base year=100=2012).

Prices in real terms for many key herbicides within the Herbert region have tended to fall over the period 2006-7 to 2011-12 (see Figure 7). While herbicides are key inputs in sugarcane production to manage weeds, they are not a major cost of production compared with fuel, harvesting, and fertiliser costs. Since prices for herbicides used in sugarcane production are generally not publicly available, price data has been collected on an annual basis and is limited to the past six years.

Figure 7: Indicative herbicide prices in real terms, 2007 to 2012

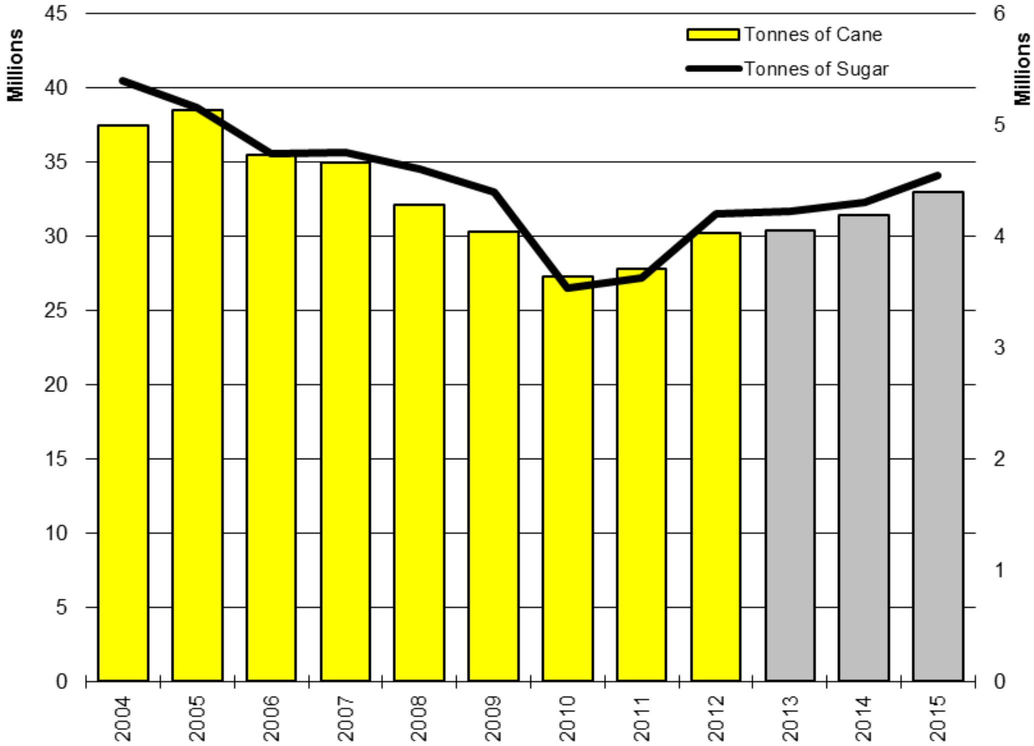


Source: Wholesale prices sourced from resellers in the Herbert region. Prices deflated using CPI measures sourced from ABS, 2013 (base year=100=2012).

The level of sugar production in Australian has tended to trend downwards during the last decade with resurgence in production projected for 2012 and beyond (see Figure 8). Tonnage of cane per grower, on the other hand, has increased markedly over this period as a result of increased farm size. While weather conditions play a significant part in determining overall production levels of cane, it is interesting to note the significant decline in the number of Australian cane farm businesses from 2004 to 2009 (see Figure 9).

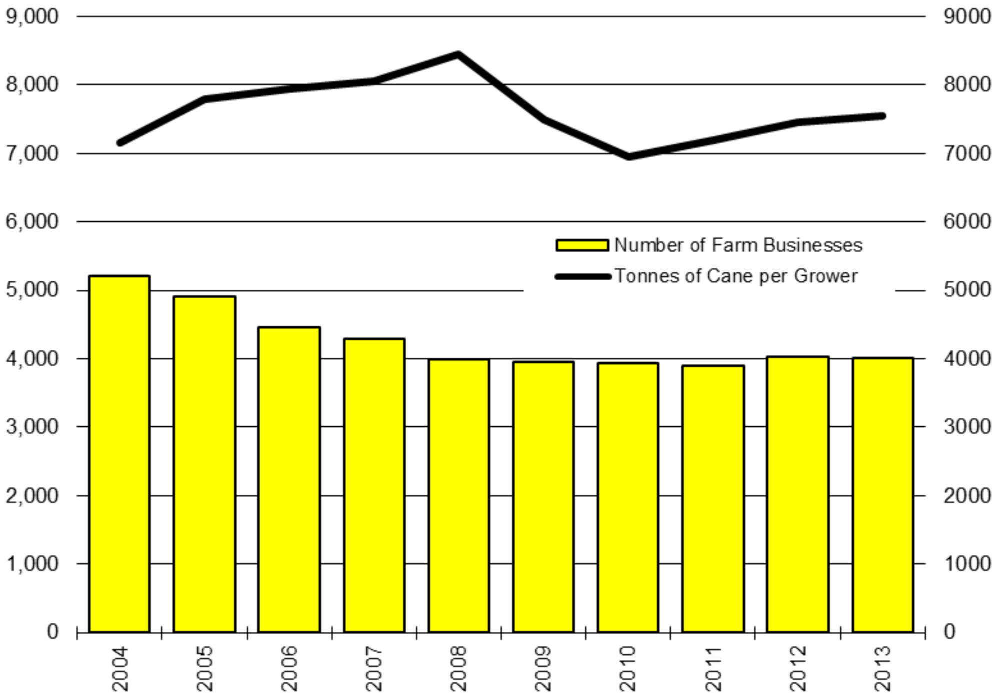
Figure 8 indicates that over the last decade the sugar industry has been going through a period of consolidation, with the decreasing number of farm businesses stabilising in 2011. CANEGROWERS note in their 2010-2011 annual report that the number of cane growers has fallen by 40 per cent during the last decade. In particular, during the period 2005-06 to 2007-08 the number of cane growers in Australia reportedly fell by 15 per cent (Hooper, 2008).

Figure 8: Recent trends in sugar cane production



Source: CANEGROWERS, 2013.

Figure 9: Recent trends in sugar cane production

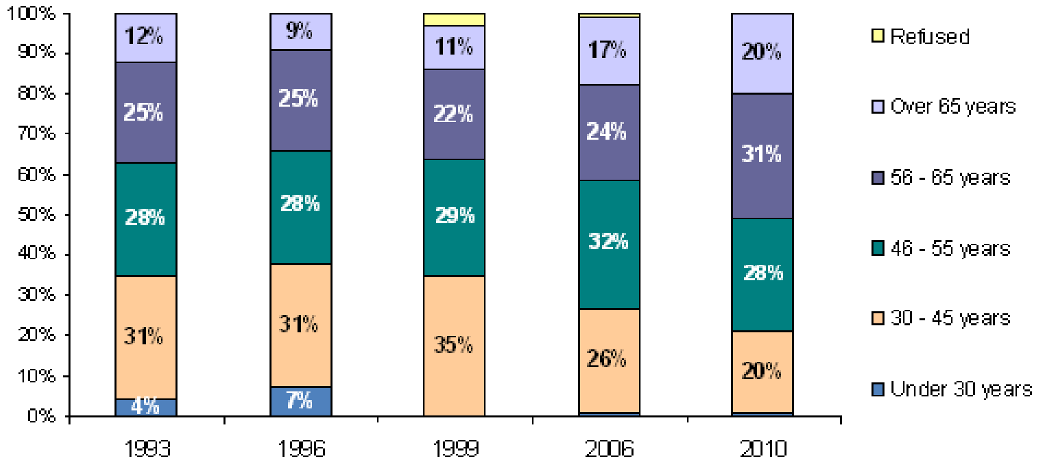


Source: CANEGROWERS, 2013.

Future upside risks for the sugar industry are that production increases in line with industry projections and that world prices strengthen due to growing consumer demand from emerging Asian economies, especially China and India. Nevertheless, any implied economic gain from increased production and/or strengthening sugar prices does not necessarily equate to higher profitability for farm businesses. Business profitability depends on whether the local market price exceeds the average cost of production. What the analysis undertaken above indicates is that, from an industry perspective, gains from higher output prices in recent years have corresponded with increased production costs for major inputs such as diesel and fertiliser as well as relatively low levels of production. Major factors causing a decline in production in recent years include adverse weather events and an incursion of sugarcane smut. Increases in fixed costs such as insurance, salaries, registrations and government charges (e.g. electricity and water), have also reinforced these pressures on grower margins.

Another key characteristic of the sugarcane industry is the ageing demographic of its farmers. Figure 10 clearly illustrates that age brackets representing cane farmers reporting to be 56 years or above have been widening over the last two decades while the 46 to 55 years bracket seems to have remained the most stable. In 2010, 20 per cent of cane farmers reported being over 65 years, 51 per cent reported being 56 or older, 79 per cent are 46 or older, while only 1 per cent are under 30 years.

Figure 10: Age of main decision-makers for cane farms



Source: CANEGROWERS, 2010a.

Industry demographics and the business environment are key points to consider when developing extension strategies focused toward encouraging the adoption of improved management practices. At present there is a lack of information exploring the risks (including economic) associated with management practices in the sugarcane industry, along with consideration of the business environment and an individual's willingness to adopt a new practice.

2.2 Key economic indicators of profit and performance

2.1.1. Economics of the farm business

Economics is the study of how people make decisions regarding the allocation and management of their scarce resources (Gans et al., 2009). Since farm managers are faced with many decisions involving how to best allocate their resources efficiently and effectively within a farming business, economics forms an integral part of the farmer's decision making process. Over time the farming business has constantly evolved with 'more and more mechanisation, continued adoption of new technologies, growing capital investment per worker, large amounts of borrowed capital, increasing farm size, new marketing techniques and increased risk' (Kay & Edwards, 1994, p.1). As the farming business changes, competitive forces place increasing demands on farmers to continually embrace practice change as Makeham and Malcolm (1993, p.vii) discussed almost two decades ago:

> "It is ironic that one outstanding feature of farming is the unchanging nature of the task and that an equally prominent aspect of farming is the constant need for change which all farmers confront. Farmers can either willingly embrace and adopt change, or have change imposed on them; avoiding change is not an option. The way of farming life is unchanging in essence but the business is constantly changing."

With the increasing complexity of the farm business there is a growing need for managers to have a clear understanding of the economic implications of their business decisions. Farm managers also need to have a clear understanding of the uncertainty of decision making and associated risk. Thus economics, as a critical part of business management, is becoming increasingly important for today's farm managers.

2.1.2. Key economic measures

Profit is the fundamental measure of economic performance at a farm level. Profitability indicators measure the relationship between revenues of the farm enterprise and the costs of the inputs (resources) required to produce its output. While a whole-of-farm economic analysis is the most comprehensive method to evaluate farm profit, the Farm Gross Margin (FGM) is a common economic measure used to evaluate the contribution of farm activities to profit. The FGM represents the marginal income derived from production once variable costs have been deducted from gross income. The FGM can thus be written as follows:

$$\text{Farm gross margin} = \text{gross revenue} - \text{variable costs} \qquad (1)$$

The FGM is a particularly useful guide when evaluating the financial impact of farming system adjustments that do not require a change in a fixed input or resource (e.g. land and fixed capital). However, FGM is not a comprehensive measure of profit as it does not take fixed costs into account. Taking fixed costs into account the operating profit is calculated as follows:

$$\text{Operating profit} = \text{total gross margin} - \text{fixed costs} \qquad (2)$$

With the development of the Farm Economic Analysis Tool (FEAT) (Cameron, 2005), it is straightforward to calculate FGM, operating profit and many other financial indicators for cane farming operations. Developed under the Queensland Government FutureCane initiative, FEAT is a computer program written specifically for evaluating cane farm enterprises. FEAT is designed to allow growers to undertake a whole-of-farm economic analysis or to compare the economics of various components of a new farming system. The adoption of FEAT has become widespread and it is commonly used to conduct economic analyses of cane farm operations.

Once farm-specific data is entered into the FEAT program the results may be transferred into custom-made spreadsheets to become input parameters for financial models such as discounted cash flow (DCF) analysis and other cost/benefit analysis approaches to conduct whole-of-farm evaluations. The DCF analysis involves calculating the present value of the future cash-flow stream (or the flow of economic benefits) using the following equation:

$$PV = \frac{C_1}{1+i} + \frac{C_2}{(1+i)^2} + \ldots + \frac{C_n}{(1+i)^n} \qquad (3)$$

where

PV = present (market) value,

C_t = expected incremental net cash flows in period t, and,

i = discount rate.

The discount rate applied to the cash-flow in each period represents the required rate of return on the project. In an economic sense, this rate of return is the opportunity cost of investing in a project that has the same risk profile. A nominal discount rate between 6 per cent and 8 per cent is generally used to convert the future cash-flow stream of the cane business into its present value in today’s dollar terms (see, for example, Poggio et al., 2010; East, 2010). The present value of the cash-flow stream given by Equation (3) is then compared with the initial cost to determine its net present value (NPV).

In practical terms, the NPV analysis provides a set of objective criteria (e.g. NPV, internal rate of return, payback period, and break-even capital expenditure) that is useful to evaluate and compare the economic effects of adopting various farm management practices within the farm enterprise (and thus quantify the relative economic advantage). Given the appropriate parameters, a positive NPV indicates that the practice change is acceptable as the economic benefit is greater than the opportunity cost to implement it. On the other hand, the practice change should be rejected if the NPV turns out to be negative as the cost will exceed the economic benefit. When comparing different scenarios a larger positive NPV is indicative of a superior investment, or higher relative advantage from a profitability perspective, over the investment horizon.

Where the expected incremental change to the net cash flows (i.e. net benefits) from Equation (3) is assumed to be a constant value each year it may be treated as an annuity. The NPV figures can then be transformed into an annualised figure using the Equivalent Annual Annuity (EAA) approach[2]. This approach is particularly useful to compare capital investments that provide economic benefits/costs over different economic horizons[3]. The Annualised Equivalent Benefit (AEB) is formally expressed as:

$$AEB = \frac{NPV}{PVAIF} \qquad (4)$$

where,

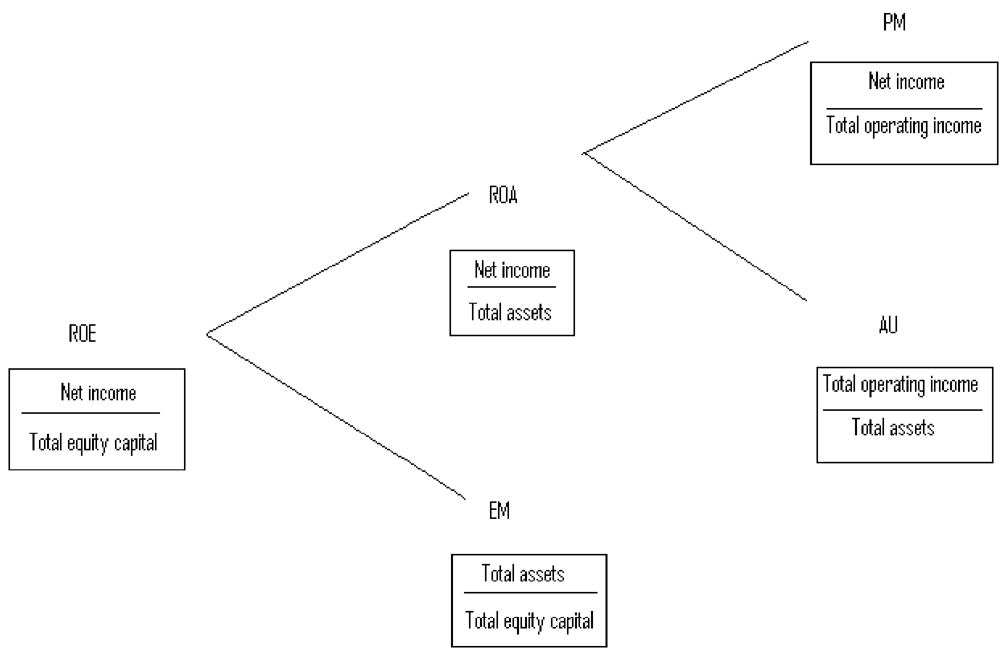
$PVAIF$ is the present value interest factor for annuities $= \left(1 - \left(\frac{1}{(1+k)^{n}}\right)\right) * k^{-1}$.

Difficulties arise when evaluating the results of a NPV analysis due to the need to estimate uncertain future cash-flows based on the assumption that variables such as future output prices, input costs and yields can be forecasted with sufficient accuracy. This is especially relevant when evaluating a change in management practice due to the volatility associated with the farming enterprise, including world prices, production and inputs. To account for this risk in an objective way several different methods can be utilised, including stochastic simulations, sensitivity analysis and scenario planning. PiRisk (Primary Industries Risk Analysis Tool) is a stochastic simulation tool frequently used in past sugarcane economic work. PiRisk, which was developed by the Queensland Department of Primary Industries & Fisheries using the Microsoft Office program, allows for random simulations to be conducted over the various sources of uncertainty. The resulting risk assessment can then be presented in a cumulative frequency distribution displaying the expected outcomes and their associated probabilities (see, for example, The State of Queensland, 2011b).

[2] See, for example, annual equivalent cost and annual equivalent benefit in Ross et al., 2011.
[3] Capital investments typically have different life spans; this implies that their cash flow streams tend to vary accordingly.

While economic analyses such as NPV may be used to evaluate latent investments, one way to measure the historical performance of the farm enterprise is by conducting a farm business performance analysis. This method is distinctly different from the economic analysis process used to assess a change in farm management practice and instead employs historical financial information to assess the past profitability of a business. This method commonly draws upon information from financial statements and presents it in a form that can be utilised for management purposes. This type of analysis allows one to evaluate financial performance over time and compare that level of performance to other investment opportunities.   This process utilises financial ratios that provide a strategic view of the farm business and thus is a useful tool to help identify potential weaknesses and problem areas relating to financial performance. The relationship between the various financial ratios is depicted in Figure 11.

Figure 11: Financial ratio analysis



Source: Adapted from Lange et al., 2007.

The return on equity (ROE) ratio represents the net income (profit) per dollar of equity. The value in equity (or net worth of the farm) is calculated by subtracting the total market value of the farm liabilities from the total value of farm assets. The ROE is dependent on the return on assets (ROA), which is the profit per dollar of total assets, and the degree of financial leverage that is captured by the equity multiplier (EM). The total value of the farm assets represents the market value of land and improvements, machinery, equipment as well as inventories of produce and inputs. ROA thus measures the extent to which the assets of the business are producing profit.

The ROA is a product of the profit margin (PM) and the asset utilisation ratio (AU). The profit margin is the profit per dollar of operating income (i.e. revenues) while the asset utilisation ratio represents the operating income per dollar of total assets. An important consideration for the farm business is the extent to which the farm's assets are being utilised efficiently and effectively. The AU therefore reveals how much revenue is being generated per dollar value of the farm's current assets.

Since net income and revenue are both flows (i.e. they accrue over a period of time) and the total value of assets is a stock (i.e. a measure of value at one particular time), it is standard practice to use the average value of the assets over the period of analysis. This is often done by taking the average of both the opening and closing balances of the assets.

2.1.3. Past economic performance of cane farming businesses

Despite the adoption of innovative farming practices in Australia leading to substantial improvements in economic performance, other factors such as weather events, pest incursions and market volatility have resulted in considerable variability in annual performance over recent years. For instance, Hooper's (2008) survey of cane industry performance during the period 2006-07 reported that farm cash incomes rose 40 per cent from the previous period to average $94,000 while in the following 2007-08 period farm cash income fell 94 per cent to average around $7,000 per farm. The average gross margin of production was estimated to be around $3.10 per tonne in 2007-08, significantly lower than margins in the preceding years of $9.10 and $11.30 per tonne reported for 2005-06 and 2006-07, respectively (Hooper, 2008).

Results from Resource Consulting Services (2012) indicate that the ROA for cane farm businesses across the Northern Region has fallen on average over the period 2008-09 to 2010-11. In 2008-09 the average ROA for a sample of 16 cane farms was 4.6 per cent. With an increased sample size of 30 cane farm businesses for the next two consecutive years, the average ROA fell to 2.8 per cent and 1.4 per cent in 2009-10 and 2010-11, respectively. What these statistics tend to reinforce is that farmers have faced difficult operating conditions in recent years with the return on investment over this period often marginal from an economic perspective. One needs to keep in mind that ROA is calculated using the net income of the farm business as a proportion of the average value of the assets over that period. Accordingly, a fall in ROA may be attributable to a relative fall in net income, capital appreciation in cane farm assets (i.e. an increase in land value), or both.

3. Review of pesticide and nutrient management practices

3.1. Cause/symptoms of environmental concern

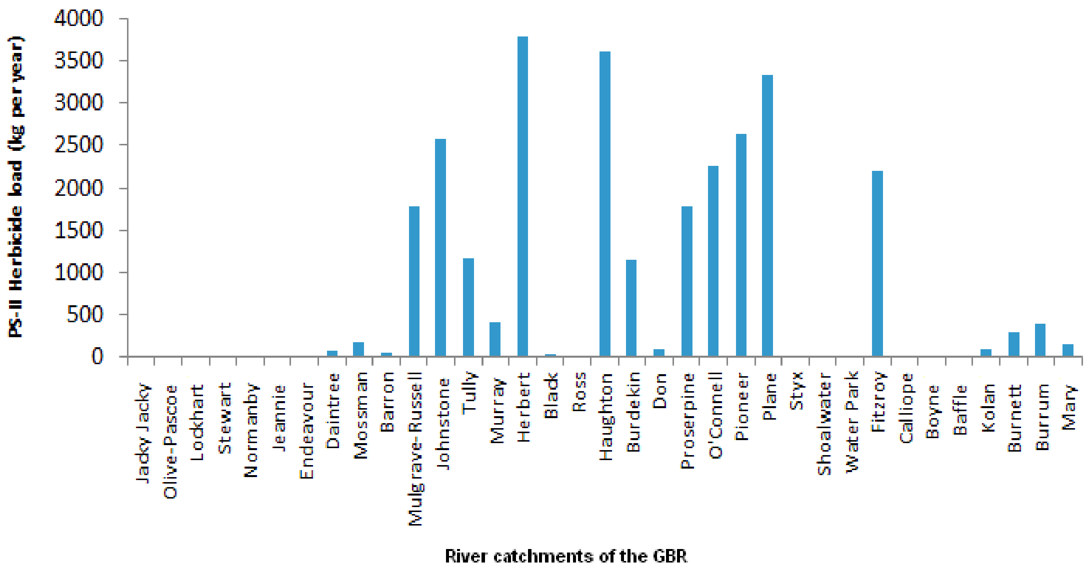
Research by De'ath et al. (2012) indicates that there has been a 50 per cent decline in coral cover within the GBR over the past twenty-seven years; with a significant proportion of that decline attributable to poor reef water quality caused by adjacent land management practices. The environmental impact from land practices that contribute to the displacement of land-based pollutants such as suspended solids, nutrients and pesticides is now a major concern to industry, the broader community and government (see, for example, van Grieken et al., 2011). The 2013 Scientific Consensus Statement (The State of Queensland, 2013b) presents a comprehensive review of the most recent scientific knowledge of water quality issues in the GBR. In this report, the decline in water quality associated with terrestrial runoff from adjacent catchments was identified as a major cause of declining marine ecosystem health: the major water quality risk to the GBR is from nitrogen discharge; while pesticides pose a risk to freshwater and coastal habitats.

Over fifteen years of scientific studies involving surveys of sediment, nutrients, and pesticide concentrations in the GBR lagoon have detected these pollutants at levels considered to constitute a potential threat to the GBR ecosystem (Lewis et al., 2009 in Cook, et al. 2011; Devlin & Lewis, 2011; Brodie et al. 2012). While the impact of pollutants at a molecular level is known, there is still little understanding of the effects of these pollutants on the GBR ecosystem. Terrestrial runoff of sediment and nutrients is thought to be affecting coastal marine ecosystems causing problems such as eutrophication, habitat degradation and loss of biodiversity (see, for example, Thorburn et al., 2011). Although the mechanisms are not fully known, outbreaks of disease on some coral reefs have been found to correlate with increases in nutrient runoff (Haapkylä et al., 2011). Pesticides in runoff (predominantly the herbicides atrazine and diuron) are of concern due to possible impacts on non-target species such as corals and seagrass (Cook et al., 2011). Other proposed links exist between runoff and crown-of-thorns starfish (COTS) that feed on hard coral polyps (Brodie et al., 2012; De'ath et al., 2012). It is posited that increased nutrient delivery from land provides the ideal conditions that are conducive to COTS outbreaks (Brodie et al., 2005).

The cane industry recognises the natural, social and economic value of the GBR and its catchments and the potential implications of its operations on biodiversity conservation, tourism, and fisheries (Wrigley, 2007). Nevertheless, the production of sugarcane currently relies on the application of nitrogen-based fertiliser to enhance/restore soil quality. Nitrogen is a highly mobile nutrient that can be removed from the soil and lost to watercourses through runoff and deep drainage, and to the air through denitrification (Biggs et al., 2012). In 2007 it was estimated that approximately 6.6 million tonnes of sediment found its way to the Reef lagoon from the catchments, which included 16,600 tonnes of nitrogen as well as 4,180 tonnes of phosphorous (The State of Queensland, 2009).

Pesticide usage is also a major component of the overall farming system for Australian cane growers and is generally recognised as a necessary input in order to remain productive and competitive. Pesticide is the generic term that describes a substance or mix of substances used to manage pests. Herbicides, a subclass of pesticides, are widely used to control undesirable competing plant growth and are thus a key component of an Integrated Weed Management Plan. In particular, diuron, atrazine, hexazinone and ametryn have been identified as herbicides commonly found in water sampling that pose the greatest risk to the health of reef ecosystems (Davis et al., 2011). Figure 12 shows recent estimates of PS-II herbicide loads discharged to the GBR from various coastal river systems. (PSII pesticides are herbicides designed specifically to inhibit photosynthesis in plants.)

Figure 12: Recent estimates of PS-II herbicide loads discharged to the GBR



Source: Devlin & Lewis, 2011. Original source: Brodie, Mitchell & Waterhouse, 2009; Brodie, Waterhouse, Lewis, Bainbridge & Johnson, 2009.

Although there are limits to controlling, or even reducing herbicide loads, some understanding of the processes contributing to these losses from farms can lead to improved on-farm management of pesticides (Simpson et al., 2000 in Davis, 2006). Various processes exist that facilitate the loss of pesticides from the farm. Whether these are of a chemical, physical or microbial nature, a key point is that not all pesticides behave in the same manner and differences in application, persistence and mobility will strongly affect the likelihood of losses after application (Davis, 2006).

The underlying message from a farm management perspective is that the major risk periods for off-site movement of pesticides tend to be confined to periods immediately after application. Irrigation or significant rainfall soon after pesticide application generates significant potential for pesticide movement in solution.

Available data suggests that a short time after application, however, the level of pesticide likely to move in solution is drastically reduced - knowledge of these risk windows is fundamental to responsible pesticide management (Simpson et al., 2000 in Davis, 2006).

Any management strategies minimising sediment losses, such as green cane trash blanketing or minimum tillage, should mitigate some of this risk for those pesticides that bind to sediment. With knowledge of the effective time-frame where the potential for off-site losses is greatest, it has been suggested that appropriate strategies can then be developed to avoid or minimise the likelihood of significant runoff or leaching during these periods (Davis, 2006).

3.2. Responses to water quality concerns

3.2.1. Management practice responses to water quality concerns

The widespread adoption of BMPs that improve water quality is considered a key mechanism in improving the overall health of the GBR ecosystem. Ideally, BMPs which focus on soil health, farm production efficiency and precision planning will assist in aligning both economic and environmental interests toward the common goal of a sustainable sugar industry over the long term. A range of management practice responses to water quality issues presently exist. Smith (2008) specifically highlighted farm design issues including initially determining land suitability (environmentally and economically) before production. This necessarily involves identification, development and management of appropriate drainage measures, grassed spoon drains and headlands to buffer and filter runoff, and using unsuitable cropping land as wetlands to trap sediment and 'polish' runoff. Furthermore, appropriate paddock management responses include cultivation practices such as targeting nutrient and pesticide applications, controlled traffic, using trash blanketing to prevent soil erosion silting up wetlands and water courses, and appropriate water management such as recycling irrigation runoff, to name but a few.

Although symptoms of inefficient nutrient management are evident in some farming enterprises, sustainable nutrient management is considered an integral part of sugarcane production (Schroeder et al., 2005). In recent years a 'Six Easy Steps' approach has been developed to facilitate on-farm adoption of best-practice nutrient management. This approach acknowledges the environmental risks associated with fertiliser application in reef catchments; particularly those pertaining to nutrient losses and loss pathways within the system. The intention of the Six Easy Steps approach was to enable growers to make logical, informed decisions about their nutrient inputs which, in turn, improved practices gradually over time. This integrated approach emphasises the importance of understanding soils and their related processes through adopting soil-specific nutrient guidelines, testing at regular intervals, leaf analysis and good record keeping (Schroeder et al., 2005).

A study by Skocaj, Hurney and Schroeder (2012) evaluated the Six Easy Steps approach in the Wet Tropics region and compared its performance to other nitrogen management strategies including the grower practice strategy (a subjective approach based on personal preference or experience prior to regulation) and the CSIRO-developed N Replacement strategy. Based on several demonstration strip trials involving ratoon crops, a main finding of the study was that the Six Easy Steps approach is effective in maintaining sugarcane yields and profitability, despite the application rates being on average 17.5 kg N/ha lower than the grower practice rates. Importantly, applying nitrogen at rates below the prescribed Six Easy Steps guidelines had an adverse affect on grower and mill viability.

Along with nutrient management, pest control is an integral part of sugarcane production. Weeds are the most significant pest for growing sugarcane and are an important issue affecting productivity and profitability (Fillows & Callows, 2011). Methods such as mechanical cultivation of plant cane and herbicides are typically used to control grass, broadleaf weed, sedge and vine (Calcino et al., 2008). Research by Bureau of Sugar Experiment Stations (BSES) has highlighted the potential for monetary loss as a consequence of yield losses if weed control is delayed or omitted. Accordingly, the effective and timely use of herbicides is an important component of an integrated weed management program.

It has been suggested that yields of ratoon cane can potentially be reduced by 7-30 per cent through weed infestation (McMahon, 1989, in Fillows & Callows, 2011). Management of the green-cane trash blanket is considered an efficient practice to manage weeds in ratoon cane. This is not applicable in areas where cane is burnt prior to harvest, such as in the Burdekin Region. Fillols (2012) reports on a number of experiments undertaken by the BSES investigating the optimal thickness of the green-cane trash blanket in addition to the optimal timing of the herbicide applications. The results showed that, in comparison to bare soil, trash at all levels reduced weed coverage and contributed to additional yield and profitability. In particular, increasing the level of trash led to improved management of broadleaf weeds and grasses and strategies involving early pre-emergent herbicides were more efficient.

It is a widely held view that the contemporary industry shift toward controlled traffic farming systems (CTF) holds real potential for improved profitability and environmental outcomes, albeit there is limited published work to support this view. The use of CTF has been largely enabled by the adoption of Precision Agriculture (PA) into the sugar production system. The advantage of using PA over traditional practices (which essentially rely on intuition) lies in the potential for farmers to realise economic benefits due to achieving greater cost-effectiveness in their cropping systems as well as increased efficiency in their fertiliser regimes. In Bramley's (2009) view the sugar industry is ideally suited to PA and suggests key reasons behind its increased adoption stem from the desire to achieve efficiency gains via modernisation of the industry, as well as the need to demonstrate the use of environmentally sustainable best-practice.

In one particular trial on CTF dating back to the mid-1990s, soil erosion from conventionally cultivated ratoon cane lands in the Wet Tropics region of North Queensland was reportedly measured in the range of 47-505 t/ha/yr, with an annual average of 148 t/ha/yr (see Davis, 2006). Trials of alternative management strategies revealed no-tillage practices significantly reduced this erosion to < 15 t/ha/yr although reduced tillage soils tend to erode finer sediment which is suspended longer and is more transportable in runoff.

More recently, a rainfall simulation trial on sugarcane at Mackay compared a CTF system and a conventional system, finding that CTF reduced runoff and that its nitrate and herbicide loads were lower (see Agnew et al., 2011). This trial highlighted a number of key management principles relating to reduced off-site contamination of water from nutrient/pesticide, including the importance of soil traits, input application rates, the length of time between application and the first runoff event, and the filtration of rainfall or irrigation.

Recent case studies have also analysed the potential for legume fallow break crops to improve soil health and reduce tractor operations in addition to fertiliser and herbicide requirements (see, for example, Poggio & Hanks, 2007; Young & Poggio, 2007). Growing a well managed legume crop can also increase soil cover over the wet season and therefore reduce the amount of erosion from surface water movement which, in turn, reduces the potential for sediments containing nutrients and chemicals to enter waterways.

3.3. Review of economic studies involving management practices on sugarcane farms

A number of key economic papers exploring the costs and benefits of improved nutrient management practices for farmers are reviewed below. Very few articles involving similar analyses conducted on pesticide management practices could be found within the literature. Rather, articles mainly addressed the adoption of a whole farming system that included pesticide management as a component within the suite of changes.

3.3.1. Examples of articles examining nutrient management

Poggio and Hanks (2007) conducted a study involving an economic analysis of various fallow management options using the FEAT program. This economic analysis compared the current situation of a bare fallow with conventional farming practices to alternative fallow practices including (a) legume (Ebony cowpeas) fallow with conventional practices; (b) legume fallow with zonal tillage practices; and (c) legume fallow with new farming system (NFS) practices. Results from this economic analysis showed that scenario (c) (i.e. well managed legume fallow with NFS practices) produced the highest FGM and the greatest operating return, which was attributed to reduced tractor operations, savings in fertiliser usage and lower weed control costs. Scenario (b) was also shown to produce a significantly higher FGM than a bare fallow due to reduced tractor labour hours. On the other hand, the legume fallow with conventional farming practices (scenario (a)) produced a similar FGM and operating return to the existing practice of the bare fallow. In this case, the accrued savings from lower fertiliser and weed control costs tended to be offset by increased costs associated with the additional cultivation requirements for the legume crop.

In a similar case study analysis using the FEAT tool, Young and Poggio (2007) compared the economic performance of a conventional farming practice to a NFS involving reduced tillage and the use of a soybean rotational crop that is harvested for seed production. They found similar results (i.e. increased FGM and higher operational return for the new system) based on the assumption that the legume crop increases the cane yield. Greater economic performance was attributed to lower variable costs (from less tractor hours and fertiliser needs) and the additional revenue from the soybean crop.

A recent study by van Grieken et al. (in press) investigated the cost-effectiveness of adopting nutrient management activities that improve water quality by reducing losses of Dissolved Inorganic Nitrogen (DIN) from sugarcane farms. The study is one project within the Reef Rescue Research and Development Water Quality Program, which is funded under the Australian Government's Caring for our Country program. The specific focus of this study was to examine the cost-effectiveness of practice change in a socio-economic, institutional, as well as financial-economic context across the Wet Tropics, Burdekin, and Mackay Whitsunday regions. The financial-economic component identified various changes to nutrient management practices that reduce DIN losses from the farm and are likely to be profitable. It also highlighted the variation in economic modelling outcomes between regions due to bio-physical characteristics and enterprise structure.

A summary of key findings from the financial economic component of the study is listed as follows (van Grieken et al., in press, p. *v*):

- "changing from old industry recommended rates to Six-Easy-Steps is profitable and provides overall water quality benefits (total DIN reduction);
- changing from Six-Easy-Steps to N-Replacement nutrient management resulted in a financial cost to the farmer, although providing a substantial water quality improvement in the Wet Tropics and Mackay Whitsunday, and with limited cases in the Burdekin;
- changing from Old Industry recommended rates to N-Replacement nutrient management rates provides a financial benefit in a legume fallow system; however, was found to come at a cost in a bare fallow system. The resultant change in practice provides a water quality benefit for both types of fallow management.
- in the absence of yield improvement, results indicate that moving from a bare fallow to a legume fallow cover crop will generally result in a financial cost to the farmer (especially for small farms due to the required capital expenditures), and will only improve DIN in specific cases (dependent on nutrient and tillage management);
- moving from high tillage to low tillage will generally provide financial benefits, with water quality benefits being quite variable and regionally specific;

- improvements in machinery operation efficiency and economies of scale are evident between small, medium and large farms;

- the results indicate that moving beyond commercially tested nutrient management is likely to come at a cost."

3.3.2. Systems approach papers

Roebeling, Smith, Biggs, Webster and Thorburn (2004) examined the cost-effectiveness of implementing BMPs for water quality improvement at the plot level for the Douglas Shire Water Quality Improvement Program. The study evaluated several BMPs with a focus on nutrient, soil and water quality using specialized agronomic production simulation models and a hydrological model combined with cost-benefit analysis. Results of the study found that improved practices such as reduced tillage, legume fallow crops and reduced nitrogen application are economically viable at the farm level. Nevertheless, the improvement in water quality resulting from the adoption of these management practices is likely to be relatively small. The authors concluded that far stronger positive effects on water quality are likely to result from the provision of incentives that lead to the adoption of management practices that are otherwise not economically viable at the farm level (e.g. spoon-shaped cane drains).

In a more recent article Roebeling, Webster, Biggs and Thorburn (2007) examined the cost-effectiveness of implementing various BMPs for water quality improvement in the Tully-Murray catchment. The study used production system simulation models in conjunction with water quality models and cost-benefit analysis to analyse the economic effect on FGM together with the implications for water quality. Results showed that a majority of the BMPs were attractive from a financial-economic perspective as well as leading to improved water quality based on the effectiveness of these BMPs in reducing water pollutant delivery (i.e. fine suspended sediment, DIN, and persistent herbicide delivery).

The results from Roebeling et al. (2007) suggest that tillage management (moving towards zero tillage) and fallow management (moving from bare to legume fallow) were found to be cost-effective from a financial-economical perspective, however, only tillage management was found to lead to a reduction in fine suspended sediment delivery. Applying nitrogen at rates that are appropriate to crop requirements is also deemed to be beneficial economically as well as environmentally from the perspective of reduced DIN delivery. On the other hand, it was found that moving towards split nitrogen application resulted in marginal changes in profitability and water pollutant delivery. While reduced herbicide application using a hooded sprayer led to a considerable reduction in persistent herbicide delivery, it was found not to be cost-effective, resulting in a small decrease in FGM.

Another paper by Strahan (2007) analysed the economic benefits of changing to more sustainable cane farming practices in two catchments of the Mackay Whitsundays region based on the Mackay Whitsunday Natural Resource

Management body's farm management classification system (ABCD framework). The study involved selecting representative cane farms and modelling the economic implications of the various changes using FEAT. A risk analysis was also performed using @risk which resulted in a set of distribution curves showing the probability of possible farm business profit for each management level. Taking into account the required capital investment, the viability of each option was evaluated using a standard discounted cash flow investment analysis.

The results indicated that significant benefits are achievable by adopting the higher level sustainable farm management practices. In comparing the relative impacts of each practice change, significant gains could be achieved by progressing from conventional (C-class) to best management (B-class) practices and these changes provide relatively greater benefits to profitability at lower cane prices. These improvements were predominantly achieved from realising savings to the cost of production which are independent of the price of cane. However, changing from C-class to B-class requires significant changes. For example, changing from C- to B-class practices involves upgrading the ripper and fertiliser box, acquiring a new spray unit and a bed former, in addition to matching row spacing with machinery width to achieve controlled traffic. Whilst making significant changes over the entire farm involves a higher level of whole farm planning, thus requiring more time to do so, there is reduced chemical use and cultivation. Strahan (2007) suggests it will take at least five years to implement these changes over the entire farm.

A series of similar papers relating to Paddock to Reef Monitoring, Modelling and Reporting work (East, 2010; Poggio & Page, 2010a; Poggio & Page, 2010b; Poggio & Page, 2010c; Poggio, Page & Van Grieken, 2010a; Poggio, Page & Van Grieken, 2010b; Poggio, Page & Van Grieken, 2010c; Van Grieken, Poggio, Page, East & Star, 2010) evaluated the transitioning to improved sugarcane management practices in the Tully, Burdekin, and Mackay Whitsunday regions. Specifically, they compared FGM, conducted capital budgeting analysis on investments associated with the transition, and performed risk analyses for cane yields and prices. Irrigation management and legume yield were also examined, as were the effects on viability considering factors such as farm size, capital investments and legume fallows.

The Paddock to Reef work found that it generally benefitted the farmer to transition from dated (D-Class) to C-class practices. In all but the Mackay Whitsunday case study, it was economically viable to transition from the C- to B-class practices, depending on the capital investment required and the length of the investment horizon. Transitioning from B- to aspirational (A-class) practices is harder to achieve and is largely dependent on the farmer's ability to successfully implement these commercially unproven practices. Negative NPVs were generally observed for transitions from B- to A-class (except in the Mackay Whitsunday case study), which highlights that appropriate incentives may be required to be provided to growers to achieve this level of change if deemed necessary for environmental improvement.

Research by Poggio et al., (in press) evaluated a multitude of management practice options in order to identify profitable abatement opportunities for PSII herbicides and their alternatives from three major sugarcane production districts located in the GBR catchment. Evaluation of the management practices are each classified on the basis of their perceived potential to improve water quality on cane farms, in particular these include:

- moving between C-class, B-class and A-class practices for herbicide management;
- moving from C-class to B-class practices for tillage and fallow management; and,
- moving from standard to alternative chemicals.

The key findings from the research are listed as follows (Poggio et al., in press, p *i*):

- "The results identified a number of key sugarcane management practice options that have the potential to improve water quality (or facilitate this process) and are also expected be worthwhile economically to implement.
- The economic and water quality results were found to be critically dependent on regional-specific variables including biophysical characteristics and enterprise structure, especially in relation to farm size and location.
- The economic analysis indicated that progressing from C- to B-Class herbicide management is generally expected to be profitable and provide the highest return on investment (IRR) across all farm sizes and cane districts. The magnitude of the return on investment has a positive relationship with farm size, primarily because the CAPEX is spread across a greater productive area on larger farms.
- The period it takes to payback the initial investment when moving from C- to B-Class herbicide management is expected to be 2 years for 50ha farms and one year for 150ha and 250ha farms.
- The water quality modelling for Tully indicated that progressing from C- to B-Class herbicide management results in a reduction of up to 14 g/ha/yr (~41%) in PSII-equivalent herbicide (PSII-HEq) losses, depending on fallow and tillage practices. Relative reductions across other cane districts are shown to be up to 10 g/ha/yr (~52%) in Mackay; up to 26 g/ha/yr (~52%) in the Burdekin Delta; and up to 55 g/ha/yr (~48%) in the BRIA.
- The profitability of moving from C- to A-Class herbicide management varies across districts: the payback period for 50ha farms taking 6 years in Tully; 8 years in the Burdekin; while the initial investment is not recoverable over 10 years in Mackay. Payback periods for 150ha farms are 2 years for Tully and the Burdekin and 3 years for Mackay. Similarly, it is 2 years for all 250ha farms.
- Water quality modelling showed progressing from C- to A-Class herbicide management results in a reduction of PSII-HEq losses of up to 29 g/ha/yr

(~83%) in Tully; up to 15 g/ha/yr (~76%) in Mackay; up to 49 g/ha/yr (~98%) in the Burdekin Delta; and up to 109 g/ha/yr (~97%) in the BRIA.

- Moving from B- to A-Class herbicide management is expected to come at an economic cost for 50ha farms. This is predominantly due to the amount of capital expenditure required relative to size of the farming area.

- A change from B- to A-Class herbicide management is expected to be profitable for 150ha and 250ha farms. Results highlight the importance of farm size and the efficient utilisation of capital expenditure.

- Moving from B- to A-Class herbicide management shows significant improvements to water quality: a reduction of up to 15 g/ha/yr (~72%) in PSII-HEq losses for Tully; up to 5 g/ha/yr (~50%) in Mackay; up to 23 g/ha/yr (~95%) in the Burdekin Delta; and up to 55 g/ha/yr (~94%) in the BRIA.

- Risk analysis illustrates the importance of ensuring production is maintained in order to remain profitable. This is especially the case when progressing to A-Class herbicide management, which is based on practices under research and not thoroughly tested on a commercial scale.

- When progressing to improved herbicide management, the combination of fallow and tillage management tends to have a relatively negligible impact on the economic results between comparative scenarios in Tully. In Mackay, progressing to improved herbicide management under a legume fallow and low tillage farming system is marginally more profitable.

- In the Burdekin, progressing to improved herbicide management from C-Class under a bare fallow and high tillage farming system is substantially more profitable than moving under a legume fallow and low tillage system.

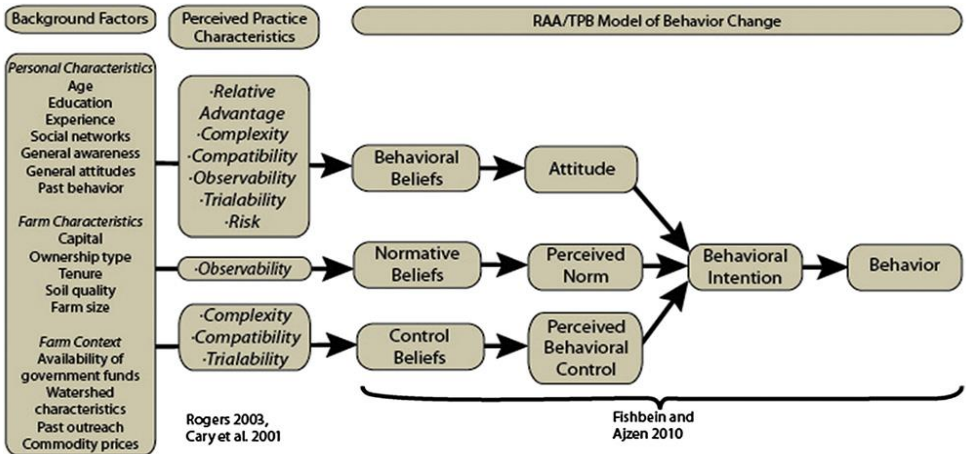
- PSII-HEq losses are greater under a bare fallow and high tillage farming system than under a legume fallow and low tillage system across all cane districts.

- Despite showing substantial water quality benefits, changing from standard to alternative chemicals at current market prices will generally come at an economic cost irrespective of the combination of fallow and tillage practices. However, these costs are relatively lower when using a higher class of herbicide management."

3.3.3. Theoretical concepts of the adoption process

Adoption of practice change by farmers involves a dynamic learning process. While a critical part of beginning to understand the adoption process is knowledge of the economic implications, one also needs to consider other factors that influence adoption. Pannell, Marshall, Barr, Curtis, Vanclay and Wilkinson (2006) acknowledge that these influences are broad in nature encompassing economic, personal, social and cultural factors as well as the characteristics of the practice change itself (see Appendix 1 – Characteristics of management practice adoption). More recently, Reimer, Weinkauf and Prokopy (2011) combine these concepts into a framework (see Figure 13) which models the adoption decision as a function of background factors, the perceived characteristics of the practice change as well as cognitive/behavioural aspects.

Figure 13: Conceptual framework of adoption through behavioural change



Source: Reimer et al., 2011.

Rogers (2003) lists five key characteristics of practice change that help explain the rate of adoption including *relative advantage, complexity, compatibility, trialability,* and *observability*. A relative advantage exists when one particular innovation is perceived to be superior to the idea or practice that it supersedes (Rogers, 2003; Pannell et al., 2006). In this sense, innovations are more likely to be adopted when they have a high relative advantage especially when it is characterised by an economic benefit (Hamilton, 2009). The economic advantage, in terms of the magnitude of the benefit relative to the cost of change, may be evaluated differently by individual farmers. This highlights that economic analyses need to be communicated effectively to non-economists so that they can understand the results and subsequently gauge the relevance of the outcomes to their individual circumstances.

The likelihood of adoption also depends on the ease by which the key drivers of change can be identified and managed beneficially by the farmer (Bramley, 2009). New practices that are viewed as either incompatible with current operations or too complex to implement, thus requiring additional skills and knowledge, will not likely be adopted by farmers (Rogers, 2003). Accordingly, if the farmer has a difficult time trialling or using an innovation, or its benefits are not intuitive to the farmer, this will likely present as a barrier to adoption (Rogers, 2003). The adage 'what the neighbour will think' is also relevant to those living in close-knit, rural communities since growers frequently rely on fellow producers for information regarding farm management and production decisions (see Hooper, 2008).

There is compelling evidence that adoption is also strongly affected by risk-related issues (Sattler & Nagel, 2008; Marra et al., 2003; Beal, 1996 in Greiner et al., 2009). Risk, in an economic sense, is the likelihood that things will not turn out as expected. Deciding on whether to change to an alternative management practice when the consequence of doing so is uncertain is a risky decision for a farmer. Hence, a farmer's individual perceptions about the riskiness of a particular technology and attitude to risk more generally are critical aspects of adoption (Greiner et al., 2009).

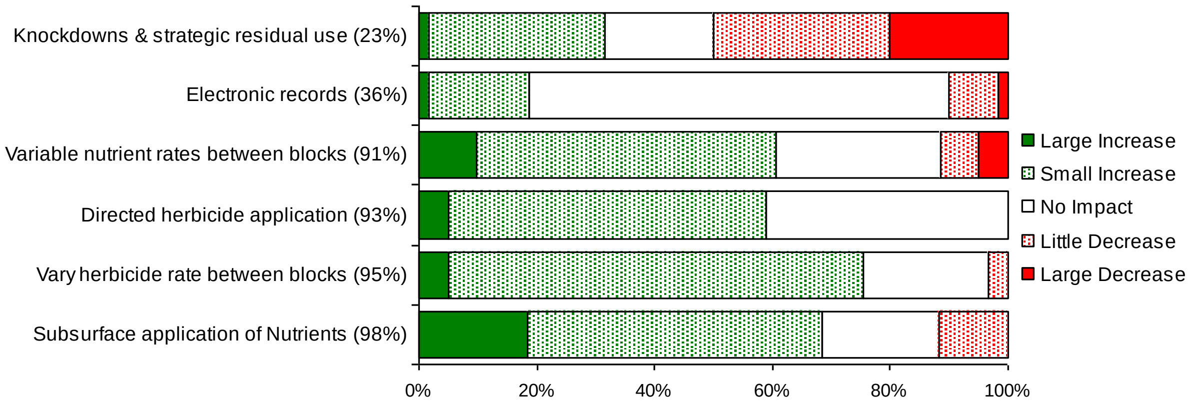
Industry and government have together invested a significant amount of resources aimed specifically at increasing the adoption of management practices leading to water quality improvement. Unsurprisingly, non-adoption or low-adoption of new conservation practices is often explicable in terms of a failure to provide clear evidence of any relative advantage in economic terms (Pannell et al., 2006). Reimer et al. (2011) found that relative disadvantages and incompatibility were the primary barriers to adoption while relative advantage, compatibility, and observability were the most important factors affecting a farmer's decision to adoption improved practices that lead to water quality improvements. What this tends to indicate is that suitable policy interventions that have a low relative advantage (or disadvantage) may require a more focused extension effort than if a high relative advantage is present. Moreover, where little relative advantage exists, positive incentives may be required to facilitate the adoption of practice change.

A recent report by Thompson et al. (in press) collected survey data from over sixty North Queensland cane farmers from Ayr, Ingham, and Tully with the purpose to develop a profile of grower's perceptions toward the characteristics of various management practices. Characteristics targeted in the survey questions included: the implications for profitability from adopting the practice; trialability of the practice; the capital investment requirements to adopt the practice; and compatibility of the practice to fit in with the existing farming system. The adoption rate for each practice was also noted (see Appendix 3 – Average perceptions of practice adoption).

Practices that were found to have high adoption rates were perceived by growers to have a positive impact on profitability (see Figure 14). These practices included: *sub-surface application of nutrients* (98 per cent adoption rate); *vary herbicide rate between blocks* (95 per cent); *directed herbicide application* (95 per cent); and *variable nutrient rates between blocks* (91 per cent). Conversely, the second least adopted practice *knockdowns and strategic residual use excluding Diuron, Atrazine, Ametryn and Hexazinone* (23 per cent) was perceived to have the greatest negative impact on profitability (see Figure 14).

Similarly, practices with relatively high adoption rates had perceived characteristics that would appear to incentivise adoption. A majority of growers generally agreed that these practices were compatible with existing farming systems and they were easy to trial. On the other hand, these growers tended to disagree that the practice requires a high capital investment, new skills and contractors to implement. Other management practices had characteristics that could be deemed to be potential barriers to adoption. For instance, despite both practices being perceived as profitable, *variable nutrient rates within blocks* and *precision and directed herbicide* *application* had the lowest (7 per cent) and fourth lowest (48 per cent) adoption rate, respectively. This is unsurprising, however, given that the majority of growers strongly agreed that: adopting *variable nutrient rates within blocks* requires a high capital investment as well as new skills and information; and adopting *precision and directed herbicide application* requires a high capital investment. The third least adopted practice, *electronic record keeping* (36 per cent), is also a case in point. Given that this practice is mostly perceived as having no impact on profitability (see Figure 14), there is little financial incentive for adoption. Furthermore, most growers tended to strongly agree that the practice requires new skills and information.

Figure 14: A comparison of the perceived impact on profitability from practice adoption



Source: Adapted from Thompson et al. (in press); adoption rate for each practice in brackets.

Growers were also classified into either adopters or non-adopters in order to analyse whether there was a statistical difference between their perceptions. Finding evidence about the differences in perceptions between growers may provide further opportunities to better target extension and ultimately enhance practice adoption. Accordingly, profitability and compatibility within the existing farming system were both found to be critical factors that affect the adoption decision. On average, the findings indicated that adopters were more inclined to perceive practice adoption as resulting in greater profitability than non-adopters; while adopters perceived practices to have greater compatibility within their existing farming system. A practice being perceived as having a relatively high capital investment requirement was also found to be an important consideration affecting the decision to adopt *precision and directed herbicide application*.

Interestingly, farm and farmer characteristics (e.g. age, education, farm size, etc) were found to be relatively insignificant in determining whether to adopt a new practice. Notable exceptions to this were: the farmer's age in the case of adopting *precision and directed herbicide application* and *electronic records;* and farm size in the case of adopting *precision and directed herbicide application*.

4. Key findings and information gaps

A number of key aspects concerning industry economics and water quality issues that directly relate to the RWQ economic research project have been discussed in this report. First, years of scientific literature acknowledges that water entering the reef from the three key cane growing areas (Wet Tropics, Dry Tropics/Burdekin and Mackay Whitsundays) poses a significant risk to the health of the GBR ecosystem. Second, finding tractable solutions to minimise nutrient and pesticide runoff entering the GBR catchment have become primary issues for concern. Third, the efficient adoption of BMPs that maintain/improve production and profitability, while improving water quality, is considered a key mechanism in improving the overall health of the GBR ecosystem. Fourth, there has been limited economic work carried out linking practice change to environmental and social issues in the GBR catchment.

Today, the relevance of employing economics to solve problems primarily concerned with the efficient and effective allocation of resources often fails to find traction within many of the public programs seeking to find innovative solutions that improve the environment while at the same time increasing the profitability of industry. The analysis of recent economic conditions in the sugar industry indicates that cane businesses are under substantial pressure from cost-price squeeze and volatility from market and production risks. In this operating environment it is clear that priority should be given to identifying BMPs that are cost-effective and profitable to implement. Unsurprisingly, recent research presented in this report indicates that BMPs with high adoption rates tend to have a positive relationship with grower perceptions about their impact on profitability (Thompson et al., in press).

The Initial Synthesis Report (Smith, Poggio & Larard, 2012) highlighted the fact that previous studies have tended to analyse practice change from an academic perspective, placing little emphasis on the heterogeneity of farm enterprises across individual landholders and regions. Each sugarcane production region has unique biophysical and socio-economic characteristics that influence the sugarcane production system and management practices used by the landholder. In order for landholders to proactively adopt these practices it is thus critical to identify specific management practices that are most likely to lead to both water quality improvement and increased profitability. Whilst this report identified abundant literature on sugarcane management practices that minimise environmental risk, often that literature lacks an accompanying economic assessment of implementing those management practices. What is apparent from the literature review is the paucity of studies that undertake economic analyses of the cost to change individual practices and how this affects the farm business at both an operational and economic level.

Recent studies by Poggio et al. (in press) and Van Grieken et al. (in press) aimed to address some of the issues identified in the Initial Synthesis Report. These studies undertake economic work at the practice level and integrate water quality data into the analysis to identify the most cost-effective practices that achieve desirable water quality outcomes. Analysing at a practice level for pesticides and nutrient management is beneficial in terms of being able to isolate an incremental change in management practice and its resultant impact on farm profitability, water quality, and adoption characteristics. Enterprise heterogeneity was also taken into account in this study by incorporating location, farm size, soil type, and management practice characteristics.

With respect to information gaps, work undertaken by Poggio et al. (in press) acknowledges that there is a lack of knowledge about the water quality and economic implications of irrigation recycling pits. Addressing this information gap would increase the accuracy of the water quality results in the Burdekin region and provide a better understanding of the economic implications. Furthermore, testing is required to enhance the original water quality modelling work on herbicides, such as revisiting the assumption that the combined effect of herbicides in a mixture is concentration additive. There is also a need for future research to investigate mixture toxicity of herbicides on locally important species relevant to the GBR, particularly with respect to the relatively new alternative chemicals analysed in this project. This is especially the case where sparse scientific work has been previously undertaken.

A review of existing literature identified a gap in reported data pertaining to the performance and profitability of cane businesses. Access to a small amount of industry financial information (such as, for example, ROA reported in Section 2.2.3) has been achieved due to related work in other projects, however, this has been taken from a relatively small sample group consisting of just three years of financial reporting. Acquiring and collating more data in this area will help make information more accessible in line with other agricultural industries (e.g. beef industry), which may indeed enhance policies to improve adoption.

5. Future research

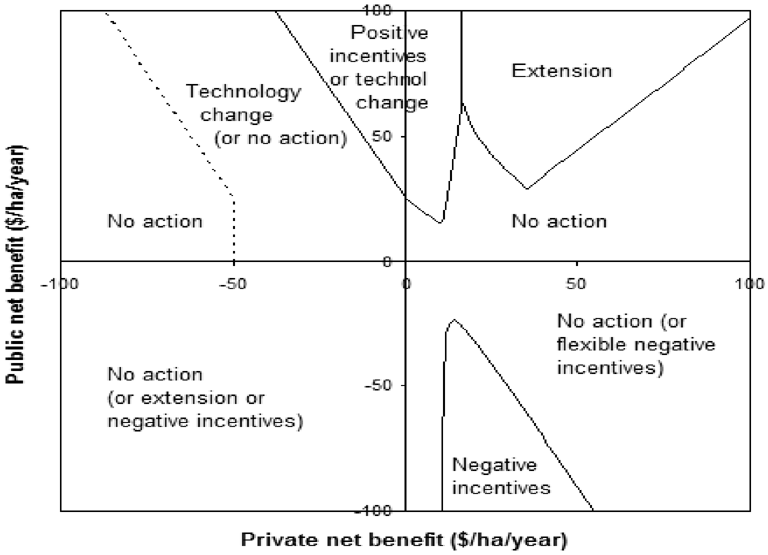
There are a number of avenues for further economic research that will build on recent economic work to support policy development in the future. A targeted analysis focused on specific case studies would serve to confirm the findings from the stylised scenarios examined here, especially in light of the heterogeneous nature of each region. This is particularly the case regarding A-Class management practices, which are based on practices under research and not thoroughly tested on a commercial scale. Accordingly, this would necessary involve continuing to work together with agronomists and individual growers to demonstrate the practical implications of these management practices in a commercial setting. Furthermore, this would assist with extension efforts to increase adoption and to verify the bio-physical, economic, and water quality results.

There is also a need to better understand the economic implications for achieving concrete ecological targets to achieve the environmental aims set out in Reef Plan. The recent economic work undertaken in the cane industry provides a very solid foundation for this work to occur. In turn, this would enable the current economic and water quality modelling results to be used to determine the costs and benefits of achieving these aims as well as optimal combinations of growers to target by farm size and by region.

Another interesting avenue is concept work that develops an integrated framework in which appropriate policy mechanisms to improve adoption by growers can be assigned directly to social and economic barriers to adoption. For instance, Pannell (2008) developed an adoption framework (see Figure 14) that seeks to objectively identify the appropriate policy mechanisms to encourage farmers to modify their current land use. In particular, the framework proposes that the relative levels of private (internal) and public (external) net benefits[4] should play a critical role in the selection of policy approaches to encourage environmentally beneficial land usage. Gaining a firmer understanding of the relationship between these private and public net benefits, as well as to what extent these benefits are measurable across the various sugar cane regions, will ideally enable a more targeted policy approach.

[4] Private net benefits are benefits less the cost that accrue exclusively to the private land manager, while public net benefits are benefits less the cost that accrue to everyone else except the private land manager (see Pannell, 2008).

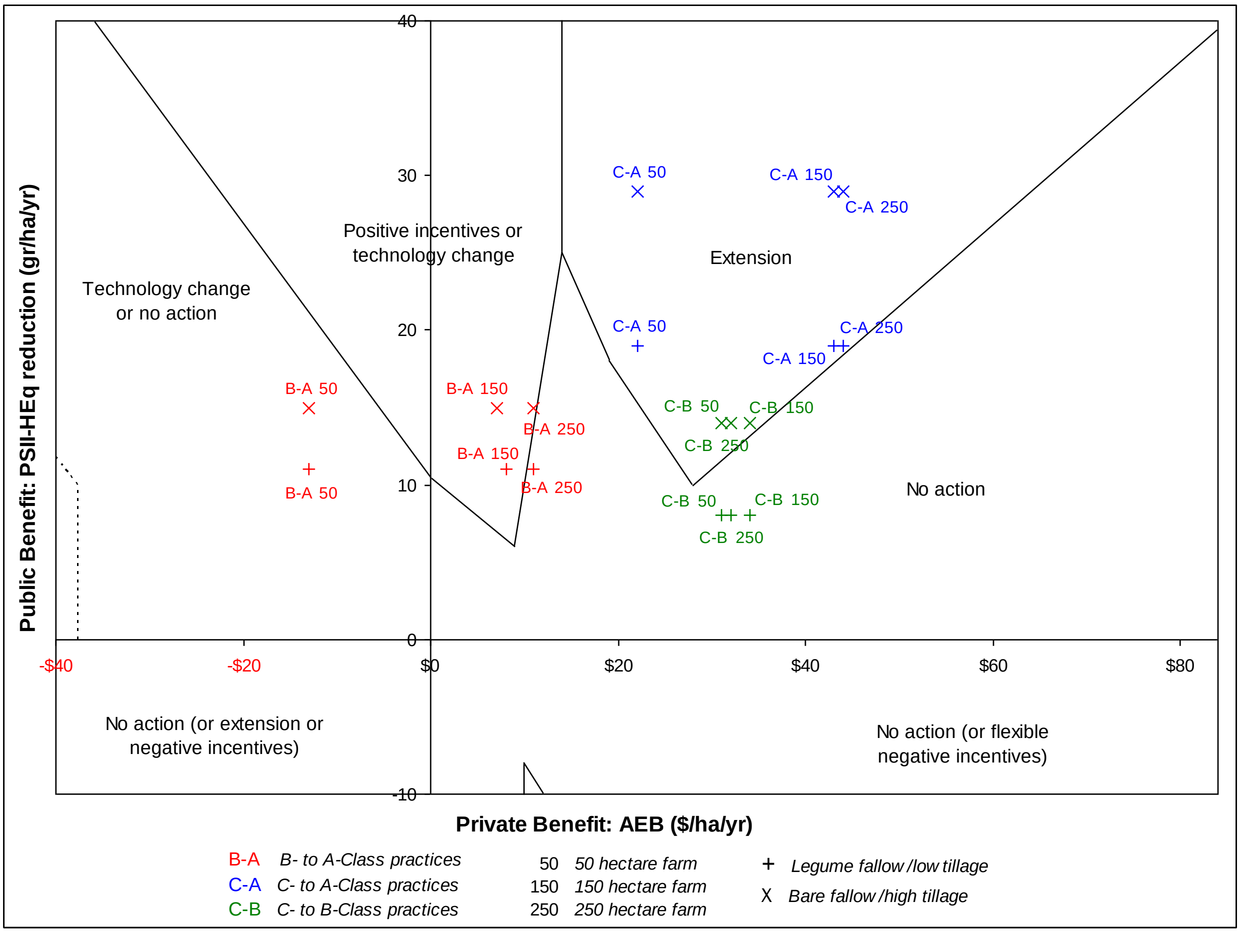
Figure 15: Efficient policy mechanisms for encouraging land use on private land



Source: Pannell, 2008. Model refined to account for lags to adoption and learning costs, and assuming that managers require benefit:cost ratio ≥ 2.0.

Preliminary work has been undertaken to demonstrate the practical application of this work through the merger of empirical results from Poggio et al. (in press) into the theoretical frameworks proposed by Pannell (2008). This work aims to assist Natural Resource Management (NRM) organisations and policy-makers to choose appropriate policy mechanisms that encourage growers to adopt improved herbicide management practices and maximise the net benefit of intervention. An example of this work is presented in Figure 16.

Figure 16: Efficient policy mechanisms to encourage improved herbicide management in Tully



An important issue with integrating this new work into Pannell's (2008) model is that the public benefits on the y-axis are not measured in monetised value. Instead, these values are plotted in terms of the physical level of PSII- HEq abatement when implementing each change in herbicide management. While, in its present form, the graph in Figure 16 is not functionally equivalent to the Pannell model, transposing the conceptual aspects of the model onto the findings from Poggio et al. (in press) tends to produce intuitive results.

For instance, in Tully, *extension*[5] efforts are best targeted on encouraging growers to shift to improved herbicide management where there is likely to be a relatively large public as well as private benefit in doing so. This is represented on the graph by transitions from C- to B-Class herbicide management (bare fallow and high tillage combination) and also from C- to A- Class management.

On the other hand, encouraging growers to transition from B- to A-Class herbicide management may warrant *positive incentives*[6] *or technology change*[7]. Some of these practices are shown to come at a cost to the grower to adopt.

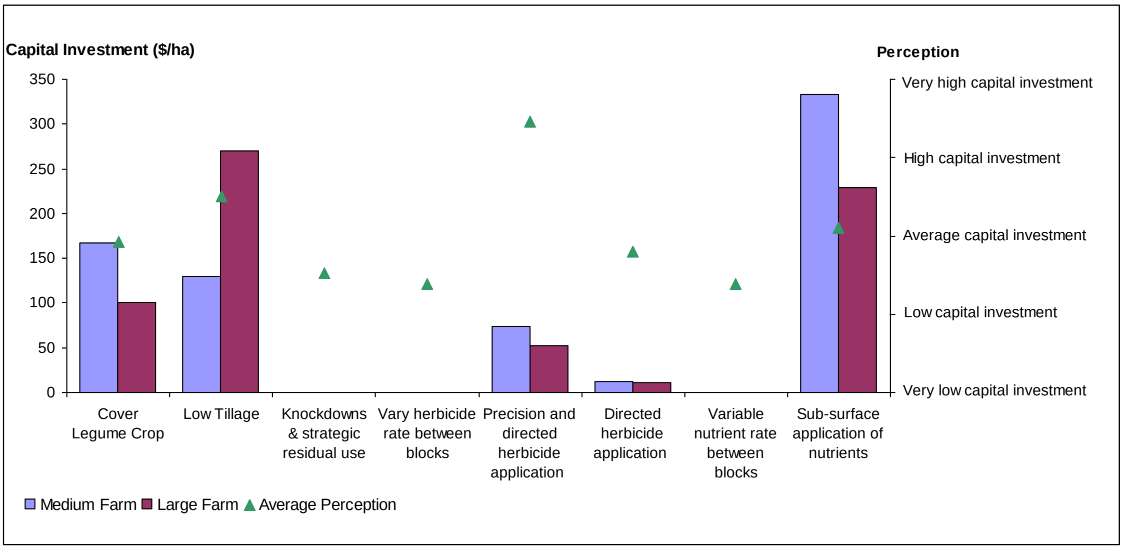
[5] Extension includes technology transfer, education, communication and demonstrations.
[6] Positive incentives comprise of landholder payments.

The few practices located in the *no action* segment of the graph are those changes in which the private benefit exceeds the public benefit (i.e. C- to B-Class herbicide management with legume fallow and low tillage combination). Hence, there are reasonable prospects that these growers will likely make the transitions without the need for any intervention.

In order to fully implement Pannell's (2008) policy mechanism model, the public benefits are first required to be converted to a monetary value that is directly proportional to the physical abatement levels. The assignment of appropriate monetised values for the public benefits will enable a direct comparison with the private benefits and overcome scaling issues regarding the non-monetised y-axis, which is critical to the interpretation of Pannell's model. However, this is non-trivial matter that will require an investigation into the feasibility of deriving these values in the absence of any market-traded prices or suitable proxy measures currently available.

Efforts to enhance the understanding of the adoption process by contrasting the recent economic research (van Grieken et al. (in press) and Poggio et al. (in press)) with grower perceptions of profitability (Thompson et al. (in press)) also provides scope for future research. Ideally, this work will help to identify areas of disparity between the subjective opinion of growers and the results of objective economic modelling. For example, Figure 17 shows the relationship between how the capital investment needed for management practice adoption is perceived by growers from very low to very high (Thompson et al., in press) and the cost of requisite equipment ($/ha) estimated through research, local advice and expert opinion (van Grieken et al. (in press); Poggio et al. (in press)).

Figure 17: Perceptions of required capital investment versus economic analysis



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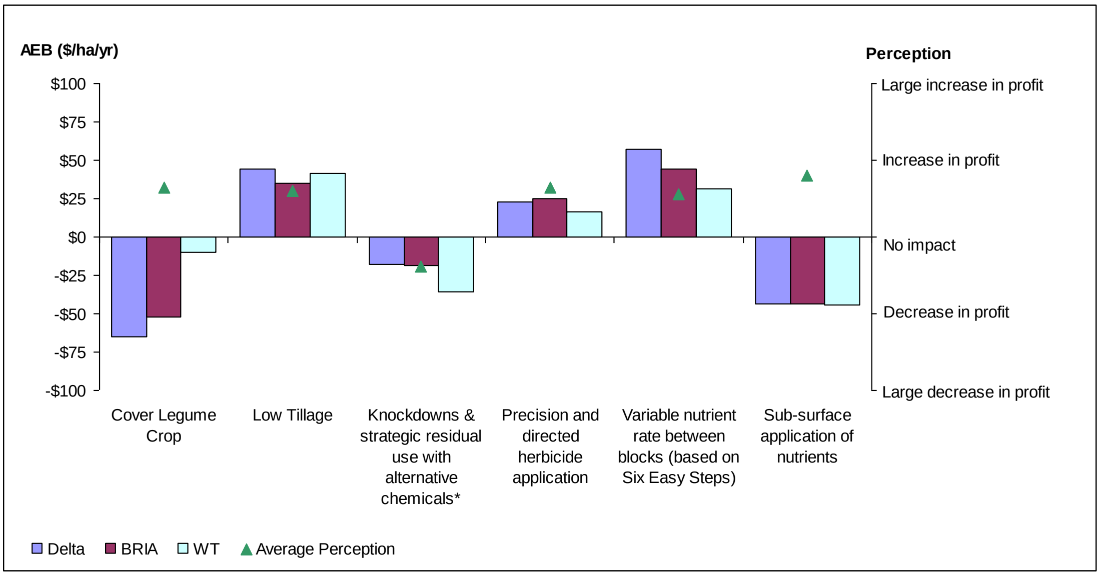
[7] Technology change refers to strategic and participatory research and development to optimise outcomes.

Contrasting the data from both studies indicates that grower's perceptions about the cost of the equipment required to adopt new management practices are quite consistent with the results of the economic modelling. An outstanding observation, however, is how high growers perceive the required capital investment for adopting precision herbicide application. On average, growers perceive this practice as requiring a high to very high capital investment; while the economic research suggests the capital investment required is relatively low compared with the other capital expenditure requirements.

Figure 18 shows the relationship between how growers perceive the impact of management practice adoption on farm profit and the economic findings from the study conducted by Poggio et al. (in press). The economic study investigated the profitability of management practices using a measure of AEB ($/ha/yr).

Figure 18: Perceptions of the impact on farm profitability versus economic analysis



The graph illustrates that grower's perceptions about whether a change in management practices is profitable are generally consistent with results of the economic analysis with two exceptions: adopting a cover legume crop; and sub-surface nutrient application. While growers indicated that they believed that both these changes in farming practices are likely to impact positively on farm profit, the economic analysis indicated that it was likely to cost growers. This disparity in results raises further questions about possible extension gaps and highlights possible barriers to adoption that may warrant further investigation.

6. Conclusion

There are a number of key messages from this synthesis report that directly relate to the RWQ economic research project and which validate the importance of the economic component to identify management practices that can be implemented cost-effectively and are likely to achieve the greatest water quality improvement at the property scale. First, the economic research presented in this report indicates that over the past decade the sugarcane industry has experienced economic conditions that are less than ideal. The industry has undergone a significant degree of restructure and consolidation over this time, while weather events as well as pest incursions have had adverse implications for production.

Second, the environmental impact of land practices that result in the displacement of land-based pollutants such as suspended solids, nutrients, and pesticides is now a major concern to industry, the broader community, and government. There is a currently a gamut of scientific research being undertaken to quantify the environmental impacts of sediment, nutrients and pesticide concentrations on the GBR ecosystem. While the efficient adoption of BMPs that improve water quality is considered a key mechanism in improving the overall health of the GBR ecosystem, there has been limited economic work carried out linking the adoption of BMPs to environmental and social issues in the GBR catchment.

Third, whilst abundant literature exists on sugarcane management practices to minimise environmental risk, often that literature fails to address the economic impacts of these changes. Furthermore, few studies provide an economic assessment of BMP adoption that takes into account the unique biophysical and socio-economic characteristics of each NRM region. Adoption of new practices by landholders (whether they be to improve environmental outcomes or productivity) results from a complex decision-making process where relative advantage, especially in economic terms, is a key motivator. Growers will be unlikely to readily adopt unproven practices if the changes are perceived as a high risk to farm profitability.

Appendix 1 - Characteristics of management practice adoption

Characteristic category	Factors	Term for survey	Notes
Relative advantage: The perceived net benefits of adoption	Short term input costs, yields and output prices of the innovation or of other activities that it affects	Short term profitability	Short term profitability expectations
	The innovation's impact on profits in the medium to long term	Medium to long term profitability	Long term profitability expectations
	The innovation's impact on other parts of the system within which it will be embedded	Impact on production	The innovation may for instance positively or negatively affect production (e.g. legume crop affects yield on subsequent crop)
	Adjustment costs involved in adoption of the innovation	Adjustment costs	Investments in machinery, adjustments
	The innovation's impact on the riskiness of production	Perceived production risk	E.g. price risks, productivity risks, weather risks
	The innovation's compatibility with a landholder's existing set of technologies, practices and resources	Compatibility with existing technology	Current machinery, soil types, management skills
	The innovation's complexity	Complexity of the practice	Inconvenience, stress, risk
	Government policies	Government policy	Policies can positively or negatively affect adoption
	The cost or profitability of the traditional practice which the innovation would replace	Profitability compared to current practice	Input prices, skill levels
	The compatibility of a practice with existing beliefs and values	Consistency with beliefs and values	Farmers may consider themselves to be tied in with a specific production or method of production
	The impact of the innovation upon the family lifestyle	Impact upon family lifestyle	E.g. impacts on leisure time
	Self-image and brand loyalty	Self-image	To what extent the innovation changes the social standing of farmers in the local culture; social stigmas; peer pressure
	The perceived environmental credibility of the practice	Perceived environmental benefits	Environmental benefits are not always clearly observable
Factors that tend to reduce the relative advantage:	High establishment costs	Establishment costs (one-off)	High upfront costs; investment
	Long time scales	Time scale of effects	It can take a long time for innovations to take effect
	Riskiness	Perceived risk (other)	Production; markets; technologies; natural events
	Complexity	Complexity of the innovation	Requiring a great intensity of management
	Spillovers	Spill-overs (free riders)	The benefits extend beyond the farmer adopting the practice; free rider problem
Trialabilty: Ease of adoption via a learning phase	The divisibility (scale) of an innovation	Scale of the innovation	A degree of divisibility is essential to allow for small scale trialing for learning purposes
	The observability of results from an innovation	Observability of results	Higher observability means that fewer trials are needed to reduce the uncertainty to make the choice between adoption and non-adoption. Observability also promotes the diffusion of a specific practice (over the fence learning by neighbours)
	Time lags of an innovation	Time lags	The longer the lag, the less trialable is the innovation. It may take a long time before the uncertainty around the soundness/effectiveness of a practice is reduced
	The complexity of an innovation	Complexity of the innovation	The greater the complexity of a practice, the greater the information required to reduce uncertainty of adoption
	The cost of undertaking a trial	Trialling costs	The larger the cost of a trial, the less attractive it is to a landholder

Trialabilty (continued):	The risk of failure of a trial	Trialling risks	Threats to a biological trial include drought, diseases, pests, and establishment failure. The larger the scale of a trial, the higher the risk of failure
	The trial needs to be indicative of the innovation's performance in the long run	Long run performance indication	If the technology is implemented poorly, the less likely the practice is to meet this requirement. Poor implementation is more likely when the practice is radically different from current technology
	Similarity in behaviour of the innovation to a familiar practice can be helpful in the learning process	Similarity with existing technology	Similarity can be helpful in the learning process, and so, can enhance trialability
	Spillover effects can reduce the motivation for trialling	Spill-over effects	Spill over effects from management by neighbours that may affect the results of trialing a technology, may limit the willingness to trial

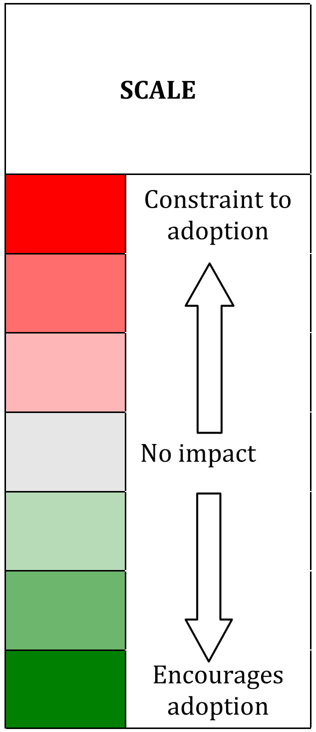
Source: Pannell et al., 2011.

Appendix 2 – Key sugarcane principles and herbicide management options

Key Principle	Management Practice Options	Code	FEAT Modelling	HowLeaky Modelling
Application rate management	Use of Electronic Rate Controller. Rate varies between blocks with consideration of weed type and pressure. Frequent calibration (for each block and automated).	AA	Y	Y
	Rate varies between blocks with consideration of weed type and pressure. Regular calibration (for each application).	AB	Y	Y
	High recommended label rate across farm and not block-specific. Limited calibration.	AC	Y	Y
Fallow management	Grain legume crop.	FA	N	N
	Cover legume crop (requires legume planter).	FB	Y	Y
	Bare fallow.	FC	Y	Y
Herbicide selection	Knockdowns & residual herbicide using alternative chemicals (excluding PSII herbicides diuron, atrazine, hexazinone & ametryn).	SB2	Y	Y
	Knockdowns & residual herbicide using standard chemicals (including PSII herbicides diuron, atrazine, hexazinone & ametryn).	SB	Y	Y
Strategic use of residual herbicides	Strategic residual use.	HB	Y	Y
	Non-strategic residual use.	HC	Y	Y
Application method	Incorporates the use of precision and directed application equipment with appropriate nozzles. Includes hooded-sprayer, two tanks, and air inducted nozzles. Nozzles changed regularly based on label requirements.	MA	Y	Y
	Incorporates the use of directed application equipment and appropriate nozzles. Includes Irvin legs, octopus bar and air inducted nozzles. Nozzles changed regularly based on label requirements.	MB	Y	Y
	Use of directed application and non-specific nozzles. Nozzles not changed regularly.	MC	Y	Y
Application timing	Consideration of crop stage, weed size and type, crop cycle, environmental conditions, irrigation and climate forecasting.	TA	Y	N
	Consideration of crop stage, weed size and type, crop cycle and environmental conditions and irrigation.	TB	Y	N
	Consideration of crop stage, weed size and type.	TC	Y	N
Record keeping and planning	Electronic records, mandatory requirements and IWM plan.	RA	N	N
	Electronic records and mandatory requirements.	RB	N	N
	Paper records and mandatory requirements.	RC	N	N
Tillage management	Low (reduced) tillage using zonal ripper -rotary hoe.	GB	Y	Y
	High (conventional) tillage.	GC	Y	Y

Appendix 3 – Average perceptions of practice adoption (heat map)

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



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

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