The Economics of Adopting Pesticide Management Practices Leading to Water Quality Improvement on Sugarcane Farms

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

RP62c Technical Report

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Executive Summary

This RP62c project evaluates a multitude of management practice options in order to identify profitable abatement opportunities for PSII herbicides (herbicides designed to inhibit photosynthesis at photosystem II in plants) and their alternatives from three major sugarcane production districts located in the GBR catchment. At present, there are few economics studies that investigate enterprise heterogeneity in conjunction with water quality information with a view to enhance adoption of new practices in GBR catchments. Growers will be unlikely to readily adopt unproven practices if the changes are perceived as a high risk to farm profitability. The focus of the RP62c project was thus to provide a substantial contribution to the current understanding of the costs and benefits associated with improving water quality management on cane farms through investigating several research questions as follows:

1) What is an objective method to evaluate the economic implications of preventive weed control across a multitude of pesticide management scenarios?

2) What are the economic implications of adopting effective cane farm management systems that minimise the use and losses of PSII pesticides?

3) What changes to farming systems and practices are likely to be profitable while simultaneously reducing the losses of PSII pesticides from cane farms into waterways?

A summary of the key findings of the RP62c project is listed as follows:

- 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.

- Several constraints within the project are acknowledged in this report along with future avenues of research outlining how a number of these limitations may be addressed.

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Acronyms

ABARES	Australian Bureau of Agricultural & Resource Economics & Sciences
AEB	Annualised equivalent benefit
ANZECC	Australian and New Zealand Environment and Conservation Council
APSIM	Agricultural Production Systems sIMulator
BDT	Burdekin Dry Tropics
BMP	Best management practice
BRIA	Burdekin River Irrigation Area
BSES	Bureau of Sugar Experiment Stations
CBA	Cost-Benefit Analysis
CCS	Commercial cane sugar
CEA	Cost-effectiveness analysis
COT	Crown of thorns
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DCF	Discounted cash flow
FEAT	Farm Economic Analysis Tool
FGM	Farm gross margin
GBR	Great Barrier Reef
GPS	Global positioning system
IWMP	Integrated weed management plan
IPS	International Polarity Standard
IRR	Internal rate of return
MWS	Mackay Whitsunday
NPV	Net present value
NRM	Natural Resource Management
QDAFF	Queensland Department of Agriculture, Fisheries and Forestry
P2R	Paddock to Reef
PED	Pesticide Ecotoxicity Database
PPED	Pesticide Properties Database
RRRD	Reef Rescue Research & Development
WACC	Weighted average cost of capital
WQI	Water Quality Improvement Plan
WT	Wet Tropics

1. Introduction

There is a growing body of literature[1] documenting scientific concern for the mortality and resilience of the Great Barrier Reef (GBR) ecosystem. The widespread adoption of Best Management Practices (BMPs) that improve water quality leaving farms is heralded as a key mechanism to improve the overall health of the GBR ecosystem. However, 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[2]. Landholders will be unlikely to readily adopt unproven practices if the changes are perceived as a high risk to farm profitability.

Industry and government have together invested a significant amount of resources aimed specifically at increasing the adoption of management practices leading to improved water quality outcomes on farms. In particular, the Reef Water Quality Protection Plan 2009 (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. The Reef Plan initiative consists of a range of major programs covering monitoring, modelling, and reporting of water quality outcomes, research programs focused on improving knowledge about the economic and environmental impact of different farm management practices, and increasing the adoption by growers of management practices that improve water quality.

As an integral part of the 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 RP62c Cane Science Reef Protection Project aims to contribute to the RWQ program by evaluating various pesticide management options to identify profitable abatement opportunities that reduce PSII herbicide loads entering the GBR. In line with this objective, this report addresses the following specific research questions:

1) What is an objective method to evaluate the economic implications of preventive weed control across a multitude of pesticide management scenarios?

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[1] See Devlin & Lewis, 2011 for a comprehensive annotated summary of this literature.
[2] See Pannell et al., 2006.

2) What are the economic implications of adopting effective cane farm management systems that minimise the use and losses of PSII pesticides?

3) What changes to systems and practices are likely to be profitable while simultaneously reducing the loss of PSII pesticides from cane farms to waterways?

This technical report has been developed in parallel with the RRRDO39 cane-science research project[3] in which a similar analysis has been undertaken regarding the economics of adopting nutrient management practices with a focus on improved water quality outcomes. Findings from the two projects provide a substantial contribution to the current understanding of the costs and benefits associated with improving water quality on cane farms and this information will be integrated into a final synthesis report. The purpose of this report is to support policy development and extension delivery that is aimed at increasing the adoption of best practice for water quality improvement and compliance with Reef Protection regulatory requirements.

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[3] van Grieken et al., in press.

2. Background

2.1. Impetus for the RP62c Cane Science Project

The Queensland sugar industry produces approximately 95 per cent of Australia's total raw sugar, which is typically worth around 1.5 – 2.5 billion dollars to the Australian economy[4]. 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 and production is most concentrated in the north of the state where three key growing regions make up the northern cane industry: Wet Tropics; Burdekin Dry Tropics; and Mackay Whitsunday.

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[5]. Recent research[6] suggests that the GBR has experienced a fifty per cent decline in coral cover over the past twenty-seven years, with a significant proportion of that decline attributable to storm and cyclone activity, outbreaks of the invasive starfish species Crown of Thorns (COTS), and poor reef water quality due to runoff from agricultural and coastal development activities. Regarding the latter, 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[7] to the GBR ecosystem. While the impact of pollutants at a molecular level is known, there is still much to be understood regarding the impact of these pollutants on the complex and dynamic GBR ecosystem. Nonetheless, the environmental impact from land management activities that contributes to the displacement of land-based pollutants is an emergent issue affecting water

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[4] See Department of Agriculture, Fisheries and Forestry (2012); CANEGROWERS (2012).

[5] The State of Queensland, 2011.

[6] See De'ath et al., 2012.

[7] 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 (Haapkyla¨ 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). 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). Non-target species affected may also include algae, fish and marine invertebrates.

quality in the GBR catchment, with waters within twenty kilometres of the shore at highest risk of degradation[8].

The primary sources of pollutants from land-based agricultural activities differ across industries, as do the types of chemicals used (i.e. active compounds and their modes of action). While sediment exports are primarily delivered in runoff as a consequence of grazing activities, nutrient and herbicide delivery is largely attributed to cropping activities dominated by sugarcane production on land adjacent to the GBR. The most important reef pollutants coming from sugarcane farming are nutrients (especially nitrogen and phosphorus) and PSII pesticides used for weed management. Recent research suggests that the mean annual pesticide load delivered to the GBR is approaching thirty tonnes per year[9]; however, these loads are typically seasonal and vary annually[10]. While sediment-related water quality decline is also a concern to reef water quality, the adoption of practices such as green cane trash blanketing and reduced tillage has aided to address this issue in the cane industry.

Pesticide usage (especially the application of pesticides) is a major component of the overall farming system for Australian cane growers and is generally recognised as a necessary input in order for growers to remain productive and competitive. Pesticide is a 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. Mechanical cultivation of plant cane and application of herbicides are typically used to control grasses, broadleaf weeds, sedges and vines[11]. Weeds are the most significant pest of growing sugarcane and are an important issue affecting productivity and profitability[12].

Research previously undertaken by the BSES Limited (formally the Bureau of Sugar Experiment Stations)[13] has highlighted the potential for monetary loss as a consequence of yield losses if weed control is delayed or omitted. It has been suggested that yields of ratoon cane can potentially be reduced by 7 to

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[8] See The State of Queensland, 2011.

[9] See Devlin & Lewis, 2011.

[10] The 2013 Scientific Consensus Statement states that “mean-annual modelled loads of photosystem II inhibiting herbicides, namely ametryn, atrazine, diuron, hexazinone, tebuthiuron and simazine, are estimated to range between 16,000 and 17,000 kilograms per year. The total pesticide load to the Great Barrier Reef lagoon is likely to be considerably larger, given that another 28 pesticides have been detected in the rivers” (see Reef Water Quality Protection Plan, 2013).

[11] Calcino et al., 2008.

[12] Fillows & Callows, 2011.

[13] In August, 2013, BSES Limited was incorporated into Sugar Research Australia.

30 percent through weed infestation[14]. Green cane harvesting and retention of the trash blanket was introduced into the north Queensland cane industry in the late 1970s and was quickly adopted there. Management of the green-cane trash blanket is considered an efficient practice to manage weeds in ratoon cane, but is not applicable in areas where cane is burnt prior to harvest, such as in the Burdekin Region. A number of experiments were also undertaken by BSES to investigate the optimal thickness of the green-cane trash blanket as well as the optimal timing of herbicide applications[15]. The results showed that, in comparison to bare soil, trash at all levels reduced weed competition 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 application of pre-emergent herbicides were more efficient.

The PSII herbicides (herbicides designed to inhibit plant photosynthesis) diuron, atrazine, hexazinone and ametryn are identified as being commonly found in water samples and, in turn, pose the greatest risk to the health of reef ecosystems[16]. There are various processes that facilitate the loss of pesticides from farms. Irrespective of 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[17]. Although there are limits to controlling, or even reducing these losses, some understanding of the processes contributing to these losses can lead to improved on-farm management of pesticides[18].

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[19]. Moreover, 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. The underlying message from a farm management perspective is that higher risk periods for off-site movement of pesticides tend to be associated with time periods immediately after application[20]. Irrigation, or significant rainfall soon after pesticide application, generates significant potential for pesticide movement in solution. Knowledge about these risk

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[14] McMahon, 1989 in Fillows & Callows, 2011.

[15] See Fillols, 2012.

[16] Davis et al., 2011; Devlin & Lewis, 2011; Reef Water Quality Protection Plan, 2013.

[17] Davis, 2006.

[18] Davis, 2006.

[19] Davis, 2006.

[20] See Davis, 2006.

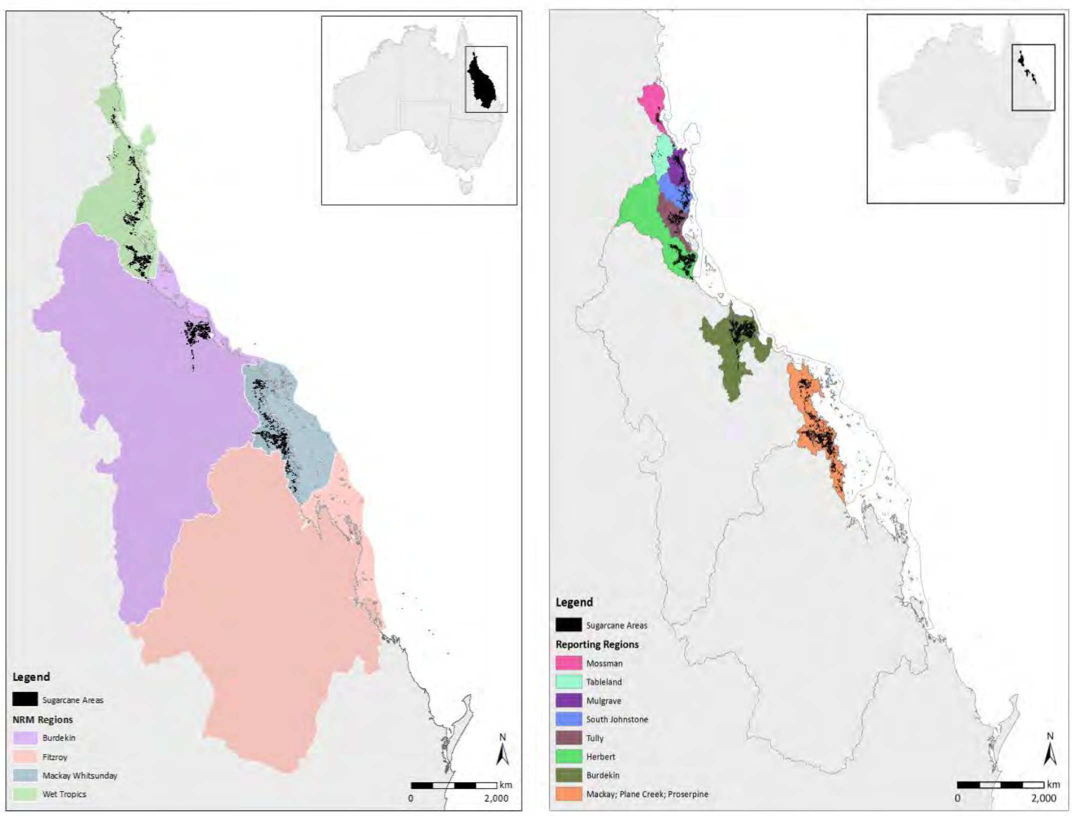
windows, and using that information to manage the timing of application, is fundamental to responsible pesticide management.

3. Methods of analysis

3.1. Site selection

The scope of the RP62c project includes key sugarcane production areas that extend along the north-east coast of Queensland adjacent to the GBR catchment. The particular focus of this RWQ economics research project is to identify profitable herbicide management practices that result in water quality improvement within the Wet Tropics, Burdekin Dry Tropics, and Mackay Whitsunday sugarcane-growing regions (see Figure 1). Collectively, these regions constitute a significant part of the total cane growing area that impacts on the GBR.

Figure 1: Sugarcane land in the NRM regions (left) and reporting regions (right)



Source: van Grieken et al., in press.

Within these three major sugarcane growing regions, four core districts are selected: Tully; Burdekin Delta; Burdekin River Irrigation Area (BRIA); and Mackay. Between each of these districts, there is considerable regional variation in terms of rainfall, soil types, average farm size, industry dynamics, average cane yields, and sugar content (measured as Commercial Cane Sugar (CCS) (see Table 1). In conjunction with landform patterns and soil type, climatic conditions are important considerations that determine the suitability of management practices within each region.

Table 1: Regional characteristics and industry dynamics of sugarcane growing districts

Regional characteristics	Wet Tropics	Burdekin	Mackay Whitsunday
Mill district	Tully Mill	Burdekin Mills	Mackay Mills
Average annual rainfall (mm/yr) [a]	4127.4 (Tully Sugar Mill) Years 1925-2012	972.6 (Ayr DPI Research Station) Years 1952-2012	1657.6 (Mackay Post Office) Years 1871-2012
Predominant soil types	→ Flood plain: heavy alluvials → Slopes: light soils	→ Coastal Delta: light soils → BRIA: heavy soils	→ Volcanic clay soils → Sandy/clay duplex → Heavy cracking clays
Average farm size (ha)	85	104	84
Average farm size breakdown (%) [b]	60:25:15	60:25:15	69:25:6
Average sugarcane yield (t/ha) [c] **Range (t/ha)**	84.4 (63.9 – 98)	115.1 (95.3 – 129.7)	76.3 (64.9 – 87.9)
Average relative CCS [c] **Range (t/ha)**	12.7 (11.13 – 14.12)	14.9 (13.67 – 15.1)	13.9 (12.94 – 14.9)

[a] Australian Government Bureau of Meteorology website: <http://www.bom.gov.au>.

[b] Breakdown (small:medium:large) small < 100ha; 100ha < medium < 200ha; large > 200ha; Canegrowers, 2010.

[c] BSES Limited, 2012: 10-year averages (2001-2010).

Tully, in the Wet Tropics region, is renowned for its very high rainfall. This area typically experiences storm rainfall events that cause heavy erosion, flood events, and months of saturated soils in the wet season. Unseasonal rainfall events in the dry season have a significant bearing on farming practices. Consequently, farming operations often have to be carried out in less than ideal conditions and production levels are quite variable.

In contrast, the Burdekin Delta and BRIA areas are situated within the Dry Tropics region. This region typically experiences short wet seasons when 70 per cent of the annual rainfall is received. The extended dry season makes irrigation imperative for sugarcane production. The Burdekin has also a relatively flat topography making it ideal for furrow irrigation; very few cane farms use any other style of irrigation (e.g. drip or overhead low pressure systems). Runoff of irrigation water and deep drainage (i.e. leaching) are the primary sources of nutrient and pesticides losses from Burdekin farms. It is largely influenced by dry season runoff into drains and natural watercourses, which is in contrast to other cane growing regions where wet season events are the usual mode of pollutant movement[21].

Mackay commonly experiences storms and flooding; however, it can be extremely dry from May to December often resulting in the need for irrigation. In contrast, excessive unexpected unseasonal rainfall that is disruptive to farming operations can also occur in the dry season.

3.2. Integrated modelling and desktop analysis

In line with the objectives of the RP62c project, this report addresses the following specific research questions:

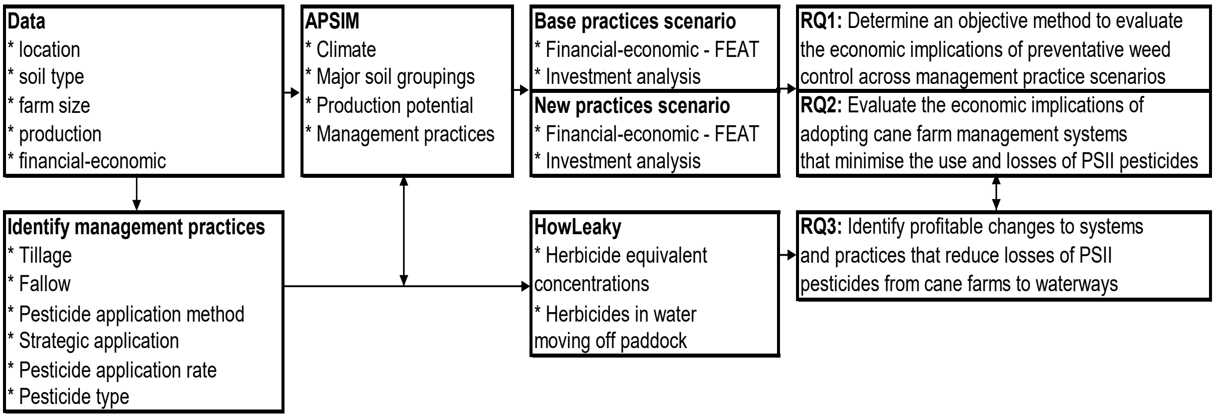
1) What is an objective method to evaluate the economic implications of preventive weed control across a multitude of pesticide management scenarios?

2) What are the economic implications of adopting effective cane farm management systems that minimise the use and losses of PSII pesticides?

3) What changes to farming systems and practices are likely to be profitable while simultaneously reducing the losses of PSII pesticides from cane farms into waterways?

The methodology that is implemented to address these research questions is outlined in the theoretical framework presented in Figure 2.

Figure 2: Theoretical framework of the RP62C project



As Figure 2 illustrates, implementing the RP62c theoretical framework involves the collation of many sources of data as well as the integration of the outputs from several models. Given that each of the selected sugarcane-

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[21] See Davis et al., 2011.

growing regions identified above (i.e. Wet Tropics, Burdekin Dry Tropics, and Mackay Whitsunday) have unique biophysical characteristics, the APSIM model is initially used to estimate the production potential within each region based on historical climate data and the major soils types under the Six-Easy-Steps nutrient management regime.

These production outputs are then entered along with other relevant farm data into the Farm Economic Analysis Tool[22] (FEAT) to calculate the Farm Gross Margin (FGM) under a multitude of selected[23] management practice scenarios. The FGMs from the FEAT analyses are then tabulated into a matrix using the Microsoft Excel program. The marginal changes to the FGM when transitioning between each of the selected scenarios are then entered as input parameters into an investment analysis framework.

The potential herbicide delivery at the farm gate is modelled for each of the selected scenarios using the HowLeaky pesticide model. Under this modelling, the total herbicide delivery is derived from a function of the active compounds and the cumulative level of toxicity (i.e. potency relative to diuron) with respect to its effect on certain marine organisms. The concentrations for each herbicide are calculated and then treated additively to determine the total herbicide lost annually in runoff for each scenario. The herbicide delivery totals for each scenario are then matched with the corresponding economic results to compare the dollar cost/benefit to reduce herbicide-equivalent losses in farm runoff in both absolute terms and relative terms per hectare, per year.

3.3. Management practice selection

Production in each sugarcane region is characterised by an elaborate function of biophysical variables including soil type, rainfall and climatic variables, as well as enterprise variables such as farm size and operating strategy, capital and labour constraints, and farmer's management objectives. Using previous research[24] as a starting basis, a number of key sugarcane farming principles and management practice options were identified as having the potential to improve water quality (or facilitate this process). A multitude of management practice scenarios were subsequently contrived through consultation with local experts including growers, agronomists, and extension

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[22] Cameron, 2005. FEAT is a computer program developed by the Queensland Government under the FutureCane initiative, which is written specifically for evaluating cane farm enterprises.

[23] The various management practice scenarios were contrived through consultation with local experts including growers, agronomists and extension officers.

[24] This includes, for example, Paddock to Reef M&M Metrics, MTSRF 3.7.5, CSIRO's RWQO project, Reef Rescue ABCD Framework and Industry BMP Guidelines.

officers. Importantly, all scenarios were developed on the basis of providing effective weed control within the product label requirements. The management principles and practices selected for this project are outlined in Table 2.

Table 2: Key sugarcane principles and herbicide management practice options selected for analysis

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

Each complete farming system analysed in this project included the selection of a management practice for each key principle (Table 2). It is noted that while separate herbicide management principles can change within a particular system, a system cannot operate without one principle or the other. For instance, an effective herbicide management strategy requires the landholder to select certain types of herbicides (coded *SB* or *SB2*) and apply these chemicals at a certain rate (coded prefix letter *A*) using the appropriate equipment and precision application methods (coded prefix letter *M*) that may or may not involve the strategic use of residual herbicides (coded prefix letter *H*). The landholder must also decide how to manage their fallow (coded prefix letter *F*) and cultivate the land using either low or high intensity tillage methods (coded prefix letter *G*). The suffix codes, *A*, *B* and *C*, indicate the class rating of the practice in terms of its perceived potential to improve water quality outcomes. It should be noted that an *A-Class* rating represents a higher degree of risk to the landholder due to lack of scientific evidence and/or because they are not commonly undertaken on a commercial basis in the sugarcane industry.

Due to limitations on the extent of the analysis and capability of the models, not all of the identified practices listed have been explicitly examined in the RP62c project. Accordingly, practices that were not examined in the project are highlighted in grey (see Table 2). Application timing is unique to other practices, and although not directly measured financially, it is considered in the development of herbicide management scenarios through several key areas. For example, improved timing is critical to achieving efficiency gains in application rates and in the strategic use of residuals. It is also reflected through residuals being applied with a greater time buffer from application to the start of the wet season for *A-* and *B-Class* herbicide management practices. It is important to note that the proposed set of management practices that were modelled in this project is only one of myriad possible scenarios that could equally suit each management class.

3.4. Farm gross margins analysis

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. The Farm Gross Margin (FGM) is a common economic measure used to evaluate the contribution of farm activities to profit. FGM is defined as gross revenue (i.e. income from production) less variable costs (i.e. those that vary with production). This is written as:

$$\text{FGM} = \text{Gross Revenue} - \text{Variable Costs} \qquad (1)$$

The gross margin is a particularly useful guide when evaluating the financial impact of farming system adjustments. It is, however, only a relative concept of profitability as it does not take overhead costs (i.e. fixed costs that are incurred independently of the level of production) into account. Accordingly, to evaluate the impact on profitability taking into account overhead costs, the farm operating return (i.e. the profit in dollar terms[25]) is stated as:

$$\text{Farm operating return} = \text{Gross revenue} - \text{Total cost} \quad (2)$$

Total gross revenue is measured quite simply as the product of the quantity of the farm's output and the average price[26] at which it sells its output. Measuring the farm's total cost, however, is more subtle. Total cost is made up of two components: overhead costs that are incurred from factors of production that are fixed[27] in the short run and independent of the level of output; and variable costs that are dependent upon production decisions made at the farm level. In an economic sense, the short run acknowledges that a number of the factors of production are only able to be changed over several years (e.g. the size of the farming area). When implementing new management practices within a particular farming system, the financial-economic impact is captured in the discrete periodic change, Δ, for each of the terms within Equation (2) as follows:

$$\Delta\text{Farm operating return} = \Delta\text{Gross Revenue} - \Delta\text{Variable Costs} - \Delta\text{Fixed Costs} \quad (3)$$

For those changes to management practice settings that do not require expenditures on additional land or fixed capital, the fixed costs of production are unaffected. Thus the term $\Delta\text{Fixed Costs} = 0$, implying that:

$$\Delta\text{Farm operating return} = \Delta\text{Gross Revenue} - \Delta\text{Variable Costs} \quad (4)$$

Substituting terms in Equation (1) and Equation (4), we derive the expression:

$$\Delta\text{Farm operating return} = \Delta\text{Gross Revenue} - \Delta\text{Variable Costs} = \Delta\text{FGM} \quad (5)$$

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[25] The return on investment (in percentage terms) is the farm operating return as a proportion of the total value of farm assets. From an accounting perspective, the value of total farm assets is typically calculated as the average value of the opening and closing balances of the assets over the appropriate period of time.

[26] Total revenue / output = average revenue = price. Average sugar price is a function of relative CCS for plant and ratoon cane.

[27] Farm overhead costs may include items such as permanent salaries, insurance, annual fixed water rates, depreciation of farm assets, land taxes and municipal rates, etc.

The change in the FGM essentially provides a measure of farm performance that is independent of the effects of financing and accounting decisions (such as capital structure and the treatment of depreciation for tax purposes), which are beyond the scope of this project. Hence, this relative change is used to gauge the implications for farm profitability when adopting a new system of management that does not require additional capital expenditures on land or fixed capital. The financial-economic implications arising from the purchase of new capital items required to implement changes within the farming system is the subject of Section 3.5.

3.5. The Discounted Cash Flow method

A fundamental concept of financial-economics is the relationship between the present and future value of money. The future value of a principal amount invested today for one period at an appropriate interest rate is given as follows:

$$FV = PV + (PV * k) \qquad (6)$$

where,

FV = the future value of the principal amount;

PV = the present value of the principal amount; and,

k = the appropriate interest rate.

Simplifying and rearranging Equation (6) yields:

$$FV = PV(1+k)$$

$$PV = \frac{FV}{(1+k)} \qquad (7)$$

Equation (7) is used to determine the present value of an amount of money to be received at some time in the future. The time value of money[28] implies that

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[28] The time value of money is based on the notion that economic agents have a positive preference for consuming what money can buy today rather than what it may be able to buy in the future (Kidwell et al., 2011).

a dollar amount of money to be received in the future is worth less than the *same* dollar amount today; this is because money today may be invested so that it will grow over time at a rate of interest. What this rate of interest *should be* will depend on what is referred to as the opportunity cost. The opportunity cost represents the consideration foregone when investing funds into one project rather than into another that assumes the same element of risk. For this reason, the interest rate applied to discount the value of a future cash flow to determine its present value is often referred to as the required rate of return.

When analysing an investment that provides cash flows in concurrent periods, the Discounted Cash Flow (DCF) technique is the traditional method used to evaluate the present value of a stream of future cash flows (or the flow of economic benefits) over a predetermined investment horizon. The general application of the DCF method is defined by the following expression[29]:

$$PV = \frac{C_1}{1+k} + \frac{C_2}{(1+k)^2} + \ldots + \frac{C_n}{(1+k)^n} \qquad (8)$$

where,

PV = the present value;

C_t = the expected marginal change to net cash flows (i.e. gross margin) in period, t;

k = the required rate of return; and,

n = the total number of periods, t.

The total number of periods (i.e. the economic horizon) of the cash flow stream is thus contingent on the operative life span of the investment. For example, an economic horizon of ten years is appropriate for an investment in capital (e.g. farm machinery) which has a useful life of ten years. As implied by Equation (8), the discount rate compounds periodically on the basis that

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[29] See, for example, Brennan & Schwartz, 1985.

the principal and interest for each period is reinvested at the required rate of return.

Whereby the expected marginal change to net cash flows (i.e. the change to gross margin calculated using Equation (5)) is assumed to be a constant value each year it may be treated as an annuity. As such, the DCF method is simplified and the present value is calculated as:

$$PV = C\left[\left(1-\left(\frac{1}{(1+k)^{n}}\right)\right) * k^{-1}\right] \tag{9}$$

where, again, *C* is the periodic change to the farm gross margin, *n* is the total number of years, and *k* is the required rate of return.

3.6. Net Present Value

A Net Present Value (NPV) analysis provides a set of objective criteria[30] to be used to decide whether or not a specific change in management practices is acceptable[31] from an economic perspective. In practical terms, the NPV analysis is an extension to the DCF method that takes into account capital expenditure requirements. Implementing new management practices across the farming enterprise will typically involve purchasing new capital, which also depends on the size and scale of the farming operations. Following from Equation (9), the NPV formula is written as follows[32]:

$$NPV = PV - I_{(t=0)} \tag{10}$$

where,

PV = the present value of the cash flow stream (i.e. Equation (9)); and,

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[30] A NPV analysis provides other financial indicators such as the internal rate of return, payback period, break-even capital requirements, and benefit to cost ratio.
[31] In defining what is acceptable, it is profitable from an economic perspective only if the investment provides a satisfactory rate of return.
[32] See Ross et al., 2011.

$I_{(t=0)}$ = the present value of capital investments, whereby all capital expenditures are assumed to be purchased at the outset.

Equation (10) essentially states that the NPV is the difference between the present market value of a capital investment and its cost. Changes to management practices that result in a positive NPV are considered to be acceptable; this is in the sense that they are likely to provide a return on investment that is greater than the cost of investment (including capital expenditure and the associated opportunity cost of those funds) and operating costs. Conversely, those resulting in a negative NPV should be rejected, as this indicates that the return on investment is less than the assigned hurdle rate of return.

A discount rate of six per cent (6%) is applied in the RP62c project, which is consistent with related projects[33]. For completeness, however, the Internal Rate of Return[34] (IRR) as well as several other financial indicators including the payback period and break-even capital expenditure amount is also calculated. These financial indicators provide important information about business risk, which is fundamental to understanding the relationship between risk and return for each management decision.

The IRR is the expected rate of return for each year over the life of the investment. The NPV and the IRR are both important profitability indicators; nevertheless, the IRR and NPV only lead to identical decisions about which change in management is the better investment under two specific conditions[35]:

1) "*The project's cash flows must be conventional, meaning that the first cash flow (the initial investment) is negative and all the rest are positive.*

2) The project must be independent, meaning that the decision to accept or reject this project does not affect the decision to accept or reject any another."

Growers deciding whether to change from *B-* to *A-Class* herbicide management are not the same growers as those considering whether to change from *C-Class* to either *B-* or *A-Class* herbicide management.

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[33] These include the RRRDO39 cane-science research project (see van Grieken et al., in press) investigating the cost-effectiveness of changing nutrient management practices, as well as the RP72c research that examines sediment management practices in grazing.
[34] The IRR is calculated by iteratively adjusting the discount rate to result in a NPV equal to zero.
[35] Ross et al., 2011, p 228.

Changing from C- to *B-Class* and *C-* to *A-Class* herbicide management are, for the most part, not independent projects[36]. This implies that the first condition is satisfied by Equations 8 and 9; however, the second condition is violated because a grower currently in *C-Class* must decide from the outset to move to either *B- or A-Class*. And while the NPV figure is the preferred indicator to IRR when assessing which project is most likely to provide the largest economic value to the farming business over a given investment horizon, it is only able to be estimated accurately if the required rate of return is known for each of the projects being considered.

The appropriate rate of return that provides sufficient incentive for individual growers to adopt improved herbicide management can only be determined by surveying each grower separately. In particular, recent research indicates that growers have different perceptions about the cost involved with implementing new management practices as well as how they are likely to affect production and profitability[37]. An important practical advantage of the IRR over NPV is that the IRR is still able to be calculated for each investment opportunity despite not knowing the appropriate rate of return required by individual growers. Moreover, sophisticated investors and financial analysts usually prefer to compare the rates of return on investments instead of dollar values[38].

3.6.1. Perspectives on the required rate of return

Accounting standards warrant cash flow information and discount rates that appear reasonable in relation to historical cash flows, market information and future expectations[39]. The DCF method relies on the assignment of an arbitrary interest rate (from the outset) to account for the uncertainty in future business conditions as they are forecast to evolve over the life of the investment. In this respect, the required rate of return is often referred to as the risk-adjusted rate of return[40]. Due to their private and indeed subjective nature, discount rates are rarely published in practice and their publication is typically limited to independent valuation reports. The rate of return on government bonds is typically used as the initial basis from which to formulate the risk-adjusted rate of return[41][42]. An analysis involving ten years of daily

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[36] The investment decisions C- to B-Class and C- to A-Class are mutually exclusive projects in practices involving application rate management and application method. However, they are not strictly independent because they are mutually inclusive in moving to the same practices regarding strategic use of chemicals.

[37] See Thompson et al. (in press).

[38] Ross et al., 2011.

[39] See Australian Accounting Standards Board (2009) for accounting treatment and disclosures regarding agricultural activities in Australia.

[40] See Smith (2012).

[41] See *Capital Market Theory* in Ross et al., 2011.

data from 2004 to 2013[43] found the yield for 10-year Commonwealth Treasury Bonds to be on average marginally higher than five per cent (5.14%). However, given the heuristic that potential returns rise with an increase in risk[44], landholders who are price-takers may indeed require a relatively higher rate of return to compensate for a greater level of business risk - especially production risk.

Accordingly, a number of heterogeneous risk factors were identified in Section 3.1 that affect sugarcane production conditions across (and also within) the various regions. For example, crops in the Wet Tropics, which is an area renowned for its wet climate, are not irrigated. This implies that production within this region is critically dependent upon prevailing weather conditions, which typically involves storm rainfall events that cause heavy erosion, flood events, and months of saturated soils in the wet season. Unseasonal rainfall events in the dry season have a significant bearing on farming operations, which are often carried out in less than ideal conditions, and production levels are indeed quite variable.

In contrast, due to an extended dry season and a relatively flat topography making it ideal for furrow irrigation, landholders in the Burdekin Dry Tropics have much greater control over their production due to widespread irrigation. To some extent this is also the case in areas within the Mackay Whitsunday region where supplementary irrigation is practised. It is not surprising, therefore, that the average potential yield data produced by the Agricultural Production Systems sIMulator (APSIM) for Tully is (in relative terms) seven per cent (7%) lower than in Mackay, thirty-two per cent (32%) lower than in the BRIA, and seventy-seven per cent (77%) lower than in the Burdekin Delta[45].

Financial risk relating to the capital structure[46] of an individual business (in particular, the level of farm debt) is another factor to consider when determining the appropriate risk-adjusted rate of return. When making an investment decision, businesses whose assets are funded through a capital structure involving both debt and equity often use the Weighted Average Cost

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[42] Unlike corporate securities, securities issued by the Commonwealth Government are assumed to be free from risk. This is on the basis that its revenues can be expropriated by means of taxes throughout the economy and money can also be printed electronically to retire the Commonwealth's existing financial liabilities by conducting open market operations.

[43] Sourced from Reserve Bank of Australia, 2013.

[44] Risk, in an economic sense, is the likelihood that things will not turn out as expected.

[45] See Table 6.

[46] Under double entry accounting standards, the balance sheet of a company equates the value of the assets of a company to the value of its liabilities. Capital structure refers to formula describing how financial proceeds generated by the assets are distributed between the owner/s of a business and its debt holder/s.

of Capital (WACC) as the nominal, required rate of return. The WACC is a weighted average of the expected return on equity and the rate of interest that a business pays on its debt. The after-tax WACC is formally written as follows[47]:

$$WACC = (E/V)R_E + (D/V)R_D(1-T_c) \qquad (11)$$

where

V = the total combined market value represented by equity and debt;

E = the total market value of equity;

D = the total market value of debt;

R_E = the cost (i.e. the required rate of return) of equity;

R_D = the cost of debt; and,

T_C = the corporate tax rate.

The WACC is used to determine the appropriate rate of return that is required to be earned on current assets to maintain the value of the owner's equity (i.e. the net worth) of a business. Focusing on the source of funds, the term $(D/V)R_D(1-T_c)$ in Equation (11) suggests that it is tax-effective to use debt rather than equity to fund business assets because interest on the debt is deductible from gross income when calculating tax liability. However, a rising debt-to-equity ratio (i.e. the relative degree of financial leverage) has important implications for the liquidity and solvency of the business because equity capital buffers the balance sheet in the event of unexpected losses.

Given that debt holders have preferential rights over the assets of a business in the case of insolvency[48], it is quite reasonable to expect creditors to respond to a rising debt-to-equity ratio by becoming more apprehensive about continuing to lend funds to the business and possibly prompted to call in

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[47] See Ross et al., 2011.

[48] Insolvency occurs when the total market value of the assets of a business is worth less than its liabilities in debt, thus resulting in negative equity (i.e. negative net worth).

existing loans (i.e. foreclosure). In contrast to publicly-listed companies that enjoy access to capital markets, the problem of borrowing funds (whether for liquidity or investment purposes) is especially acute for proprietors that rely solely on financial intermediation through retail banking services to source their debt. Similar to the case of shareholders in a publicly listed company (which have only residual rights in the dissolution of assets in case of insolvency), it would be imprudent for the proprietor/s of a farming business not to demand greater returns on their equity to compensate for the relatively high financial risk. What this tends to reinforce is that farming businesses with high levels of farm debt relative to their equity will ideally require a higher rate of return when considering whether a capital investment in new management practices is attractive.

3.6.2. Capital expenditures

Capital expenditure at market prices is presented in Table 3 along with the equipment descriptions. These prices were obtained from various industry sources that supply equipment within each of the regions investigated and are thus assumed to be equally applicable across those regions.

Table 3: Capital expenditure requirements

Farm size	AC&AB to AA	MC to MB	MC to MA	MB to MA	FC to FB	GC to GB
Small (50ha)	$5,437	$1,870	$6,138	$5,647	$25,000	$12,500
Medium (150ha)	$5,437	$1,870	$6,138	$5,647	$25,000	$19,500
Large (250ha)	$5,437	$2,750	$8,331	$7,649	$25,000	$67,500
Equipment description:	Rate controller: Teejet 844 console and harness; flow meter; electronic regulating valves; GPS integration.	Octopus bars; tracking legs; air-inducted nozzles[a]; triplet air-inducted nozzle heads and connections.	Hoods for sprayer; spray bar; adjustable size; spray tanks; electric pump; all appropriate connections; air-inducted nozzles[a]; triplet nozzle heads and connections.	Hoods for sprayer; spray bar; adjustable size; spray tanks; electric pump; all appropriate connections.	Zero Till Legume planter.	Zonal ripper - rotary hoe.

[a] Ongoing nozzle replacement costs are factored into the gross margin calculations.

The sale of existing equipment (i.e. selling the rate controller when moving from *AA* to *AC*) was not considered in this project. The movement between management scenarios is also not transitive because of the capital expenditures involved. In other words, moving backwards and forwards between scenarios involving *AC-* or *AB-Class* application rate management practices to those with *AA-Class* practices (that includes the purchase of a rate controller), will not result in an inverse economic outcome[49].

3.7. The Equivalent Annual Annuity approach and the Annualised Equivalent Benefit

The Equivalent Annual Annuity (EAA) approach[50] is a transformation of the NPV figure, which is especially useful to compare capital investments that provide economic benefits/costs over different economic horizons[51]. Following from Equation (10), the Annualised Equivalent Benefit (AEB) is formally expressed as:

$$AEB = \frac{NPV}{PVAIF} \qquad (12)$$

where,

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

Substituting and simplifying yields:

$$AEB = \frac{C\left(1-\left(\frac{1}{(1+k)^n}\right)\right) * k^{-1} - I}{\left(1-\left(\frac{1}{(1+k)^n}\right)\right) * k^{-1}}$$

$$\Rightarrow AEB = \frac{C\left(1-\left(\frac{1}{(1+k)^n}\right)\right) * k^{-1}}{\left(1-\left(\frac{1}{(1+k)^n}\right)\right) * k^{-1}} - \frac{I}{\left(1-\left(\frac{1}{(1+k)^n}\right)\right) * k^{-1}}$$

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[49] Reversing the sequence of a management practice change will not result in an opposite outcome. E.g. given a progressive move from B-class to A-class resulting in a NPV of $100, does not imply that a move from A-class to B-class will result in a NPV of -$100.

[50] See, for example, annual equivalent cost and annual equivalent benefit in Ross et al., 2011.

[51] Capital investments typically have different life spans; this implies that their cash flow streams tend to vary accordingly.

$$\Rightarrow AEB = C - \frac{I}{PVAIF}$$

Moreover, standardising the NPVs for each scenario in terms of dollars, per hectare, and per year ($/ha/yr) enables direct comparison to the herbicide loss from farms that are measured in terms of grams, per hectare, per year (g/ha/yr).

By inspection, however, difficulties arise when considering a management-practice change that requires a set of individual capital investments with different productive lives. For instance, a change from *C-* to *A-Class* pesticide application methods in conjunction with a change from *C-* to *B-Class* tillage practices requires the purchase of a rate controller and a zonal ripper - rotary hoe, respectively. While each of these capital expenditures may be purchased together at the outset, a rate controller may only last for five years and the rotary hoe for twenty years. Furthermore, each of these investments may maintain a salvage value[52] at maturity of their useful lives.

Taking account of divestiture in redundant farm machinery and equipment and predicting the useful life of capital introduces a dimension to the economic modelling that warrants a more subjective and indeed dynamic analysis[53]. By the same token, over time through improved knowledge and technical innovation, the management practice scenarios selected for this project (including the respective capital expenditure items) may be rendered obsolete. Therefore, for purposes of simplicity, each capital investment is assumed to have an economic horizon of ten years and a zero salvage value.

3.8. Water Quality Modelling

3.8.1. The APSIM crop model

In the current study, APSIM modelling completed for the Paddock to Reef (P2R) modelling program was used to simulate the water balance of a cane crop[54]. At any given time point in the simulations there was a scenario modelled to represent a fallow, plant, and four ratoon crop stages for Tully and Mackay, and a fallow, plant, and three ratoons for the Burdekin. Runoff

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[52] In this case, it is appropriate to account for additional cash flow injections (i.e. additions to current assets) into the cash flow stream at the time of sale.

[53] For instance, taking these considerations into account, the AEB may indeed be alternatively modelled as $AEB = C_{i,j} - \sum \left(\frac{I_{i,j}}{PVAIF_{i,j}} \right)$, where C is the total annual change to gross margin and each capital investment is annualised separately and treated additively.

[54] Biggs & Thorburn, 2013.

and erosion losses for a given day were taken as the mean of each of these situations and the sum of losses for each day calculated to provide annual loads. Variability in annual runoff and erosion represented the effects of both crop stage and climatic differences between years. Soil management was represented as a collection of practices referred to as either *B-class* (i.e. including a legume fallow in conjunction with low tillage practices) or *C-class* (i.e. including a bare fallow in conjunction with high tillage practices). Separate model scenarios were not run to represent combinations of *B-class* and *C-class* tillage and fallow management (e.g. including a legume fallow in conjunction with high tillage practices, or low tillage practices in conjunction with a bare fallow).

Of the simulations prepared for the P2R program, those that were representative of the greatest area of cane farming in each region were selected for use in the pesticide modelling in this study. The cane crop simulated for the Wet Tropics was represented by crop on Brown Dermosol soil in the Tully area. In the Mackay Whitsunday region, the Plane Creek area was used as the representative climate and the soil type was a Brown Chromosol. Simulations for the Burdekin were completed using the APSIM runs on a Sodosol soil type in the Burdekin River Irrigation Area (BRIA) and on a Vertosol soil type in the Delta.

The APSIM simulations for the Burdekin include a large amount of runoff due to frequent irrigations. It is important to note that many growers in the Burdekin capture runoff due to irrigation in recycling pits; however, this practice is not represented here. The results thus represent the herbicide in water moving off the paddock without taking into account processes capable of capturing or trapping that water before it escapes the farm gate.

3.8.2. The HowLeaky pesticide modelling

Herbicides vary in both their potential for off-site transport following application and in their toxicity to living organisms. The HowLeaky pesticide model[55] has been used to predict the off-site transport as annual average load of each herbicide lost in runoff under the management scenarios tested. Water balance and crop cover results from the APSIM modelling were used as inputs to simulate herbicide fate. The HowLeaky pesticide model operates on a daily time step and simulates the application of pesticide products onto soil, crop residues, and/or the crop depending on the level of cover present. Pesticide residues decayed over time according to first order degradation kinetics and responded to temperature according to an Arrhenius

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[55] Shaw et al., 2011.

relationship[56]. Pesticide losses to runoff, both dissolved and bound to sediments, or those leaching from the soil surface, were predicted.

Daily herbicide loads lost in runoff were summarised as total annual (calendar year) losses for active ingredients of individual herbicides within each scenario. For each level of soil management modelled in APSIM, three levels of herbicide management were simulated (*A*, *B* or *C*)[57]. Typical application scenarios were developed through consultation with local agronomists in each region. These scenarios differed in terms of the choice of herbicide products, application rates, and the methods of application. Separate pesticide profiles were developed to simulate a reliance on the photosystem II inhibiting herbicides, which currently have additional regulations in the GBR catchment ('PSII'), or a shift towards 'alternative' residual herbicides ('non-PSII') (see Table 4). *A-class* herbicide management included instances of application using hooded-sprayers and these were modelled as application to the equivalent of fifty per cent of the total paddock area.

It is important to note that for the herbicides imazethapyr (Spinnaker), fluroxypyr (Starane), isoxaflutole (Balance), imazapic (Flame), haloxyfop (Verdict) and acifluorofen (Blazer) there is currently no field validation data available. Isoxaflutole has been modelled using a half-life that represents the degradation of both the parent compound and the diketonitrile metabolite (DKN), which is the herbicidally active component. The herbicide is applied as isoxaflutole since this form is preferentially taken up by the plants[58]. However, isoxaflutole is rapidly converted to DKN in the plants, and this is the phytotoxic compound. Abiotic conversion of isoxaflutole to DKN also occurs in soil. A study[59] conducted in Minnesota, U.S.A, on three soil types recorded half-lives of isoxaflutole plus the diketonitrile metabolite as 8-18 days. A half-life that is representative of both isoxaflutole and DKN (14 days) has been applied in the current study. A study[60] comparing the degradation of herbicides on common Queensland cropping soils under controlled temperature and moisture conditions has recently been completed and will improve future modelling efforts for many of these herbicides.

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[56] European Food Safety Authority (EFSA), 2007; Wu & Nofziger, 1999.
[57] All regional management practice scenarios are provided in the Appendix.
[58] Pallett et al., 2001.
[59] Papiernik et al., 2007.
[60] Shaw et al. - in preparation.

Table 4: Selected physical chemical properties of modelled herbicides - Photosystem II (PSII) herbicides regulated in the GBR catchment listed in bold.

Active Ingredient	Product Name (A.I. g/kg or g/L)	$T_{1/2}$ Soil[a] (days)	Koc[a,d] (ml/g)	Washoff Coeff[f]
Diuron	Velpar K4 (468)	39 [b]	1067	0.45
Hexazinone	Velpar K4 (132)	19 [b]	54	0.9
Atrazine	Atradex (900)	29	100	0.45
Metribuzin	Soccer (700)	19	38 [e]	0.8
S-metolachlor	Dual Gold (960)	21	226.1 [e]	0.6
Pendimethalin	Stomp Xtra (455)	90	15744	0.4
Imazapic	Flame (240)	232	137	0.63
Isoxaflutole	Balance (750)	14 [c]	145	0.45
Haloxyfop	Verdict (520)	9	75	0.41
Imazethapyr	Spinnaker (700)	51	52	0.61
Fluroxypyr	Starane (333)	51	68 [e]	0.66
Acifluorfen	Blazer (224)	54	113	0.95
Glyphosate	Roundup DST (470)	12	21699	0.6
Paraquat dichloride	Gramoxone (250)	365	100000	0.6
2,4-D	Amicide Advance (700)	10	88.4	0.45

[a] Pesticides Properties Database (PPDB), University of Hertfordshire. A reference temperature of 25 °C was assumed.

[b] Paddock to Reef field measured data, see Armour et al., 2011.

[c] Papiernik et al., 2007.

[d] Soil organic carbon partitioning factor (linear). The soil partitioning coefficient (Kd) applied in the model was predicted from site specific soil properties (pH, clay and organic carbon content) where relationships were available (Weber et al., 2004). Otherwise, they were predicted as a function of Koc and soil organic carbon.

[e] Freundlich Koc, rather than linear.

[f] Neitsch et al., 2004.

3.8.3. Toxic equivalency factors

Environmental implications of each management scenario were assessed by calculation of a toxic load based on the relative potency of each herbicide in runoff. Two herbicide toxic equivalency (HEq) measures were applied; a PSII herbicide equivalent (PSII-HEq) and an overall herbicide equivalent (h-HEq), which included each of the modelled herbicides (Table 5). The PSII-HEq has been developed for reporting of regulated herbicides detected in the GBR[61]. This approach calculates the relative photosynthetic inhibition of each of the PSII herbicides relative to diuron over acute exposure times. The h-HEq was developed for this study using EC_{50} data for population growth and abundance endpoints over chronic exposure times (>72 hrs).

Data was collated from the Pesticide Ecotoxicity Database (PED), which includes all EPA-reviewed ecotoxicity endpoints for pesticides registered in the U.S.A.[62]. Tests included in the PED were conducted according to U.S. data requirements for pesticide registration (FIRFA 158.540) either Tier I Aquatic Plant Growth-single dose or Tier II Aquatic Plant Growth-multi dose. Equivalency factors were calculated for aquatic plant species only, since all products included in the current study are herbicides. These included duckweed, freshwater and marine algae, and marine diatoms. An equivalency factor could be determined where an effect concentration had been measured under comparable test conditions for both the test herbicide and the reference herbicide: diuron. Comparable test conditions were assumed if: a) the same species (or genus in the case of chlorella) was tested; b) test exposure times were >72 hrs and ±24 hrs; and, c) the dosage regime (either multiple or single) was consistent. The median value of all valid equivalency factors was taken. Where appropriate, additional data points were sourced from studies in literature, which provided a direct comparison of diuron and a test herbicide. These toxicity studies were first assessed according to quality criteria specified in the Australian and New Zealand Environment and Conservation Council (ANZECC) water quality guidelines[63].

The herbicide equivalent concentrations were formally calculated using the following functional expression[64]:

$$HEq = \sum_{i=1}^{n} C_{iW} REP \qquad (13)$$

where,

HEq = herbicide equivalent concentrations. Calculated for PSII herbicides only (PSII-HEq) or all modelled herbicides (h-HEq);

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[61] Kennedy et al., 2012.
[62] United States Department of Agriculture, 2011.
[63] ANZECC, 2000.
[64] See Kennedy et al., 2012:1.

C_{iW} = the time averaged concentration of each individual PSII herbicide; and,

REP = the relative potency of the herbicide with respect to the reference herbicide Diuron.

A delivery ratio of eighty per cent (80%) was applied to the sediment bound fraction of the total load prior to calculation of a HEq. This reflected the fact that a portion of eroded sediment would be redeposited prior to reaching the edge of the farm. However, under situations where the crop and crop residue levels are high (>65 per cent), as simulated here, a high proportion (approx. 70-90%) of the small amount of eroded soil has been shown to be within the fine particle size fraction that can be expected to remain suspended[65].

The application of these toxic equivalency values assumes that the combined effect of these herbicides in a mixture is concentration additive. Further, it should be noted that the application of this approach assumes that the dose-response pattern for each of the herbicides follows the same trend, meaning that the dose-response curves should be parallel. The PSII herbicides have a common mode of action and the success of predicting mixture toxicity based on a TEQ approach has been demonstrated in several studies[66]. However, these assumptions have not been tested for the remaining herbicides included in the h-HEq. As these herbicides follow different modes of action (see Table 5), it is less likely that a simple concentration addition model will explain the mixture toxicity. However, concentration addition has been found to be a conservative measure in absence of information on the interactions between different modes of action with relatively small likelihood of underestimating effects[67]. Therefore, this measure represents the best currently available assessment. There is a need for future research to investigate mixture toxicity of herbicides relevant to the GBR on locally important species.

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[65] Silburn et al., 2011.
[66] Bengtson-Nash et al., 2005.
[67] Belden et al., 2007.

Table 5: Relative potencies for PSII-herbicides on photosynthesis (PSII-REP) and for all modelled herbicides based on EC_{50} values for population growth or abundance endpoints (h-REP) with respect to the reference herbicide diuron (REP=1)

Active Ingredient	PSII-REP[a]	h-REP (Median)	h-REP (n)	h-REP (Range)	Mode of Action[b]
Diuron	1	1	-	-	Inhibitor of photosynthesis at PSII
Hexazinone	0.38	0.35	5	0.29-2.9	Inhibitor of photosynthesis at PSII
Atrazine	0.15	0.15	22	0.00062-0.86	Inhibitor of photosynthesis at PSII
Ametryn	1.3	1.0	21	0.059-1.7	Inhibitor of photosynthesis at PSII
Metribuzin	NA[c]	0.12	3	0.081-0.29	Inhibitor of photosynthesis at PSII
S-metolachlor	NA	0.30	3	0.026-0.62	Inhibitor of cell division
Pendimethalin	NA	0.0059	5	0.0032-0.015	Inhibitors of microtubule assembly
Imazapic as ammonium salt[d]	NA	1.6	2	0.046-3.1	Inhibits the production of amino acids necessary for cell division and growth
Isoxaflutole	NA	1.3	2	0.017-2.7	Acts by indirect carotenoid biosynthesis inhibition
Haloxyfop-R-methyl ester	NA	0.00039	5	0.00016-0.00065	ACCase inhibitor
Imazethapyr	NA	0.80	2	0.000041-1.6	Acetolactate synthase (ALS) inhibitor
Fluroxypyr as metpyl ester	NA	0.0036	4	0.0015-0.0093	Synthetic auxin
Acifluorfen as sodium salt[d]	NA	0.022	2	0.009-0.035	Cell membrane disruption - PPO inhibitor
Glyphosate as ipa	NA	0.00052	3	0.0002-0.0011	Inhibition of lycopene cyclase.
Paraquat dichloride	NA	0.0015	6	0.0002-0.13	Photosystem I inhibitor
2,4-D amine	NA	0.011	2	0.000047-0.022	Synthetic auxin

[a] Kennedy et al., 2012.

[b] Pesticides Properties Database (PPDB), University of Hertfordshire.

[c] Although metribuzin is a PSII herbicide, it is not included in Reef Plan as a priority herbicide and so has not previously been included in PSII equivalency calculations for the marine monitoring program or other components of the Paddock to Reef program. For consistency metribuzin has therefore also been excluded from the PSII-HEq calculations in the current study.

[d] Due to a lack of data meeting the established criteria, data of lower quality were accepted for these comparisons.

4. Results

4.1. FGM Analysis

Multiple representative farm scenarios were constructed according to the following scheme: 4 regions (i.e. Tully, Burdekin Delta, BRIA, and Mackay) x 3 farm sizes (i.e. small, medium and large) x 24 pesticide management scenarios = 288 FEAT scenarios.

4.1.1. Key parameters and assumptions

Key parameters used to calculate the FGM for each scenario are listed as follows:

- net sugar price is set at $410 per tonne (International Polarity Standard – (IPS)) and assumed constant - this is the 5 year moving-average sugar price from 2007 to 2011 for the Queensland Sugar Limited Seasonal Pool[68];
- sugarcane production estimates provided by the APSIM model based on regional production potential calculated using historical climate data and the major soil types under the Six-Easy-Steps nutrient management regime. Due to the project focusing on effective weed management scenarios and operating within label requirements, production is assumed to be constant when changing between herbicide management practices;
- fuel price is set at $1 per litre (net of GST and rebate);
- input costs (nutrient & chemical) are based on 2012 data and assumed constant – costs were provided by local Agribusiness;
- field labour cost is set at $30 per hour and assumed constant;
- electricity prices are 2012 tariffs obtained from Ergon Energy and assumed constant;
- the sugarcane crop cycle is assumed to consist of a fallow, plant and four ratoon crops in the Tully and Mackay areas, while a three-ratoon crop cycle is assumed for the Burdekin Delta and BRIA areas. Each phase of the crop cycle is allocated an equal proportion of the total farm area;

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[68] Sugar prices were sourced from ABARES, 2013 and Queensland Sugar Limited.

- all farms are assumed to use controlled traffic on a 1.8m row spacing;
- lime is applied to the fallow area for soil remediation purposes in the Tully and Mackay areas, while gypsum is applied in the Burdekin Delta and BRIA areas; and,
- figures are exclusive of GST where applicable.

4.1.2. Results - FGMs analysis of management practice scenarios by class

The results of the FGM calculations for each scenario are presented on a per-hectare basis in dollars per hectare (Table 6) along with the descriptive statistics for each region and farm size.

Table 6: Descriptive statistics of FGMs analysis ($/ha) for scenarios grouped by management practice classification

Application rate	Fallow	Herbicide selection	Strategic use	Method of application	Tillage	Tully 50ha	Tully 150ha	Tully 250ha	Mackay 50ha	Mackay 150ha	Mackay 250ha	BDT Delta 50ha	BDT Delta 150ha	BDT Delta 250ha	BRIA 50ha	BRIA 150ha	BRIA 250ha
AA	FB	SB	HB	MA	GB	1041	1067	1106	1281	1310	1356	3197	3227	3272	1976	2011	2060
AA	FB	SB2	HB	MA	GB	1032	1058	1097	1271	1300	1345	3192	3222	3267	1965	2006	2055
AA	FC	SB	HB	MA	GC	962	989	1030	1265	1292	1335	3182	3210	3257	1966	2007	2046
AA	FC	SB2	HB	MA	GC	952	979	1019	1255	1282	1324	3183	3210	3257	1967	2008	2047
AB	FB	SB	HB	MB	GB	1024	1049	1088	1275	1302	1342	3178	3208	3250	1958	1992	2038
AB	FB	SB2	HB	MB	GB	1001	1026	1064	1258	1285	1326	3149	3178	3221	1929	1962	2009
AB	FC	SB	HB	MB	GC	945	972	1011	1259	1285	1322	3166	3193	3238	1952	1981	2027
AB	FC	SB2	HB	MB	GC	922	949	988	1243	1268	1305	3142	3169	3214	1928	1957	2003
AC	FB	SB	HC	MC	GB	988	1013	1055	1250	1276	1319	3167	3195	3237	1947	1979	2025
AC	FB	SB2	HC	MC	GB	915	940	980	1231	1258	1300	3142	3171	3213	1922	1955	2001
AC	FC	SB	HC	MC	GC	909	936	978	1234	1260	1299	3141	3167	3212	1927	1955	2002
AC	FC	SB2	HC	MC	GC	835	862	903	1216	1241	1280	3117	3143	3188	1899	1927	1974
Average FGM ($/ha)						960	987	1026	1253	1283	1321	3163	3191	3235	1945	1978	2024
Minimum FGM ($/ha)						835	862	903	1216	1241	1280	3117	3143	3188	1899	1927	1974
Maximum FGM ($/ha)						1041	1067	1106	1281	1310	1356	3197	3227	3272	1976	2011	2060
Range in FGM ($/ha)						106	105	103	65	69	76	80	84	84	77	84	86
Range in FGM as a proportion of average FGM						21%	21%	20%	5%	5%	6%	3%	3%	3%	4%	4%	4%
Standard deviation FGM ($/ha)						60	60	59	19	20	22	25	26	26	23	27	26
Coefficient of variation						6.3%	6.1%	5.8%	1.5%	1.6%	1.6%	0.7%	0.8%	0.8%	1.2%	1.4%	1.3%
Average yield in relative terms (t/ha) (base = Tully = 100)							100			107			177			132	

The data provided in Table 6 clearly illustrate that there is quite a substantial difference in the magnitude of results from the FGMs analysis between cane districts and across respective farm sizes. For example, the minimum FGM shown in the table is $835 per hectare for a 50ha farm in Tully, while the maximum is $3,272 per hectare for a 250ha farm in the Burdekin Delta. Cane yields are the primary factor driving the difference in these magnitudes: the average yield data for Tully in relative terms is seven per cent (7%) lower than in Mackay; thirty-two per cent (32%) lower than the BRIA; and seventy-seven per cent (77%) lower than the Burdekin Delta.

Looking at the descriptive statistics between districts, the Tully FGM data has the largest range between the minimum and maximum values and the greatest variance (indicative of the standard deviation). In relative terms, the range in the FGM as a proportion of the average FGM is much greater for Tully (~20%) compared to Burdekin and Mackay (~3% to 6%, respectively). Similarly, the coefficient of variation in the FGM across districts (i.e. the standard deviation as a proportion of the average FGM) ranges from over 6% in Tully to less than 1% in the Burdekin Delta. The variation between districts is an implication of the unique climate and soil type within each region as well as specific production systems that take the natural conditions into consideration.

The following series of graphs (Figures 3 to 6) display the results for the FGM analysis for each region when using various herbicide management practices within a farming system. The code for each management practice depicted on the x-axis represents the underlying combination of practices according to data that is grouped by *A*-, *B*- and *C-Class* herbicide practices[69] together with different combinations of fallow, herbicide selection, and tillage classes.

Figure 3: Tully - FGM by management practice classification

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[69] These are arranged by management practice classification involving the underlying practice options regarding the rate, application method and residual use strategy.

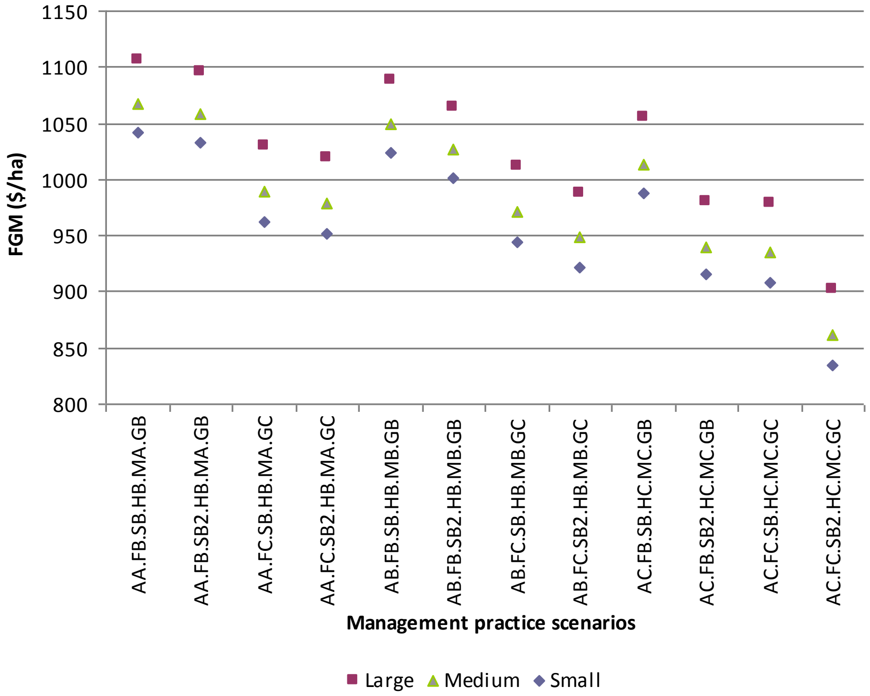


Figure 4: **Mackay - FGM by management practice classification**

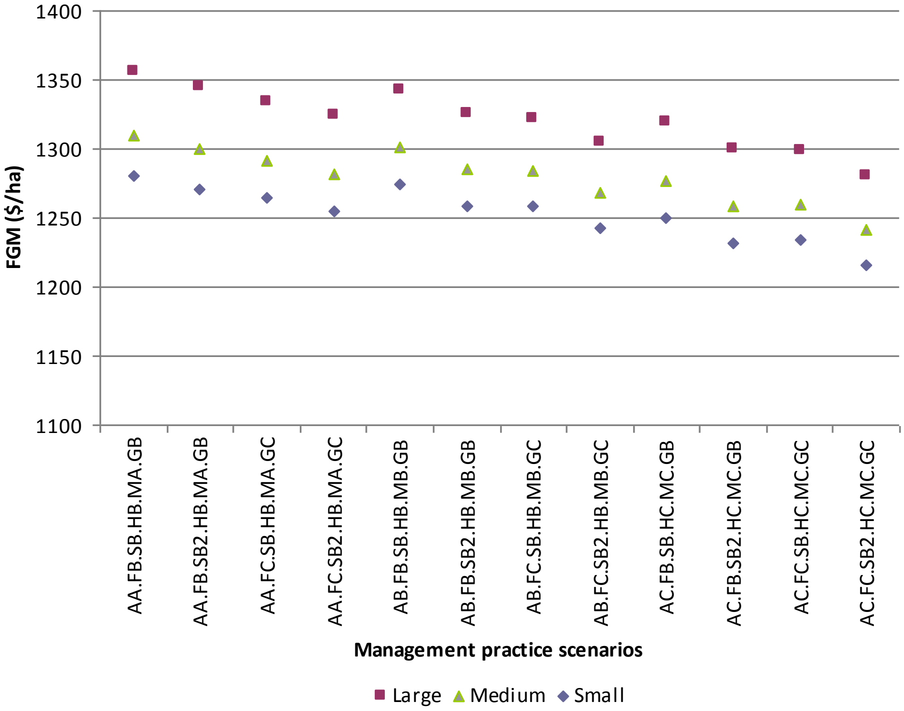


Figure 5: **Delta - FGM by management practice classification**

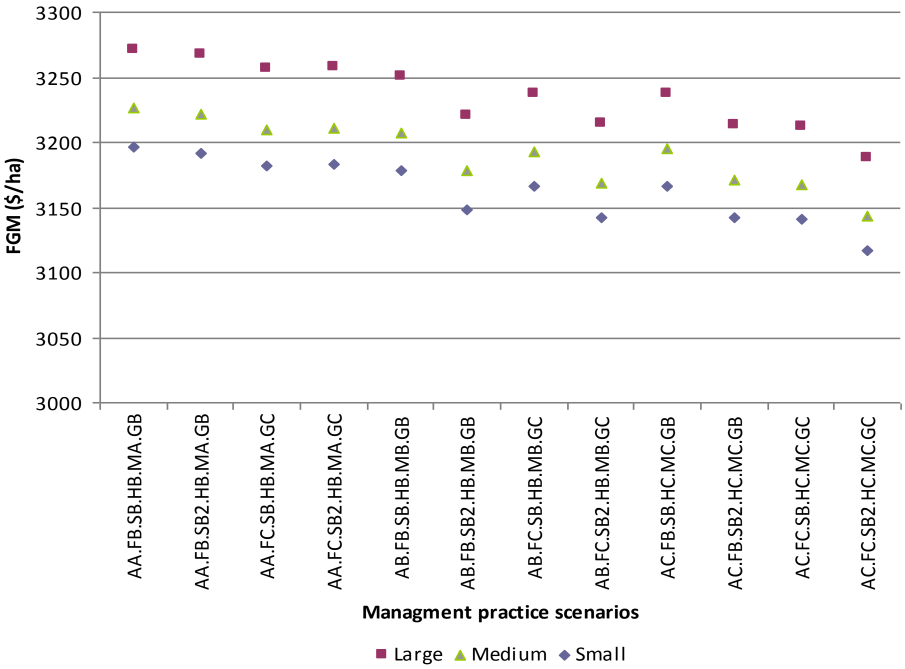
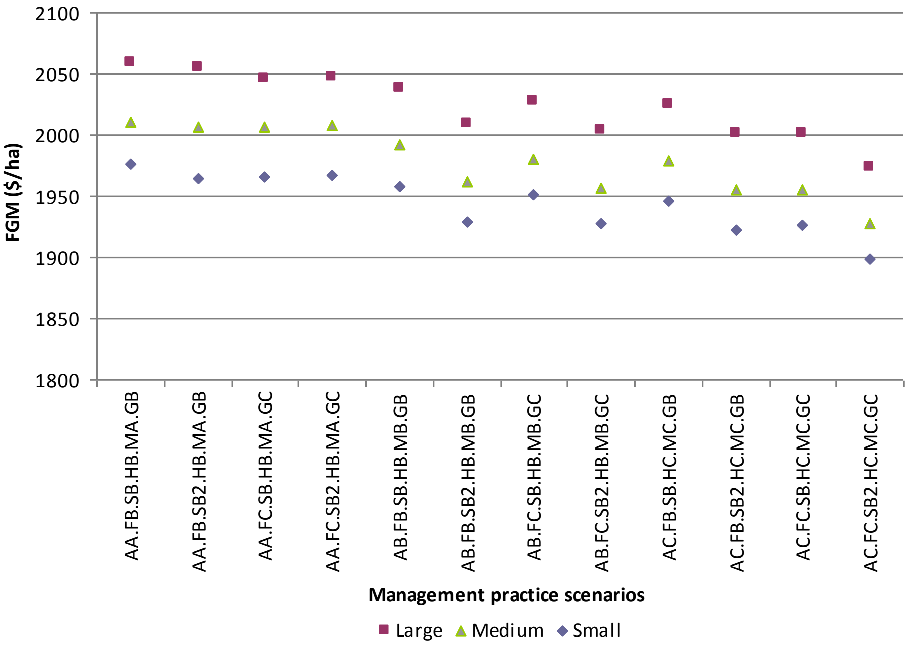


Figure 6: BRIA - FGM by management practice classification



The FGMs data provides initial insight into the financial performance of the farming system when the farm is under a particular set of management practices. For instance, the results indicate that across all regions a general pattern of a decreasing FGM can be observed from left to right in logical progression from *A-Class* through to *C-Class* herbicide management practices. The graphs also depict the relative differences in the spread between practices. For instance, in Tully the spread of the FGM for the *C-Class* herbicide options across the various farm sizes is approximately $220/ha ($1,055 - $835), while for *B-Class* it is $166/ha ($1,088 - $922) and $154/ha ($1,106 - $952) in *A-Class*. Although considerably smaller by magnitude, the same pattern is observed when comparing the spread of the FGM for *C-* through to *A-Class* management practices in Mackay: *C* - $103/ha, *B* - $99/ha and *A* - $55/ha; for Delta *C* - $120/ha, *B* - $108/ha and *A* - $90/ha; and for BRIA *C* - $126/ha, *B* - $110/ha and *A* - $94/ha.

The larger spread of the FGMs data within *C-Class* is a consequence of a higher input system: *C-Class* herbicide management is characteristic of high rates; non-strategic use; and standard application methods. Therefore, any incremental change, particularly with respect to herbicide selection[70], causes a relatively greater impact on the FGM compared with the lower input systems. The high tillage scenario in Tully also includes a tillage operation in each ratoon crop (i.e. ripper coulter) that is not represented in the low tillage scenario. Similarly, there are assumed to be no tillage operations performed in ratoon cane crops in Mackay and the Burdekin.

Also evident across all graphs is the differences in FGM between small, medium and large farm sizes. A higher gross margin for the large farms is a result of greater machinery efficiencies associated with the larger farming area. Accordingly, operational efficiency is higher for larger farms because greater asset utilisation exists.

The series of Figures 7 to 10 present an analysis of the FGM for a medium size farm in the Tully, Mackay, Delta, and BRIA districts grouped according to the key principles of herbicide management (i.e. rate, application method and strategy), fallow management and herbicide selection as listed across the x-axis. These graphs show the average FGM as well as its range, in the context of how the rest of the farming system is managed. Only the results for the medium farm size are presented since these are representative of the similar patterns observed for both the 50 hectare and 250 hectare farm scenarios.

Figure 7: Tully FGM by management practice principle (150 hectares)

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[70] Herbicide selection evaluates the use of standard (*SB*) versus alternative herbicides (*SB2*), where the alternative scenario excludes the use of commonly-used PSII herbicides (i.e. diuron, ametryn, atrazine and hexazinone).

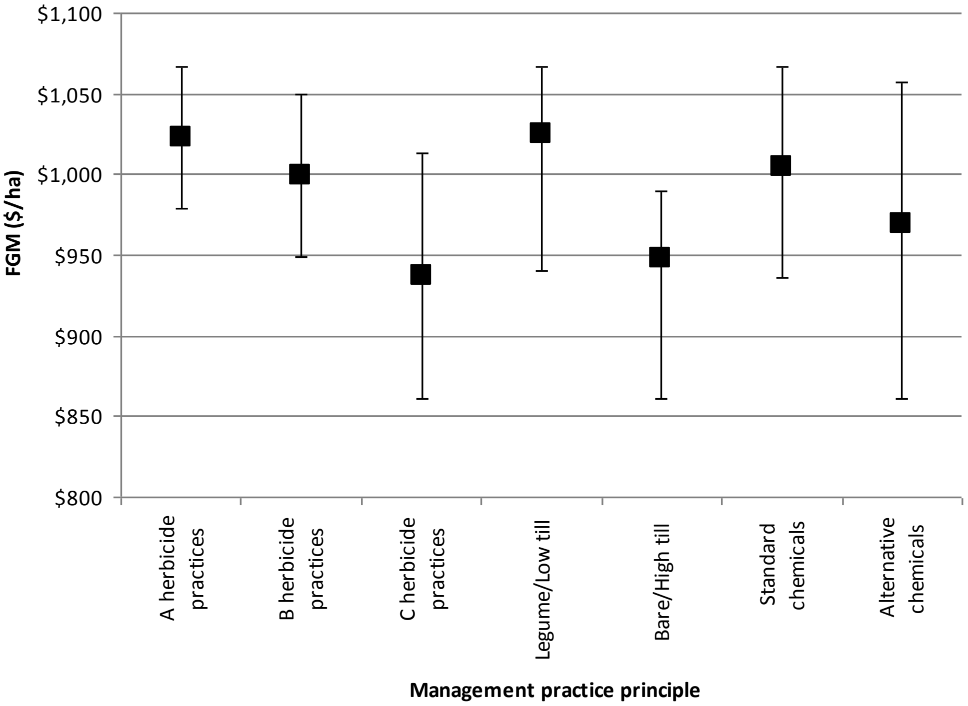


Figure 8: Mackay FGM by management practice principle (150 hectares)

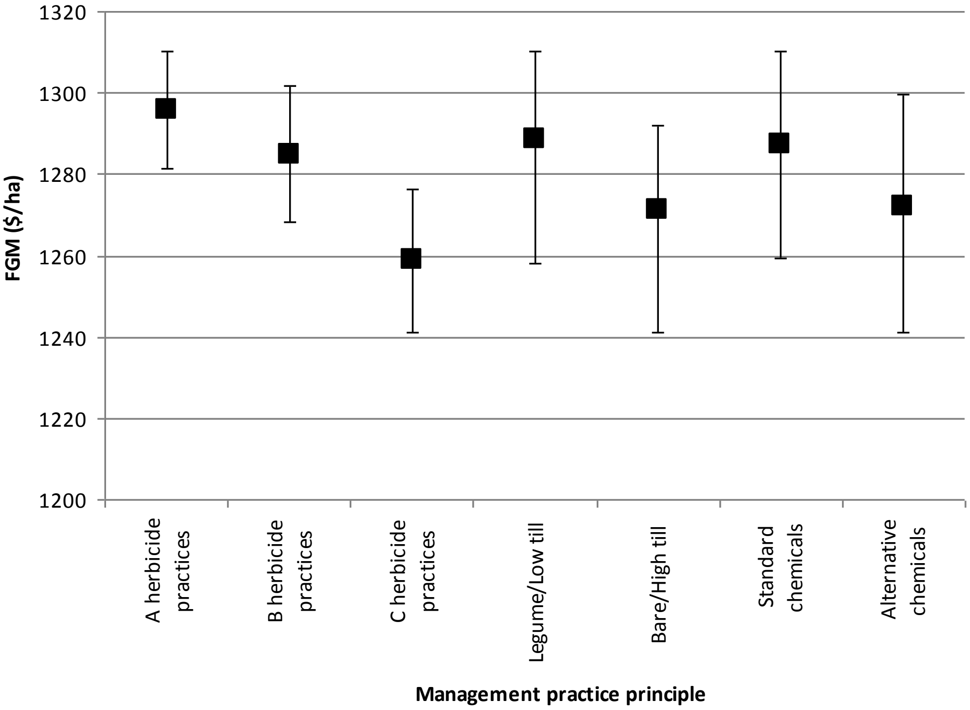


Figure 9: Delta FGM by management practice principle (150 hectares)

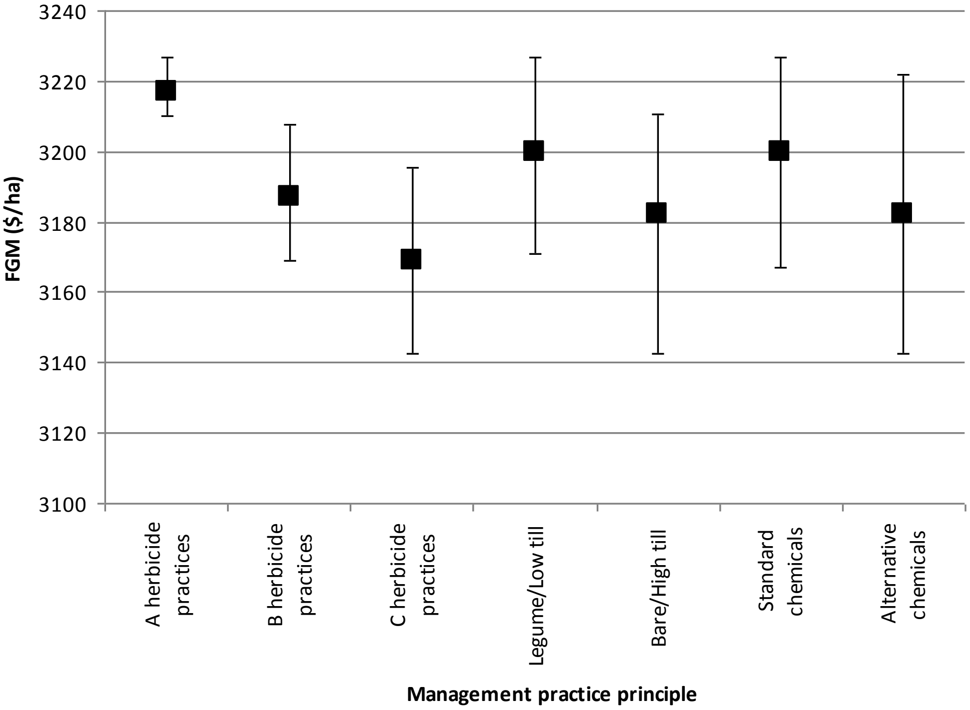
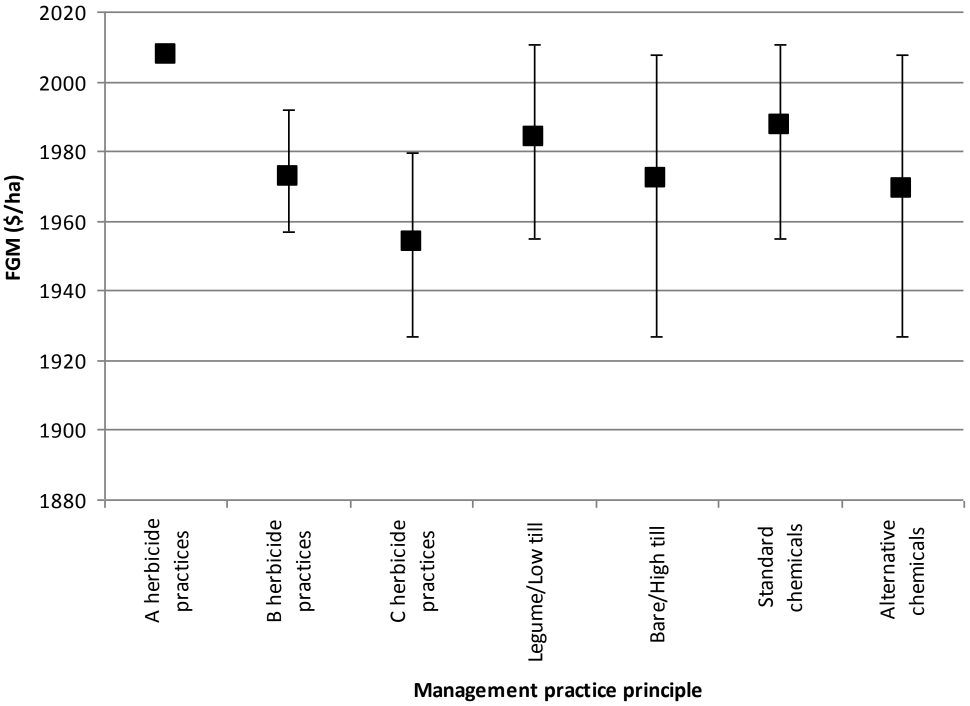


Figure 10: BRIA FGM by management practice principle (150 hectares)



The first three plots on the left side of Figures 7 to 10 illustrate the average FGM across all regions increasing when progressing from *C-* to *A-Class* herbicide management[71]. For instance, the average FGM for Tully *C-Class* herbicide management is approximately $61/ha and $86/ha less than for the *B-* and *A-Class*, respectively (see Figure 7). When comparing a progressive step change in herbicide management, the largest financial benefit apparently occurs when changing from *C-Class* to *A-Class* herbicide management. It is important to note that the range in the FGM for each management principle is much greater in Tully than in the other regions. Again, this is explained in part by the high tillage scenario (i.e. *FC-GC*) involving a tillage operation in each ratoon crop (i.e. ripper coulter) in Tully that is not represented in the other regions.

When comparing the average FGMs for each of the fallow and tillage combinations across regions, the results indicate a benefit ranging from $12/ha (BRIA) to $78/ha (Tully) for a legume cover crop and low tillage combination. However, while the yield modelled by APSIM is similar in both scenarios, previous research has indeed shown potential for yield improvements under a legume fallow scenario[72].

A review of herbicide selection indicates that the use of alternative herbicides will generally come at a cost, with a decrease in the average FGM ranging from $15/ha (Mackay) to $35/ha (Tully) across all regions. These results are influenced to a considerable degree by the regional variability in weed management practices and the specific selection of herbicide products.

4.2. Results of the investment analysis

4.2.1. Results of NPV analysis for changing herbicide management involving standard chemicals

This section presents the results of the NPV analyses for changing herbicide management classes using standard chemicals in conjunction with different combinations of fallow and tillage management practices within each region. Herbicide management is evaluated in detail due to it being the prime focus of this report and because of its direct importance to water quality outcomes. Management options involving tillage, fallow and herbicide selection are each evaluated in further detail in subsequent sections of this report.

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[71] A-Class includes an optimised rate, use of precision application equipment and strategic use of residuals.

[72] Garside & Bell (2011a, 2011b); Poggio & Hanks, 2007; Young & Poggio, 2007.

Each of the figures presented in Tables 7 to 10 are colour coded to indicate a positive (black) or negative (red) economic outcome based on the parameters used in the analysis. The first column provides a description of the changes to herbicide management that is being examined. These changes are arranged progressively from *C- to A-Class* management and grouped together with the appropriate combination of tillage and fallow management. The total capital expenditure requirements (see Table 3) to make those described changes are subsequently listed in the second column.

The change to the annual FGM that results from each management change is presented in the third column. The change to the FGM is used to evaluate the contribution of farm activities to profit when adopting each new system of management. The fourth column provides the Net Present Value (NPV) calculations for adopting each management change. The NPV figure is calculated by subtracting the CAPEX in the first column from the accumulated changes to the FGM over a period of ten years, which are discounted back to their present value using a required rate of return on investment of six per cent per annum.

The Internal Rate of Return (IRR) for each of the practice changes is listed in the fifth column of each table. The IRR essentially provides the ratio of the changes to the FGM each year as a percentage of the CAPEX, thus providing the rate of return on investment that each management change is expected to provide to the landholder for each of the ten years. Similar to the NPV, the IRR is a critical indicator of profitability. Unlike the NPV figure, the IRR does not rely on the assignment of a discount rate to inform the investment decision. Given that individual farm businesses face different business risks (e.g. production and financial), the IRR enables landholders to consider whether the expected return on investment is sufficient compensation for the inherent risk to their particular businesses from changing management practices.

Individual landholders will likely hold different perceptions about the appropriate timing of the investment. The benefits of practice change are only realised over time and growers may perceive a 10-year investment horizon to be too far into the future to receive an appropriate return on their capital investment. Hence, the payback period provided in the sixth column of each table shows the year in which the CAPEX for each management change will be recovered based on the accumulated present value of the annual changes to the FGM. Last, the break-even CAPEX over the ten years is shown in the far right column. Although these figures are presented as absolute numbers, it is acknowledged that variation in capital expenditure costs will likely occur amongst landholders.

The results for the Tully analysis are first presented, while summary reports for the other regions follow.

Table 7: Tully – Results of investment analysis

50 hectare farm

Description	CAPEX ($)	Change in FGM ($/yr)	Net Present Value ($/10yr @ 6%)	Internal Rate of Return (%/yr)	Payback period (yrs)	Break-even CAPEX ($)
C- to B-Class (Bare & High Tillage)	1870	1800	11381	96.2%	2	13251
C- to A-Class (Bare & High Tillage)	11575	2665	8055	19.0%	6	19630
B- to A-Class (Bare & High Tillage)	11084	865	-4706	-4.2%	>10	6378[a]
C- to B-Class (Legume & Low Tillage)	1870	1800	11381	96.2%	2	13251
C- to A-Class (Legume & Low Tillage)	11575	2675	8115	19.1%	6	19690
B- to A-Class (Legume & Low Tillage)	11084	875	-4645	-4.1%	>10	6439[a]

150 hectare farm

Description	CAPEX ($)	Change in FGM ($/yr)	Net Present Value ($/10yr @ 6%)	Internal Rate of Return (%/yr)	Payback period (yrs)	Break-even CAPEX ($)
C- to B-Class (Bare & High Tillage)	1870	5400	37855	288.7%	1	39725
C- to A-Class (Bare & High Tillage)	11575	8000	47329	68.8%	2	58903
B- to A-Class (Bare & High Tillage)	11084	2605	8094	19.6%	6	19178
C- to B-Class (Legume & Low Tillage)	1870	5400	37856	288.7%	1	39725
C- to A-Class (Legume & Low Tillage)	11575	8030	47510	69.0%	2	59085
B- to A-Class (Legume & Low Tillage)	11084	2630	8276	19.9%	6	19851

250 hectare farm

Description	CAPEX ($)	Change in FGM ($/yr)	Net Present Value ($/10yr @ 6%)	Internal Rate of Return (%/yr)	Payback period (yrs)	Break-even CAPEX ($)
C- to B-Class (Bare & High Tillage)	2750	8290	58249	301.4%	1	61000
C- to A-Class (Bare & High Tillage)	13768	12840	80753	93.1%	2	94521
B- to A-Class (Bare & High Tillage)	13086	4555	20436	32.8%	4	33522
C- to B-Class (Legume & Low Tillage)	2750	8290	58249	301.4%	1	61000
C- to A-Class (Legume & Low Tillage)	13768	12880	81057	93.4%	2	94825
B- to A-Class (Legume & Low Tillage)	13086	4595	20739	33.1%	4	33825

[a] Results indicate that an investment in this practice is warranted if the CAPEX is less than the break-even amount.

The variation in results across the Tully scenarios (Table 7) indicates that certain investments in progressive herbicide management are expected to provide more attractive economic incentives to change than others. The results clearly indicate also that these economic outcomes have a positive relationship with farm size, primarily because the CAPEX is spread across a greater productive area as the size of the farm increases. Interestingly, the combination of fallow and tillage management tends to have a relatively negligible impact on the results between comparative scenarios of herbicide management.

A change towards improved herbicide management generally provides a positive economic outcome in most cases (i.e. providing an annual rate of return on the CAPEX equal to or greater than 6%). The exception to this occurs when changing from *B-* to *A-Class* herbicide management practices for a 50ha farm. The negative NPV implies that the accumulated present value of each of the changes to the gross margin over ten years is not sufficient to cover the initial CAPEX. For instance, the case of moving from *B-* to *A-Class* practices under bare fallow and high tillage results in an NPV of

-$4,706, which is the difference between the accumulated present value of changes to the FGM of $6,378.51 and the CAPEX of $11,084. The negative IRR implies that this particular investment will provide an annual *loss* at a rate equivalent to -4.24 per cent of the $11,084 (i.e. approximately $470) for each year over the ten year investment period.

NPV and IRR are both important indicators of profitability. In Table 7, the largest NPV over 10 years results when changing from *C-* to *B-Class* herbicide management for a 50ha farm and from *C-* to *A-Class* for 150ha and 250ha farms. Over the same time, however, the results indicate that the highest returns on investment (IRR) occur changing from *C-* to *B-Class* herbicide management across all farm sizes.

There is no general rule about which indicator to accept when the NPV and IRR do not lead to identical decisions for independent projects (see Section 3.6). In the case of 150ha and 250ha farms, the investment decision will ultimately depend on the grower's individual perceptions about whether or not the discount rate used in the NPV analysis is appropriate for the level of business risk for each project considered. In addition, other financial indicators are useful to inform the investment decision: for example, moving from *C-* to *B-Class* herbicide management has a shorter investment payback period across all farm sizes than moving from *C-* to *A-Class*.

A higher IRR corresponds with a larger margin between the CAPEX and its break-even point, which implies an increased buffer around the financial risk associated with a change in practice. In a practical sense, the break-even CAPEX calculation represents the maximum amount of funds that can be invested in order to meet the minimum 6 per cent per annum required rate of return used in this analysis. For example, focusing on the aforementioned change from *B-* to *A-Class* herbicide management in the 50ha farm scenario, the break-even analysis indicates the change will result in a positive economic benefit only if the CAPEX is less than approximately $6,378. In other words, investment in this improved practice change is warranted if savings can be achieved in the amount invested, thus reducing the negative NPV (i.e. the difference between the CAPEX and the break-even amount).

Table 8: Mackay – Results of investment analysis

50 hectare farm

Description	CAPEX ($)	Change in FGM ($/yr)	Net Present Value ($/10yr @ 6%)	Internal Rate of Return (%/yr)	Payback period (yrs)	Break-even CAPEX ($)
C- to B-Class (Bare & High Tillage)	1870	1230	7203	65.5%	2	9073
C- to A-Class (Bare & High Tillage)	11575	1525	-336	5.4%	>10	11239[a]
B- to A-Class (Bare & High Tillage)	11084	295	-8918	-18.9%	>10	2166[a]
C- to B-Class (Legume & Low Tillage)	1870	1240	7265	65.9%	2	9135
C- to A-Class (Legume & Low Tillage)	11575	1570	-17	5.9%	>10	11558[a]
B- to A-Class (Legume & Low Tillage)	11084	330	-8661	-17.6%	>10	2424[a]

150 hectare farm

Description	CAPEX ($)	Change in FGM ($/yr)	Net Present Value ($/10yr @ 6%)	Internal Rate of Return (%/yr)	Payback period (yrs)	Break-even CAPEX ($)
C- to B-Class (Bare & High Tillage)	1870	3770	25868	201.5%	1	27738
C- to A-Class (Bare & High Tillage)	11575	4870	24260	40.7%	3	35835
B- to A-Class (Bare & High Tillage)	11084	1100	-2987	-0.1%	>10	8097[a]
C- to B-Class (Legume & Low Tillage)	1870	3790	26026	202.7%	1	27896
C- to A-Class (Legume & Low Tillage)	11575	5045	25546	42.3%	3	37121
B- to A-Class (Legume & Low Tillage)	11084	1255	-1859	2.3%	>10	9225[a]

250 hectare farm

Description	CAPEX ($)	Change in FGM ($/yr)	Net Present Value ($/10yr @ 6%)	Internal Rate of Return (%/yr)	Payback period (yrs)	Break-even CAPEX ($)
C- to B-Class (Bare & High Tillage)	2750	5830	40149	212%	1	42899
C- to A-Class (Bare & High Tillage)	13768	8960	52198	64.7%	2	65967
B- to A-Class (Bare & High Tillage)	13086	3135	9981	20.1%	5	23068
C- to B-Class (Legume & Low Tillage)	2750	5870	40453	213.4%	1	43202
C- to A-Class (Legume & Low Tillage)	13768	9195	53907	66.4%	2	67675
B- to A-Class (Legume & Low Tillage)	13086	3325	11385	21.9%	5	24472

[a] Results indicate that an investment in this practice is warranted if the CAPEX is less than the break-even amount.

Results summary of investment analysis for Mackay:

- All progressive changes in herbicide management are expected to result in a positive economic outcome for 150ha and 250ha farms.
- 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 in larger farms.
- The largest NPV results when changing from *C-* to *B-Class* herbicide management practices for 50ha and 150ha farms and from *C-* to *A-Class* for 250ha farms.
- Progressing from *C-* to *B-Class* herbicide management provides the highest returns on investment (i.e. highest IRR) across all farm sizes.
- Changing from *C-* to *B-Class* herbicide practices is the only scenario that can be expected to provide a positive economic benefit across all farm sizes.

- It is viable to transition from *C-* to *A-Class* herbicide management for the 150ha and 250ha only. Assets are utilised relatively less effectively on small farms than on larger farms and the capital costs are spread over a lower level of output (i.e. economies of scale).
- Progressing from *B-* to *A-Class* is only viable for a 250ha farm.
- In cases where the economic results are positive, transitioning to improved herbicide management is marginally more profitable under a legume fallow and low tillage practices than under bare fallow and high tillage practices.

Table 9: Burdekin Delta – Results of investment analysis

50 hectare farm

Description	CAPEX ($)	Change in FGM ($/yr)	Net Present Value ($/10yr @ 6%)	Internal Rate of Return (%/yr)	Payback period (yrs)	Break-even CAPEX ($)
C- to B-Class (Bare & High Tillage)	1870	1245	7289	66.1%	2	9159
C- to A-Class (Bare & High Tillage)	11575	2060	3577	12.1%	8	15152
B- to A-Class (Bare & High Tillage)	11084	815	-5091	-5.2%	>10	5993[a]
C- to B-Class (Legume & Low Tillage)	1870	590	2465	29.0%	4	4335
C- to A-Class (Legume & Low Tillage)	11575	1505	-492	5.1%	>10	11083[a]
B- to A-Class (Legume & Low Tillage)	11084	915	-4336	-3.3%	>10	6748[a]

150 hectare farm

Description	CAPEX ($)	Change in FGM ($/yr)	Net Present Value ($/10yr @ 6%)	Internal Rate of Return (%/yr)	Payback period (yrs)	Break-even CAPEX ($)
C- to B-Class (Bare & High Tillage)	1870	3880	26668	207.4%	1	28537
C- to A-Class (Bare & High Tillage)	11575	6420	35661	54.7%	2	47236
B- to A-Class (Bare & High Tillage)	11084	2540	7614	18.8%	6	18698
C- to B-Class (Legume & Low Tillage)	1870	1845	11695	98.5%	2	13565
C- to A-Class (Legume & Low Tillage)	11575	4690	22954	39.0%	3	34529
B- to A-Class (Legume & Low Tillage)	11084	2850	9879	22.3%	5	20964

250 hectare farm

Description	CAPEX ($)	Change in FGM ($/yr)	Net Present Value ($/10yr @ 6%)	Internal Rate of Return (%/yr)	Payback period (yrs)	Break-even CAPEX ($)
C- to B-Class (Bare & High Tillage)	2750	6400	44343	232.7%	1	47093
C- to A-Class (Bare & High Tillage)	13768	11140	68233	80.7%	2	81991
B- to A-Class (Bare & High Tillage)	13086	4740	21812	34.3%	4	34898
C- to B-Class (Legume & Low Tillage)	2750	3240	21089	117.7%	1	23839
C- to A-Class (Legume & Low Tillage)	13768	8560	49219	61.6%	2	62987
B- to A-Class (Legume & Low Tillage)	13086	5320	26062	39.2%	3	39149

[a] Results indicate that an investment in this practice is warranted if the CAPEX is less than the break-even amount.

Results summary of investment analysis for Burdekin Delta:

- All progressive changes in herbicide management are expected to result in a positive economic outcome for 150ha and 250ha farms.
- 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 in larger farms.
- The largest NPV results when changing from *C-* to *B-Class* herbicide management practices for 50ha farms and from *C-* to *A-Class* for 150ha and 250ha farms.
- Progressing from *C-* to *B-Class* herbicide management is expected to provide the highest return on investment across all farm sizes.
- Progressing from *C-* to *A-Class* results in a negative NPV under a legume cover crop and low tillage scenario. Albeit, the return on investment is only marginally less than the required six per cent return.
- Progressing, from *B-* to *A-Class* is only expected to provide economic benefits for 150ha and 250ha farms. Assets are utilised relatively less effectively on small farms than on larger farms and the capital costs are spread over a lower level of output (i.e. economies of scale).
- Progressing to improved herbicide management under a bare fallow and high tillage farming system is substantially more profitable when progressing from *C-Class* in those cases where it is economically worthwhile to do so. On the other hand, it is more profitable moving from *B-* to *A-Class* under legume fallow and low tillage practices.

Table 10: BRIA – Results of investment analysis

50 hectare farm

Description	CAPEX ($)	Change in FGM ($/yr)	Net Present Value ($/10yr @ 6%)	Internal Rate of Return (%/yr)	Payback period (yrs)	Break-even CAPEX ($)
C- to B-Class (Bare & High Tillage)	1870	1245	7289	66.1%	2	9159
C- to A-Class (Bare & High Tillage)	11575	1980	2989	11.2%	8	14564
B- to A-Class (Bare & High Tillage)	11084	735	-5680	-6.9%	>10	5404 [a]
C- to B-Class (Legume & Low Tillage)	1870	590	2464	29.0%	4	4334
C- to A-Class (Legume & Low Tillage)	11575	1455	-861	4.4%	>10	10714 [a]
B- to A-Class (Legume & Low Tillage)	11084	865	-4703	-4.2%	>10	6380 [a]

150 hectare farm

Description	CAPEX ($)	Change in FGM ($/yr)	Net Present Value ($/10yr @ 6%)	Internal Rate of Return (%/yr)	Payback period (yrs)	Break-even CAPEX ($)
C- to B-Class (Bare & High Tillage)	1870	3875	26668	207.3%	1	28538
C- to A-Class (Bare & High Tillage)	11575	7870	46372	67.6%	2	57948
B- to A-Class (Bare & High Tillage)	11084	3995	18326	34.1%	4	29410
C- to B-Class (Legume & Low Tillage)	1870	1840	11695	98.5%	2	13565
C- to A-Class (Legume & Low Tillage)	11575	4690	22954	39.0%	3	34529
B- to A-Class (Legume & Low Tillage)	11084	2850	9880	22.3%	5	20964

250 hectare farm

Description	CAPEX ($)	Change in FGM ($/yr)	Net Present Value ($/10yr @ 6%)	Internal Rate of Return (%/yr)	Payback period (yrs)	Break-even CAPEX ($)
C- to B-Class (Bare & High Tillage)	2750	6400	44343	232.6%	1	47093
C- to A-Class (Bare & High Tillage)	13768	11140	68223	80.7%	2	81991
B- to A-Class (Bare & High Tillage)	13086	4740	21812	34.3%	4	34898
C- to B-Class (Legume & Low Tillage)	2750	3240	21092	117.7%	1	23842
C- to A-Class (Legume & Low Tillage)	13768	8560	49223	61.7%	2	62991
B- to A-Class (Legume & Low Tillage)	13086	5320	26062	39.2%	3	39149

[a] Results indicate that an investment in this practice is warranted if the CAPEX is less than the break-even amount.

Results summary of investment analysis for BRIA:

- All progressive changes in herbicide management are expected to result in a positive economic outcome for 150ha and 250ha farms.
- 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 in larger farms.
- The largest NPV results when changing from *C-* to *B-Class* herbicide management practices for 50ha farms and from *C-* to *A-Class* for 150ha and 250ha farms.
- Progressing from *C-* to *B-Class* herbicide management is expected to provide the highest return on investment across all farm sizes.
- Progressing from *C-* to *A-Class* results in a negative NPV for a 50ha farm under a legume cover crop and low tillage farming system.
- While progressing from *B-* to *A-Class* is expected to come at an economic cost for 50ha farms, it is expected to provide economic benefits for 150ha and 250ha farms.

- In those cases where it is economically worthwhile to progress from *C-Class* to improved herbicide management it is substantially more profitable to do so under a bare fallow and high tillage farming system.

4.3. Integration of economic and water quality results

This section presents the outputs from the water quality modelling and the subsequent integration of these results with financial-economic modelling for each of the four core cane growing districts selected. In particular, the following results focus on improved herbicide management involving standard chemicals in conjunction with different fallow and tillage management practices.

4.3.1. Annualised results of the investment analysis

The NPV figures for all the herbicide management scenarios examined in this project were annualised using the AEB approach[73] (calculations are listed in Tables 32 to 35 in the appendices). Detailed results of the investment analysis for changing herbicide management class using standard chemicals were previously provided in Section 4.2.1., and are thus not revisited here. Despite being only a secondary focus of this project, the AEB results also include economic results for changing to alternative chemicals. (Results for limited work undertaken on changing fallow and tillage practices are also presented in the appendices.)

In most cases, the results indicate that a change in herbicide management is likely to provide a greater economic benefit using alternative chemicals compared with standard chemicals, which is an implication of the prices of different chemicals. Since alternative chemicals are more expensive than the standard chemicals, there is a relatively large savings in cost to be realised as a consequence of the reduction in overall chemical use when moving to an improved herbicide management strategy. For example, the results for Mackay indicate a positive AEB when changing from *C-* to *A-Class* herbicide management for both types of fallow and tillage management scenarios using alternative chemicals. On the other hand, a negative economic outcome is shown when making the same changes using standard chemicals.

Changing from standard to alternative chemicals, with all else held constant, will generally provide a negative AEB. It can be noted that an exception to

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[73] The AEB approach provides an annualised measure of the NPV, which enables the economic results to be interpreted using a standardised unit of measure (i.e. comparable in farm area and time).

this particular finding is reflected in the results for the Burdekin, whereby changing herbicide selection in *A-Class* herbicide management under a bare fallow and high tillage indicates a positive AEB outcome. Changing to improved fallow and tillage management practices will provide a negative AEB outcome across all regions and scenarios evaluated with the exception of Tully, where the AEB is found to be positive for 150ha and 250ha farms. It is important to note that this is a consequence of the required CAPEX used in the analysis and the comparatively similar yield data produced by the APSIM modelling.

4.3.2. Results of water quality modelling using standard chemicals

Results for the water quality modelling PSII herbicide-equivalent (PSII-HEq) outputs using standard chemicals are presented in Table 11. The PSII-HEq has been developed for reporting of regulated herbicides detected in the GBR. This approach focuses on the PSII herbicide-equivalent (PSII-HEq) outputs using the established methodology utilised by the P2R program (see Section 3.8).

Table 11: Results of water quality modelling for on-farm PSII herbicide-equivalent (PSII-HEq) rates by regions and management practice setting

Application rate	Fallow	Herbicide selection	Strategic use	Method of application	Tillage	Tully (g/ha/yr)	Mackay (g/ha/yr)	Delta (g/ha/yr)	BRIA (g/ha/yr)
AA	**FB**	**SB**	**HB**	**MA**	**GB**	3.91	1.87	0.65	1.11
AA	**FC**	**SB**	**HB**	**MA**	**GC**	5.60	4.95	1.11	3.71
AB	**FB**	**SB**	**HB**	**MB**	**GB**	14.94	5.98	8.98	16.24
AB	**FC**	**SB**	**HB**	**MB**	**GC**	20.26	9.87	23.76	58.49
AC	**FB**	**SB**	**HC**	**MC**	**GB**	21.93	12.50	21.97	38.24
AC	**FC**	**SB**	**HC**	**MC**	**GC**	34.13	20.30	50.60	113.20

The effects of management practices not directly related to herbicide applications, including tillage and fallow management, can be seen in these results. Comparison of the PSII-HEq from scenarios including the same herbicide related practices (application rate/product selections/method of application) show factor differences of 1.4 to 2.6 in Tully, Mackay, and in the Burdekin Delta. By comparison, non-herbicide related management options exerted a larger influence in the BRIA scenario for the Burdekin region (~3 to 3.6 times). This is likely due to the influence of irrigation in the BRIA simulations, where frequent runoff events due to irrigation exacerbate the effects of tillage management.

Reductions in the PSII-HEq measure due to changes in the herbicide management practices were larger than those due to changes in tillage/fallow management. In Tully and Mackay, the PSII-Heq for the *AA* scenario was ~6 to 7 times smaller than the *AC* scenario. In both the Delta and BRIA scenarios in the Burdekin the *AA* PSII-HEq was ~30-35 times lower than the

AC scenario. This reflects a shift in the selection of herbicide products occurring concurrent with a reduction in application rate and frequency between these scenarios (see Appendix 1).

4.3.3. Cost-effectiveness Analysis of changing management practices using standard chemicals

Cost-effectiveness Analysis (CEA) is an analytical tool used effectively to compare the costs/benefits associated with various options when the underlying effect being examined does not represent a monetary value[74]. In this section, the cost-effectiveness of progressively changing management practices using standard chemicals is examined. Presenting the CEA in a cost-effectiveness plane provides a visual display of the outcomes in absolute terms. Subsequently, the ratio of the two outcomes may be calculated to enable each of the alternative options to be compared in relative terms. CEA is thus useful for landholders to evaluate which practice changes with water quality benefits are relatively more profitable to adopt per unit of herbicide abatement. Furthermore, it is useful to policy makers concerned with allocating resources efficiently, particularly with respect to pesticide abatement targets and budgetary constraints. Indeed, this presents an optimisation problem, which is beyond the scope of this project.

Wet Tropics

Figure 11 presents the cost-effectiveness plane for changing management practices in all cases examined in the Tully region. Intuitively, the water quality effects that result from changing management practices are measured along the horizontal axis, while the corresponding financial-economic impacts are measured on the vertical axis. The respective outcomes are depicted by each data point located along the plane.

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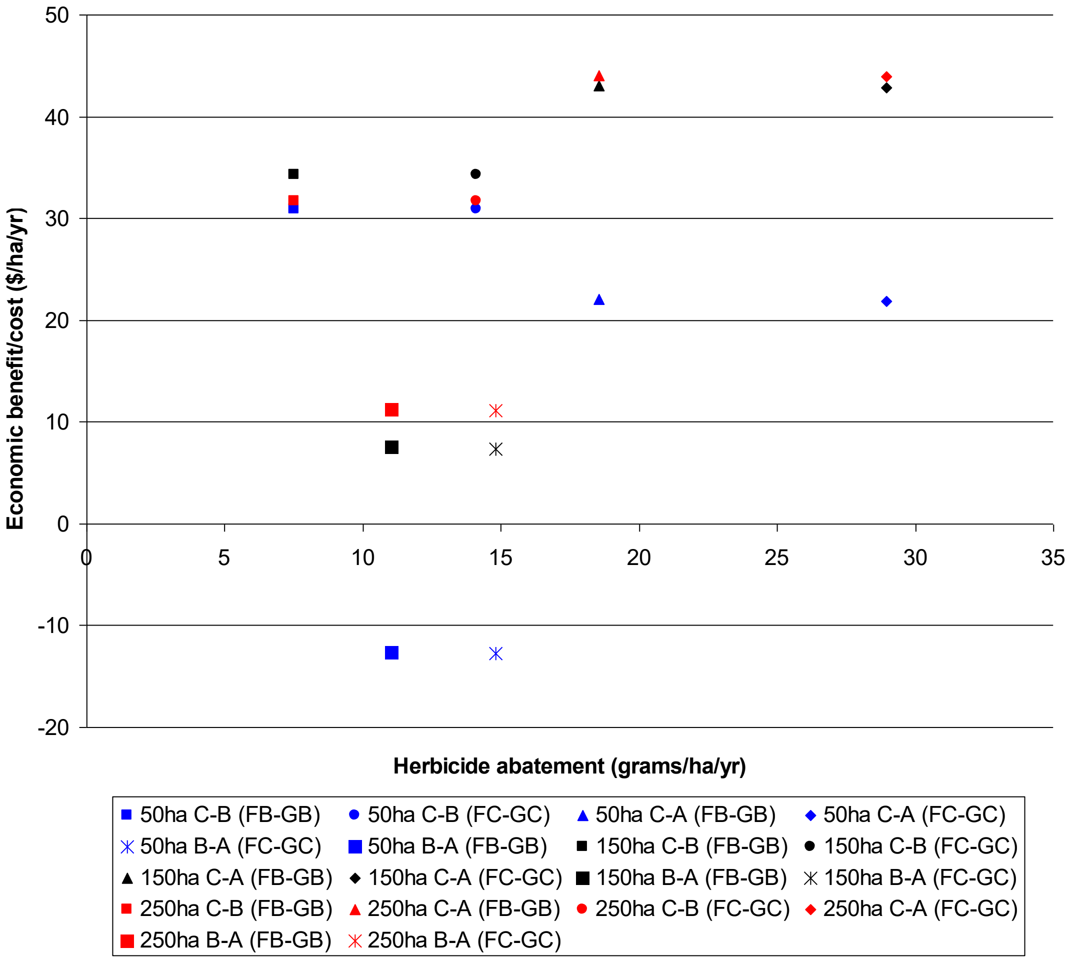
[74] CEA is distinct from cost-benefit analysis, which compares two outcomes that are both represented in monetary terms.

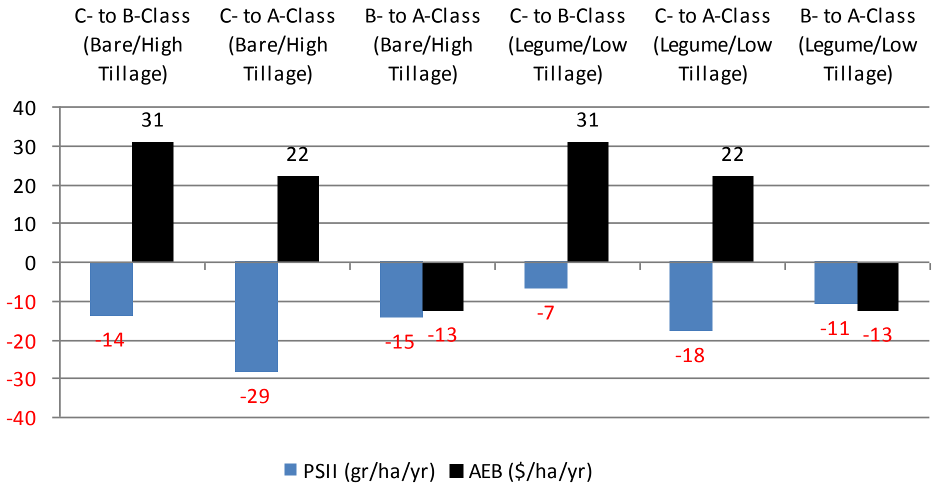
Figure 11: Tully - cost-effectiveness plane



While the cost-effectiveness plane theoretically consists of four specific quadrants, only two of these are shown here (Figure 11). This is a consequence of the project design, whereby all progressive changes to management practices result in positive water quality outcomes. Those that provide both economic and water quality benefits are located in the top half of the diagram, while those that present a trade-off between water quality benefits and economic costs are located in the bottom half. The data points that appear further towards the top-right of the diagram represent the largest combination of economic and water quality benefits. Conversely, those appearing further towards the bottom-left of the plane represent the poorest combinations. For example, it can be seen along the cost-effectiveness plane for Tully that transitioning from *C-* to *A-Class* practices under bare fallow and high tillage (for 150ha and 250ha farms, in particular) provides the largest combination of economic and water quality benefits in absolute terms.

The remainder of this section presents the calculations from the integration of the water quality and economic outcomes in order to determine the dollar benefit/cost per unit of herbicide abatement for each of the changes in herbicide management. Graphs are initially provided, which juxtapose the water quality and economic outcomes of changing herbicide management in absolute terms. Results are presented in terms of their relative values in the accompanying tables.

Figure 12: Graphical presentation of results for Tully 50ha



The layout of Figure 12 (as well as for all similar graphs presented) consists of the described change in management practice settings, which are presented along the top of the graph in accordance with the pesticide principles and management options listed in Table 2. The blue bar denotes the reduction in PSII herbicides, while the black bar illustrates the corresponding financial-economic benefits/costs. Moving progressively from left to right[75], the first two columns depict the water quality and economic outcomes for changing from a *C-Class* herbicide management setting using standard chemicals in conjunction with a bare fallow and high tillage practices to a *B-Class* setting, all else equal. The outcomes of changing from a *C-Class* practice setting to an *A-Class* setting are subsequently depicted in the second two columns, and so on.

Calculations resulting from the integration of these outcomes are listed in Table 12. The first column of figures displays the water quality benefits in terms of total reduction in PSII-HEq herbicides (gr/ha/yr), while the next column states the percentage reduction in terms of the change to the base level[76]. The AEB ($/ha/yr) is presented along with the return on investment in

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[75] Refer to Section 2.2 for a detailed clarification and description of the coding.

[76] For instance, if progressing from C- to B-Class herbicide management, the relative reduction is the total reduction in the level of PSII-HEq herbicide as a proportion of the initial level at C-Class.

the following columns. The calculations presented in the far-right column are expressed as the ratio of the AEB to the total reduction of herbicides. This ratio provides a comparative assessment of the economic outcomes of different management practices in terms of a *per unit reduction* in PSII herbicides leaving the farm. Intuitively, a positive value implies that the change to the management practice is likely to be profitable for the landholder. Conversely, a negative value (denoted in red) indicates that there is likely to be a financial-economic cost for the landholder.

Table 12: Results summary of AEB per unit reduction of PSII-HEq herbicide for 50ha Tully farm

Description	Water quality benefit: Δ PSII-HEq (g/ha /yr)	Relative reduction in PSII-HEq (%/yr)	Economic benefit/cost: (AEB) ($/ha /yr)	Return on investment: (IRR) (%/yr)	Economic benefit/ cost per gram of herbicide abatement: AEB / ΔPSII-HEq ($/g)
C- to B-Class (Bare & High Tillage)	**14**	**-40.7%**	**31**	**96.2%**	**2.23**
C- to A-Class (Bare & High Tillage)	**29**	**-83.6%**	**22**	**19.0%**	**0.77**
B- to A-Class (Bare & High Tillage)	**15**	**-72.3%**	**-13**	**-4.2%**	**-0.87**
C- to B-Class (Legume & Low Tillage)	**7**	**-31.9%**	**31**	**96.2%**	**4.43**
C- to A-Class (Legume & Low Tillage)	**18**	**-82.2%**	**22**	**19.1%**	**1.22**
B- to A-Class (Legume & Low Tillage)	**11**	**-73.8%**	**-13**	**-4.1%**	**-1.14**

Results summary for a 50ha farm in Tully:

- Progressing from *C-* to *A-Class* herbicide management under a bare fallow and high tillage farm system results in the greatest water quality benefit (29 grams ha/yr; ~84% reduction from previous level).

- Progressing from *C-* to *B-Class* herbicide management provides both the largest annualised NPV ($31 ha/yr) as well as the highest return on investment (~96 %/yr).

- The transition from *B-* to *A-Class* herbicide management is expected to come at an economic cost to reduce PSII equivalent herbicide losses from the farm. This is predominantly due to the size of the CAPEX requirement relative to annual economic benefits.

- Progressing from *C-* to *B-Class* herbicide abatement is expected to provide the largest economic benefit per unit of PSII-HEq herbicide abatement. The benefit is $4.43 per gram under a legume fallow and low tillage farming system and $2.23 a gram for the same changes under a bare fallow and high tillage farming system.

Figure 13: Graphical presentation of results for Tully 150ha

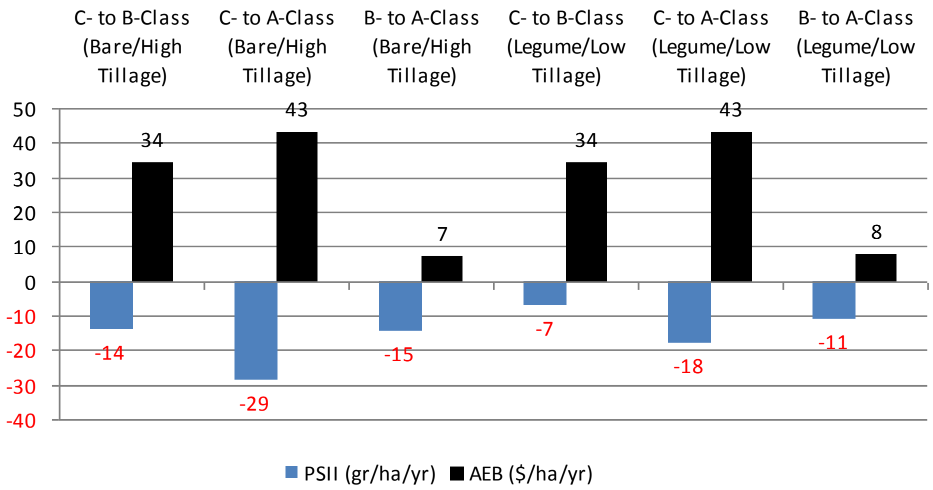


Table 13: Results summary of AEB per unit reduction of PSII-HEq herbicide for Tully 150ha

Description	Water quality benefit: Δ PSII-HEq (g/ha /yr)	Relative reduction in PSII-HEq (%/yr)	Economic benefit/cost: (AEB) ($/ha /yr)	Return on investment: (IRR) (%/yr)	Economic benefit/ cost per gram of herbicide abatement: AEB / ΔPSII-HEq ($/g)
C- to B-Class (Bare & High Tillage)	**14**	**-40.7%**	**34**	**288.7%**	**2.47**
C- to A-Class (Bare & High Tillage)	**29**	**-83.6%**	**43**	**68.8%**	**1.50**
B- to A-Class (Bare & High Tillage)	**15**	**-72.3%**	**7**	**19.6%**	**0.50**
C- to B-Class (Legume & Low Tillage)	**7**	**-31.9%**	**34**	**288.7%**	**4.91**
C- to A-Class (Legume & Low Tillage)	**18**	**-82.2%**	**43**	**69.0%**	**2.39**
B- to A-Class (Legume & Low Tillage)	**11**	**-73.8%**	**8**	**19.9%**	**0.68**

Results summary for a 150ha farm in Tully:

- Progressing from *C-* to *A-Class* herbicide management under a bare fallow and high tillage farm system results in the greatest water quality benefit (29 grams ha/yr; ~84% reduction from previous level).
- All progressive changes in herbicide management are expected to provide a positive economic benefit.
- Progressing from *C-* to *A-Class* herbicide management results in the largest annualised NPV ($43 ha/yr).

- Progressing from *C*- to *B-Class* herbicide management provides the highest return on investment (~289 %/yr).

- Progressing from *C*- to *B-Class* herbicide abatement is expected to provide the largest economic benefit per unit of PSII-HEq herbicide abatement. The benefit is $4.91 per gram under a legume fallow and low tillage farming system and $2.47 a gram for the same changes under a bare fallow and high tillage farming system.

Figure 14: Graphical presentation of results for Tully 250ha

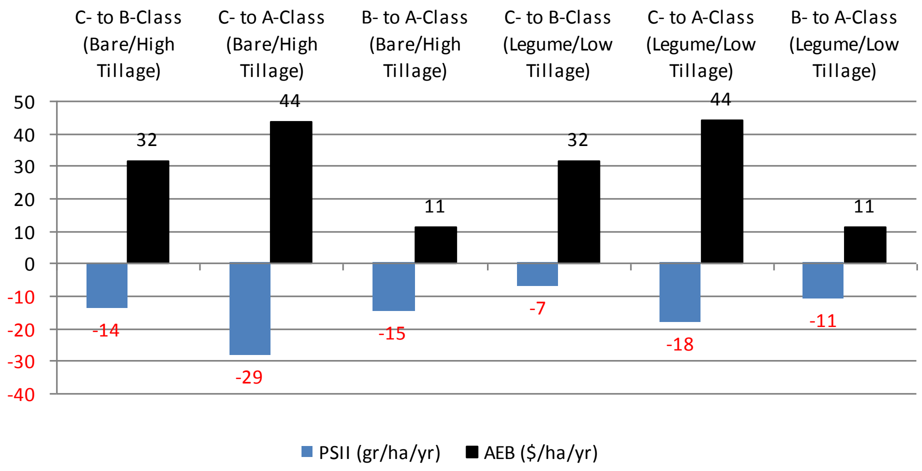


Table 14: Results summary of AEB per unit reduction of PSII-HEq herbicide for Tully 250ha

Description	Water quality benefit: Δ PSII-HEq (gr/ha /yr)	Relative reduction in PSII-HEq (%/yr)	Economic benefit/cost: (AEB) ($/ha /yr)	Return on investment: (IRR) (%/yr)	Economic benefit/ cost per gram of herbicide abatement: AEB / ΔPSII-HEq ($/gr)
C- to B-Class (Bare & High Tillage)	**14**	**-40.7%**	**32**	**301.4%**	**2.28**
C- to A-Class (Bare & High Tillage)	**29**	**-83.6%**	**44**	**93.1%**	**1.54**
B- to A-Class (Bare & High Tillage)	**15**	**-72.3%**	**11**	**32.8%**	**0.76**
C- to B-Class (Legume & Low Tillage)	**7**	**-31.9%**	**32**	**301.4%**	**4.53**
C- to A-Class (Legume & Low Tillage)	**18**	**-82.2%**	**44**	**93.4%**	**2.44**
B- to A-Class (Legume & Low Tillage)	**11**	**-73.8%**	**11**	**33.1%**	**1.02**

Results summary for a 250ha farm in Tully:

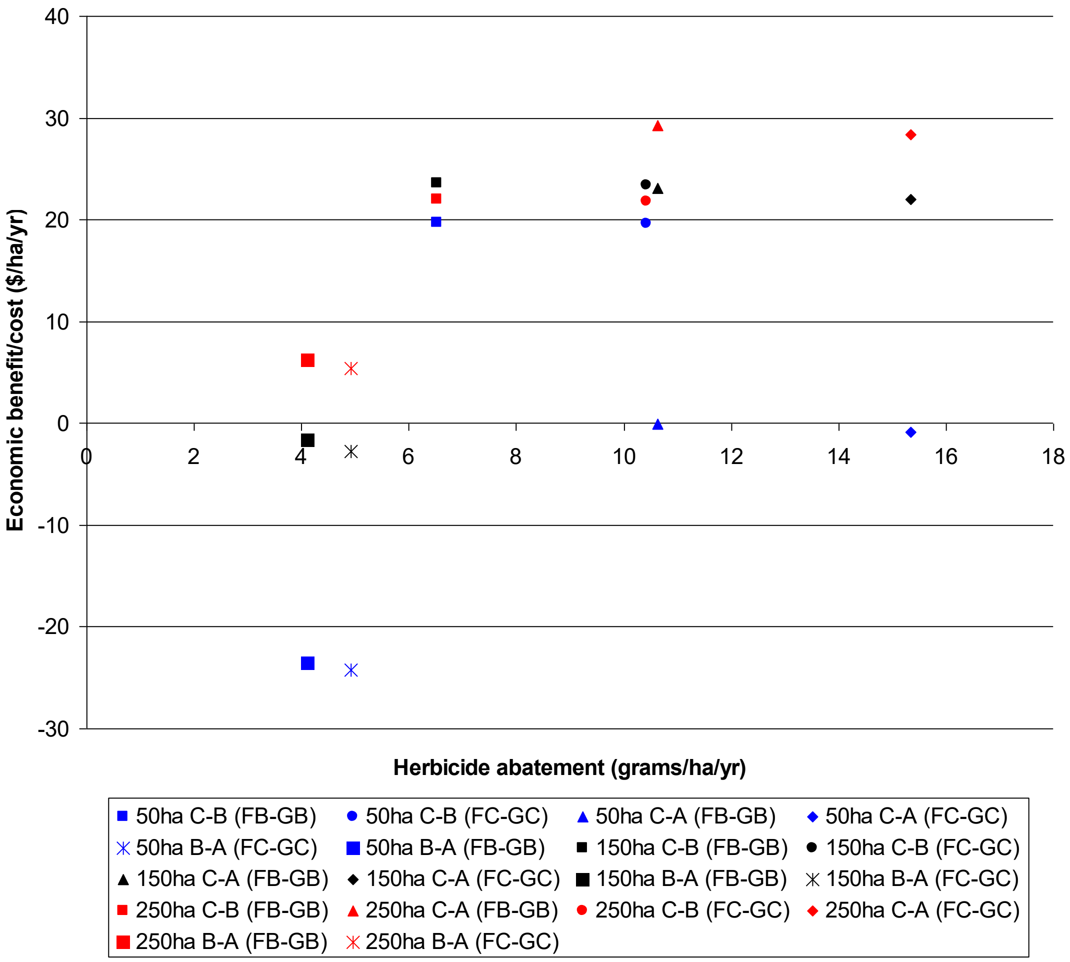
- Progressing from *C*- to *A-Class* herbicide management under a bare fallow and high tillage farm system results in the greatest water quality benefit (29 grams ha/yr; ~84% reduction from previous level).

- All progressive changes in herbicide management are expected to provide a positive economic benefit.
- Progressing from *C*- to *A-Class* herbicide management results in the largest annualised NPV ($44 ha/yr).
- Progressing from *C*- to *B-Class* herbicide management provides the highest return on investment (~301 %/yr).
- Progressing from *C*- to *B-Class* herbicide abatement under a legume fallow and low tillage farming system is expected to provide the largest economic benefit per unit of PSII-HEq herbicide abatement (i.e. the benefit is $4.53 per gram).

Mackay Whitsunday

The cost-effectiveness plane for the Mackay region is presented in Figure 15 below.

Figure 15: Mackay - cost-effectiveness plane



The cost-effectiveness plane for Mackay shows a similar pattern to Tully, where transitioning from *C-* to *A-Class* for 150ha and 250ha farms under bare fallow and high tillage practices provides the best combination of economic and water quality benefits in absolute terms. The calculations resulting from the integration of the economic and water quality outcomes for Mackay are presented by farm size as follows.

Figure 16: Graphical presentation of results for Mackay 50ha

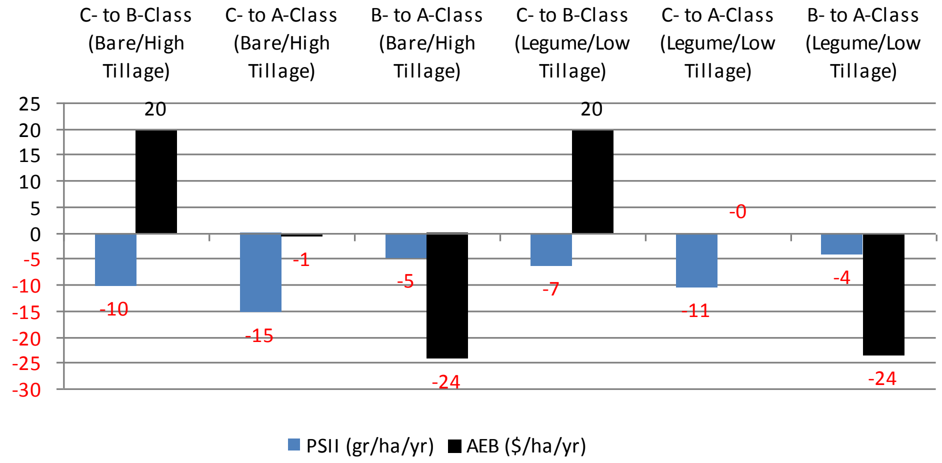


Table 15: Results summary of AEB per unit reduction of PSII-HEq herbicide for Mackay 50ha

Description	Water quality benefit: Δ PSII-HEq (g/ha /yr)	Relative reduction in PSII-HEq (%/yr)	Economic benefit/cost: (AEB) ($/ha /yr)	Return on investment: (IRR) (%/yr)	Economic benefit/ cost per gram of herbicide abatement: AEB / ΔPSII-HEq ($/g)
C- to B-Class (Bare & High Tillage)	10	-51.4%	20	65.5%	1.88
C- to A-Class (Bare & High Tillage)	15	-75.6%	-1	5.4%	-0.06
B- to A-Class (Bare & High Tillage)	5	-49.9%	-24	-18.9%	-4.92
C- to B-Class (Legume & Low Tillage)	7	-52.2%	20	65.9%	3.02
C- to A-Class (Legume & Low Tillage)	11	-85.0%	-0	5.9%	0.00
B- to A-Class (Legume & Low Tillage)	4	-68.6%	-24	-17.6%	-5.74

Results summary for a 50ha farm in Mackay:

- Progressing from *C-* to *A-Class* herbicide management under a bare fallow and high tillage farm system results in the greatest water quality benefit (15 grams ha/yr; ~76% reduction from previous level).

- Progressing from *C-* to *B-Class* herbicide management is the only change that appears to provide an annualised NPV ($20 ha/yr) and return on investment that is higher than 6% (~66 %/yr).

- The transition from *B-* to *A-Class* herbicide management is expected to come at an economic cost to reduce PSII herbicide losses from the farm. This is predominantly due to the size of the CAPEX requirement relative to the annual economic benefits.

- Progressing from *C-* to *B-Class* herbicide abatement is expected to provide the largest economic benefit per unit of PSII-HEq herbicide abatement. The benefit is $3.02 per gram under a legume fallow and low tillage farming system and $1.88 a gram for the same changes under a bare fallow and high tillage farming system.

Figure 17: Graphical presentation of results for Mackay 150ha

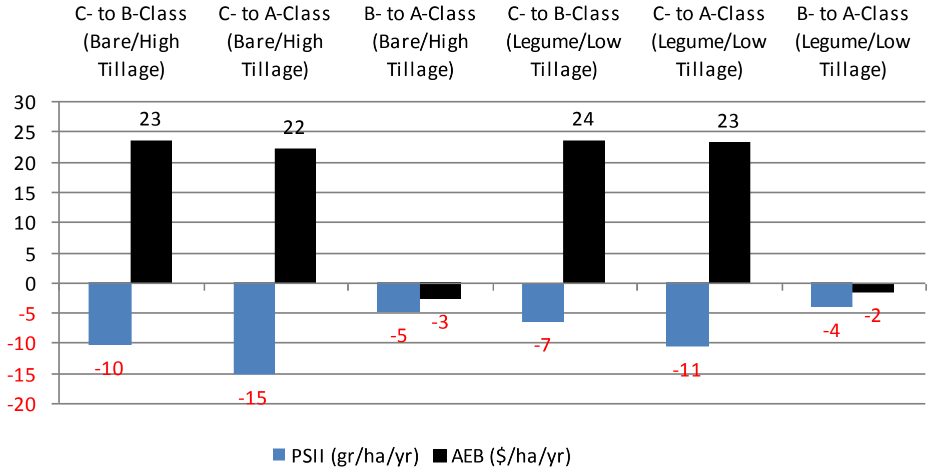


Table 16: Results summary of AEB per unit reduction of PSII-HEq herbicide for Mackay 150ha

Description	Water quality benefit: Δ PSII-HEq (g/ha /yr)	Relative reduction in PSII-HEq (%/yr)	Economic benefit/cost: (AEB) ($/ha /yr)	Return on investment: (IRR) (%/yr)	Economic benefit/ cost per gram of herbicide abatement: AEB / ΔPSII-HEq ($/g)
C- to B-Class (Bare & High Tillage)	**10**	**-51.4%**	**23**	**201.5%**	**2.25**
C- to A-Class (Bare & High Tillage)	**15**	**-75.6%**	**22**	**40.7%**	**1.43**
B- to A-Class (Bare & High Tillage)	**5**	**-49.9%**	**-3**	**-0.1%**	**-0.55**
C- to B-Class (Legume & Low Tillage)	**7**	**-52.2%**	**24**	**202.7%**	**3.61**
C- to A-Class (Legume & Low Tillage)	**11**	**-85.0%**	**23**	**42.3%**	**2.18**
B- to A-Class (Legume & Low Tillage)	**4**	**-68.6%**	**-2**	**2.3%**	**-0.41**

Results summary for a 150ha farm in Mackay:

- Progressing from *C-* to *A-Class* herbicide management under a bare fallow and high tillage farm system results in the greatest water quality benefit (15 grams ha/yr; ~76% reduction from previous level).
- Progressing from *C-* to *B-Class* herbicide management under a legume fallow and low tillage farm system results in the largest annualised NPV ($24 ha/yr).
- Progressing from *C-* to *B-Class* herbicide management under a legume fallow and low tillage farm system provides the highest return on investment (~203 %/yr).
- The transition from *B-* to *A-Class* herbicide management is expected to come at an economic cost to reduce PSII herbicide losses from the farm. This is predominantly due to the size of the CAPEX requirement relative to annual economic benefits.
- Progressing from *C-* to *B-Class* herbicide abatement is expected to provide the largest economic benefit per unit of PSII-HEq herbicide abatement. The benefit is $3.61 per gram under a legume fallow and low tillage farming system and $2.25 a gram for the same changes under a bare fallow and high tillage farming system.

Figure 18: Graphical presentation of results for Mackay 250ha

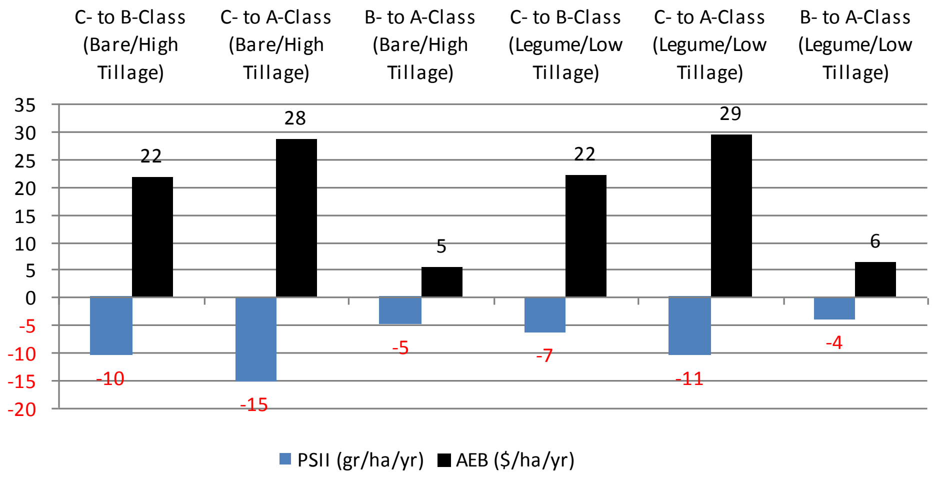


Table 17: Results summary of AEB per unit reduction of PSII-HEq herbicide for Mackay 250ha

Description	Water quality benefit: Δ PSII-HEq (g/ha /yr)	Relative reduction in PSII-HEq (%/yr)	Economic benefit/cost: (AEB) ($/ha /yr)	Return on investment: (IRR) (%/yr)	Economic benefit/ cost per gram of herbicide abatement: AEB / ΔPSII-HEq ($/g)
C- to B-Class (Bare & High Tillage)	**10**	**-51.4%**	**22**	**212.0%**	**2.09**
C- to A-Class (Bare & High Tillage)	**15**	**-75.6%**	**28**	**64.7%**	**1.85**
B- to A-Class (Bare & High Tillage)	**5**	**-49.9%**	**5**	**20.1%**	**1.10**
C- to B-Class (Legume & Low Tillage)	**7**	**-52.2%**	**22**	**213.4%**	**3.37**
C- to A-Class (Legume & Low Tillage)	**11**	**-85.0%**	**29**	**66.4%**	**2.76**
B- to A-Class (Legume & Low Tillage)	**4**	**-68.6%**	**6**	**21.9%**	**1.51**

Results summary for a 250ha farm in Mackay:

- Progressing from *C-* to *A-Class* herbicide management under a bare fallow and high tillage farm system results in the greatest water quality benefit (15 grams ha/yr; ~76% reduction from previous level).

- All progressive changes in herbicide management are expected to provide a positive economic benefit.

- Progressing from *C-* to *B-Class* herbicide management under a legume fallow and low tillage farm system results in the largest annualised NPV ($29 ha/yr).

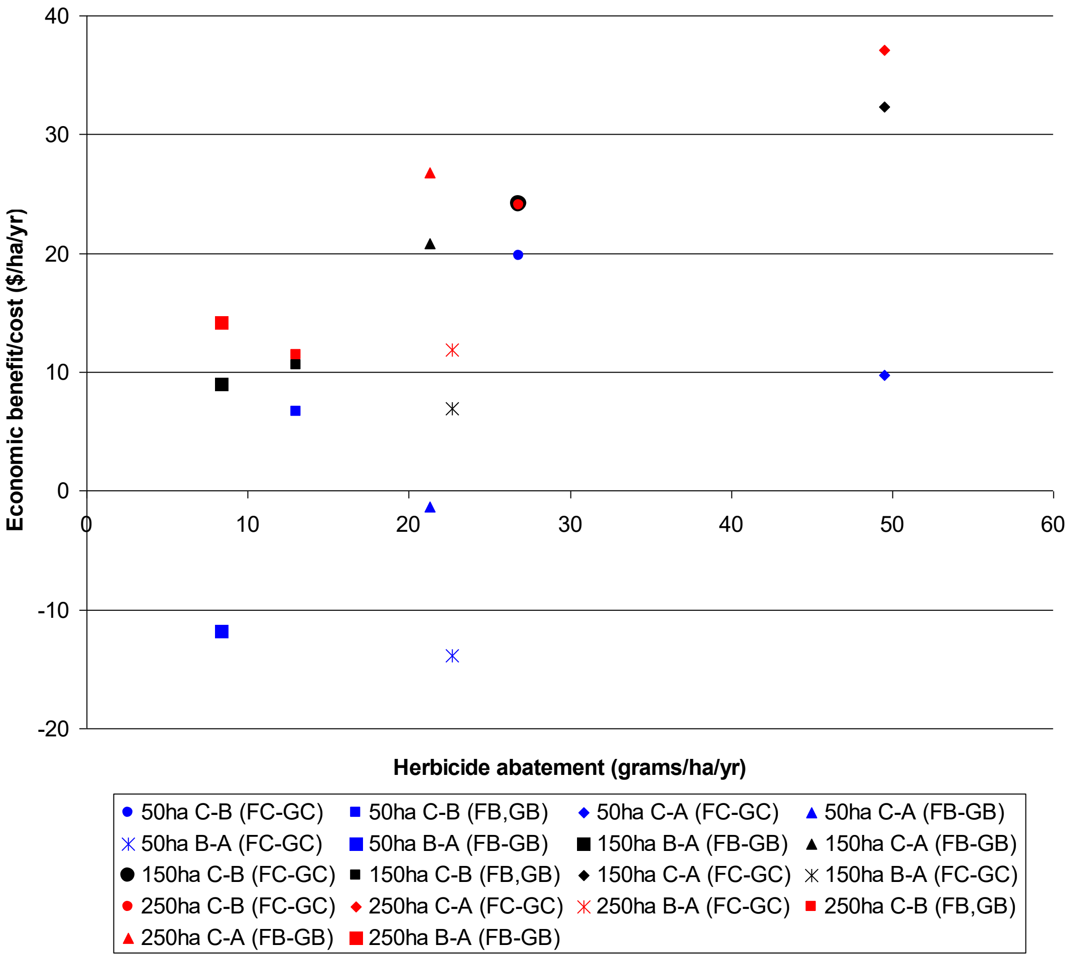
- Progressing from *C-* to *B-Class* herbicide management under a legume fallow and low tillage farm system provides the highest return on investment (~213 %/yr).

- Progressing from *C-* to *B-Class* herbicide abatement under a legume fallow and low tillage farming system is expected to provide the largest economic benefit per unit of PSII-HEq herbicide abatement (i.e. the benefit is $3.37 per gram).

Burdekin Dry Tropics (Delta)

The cost-effectiveness plane for the Burdekin Delta region is presented in Figure 19.

Figure 19: Burdekin Delta - cost-effectiveness plane



The cost-effectiveness of transitioning from *C-* to *A-Class* practices for 150ha and 250ha farms in the Burdekin Delta under bare fallow and high tillage provides the best combination of economic and water quality benefits in absolute terms. The calculations resulting from the integration of the economic and water quality outcomes for Burdekin Delta are presented by farm size as follows.

Figure 20: Graphical presentation of results for BDT Delta 50ha

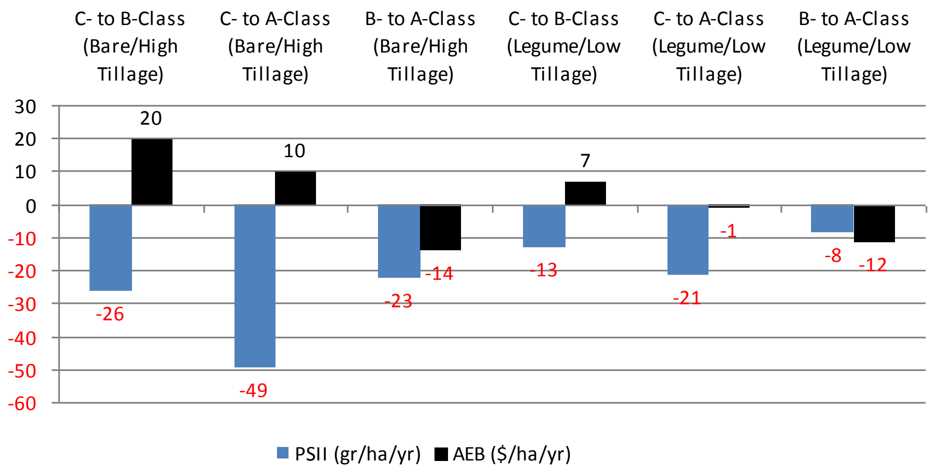


Table 18: Results summary of AEB per unit reduction of PSII-HEq herbicide for BDT Delta 50ha

Description	Water quality benefit: Δ PSII-HEq (g/ha /yr)	Relative reduction in PSII-HEq (%/yr)	Economic benefit/cost: (AEB) ($/ha /yr)	Return on investment: (IRR) (%/yr)	Economic benefit/ cost per gram of herbicide abatement: AEB / ΔPSII-HEq ($/g)
C- to B-Class (Bare & High Tillage)	**26**	**-52.3%**	**20**	**66.1%**	**0.75**
C- to A-Class (Bare & High Tillage)	**49**	**-97.8%**	**10**	**12.1%**	**0.20**
B- to A-Class (Bare & High Tillage)	**23**	**-95.3%**	**-14**	**-5.2%**	**-0.61**
C- to B-Class (Legume & Low Tillage)	**13**	**-59.1%**	**7**	**29.0%**	**0.52**
C- to A-Class (Legume & Low Tillage)	**21**	**-97.0%**	**-1**	**5.1%**	**-0.06**
B- to A-Class (Legume & Low Tillage)	**8**	**-92.7%**	**-12**	**-3.3%**	**-1.41**

Results summary for a 50ha farm in Burdekin Delta:

- Progressing from *C-* to *A-Class* herbicide management under a bare fallow and high tillage farm system results in the greatest water quality benefit (49 grams ha/yr; ~98% reduction from previous level).
- Progressing from *C-* to *B-Class* herbicide management under a bare fallow and high tillage farm system provides the largest annualised NPV ($20 ha/yr).
- Progressing from *C-* to *B-Class* herbicide management under a bare fallow and high tillage farm system provides the highest return on investment (~66 %/yr).

- The transition from *B-* to *A-Class* herbicide management is expected to come at an economic cost to reduce PSII equivalent herbicide losses from the farm. This is predominantly due to the size of the CAPEX requirement relative to annual economic benefits.

- The transition from *C-* to *A-Class* herbicide management under a legume fallow and low tillage farm system is expected to come at an opportunity cost (i.e. IRR < 6%) to reduce PSII equivalent herbicide losses from the farm.

- Progressing from *C-* to *B-Class* herbicide abatement is expected to provide the largest economic benefit per unit of PSII-HEq herbicide abatement. The benefit is $0.75 per gram under a bare fallow and high tillage farming system and $0.52 a gram for the same changes under a legume fallow and low tillage farming system.

Figure 21: Graphical presentation of results for BDT Delta 150ha

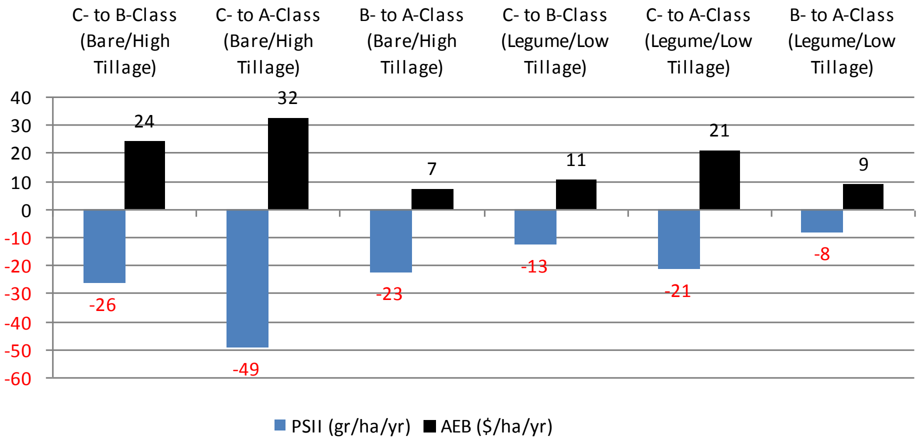


Table 19: Results summary of AEB per unit reduction of PSII-HEq herbicide for BDT Delta 150ha

Description	Water quality benefit: Δ PSII-HEq (g/ha /yr)	Relative reduction in PSII-HEq (%/yr)	Economic benefit/cost: (AEB) ($/ha /yr)	Return on investment: (IRR) (%/yr)	Economic benefit/ cost per gram of herbicide abatement: AEB / ΔPSII-HEq ($/g)
C- to B-Class (Bare & High Tillage)	**26**	**-52.3%**	**24**	**207.4%**	**0.91**
C- to A-Class (Bare & High Tillage)	**49**	**-97.8%**	**32**	**54.7%**	**0.65**
B- to A-Class (Bare & High Tillage)	**23**	**-95.3%**	**7**	**18.8%**	**0.30**
C- to B-Class (Legume & Low Tillage)	**13**	**-59.1%**	**11**	**98.5%**	**0.82**
C- to A-Class (Legume & Low Tillage)	**21**	**-97.0%**	**21**	**39.0%**	**0.98**
B- to A-Class (Legume & Low Tillage)	**8**	**-92.7%**	**9**	**22.3%**	**1.07**

Results summary for a 150ha farm in Burdekin Delta:

- Progressing from *C-* to *A-Class* herbicide management under a bare fallow and high tillage farm system results in the greatest water quality benefit (49 grams ha/yr; ~98% reduction from previous level).
- All progressive changes in herbicide management are expected to provide a positive economic benefit.
- Progressing from *C-* to *A-Class* herbicide management under a bare fallow and high tillage farm system provides the largest annualised NPV ($32 ha/yr).
- Progressing from *C-* to *B-Class* herbicide management under a bare fallow and high tillage farm system provides the highest return on investment (~207 %/yr).
- Progressing from *B-* to *A-Class* herbicide abatement under a legume fallow and low tillage farming system is expected to provide the largest economic benefit per unit of PSII-HEq herbicide abatement (i.e. a benefit of $1.07 per gram).

Figure 22: Graphical presentation of results for BDT Delta 250ha

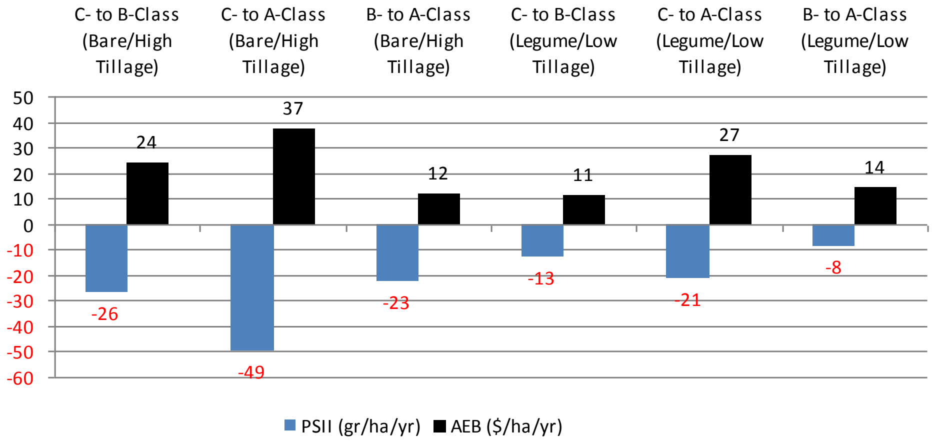


Table 20: Results summary of AEB per unit reduction of PSII-HEq herbicide for BDT Delta 250ha

Description	Water quality benefit: Δ PSII-HEq (g/ha /yr)	Relative reduction in PSII-HEq (%/yr)	Economic benefit/cost: (AEB) ($/ha /yr)	Return on investment: (IRR) (%/yr)	Economic benefit/ cost per gram of herbicide abatement: AEB / ΔPSII-HEq ($/g)
C- to B-Class (Bare & High Tillage)	**26**	**-52.3%**	**24**	**232.6%**	**0.91**
C- to A-Class (Bare & High Tillage)	**49**	**-97.8%**	**37**	**80.7%**	**0.75**
B- to A-Class (Bare & High Tillage)	**23**	**-95.3%**	**12**	**34.3%**	**0.52**
C- to B-Class (Legume & Low Tillage)	**13**	**-59.1%**	**11**	**117.7%**	**0.88**
C- to A-Class (Legume & Low Tillage)	**21**	**-97.0%**	**27**	**61.6%**	**1.25**
B- to A-Class (Legume & Low Tillage)	**8**	**-92.7%**	**14**	**39.2%**	**1.70**

Results summary for a 250ha farm in Burdekin Delta:

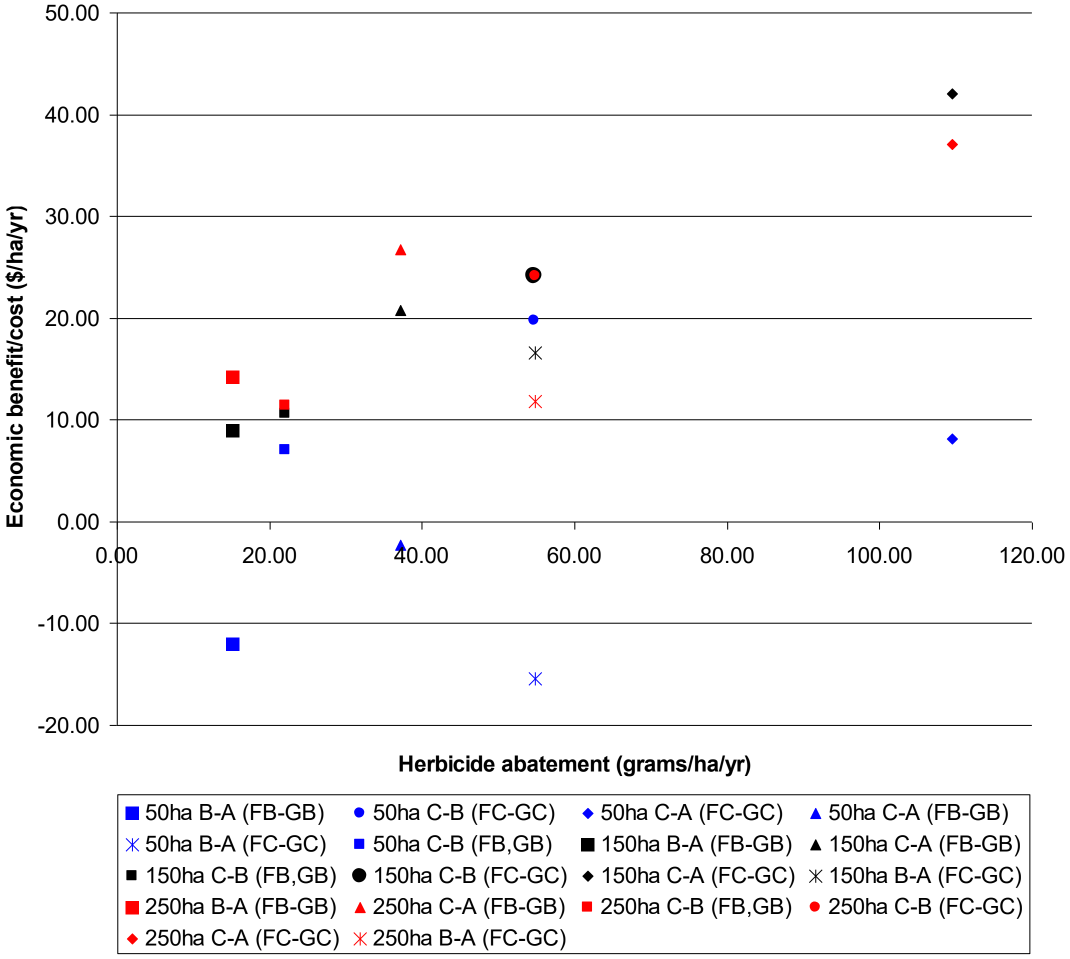
- Progressing from *C-* to *A-Class* herbicide management under a bare fallow and high tillage farm system results in the greatest water quality benefit (49 grams ha/yr; ~98% reduction from previous level).
- All progressive changes in herbicide management are expected to provide a positive economic benefit.
- Progressing from *C-* to *A-Class* herbicide management under a bare fallow and high tillage farm system provides the largest annualised NPV ($37 ha/yr).
- Progressing from *C-* to *B-Class* herbicide management under a bare fallow and high tillage farm system provides the highest return on investment (~233 %/yr).

- Progressing from *B-* to *A-Class* herbicide abatement under a legume fallow and low tillage farming system is expected to provide the largest economic benefit per unit of PSII-HEq herbicide abatement (i.e. a benefit of $1.70 per gram).

Burdekin Dry Tropics (BRIA)

The cost-effectiveness plane for the BRIA is presented in Figure 23.

Figure 23: BRIA - cost-effectiveness plane



Transitioning from *C-* to *A-Class* practices for 150ha and 250ha farms in the BRIA under bare fallow and high tillage provides the best combination of economic and water quality benefits in absolute terms. The calculations resulting from the integration of the economic and water quality outcomes for the BRIA are presented by farm size as follows.

Figure 24: Graphical presentation of results for BDT BRIA 50ha

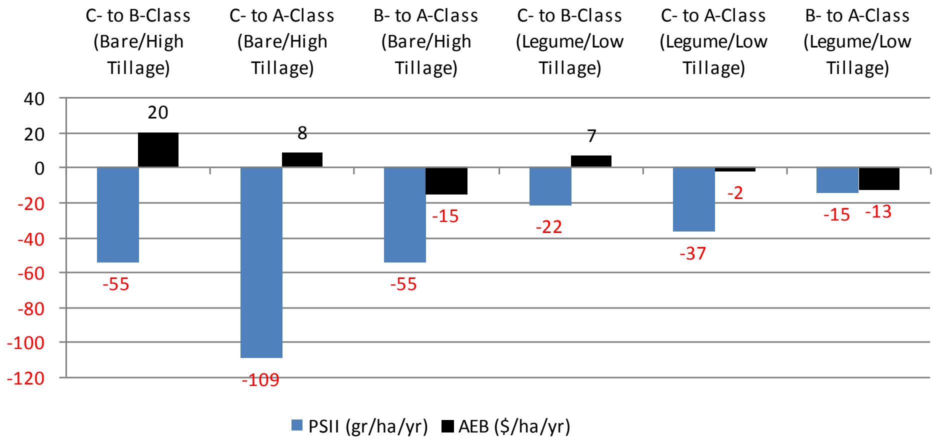


Table 21: Results summary of AEB per unit reduction of PSII-HEq herbicide for BDT BRIA 50ha

Description	Water quality benefit: Δ PSII-HEq (g/ha /yr)	Relative reduction in PSII-HEq (%/yr)	Economic benefit/cost: (AEB) ($/ha /yr)	Return on investment: (IRR) (%/yr)	Economic benefit/ cost per gram of herbicide abatement: AEB / ΔPSII-HEq ($/g)
C- to B-Class (Bare & High Tillage)	**55**	**-48.3%**	**20**	**66.1%**	**0.36**
C- to A-Class (Bare & High Tillage)	**109**	**-96.7%**	**8**	**11.2%**	**0.07**
B- to A-Class (Bare & High Tillage)	**55**	**-93.7%**	**-15**	**-6.9%**	**-0.28**
C- to B-Class (Legume & Low Tillage)	**22**	**-57.5%**	**7**	**29.0%**	**0.31**
C- to A-Class (Legume & Low Tillage)	**37**	**-97.1%**	**-2**	**4.4%**	**-0.06**
B- to A-Class (Legume & Low Tillage)	**15**	**-93.2%**	**-13**	**-4.2%**	**-0.84**

Results summary for a 50ha farm in BRIA:

- Progressing from *C-* to *A-Class* herbicide management under a bare fallow and high tillage farm system results in the greatest water quality benefit (109 grams ha/yr; ~97% reduction from previous level).

- Progressing from *C-* to *B-Class* herbicide management under a bare fallow and high tillage farm system provides the largest annualised NPV ($20 ha/yr).

- Progressing from *C-* to *B-Class* herbicide management under a bare fallow and high tillage farm system provides the highest return on investment (~66 %/yr).

- The transition from *C-* to *A-Class* herbicide management under a legume fallow and low tillage farm system is expected to come at an opportunity cost (i.e. IRR < 6%) to reduce PSII equivalent herbicide losses from the farm.

- The transition from *B-* to *A-Class* herbicide management under a bare fallow and high tillage farm system is expected to come at an economic cost to reduce PSII equivalent herbicide losses from the farm. This is predominantly due to the size of the CAPEX requirement relative to annual economic benefits.
- Progressing from *B-* to *A-Class* herbicide abatement under a legume fallow and low tillage farming system is expected to provide the largest economic benefit per unit of PSII-HEq herbicide abatement (i.e. a benefit of $0.38 per gram).

Figure 25: Graphical presentation of results for BDT BRIA 150ha

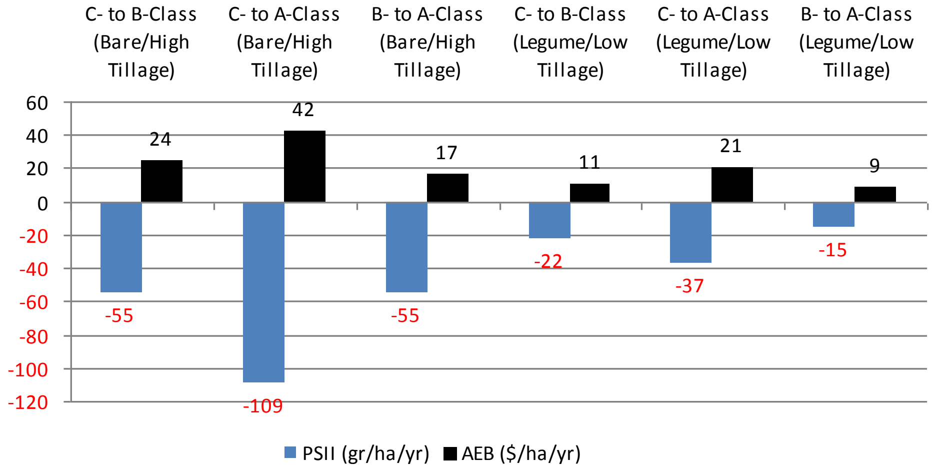


Table 22: Summary of AEB per unit reduction of PSII-HEq herbicide for BDT BRIA 150ha

Description	Water quality benefit: Δ PSII-HEq (g/ha /yr)	Relative reduction in PSII-HEq (%/yr)	Economic benefit/cost: (AEB) ($/ha /yr)	Return on investment: (IRR) (%/yr)	Economic benefit/ cost per gram of herbicide abatement: AEB / ΔPSII-HEq ($/g)
C- to B-Class (Bare & High Tillage)	**55**	**-48.3%**	**24**	**207.4%**	**0.44**
C- to A-Class (Bare & High Tillage)	**109**	**-96.7%**	**42**	**67.6%**	**0.38**
B- to A-Class (Bare & High Tillage)	**55**	**-93.7%**	**17**	**34.1%**	**0.30**
C- to B-Class (Legume & Low Tillage)	**22**	**-57.5%**	**11**	**98.5%**	**0.48**
C- to A-Class (Legume & Low Tillage)	**37**	**-97.1%**	**21**	**39.0%**	**0.56**
B- to A-Class (Legume & Low Tillage)	**15**	**-93.2%**	**9**	**22.3%**	**0.59**

Results summary for a 150ha farm in BRIA:

- Progressing from *C-* to *A-Class* herbicide management under a bare fallow and high tillage farm system results in the greatest water quality benefit (109 grams ha/yr; ~97% reduction from previous level).
- All progressive changes in herbicide management are expected to provide a positive economic benefit.
- Progressing from *C-* to *A-Class* herbicide management under a bare fallow and high tillage farm system provides the largest annualised NPV ($42 ha/yr).
- Progressing from *C-* to *B-Class* herbicide management under a bare fallow and high tillage farm system provides the highest return on investment (~207 %/yr).
- Progressing from *B-* to *A-Class* herbicide abatement under a legume fallow and low tillage farming system is expected to provide the largest economic benefit per unit of PSII-HEq herbicide abatement (i.e. a benefit of $0.59 per gram).

Figure 26: Graphical presentation of results for BDT BRIA 250ha

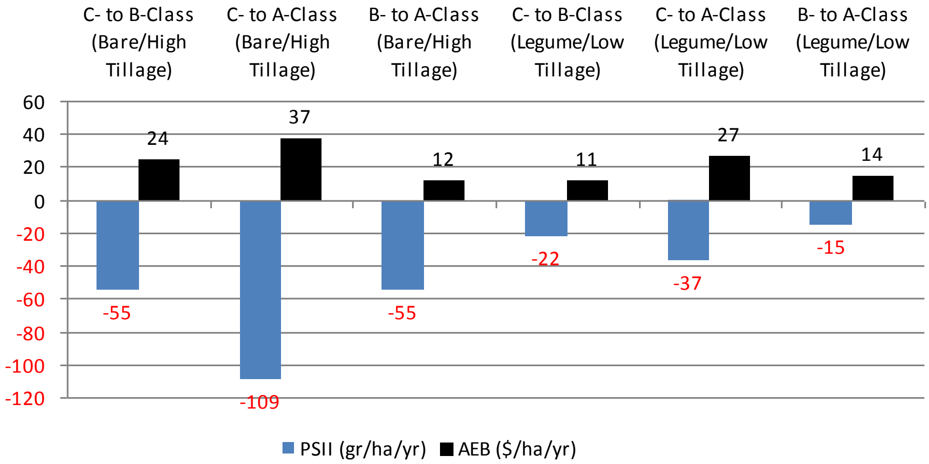


Table 23: Results summary of AEB per unit reduction of PSII-HEq herbicide for BDT BRIA 250ha

Description	Water quality benefit: Δ PSII-HEq (g/ha /yr)	Relative reduction in PSII-HEq (%/yr)	Economic benefit/cost: (AEB) ($/ha /yr)	Profitability: (IRR) (%/yr)	Economic benefit/ cost per gram of herbicide abatement: AEB / ΔPSII-HEq ($/g)
C- to B-Class (Bare & High Tillage)	**55**	**-48.3%**	**24**	**232.6%**	**0.44**
C- to A-Class (Bare & High Tillage)	**109**	**-96.7%**	**37**	**80.7%**	**0.34**
B- to A-Class (Bare & High Tillage)	**55**	**-93.7%**	**12**	**34.3%**	**0.22**
C- to B-Class (Legume & Low Tillage)	**22**	**-57.5%**	**11**	**117.7%**	**0.52**
C- to A-Class (Legume & Low Tillage)	**37**	**-97.1%**	**27**	**61.7%**	**0.72**
B- to A-Class (Legume & Low Tillage)	**15**	**-93.2%**	**14**	**39.2%**	**0.94**

Results summary for a 250ha farm in BRIA:

- Progressing from *C-* to *A-Class* herbicide management under a bare fallow and high tillage farm system results in the greatest water quality benefit (109.5 grams ha/yr; ~97% reduction from previous level).

- All progressive changes in herbicide management are expected to provide a positive economic benefit.

- Progressing from *C-* to *A-Class* herbicide management under a bare fallow and high tillage farm system provides the largest annualised NPV ($37 ha/yr).

- Progressing from *C-* to *B-Class* herbicide management under a bare fallow and high tillage farm system provides the highest return on investment (~233 %/yr).
- Progressing from *B-* to *A-Class* herbicide abatement under a legume fallow and low tillage farming system is expected to provide the largest economic benefit per unit of PSII-HEq herbicide abatement (i.e. a benefit of $0.94 per gram).

4.3.4. Results of water quality modelling using alternative chemicals

This water quality modelling incorporates the regulated PSII herbicides as well as knockdown herbicides and other alternative residual products. An herbicide toxicity equivalency measure (h-HEq) has been developed to report the relative toxicity of scenarios incorporating all herbicide products in the current study (see Section 3.7). These water quality modelling results are presented in Table 29.

Table 24: Results of water quality modelling for alternative herbicide rates by region and management practice (as h-HEq)

Application rate	Fallow	Herbicide selection	Strategic use	Method of application	Tillage	Tully (g/ha/yr)	Mackay (g/ha/yr)	Delta (g/ha/yr)	BRIA (g/ha/yr)
AA	FB	SB	HB	MA	GB	4.25	2.04	0.63	1.09
AA	FB	SB2	HB	MA	GB	0.15	0.40	0.44	0.35
AA	FC	SB	HB	MA	GC	6.20	3.23	1.18	3.95
AA	FC	SB2	HB	MA	GC	0.37	0.22	0.07	0.20
AB	FB	SB	HB	MB	GB	15.56	6.12	8.97	16.25
AB	FB	SB2	HB	MB	GB	0.32	0.48	2.35	3.78
AB	FC	SB	HB	MB	GC	21.39	9.85	23.74	58.64
AB	FC	SB2	HB	MB	GC	0.71	0.68	2.23	5.21
AC	FB	SB	HC	MC	GB	22.52	12.64	21.86	38.20
AC	FB	SB2	HC	MC	GB	3.41	0.67	3.00	4.98
AC	FC	SB	HC	MC	GC	35.21	20.28	50.46	113.24
AC	FC	SB2	HC	MC	GC	6.59	1.11	2.97	6.93

Relatively large reductions were observed in these herbicide equivalent loads from the *SB2* (alternative herbicide) scenarios compared to the *SB* (regulated PSII herbicide) options. Taking the Tully scenarios as an example, there are not large differences in water quality loads summed prior to incorporation of the herbicide relative potency (*SB*=5.4g/ha; *SB2*= 3.99g/ha for scenarios with legume fallow and low tillage). In these examples the loads of most herbicides are the same or similar, which is consistent with the application profiles (see Appendix). However, there is a ~48 time difference (15.56 compared to 0.35) between the h-HEq scores. This is primarily attributable to the replacement of 5 applications of PSII herbicides in the *SB* profile across the plant and 4 ratoon crop cycle by 5 applications using alternative herbicides (Soccer and Balance) in the *SB2* profile. Soccer has a REP of 0.1 times that of diuron and is applied less frequently. Therefore, product choices in these profiles have a significant impact on the relative results.

4.3.5. Relative cost-effectiveness of changing from standard to alternative chemicals

The following graphs show the relative cost-effectiveness of changing from standard to alternative chemicals when in a particular class of herbicide management under different fallow and tillage management options. The blue bar displays the total h-HEq abatement (gr/ha/yr) and the black bar the AEB ($/ha/yr). Results are shown for 150ha farms, which are consistent across farm sizes in each region because the type of herbicide being used is the only change made within the farming system.

Figure 27: Graphical presentation of results for changing from standard to alternative chemicals Tully 150ha

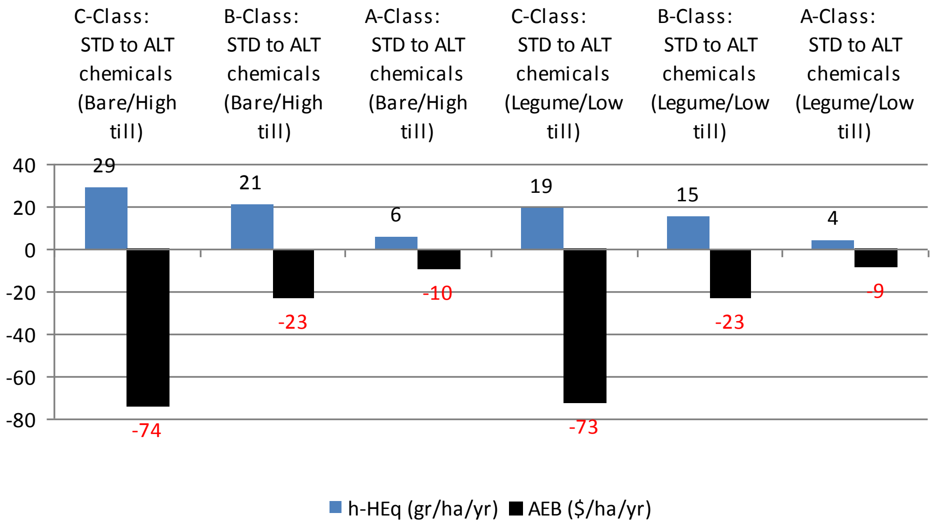


Figure 28: Graphical presentation of results for changing from standard to alternative chemicals Mackay 150ha

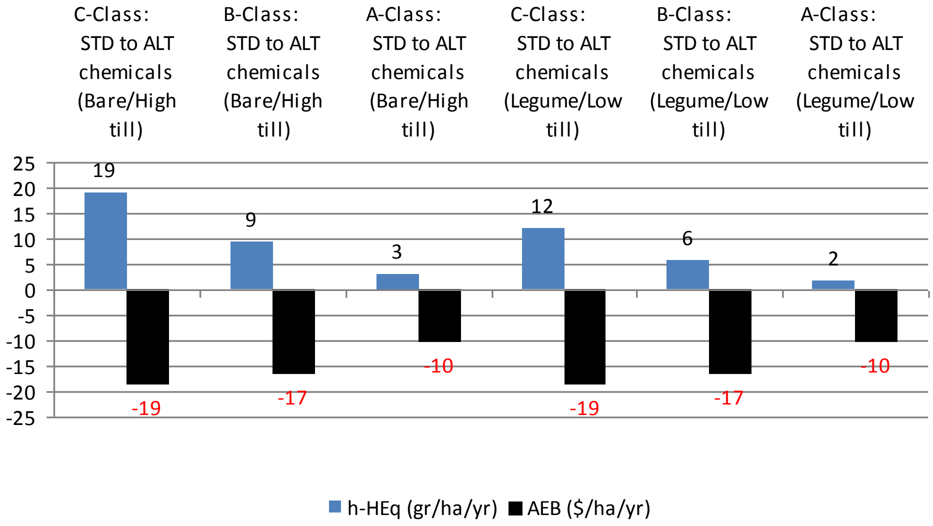


Figure 29: Graphical presentation of results for changing from standard to alternative chemicals BDT Delta 150ha

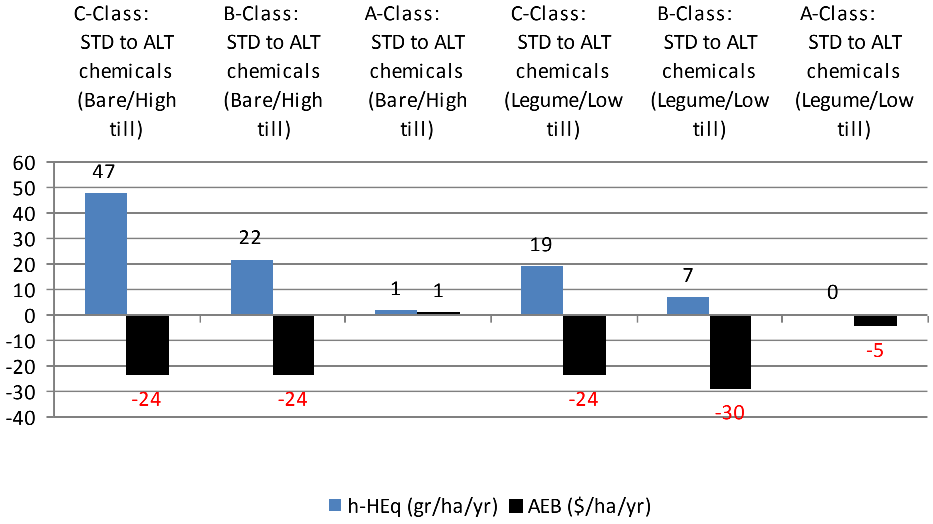
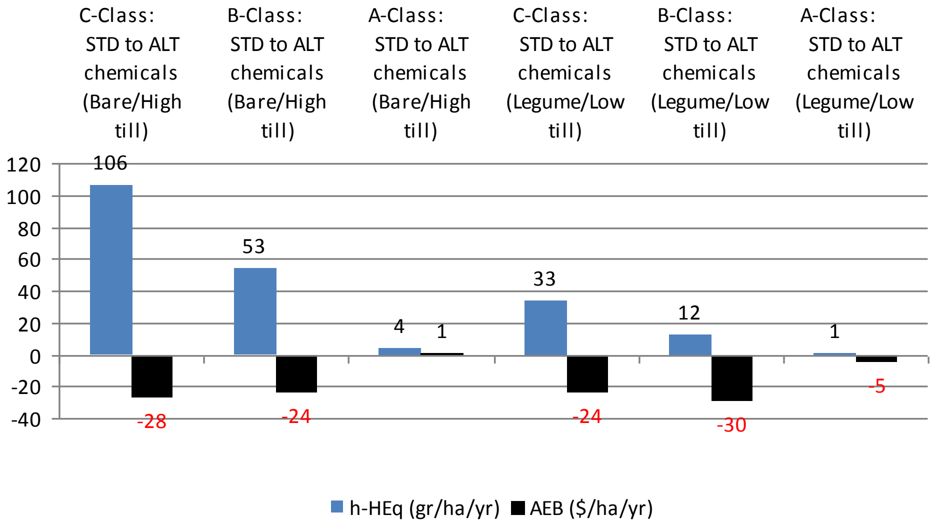


Figure 30: Graphical presentation of results for changing from standard to alternative chemicals BRIA 150ha



The analyses of the cost-effectiveness of substituting herbicide products generally indicate that a change from standard to alternative chemicals is expected to come at an economic cost to landholders across all regions investigated. However, there is one exceptional case in the Burdekin region where the farm is currently practicing *A-Class* herbicide management under a bare fallow & high tillage farm system. In this case, the change provides a modest economic benefit ranging between $0.57 per ha/yr (50ha & 150ha farms) and $0.83 per ha/yr (250ha farm). This results in an economic benefit of $0.15 and $0.75 per gram of herbicide abatement, respectively. The least costly change in Tully occurs with *B-Class* herbicide management, while this is the case for *C-Class* in Mackay and *A-Class* in the Burdekin Delta and BRIA. These results highlight the heterogeneity between the regions regarding weed management practices and the specific selection of herbicide products.

Results showed across all scenarios and regions that a change to alternative chemicals will result in a reduction in the overall herbicide equivalent measure (h-HEq). Although the extent of abatement measured by h-HEq differs between regions, there is a general tendency for greater abatement to occur with *C-Class* practices, then with *B-Class*, with the least abatement occurring within *A-Class* herbicide management. The difference between abatement levels within these classes is a function the type and amount of chemical applied, the toxicity of these chemicals relative to the reference herbicide diuron, as well as the method of application.

4.3.6. Risk analysis: Sensitivity analysis of financial-economic results to changes in yield

The consideration of uncertainty is critical to gain a better understanding of the business risk around changing management practices. Most often, the greatest risk in sugarcane production systems is variation in price and yield. In respect to price risk, the expected impact on the economic results is likely to be limited due to the nature of the management practices evaluated and the design of the project[77]. The evaluation of risk pertaining to yield is examined due to its direct importance to the outcome of project results. In particular, the analysis focuses on the risk to cane yield for a change from *B-* to *A-Class* herbicide management practices *along with C-* to *B-Class* fallow and tillage management practices.

In the following Tables 25 to 28, the sensitivity of decreasing yields when changing from B-Class to *A-Class* herbicide management practices is examined. The adoption of *A-Class* herbicide management practice has a higher degree of risk because of uncertainty around the effectiveness of weed management and limited adoption on a commercial basis within the sugarcane industry. For instance, potential risks include poor herbicide efficacy or phytotoxicity to the crop, thus resulting in adverse impacts on crop yield. Interestingly, the sensitivity analysis results indicate that a decrease in average yield of just one per cent (1%) or greater will result in a negative economic outcome across all regions.

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[77] Cane farmers are price takers; whilst they do have hedging options, they have no market power to individually influence the market prices offered by their marketing agents. Accordingly, the sugar price is held constant in this project across all scenarios to eliminate price as a deterministic variable.

Table 25: Sensitivity analysis of AEB to a decrease in yield progressing from *B-Class* to *A-Class* practices – Tully 250ha

AB.FB.SB.HB.MB.GB to AA.FB.SB.HB.MA.GB										
Plant	1st Rat	2nd Rat	3rd Rat	4th Rat	Average Yield	Change to average yield	FGM	Change in FGM		AEB
(t/ha)	(t/ha)	(t/ha)	(t/ha)	(t/ha)	(t/ha)	(%)	($/ha)	($/ha)	(%)	($/ha/yr)
100	**89**	**89**	**89**	**102**	**94**	**0.00%**	**1106**	**0.00**	**0.00%**	**11.27**
99	88	89	88	101	93	-1.00%	1088	-18.25	-1.65%	-6.97
98	87	88	88	100	92	-2.00%	1070	-36.58	-3.31%	-25.31
97	86	87	87	99	91	-3.00%	1051	-54.92	-4.96%	-43.65
96	85	86	86	98	90	-4.00%	1033	-73.26	-6.62%	-61.99
95	84	85	85	97	89	-5.00%	1015	-91.60	-8.28%	-80.33

Table 26: Sensitivity analysis of AEB to a decrease in yield progressing from *B-Class* to *A-Class* practices – Mackay 250ha

AB.FB.SB.HB.MB.GB to AA.FB.SB.HB.MA.GB										
Plant	1st Rat	2nd Rat	3rd Rat	4th Rat	Average Yield	Change to average yield	FGM	Change in FGM		AEB
(t/ha)	(t/ha)	(t/ha)	(t/ha)	(t/ha)	(t/ha)	(%)	($/ha)	($/ha)	(%)	($/ha/yr)
105	**103**	**102**	**97**	**95**	**101**	**0.00%**	**1356**	**0.00**	**0.00%**	**6.19**
104	102	99	97	95	99	-1.00%	**1348**	-7.91	-0.58%	-1.73
103	101	98	96	94	98	-2.00%	**1324**	-31.89	-2.35%	-25.70
102	**100**	**97**	95	93	97	-3.00%	**1300**	-55.85	-4.12%	-49.67
101	99	96	94	92	96	-4.00%	**1276**	-79.83	-5.89%	-73.64
100	98	95	93	91	95	-5.00%	**1252**	-103.80	-7.66%	-97.61

Table 27: Sensitivity analysis of AEB to a decrease in yield progressing from *B-Class* to *A-Class* practices – Delta 250ha

AB.FB.SB.HB.MB.GB to AA.FB.SB.HB.MA.GB										
Plant	1st Rat	2nd Rat	3rd Rat	4th Rat	Average Yield	Change to average yield	FGM	Change in FGM		AEB
(t/ha)	(t/ha)	(t/ha)	(t/ha)	(t/ha)	(t/ha)	(%)	($/ha)	($/ha)	(%)	($/ha/yr)
155	**167**	**169**	**170**	**N/A**	**165**	**0.00%**	**3272**	**0.00**	**0.00%**	**14.16**
153	165	167	168	N/A	164	-1.00%	3229	-42.49	-1.30%	-28.33
152	164	166	167	N/A	162	-2.00%	3187	-84.99	-2.60%	-70.83
150	162	164	165	N/A	160	-3.00%	3144	-127.48	-3.90%	-113.32
149	160	162	163	N/A	159	-4.00%	3102	-169.98	-5.20%	-155.81
147	159	161	162	N/A	157	-5.00%	3059	-212.47	-6.49%	-198.31

Table 28: Sensitivity analysis of AEB to a decrease in yield progressing from *B-Class* to *A-Class* practices – BRIA

AB.FB.SB.HB.MB.GB to AA.FB.SB.HB.MA.GB										
Plant	**1st Rat**	**2nd Rat**	**3rd Rat**	**4th Rat**	**Average Yield**	**Change to average yield**	**FGM**	**Change in FGM**		**AEB**
(t/ha)	**(t/ha)**	**(t/ha)**	**(t/ha)**	**(t/ha)**	**(t/ha)**	**(%)**	**($/ha)**	**($/ha)**	**(%)**	**($/ha/yr)**
127	**118**	**125**	**126**	**N/A**	**124**	**0.00%**	**2060**	**0.00**	**0.00%**	**14.16**
126	117	124	125	N/A	123	-1.00%	2028	-31.80	-1.54%	-17.64
124	116	123	123	N/A	122	-2.00%	1996	-63.61	-3.09%	-49.44
123	114	121	122	N/A	120	-3.00%	1964	-95.41	-4.63%	-81.25
122	113	120	121	N/A	119	-4.00%	1933	-127.21	-6.18%	-113.05
121	112	119	120	N/A	118	-5.00%	1901	-159.02	-7.72%	-144.85

The AEB figures (see Appendix) indicate that it is only profitable to progress from the combination of a bare fallow with high tillage farming system to a legume fallow and low tillage farming system in Tully[78]. Furthermore, this is only the case for a farm size of 150ha and 250ha. Past research[79] in the sugarcane industry has indicated that the adoption of a well-managed legume fallow has the potential to increase subsequent cane yields through improved soil health. Given the AEB results incorporate APSIM-modelled yield data, which predicts comparatively similar yields under bare and legume fallow farming systems, the sensitivity of the AEB was analysed in the context of switching from *C-* to *B-Class* fallow and tillage management practices in order to account for possible increases in yield.

Hence, the results presented in Tables 29 to 31 demonstrate the appropriate changes to the average yield required to result in these practices becoming profitable for a 250 hectare farm within each region. Tully is not included in this analysis because the results suggest the transition is expected to be profitable. As can be observed, a change to the average yield of two per cent (2%) in the remaining regions will result in a profitable outcome.

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[78] This is despite the legume fallow providing a significant addition to soil nitrogen for the plant cane crop, thus saving on fertiliser costs.

[79] Garside & Bell, 2011a; Garside & Bell 2011b; Poggio & Hanks, 2007;Young & Poggio, 2007.

Table 29: Sensitivity analysis of AEB to an increase in yield progressing from a bare fallow with high tillage to a legume fallow with low tillage - Mackay 250ha

AB.FC.SB.HB.MB.GC to AB.FB.SB.HB.MB.GB										
Plant	**1st Rat**	**2nd Rat**	**3rd Rat**	**4th Rat**	**Average Yield**	**Change to average yield**	**FGM**	**Change in FGM**		**AEB**
(t/ha)	**(t/ha)**	**(t/ha)**	**(t/ha)**	**(t/ha)**	**(t/ha)**	**(%)**	**($/ha)**	**($/ha)**	**(%)**	**($/ha/yr)**
105	**103**	**102**	**97**	**95**	**101**	**0.00%**	**1342**	**0.00**	**0.00%**	**-29.63**
106	104	101	99	97	102	1.00%	**1358**	15.46	1.15%	-14.17
107	105	102	100	98	103	2.00%	**1382**	39.19	2.92%	9.56
108	106	103	101	99	104	3.00%	**1405**	62.91	4.69%	33.29
109	107	104	102	100	105	4.00%	**1429**	86.64	6.45%	57.02
110	108	105	103	101	106	5.00%	**1453**	110.37	8.22%	80.74

Table 30: Sensitivity analysis of AEB to an increase in yield progressing from a bare fallow with high tillage to a legume fallow with low tillage - Delta 250ha

AB.FC.SB.HB.MB.GC to AB.FB.SB.HB.MB.GB										
Plant	**1st Rat**	**2nd Rat**	**3rd Rat**	**4th Rat**	**Average Yield**	**Change to average yield**	**FGM**	**Change in FGM**		**AEB**
(t/ha)	**(t/ha)**	**(t/ha)**	**(t/ha)**	**(t/ha)**	**(t/ha)**	**(%)**	**($/ha)**	**($/ha)**	**(%)**	**($/ha/yr)**
155	**167**	**169**	**170**	**N/A**	**165**	**0.00%**	**3250**	**0.00**	**0.00%**	**-37.22**
157	169	171	172	N/A	167	1.00%	**3293**	43.04	1.32%	-6.96
158	170	172	173	N/A	169	2.00%	**3337**	86.91	2.67%	36.91
160	172	174	175	N/A	170	3.00%	**3382**	131.59	4.05%	81.59
161	174	176	177	N/A	172	4.00%	**3427**	176.83	5.44%	126.83
163	176	178	179	N/A	174	5.00%	**3474**	223.44	6.87%	173.44

Table 31: Sensitivity analysis of AEB an increase in yield progressing from a bare fallow with high tillage to a legume fallow with low tillage - BRIA 250ha

AB.FC.SB.HB.MB.GC to AB.FB.SB.HB.MB.GB										
Plant	**1st Rat**	**2nd Rat**	**3rd Rat**	**4th Rat**	**Average Yield**	**Change to average yield**	**FGM**	**Change in FGM**		**AEB**
(t/ha)	**(t/ha)**	**(t/ha)**	**(t/ha)**	**(t/ha)**	**(t/ha)**	**(%)**	**($/ha)**	**($/ha)**	**(%)**	**($/ha/yr)**
127	**118**	**125**	**126**	**N/A**	**124**	**0.00%**	**2038**	**0.00**	**0.00%**	**-38.75**
128	119	126	127	N/A	125	1.00%	**2071**	32.05	1.57%	-17.95
130	120	128	129	N/A	127	2.00%	**2103**	64.86	3.18%	14.86
131	122	129	130	N/A	128	3.00%	**2137**	98.42	4.83%	48.42
132	123	130	131	N/A	129	4.00%	**2171**	132.47	6.50%	82.47
134	124	132	133	N/A	131	5.00%	**2206**	167.28	8.21%	117.28

5. Key messages and limitations of project findings

This research project examined a multitude of pesticide management practice options in order to identify profitable abatement opportunities that reduce losses of PSII herbicides and their alternatives from three major sugarcane production districts located in the GBR catchment. The project addressed several key research questions and identified a number of changes to cane farming management systems and practices that can be expected to be profitable, while simultaneously reducing losses of PSII pesticides from cane farms to waterways. A cost-effectiveness analysis was also undertaken to compare each alternative in terms of the annualised dollar benefit/cost per gram of herbicide equivalent abatement. This ratio essentially provides a relative value by which to compare the various options according to their potential to improve water quality. The findings from this research provide a substantial contribution to the current understanding of the costs and benefits associated with improving water quality in cane growing catchments by pesticide management on cane farms. It has practical implications for landholders, the sugar industry, and policy-makers.

5.1. Wet tropics

5.1.1. Herbicide management

The results from changes in herbicide management within the Tully cane growing district show a considerable degree of variation between individual management practices as well as farm sizes, which highlights the heterogeneity and the Wet Tropics region more generally. The Tully analyses indicated that a transition from *C-* to *B-Class* herbicide management (legume fallow & low tillage) was likely to provide the greatest economic benefit per unit abatement of PSII pesticides, regardless of farm size. In turn, this was then followed by progressive changes from *C-* to *A-Class* and then from *B-* to *A-Class*, with a bare fallow and high tillage farming system exhibiting a relatively lower per unit cost-effectiveness between comparative herbicide management classes.

Despite the water quality results showing that all progressive changes in herbicide management provide a positive level of PSII herbicide abatement, some management practices were found to have an adverse impact on farm profitability. In particular, a transition from *B-* to *A-Class* herbicide management is expected to increase costs for a 50ha farm in Tully. This negative economic outcome is predominantly due to the size of the capital expenditure required relative to the farming area (i.e. because assets are utilised relatively less effectively on small farms than on larger farms the capital costs are spread over a lower level of output). The results further indicated that an economic benefit will only exist if the actual capital expenditure is substantially less than the expected costs (i.e. requiring approximately 40% reduction in these costs). Alternatively, a small farm will need to look at other avenues to improve the utilisation of capital expenditure or potentially use a contractor if suitable services are available within the region. An important implication from this finding is that farm size and the efficient utilisation of capital expenditure matters; which is especially the case where capital costs are required to adopt new practices.

Although the adoption of *A-Class* herbicide management practices tended to be profitable for a 150ha and 250ha farm, the risk analysis highlighted the importance of ensuring production is maintained in order to remain profitable. In particular, a decrease in the average yield of just one per cent (1%) or greater was found to result in a negative impact on profitability for a 250ha farm. Given that *A-Class* practices are currently not commonly used in the industry and are thus largely unproven commercially, this level of operational risk suggests that more field work may be required to reinforce these findings.

5.1.2. Herbicide selection

Regarding herbicide selection, the variation in the economic outcomes observed between the alternative management options is largely the result of regional heterogeneity in weed management practices and the specific selection of herbicide products. In particular, the economic analyses indicated that changing from standard to alternative chemicals will generally come at a financial cost across all herbicide management classes, irrespective of the fallow and tillage management choices. The financial cost is generally lower when operating in a higher class of herbicide management. This essentially implies that a change to alternative chemicals is likely to present a trade-off between an economic cost and environmental benefits.

It can be observed generally across all scenarios and all regions that a change to alternative chemicals will result in a reduction in the overall herbicide equivalent measure (h-HEq). The differences observed between abatement levels within each of the classes is a function the type and amount of chemical applied, the toxicity of these chemicals relative to the reference herbicide diuron, as well as the method of application. Interestingly, the most cost-effective practice change for Tully occurs in *B-Class* management, which is distinct from other regions. From a purely financial perspective, a change to alternative chemicals is less costly when in an improved class of herbicide management is involved due to more efficient use of inputs.

Evaluating progressive changes in herbicide management using alternative chemicals was a secondary focus of this research. Albeit, a progressive change in herbicide management while using the alternatives was found to be more likely to provide a positive AEB result compared to standard chemicals. This is explained by the different prices of standard and alternative chemicals. Since alternative chemicals are generally more expensive than the standard chemicals, there is a relatively large savings in cost to be realised as a consequence of the reduction in chemical use when moving to an improved herbicide management strategy.

5.1.3. Fallow and tillage

The combination of fallow and tillage management was found to have a relatively negligible impact on the economic results. PSII-HEq losses are shown to be greater under the combination of a bare fallow and high tillage farming system than under a legume fallow and low tillage system. Water quality implications associated with changing fallow and tillage management practices (i.e. from *C-* to *B-Class* practices) were not a primary focus of this project and thus were not examined in detail. However, the economic results showed it was not profitable for a 50ha farm once capital expenditure requirements were taken into account; however, it was profitable for a 150ha and 250ha farms. In light of the comparatively similar yield data modelled by APSIM, more research to verify the potential of legume fallow practices to increase yields due to soil health implications will help to verify this finding.

5.2. Mackay Whitsundays

5.2.1. Herbicide management

As was the case with Tully, the results illustrated that there is a considerable degree of variation between individual management practices as well as farm sizes. Interestingly, the magnitude in the relative cost-effectiveness calculations for changing practices on farms located in Mackay is generally lower than for those located in Tully. This is mathematically explained by the lower economic benefits associated with changing practices in Mackay relative to the respective size of pesticide abatement.

A transition from *C-* to *B-Class* herbicide management (legume fallow & low tillage) provided the greatest economic benefit per unit abatement of PSII pesticides, regardless of farm size. In terms of profitability, a change from *C-* to *B-Class* herbicide management was the only option found to be profitable for a 50ha farm. In line with findings for Tully, this implies that farm size is critical where capital expenditures are required because assets are utilised relatively less effectively on small farms than on larger farms (because costs are spread over a lower level of output).

While in the majority of cases, profitability showed a positive relationship with an increase in farm size, however, a transition from *B-* to *A-Class* herbicide management was not economically acceptable for a 150ha farm. In particular, the break-even CAPEX showed that a substantial reduction in CAPEX is required to ensure that this particular change in herbicide management is economically acceptable. This case further demonstrates the significance of production risk when changing to practices that are unproven commercially and thus have an inherently higher degree of uncertainty. A decrease in average yield of just one per cent (1%) or greater will result in a negative impact on profitability.

5.2.2. Herbicide selection

The results further indicated that a change from standard to alternative chemicals in Mackay will have a negative impact on profitability across all herbicide management classes, irrespective of the fallow and tillage management practice. In a departure from other regions, a change to alternative herbicides in *C-Class* herbicide management is most cost-effective. While the order of cost-effectiveness differs in Mackay from other regions because of regional heterogeneity in weed management practices, the results show that a change to alternative chemicals is similarly expected to improve water quality (i.e. a reduction in the overall herbicide equivalent measure, h-HEq). Although the overall level of h-HEq abatement is unique to each region, the general tendency for greater abatement to occur within *C-Class*, then within *B-Class*, and the least abatement within *A-Class* herbicide management is similarly reflected in the case of Mackay. Similar to the results for Tully, a progressive change in herbicide management while presently using alternative chemicals was more likely to provide a positive AEB result compared to standard chemicals.

5.2.3. Fallow and tillage

Progressing to improved herbicide management under a legume fallow and low tillage farming system was found to be marginally more profitable than under a legume fallow and low tillage system in those cases where the economic impacts are positive. Results for Mackay indicated that it is not profitable to change from bare fallow and high tillage practices to legume fallow and low tillage practices. While results show an increase in the farm gross margin, it is not sufficient to make the investment in capital expenditure worthwhile. However, the results of a sensitivity analysis showed that the average yield for a 250ha farm needed to rise by just 2 per cent (2%) for improved fallow and tillage management practices to become profitable.

5.3. Burdekin Dry Tropics

5.3.1. Herbicide management

As a consequence of characteristics unique to each of the Delta and BRIA regions, the Burdekin Dry Tropics exhibited some rather substantial differences in the results of the relative cost-effectiveness calculations per unit of herbicide abatement. In most cases, values for the BRIA tended to have smaller ranges than the Delta within each of the relative cost-effectiveness tables presented. This is predominantly due to substantially higher levels of PSII abatement being observed compared to the Delta; and for the other regions for that matter. The high levels of PSII herbicide loads in the BRIA simulations are likely to be a result of the fully irrigated system causing frequent runoff events on the heavy clay soil type. It is important to note that many growers in the Burdekin capture runoff with recycling pits; however, the subsequent capture of runoff is not represented in this analysis. Given the ability of recycling pits to potentially reduce herbicide losses, further analysis is needed to evaluate their impact on the economics and water quality outcomes.

Collectively, the Burdekin figures were lower generally compared to the other regions. This is largely explained by the lower economic benefits associated with changing practices in the Burdekin relative to the respective size of the PSII abatement. A general pattern of improved cost-effectiveness as farm size increases again highlights the importance of farm size in making a prudent investment decision. Appropriate strategies to improve capital expenditure utilisation, and subsequently adoption, may include the use of farmer collaborative arrangements to share equipment or the use of contractors to perform the farming operation.

A number of practice changes were found to be unprofitable for a 50ha farm in the Delta and BRIA regions. Generally, a transition to *A-Class* herbicide management resulted in an unacceptable outcome due to the high capital investment. Options to improve profitability in this situation (e.g. 50ha farm) include savings in the amount of actual capital expenditure and/or increasing the area over which the investment is utilised. In line with the other regions, the risk analysis highlighted the sensitivity of the economic results to changes in yield. This reinforces the importance of assessing the production implications of a change in herbicide management, particularly towards *A-Class* practices.

5.3.2. Herbicide selection

The results indicate that a change to alternative herbicide products will generally come at a cost to growers in the Burdekin region. Unlike other regions there was one exception: the case where a small financial benefit was observed for *A-Class* herbicide management under bare fallow & high tillage. This highlights the reduced impact or, in some cases, a possible financial benefit, when changing to alternative chemicals in a higher class of herbicide management. It was consistently observed across the BRIA and Delta that a change to alternative chemicals will result in a reduction in the overall herbicide equivalent measure (h-HEq). This essentially implies that a change to alternative chemicals is likely to present a trade-off between environmental benefits and adverse economic outcomes for growers. Similar to other regions, the variation in herbicide selection results is primarily the result of regional heterogeneity in weed management practices and the specific selection of herbicide products.

As is the case across the other districts, a progressive change in herbicide management practice using alternative chemicals was found to be more likely to provide a positive AEB result when compared to standard chemicals. Interestingly, the only case where a change to new chemicals was found to be profitable was in *A-Class* practices within the Burdekin Dry Tropics; although the benefit was indeed marginal.

5.3.3. Fallow and tillage

In general, progressing to improved herbicide management from *C-Class* is substantially more profitable under a bare fallow and high tillage farming system than under a legume fallow and low tillage system in the Burdekin. Results from the investment analysis further indicated that a change to improved fallow and tillage practices is not profitable when considering the required level of capital expenditure. In light of the comparatively similar yield data modelled by APSIM, more research to verify the potential of legume fallow practices to increase yields due to soil health and fertility implications will help to clarify this finding. For instance, a sensitivity analysis performed over the average yield for a 250ha farm indicated that a gain of 2 per cent (2%) will be required to result in improved fallow and tillage management practices becoming profitable. Therefore, the economic outcome of a change to improved fallow and tillage management is critically dependent on achieving an expected yield improvement as well as the accuracy in the capital investment requirements assumed in the analysis.

5.4. Limitations concerning the economic modelling

The economic modelling of the RP62c project involved a number of limitations that required simplifying assumptions to be made in order to complete the analysis. While many of those assumptions specific to the modelling were treated in previous sections, several more general caveats need to be considered with respect to interpreting and distributing the information from this report.

First, it is important to consider that each farming business is essentially unique and therefore each of the generalised parameters and assumptions used in this analysis will not necessarily reflect each farm's particular circumstances. Landholders may indeed have higher or lower costs of transitioning to improved practices: even those practicing similar operations may end up with higher or lower gross margins than those that form the basis of this investment analysis.

Second, yield data used within this project was estimated using APSIM, which provides an indication of yield *potential* that is not necessarily representative of *anecdotal* production averages within each cane growing district or region. Furthermore, the cane yield modelled by APSIM is very similar in a legume fallow and a bare fallow farming system. Recent case studies[80] indicate growing a well-managed legume fallow crop can increase yields through improved soil health by breaking the sugarcane monoculture cycle.

Third, the information presented on *A-Class* management is based on practices under research and not thoroughly tested on a commercial scale. Moving to *A-Class* management practices is likely to be perceived by growers as representing a greater business risk than moving to *B-Class* management[81]. The economic analysis applied the same discount rate across all herbicide management options and included no adjustments to account for differences in business risk between landholders and regions. Assigning a higher required rate of return to riskier management practices will imply a lower NPV and a higher payback period.

Fourth, the herbicide management scenarios were developed in consultation with local growers and agronomists with expertise in weed management. Utilising previous research undertaken in the Paddock to Reef Program as a starting basis, the scenarios were developed to reflect realistic practices used in the regions in order to achieve effective weed management. They also take into account regional specific details such as the soil types and the

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[80] See, for example, Garside & Bell (2011a; 2011b); Poggio & Hanks, 2007; Young & Poggio, 2007.

[81] See Thompson et al. (in press).

farming systems modelled for this project. In general, using only alternative herbicides as part of a weed management program is not as common as the use of standard herbicides (see Section 3.2.1). Therefore, there is a higher degree of uncertainty regarding the use of alternative herbicides within the sugarcane farming system and in some cases there may be limitations on the suitability of products in certain situations (e.g. soil types).

Lastly, the RP62c project has only analysed the concept of profitability at the farm level. However, it is important to consider more broadly the potential impacts that changing farming systems may have on other sectors of the cane industry. The areas that may be affected include, for example, harvesting contractors and millers, as well as agri-businesses linked throughout the local supply chain.

5.5. Limitations concerning the water quality modelling

This modelling has been completed using scenarios of typical herbicide applications. As such, the results are not prescriptive for every landholder and therefore may not reflect the actual practices on an individual property. The potential for offsite transport and degradation, as well as toxicity, varies between individual herbicide products so variations in the applications of products from those simulated here could alter the relative results.

The modelling scenarios specified the timing of pesticide application as the number of days after a crop was planted/harvested and were based on typical scenarios. Applications occurred irrespective of current or future rainfall and therefore did not consider the fact that a grower may delay application if heavy rainfall was predicted for coming days.

Locally relevant properties of the pesticides, in particular the half-lives of the alternate herbicides, are not well known. Values applied in the current study have been taken from the Pesticide Properties Database, and adjusted for local conditions based on daily temperature. However, other factors such as soil type and soil moisture will also affect their local half-lives. Recent field and controlled environment studies of degradation in Queensland will be available to apply in future modelling but were not available for use in the current study.

The Burdekin APSIM simulations include a large amount of runoff due to frequent irrigations. It is important to note that growers in the Burdekin may capture runoff from irrigation in recycling pits; however, this practice is not represented here. The results thus represent the herbicide in water moving off the paddock without taking into account processes capable of capturing or trapping that water before it moves from the farm.

Caution should be applied in interpretation of the relative toxicity results. The h-HEq factors developed for use in the current study were in some cases based on a limited number of comparative data points (n=2 for 5 herbicides). Further, as has been noted in Section 3.7.3, the derivation of these toxic equivalency values assumes that the combined effect of these herbicides in a mixture is concentration additive and makes the assumption that the dose response pattern for each of the herbicides is parallel. While these assumptions are valid for the herbicides included in the PSII-HEq, these assumptions have not been tested for the remaining herbicides included in the h-HEq.

It is also important to note that the comparative toxicity scores applied in this project are only relevant to organisms that photosynthesise (phototrophs). The assessment was based on phototrophs since the application scenarios only consider herbicide products which target plants. Additionally, phototrophs represent important species in the GBR ecosystem (e.g. corals, seagrass, and algae) which is downstream from the regions under consideration. However, differences in the relative toxicity between diuron and other herbicides would be expected if the assessment was carried out for fish or macroinvertebrates. As an indicative example, according to the PPDB[82] the toxicity of Pendimethalin (Stomp) to fish and macroinvertebrates relative to diuron is orders of magnitude higher (~60 and 6x respectively) than when pendimethalin is compared to diuron for plants (0.006). Therefore, the results are not representative of whole-of-ecosystem toxicity. There is a need for future research to investigate mixture toxicity of herbicides relevant to the GBR on locally important species.

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[82] University of Hertfordshire, 2013.

6. Conclusion and Future Research

This project evaluated a multitude of pesticide management practice options to identify profitable abatement opportunities to reduce losses of PSII herbicides and their alternatives from three major sugarcane production districts located in the GBR catchment. 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 economically worthwhile to implement. Nonetheless, the 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.

Looking at the water quality implications, moving from *C-* to *B-Class* herbicide management in Tully 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.

Moving from *C-* to *A-Class* herbicide management was also found to be profitable in many cases; however, the payback period for 50ha farms varies across districts. It was shown to take 6 years in Tully and 8 years in the Burdekin, while the initial investment is not recoverable over 10 years in Mackay. Payback periods for 150ha farms were 2 years for Tully and the Burdekin and 3 years for Mackay. Similarly, it was 2 years for all 250ha farms. Corresponding modelling showed water quality benefits in the reduction of PSII-HEq losses by 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 farming area. On the other hand, it is expected to be profitable for 150ha and 250ha farms, which highlights the importance of farm size and the efficient utilisation of capital expenditure. Risk analysis also illustrates the importance of ensuring production is maintained in order to remain profitable given that *A-Class* herbicide management is based on practices under research and not thoroughly tested on a commercial scale. Moving from *B-* to *A-Class* herbicide management showed 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.

PSII-HEq losses were shown to be greater under a bare fallow and high tillage farming system than under a legume fallow and low tillage system across all cane districts. Reductions in these losses were found also to be larger when transitioning to improved herbicide management under a bare fallow and high tillage farming system. And while water quality implications of moving from bare fallow and high tillage practices to legume fallow and low tillage practices (i.e. from *C-* to *B-Class* practices) were not examined in this project, the economic results showed that it is only profitable for 150ha and 250ha farms in Tully.

The combination of fallow and tillage management tended to have a relatively negligible impact on the economic results between comparative scenarios when progressing to improved herbicide management in Tully. In Mackay, progressing to improved herbicide management under a legume fallow and low tillage farming system is marginally more profitable. Progressing to improved herbicide management from *C-Class* under a bare fallow and high tillage farming system is substantially more profitable in the Burdekin.

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 were found to be relatively lower when using a higher class of herbicide management.

With this project, several worthwhile avenues for future research were also identified. Regarding future economic work, 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.

With respect to the water quality outcomes, the report acknowledges that many growers in the Burdekin capture runoff from irrigation in recycling pits, which was not represented within the stylised scenarios analysed in this report. Contriving scenarios that account for this in future work would increase the accuracy of the water quality results in this region. In addition, including application timing with consideration of weather forecasts into the water quality modelling would be interesting to determine the impact of delaying spraying if heavy rainfall is forecast within the next 48hrs. The water quality assessments would also benefit from 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.

On a final note, there is a real need to establish concrete ecological targets to achieve the environmental aims set out in Reef Plan. 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.

Appendix 1: Pesticide management practice scenarios

Tully: standard chemicals, legume fallow and low tillage		**A-Class practices**	**AA.FB.SB.HB.MA.GB**			**B-Class practices**	**AB.FB.SB.HB.MB.GB**			**C-Class practices**	**AC.FB.SB.HC.MC.GB**		
		Product	**AR (L or kg/ha)**	**Method**	**Placement**	**Product**	**AR (L or kg/ha)**	**Method**	**Placement**	**Product**	**AR (L or kg/ha)**	**Method**	**Placement**
Fallow (15 November)	**DAH**	**Legume fallow & Including Diuron, Hexazinone, Ametryn & Atrazine**				**Legume fallow & Including Diuron, Hexazinone, Ametryn & Atrazine**				**Legume fallow & Including Diuron, Hexazinone, Ametryn & Atrazine**			
Cane Spray-out (18th December)	33	Roundup DST	5		canopy from above	Roundup DST	5		canopy from above	Roundup DST	6.9		canopy from above
		2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1.6		canopy from above
Possible post-emergent in legume c	76	Verdict 520	0.15		canopy from above	Verdict 520	0.15		canopy from above	Verdict 520	0.15		canopy from above
Legume spray-out (6 April)	120	Roundup DST	2.5		canopy from above	Roundup DST	2.5		canopy from above	Roundup DST	4		canopy from above
		2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1.6		canopy from above
Plant (15 July)	**DAS**												
Plant spray 1 (5 August)	21	Atradex	2	Directed	whole area	Atrazine	2	Directed	whole area	Atradex	2.5	Directed	whole area
Spike		Stomp Xtra	2.25	Directed	whole area	Stomp Xtra	2.25	Directed	whole area	Stomp Xtra	3.4	Directed	whole area
		Gromoxone	1.2	Directed	whole area	Gramoxone	1.2	Directed	whole area	Gramxone	1.6	Directed	whole area
Plant spray 2 (15 October)	92	2,4-D Advance 700	1	Directed	whole area	2,4-D Advance 700	1	Directed	whole area	2,4-D Advance 700	1.6	Directed	whole area
Stooling-OOH		Gromoxone	1.2	Directed	whole area	Gramoxone	1.2	Directed	whole area	Gramxone	1.6	Directed	whole area
Plant spray 3 (2 November)	109	Roundup DST	1.5	Shield	inter-row	Gramoxone	1.2	Directed	whole area	Gramoxone	1.6	Directed	whole area
OOH		2,4-D Advance 700	1	Shield	inter-row	Dual Gold	1.5	Directed	whole area	Dual Gold	1.8	Directed	whole area
		Gramoxone	1.2	Directed	stool/bed	2,4-D Advance 700	1	Directed	whole area	2,4-D Advance 700	1.6	Directed	whole area
		Dual Gold	1.5	Directed	stool/bed								
		2,4-D Advance 700	1	Directed	stool/bed								
Ratoon 1 (15 July)	**DAS**												
Ratoon spray 1 (24 September)	78	Gramoxone	1.2	Directed	whole area	Gramoxone	1.2	Directed	whole area	Gramoxone	1.6	Directed	whole area
Stooling-OOH		2,4-D Advance 700	1	Directed	whole area	2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1.6	directed	whole area
						Diuron+Hexazinone (VK4)	0.9	Directed	whole area	Diuron+Hexazinone (VK4)	0.9	Directed	whole area
Ratoon spray 2 (9 January)	184									Gramoxone	1.6	Directed	whole area
										Atradex	1.5	Directed	whole area
										2,4-D Advance 700	1.6		canopy from above
Ratoon 2 (15 August)	**DAS**												
Ratoon spray 1 (1 November)	78	Gramoxone	1.2	Directed	whole area	Gramoxone	1.2	Directed	whole area	Gramoxone	1.6	Directed	whole area
Stooling-OOH		2,4-D Advance 700	1	Directed	whole area	2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1.6	directed	whole area
						Diuron+Hexazinone (VK4)	0.9	Directed	whole area	Diuron+Hexazinone (VK4)	0.9	Directed	whole area
Ratoon spray 2 (9 January)	153					Paraquat	1.2	Directed	whole area	Gramoxone	1.6	Directed	whole area
						2,4-D Advance 700	1		canopy from above	Atradex	1.5	Directed	whole area
OOH										2,4-D Advance 700	1.6		canopy from above
Ratoon 3 (15 September)	**DAS**												
Ratoon spray 1 (2 December)	78	Gramoxone	1.2	Directed	whole area	Gramoxone	1.2	Directed	whole area	Gramoxone	1.6	Directed	whole area
Stooling-OOH		2,4-D Advance 700	1	Directed	whole area	2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1.6	directed	whole area
		Diuron+Hexazinone	0.9	Directed	whole area	Diuron+Hexazinone (VK4)	0.9	Directed	whole area	Diuron+Hexazinone (VK4)	0.9	Directed	whole area
Ratoon spray 2 (9 February)	153	Roundup DST	1.5	Shield	inter-row	Gramoxone	1.2	Directed	whole area	Gramoxone	1.6	Directed	whole area
		2,4-D Advance 700	0.8	Shield	inter-row	2,4-D Advance 700	1		canopy from above	Atradex	1.5	Directed	whole area
OOH		Gramoxone	1.2	Directed	Stool/bed					2,4-D Advance 700	1.6		canopy from above
Ratoon 4 (15 October)	**DAS**												
Ratoon spray 1 (26 December)	78	Roundup DST	1.5	Shield	inter-row	Gramoxone	1.2	Directed	whole area	Gramoxone	1.6	Directed	whole area
Stooling-OOH		2,4-D Advance 700	0.8	Shield	inter-row	2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1.6	directed	whole area
		Gramoxone	1.2	Directed	Stool/bed	Diuron+Hexazinone (VK4)	0.9	Directed	whole area	Diuron+Hexazinone (VK4)	0.9	Directed	whole area
Ratoon spray 2 (8 February)	122									Gramoxone	1.6	Directed	whole area
										Atradex	1.5	Directed	whole area
OOH										2,4-D Advance 700	1.6		canopy from above

Tully: alternative chemicals, legume fallow and low tillage		**A-Class practices**	**AA.FB.SB2.HB.MA.GB**			**B-Class practices**	**AB.FB.SB2.HB.MB.GB**			**C-Class practices**	**AC.FB.SB2.HC.MC.GB**		
		Product	**AR (L or kg/ha)**	**Method**	**Placement**	**Product**	**AR (L or kg/ha)**	**Method**	**Placement**	**Product**	**AR (L or kg/ha)**	**Method**	**Placement**
Fallow (15 November)	**DAH**	**Legume fallow & Excluding Diuron, Hexazinone, Ametryn & Atrazine**				**legume fallow & Excluding Diuron, Hexazinone, Ametryn & Atrazine**				**Legume fallow & Excluding Diuron, Hexazinone, Ametryn & Atrazine**			
Cane Spray-out (18th December)	33	Roundup DST	5		canopy from above	Roundup DST	5		canopy from above	Roundup DST	6.9		canopy from above
		2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1.6		canopy from above
Possible post-emergent in legume crop (1 February)		Verdict 520	0.15		canopy from above	Verdict 520	0.15		canopy from above	Verdict 520	0.15		canopy from above
Legume spray-out (6 April)	120	Roundup DST	2.5		canopy from above	Roundup DST	2.5		canopy from above	Roundup DST	4		canopy from above
		2,4-D Advance 700	1	`	canopy from above	2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1.6		canopy from above
Plant (15 July)	**DAS**												
Plant spray 1 (5 August)	21	Soccer	1.5	Directed	whole area	Soccer	1.5	Directed	whole area	Soccer	2	Directed	whole area
Spike		Stomp Xtra	2.25	Directed	whole area	Stomp Xtra	2.25	Directed	whole area	Stomp Xtra	3.4	Directed	whole area
		Gramoxone	1.2	Directed	whole area	Gramoxone	1.2	Directed	whole area	Gramoxone	1.6	Directed	whole area
Plant spray 2 (15 October)	92	2,4-D Advance 700	1	Directed	whole area	2,4-D Advance 700	1	Directed	whole area	2,4-D Advance 700	1.6	Directed	whole area
Stooling-OOH		Gramoxone	1.2	Directed	whole area	Gramoxone	1.2	Directed	whole area	Gramoxone	1.6	Directed	whole area
Plant spray 3 (2 November)	109	Roundup DST	1.5	Shield	inter-row	Gramoxone	1.2	Directed	whole area	Gramoxone	1.6	Directed	whole area
OOH		2,4-D Advance 700	1	Shield	inter-row	Balance	0.2	Directed	whole area	Balance	0.2	Directed	whole area
		Gramoxone	1.2	Directed	stool/bed	2,4-D Advance 700	1	Directed	whole area	2,4-D Advance 700	1.6	Directed	whole area
		Balance	0.2	Directed	stool/bed								
		2,4-D Advance 700	1	Directed	stool/bed								
Ratoon 1 (15 July)	**DAS**												
Ratoon spray (26 August)	35									Soccer	2	Directed	whole area
Small cane										2,4-D Advance 700	1.6	directed	whole area
Ratoon spray (24 September)	78	Gramoxone	1.2	Directed	whole area	Gramoxone	1.2	Directed	whole area				
Stooling-OOH		2,4-D Advance 700	1	Directed	whole area	2,4-D Advance 700	1	directed	whole area				
Ratoon spray (9 January)	184									Gramoxone	1.6	Directed	whole area
OOH										Balance	0.2	Directed	whole area
										2,4-D Advance 700	1.6		canopy from above
Ratoon 2 (15 August)	**DAS**												
Ratton spray (19 September	35					Soccer	1.5	Directed	whole area	Soccer	2	Directed	whole area
Small cane						2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1.6	directed	whole area
Ratoon spray 1 (1 November)	78	Gramoxone	1.2	Directed	whole area								
Stooling-OOH		2,4-D Advance 700	1	Directed	whole area								
Ratoon spray 2 (9 January)	153					Gramoxone	1.2	Directed	whole area	Gramoxone	1.6	Directed	whole area
OOH						2,4-D Advance 700	1		canopy from above	Balance	0.2	Directed	whole area
										2,4-D Advance 700	1.6		canopy from above
Ratoon 3 (15 September)	**DAS**												
Ratoon spray 1 (20 October)	35	Soccer	1.5	Directed	whole area	Soccer	1.5	Directed	whole area	Soccer	2	Directed	whole area
Small cane		2,4-D Advance 700	1	Directed	whole area	2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1.6	directed	whole area
Ratoon spray 2 (9 February)	153	Roundup DST	1.5	Shield	inter-row	Gramoxone	1.2	Directed	whole area	Gramoxone	1.6	Directed	whole area
OOH		2,4-D Advance 700	0.8	Shield	inter-row	2,4-D Advance 700	1		canopy from above	Balance	0.2	Directed	whole area
		Gramoxone	1.2	Directed	Stool/bed					2,4-D Advance 700	1.6		canopy from above
Ratoon 4 (15 October)	**DAS**												
Ratoon spray 1 (26 December)	78	Roundup DST	1.5	Shield	inter-row	Gramoxone	1.2	Directed	whole area	Gramoxone	1.6	Directed	whole area
Stooling-OOH		2,4-D Advance 700	0.8	Shield	inter-row	2,4-D Advance 700	1	Directed	whole area	2,4-D Advance 700	1.6	directed	whole area
		Gramoxone	1.2	Directed	Stool/bed	Balance	0.2	Directed	whole area	Balance	0.2	Directed	whole area
Ratoon spray 2 (8 February)	122									Gramoxone	1.6	Directed	whole area
OOH										Soccer	2	Directed	whole area
										2,4-D Advance 700	1.6		canopy from above

Tully: standard chemicals, bare fallow and high tillage		**A-Class practices**	**AA.FC.SB.HB.MA.GC**			**B-Class practices**	**AB.FC.SB.HB.MB.GC**			**C-Class practices**	**AC.FC.SB.HC.MC.GC**		
		Product	**AR (L or kg/ha)**	**Method**	**Placement**	**Product**	**AR (L or kg/ha)**	**Method**	**Placement**	**Product**	**AR (L or kg/ha)**	**Method**	**Placement**
Fallow (15 November)	**DAH**	**Bare fallow & Including Diuron, Hexazinone, Ametryn & Atrazine**				**Bare fallow & Including Diuron, Hexazinone, Ametryn & Atrazine**				**Bare fallow & Including Diuron, Hexazinone, Ametryn & Atrazine**			
Cane Spray-out (18th December)	33	Roundup DST	5		canopy from above	Roundup DST	5		canopy from above	Roundup DST	6.9		canopy from above
		2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1.6		canopy from above
Fallow clean-up spray (6 April)	120	Roundup DST	2.5		canopy from above	Roundup DST	2.5		canopy from above	Roundup DST	4		canopy from above
		2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1.6		canopy from above
Plant (15 July)	**DAS**												
Plant spray 1 (5 August)	21	Atradex	2	Directed	whole area	Atrazine	2	Directed	whole area	Atrazine	2.5	Directed	whole area
Spike		Stomp Xtra	2.25	Directed	whole area	Stomp Xtra	2.25	Directed	whole area	Stomp Xtra	3.4	Directed	whole area
		Gramoxone	1.2	Directed	whole area	Gramoxone	1.2	Directed	whole area	Gramoxone	1.6	Directed	whole area
Plant spray 2 (15 October)	92	2,4-D Advance 700	1	Directed	whole area	2,4-D Advance 700	1	Directed	whole area	2,4-D Advance 700	1.6	Directed	whole area
Stooling-OOH		Gramoxone	1.2	Directed	whole area	Gramoxone	1.2	Directed	whole area	Paraquat	1.6	Directed	whole area
Plant spray 3 (2 November)	109	Roundup DST	1.5	Shield	inter-row	Gramoxone	1.2	Directed	whole area	Gramoxone	1.6	Directed	whole area
OOH		2,4-D Advance 700	1	Shield	inter-row	Dual Gold	1.5	Directed	whole area	Dual Gold	1.8	Directed	whole area
		Gramoxone	1.2	Directed	stool/bed	2,4-D Advance 700	1	Directed	whole area	2,4-D Advance 700	1.6	Directed	whole area
		Dual Gold	1.5	Directed	stool/bed								
		2,4-D Advance 700	1	Directed	stool/bed								
Ratoon 1 (15 July)	**DAS**												
Ratoon spray 1 (24 September)	78	Gramoxone	1.2	Directed	whole area	Gramoxone	1.2	Directed	whole area	Gramoxone	1.6	Directed	whole area
Stooling-OOH		2,4-D Advance 700	1	Directed	whole area	2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1.6	directed	whole area
						Diuron+Hexazinone	0.9	Directed	whole area	Diuron+Hexazinone	0.9	Directed	whole area
Ratoon spray 2 (9 January)	184									Gramoxone	1.6	Directed	whole area
										Atradex	1.5	Directed	whole area
										2,4-D Advance 700	1.6		canopy from above
Ratoon 2 (15 August)	**DAS**												
Ratoon spray 1 (1 November)	78	Gramoxone	1.2	Directed	whole area	Gramoxone	1.2	Directed	whole area	Gramoxone	1.6	Directed	whole area
Stooling-OOH		2,4-D Advance 700	1	Directed	whole area	2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1.6	directed	whole area
						Diuron+Hexazinone	0.9	Directed	whole area	Diuron+Hexazinone	0.9	Directed	whole area
Ratoon spray 2 (9 January)	153					Gramoxone	1.2	Directed	whole area	Gramoxone	1.6	Directed	whole area
						2,4-D Advance 700	1		canopy from above	Atradex	1.5	Directed	whole area
OOH										2,4-D Advance 700	1.6		canopy from above
Ratoon 3 (15 September)	**DAS**												
Ratoon spray 1 (2 December)	78	Gramoxone	1.2	Directed	whole area	Gramoxone	1.2	Directed	whole area	Gramoxone	1.6	Directed	whole area
Stooling-OOH		2,4-D Advance 700	1	Directed	whole area	2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1.6	directed	whole area
		Diuron+Hexazinone	0.9	Directed	whole area	Diuron+Hexazinone	0.9	Directed	whole area	Diuron+Hexazinone	0.9	Directed	whole area
Ratoon spray 2 (9 February)	153	Roundup DST	1.5	Shield	inter-row	Gramoxone	1.2	Directed	whole area	Gramoxone	1.6	Directed	whole area
		2,4-D Advance 700	0.8	Shield	inter-row	2,4-D Advance 700	1		canopy from above	Atradex	1.5	Directed	whole area
OOH		Paraquat	1.2	Directed	Stool/bed					2,4-D Advance 700	1.6		canopy from above
Ratoon 4 (15 October)	**DAS**												
Ratoon spray 1 (26 December)	78	Roundup DST	1.5	Shield	inter-row	Gramoxone	1.2	Directed	whole area	Gramoxone	1.6	Directed	whole area
Stooling-OOH		2,4-D Advance 700	0.8	Shield	inter-row	2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1.6	directed	whole area
		Gramoxone	1.2	Directed	Stool/bed	Diuron+Hexazinone	0.9	Directed	whole area	Diuron+Hexazinone	0.9	Directed	whole area
Ratoon spray 2 (8 February)	122									Gramoxone	1.6	Directed	whole area
										Atradex	1.5	Directed	whole area
OOH										2,4-D Advance 700	1.6		canopy from above

Tully: alternative chemicals, bare fallow and high tillage		**A-Class practices**	**AA.FC.SB2.HB.MA.GC**			**B-Class practices**	**AB.FC.SB2.HB.MB.GC**			**C-Class practices**	**AC.FC.SB2.HC.MC.GC**		
		Product	**AR (L or kg/ha)**	**Method**	**Placement**	**Product**	**AR (L or kg/ha)**	**Method**	**Placement**	**Product**	**AR (L or kg/ha)**	**Method**	**Placement**
Fallow (15 November)	**DAH**	**Bare fallow & Excluding Diuron, Hexazinone, Ametryn & Atrazine**				**Bare fallow & Excluding Diuron, Hexazinone, Ametryn & Atrazine**				**Bare fallow & Excluding Diuron, Hexazinone, Ametryn & Atrazine**			
Cane Spray-out (18th December)	33	Roundup DST	5		canopy from above	Roundup DST	5		canopy from above	Roundup DST	6.9		canopy from above
		2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1.6		canopy from above
Fallow clean-up spray (6 April)	120	Roundup DST	2.5		canopy from above	Roundup DST	2.5		canopy from above	Roundup DST	4		canopy from above
		2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1.6		canopy from above
Plant (15 July)	**DAS**												
Plant spray 1 (5 August)	21	Soccer	1.5	Directed	whole area	Soccer	1.5	Directed	whole area	Soccer	2	Directed	whole area
Spike		Stomp Xtra	2.25	Directed	whole area	Stomp Xtra	2.25	Directed	whole area	Stomp Xtra	3.4	Directed	whole area
		Gramoxone	1.2	Directed	whole area	Gramoxone	1.2	Directed	whole area	Gramoxone	1.6	Directed	whole area
Plant spray 2 (15 October)	92	2,4-D Advance 700	1	Directed	whole area	2,4-D Advance 700	1	Directed	whole area	2,4-D Advance 700	1.6	Directed	whole area
Stooling-OOH		Gramoxone	1.2	Directed	whole area	Gramoxone	1.2	Directed	whole area	Paraquat	1.6	Directed	whole area
Plant spray 3 (2 November)	109	Roundup DST	1.5	Shield	inter-row	Gramoxone	1.2	Directed	whole area	Gramoxone	1.6	Directed	whole area
OOH		2,4-D Advance 700	1	Shield	inter-row	Balance	0.2	Directed	whole area	Balance	0.2	Directed	whole area
		Gramoxone	1.2	Directed	stool/bed	2,4-D Advance 700	1	Directed	whole area	2,4-D Advance 700	1.6	Directed	whole area
		Balance	0.2	Directed	stool/bed								
		2,4-D Advance 700	1	Directed	stool/bed								
Ratoon 1 (15 July)	**DAS**												
Ratoon spray (26 August)	35									Soccer	2	Directed	whole area
Small cane										2,4-D Advance 700	1.6	directed	whole area
Ratoon spray (24 September)	78	Gramoxone	1.2	Directed	whole area	Gramoxone	1.2	Directed	whole area				
Stooling-OOH		2,4-D Advance 700	1	Directed	whole area	2,4-D Advance 700	1	directed	whole area				
Ratoon spray (9 January)	184									Gramoxone	1.6	Directed	whole area
OOH										Balance	0.2	Directed	whole area
										2,4-D Advance 700	1.6		canopy from above
Ratoon 2 (15 August)	**DAS**												
Ratton spray (19 September	35					Soccer	1.5	Directed	whole area	Soccer	2	Directed	whole area
Small cane						2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1.6	directed	whole area
Ratoon spray 1 (1 November)	78	Gramoxone	1.2	Directed	whole area								
Stooling-OOH		2,4-D Advance 700	1	Directed	whole area								
Ratoon spray 2 (9 January)	153					Gramoxone	1.2	Directed	whole area	Gramoxone	1.6	Directed	whole area
OOH						2,4-D Advance 700	1		canopy from above	Balance	0.2	Directed	whole area
										2,4-D Advance 700	1.6		canopy from above
Ratoon 3 (15 September)	**DAS**												
Ratoon spray 1 (20 October)	35	Soccer	1.5	Directed	whole area	Soccer	1.5	Directed	whole area	Soccer	2	Directed	whole area
Small cane		2,4-D Advance 700	1	Directed	whole area	2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1.6	directed	whole area
Ratoon spray 2 (9 February)	153	Roundup DST	1.5	Shield	inter-row	Gramoxone	1.2	Directed	whole area	Gramoxone	1.6	Directed	whole area
OOH		2,4-D Advance 700	0.8	Shield	inter-row	2,4-D Advance 700	1		canopy from above	Balance	0.2	Directed	whole area
		Gramoxone	1.2	Directed	Stool/bed					2,4-D Advance 700	1.6		canopy from above
Ratoon 4 (15 October)	**DAS**												
Ratoon spray 1 (26 December)	78	Roundup DST	1.5	Shield	inter-row	Gramoxone	1.2	Directed	whole area	Gramoxone	1.6	Directed	whole area
Stooling-OOH		2,4-D Advance 700	0.8	Shield	inter-row	2,4-D Advance 700	1	Directed	whole area	2,4-D Advance 700	1.6	directed	whole area
		Gramoxone	1.2	Directed	Stool/bed	Balance	0.2	Directed	whole area	Balance	0.2	Directed	whole area
Ratoon spray 2 (8 February)	122									Gramoxone	1.6	Directed	whole area
OOH										Soccer	2	Directed	whole area
										2,4-D Advance 700	1.6		canopy from above

Mackay: standard chemicals, legume fallow and low tillage		**A-Class practices**	**AA.FB.SB.HB.MA.GB**			**B-Class practices**	**AB.FB.SB.HB.MB.GB**			**C-Class practices**	**AC.FB.SB.HC.MC.GB**		
		Product	**AR (kg/ha)**	**Method**	**Placement**	**Product**	**AR (kg/ha)**	**Method**	**Placement**	**Product**	**AR (kg/ha)**	**Method**	**Placement**
Fallow (15 November)	**DAH**	**Legume fallow & Including Diuron, Hexazinone, Ametryn & Atrazine**				**Legume fallow & Including Diuron, Hexazinone, Ametryn & Atrazine**				**Legume fallow & Including Diuron, Hexazinone, Ametryn & Atrazine**			
Cane Spray-out (18 December)	33	Roundup DST	5		canopy from above	Roundup DST	5		canopy from above	Roundup DST	6.9		canopy from above
		2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1.6		canopy from above
Possible post-emergent in legume crop (1st Feb)	76	Sprinnaker	0.14		canopy from above	Sprinnaker	0.14		canopy from above	Sprinnaker	0.14		canopy from above
Legume spray-out (6 April)	120	Roundup DST	3.5		canopy from above	Roundup DST	3.5		canopy from above	Roundup DST	4.5		canopy from above
		Starane Advanced	0.6		canopy from above	Starane Advanced	0.6		canopy from above	Starane Advanced	0.9		canopy from above
Plant (15 May)	**DAS**												
Plant spray 1 (4 June)	20	Atradex	2	Directed	whole area	Atradex	2	Directed	whole area	Atradex	2.5	Directed	whole area
Spike		Stomp Xtra	2.25	Directed	whole area	Stomp Xtra	2.25	Directed	whole area	Stomp Xtra	3.4	Directed	whole area
		Gromoxone	1.2	Directed	whole area	Gromoxone	1.2	Directed	whole area	Gramxone	1.6	Directed	whole area
Plant spray 2 (3 August)	80	Roundup DST	1.5	Shield	inter-row	2,4-D Advance 700	1	Directed	whole area	2,4-D Advance 700	1.6	Directed	whole area
Stooling		Gramoxone	1.2	directed	stool/bed	Gramoxone	1.2	Directed	whole area	Gramxone	1.6	Directed	whole area
Plant spray 3 (22 September)	130	Roundup DST	1.5	Shield	inter-row	Diuron+Hexazinone (VK4)	2.5	directed	whole area	Diuron+Hexazinone (VK4)	3	Directed	whole area
OOH		Diuron+Hexazinone (VK4)	2.5	directed	stool/bed	Gramoxone	1.2	directed	whole area	Gramoxone	1.6	Directed	whole area
		Gramoxone	1.2	directed	stool/bed								
Plant spray 4 OOH (22 September)	130									2,4-D Advance 700	1.6		canopy from above
Ratoon 1 (15 July)	**DAS**												
Ratoon spray 1 (1 September)	50	Roundup DST	1.5	Shield	inter-row	Diurex	0.5	directed	whole area	Diurex	0.75	directed	whole area
Stooling		Gramoxone	1.2	directed	stool/bed	Gramoxone	1.2	directed	whole area	Gramoxone	1.6	directed	whole area
						2,4-D Advance 700	1	Directed	whole area	2,4-D Advance 700	1	Directed	whole area
Ratoon spray 2 (10 November)	120	2,4-D Advance 700	1		canopy from below	2,4-D Advance 700	1		canopy from above	Diurex	0.75	directed	whole area
Ratoon 2 (15 August)	**DAS**												
Ratoon spray 1 (29 September)	45	Roundup DST	1.5	Shield	inter-row	Diurex	0.5	directed	whole area	Diurex	0.75	directed	whole area
Stooling		Gramoxone	1.2	directed	stool/bed	Gramoxone	1.2	directed	whole area	Gramoxone	1.6	directed	whole area
		Diurex	0.5	Directed	stool/bed	2,4-D Advance 700	1	Directed	whole area	2,4-D Advance 700	1	Directed	whole area
Ratoon spray 2 (1 December)	110	2,4-D Advance 700	1	Directed	canopy from below	2,4-D Advance 700	1		canopy from below	2,4-D Advance 700	1.6		canopy from above
Ratoon 3 (15 September)	**DAS**												
Ratoon spray 1 (20 October)	35	Roundup DST	1.5	Shield	inter-row	Diurex	0.5	directed	whole area	Diurex	0.75	directed	whole area
Stooling		Gramoxone	1.2	directed	stool/bed	Gramoxone	1.2	directed	whole area	Gramoxone	1.6	directed	whole area
		Diurex	0.5	directed	stool/bed								
Ratoon spray 2 (9 December)	85	2,4-D Advance 700	1	Directed	canopy from below	Diurex	0.5	directed	whole area	Diurex	0.75	directed	whole area
OOH						Gramoxone	1.6	directed	whole area	Gramoxone	1.6	directed	whole area
						2,4-D Advance 700	1.6		canopy from above	2,4-D Advance 700	1.6		canopy from above
Ratoon 4 (15 October)	**DAS**												
Ratoon spray 1 (30 October)	15	Roundup DST	1.5	Shield	inter-row	Diurex	0.5	directed	whole area	Diurex	0.75	Directed	whole area
Stooling		Gramoxone	1.2	directed	stool/bed	Gramoxone	1.2	directed	whole area	Gramoxone	1.6	directed	whole area
Ratoon spray 2 (7 December)	60	2,4-D Advance 700	1	Directed	canopy from below	2,4-D Advance 700	1		canopy from below	Diurex	0.75	directed	whole area
OOH										Gramoxone	1.6	directed	whole area
										2,4-D Advance 700	1.6		canopy from above

Mackay: alternative chemicals, legume fallow and low tillage		**A-Class practices**	**AA.FB.SB2.HB.MA.GB**			**B-Class practices**	**AB.FB.SB.HB.MB.GB**			**C-Class practices**	**AC.FB.SB.HC.MC.GB**		
		Product	**AR (kg/ha)**	**Method**	**Placement**	**Product**	**AR (kg/ha)**	**Method**	**Placement**	**Product**	**AR (kg/ha)**	**Method**	**Placement**
Fallow (15 November)	**DAH**	**Legume fallow & Excluding Diuron, Hexazinone, Ametryn & Atrazine**				**Legume fallow & Excluding Diuron, Hexazinone, Ametryn & Atrazine**				**Legume fallow & Excluding Diuron, Hexazinone, Ametryn & Atrazine**			
Cane Spray-out (18 December)	33	Roundup DST	5		canopy from above	Roundup DST	5		canopy from above	Roundup DST	6.9		canopy from above
		2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1.6		canopy from above
Possible post-emergent in legume crop (1 Feb)	76	Sprinnaker	0.14		canopy from above	Sprinnaker	0.14		canopy from above	Sprinnaker	0.14		canopy from above
Legume spray-out (6 April)	120	Roundup DST	3.5		canopy from above	Roundup DST	3.5		canopy from above	Roundup DST	4.5		canopy from above
		Starane Advanced	0.6		canopy from above	Starane Advanced	0.6		canopy from above	Starane Advanced	0.9		canopy from above
Plant (15 May)	**DAS**												
Plant spray 1 (4 June)	20	Soccer	1.5	Directed	whole area	Soccer	1.5	Directed	whole area	Soccer	2	Directed	whole area
Spike		Stomp Xtra	2.25	Directed	whole area	Stomp Xtra	2.25	Directed	whole area	Stomp Xtra	3.4	Directed	whole area
		Gromoxone	1.2	Directed	whole area	Gromoxone	1.2	Directed	whole area	Gramxone	1.6	Directed	whole area
Plant spray 2 (3 August)	80	Roundup DST	1.5	Shield	inter-row	2,4-D Advance 700	1	Directed	whole area	2,4-D Advance 700	1.6	Directed	whole area
Stooling		Gramoxone	1.2	directed	stool/bed	Gramoxone	1.2	Directed	whole area	Gramxone	1.6	Directed	whole area
Plant spray 3 (22 September)	130	Roundup DST	1.5	Shield	inter-row	Balance	0.2	directed	whole area	Balance	0.2	Directed	whole area
OOH		Balance	0.2	directed	stool/bed	Gramoxone	1.2	directed	whole area	Gramoxone	1.6	Directed	whole area
		Gramoxone	1.2	directed	stool/bed	Soccer	1.5	directed	whole area	Soccer	2	Directed	whole area
		Soccer	1.5	directed	stool/bed								
Ratoon 1 (15 July)	**DAS**												
Ratoon spray 1 (1 September)	50	Roundup DST	1.5	Shield	inter-row	Gramoxone	1.2	directed	whole area	Gramoxone	1.6	directed	whole area
Stooling		Gramoxone	1.2	directed	stool/bed	2,4-D Advance 700	1	Directed	whole area	2,4-D Advance 700	1	Directed	whole area
Ratoon spray 2 (10 November)	120	2,4-D Advance 700	1		canopy from below	2,4-D Advance 700	1		canopy from above	Gramoxone	1.6	directed	whole area
OOH										2,4-D Advance 700	1.6		canopy from above
Ratoon 2 (15 August)	**DAS**												
Ratoon spray 1 (20 August)	5					Flame	0.3	directed	whole area	Flame	0.4	directed	whole area
After harvest													
Ratoon spray 2 (29 September)	45	Roundup DST	1.5	Shield	inter-row								
Stooling		Gramoxone	1.2	directed	stool/bed								
		Flame	0.3	Directed	stool/bed								
Ratoon spray 3 (1 December)	110	2,4-D Advance 700	1	Directed	canopy from below	Gramoxone	1.2	directed	whole area	Gramoxone	1.6	directed	whole area
OOH						2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1		canopy from above
Ratoon 3 (15 September)	**DAS**												
Ratoon spray 1 (20 October)	35	Roundup DST	1.5	Shield	inter-row	Gramoxone	1.2	directed	whole area	Gramoxone	1.6	directed	whole area
Stooling		Gramoxone	1.2	directed	stool/bed	2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1	Directed	whole area
Ratoon spray 2 (9 December)	85	2,4-D Advance 700	1	Directed	canopy from below	2,4-D Advance 700	1.6		canopy from above	Gramoxone	1.6	directed	whole area
OOH										Soccer	1	directed	whole area
Ratoon 4 (15 October)	**DAS**												
Ratoon spray 1 (30 October)	15	Roundup DST	1.5	Shield	inter-row	Gramoxone	1.2	directed	whole area	Gramoxone	1.6	directed	whole area
Stooling		Gramoxone	1.2	directed	stool/bed	2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1	Directed	whole area
Ratoon spray 2 (7 December)	60	2,4-D Advance 700	1	Directed	canopy from below	2,4-D Advance 700	1		canopy from below	Gramoxone	1.6	directed	whole area
OOH										Soccer	1	directed	whole area

Mackay: standard chemicals, bare fallow and high tillage		**A-Class practices**	**AA.FC.SB.HB.MA.GC**			**B-Class practices**	**AB.FC.SB.HB.MB.GC**			**C-Class practices**	**AC.FC.SB.HC.MC.GC**		
		Product	**AR (kg/ha)**	**Method**	**Placement**	**Product**	**AR (kg/ha)**	**Method**	**Placement**	**Product**	**AR (kg/ha)**	**Method**	**Placement**
Fallow (15 November)	**DAH**	**Bare fallow & Including Diuron, Hexazinone, Ametryn & Atrazine**				**Bare fallow & Including Diuron, Hexazinone, Ametryn & Atrazine**				**Bare fallow & Including Diuron, Hexazinone, Ametryn & Atrazine**			
Cane Spray-out (18 December)	33	Roundup DST	5		canopy from above	Roundup DST	5		canopy from above	Roundup DST	6.9		canopy from above
		2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1.6		canopy from above
Fallow clean-up spray (6 April)	120	Roundup DST	2.5		canopy from above	Roundup DST	2.5		canopy from above	Roundup DST	4		canopy from above
		2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1.6		canopy from above
Plant (15 May)	**DAS**												
Plant spray 1 (4 June)	20	Atradex	2	Directed	whole area	Atradex	2	Directed	whole area	Atradex	2.5	Directed	whole area
Spike		Stomp Xtra	2.25	Directed	whole area	Stomp Xtra	2.25	Directed	whole area	Stomp Xtra	3.4	Directed	whole area
		Gromoxone	1.2	Directed	whole area	Gromoxone	1.2	Directed	whole area	Gramxone	1.6	Directed	whole area
Plant spray 2 (3 August)	80	Roundup DST	1.5	Shield	inter-row	2,4-D Advance 700	1	Directed	whole area	2,4-D Advance 700	1.6	Directed	whole area
Stooling		Gramoxone	1.2	directed	stool/bed	Gramoxone	1.2	Directed	whole area	Gramxone	1.6	Directed	whole area
Plant spray 3 (22 September)	130	Roundup DST	1.5	Shield	inter-row	Diuron+Hexazinone (VK4)	2.5	directed	whole area	Diuron+Hexazinone (VK4)	3	Directed	whole area
OOH		Diuron+Hexazinone (VK4)	2.5	directed	stool/bed	Gramoxone	1.2	directed	whole area	Gramoxone	1.6	Directed	whole area
		Gramoxone	1.2	directed	stool/bed								
Plant spray 4 OOH (22 September)	130									2,4-D Advance 700	1.6		canopy from above
Ratoon 1 (15 July)	**DAS**												
Ratoon spray 1 (1 September)	50	Roundup DST	1.5	Shield	inter-row	Diurex	0.5	directed	whole area	Diurex	0.75	directed	whole area
Stooling		Gramoxone	1.2	directed	stool/bed	Gramoxone	1.2	directed	whole area	Gramoxone	1.6	directed	whole area
						2,4-D Advance 700	1	Directed	whole area	2,4-D Advance 700	1	Directed	whole area
Ratoon spray 2 (10 November)	120	2,4-D Advance 700	1		canopy from below	2,4-D Advance 700	1		canopy from above	Diurex	0.75	directed	whole area
OOH										Gramoxone	1.6	directed	whole area
										2,4-D Advance 700	1.6		canopy from above
Ratoon 2 (15 August)	**DAS**												
Ratoon spray 1 (29 September)	45	Roundup DST	1.5	Shield	inter-row	Diurex	0.5	directed	whole area	Diurex	0.75	directed	whole area
Stooling		Gramoxone	1.2	directed	stool/bed	Gramoxone	1.2	directed	whole area	Gramoxone	1.6	directed	whole area
		Diurex	0.5	Directed	stool/bed	2,4-D Advance 700	1	Directed	whole area	2,4-D Advance 700	1	Directed	whole area
Ratoon spray 2 (1 December)	110	2,4-D Advance 700	1	Directed	canopy from below	2,4-D Advance 700	1		canopy from below	2,4-D Advance 700	1.6		canopy from above
Ratoon 3 (15 September)	**DAS**												
Ratoon spray 1 (20 October)	35	Roundup DST	1.5	Shield	inter-row	Diurex	0.5	directed	whole area	Diurex	0.75	directed	whole area
Stooling		Gramoxone	1.2	directed	stool/bed	Gramoxone	1.2	directed	whole area	Gramoxone	1.6	directed	whole area
		Diurex	0.5	directed	stool/bed								
Ratoon spray 2 (9 December)	85	2,4-D Advance 700	1	Directed	canopy from below	Diurex	0.5	directed	whole area	Diurex	0.75	directed	whole area
OOH						Gramoxone	1.6	directed	whole area	Gramoxone	1.6	directed	whole area
						2,4-D Advance 700	1.6		canopy from above	2,4-D Advance 700	1.6		canopy from above
Ratoon 4 (15 October)	**DAS**												
Ratoon spray 1 (30 October)	15	Roundup DST	1.5	Shield	inter-row	Diurex	0.5	directed	whole area	Diurex	0.75	Directed	whole area
Stooling		Gramoxone	1.2	directed	stool/bed	Gramoxone	1.2	directed	whole area	Gramoxone	1.6	directed	whole area
Ratoon spray 2 (7 December)	60	2,4-D Advance 700	1	Directed	canopy from below	2,4-D Advance 700	1		canopy from below	Diurex	0.75	directed	whole area
OOH										Gramoxone	1.6	directed	whole area
										2,4-D Advance 700	1.6		canopy from above

Mackay: alternative chemicals, bare fallow and high tillage		**A-Class practices**	**AA.FC.SB2.HB.MA.GC**			**B-Class practices**	**AB.FC.SB2.HB.MB.GC**			**C-Class practices**	**AC.FC.SB2.HC.MC.GC**		
		Product	**AR (kg/ha)**	**Method**	**Placement**	**Product**	**AR (kg/ha)**	**Method**	**Placement**	**Product**	**AR (kg/ha)**	**Method**	**Placement**
Fallow (15 November)	**DAH**	**Bare fallow & Excluding Diuron, Hexazinone, Ametryn & Atrazine**				**Bare fallow & Excluding Diuron, Hexazinone, Ametryn & Atrazine**				**Bare fallow & Excluding Diuron, Hexazinone, Ametryn & Atrazine**			
Cane Spray-out (18 December)	33	Roundup DST	5		canopy from above	Roundup DST	5		canopy from above	Roundup DST	6.9		canopy from above
		2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1.6		canopy from above
Fallow clean-up spray (6 April)	120	Roundup DST	3.5		canopy from above	Roundup DST	3.5		canopy from above	Roundup DST	4.5		canopy from above
		2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1.6		canopy from above
Plant (15 May)	**DAS**												
Plant spray 1 (4 June)	20	Soccer	1.5	Directed	whole area	Soccer	1.5	Directed	whole area	Soccer	2	Directed	whole area
Spike		Stomp Xtra	2.25	Directed	whole area	Stomp Xtra	2.25	Directed	whole area	Stomp Xtra	3.4	Directed	whole area
		Gromoxone	1.2	Directed	whole area	Gromoxone	1.2	Directed	whole area	Gramxone	1.6	Directed	whole area
Plant spray 2 (3 August)	80	Roundup DST	1.5	Shield	inter-row	2,4-D Advance 700	1	Directed	whole area	2,4-D Advance 700	1.6	Directed	whole area
Stooling		Gramoxone	1.2	directed	stool/bed	Gramoxone	1.2	Directed	whole area	Gramxone	1.6	Directed	whole area
Plant spray 3 (22 September)	130	Roundup DST	1.5	Shield	inter-row	Balance	0.2	directed	whole area	Balance	0.2	Directed	whole area
OOH		Balance	0.2	directed	stool/bed	Gramoxone	1.2	directed	whole area	Gramoxone	1.6	Directed	whole area
		Gramoxone	1.2	directed	stool/bed	Soccer	1.5	directed	whole area	Soccer	2	Directed	whole area
		Soccer	1.5	directed	stool/bed								
Ratoon 1 (15 July)	**DAS**												
Ratoon spray 1 (1 September)	50	Roundup DST	1.5	Shield	inter-row	Gramoxone	1.2	directed	whole area	Gramoxone	1.6	directed	whole area
Stooling		Gramoxone	1.2	directed	stool/bed	2,4-D Advance 700	1	Directed	whole area	2,4-D Advance 700	1	Directed	whole area
Ratoon spray 2 (10 November)	120	2,4-D Advance 700	1		canopy from below	2,4-D Advance 700	1		canopy from above	Gramoxone	1.6	directed	whole area
OOH										2,4-D Advance 700	1.6		canopy from above
Ratoon 2 (15 August)	**DAS**												
Ratoon spray 1 (20 August)	5					Flame	0.3	directed	whole area	Flame	0.4	directed	whole area
After harvest													
Ratoon spray 2 (29 September)	45	Roundup DST	1.5	Shield	inter-row								
Stooling		Gramoxone	1.2	directed	stool/bed								
		Flame	0.3	Directed	stool/bed								
Ratoon spray 3 (1 December)	110	2,4-D Advance 700	1	Directed	canopy from below	Gramoxone	1.2	directed	whole area	Gramoxone	1.6	directed	whole area
OOH						2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1		canopy from above
Ratoon 3 (15 September)	**DAS**												
Ratoon spray 1 (20 October)	35	Roundup DST	1.5	Shield	inter-row	Gramoxone	1.2	directed	whole area	Gramoxone	1.6	directed	whole area
Stooling		Gramoxone	1.2	directed	stool/bed	2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1	Directed	whole area
Ratoon spray 2 (9 December)	85	2,4-D Advance 700	1	Directed	canopy from below	2,4-D Advance 700	1.6		canopy from above	Gramoxone	1.6	directed	whole area
OOH										Soccer	1	directed	whole area
Ratoon 4 (15 October)	**DAS**												
Ratoon spray 1 (30 October)	15	Roundup DST	1.5	Shield	inter-row	Gramoxone	1.2	directed	whole area	Gramoxone	1.6	directed	whole area
Stooling		Gramoxone	1.2	directed	stool/bed	2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1	Directed	whole area
Ratoon spray 2 (7 December)	60	2,4-D Advance 700	1	Directed	canopy from below	2,4-D Advance 700	1		canopy from below	Gramoxone	1.6	directed	whole area
OOH										Soccer	1	directed	whole area

Burdekin standard chemicals, legume fallow and low tillage		**A-Class practices**	**AA.FB.SB.HB.MA.GB**			**B-Class practices**	**AB.FB.SB.HB.MB.GB**			**C-Class practices**	**AC.FB.SB.HC.MC.GB**		
		Product	**AR (kg/ha)**	**Method**	**Placement**	**Product**	**AR (kg/ha)**	**Method**	**Placement**	**Product**	**AR (kg/ha)**	**Method**	**Placement**
Fallow (15 October)	**DAH**	**Legume fallow & Including Diuron, Hexazinone, Ametryn & Atrazine**				**Legume fallow & Including Diuron, Hexazinone, Ametryn & Atrazine**				**Legume fallow & Including Diuron, Hexazinone, Ametryn & Atrazine**			
Cane knock out (15 November)	30	Roundup DST	5		canopy from above	Roundup DST	5		canopy from above	Roundup DST	6.9		canopy from above
		2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1.6		canopy from above
Plant legume (15 December)	60	Roundup DST	1.5		canopy from above	Roundup DST	1.5		canopy from above	Roundup DST	2.3		canopy from above
		Dual Gold	1.5		canopy from above	Dual Gold	1.5		canopy from above	Dual Gold	1.8		canopy from above
Legume post-emergent (15th January)	90	Blazer	1.0		canopy from above	Blazer	1.0		canopy from above				
Legume spray-out (1 May)	160	Roundup DST	3.5		canopy from above	Roundup DST	3.5		canopy from above	Roundup DST	4.5		canopy from above
		Starane Advanced	0.6		canopy from above	Starane Advanced	0.6		canopy from above	Starane Advanced	0.9		canopy from above
Plant (15 May)	**DAS**												
Plant spray 1 (29 May)	14	Paraquat	1.2	Directed	Whole area	Diurex	0.5	directed	whole area	Diurex	0.5	directed	whole area
Spike		2,4-D Advance 700	1	Directed	Whole area	Paraquat	1.2	directed	whole area	Paraquat	1.6	directed	whole area
						2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1.6	directed	whole area
Plant spray 2 (9 July)	90	Paraquat	1.2	directed	stool/bed	Diurex	0.5	directed	whole area	Diurex	0.5	directed	whole area
Stooling-OOH		2,4-D Advance 700	1	directed	stool/bed	Paraquat	1.2	directed	whole area	Paraquat	1.6	directed	whole area
		Diurex	0.5	directed	stool/bed	2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1.6	directed	whole area
		Roundup DST	1	shielded sprayer	inter-row								
Plant spray 3 (22 October)	160					Paraquat	1.2	directed	whole area	Diurex	0.5	directed	whole area
OOH						2,4-D Advance 700	1	directed	whole area	Atradex	2	directed	whole area
										Paraquat	1.6	directed	whole area
										2,4-D Advance 700	1.6	directed	whole area
Ratoon 1 (15 July)	**DAS**												
Ratoon spray 1 (5 August)	14	Paraquat	1.2	directed	whole area	Diurex	0.5	directed	whole area	Diurex	0.5	directed	whole area
		2,4-D Advance 700	1	directed	whole area	Paraquat	1.2	directed	whole area	Paraquat	1.6	directed	whole area
						2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1.6	directed	whole area
Ratoon spray 3 (13 October)	90	Paraquat	1.2	directed	stool/bed	Diurex	0.5	directed	whole area	Diurex	1.2	directed	whole area
OOH		2,4-D Advance 700	1	directed	stool/bed	Paraquat	1.2	directed	whole area	Paraquat	1.6	directed	whole area
		Roundup DST	1	shielded sprayer	inter-row	2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1.6		canopy from above
Ratoon 2 (15 Aug)	**DAS**												
Ratoon spray 1 (25 August)	14	Paraquat	1.2	directed	whole area	Diurex	0.5	directed	whole area	Diurex	0.5	directed	whole area
		2,4-D Advance 700	1	directed	whole area	Paraquat	1.2	directed	whole area	Paraquat	1.6	directed	whole area
						2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1.6	directed	whole area
Ratoon spray 3 (14 October)	90	Paraquat	1.2	directed	stool/bed	Diurex	0.5	directed	whole area	Diurex	1.2	directed	whole area
OOH		2,4-D Advance 700	1	directed	stool/bed	Paraquat	1.2	directed	whole area	Paraquat	1.6	directed	whole area
		Roundup DST	1	shielded sprayer	inter-row	2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1.6		canopy from above
Ratoon 3 (15 Sept)	**DAS**												
Ratoon spray 1 (25 Sept)	14	Paraquat	1.2	directed	stool/bed	Diurex	0.5	directed	whole area	Diurex	0.5	directed	whole area
		2,4-D Advance 700	1	directed	stool/bed	Paraquat	1.2	directed	whole area	Paraquat	1.6	directed	whole area
						2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1.6	directed	whole area
Ratoon spray 3 (14 November)	60	Paraquat	1.2	directed	stool/bed	Diurex	0.5	directed	whole area	Diurex	1.2	directed	whole area
OOH		2,4-D Advance 700	1	directed	stool/bed	Paraquat	1.2	directed	whole area	Paraquat	1.6	directed	whole area
		Roundup DST	1	shielded sprayer	inter-row	2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1.6		canopy from above

Burdekin: alternative chemicals, legume fallow and low tillage		A-Class practices	AA.FB.SB2.HB.MA.GB			B-Class practices	AB.FB.SB.HB.MB.GB			C-Class practices	AC.FB.SB.HC.MC.GB		
		Product	AR (kg/ha)	Method	Placement	Product	AR (kg/ha)	Method	Placement	Product	AR (kg/ha)	Method	Placement
Fallow (15 October)	**DAH**	**Legume fallow & Excluding Diuron, Hexazinone, Ametryn & Atrazine**				**Legume fallow & Excluding Diuron, Hexazinone, Ametryn & Atrazir**				**Legume fallow & Excluding Diuron, Hexazinone, Ametryn & Atrazine**			
Cane knock out (15 November)	30	Roundup DST	5		canopy from above	Roundup DST	5		canopy from above	Roundup DST	6.9		canopy from above
		2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1.6		canopy from above
Plant legume (15 December)	60	Roundup DST	1.5		canopy from above	Roundup DST	1.5		canopy from above	Roundup DST	2.3		canopy from above
		Dual Gold	1.5		canopy from above	Dual Gold	1.5		canopy from above	Dual Gold	1.8		canopy from above
Legume post-emergent (15th January)	90	Blazer	1.5		canopy from above	Blazer	1.5		canopy from above				
Legume spray-out (1 May)	160	Roundup DST	3.5		canopy from above	Roundup DST	3.5		canopy from above	Roundup DST	4.5		canopy from above
		Starane Advanced	0.6		canopy from above	Starane Advanced	0.6		canopy from above	Starane Advanced	0.9		canopy from above
Plant (15 May)	**DAS**												
Plant spray 1 (29 May)	14	Paraquat	1.2	Directed	Whole area	Soccer	0.8	directed	whole area	Soccer	1	directed	whole area
Spike		2,4-D Advance 700	1	Directed	Whole area	Paraquat	1.2	directed	whole area	Paraquat	1.6	directed	whole area
						2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1.6	directed	whole area
Plant spray 2 (9 July)	90	Paraquat	1.2	directed	stool/bed	Paraquat	1.2	directed	whole area	Paraquat	1.6	directed	whole area
Stooling-OOH		2,4-D Advance 700	1	directed	stool/bed	2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1.6	directed	whole area
		Roundup DST	1	shielded sprayer	inter-row								
Plant spray 3 (22 October)	160					Paraquat	1.2	directed	whole area	Paraquat	1.6	directed	whole area
OOH						2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1.6	directed	whole area
						Soccer	0.8	directed	whole area	Soccer	1	directed	whole area
Ratoon 1 (15 July)	**DAS**												
Ratoon spray 1 (5 August)	14	Paraquat	1.2	directed	whole area	Paraquat	1.2	directed	whole area	Paraquat	1.6	directed	whole area
		2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1.6	directed	whole area
Ratoon spray 3 (13 October)	90	Paraquat	1.2	directed	stool/bed	Soccer	1.5	directed	whole area	Soccer	2	directed	whole area
OOH		2,4-D Advance 700	1	directed	stool/bed	Paraquat	1.2	directed	whole area	Paraquat	1.6	directed	whole area
		Roundup DST	1	shielded sprayer	inter-row	2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1.6		canopy from above
Ratoon 2 (15 Aug)	DAS												
Ratoon spray 1 (25 August)	14	Paraquat	1.2	directed	whole area	Paraquat	1.2	directed	whole area	Paraquat	1.6	directed	whole area
		2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1.6	directed	whole area
Ratoon spray 3 (14 October)	90	Paraquat	1.2	directed	stool/bed	Soccer	1.5	directed	whole area	Soccer	2	directed	whole area
OOH		2,4-D Advance 700	1	directed	stool/bed	Paraquat	1.2	directed	whole area	Paraquat	1.6	directed	whole area
		Roundup DST	1	shielded sprayer	inter-row	2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1.6		canopy from above
Ratoon 3 (15 Sept)	DAS												
Ratoon spray 1 (25 Sept)	14	Paraquat	1.2	directed	stool/bed	Paraquat	1.2	directed	whole area	Paraquat	1.6	directed	whole area
		2,4-D Advance 700	1	directed	stool/bed	2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1.6	directed	whole area
Ratoon spray 3 (14 November)	60	Paraquat	1.2	directed	stool/bed	Soccer	1.5	directed	whole area	Soccer	2	directed	whole area
OOH		2,4-D Advance 700	1	directed	stool/bed	Paraquat	1.2	directed	whole area	Paraquat	1.6	directed	whole area
		Roundup DST	1	shielded sprayer	inter-row	2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1.6		canopy from above

Burdekin: standard chemicals, bare fallow and high tillage		**A-Class practices**	**AA.FC.SB.HB.MA.GC**			**B-Class practices**	**AB.FC.SB.HB.MB.GC**			**C-Class practices**	**AC.FC.SB.HC.MC.GC**		
		Product	**AR (kg/ha)**	**Method**	**Placement**	**Product**	**AR (kg/ha)**	**Method**	**Placement**	**Product**	**AR (kg/ha)**	**Method**	**Placement**
Fallow (15 October)	DAH	**Bare fallow & Excluding Diuron, Hexazinone, Ametryn & Atrazine**				**Bare fallow & Excluding Diuron, Hexazinone, Ametryn & Atrazine**				**Bare fallow & Excluding Diuron, Hexazinone, Ametryn & Atrazine**			
Cane knock out (15 November)	30	Roundup DST	5		canopy from above	Roundup DST	5		canopy from above	Roundup DST	6.9		canopy from above
		2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1.6		canopy from above
Fallow clean-up spray (1 May)	160	Roundup DST	2.5		canopy from above	Roundup DST	2.5		canopy from above	Roundup DST	4		canopy from above
		2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1.6		canopy from above
Plant (15 May)	**DAS**												
Plant spray 1 (29 May)	14	Paraquat	1.2	Directed	Whole area	Diurex	0.5	directed	whole area	Diurex	0.5	directed	whole area
Spike		2,4-D Advance 700	1	Directed	Whole area	Paraquat	1.2	directed	whole area	Paraquat	1.6	directed	whole area
						2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1.6	directed	whole area
Plant spray 2 (9 July)	90	Paraquat	1.2	directed	stool/bed	Diurex	0.5	directed	whole area	Diurex	0.5	directed	whole area
Stooling-OOH		2,4-D Advance 700	1	directed	stool/bed	Paraquat	1.2	directed	whole area	Paraquat	1.6	directed	whole area
		Diurex	0.5	directed	stool/bed	2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1.6	directed	whole area
		Roundup DST	1	shielded sprayer	inter-row								
Plant spray 3 (22 October)	160					Paraquat	1.2	directed	whole area	Diurex	0.5	directed	whole area
OOH						2,4-D Advance 700	1	directed	whole area	Atradex	2	directed	whole area
										Paraquat	1.6	directed	whole area
										2,4-D Advance 700	1.6	directed	whole area
Ratoon 1 (15 July)	**DAS**												
Ratoon spray 1 (5 August)	14	Paraquat	1.2	directed	whole area	Diurex	0.5	directed	whole area	Diurex	0.5	directed	whole area
		2,4-D Advance 700	1	directed	whole area	Paraquat	1.2	directed	whole area	Paraquat	1.6	directed	whole area
						2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1.6	directed	whole area
Ratoon spray 3 (13 October)	90	Paraquat	1.2	directed	stool/bed	Diurex	0.5	directed	whole area	Diurex	1.2	directed	whole area
OOH		2,4-D Advance 700	1	directed	stool/bed	Paraquat	1.2	directed	whole area	Paraquat	1.6	directed	whole area
		Roundup DST	1	shielded sprayer	inter-row	2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1.6		canopy from above
Ratoon 2 (15 Aug)	**DAS**												
Ratoon spray 1 (25 August)	14	Paraquat	1.2	directed	whole area	Diurex	0.5	directed	whole area	Diurex	0.5	directed	whole area
		2,4-D Advance 700	1	directed	whole area	Paraquat	1.2	directed	whole area	Paraquat	1.6	directed	whole area
						2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1.6	directed	whole area
Ratoon spray 3 (14 October)	90	Paraquat	1.2	directed	stool/bed	Diurex	0.5	directed	whole area	Diurex	1.2	directed	whole area
OOH		2,4-D Advance 700	1	directed	stool/bed	Paraquat	1.2	directed	whole area	Paraquat	1.6	directed	whole area
		Roundup DST	1	shielded sprayer	inter-row	2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1.6		canopy from above
Ratoon 3 (15 Sept)	**DAS**												
Ratoon spray 1 (25 Sept)	14	Paraquat	1.2	directed	stool/bed	Diurex	0.5	directed	whole area	Diurex	0.5	directed	whole area
		2,4-D Advance 700	1	directed	stool/bed	Paraquat	1.2	directed	whole area	Paraquat	1.6	directed	whole area
						2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1.6	directed	whole area
Ratoon spray 3 (14 November)	60	Paraquat	1.2	directed	stool/bed	Diurex	0.5	directed	whole area	Diurex	1.2	directed	whole area
OOH		2,4-D Advance 700	1	directed	stool/bed	Paraquat	1.2	directed	whole area	Paraquat	1.6	directed	whole area
		Roundup DST	1	shielded sprayer	inter-row	2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1.6		canopy from above

Burdekin: alternative chemicals, bare fallow and high tillage		A-Class practices	AA.FC.SB2.HB.MA.GC			B-Class practices	AB.FC.SB2.HB.MB.GC			C-Class practices	AC.FC.SB2.HC.MC.GC		
		Product	AR (kg/ha)	Method	Placement	Product	AR (kg/ha)	Method	Placement	Product	AR (kg/ha)	Method	Placement
Fallow (15 October)	**DAH**	**Bare fallow & Excluding Diuron, Hexazinone, Ametryn & Atrazine**				**Bare fallow & Excluding Diuron, Hexazinone, Ametryn & Atrazine**				**Bare fallow & Excluding Diuron, Hexazinone, Ametryn & Atrazine**			
Cane knock out (15 November)	30	Roundup DST	5		canopy from above	Roundup DST	5		canopy from above	Roundup DST	6.9		canopy from above
		2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1.6		canopy from above
Fallow clean-up spray (1 May)	160	Roundup DST	2.5		canopy from above	Roundup DST	2.5		canopy from above	Roundup DST	4		canopy from above
		2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1.6		canopy from above
Plant (15 May)	**DAS**												
Plant spray 1 (29 May)	14	Paraquat	1.2	Directed	Whole area	Soccer	0.8	directed	whole area	Soccer	1	directed	whole area
Spike		2,4-D Advance 700	1	Directed	Whole area	Paraquat	1.2	directed	whole area	Paraquat	1.6	directed	whole area
						2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1.6	directed	whole area
Plant spray 2 (9 July)	90	Paraquat	1.2	directed	stool/bed	Paraquat	1.2	directed	whole area	Paraquat	1.6	directed	whole area
Stooling-OOH		2,4-D Advance 700	1	directed	stool/bed	2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1.6	directed	whole area
		Roundup DST	1	ielded spray	inter-row								
Plant spray 3 (22 October)	160					Paraquat	1.2	directed	whole area	Paraquat	1.6	directed	whole area
OOH						2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1.6	directed	whole area
						Soccer	0.8	directed	whole area	Soccer	1	directed	whole area
Ratoon 1 (15 July)	**DAS**												
Ratoon spray 1 (5 August)	14	Paraquat	1.2	directed	whole area	Paraquat	1.2	directed	whole area	Paraquat	1.6	directed	whole area
		2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1.6	directed	whole area
Ratoon spray 3 (13 October)	90	Paraquat	1.2	directed	stool/bed	Soccer	1.5	directed	whole area	Soccer	2	directed	whole area
OOH		2,4-D Advance 700	1	directed	stool/bed	Paraquat	1.2	directed	whole area	Paraquat	1.6	directed	whole area
		Roundup DST	1	shielded spr	inter-row	2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1.6		canopy from above
Ratoon 2 (15 Aug)	**DAS**												
Ratoon spray 1 (25 August)	14	Paraquat	1.2	directed	whole area	Paraquat	1.2	directed	whole area	Paraquat	1.6	directed	whole area
		2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1.6	directed	whole area
Ratoon spray 3 (14 October)	90	Paraquat	1.2	directed	stool/bed	Soccer	1.5	directed	whole area	Soccer	2	directed	whole area
OOH		2,4-D Advance 700	1	directed	stool/bed	Paraquat	1.2	directed	whole area	Paraquat	1.6	directed	whole area
		Roundup DST	1	shielded spr	inter-row	2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1.6		canopy from above
Ratoon 3 (15 Sept)	**DAS**												
Ratoon spray 1 (25 Sept)	14	Paraquat	1.2	directed	stool/bed	Paraquat	1.2	directed	whole area	Paraquat	1.6	directed	whole area
		2,4-D Advance 700	1	directed	stool/bed	2,4-D Advance 700	1	directed	whole area	2,4-D Advance 700	1.6	directed	whole area
Ratoon spray 3 (14 November)	60	Paraquat	1.2	directed	stool/bed	Soccer	1.5	directed	whole area	Soccer	2	directed	whole area
OOH		2,4-D Advance 700	1	directed	stool/bed	Paraquat	1.2	directed	whole area	Paraquat	1.6	directed	whole area
		Roundup DST	1	shielded spr	inter-row	2,4-D Advance 700	1		canopy from above	2,4-D Advance 700	1.6		canopy from above

Appendix 2: Results for AEB calculations

Table 32: AEB results for Tully

Changes to management practice setting	Constant management practice setting	Coding	Tully (50ha) ($/ha/yr)	Tully (150ha) ($/ha/yr)	Tully (250ha) ($/ha/yr)
C-Class to B-Class (herbicide rates, strategic use & method)	Standard chemicals (SB) with bare fallow (FC) and high tillage (GC)	AC.FC.SB.HC.MC.GC **to** AB.FC.SB.HB.MB.GC	30.93	34.29	31.66
C-Class to A-Class (herbicide rates, strategic use & method)	Standard chemicals (SB) with bare fallow (FC) and high tillage (GC)	AC.FC.SB.HC.MC.GC **to** AA.FC.SB.HB.MA.GC	21.89	42.87	43.89
B-Class to A-Class (herbicide rates, strategic use & method)	Standard chemicals (SB) with bare fallow (FC) and high tillage (GC)	AB.FC.SB.HB.MB.GC **to** AA.FC.SB.HB.MA.GC	-12.79	7.33	11.11
C-Class to B-Class (herbicide rates, strategic use & method)	Standard chemicals (SB) with legume fallow (FB) and low tillage (GB)	AC.FB.SB.HC.MC.GB **to** AB.FB.SB.HB.MB.GB	30.93	34.29	31.66
C-Class to A-Class (herbicide rates, strategic use & method)	Standard chemicals (SB) with legume fallow (FB) and low tillage (GB)	AC.FB.SB.HC.MC.GB **to** AA.FB.SB.HB.MA.GB	22.05	43.03	44.05
B-Class to A-Class (herbicide rates, strategic use & method)	Standard chemicals (SB) with legume fallow (FB) and low tillage (GB)	AB.FB.SB.HB.MB.GB **to** AA.FB.SB.HB.MA.GB	-12.62	7.50	11.27
C-Class to B-Class (herbicide rates, strategic use & method)	Alternative chemicals (SB2) with bare fallow (FC) and high tillage (GC)	AC.FC.SB2.HC.MC.GC **to** AB.FC.SB2.HB.MB.GC	82.06	85.60	83.49
C-Class to A-Class (herbicide rates, strategic use & method)	Alternative chemicals (SB2) with bare fallow (FC) and high tillage (GC)	AC.FC.SB2.HC.MC.GC **to** AA.FC.SB2.HB.MA.GC	85.74	107.07	109.13
B-Class to A-Class (herbicide rates, strategic use & method)	Alternative chemicals (SB2) with bare fallow (FC) and high tillage (GC)	AB.FC.SB2.HB.MB.GC **to** AA.FC.SB2.HB.MA.GC	-0.08	20.22	24.51
C-Class to B-Class (herbicide rates, strategic use & method)	Alternative chemicals (SB2) with legume fallow (FB) and low tillage (GB)	AC.FB.SB2.HC.MC.GB **to** AB.FB.SB2.HB.MB.GB	81.01	84.54	82.43
C-Class to A-Class (herbicide rates, strategic use & method)	Alternative chemicals (SB2) with legume fallow (FB) and low tillage (GB)	AC.FB.SB2.HC.MC.GB **to** AA.FB.SB2.HB.MA.GB	85.78	107.11	109.17
B-Class to A-Class (herbicide rates, strategic use & method)	Alternative chemicals (SB2) with legume fallow (FB) and low tillage (GB)	AB.FB.SB2.HB.MB.GB **to** AA.FB.SB2.HB.MA.GB	1.03	21.32	25.61
Standard chemicals to alternative chemicals	C-Class herbicide practices (AC.HC.MC) with bare fallow (FC) and high tillage (GC)	AC.FC.SB.HC.MC.GC **to** AC.FC.SB2.HC.MC.GC	-73.67	-74.19	-75.75
Standard chemicals to alternative chemicals	B-Class herbicide practices (AB.HB.MB) with bare fallow (FC) and high tillage (GC)	AB.FC.SB.HB.MB.GC **to** AB.FC.SB2.HB.MB.GC	-22.53	-22.88	-23.92
Standard chemicals to alternative chemicals	A-Class herbicide practices (AA.HB.MA) with bare fallow (FC) and high tillage (GC)	AA.FC.SB.HB.MA.GC **to** AA.FC.SB2.HB.MA.GC	-9.82	-9.99	-10.51
Standard chemicals to alternative chemicals	C-Class herbicide practices (AC.HC.MC) with legume fallow (FB) and low tillage (GB)	AC.FB.SB.HC.MC.GB **to** AC.FB.SB2.HC.MC.GB	-72.61	-73.13	-74.69
Standard chemicals to alternative chemicals	B-Class herbicide practices (AB.HB.MB) with legume fallow (FB) and low tillage (GB)	AB.FB.SB.HB.MB.GB **to** AB.FB.SB2.HB.MB.GB	-22.53	-22.88	-23.92
Standard chemicals to alternative chemicals	A-Class herbicide practices (AA.HB.MA) with legume fallow (FB) and low tillage (GB)	AA.FB.SB.HB.MA.GB **to** AA.FB.SB2.HB.MA.GB	-8.88	-9.06	-9.58
Bare fallow – high tillage to legume fallow – low tillage	C-Class herbicide practices (AC.HC.MC) with standard chemicals (SB)	AC.FC.SB.HC.MC.GC **to** AC.FB.SB.HC.MC.GB	-22.92	37.06	26.37
Bare fallow – high tillage to legume fallow – low tillage	B-Class herbicide practices (AB.HB.MB) with standard chemicals (SB)	AB.FC.SB.HB.MB.GC **to** AB.FB.SB.HB.MB.GB	-22.92	37.06	26.37
Bare fallow – high tillage to legume fallow – low tillage	A-Class herbicide practices (AA.HB.MA) with standard chemicals (SB)	AA.FC.SB.HB.MA.GC **to** AA.FB.SB.HB.MA.GB	-22.76	37.22	26.53
Bare fallow – high tillage to legume fallow – low tillage	C-Class herbicide practices (AC.HC.MC) with alternative chemicals (SB2)	AC.FC.SB2.HC.MC.GC **to** AC.FB.SB2.HC.MC.GB	-21.86	38.12	27.43
Bare fallow – high tillage to legume fallow – low tillage	B-Class herbicide practices (AB.HB.MB) with alternative chemicals (SB2)	AB.FC.SB2.HB.MB.GC **to** AB.FB.SB2.HB.MB.GB	-22.92	37.06	26.37
Bare fallow – high tillage to legume fallow – low tillage	A-Class herbicide practices (AA.HB.MA) with alternative chemicals (SB2)	AA.FC.SB2.HB.MA.GC **to** AA.FB.SB2.HB.MA.GB	-21.82	38.16	27.47

Table 33: AEB results for Mackay

Changes to management practice setting	Constant management practice setting	Coding	Mackay (50ha) ($/ha/yr)	Mackay (150ha) ($/ha/yr)	Mackay (250ha) ($/ha/yr)
C-Class to B-Class (herbicide rates, strategic use & method)	Standard chemicals (SB) with bare fallow (FC) and high tillage (GC)	AC.FC.SB.HC.MC.GC **to** AB.FC.SB.HB.MB.GC	19.57	23.43	21.82
C-Class to A-Class (herbicide rates, strategic use & method)	Standard chemicals (SB) with bare fallow (FC) and high tillage (GC)	AC.FC.SB.HC.MC.GC **to** AA.FC.SB.HB.MA.GC	-0.91	21.97	28.37
B-Class to A-Class (herbicide rates, strategic use & method)	Standard chemicals (SB) with bare fallow (FC) and high tillage (GC)	AB.FC.SB.HB.MB.GC **to** AA.FC.SB.HB.MA.GC	-24.23	-2.71	5.42
C-Class to B-Class (herbicide rates, strategic use & method)	Standard chemicals (SB) with legume fallow (FB) and low tillage (GB)	AC.FB.SB.HC.MC.GB **to** AB.FB.SB.HB.MB.GB	19.74	23.57	21.98
C-Class to A-Class (herbicide rates, strategic use & method)	Standard chemicals (SB) with legume fallow (FB) and low tillage (GB)	AC.FB.SB.HC.MC.GB **to** AA.FB.SB.HB.MA.GB	-0.05	23.14	29.30
B-Class to A-Class (herbicide rates, strategic use & method)	Standard chemicals (SB) with legume fallow (FB) and low tillage (GB)	AB.FB.SB.HB.MB.GB **to** AA.FB.SB.HB.MA.GB	-23.53	-1.68	6.19
C-Class to B-Class (herbicide rates, strategic use & method)	Alternative chemicals (SB2) with bare fallow (FC) and high tillage (GC)	AC.FC.SB2.HC.MC.GC **to** AB.FC.SB2.HB.MB.GC	21.53	25.39	23.78
C-Class to A-Class (herbicide rates, strategic use & method)	Alternative chemicals (SB2) with bare fallow (FC) and high tillage (GC)	AC.FC.SB2.HC.MC.GC **to** AA.FC.SB2.HB.MA.GC	7.18	30.08	36.48
B-Class to A-Class (herbicide rates, strategic use & method)	Alternative chemicals (SB2) with bare fallow (FC) and high tillage (GC)	AB.FC.SB2.HB.MB.GC **to** AA.FC.SB2.HB.MA.GC	-18.10	3.45	11.58
C-Class to B-Class (herbicide rates, strategic use & method)	Alternative chemicals (SB2) with legume fallow (FB) and low tillage (GB)	AC.FB.SB2.HC.MC.GB **to** AB.FB.SB2.HB.MB.GB	21.70	25.53	23.94
C-Class to A-Class (herbicide rates, strategic use & method)	Alternative chemicals (SB2) with legume fallow (FB) and low tillage (GB)	AC.FB.SB2.HC.MC.GB **to** AA.FB.SB2.HB.MA.GB	8.06	31.25	37.41
B-Class to A-Class (herbicide rates, strategic use & method)	Alternative chemicals (SB2) with legume fallow (FB) and low tillage (GB)	AB.FB.SB2.HB.MB.GB **to** AA.FB.SB2.HB.MA.GB	-17.38	4.47	12.34
Standard chemicals to alternative chemicals	C-Class herbicide practices (AC.HC.MC) with bare fallow (FC) and high tillage (GC)	AC.FC.SB.HC.MC.GC **to** AC.FC.SB2.HC.MC.GC	-18.53	-18.53	-18.53
Standard chemicals to alternative chemicals	B-Class herbicide practices (AB.HB.MB) with bare fallow (FC) and high tillage (GC)	AB.FC.SB.HB.MB.GC **to** AB.FC.SB2.HB.MB.GC	-16.58	-16.57	-16.57
Standard chemicals to alternative chemicals	A-Class herbicide practices (AA.HB.MA) with bare fallow (FC) and high tillage (GC)	AA.FC.SB.HB.MA.GC **to** AA.FC.SB2.HB.MA.GC	-10.44	-10.42	-10.42
Standard chemicals to alternative chemicals	C-Class herbicide practices (AC.HC.MC) with legume fallow (FB) and low tillage (GB)	AC.FB.SB.HC.MC.GB **to** AC.FB.SB2.HC.MC.GB	-18.53	-18.53	-18.53
Standard chemicals to alternative chemicals	B-Class herbicide practices (AB.HB.MB) with legume fallow (FB) and low tillage (GB)	AB.FB.SB.HB.MB.GB **to** AB.FB.SB2.HB.MB.GB	-16.57	-16.57	-16.57
Standard chemicals to alternative chemicals	A-Class herbicide practices (AA.HB.MA) with legume fallow (FB) and low tillage (GB)	AA.FB.SB.HB.MA.GB **to** AA.FB.SB2.HB.MA.GB	-10.42	-10.42	-10.42
Bare fallow – high tillage to legume fallow – low tillage	C-Class herbicide practices (AC.HC.MC) with standard chemicals (SB)	AC.FC.SB.HC.MC.GC **to** AC.FB.SB.HC.MC.GB	-86.70	-23.41	-29.79
Bare fallow – high tillage to legume fallow – low tillage	B-Class herbicide practices (AB.HB.MB) with standard chemicals (SB)	AB.FC.SB.HB.MB.GC **to** AB.FB.SB.HB.MB.GB	-86.54	-23.26	-29.63
Bare fallow – high tillage to legume fallow – low tillage	A-Class herbicide practices (AA.HB.MA) with standard chemicals (SB)	AA.FC.SB.HB.MA.GC **to** AA.FB.SB.HB.MA.GB	-85.84	-22.24	-28.86
Bare fallow – high tillage to legume fallow – low tillage	C-Class herbicide practices (AC.HC.MC) with alternative chemicals (SB2)	AC.FC.SB2.HC.MC.GC **to** AC.FB.SB2.HC.MC.GB	-86.70	-23.41	-29.79
Bare fallow – high tillage to legume fallow – low tillage	B-Class herbicide practices (AB.HB.MB) with alternative chemicals (SB2)	AB.FC.SB2.HB.MB.GC **to** AB.FB.SB2.HB.MB.GB	-86.53	-23.26	-29.63
Bare fallow – high tillage to legume fallow – low tillage	A-Class herbicide practices (AA.HB.MA) with alternative chemicals (SB2)	AA.FC.SB2.HB.MA.GC **to** AA.FB.SB2.HB.MA.GB	-85.81	-22.24	-28.86

Table 34: AEB results for BDT Delta

Changes to management practice setting	Constant management practice setting	Coding	Delta (50ha) ($/ha/yr)	Delta (150ha) ($/ha/yr)	Delta (250ha) ($/ha/yr)
C-Class to B-Class (herbicide rates, strategic use & method)	Standard chemicals (SB) with bare fallow (FC) and high tillage (GC)	AC.FC.SB.HC.MC.GC **to** AB.FC.SB.HB.MB.GC	19.81	24.16	24.10
C-Class to A-Class (herbicide rates, strategic use & method)	Standard chemicals (SB) with bare fallow (FC) and high tillage (GC)	AC.FC.SB.HC.MC.GC **to** AA.FC.SB.HB.MA.GC	9.72	32.30	37.08
B-Class to A-Class (herbicide rates, strategic use & method)	Standard chemicals (SB) with bare fallow (FC) and high tillage (GC)	AB.FC.SB.HB.MB.GC **to** AA.FC.SB.HB.MA.GC	-13.83	6.90	11.85
C-Class to B-Class (herbicide rates, strategic use & method)	Standard chemicals (SB) with legume fallow (FB) and low tillage (GB)	AC.FB.SB.HC.MC.GB **to** AB.FB.SB.HB.MB.GB	6.70	10.59	11.46
C-Class to A-Class (herbicide rates, strategic use & method)	Standard chemicals (SB) with legume fallow (FB) and low tillage (GB)	AC.FB.SB.HC.MC.GB **to** AA.FB.SB.HB.MA.GB	-1.34	20.79	26.75
B-Class to A-Class (herbicide rates, strategic use & method)	Standard chemicals (SB) with legume fallow (FB) and low tillage (GB)	AB.FB.SB.HB.MB.GB **to** AA.FB.SB.HB.MA.GB	-11.78	8.95	14.16
C-Class to B-Class (herbicide rates, strategic use & method)	Alternative chemicals (SB2) with bare fallow (FC) and high tillage (GC)	AC.FC.SB2.HC.MC.GC **to** AB.FC.SB2.HB.MB.GC	20.38	24.73	24.67
C-Class to A-Class (herbicide rates, strategic use & method)	Alternative chemicals (SB2) with bare fallow (FC) and high tillage (GC)	AC.FC.SB2.HC.MC.GC **to** AA.FC.SB2.HB.MA.GC	34.60	57.18	62.21
B-Class to A-Class (herbicide rates, strategic use & method)	Alternative chemicals (SB2) with bare fallow (FC) and high tillage (GC)	AB.FC.SB2.HB.MB.GC **to** AA.FC.SB2.HB.MA.GC	10.47	31.20	36.42
C-Class to B-Class (herbicide rates, strategic use & method)	Alternative chemicals (SB2) with legume fallow (FB) and low tillage (GB)	AC.FB.SB2.HC.MC.GB **to** AB.FB.SB2.HB.MB.GB	1.43	5.33	6.19
C-Class to A-Class (herbicide rates, strategic use & method)	Alternative chemicals (SB2) with legume fallow (FB) and low tillage (GB)	AC.FB.SB2.HC.MC.GB **to** AA.FB.SB2.HB.MA.GB	18.28	40.41	46.37
B-Class to A-Class (herbicide rates, strategic use & method)	Alternative chemicals (SB2) with legume fallow (FB) and low tillage (GB)	AB.FB.SB2.HB.MB.GB **to** AA.FB.SB2.HB.MA.GB	13.10	33.84	39.05
Standard chemicals to alternative chemicals	C-Class herbicide practices (AC.HC.MC) with bare fallow (FC) and high tillage (GC)	AC.FC.SB.HC.MC.GC **to** AC.FC.SB2.HC.MC.GC	-24.31	-24.31	-24.31
Standard chemicals to alternative chemicals	B-Class herbicide practices (AB.HB.MB) with bare fallow (FC) and high tillage (GC)	AB.FC.SB.HB.MB.GC **to** AB.FC.SB2.HB.MB.GC	-23.74	-23.74	-23.74
Standard chemicals to alternative chemicals	A-Class herbicide practices (AA.HB.MA) with bare fallow (FC) and high tillage (GC)	AA.FC.SB.HB.MA.GC **to** AA.FC.SB2.HB.MA.GC	0.57	0.57	0.83
Standard chemicals to alternative chemicals	C-Class herbicide practices (AC.HC.MC) with legume fallow (FB) and low tillage (GB)	AC.FB.SB.HC.MC.GB **to** AC.FB.SB2.HC.MC.GB	-24.31	-24.31	-24.31
Standard chemicals to alternative chemicals	B-Class herbicide practices (AB.HB.MB) with legume fallow (FB) and low tillage (GB)	AB.FB.SB.HB.MB.GB **to** AB.FB.SB2.HB.MB.GB	-29.57	-29.57	-29.57
Standard chemicals to alternative chemicals	A-Class herbicide practices (AA.HB.MA) with legume fallow (FB) and low tillage (GB)	AA.FB.SB.HB.MA.GB **to** AA.FB.SB2.HB.MA.GB	-4.69	-4.68	-4.68
Bare fallow – high tillage to legume fallow – low tillage	C-Class herbicide practices (AC.HC.MC) with standard chemicals (SB)	AC.FC.SB.HC.MC.GC **to** AC.FB.SB.HC.MC.GB	-76.55	-12.12	-24.59
Bare fallow – high tillage to legume fallow – low tillage	B-Class herbicide practices (AB.HB.MB) with standard chemicals (SB)	AB.FC.SB.HB.MB.GC **to** AB.FB.SB.HB.MB.GB	-89.66	-25.69	-37.22
Bare fallow – high tillage to legume fallow – low tillage	A-Class herbicide practices (AA.HB.MA) with standard chemicals (SB)	AA.FC.SB.HB.MA.GC **to** AA.FB.SB.HB.MA.GB	-87.61	-23.63	-34.91
Bare fallow – high tillage to legume fallow – low tillage	C-Class herbicide practices (AC.HC.MC) with alternative chemicals (SB2)	AC.FC.SB2.HC.MC.GC **to** AC.FB.SB2.HC.MC.GB	-76.55	-12.12	-24.59
Bare fallow – high tillage to legume fallow – low tillage	B-Class herbicide practices (AB.HB.MB) with alternative chemicals (SB2)	AB.FC.SB2.HB.MB.GC **to** AB.FB.SB2.HB.MB.GB	-95.50	-31.52	-43.06
Bare fallow – high tillage to legume fallow – low tillage	A-Class herbicide practices (AA.HB.MA) with alternative chemicals (SB2)	AA.FC.SB2.HB.MA.GC **to** AA.FB.SB2.HB.MA.GB	-92.86	-28.89	-40.42

Table 35: AEB results for BRIA

Changes to management practice setting	Constant management practice setting	Coding	BRIA (50ha) ($/ha/yr)	BRIA (150ha) ($/ha/yr)	BRIA (250ha) ($/ha/yr)
C-Class to B-Class (herbicide rates, strategic use & method)	Standard chemicals (SB) with bare fallow (FC) and high tillage (GC)	AC.FC.SB.HC.MC.GC **to** AB.FC.SB.HB.MB.GC	19.81	24.16	24.10
C-Class to A-Class (herbicide rates, strategic use & method)	Standard chemicals (SB) with bare fallow (FC) and high tillage (GC)	AC.FC.SB.HC.MC.GC **to** AA.FC.SB.HB.MA.GC	8.12	42.00	37.08
B-Class to A-Class (herbicide rates, strategic use & method)	Standard chemicals (SB) with bare fallow (FC) and high tillage (GC)	AB.FC.SB.HB.MB.GC **to** AA.FC.SB.HB.MA.GC	-15.43	16.60	11.85
C-Class to B-Class (herbicide rates, strategic use & method)	Standard chemicals (SB) with legume fallow (FB) and low tillage (GB)	AC.FB.SB.HC.MC.GB **to** AB.FB.SB.HB.MB.GB	6.69	10.59	11.46
C-Class to A-Class (herbicide rates, strategic use & method)	Standard chemicals (SB) with legume fallow (FB) and low tillage (GB)	AC.FB.SB.HC.MC.GB **to** AA.FB.SB.HB.MA.GB	-2.29	20.79	26.75
B-Class to A-Class (herbicide rates, strategic use & method)	Standard chemicals (SB) with legume fallow (FB) and low tillage (GB)	AB.FB.SB.HB.MB.GB **to** AA.FB.SB.HB.MA.GB	-12.73	8.95	14.16
C-Class to B-Class (herbicide rates, strategic use & method)	Alternative chemicals (SB2) with bare fallow (FC) and high tillage (GC)	AC.FC.SB2.HC.MC.GC **to** AB.FC.SB2.HB.MB.GC	23.79	28.14	28.08
C-Class to A-Class (herbicide rates, strategic use & method)	Alternative chemicals (SB2) with bare fallow (FC) and high tillage (GC)	AC.FC.SB2.HC.MC.GC **to** AA.FC.SB2.HB.MA.GC	36.41	70.29	65.62
B-Class to A-Class (herbicide rates, strategic use & method)	Alternative chemicals (SB2) with bare fallow (FC) and high tillage (GC)	AB.FC.SB2.HB.MB.GC **to** AA.FC.SB2.HB.MA.GC	8.87	40.90	36.42
C-Class to B-Class (herbicide rates, strategic use & method)	Alternative chemicals (SB2) with legume fallow (FB) and low tillage (GB)	AC.FB.SB2.HC.MC.GB **to** AB.FB.SB2.HB.MB.GB	1.43	5.33	6.20
C-Class to A-Class (herbicide rates, strategic use & method)	Alternative chemicals (SB2) with legume fallow (FB) and low tillage (GB)	AC.FB.SB2.HC.MC.GB **to** AA.FB.SB2.HB.MA.GB	11.34	40.41	46.37
B-Class to A-Class (herbicide rates, strategic use & method)	Alternative chemicals (SB2) with legume fallow (FB) and low tillage (GB)	AB.FB.SB2.HB.MB.GB **to** AA.FB.SB2.HB.MA.GB	6.16	33.84	39.05
Standard chemicals to alternative chemicals	C-Class herbicide practices (AC.HC.MC) with bare fallow (FC) and high tillage (GC)	AC.FC.SB.HC.MC.GC **to** AC.FC.SB2.HC.MC.GC	-27.72	-27.72	-27.72
Standard chemicals to alternative chemicals	B-Class herbicide practices (AB.HB.MB) with bare fallow (FC) and high tillage (GC)	AB.FC.SB.HB.MB.GC **to** AB.FC.SB2.HB.MB.GC	-23.74	-23.74	-23.74
Standard chemicals to alternative chemicals	A-Class herbicide practices (AA.HB.MA) with bare fallow (FC) and high tillage (GC)	AA.FC.SB.HB.MA.GC **to** AA.FC.SB2.HB.MA.GC	0.57	0.57	0.82
Standard chemicals to alternative chemicals	C-Class herbicide practices (AC.HC.MC) with legume fallow (FB) and low tillage (GB)	AC.FB.SB.HC.MC.GB **to** AC.FB.SB2.HC.MC.GB	-24.31	-24.31	-24.31
Standard chemicals to alternative chemicals	B-Class herbicide practices (AB.HB.MB) with legume fallow (FB) and low tillage (GB)	AB.FB.SB.HB.MB.GB **to** AB.FB.SB2.HB.MB.GB	-29.57	-29.57	-29.57
Standard chemicals to alternative chemicals	A-Class herbicide practices (AA.HB.MA) with legume fallow (FB) and low tillage (GB)	AA.FB.SB.HB.MA.GB **to** AA.FB.SB2.HB.MA.GB	-4.69	-4.69	-4.69
Bare fallow – high tillage to legume fallow – low tillage	C-Class herbicide practices (AC.HC.MC) with standard chemicals (SB)	AC.FC.SB.HC.MC.GC **to** AC.FB.SB.HC.MC.GB	-82.11	-15.62	-26.12
Bare fallow – high tillage to legume fallow – low tillage	B-Class herbicide practices (AB.HB.MB) with standard chemicals (SB)	AB.FC.SB.HB.MB.GC **to** AB.FB.SB.HB.MB.GB	-113.75	-29.18	-38.75
Bare fallow – high tillage to legume fallow – low tillage	A-Class herbicide practices (AA.HB.MA) with standard chemicals (SB)	AA.FC.SB.HB.MA.GC **to** AA.FB.SB.HB.MA.GB	-92.52	-36.84	-36.44
Bare fallow – high tillage to legume fallow – low tillage	C-Class herbicide practices (AC.HC.MC) with alternative chemicals (SB2)	AC.FC.SB2.HC.MC.GC **to** AC.FB.SB2.HC.MC.GB	-78.70	-12.21	-22.70
Bare fallow – high tillage to legume fallow – low tillage	B-Class herbicide practices (AB.HB.MB) with alternative chemicals (SB2)	AB.FC.SB2.HB.MB.GC **to** AB.FB.SB2.HB.MB.GB	-101.06	-35.02	-44.59
Bare fallow – high tillage to legume fallow – low tillage	A-Class herbicide practices (AA.HB.MA) with alternative chemicals (SB2)	AA.FC.SB2.HB.MA.GC **to** AA.FB.SB2.HB.MA.GB	-103.77	-42.09	-41.95

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