Economic assessment of best management practices for banana growing

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

RP140B Initial synthesis report 2016

Source: Kukulies, T, “Banana farm grassed inter-rows”, 2015. jpg.

Queensland Government

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Executive summary

This report provides an overview of the currently available literature relating to the economics of Best Management Practice (BMP) for the Australian banana industry. The industry is almost entirely made up of the domestic market with zero current imports and minor exports, with the primary variety produced being Cavendish.

National banana production is mainly focused in the Wet Tropics area of north Queensland. There are two sub-regions within the Wet Tropics, Tully and Innisfail, which constitute the majority of the banana supply. When comparing the two sub-regions, there are minor regional variances overall. This is most likely due to their close geographical proximity, however, average farm size is much higher in Tully.

Bananas are a perennial crop with an all-year-round supply, which helps to compete with seasonal fresh fruit. There are several key farm inputs that go into banana production, such as: labour, fuel, fertiliser and pesticides. Other inputs include irrigation and electricity.

There are a number of risks that affect the profitability of banana production, with major factors including price volatility, rising input costs, pest and disease incursion and tropical cyclones. For example, Panama Disease Tropical Race 4 (TR4) has the potential to severely impact production in the Wet Tropics. How these risks are managed and their eventuation will have significant economic implications for growers.

Due to the specific application techniques commonly used for pest and disease management in the banana industry, the main pollutants of concern are nutrients in the form of dissolved inorganic nitrogen (DIN), particulate nitrogen (PN) and total suspended sediments (TSS). Past research indicates that these pollutant levels can be reduced through BMP adoption.

The extensive adoption of BMPs that improve water quality is considered a vital mechanism in improving the overall health of the Great Barrier Reef (GBR) ecosystem. A number of management practice responses to water quality issues currently exist, including targeted nutrient management, fertigation and enhanced efficiency fertilisers (EEF). Pannell et al. (2006) identified that practices are more likely to be adopted if they are perceived to have a relative advantage, are readily trialable as well as being consistent with farmers personal goals (economic, social and environmental). Adoption can also be supported by a Decision Support Tool (DST), which is a computer program or application that analyses data and presents it so users can make decisions more easily. DSTs can be utilised over a wide range of economic and environmental areas.

Despite the focus on improving water quality from agricultural land in the GBR catchments over the past ten years, banana growing has a noticeable lack of published reports on the economic implications of shifting to improved management practices. For this initial synthesis report we have found just four studies that have included an economic analysis of some description of moving to particular management practices or a farming system that incorporates a number of improved management practices.

This research project led by the Queensland Department of Agriculture and Fisheries (DAF) and funded through the Department of Environment and Heritage Protection (DEHP) Reef Water Quality Science Program will contribute to the economic information available for industry, government and community. The project aims to provide banana growers and industry stakeholders with greater confidence as to the likely profitability and water quality benefits of Banana Best Management Practices (BMP) adoption. This project will produce the following deliverables: grower case studies, initial and final synthesis report, adoption innovation profile report, regional summary fact sheets and extension of information to industry stakeholders. A more detailed description of the project is included in this report.

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List of acronyms

- ABARES – Australian Bureau of Agricultural and Resource Economics and Sciences
- ABCD – Aspirational Best Conventional Dated
- ABGC – Australian Banana Growers Council
- ADR – Areal Delivery Ratio
- APSIM – Agricultural Production Systems Simulator
- ARM – Agricultural Risk Management
- BMP – Best Management Practice
- BOM – Bureau of Meteorology
- CPI – Consumer Price Index
- DAF – Department of Agriculture and Fisheries
- DAFF – Department of Agriculture, Fisheries and Forestry.
- DCF – Discounted Cash Flow
- DIN – Dissolved Inorganic Nitrogen
- DSITI – Department of Science, Information Technology and Innovation
- DST – Decision Support Tool
- EEF – Enhanced Efficiency Fertilisers
- FSS – Fine Suspended Sediment
- GBR – Great Barrier Reef
- GM – Gross Margin
- GST – Good and Services Tax
- INFFER – Investment Framework for Environmental Resources
- IPM – Integrated Pest Management
- IPC – Improved Practices Catalogue
- IRR – Internal Rate of Return
- K – Potassium
- MCAS-S – Multi Criteria Analysis Shell for Spatial Decision Support
- N – Nitrogen
- NPV – Net Present Value
- NRM – National Resource Management
- NSW – New South Wales
- NT – Northern Territory
- P – Phosphorus
- PDS – Product Data Sheet
- PiRisk – Primary Industries Risk Analysis Tool
- PM – Profit Margin
- PN – Particulate Nitrogen
- ROA – Return on Assets
- ROE – Return on Equity
- RWQ – Reef Water Quality
- SCAMP – Soil Constraints and Management Package
- SOI – Southern Oscillation Index
- TN – Total Nitrogen
- TP – Total Phosphorus
- TR1 – Tropical Race One
- TR4 – Tropical Race Four
- TSS – Total Suspended Sediments
- WA – Western Australia
- WOF – Whole of Farm

1 Introduction

More than 90 per cent of Australia's banana production is in the Wet Tropics region of north Queensland. The Wet Tropics is an area of significant environmental value, not only is it listed as an identified United Nations Educational, Scientific and Cultural Organisation (UNESCO) World Heritage Area, it is also adjacent to the Great Barrier Reef, another UNESCO listed World Heritage Area. For reducing the relative risk of degraded water quality to the Great Barrier Reef, the Scientific Consensus Statement (2013) identified the highest management priority in the Wet Tropics region as addressing fertiliser nitrogen reduction. The land use that contributes the highest anthropogenic dissolved inorganic nitrogen (tonnes per year) is sugarcane, with bananas the second highest contributor from the Johnstone sub-catchment, in the Wet Tropics region (Queensland Government 2014: 83). The Reef Water Quality Protection Plan (2013) and the Reef 2050 Long-Term Sustainability Plan (2015) set out the commitment by government, industry and regional bodies to act to reduce the contribution of total contaminants entering waterways from agricultural land located in the Great Barrier Reef catchment area.

In addition to the ongoing commitment to improve environmental outcomes, in particular reducing the nutrients and sediments leaving farms, the banana industry is currently dealing with the detection of Panama Tropical Race 4 (TR4) disease in the Tully area. The main way in which this disease is spread is through infected planting material and in the movement of water and soil infected with the fungus. The reduced movement of soil and water off-farm will also provide benefits as an industry-wide means of targeting Panama disease.

This initial synthesis report will provide an overview of the business environment of the banana industry in the Wet Tropics to better understand key drivers for profitability and risk variables. It will collate available information on the economics of the various banana growing management practices across the industry 'best, okay and improve' categories of the Terrain NRM ABCD Management Practice Framework for bananas in the Wet Tropics region. A regional profile for the Wet Tropics banana industry will be developed to inform selection and evaluation of banana enterprises (e.g. regional variations, soil types, practices, enterprise size, business profile) for the case studies and representative economic assessments. Finally, the report sets out the approach going forward for the rest of the project to collect information on management practices, the methodology that will be used to assess these practices for cost-effectiveness in meeting water quality objectives and the approaches that will be used to disseminate the findings to industry.

The authors have aimed to synthesise the available literature in line with the scope of the project and have utilised a diverse range of published information sources. In some instances valid work may have been overlooked and the reference list is by no means exhaustive. A final report will be developed at the end of the project integrating new information which ideally addresses the gaps identified within this interim report.

2 Queensland banana growing industry

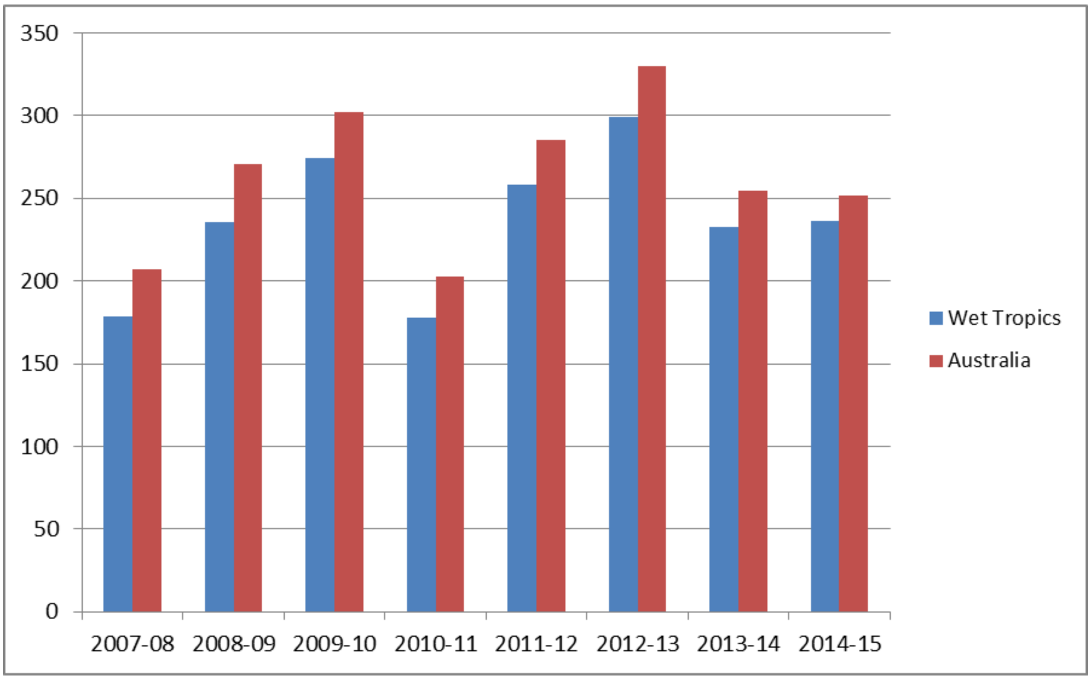
2.1 Farm business environment

The primary variety of bananas grown in Australia is Cavendish, followed by Lady Finger and other cultivars with niche markets. The Australian banana industry is almost entirely made up of the domestic market with zero current imports and minor exports. There are no imports mainly due to overseas countries being unable to economically meet Australia's stringent phytosanitary conditions under which bananas are permitted into the country. These conditions were set to quarantine the country and provide safeguards from a foreign disease incursion (Australian Government, 2009). Exports are minor predominantly due to the cost of production being higher in Australia, compared to many other banana producing countries. The minor exports are mostly from organic markets, for example, Pacific Coast Eco Bananas distribute their wax-tip fruit through a direct airline service to Hong Kong from Cairns (Queensland Government, 2015d).

In 2014-15, the Queensland banana industry produced approximately 97 per cent of the nation's bananas, with a gross value[1] of $441 million out of the national total worth $455 million.[2] In that same period, banana production in the Wet Tropics accounted for 94 per cent of national production (worth $428 million).[2] This shows that the banana industry is a substantial contributor to the economies of rural communities in north Queensland. Other regions of banana production in Queensland, in order from largest to smallest, include Cape York, Northern Gulf, Burnett Mary, South East Queensland, Burdekin and Mackay Whitsunday.[2]

Figure 1 illustrates the Wet Tropics and Australia's total banana production over eight years. The level of banana production has trended upwards from 2007-2015 and the lower years of production can be explained by tropical cyclones (Larry 2006, Yasi 2011 and Ita 2014) and seasonal conditions. Recent forecasts (Department of Agriculture and Fisheries, Agtrends, 2015a) are that consumer demand is moderately strong, prices will be maintained and good production numbers are anticipated.

Figure 1 Australian Banana Production (kt)

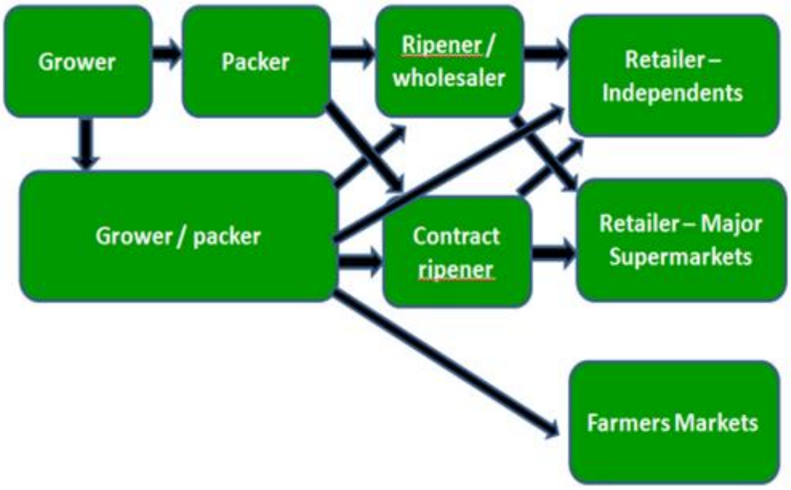


Source: Australian Bureau of Statistics, (2016a).

Bananas are a perennial crop, with an all-year-round supply, which helps them compete with other fresh fruit that are seasonal. This supply is mainly transported via full road vehicle loads and minor rail transport (Queensland Transport and Logistics Council, 2015). The supply chain usually followed by Wet Tropics growers (see figure 2) is: packer, ripener or wholesaler (approximately 25 servicing Brisbane, Newcastle, Sydney, Melbourne, Adelaide and Perth) and then to retailer (major supermarket or independent). However, supply chain cost pressures and increased retail competition can push growers to directly supply to the supermarket. It is estimated that 60 per cent of all Australian bananas are sold into the supermarket channel (Horticulture Australia Limited: 22, 2014).

[1] Gross value is the value placed on recorded production at wholesale price(s) realised in the market place.
[2] (Australian Bureau of Statistics, 2016a), (Australian Bureau of Statistics, 2016b).

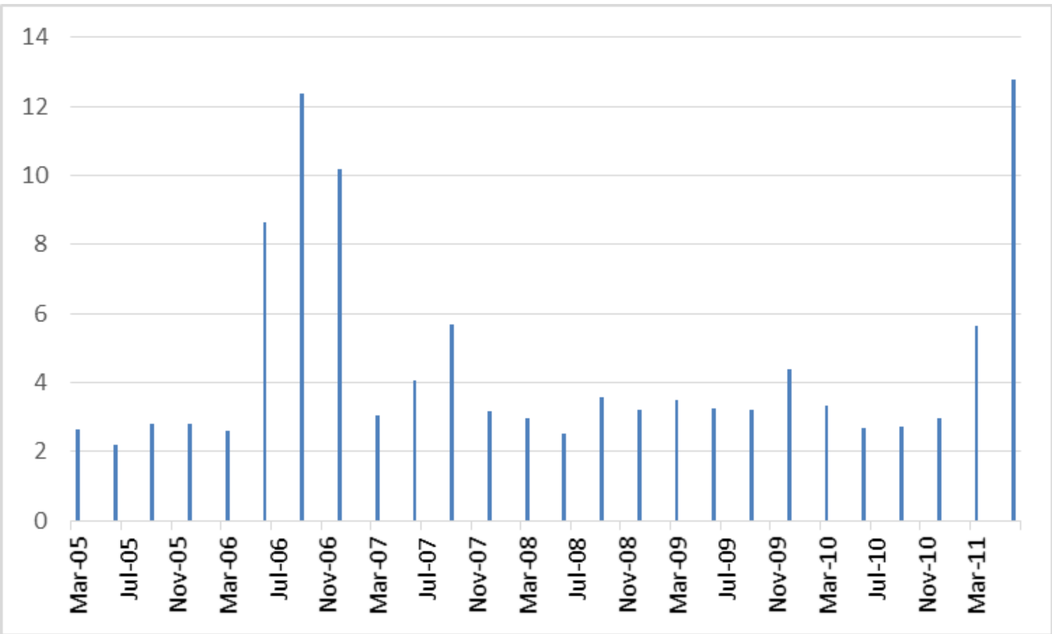
Figure 2 Wet Tropics Banana Supply Chain



Source: Horticulture Australia Limited: 22, (2014).

Figure 3 shows the nominal retail price of the Australian bananas from 2005 to 2011. The two large price spikes correspond with the two tropical cyclones Larry and Yasi, which dramatically reduced the supply from the Wet Tropics region. The price returned back to normal about a year after Larry, which coincides with the production delay of banana plantation.

Figure 3 Australian nominal retail banana price, capital city average ($/kg)

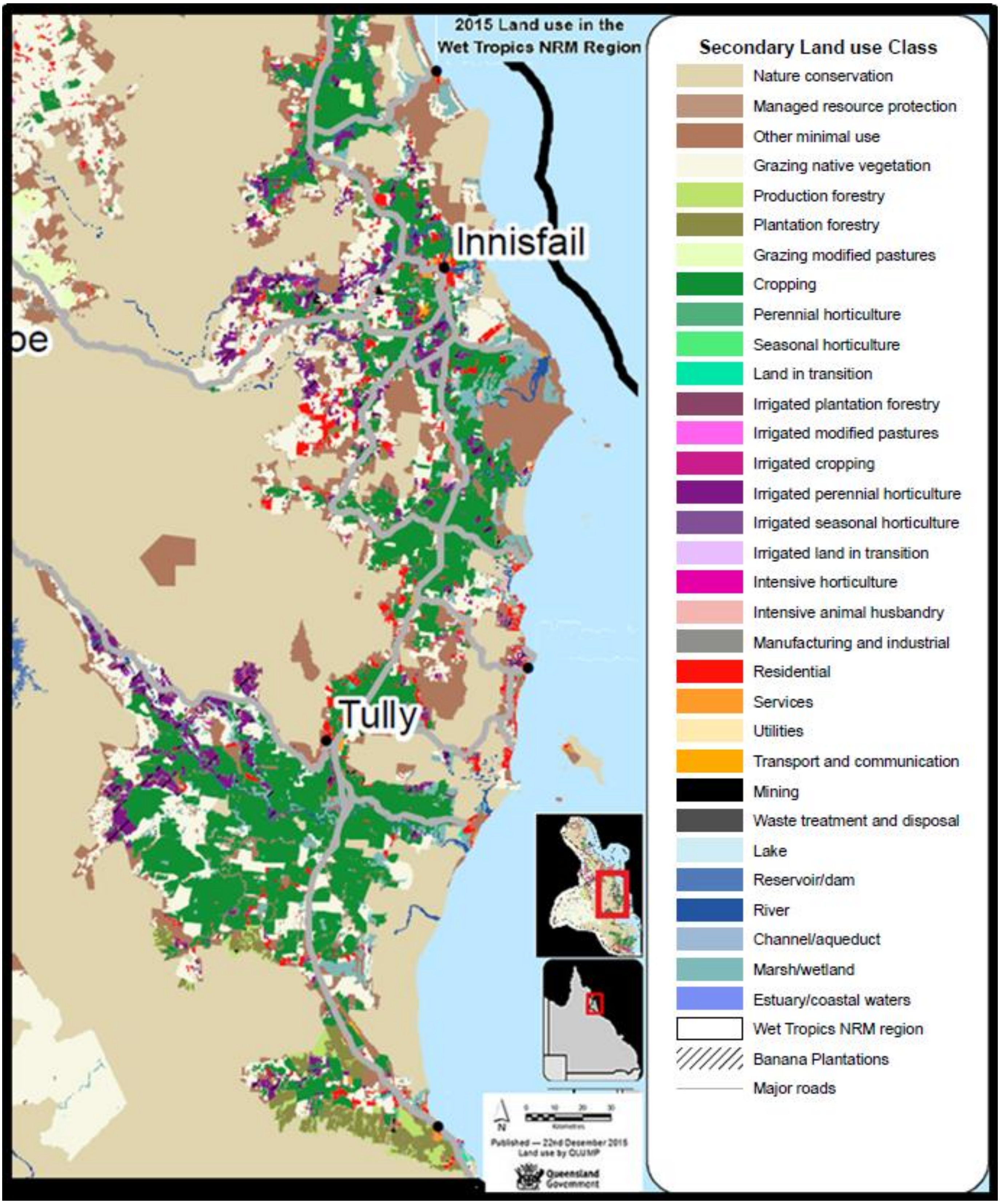


Source: Australian Bureau of Statistics, (2011).

The Wet Tropics has two sub-regions which make up the majority of the banana plantations – Tully and Innisfail. Figure 4 indicates where banana producing land is located, identified as irrigated perennial horticulture (dark purple with parallel diagonal black lines), covering 14 553 hectares, which is 0.65 per cent of the Wet Tropics total area (Department of Science, Information Technology and Innovation, 2016).[3]

[3] The infinitesimal change, *d*, in the quarterly price, P, is calculated using the statistic, $d_t = \ln(P_{t+1} / P_t)$, resulting in a mean 0.0629 and a variance rate of 0.2031. Multiplying by 4 gives an annualised mean of 25.18% and volatility (i.e. the annualised standard deviation) in these changes of 81.22% from March 2005 to June 2011.

Figure 4 **2015 Land Use in the Innisfail and Tully Region**



Source: Department of Science, Information Technology and Innovation, (2016).

2.2 Key inputs into banana production

There are several key inputs that go into banana production, such as; labour, fuel and fertiliser. Other inputs include: pesticides, irrigation and electricity. This sections goes into more detail about these inputs and their relative contribution to banana production.

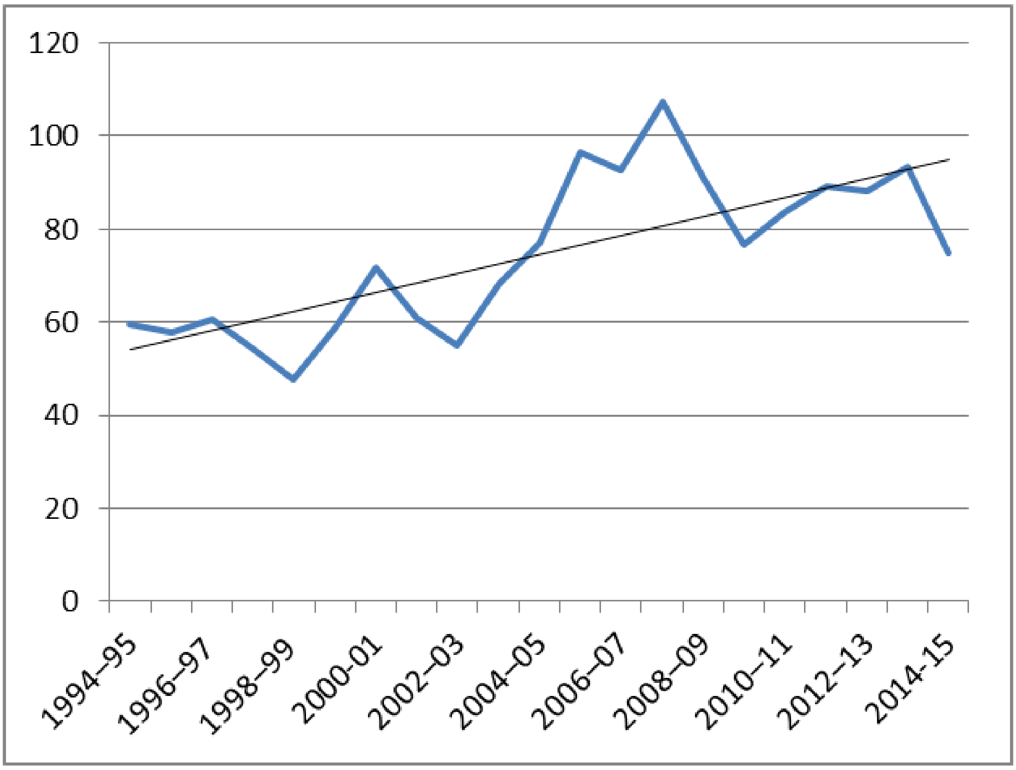
2.2.1 Labour

Labour makes up a large proportion of production costs for most banana growing enterprises. This is due to the price of labour being quite high relative to other inputs. The labour force is comprised of backpackers, seasonal workers, family and local workers. It is difficult to achieve economies of scale because the variable costs are relatively higher in bananas, compared to other agricultural industries (e.g. sugar, grains) and increasing farm size proportionally increases labour and other production costs (variable costs) (Lindsay, Stewart, pers. comm., 04/11/15).

2.2.2 Diesel

Another key input into banana production is diesel fuel. Due to the crop being perennial, plants across the farm are usually in different production stages to ensure constant supply; hence activities need to be completed in terms of individual plant, block and farm at any point in time. This results in many vehicle hours in production, such as four-wheel-drive and quad bikes. Over the past 20 years, the price of diesel has had an upward trend in real terms, impacting on the banana industry through increases in supply chain transport costs, irrigation pumping costs and farm machinery costs (Australian Bureau of Agricultural and Resource Economics and Sciences, 2015b). Figure 5 shows the average diesel price paid by Australian farmers, excluding Good and Services Tax (GST) and farm rebates, but including the fuel tax credit subsidy (Australian Tax Office, 2016).

Figure 5 Australian real Diesel price (c/L), 1993-94 to 2013-14 (base 2011-12)

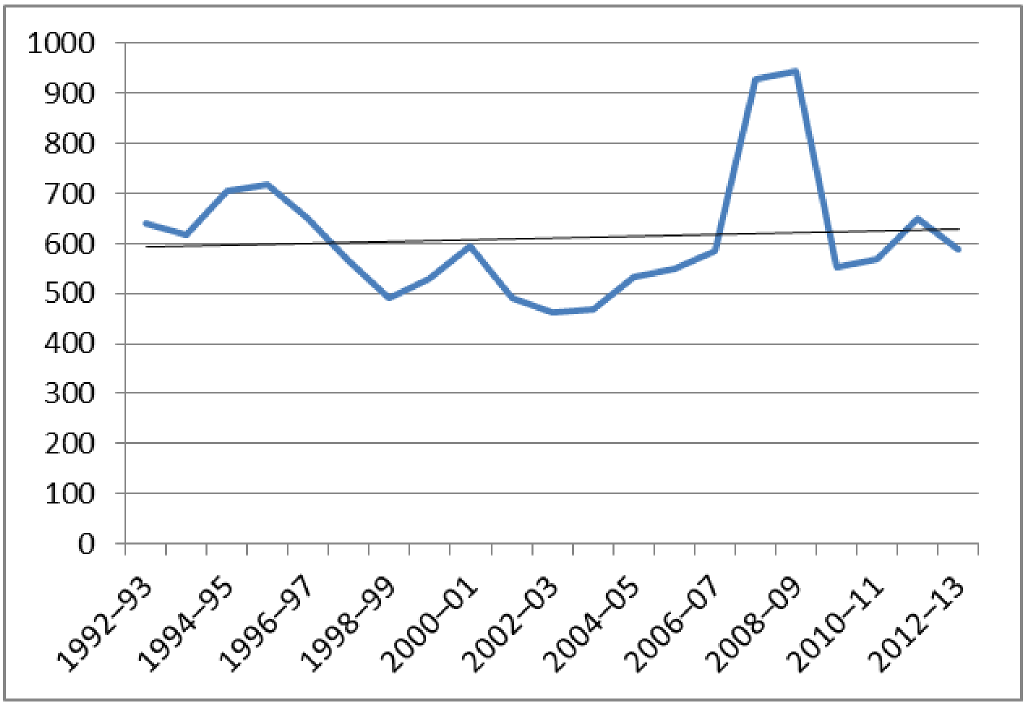


Source: Input prices sourced from ABARES, (2015b). Prices deflated using Consumer Price Index (CPI) measures sourced from: Australian Bureau of Statistics, (2015).

2.2.3 Fertiliser

Urea fertiliser is the main source of nitrogen used by banana farms. Fertigation often occurs fortnightly in the dry periods, but larger amounts of fertiliser are applied monthly using broadcast applications in the wet periods. Unlike diesel, the trend for the cost of urea in real terms over a 20 year period appears to be relatively flat (see figure 6). The real cost of urea is characterised by falling prices up to 2003-04 which is then offset by a large shock occurring in 2007-08 and 2008-09 when prices significantly increased before falling again in 2011. Figure 6 shows the bagged price from 1992 to 2001 and the bulk price from 2002 onwards.

Figure 6 Australian real Urea price ($/t), 1992-93 to 2012-13 (base 2011-12)



Source: Input prices sourced from ABARES, (2015b). Prices deflated using CPI measures sourced from: Australian Bureau of Statistics, (2015).

2.2.4 Pesticides

Pesticide is used as part of an Integrated Pest Management (IPM) program on farm. Pesticides are not deemed a high priority for water quality improvement due to the characteristics of use within the banana production system. This includes only occasional use of residual herbicides and that frequently used insecticides and fungicides are generally used in small quantities with very targeted application such as spot spraying (Terrain NRM 2015: 48).

2.2.5 Other inputs

Irrigation is supplied to the whole banana farm and can be scheduled based on soil properties, crop growth requirements, monitoring of soil moisture and weather forecasts (Department of Agriculture and Fisheries, 2014). Electricity used to power irrigation and other aspects of the farm (e.g. packing shed) is an important input to banana growing.

2.3 Risks to viable banana production

The Australian banana industry has many elements of risk to production including pest and disease outbreaks, heavy reliance on one variety and extreme weather events. This section discusses how these risks are managed and their eventuation can have significant economic implications for growers.

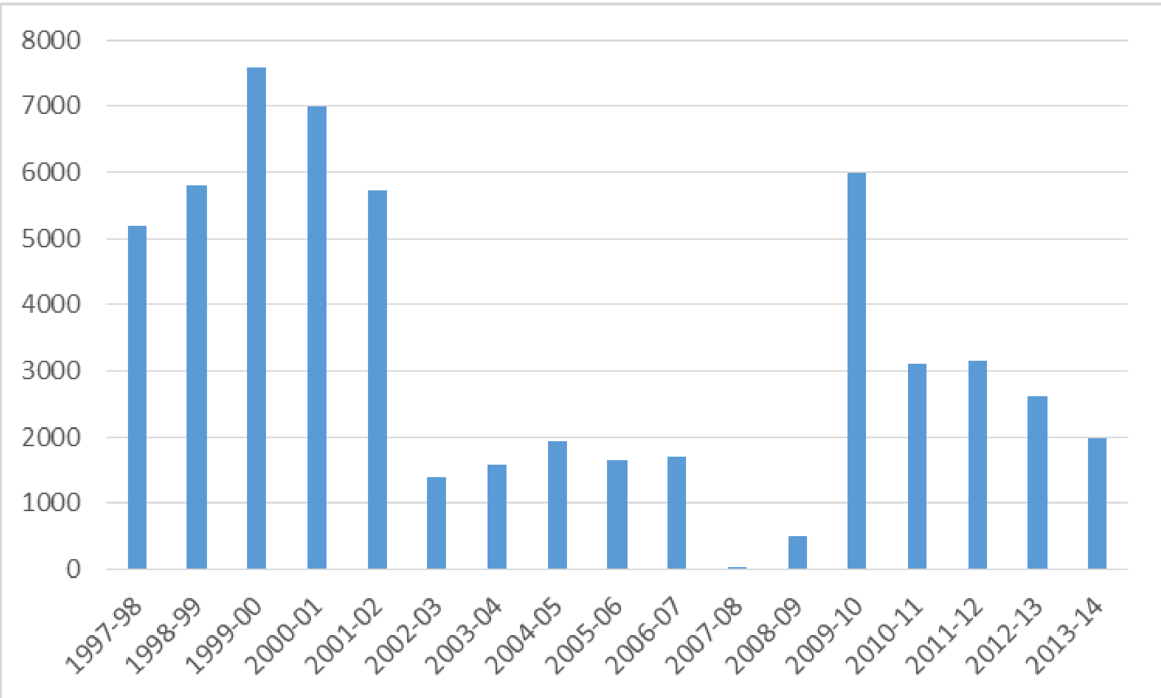
2.3.1 Panama disease

There are a multitude of pests and diseases that hamper banana plantations in Queensland, such as aphids, spider mites, Banana Freckle and Bunchy Top. However, the largest risk is currently *Fusarium oxysporum* f. sp. *cubense* otherwise known as Panama Disease, specifically the Tropical Race 4 (TR4) strain of the disease, which has the potential to severely impact Cavendish banana production in the Wet Tropics.

When banana plants arrived in Australia in the 1800's the main variety was Gros Michel. In 1876 Panama Disease Tropical Race 1 (TR1) was first reported, which affects Gros Michel and other cultivars and became an epidemic over the next few decades. In the 1950's, the Cavendish replaced Gros Michel as the main variety grown in Australia (and worldwide) due to its resistance to Panama disease TR1 (Wageningenur, 2015). However, in 1967 fusarium wilt was observed in a Cavendish plantation in Taiwan on a single plant and by 1983 approximately 30 per cent of banana plantations in Taiwan were infected (Su et al., 1986). Panama Disease TR4 spread rapidly through Southeast Asia (Philippines, Indonesia and Malaysia) and has appeared in Africa (Mozambique), Western Asia (Pakistan, China), the Middle East (Jordan, Lebanon and Oman) and Australia (Ploetz, 2015).

In 1997, there was a report in the Northern Territory (NT) of Panama disease TR4. The affected property was quarantined along with the destruction of all banana plants. The Northern Territory enforced strict quarantine measures in order to halt the spread of the disease. In 2001, a project was created to develop suitable quarantine and managements systems and to identify and test resistant varieties (Northern Territory Government, 2007). Production in the NT stayed strong from 1997-98 to 2001-02, but then drastically declined in 2002-03 due to Panama disease TR4 (see figure 7). Production remained steady until 2007-08 when it hit its lowest levels of production of only 41 tonnes. This was due to quarantine measures of temporarily closing the industry down while farms were relocated. In 2009-10 production increased and was around 2000 tonnes in 2013-14, however, production in the NT is currently negatively affected by another disease, Banana Freckle (discovered in 2013) and disease and plant eradication is currently underway (Good Fruit and Vegetables, 2015).

Figure 7 Northern Territory Banana Production (tonnes)



Source: Australian Bureau of Statistics, (2016a).

Panama disease is easily spread through the movement of infected planting material, by root systems, soil, water and contaminated equipment. Fungal spores can survive in the soil for several decades which makes prevention the most effective control method. Panama Disease has a number of identified Races: 1, 2, Subtropical Race 4 and the most serious threat to the Queensland banana industry, Tropical Race 4, which was detected on Cavendish plants in Tully in 2015.

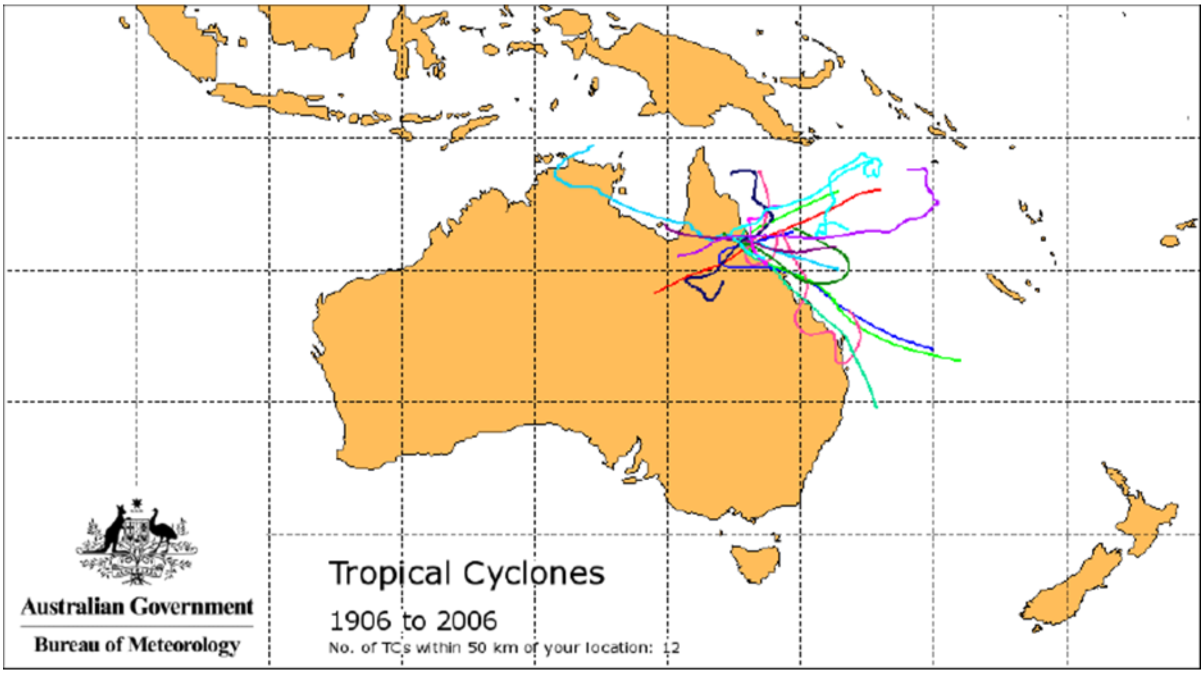
A heavy reliance on one variety exposes the banana industry to potential catastrophic outcomes from disease incursions. The Cavendish cultivar makes up the large majority of Australian bananas and as such Panama TR4 has potential to seriously impact the monoculture industry. Replacing Cavendish as the main variety would constitute a major change to current production systems, however, alternative varieties that have increased tolerance to the disease have unfortunately been found to be less productive in trials to date (Department of Agriculture and Fisheries, 2015b).

Several new biosecurity management practices have been adopted in the wake of Panama Disease TR4 being detected in QLD to prevent the spread of the disease (Biosecurity Queensland, 2015). These practices cover nearly all aspects of the farm including: personnel movement, vehicle and machinery movement, wash down facilities, fencing, tools and equipment, water management (supply, movement and disposal), waste management, farm-based animal movement, crop production (land preparation, planting) and fruit movement (harvest and packing).

2.3.2 Tropical cyclones

Bananas are a crop of the humid lowland tropics, which makes the Wet Tropics an ideal production region. However, as can be seen from Figure 1, extreme weather events during summer months, such as cyclones, can have a huge bearing on banana production. Damage from cyclones can also effect employment of banana producers and the related farm labour, service industries and supply chains, including consumers. From 1906 to 2006 there have been 12 cyclones that have struck the major banana growing area within 50km of Tully, which is a cyclone every eight to nine years (see figure 8).

Figure 8 Track Maps for cyclones within 50km of Tully from 1906 to 2006



Source: Australian Government, (2016a).

Without any pre-cyclone management practices implemented, considerable periods of undersupply and oversupply will occur in the market. Pre-cyclone management grants an earlier return to fruit production by partially or completely removing the plant canopy which reduces wind resistance.

Post-cyclone management recommendations include using nurse suckering and replanting crops over a period of time, rather than all at once, to provide a more even supply of bananas. Economic analysis shows that an average grower implementing post-cyclone management practices after Tropical Cyclone Yasi (2011) would have benefited by a minimum of $9703 per hectare compared to those who did nothing (Australian Banana Growers Council, ABGC, 2012). Apart from cyclones, other extreme weather events that can impact on banana production in Queensland include: severe storms, storm surges, floods and bushfires.

The Tully and Innisfail regions are renowned for their rainfall events that cause heavy erosion, floods and months of saturated soils in the wet season. Bananas are a crop of the humid lowland tropics, therefore this is the best banana production regions in Australia but the severe weather can widely vary production levels.

2.4 Key economic indicators of profit and performance

Profit is the main economic measure of farm level performance. Profitability measures the difference between the value of goods produced and the costs of the inputs used to produce the goods. Gross margins (GM) are commonly used to measure profitability in the economic analysis of farming activities (Garside et al. 2009). Gross margin is the revenue generated from production once variable costs have been subtracted from gross revenue. The total gross margin can therefore be written as follows:

$$Total\ GM = gross\ revenue - variable\ costs \qquad (1)$$

While useful for evaluating changes to farming systems that do not require additional land or fixed capital, gross margins do not take overhead costs into account (Garside et al. 2009). Operating profit does incorporate these costs and is calculated as follows:

$$Operating\ profit = total\ gross\ margin - overhead\ costs \qquad (2)$$

When taking into consideration the additional capital investments required for a change in farming systems and overhead costs, a whole of farm economic analysis approach can be used to calculate these key economic measures. The results from a whole of farm economic analysis can then be used to calculate the Net Present Value (NPV) of any change to farming systems as these approaches account for the large up-front payments and the stream of costs and benefits over time that these investments involve. The NPV analysis comprises calculating the flow of economic benefits over a defined period of time using the following equation:

$$NPV = -C_0 + \frac{C_1}{1+i} + \frac{C_2}{(1+i)^2} + \cdots + \frac{C_n}{(1+i)^n} + \frac{C_N}{(1+i)^N} \qquad (3)$$

where:

NPV = net present value,
n = each time period in the life of the project,
N = total number of time periods in the project,
C_0 = initial investment made at the start of the project,
C_1 = expected incremental net cash flow (inflows – outflows) in the first time period of the project,
C_2 = expected incremental net cash flow (inflows – outflows) in the second time period of the project,
C_n = expected incremental net cash flow in period in time period *n*,
C_N = expected incremental net cash flow in the last time period of the project; and
i = discount rate.

The discount rate is constant and corresponds to the interest rate at which future cash flows are discounted (Wilkinson & Klaes 2012).

The NPV can be used to compare the economic impact of adopting various farm management practices. A positive NPV would indicate that the change of practice is worthwhile as the economic benefit outweighs the costs of implementation. A negative NPV would indicate that the change is not acceptable as the costs are higher than the benefits. Another economic measure used to compare investment options is the internal rate of return (IRR), which is the discount rate required to make the NPV equal to zero.

While NPV is a useful economic measure, it is difficult to incorporate the risk and uncertainty so inherent to agricultural production into NPV calculations. This is because assumptions are made about expected future cash-flows, future output prices, input costs and yields. The volatility associated with farming, both around price and quantity of inputs and outputs at any given time, means that accounting for this uncertainty in assessing alternative farming systems is particularly important.

Risk can be accounted for using several different methods, including sensitivity analysis and scenario planning. Stochastic simulations are another way to account for the distribution of potential outcomes from particular inputs. The Queensland Department of Primary Industries & Fisheries developed a stochastic simulation tool; Primary Industries Risk Analysis Tool (PiRisk) by using Microsoft Excel. It conducts random simulations over the various sources of uncertainty producing a cumulative frequency distribution displaying the expected outcomes and their associated probabilities (see, for example, State of Queensland 2011b).

3 Water quality concerns from banana growing practices

Nutrients, pesticides and sediments have been identified as the main pollutants from agricultural land that negatively impact on water quality entering the GBR lagoon (Brodie et al. 2013, Kroon et al. 2012, Fabricius 2005, De'ath and Fabricius 2010). More specifically, nutrients and pesticides are considered the highest risk for banana production systems. Pesticides are not deemed a high priority pollutant from banana production in terms of the relative impact on water quality entering the Great Barrier Reef (Terrain NRM 2015). This is due to residual herbicides only occasionally being used and those chemicals that are frequently used (insecticides and fungicides) are generally used in small quantities with very targeted application (e.g. fungicides are used on leaves and tend to be found at very low concentrations in the environment while bunches are either spot sprayed or treated via a pesticide impregnated strip) (Terrain NRM 2015: 48). In the 2015-2020 Wet Tropics Water Quality Improvement Plan, it is estimated that pesticide use has reduced by as much as 90 per cent in last 20 years (S. Lindsay, pers. comm. in Terrain NRM 2015: 48). Subsequently, the main pollutants identified by Terrain NRM as of concern for the banana industry are nutrients in the form of dissolved inorganic nitrogen (DIN), particulate nitrogen (PN) and total suspended sediments (TSS).

Banana growing requires relatively high fertiliser rates as high yielding banana crops (such as the Cavendish variety) extract large quantities of nutrients from the soil (Lindsay et al., 1998). There is potential for nutrient losses in the Wet Tropics through a number of pathways including surface runoff, denitrification and in particular for nitrates, deep drainage (Armour et al., 2013a). Lindsay et al. (1998: section 4 pp.30) note that the two nutrients most readily lost in banana growing are nitrogen and potassium.

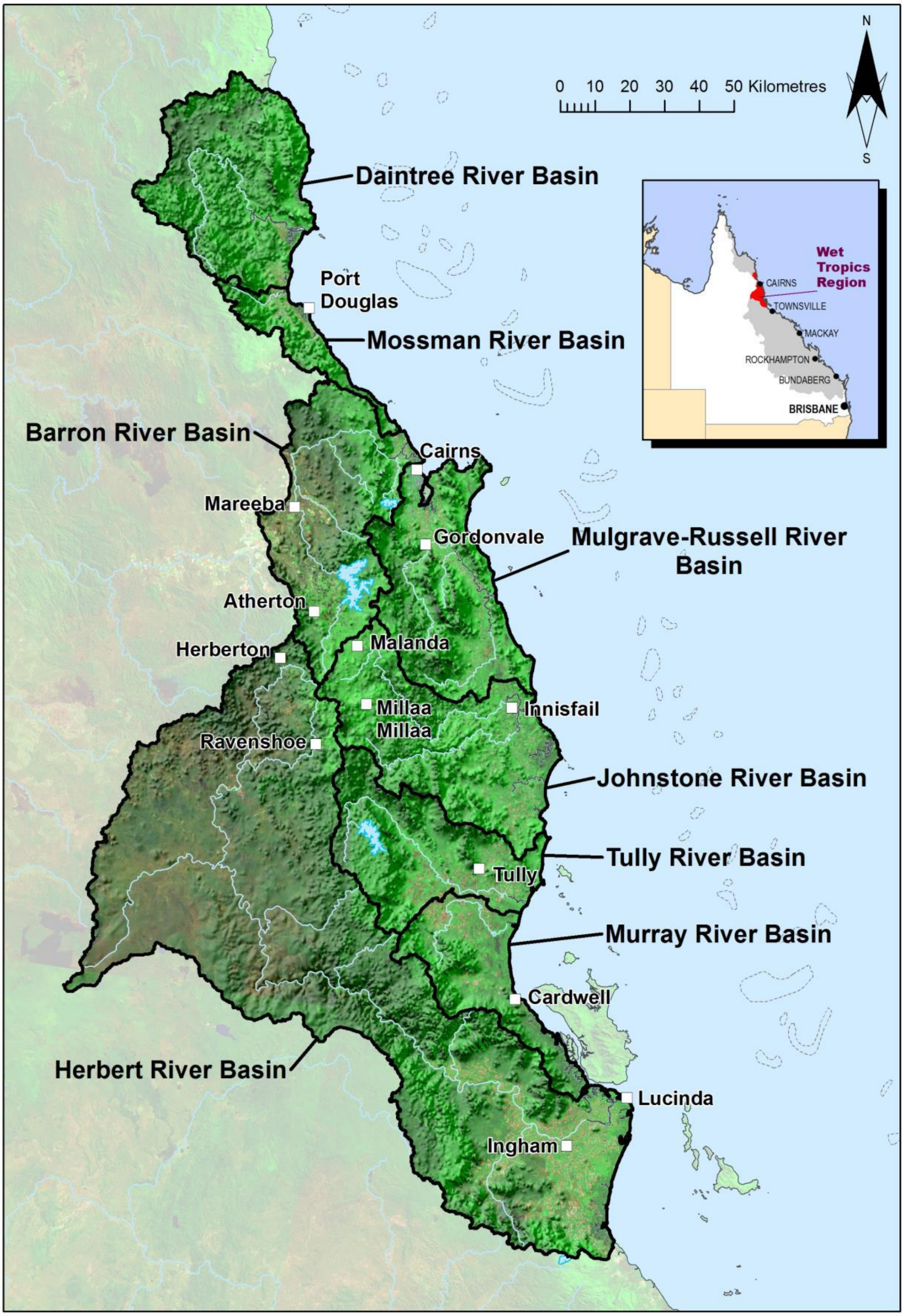
Armour et al. (2013a) measured the deep drainage losses from Banana growing over 1995 – 1997 and found the nitrogen (N) load in deep drainage attributable to N fertilisers was equivalent to 37 and 63 per cent of the fertiliser application for the treatments N400 and N600 respectively over 18 months. In particular, N leached below the root zone in well-drained soils in a high rainfall environment when fertiliser applications exceed crop demand, despite fortnightly application and doses aligning to growth rate (Armour et al., 2013a: 76). The same study also recorded oxidised nitrogen (NOx-N) concentrations in deep drainage as high as 180 mgL^{-1} under irrigated bananas (Armour et al., 2013a). Rasiah et al., (2010: 361) investigated the linkages between N in leachate, groundwater and drain water collected under a banana plantation in the Tully River catchment. The study concluded that the unused/under-utilised nitrate that leached below the root-zone was imported into the groundwater by the percolating rainwater and was exported into the drain via groundwater base-flow discharge. Specifically their results showed that approximately 62 per cent of the nitrate-N that leached below the root-zone was exported to the groundwater and approximately 40 per cent of the nitrate-N in the groundwater was exported to the drain water (Rasiah et al., 2010: 369).

Catchment modelling of sediment, nitrogen and phosphorus nutrient loads in the Tully-Murray basin by Armour et al. (2009) found bananas contributed eight per cent of the total DIN exported to the coast at 12 kg ha^{-1}year^{-1} with an areal delivery ratio (ADR)[4] of 2.9 (only sugar had a higher ADR at 5.8) from an application rate of 335 kg N ha^{-1} year^{-1}. A similar study was undertaken for the Johnstone River catchment over six years by Hunter and Walton (2008) who looked at land use effects on fluxes of sediment, nitrogen (N) and phosphorus (P). They found that there was a three to four fold increase in fluxes of sediment P from bananas, with specific fluxes of total P of 6.8 $\pm$ 4.1 kg P ha^{-1}y^{-1} compared with a flux of 2.3 $\pm$ 1.9 kg P ha^{-1}y^{-1} from the other land uses in the lower catchment (excluding sugarcane) and 0.8 $\pm$ 1.0 kg P ha^{-1}y^{-1} from all land uses in the upper catchment (Hunter & Walton 2008: 141). Specific fluxes of N from areas of bananas were modelled at 42 $\pm$ 21 kg N ha^{-1}y^{-1} were the highest of all agricultural land uses modelled in both the lower and upper catchments and approximately four times higher than that modelled for rainforest land – only fluxes of N from unsewered residential areas in the catchment were higher (Hunter and Walton 2008: 142). While banana growing only accounts for two per cent of the land area in the Johnstone River catchment, Hunter and Walton (2008: 143) estimate that it accounts for 15 per cent of mean annual flux Nitrate-N from the catchment - second only to sugarcane which accounts for 60 per cent.

Hateley et al. (2014: 32) identifies bananas as a major intensive crop grown in the Wet Tropics region with high concentrations and loads of nitrogen reported in the streams and groundwater in the sub-catchments where they are grown. Modelling by Hateley et al. (2014: 92) identifies hotspot basins for DIN export load for bananas as the Johnstone (122 t/year) and the Tully (88 t/year) basins. The range of DIN for bananas across basins was 2 kg/ha/year in the Barron Basin to 24 kg/ha/year in the Mulgrave-Russell Basin (Hateley et al., 2014: 95) (see Figure 9 for location of basins).

[4] ADR is calculated as the percentage of DIN contributed by bananas divided by the percentage area of bananas in the catchment.

Figure 9 Basins of the Wet Tropics NRM region



Source: Hateley et al. (2014)

With respect to sediment loss from banana production systems, Lindsay et al. (1998: section 3 page 5) state:

> Soil erosion can be a significant problem in banana plantations in north Queensland, especially on steep slopes and in undulating areas. High intensity rainfall produces large amounts of runoff that will remove topsoil and nutrients unless effective runoff control measures are in place.

The study by Hunter and Walton (2008: 141) on fluxes of pollutants from the Johnstone River catchment found suspended sediment fluxes from areas of bananas (4.0 ± 2.5 t $ha^{-1}y^{-1}$) to be around three to four times those from other uses in the lower catchment (excluding sugarcane). As noted previously, banana growing accounts for two per cent of the land area in the Johnstone River catchment, but estimates show that it accounts for eight per cent of mean annual flux suspended sediment from the catchment – the lowest level from agricultural land use in the lower catchment.

Results from modelling reductions of pollutant loads due to improved management practices in the Wet Tropics region by Hateley et al. (2014) found that while land used for banana growing only contributed a small proportion to the TSS export load it exhibited the largest per unit area of TSS, Total Nitrogen (TN) and Total Phosphorus (TP) to export at 1.8 t/ha/year, 25 kg/ha/year and 3.1 kg/ha/year respectively (Hateley et al., 2014: iv). This compares with per unit area of TSS, TN and TP to export of 1.2 t/ha/year, 22 kg/ha/year and 2.7 kg/ha/year from sugarcane growing, which accounts for 29 per cent of the total export load of TSS and 41 per cent of total export load of DIN and 30 per cent of total export load of TP.

4 Responses to water quality concerns

4.1 Management practice responses to water quality concerns

The extensive adoption of Best Management Practices (BMP) that improve water quality is considered a vital mechanism in improving the overall health of the GBR ecosystem. The banana industry BMP Environmental Guidelines are based on the Freshcare Environmental Code and uses a 'best, okay, improve' criteria (King, 2008) (see appendix 3). This is similar to the ABCD criteria used by Natural Resource Management (NRM) groups, except for the exclusion of the A practices.

In their recently released *Water Quality Improvement Plan 2015-20* (2015: 44) Terrain NRM state that 'current options for reducing DIN from bananas include: a targeted nutrient management approach to N applications, more widespread use of fertigation; refinement of surface, banded applications and slow release fertilisers.' These practices are briefly described below:

Targeted nutrient management – following this approach mainly involves matching crop inputs to crop requirements. Since 1995, nitrogen application rates followed by industry have reduced by as much as 40 per cent (Sing, 2012). Application frequency is important because of weather conditions and Armour (2013c) found that deep drainage nitrogen losses were slightly lower when fertiliser was applied fortnightly rather than monthly (3kg/ha and 7kg/ha respectively), keeping the total annual rate applied per hectare unchanged. Regular soil and leaf tests are required for accurate assessment of N rates, especially for determining appropriate N requirements at particular crop stages on specific blocks at certain times of the year (Terrain 2015: 46).

Widespread use of fertigation – Terrain (2015:46) note that '65 per cent of the industry now has fertigation capacity.' Fertigation can not only facilitate further reductions in N rates but also reduce the risk for N losses as a result of a high rainfall event due to more frequent applications relative to broadcast applications (Terrain 2015: 46). Daniells and Armour et al. (2003) found fertigation advantages included that nutrients are always readily available to the plant, fertiliser is applied directly where needed, fertiliser losses are nearly eliminated and there is no volatilisation losses with Urea.

Refinement of surface, banded applications – Terrain (2015: 46) state that surface applications (rather than fertigation) are acceptable when they are accurately banded on the row, applied in small amounts frequently (monthly or more often) and watered in via irrigation or rainfall. Armour et al. (2014) found surface applications of fertiliser, if managed correctly, can have DIN losses just as low as those from fertigation.

Slow release and Enhanced Efficiency Fertilisers - Similar to other Wet Tropics agricultural industries, there are trials in progress for these enhanced efficiency fertilisers (EEF) or slow release fertilisers. There is potential for reduction of N losses if they are effective in delivering N over longer time period and when the crop needs it most. EEF fertilisers look particularly promising for banana growers for their potential use as a wet weather fertiliser to complement fertigation of fertilisers during dry weather (Terrain NRM 2015: 46).

Options to reduce TSS include appropriately contoured banana blocks, permanent beds, grassed inter-rows and fallow management (Terrain NRM 2015). Both contoured blocks and permanent beds will help reduce sediment generation and transport during large rain events. Another method to control run off water is constructed wetlands, which can have a significant impact on reducing sediment and nitrogen losses (Department of Environment and Heritage Protection 2013). These options are largely targeted at controlling run off water at the paddock scale. There are currently gaps in knowledge to directly address specific practices occurring within paddocks that may be contributing to sediment and water flows, such as wheel traffic in the inter-row which can create sediment losses once wheel ruts form.

According to Reef Rescue data, 95 per cent of banana grower's applications for water quality grants were to maintain grassed inter-rows, over the initial five year round (Terrain NRM 2015). In their research, Daniells and Armour (2003) found that grassed inter-rows minimise erosion, leaching and denitrification losses. While grassed inter-rows have been shown to reduce fine suspended sediment (FSS) delivery by up to 60 per cent in plot level trials (Roebeling et al. 2007), Armour et al. (2013b: 2) have noted that they can be 'difficult to maintain in ratoon crops because of constant traffic and increased shading'.

4.2 Existing and past policy to promote adoption for water quality improvement

Policy promoting adoption of management practices for water quality improvement has included a mix of regulation, financial incentives, monitoring, extension and education on improving land management practices on farms in GBR catchments. The Great Barrier Reef Water Science Taskforce has recently released its review into policy mechanisms to deliver on both the Reef Water Quality Protection Plan and the Reef 2050 Long-Term Sustainability Plan water quality targets and has reiterated that a mix of policy tools will be required, however, a greater focus on innovation, education support for farmers and expanded monitoring of water quality has been recommended in the allocation of $90 million dollars over the next four years (Queensland Government, 2016).

4.2.1 Legislation

Legislation that the Queensland Government has implemented for reef protection includes: the *Environmental Protection Act 1994* and the *Chemicals Usage (Agricultural and Veterinary) Control Act 1998.* These two acts were amended by the *Great Barrier Reef Protection Amendment Act 2009* which does not currently apply to banana farmers, but does specify management practices for sugar cane growing and cattle grazing in the GBR catchments.

4.2.2 Reef Water Quality Protection Plan

In 2003, the Reef Water Quality Protection Plan (Reef Plan) was released to the public for discussion, which resulted in revision and endorsement by the Great Barrier Reef Ministerial Council. Since then there have been two more iterations of Reef Plan endorsed by the Australian and Queensland Governments, in 2009 and 2013. In 2007, a Reef Water Quality Partnership was established between five NRM bodies, the national and state governments to facilitate collaboration in target setting, monitoring and reporting arrangements.

Reef Plan 2013 includes 46 deliverables under nine key action areas: two of these action areas (Action Four and Action Five) focus on agriculture management practices. Action Four is about increasing understanding of farm management practices and systems, economics and water quality benefits. The first deliverable under Action Four is *to review existing commodity specific management practices and identify the most critical, cost effective and profitable management practices and systems*. The second deliverable is *to use this information to prioritise investment of the most critical, cost effective and profitable practices and systems at a catchment scale.*

Action Five is to deliver targeted and coordinated extension, BMP and incentive activities to maximise uptake of management practices and systems. The first deliverable is *to update the Extension and Education Strategy in light of best available science and new and emerging initiatives*. The second deliverable is *to formalise a ReefNet network of catchment, regional and reef-wide groups to share information and facilitate coordination of activities*. The third deliverable is *to work with industry and government to ensure that activities such as extension, incentives and best management practice are targeted and coordinated at the regional level to help accelerate long-term management system change*. The final deliverable is *to develop and implement best management practice programs for sugarcane and grazing and continue the horticulture, grains and cotton best management practice programs*.

The Australian Government Reef Programme (formerly Reef Rescue) provides incentives to encourage adoption of improved practices. These incentives are administered through the GBR NRM bodies as Water Quality Grants and are accessible to landholders in GBR catchments to commence improved management practices.

Eberhard Consulting (2011) reported feedback from twenty-five stakeholders involved with Reef Rescue who commended the program on the basis of the relative size of the investment, the flexibility of the grants model to suit regional contexts, the duration of the commitment of the program, the effective collaboration between NRM groups and industry, and its clearly articulated and ambitious targets. On the other hand, the report identified shortcomings in relation to the complexity in the contractual basis and administration of the program, the lack of established reporting standards from the outset, the conflict between accountability and collaboration, and significant coordination costs.

4.2.3 Paddock to Reef monitoring program – Reef Report Cards

The fundamental apparatus for tracking performance against the goals of Reef Plan is the Paddock to Reef Integrated Monitoring, Modelling and Reporting Program (Paddock to Reef Program). The Paddock to Reef program is intended to deliver an impartial, collaborative and ongoing assessment of catchment and GBR water quality and marine ecosystem health which it does through the Reef Report Cards (Queensland Government, 2015b). It is charged with monitoring, modelling and reporting on a range of management practices and water quality aspects from both an environmental and economic standpoint. It operates across several levels including the paddock, sub-catchment, catchment and also neighbouring marine areas. Reef Report Cards have been released since the year 2009 (baseline), indicating progress towards water quality targets set out in Reef Plan with the 2015 report card due to be released in 2016 (Queensland Government, 2015b).

4.2.4 Reef 2050 Long-Term Sustainability Plan

The Reef 2050 Long-Term Sustainability Plan, released in 2015, is now the overarching framework for the protection and management of the GBR. As well as incorporating the Reef Water Quality Protection Plan, the Reef 2050 Long-Term Sustainability Plan also addresses six other themes of biodiversity, ecosystem health, heritage, community benefits, economic benefits and governance. Its vision is to ensure the GBR continues to improve on its Outstanding Universal Value every decade between now and 2050 to be a natural wonder for each successive generation to come. To facilitate this it has also included an investment framework to facilitate public and private investment to maximise reef outcomes (Australian Government, 2015b).

The Reef Trust ($140 million over four years) is a critical component of the Reef 2050 Long-Term Sustainability Plan and provides cost effective and strategic investment to address key threats. To date there have been three investment phases which have included targeting the following water quality improvement key actions: promotion of A-class grazing management practice; controlling crown-of-thorns starfish; gully erosion control; coastal habitat and wetland rehabilitation; maintaining water quality improvement momentum in grains, dairy and horticulture; reducing erosion losses from rangeland grazing; supporting cane farmers to move beyond industry best practice and tenders in the Wet Tropics and Burdekin regions (Australian Government, 2016b).

Reef Plan Action Four of the Reef 2050 Long-Term Sustainability Plan requires the Queensland Department of Agriculture and Fisheries (DAF), as well as the local and federal government agencies, to implement innovative management approaches through the Reef Trust for improving water quality (Australian Government, 2015b).

4.2.5 NRM water quality frameworks for management practices

NRM bodies have developed a management practice framework of Aspirational, Best, Conventional and Dated (ABCD) practices to classify regionally specific management practices for industries in their catchments. These frameworks assist in identifying land management practices that maximise water quality improvements. The ABCD framework categorises farming practices on a scale of improvement from ‘outdated’ to ‘cutting edge’ practices based on their water quality outcomes. Terrain NRM has developed an ABCD framework for banana growers in the Wet Tropics region (see Appendix 1) based on the industry’s own BMP guidelines. It is intended to be a guide for banana growers applying for funding under the Australian Government’s Reef Rescue program to adopt improved farming practices. The ABCD framework hence provides a basis for identifying practices for project consideration.

5 Adoption of management practices

5.1 Theoretical concepts of the adoption process

Adoption of improved management practices, new technologies and innovations is a complex process that can take many years. Providing funding to support the process is no guarantee that it will occur, especially if the targeted management practices do not align with grower values or are not perceived as providing a relative advantage over their current farming system given its specific biophysical and enterprise characteristics. In his work investigating the diffusion of innovations, Rogers (2003) specifies that relative advantage, complexity, observability, trialability and compatibility are perceived characteristics of an innovation that, after extensive investigation, have been found to explain about 50 per cent of the variance in the rate of innovation adoption. Relative advantage is the perceived net benefit to be gained by adopting an innovation relative to the practice it supersedes. Building on Rogers’ (2003) work, Pannell et al. (2006) brought together the extensive collection of research through a cross disciplinary approach and has identified that improved management practices for conservation outcomes are more likely to be adopted by rural landholders if they are perceived to have a relative advantage (particularly economic), are readily trialable as well as being consistent with their personal goals (economic, social and environmental).

Pannell et al. (2006: 1408) also highlight that adoption is a learning process which can be divided into ‘collection, integration and evaluation of new information to allow better decisions about the innovation’ stage and a learning by doing stage where ‘improvement in the landholder’s skills in applying the innovation to their own situation.' People learn in different ways, have different preferences for interacting with information providers and have specific requirements in terms of the characteristics of their property, their farming enterprise and their personal values. Different avenues for conveying information about management practices may include such things as websites, fact sheets, field days, farm visits with a grower group, one on one with an agronomist or NRM officer or using a decision support tool to work through stylised scenarios representative of their situation.

5.2 Adoption of best management practices by banana growers

The Queensland Audit Office released its report Managing water quality in the Great Barrier Reef catchments in June 2015 and found that the horticultural industry had achieved 59 per cent of the land and catchment management targets by 2013 (80 per cent of landholders in agricultural enterprises will have adopted improved soil, nutrient and chemical management practices). More recently, the Reef Report Card (September 2015) measured the percentage area of banana growing lands in the Wet Tropics were managed using best management practice systems as at June 2014 as 52 per cent for nutrients and 53 per cent for soil. The target is 90 per cent across pesticides, nutrients and soil practices by 2018, as set out in the most recent Reef Plan (2013).

Studies on adoption of best management practices in the Great Barrier Reef catchments have mainly been confined to the grazing and sugarcane growing industries (e.g. Greiner and Gregg 2011; Thompson et al., 2014). In 2007 a survey was undertaken amongst rural landholders in the Wet Tropics region with the purpose of investigating 'key social and economic issues affecting landholders decision making in regard to the use of natural resource management practices and to examine landholders' adoption of and attitudes toward selected currently recommended practices by various industries' (Emtage & Reghenzani, 2008: 1). The survey collected 320 responses, of which 128 were classified as cropping, of which nine responses were from banana growing enterprises that covered a total area of 151 hectares and an average enterprise size of 16.8 hectares (Emtage & Reghenzani, 2008:20). While the participation rate of banana growers in this survey was too low to draw any inferences from the pooled results around adoption of management practices for the banana industry in the Wet Tropics, there were specific industry questions around nutrient use.[5] Banana growing enterprises surveyed reported applying a mean of 190 kg/ha/year of Nitrogen, 32 kg/ha/year of Phosphorus, 384 kg/ha/year of Potassium and 511 kg/ha/year of other nutrients (Emtage & Reghenzani, 2008: 26). However, the range of nutrients between the six banana growing respondents that answered these questions in the survey was quite large with minimum (maximum) of 30 (500) kg/ha/year for Nitrogen, 30 (1000) kg/ha/year for Potassium and 0.4 (2000) kg/ha/year for other nutrients.

5.3 Decision support tools

There are a number of Decision Support Tools (DSTs) available in the banana industry to support the adoption of improved management practices. DSTs are typically a computer program or application that analyses data and presents it so users can make decisions more easily. DSTs can be utilised over a wide range of economic and environmental areas. There are some DSTs that are designed specifically for banana farming and many others are general tools that can be incorporated into banana farming. The DSTs in Table 1 cover economic and management aspects: Best Management Practice, Gross Margin (GM), Whole of Farm (WOF) analysis and irrigation. The DSTs in Table 2 cover environmental aspects: panama disease, model simulation, reef report card, climate and soil.

[5] Findings from the survey for cropping enterprises, of which banana growing accounted for seven per cent, included (Emtage & Reghenzani, 2008: 4)[5]: over 80 per cent of respondents supported the statement that reduced tillage improves soil health and reduces erosion; approximately half of the respondents agreed that reduced tillage increases the need for herbicides; nearly 80 per cent of respondents think that the high cost of new machinery constrains practice change; in general, respondents reported that the use of the recommended practices surveyed would increase in the future; approximately 18 per cent of irrigators reported using their irrigation set up to apply fertiliser and less than 10 per cent reported using an automated irrigation control system.

Table 1 **Economic and Management DSTs relevant to the banana industry**

Best Management Practice	Gross Margin	Whole Of Farm	Irrigation
Banana Best Management Practices- national guideline to encourage continual improvement and adoption of best practice throughout the banana industry.[1]	*Cavendish Gross Margin –* excel spreadsheet. Farmer may be better able to identify areas within the business where the margins can be improved.[5]	*Cavendish Whole Of Farm –* excel spreadsheet, attempts to capture whole farm profit and cost to work out NPV, IRR.[a, 5]	*EconCalc –* online calculator for irrigation systems that generates improved efficiency, present value, annuity, IRR and benefit/cost ratio etc.[8]
Bananaman – currently in development, helps banana growers improve the management of crop nutrition.[2]		*Ladyfinger Whole Of Farm -* excel spreadsheet, attempts to capture whole farm profit and cost to work out NPV, IRR etc.[6]	
Best Management Practices app – currently in development, will give growers quick and easy way to record and manage information about farm practices.[3]		*Trellis Economic Analysis Tool -* excel spreadsheet, examines the profitability of trellised relative to conventional tree cropping systems. Although not specific to Banana production, the method of evaluation may help with banana economic analysis.[7]	
Improved Practices Catalogue (IPC) - hosted by DAF, aimed primarily at extension officers and exists for grazing, sugarcane and bananas. Banana IPC provides information to identify and adopt BMP's and covers nutrient rate and application, pesticide use, soil retention and water infiltration.[4]			

Modified from: [1] King, N (2008). [2] Armour, Mortimore, Pathania, Wiltshire, Daniells, Masters & Reghenzani (2014). [3] Miles, S (2015). [4] See Appendix Two. [5] Johnstone, B (1998). [6] Hinton, A (2001). [7] DAFF (2012). [8] Knowledge Management System for Irrigation (2007).

Notes: a See section 2.4 on page 16 for definitions of NPV and IRR.

Table 2 Environmental DSTs relevant to the banana industry

Panama TR4	Model Simulation	Reef Plan	Climate	Soil
Biosecurity checklist - will help identify the effectiveness of farmers' current practices.[1]	Agricultural Production Systems Simulator (*APSIM)* - results are determined by soil factors, management factors and environmental factors.[2]	*MCAS-S* - used for spatial information assessment, conveying complex information in a readily understood manner.[4]	*HowWet?* - uses farm rainfall records to estimate plant available water, nitrogen mineralisation and erosion.[6]	*SCAMP* - used to develop nutrient and soil management practices that will assist in minimising off-site losses.[11]
Surveillance app - rapid collection and analysis of surveillance data in the field and on-the-spot decision making.[1]	*HowLeaky* - examines the impact of various land uses and soil management on water quality. The results of these analyses will identify those practices which are likely to maintain or improve farm profitability as well as water quality.[3]	*INFFER* - used for developing and prioritising projects designed to address environmental issues.[5]	*Southern Oscillation Index (SOI) values* - provides a seasonal climate outlook by giving an indication of the development and intensity of El Niño or La Niña events in the Pacific Ocean.[7]	*soilMapp* - app that provides access to available soil and land information which can assist with improved land management decisions.[12]
			Climate ARM - provides the ability to analyse rainfall and other climate variables at individual locations and taking into account seasonal patterns and forecasts.[8]	
			Bureau Of Meteorology climate - view daily and monthly statistics, historical weather observations, rainfall, temperature and solar tables, graphs and data.[9]	
			Rainman streamflow - helps farmers to predict rainfall at a specific location within a specified time period.[10]	

Modified from: [1] Biosecurity Queensland, (2015). [2] CSIRO, University of Queensland, DAF (2015). [3] McClymont (2011) [4] ABARES (2015a). [5] University of Western Australia and Natural Decisions Pty Ltd. (2015). [6] Freebairn, Hamilton and Cox (1994). [7] Queensland Government (2015a). [8] DAFF (2013). [9] BOM (2015a). [10] Grains Research & Development Corporation (2014). [11] Moody and Cong (2008). [12] CSIRO, DAF, Geoscience Australia (2015).

6 Review of economic studies involving management practices on banana farms

Despite the focus on improving water quality from agricultural land in the GBR catchments over the past ten years, banana growing has a noticeable lack of published reports on the economic implications of shifting to improved management practices. For this initial synthesis report we have found just four studies that have included an economic analysis of moving to specific management practices with improved water quality outcomes (Armour et al. 2013; Anonymous 2013; Roebeling et al. 2007) or a farming system that incorporates a number of improved management practices (Poggio & Van Grieken 2010). Table 3 below provides an overview of these studies and a more detailed review of the economic findings from these studies follows.

Table 3 Summary of economic analysis on Banana BMPs

Author	Year	Location	Practices	Methodology
Roebeling, Webster, Biggs and Thorburn	2007	Tully Murray Catchment	Grassed vs Bare inter-row management Fertiliser Application rate	Undertaken at the plot level Production simulation model LUCTOR, Hydrological model SedNet/Annex and cost-benefit economic analysis,
Poggio & Van Grieken	2010	Wet Tropics	Shift from D to C, C to B and B to A practices modelled (see Table 6)	Net Present Value of shifting from a one class of practices to another over 5 and 10 year period. Whole of farm gross margins and transition capital costs estimated for a representative enterprise of 60 ha. PiRisk used to analyse impact of uncertain parameters.
Anonymous	2013	Between Innisfail and Tully	Environmental code of practice (Freshcare), GrowCom FMS, composting, reduced tillage, reduced and more targeted pesticides, soil and leaf analysis, fertigation and foliar application, machinery to minimise compaction, monitoring soil moisture, slashing rather than spraying inter-rows, longer crop cycles, minimum traffic in wet season, harvest low lying areas before wet season	Case study – estimation of Net Present Value of change in farming system for a 60 ha farm
Armour, Masters and Mortimore	2013	South Johnstone	B vs C practices: Fortnightly fertigation vs monthly broadcasting onto mounds Rate adjusted according to expected growth – 150 kg/ha/year plant and 250 kg/ha/year ratoon vs constant rate of 250 kg/ha/year plant and 375 kg/ha/year Inter-row groundcover – grassed vs bare	Partial economic analysis completed on savings in nitrogen applied and reduced use of tractor and fertiliser spreader for B practice (method and rate of fertiliser application)

In their study, Roebeling et al. (2007) simulated the impact on fine suspended sediment (FSS) and dissolved inorganic nitrogen (DIN) of adopting managed grassed inter-rows and matching fertiliser rates to crop requirements. They used the LUCTOR crop growth model to estimate changes to crop production, SedNet/Annex hydrological model to estimate the downstream delivery of sediments and nutrients and a cost-benefit approach to estimate the cost-effectiveness of each management practice modelled at the plot level (i.e. these estimates do not include implementation costs at the farm level).

Plots over three different soil types had gross margins for grassed inter-rows less than bare inter-rows by between three and nine per cent. In contrast, the grassed inter-rows reduced the amount of FSS at the plot level by 60 per cent compared with bare inter-rows while there was no impact on DIN delivery (Roebeling et al., 2007:16). In the fertiliser application trials, application rates ranged from 20 per cent to 100 per cent of the application rate required to realise maximum attainable yield. Results from these trials found that FSS declined marginally as fertiliser rates increased due to increased plant growth, canopy cover and crop residue cover while DIN increased considerably, although not equally across all soil types. The largest gross margins were attained at the 100 per cent application rate required for maximum attainable yield at N, P and K rates of 308 kg/ha, 21 kg/ha and 728 kg/ha respectively (Roebeling et al., 2007: 17).

Poggio and Van Grieken (2010) found in their analysis of implementation costs and benefits for management practices that the transition to C and B-class practices is worthwhile for banana growers but not to A-class practices. The transition to A-class practices required large capital investment in irrigation systems (167 per cent greater than that for B-class – see Table 4) and there was a small decline in whole of farm gross margins relative to B-class practices due to the additional costs of composting green waste and spreading in the field offsetting the reduction in irrigation and fertiliser costs (Poggio & Van Grieken 2010). The B-class irrigation system modelled in this analysis invested in an under canopy system and tensiometers to monitor soil moisture and A-class irrigation required investment in automated drip irrigation with fertigation capacity with scheduling based on EnviroSCAN soil moisture probes.

The methodology used in this study involved the authors determining steady state gross margins, capital requirements and a NPV analysis for transition to the next level of farming system. On the water quality modelling, there was no indicator included for bananas as at that time there was no accurate production simulation model available for banana growing.

Specific results from the Poggio and van Grieken (2010) study into banana management practices from the year 2008 are listed below in Table 4:

Table 4 2008 Banana Management Practices

Farming system	Farm GM/ha	Change in farming system	Capital Cost of practice change	NPV: 5 yr (10 yr)
A	$10 635	B to A	$420 000	-$422 748 ($-424 707)
B	$10 646	C to B	$157 021	$474 475 ($925 185)
C	$8 078	D to C	$0	$759 044 ($1 300 233)
D	$4 993	-	-	-

Modified from: Poggio & van Grieken (2010:7, 9, 10)

The management practices considered in the estimation of these gross margins and capital costs are listed below in Table 5. It is worth noting that these practices were based on the Banana ABCD management practice framework for water quality improvement developed in 2007/08 by the Wet Tropics NRM group and there has been very little change in practices in these categories between then and 2015 (see Appendix 1 for comparison).

Table 5 Management practices considered for analysis

Transition	Management practices
D to C	Avoid cultivation during high risk (heavy rainfall) periods. Use of soil and leaf testing (one test per year). Reduction in fertiliser rates (based on historical rates). Fertiliser applied less frequently and on a calendar basis. Spray equipment calibrated. Trash kept but left where it drops. Overhead sprinklers used for irrigation. Irrigation application varies with crop stage only with scheduling based on subjective tools.
C to B	Spray-out fallow with reduced cultivation. Fallow legume crop to improve soil health. Laser levelling used where appropriate. Use of soil and leaf testing on blocks to be planted. Reduced rate of fertiliser according to recommended rates. Shift towards the use of fertigation, banded surface application and soil ameliorants. Banana waste returned to paddock, leaf mulch kept on beds. Chemical application based on monitory and equipment calibrated. Reduction in the use of residual herbicides. Insecticides and fungicides application is based on monitoring. Irrigation scheduling based on tensiometers. Manually operated irrigation system under canopy irrigation.
B to A	Zonal tillage used for planting preparation, tillage only on the bed area. Fallow crop to improve soil health. Controlled traffic with machinery. Soil and yield mapping. Soil and leaf testing on a regular basis. Slashing of inter-row and ground cover maintained. Leaf mulch composted and returned to paddock. Use of knockdown herbicides instead on residuals. Automated drip irrigation with fertigation capacity and scheduling based on EnviroSCAN. Monitoring of water quality.

Source: Poggio and van Grieken (2010).

Armour et al. (2013b) looked at a number of B and C-class management practices over two adjacent treatment plots in South Johnstone. Practices on the B-class plot include: fortnightly fertigation, fertiliser rates adjusted according to the expected growth rate for the following fortnight (N rate capped at 150 kg/ha/crop cycle for plant and 250 kg/ha/crop cycle for ratoons) and grassed inter-rows. The practices on the C-class plot include: monthly broadcast of fertiliser onto the mound between the double rows of bananas, constant rate of urea and potassium chloride (N rate capped at 250 kg/year for plant and 375 kg year for ratoons) and bare inter-rows. Trials were conducted on Dermosol soil and irrigated by under tree mini sprinklers. The results found that the cost of Nitrogen fertiliser under B-class management practices was $145 per hectare less for the plant crop and produced similar yield, fruit characteristics and follower sucker growth to that achieved under C-class management practices (Armour et al., 2013b). Results on FSS and DIN from the two sites were not discussed in the case study but were reported to be measured as part of ongoing monitoring of the site.

A case study on a banana farm between Innisfail and Tully that implemented a number of improved management practices including: monitoring to identify water and nutrient needs, fertigation, reduced tillage, slashing rather than spraying rows and minimising traffic during the wet season (Anonymous 2013). A cost benefit analysis comparing the management systems found that the shift to improved management practices will translate to an annualised net present value of $160 000 (Anonymous 2013). Specifically:

- 30 per cent reduction in the use of granular fertilisers, saving $1900/ha/year by moving to fertigation
- Save $40/ha/year in irrigation costs from water monitoring
- Ripper and plough used 60 per cent less, saving $660/ha in site preparation costs
- 50 per cent reduction in herbicide use, saving $200/ha/year in herbicides from having grassed inter-rows.

Capital costs incurred with making the change to improved management costs included new irrigation system to facilitate fertigation, soil analysis and water monitoring equipment and a slasher to maintain grassed inter-rows. There are also ongoing costs associated with identifying plant nutrient requirements, liquid fertilisers and labour and maintenance. The case study did not specify the interest rate or the number of years that the net present value was calculated for. While the expected environmental benefits of adopting the improved management practices were listed, no monitoring of the impacts on FSS or DIN from adopting these practices was undertaken.

While not economic studies on the implementation of management practices for improved water quality, the *Tropical banana information kit* by Lindsay et al. (1998) and the spreadsheets by Bill Johnston (1998) and Andrew Hinton (2001a,b) provide some insights into the farming systems for Cavendish and Lady Finger bananas in north Queensland. These spreadsheets provide a snapshot in time of the practices and inputs that were used in the banana growing industry prior to the first Reef Plan.

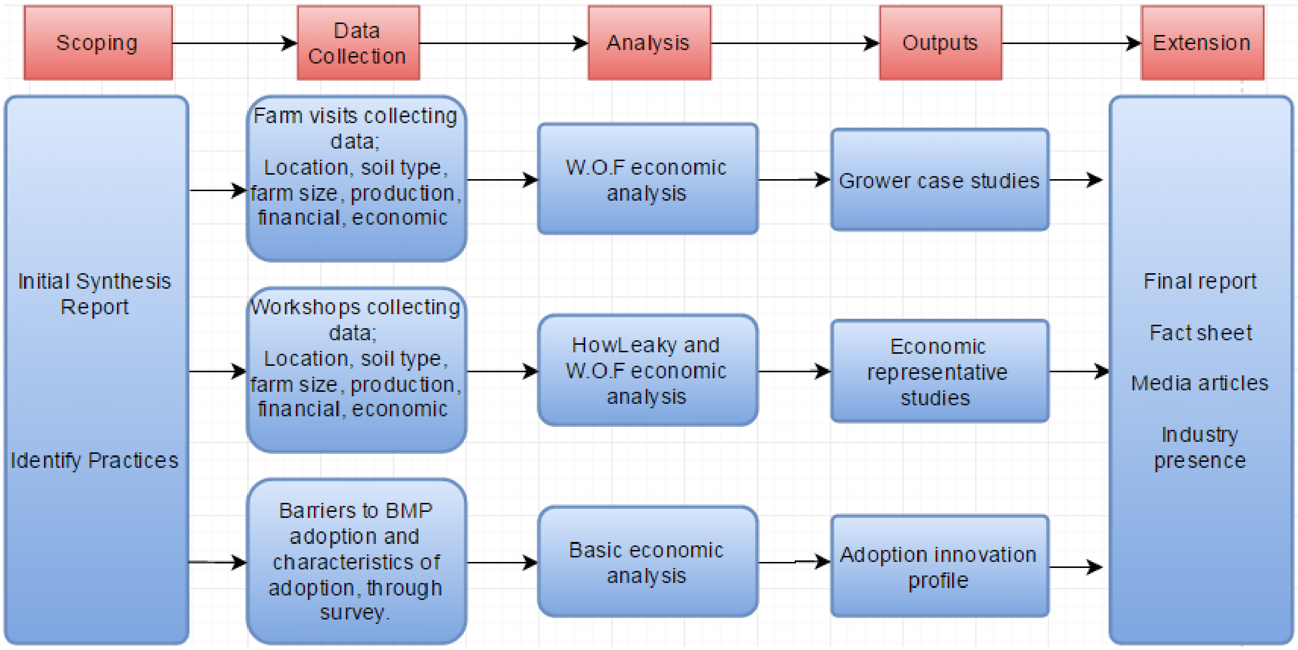
7 Scope of the economic research project

7.1 Planned economic analysis

The planned economic analysis includes grower case studies, economic representative studies and water modelling from practice change at the farm scale. The data collected for these analyses will be financial and economic information (section 2.4.2.) and farm specific information. Enterprise heterogeneity will be addressed by taking farm specific information into account, such as: the location, farm size, major soil types and the relevance of various management activities to each of the two identified regions. The project will ascertain landholder costs of changing management practices and measures the impact on water quality for the two main banana growing regions. The methodology of the RP140B project is illustrated in the framework presented in Figure 10.

The project will include grower participation through case studies, interaction at workshops and surveys to source real practice-related data. The financial economic data will be analysed using DAF tools (e.g. Banana production spreadsheets, NPV and risk analysis) and incorporate the results of long-term biophysical data from research trials and other available literature on relevant management practices.

Figure 10 Framework of the RP140b project



Past economic studies undertaken in the sugarcane industry have utilised the Agricultural Production Systems Simulator (APSIM) to estimate the biophysical results (e.g. yield) from a change in management practice. An APSIM banana module was recently created for the Paddock to Reef program to model the bio-physical and water quality effect of management practices in the banana industry in 2014. The banana module was developed through a combination of using published and unpublished data and field experimentation at South Johnstone Research Station. Due to being in its infancy, this project will not be using the APSIM banana module due to concerns about its validity, in particular the accuracy of modelled production data corresponding with a change in management practice. It simulates banana phenology for a point (equivalent of a single plant) and models the average phenology, however, banana plantations have a spread of flowering time, which can be over a number of months (Australian Government, 2015c). In addition, it is likely that the management practices evaluated will not conform to the APSIM model parameters.

The HowLeaky model (a model used to examine the impact of various land uses and soil management on water quality) will be used to determine the water quality implications from a change in management practices. Outputs from HowLeaky will include the water balance, runoff losses in sediment, DIN, TN, TP and DIN in deep drainage. The results of these analyses will identify those practices which are likely to maintain or improve profitability as well as water quality.

The perceived relative advantage and ability to trial improved management practices will also be identified to gain a better understanding of barriers to the adoption process. Profiling the management practices will also enable matching to landholder risk profiles and suitable policy mechanisms. The output will include decision support information at the landholder scale and will assist farmers in their decision-making process with regard to improving management practices.

7.2 Site selection

The focus of this project is to identify profitable banana management practices that result in water quality improvement in the Wet Tropics region. Specifically, the focus is on two core banana-growing centres within this region: Tully and Innisfail (covering South Johnstone to Babinda). Together, these regions make up the majority of the total banana growing area in the GBR catchments. These two areas were chosen because of high production concentration and the volume of previous work undertaken in these areas.

In reference to Table 6 below, there are minor regional variances overall, most likely due to the geographical proximity of the two regions, however, average farm size is much higher in Tully.

Table 6 Key business characteristics of regional banana growing centres

Regional Characteristics	Tully	Innisfail (South Johnstone to Babinda)
Average annual rainfall townships (mm/yr)[a]	4116.6 (Tully Sugar Mill) Years 1925-2014	3565.8 (Innisfail) Years 1881-2014
Mean max and min temperature (˚C)[a]	Mean max 28.7 Mean min 18.9 (Cardwell) Years 1907 - 2015	Mean max 28.0 Mean min 19.4 (Innisfail) Years 1908 - 2015
Predominant soil types[b]	Floodplain - light to medium alluvial clays (Tully)	60% - light to medium alluvial clays 40% on Slopes - basaltic krasnozem soils (Innisfail)
Average banana farm size (ha)[c]	83.4 2010-11	34.1 2010-11
Average Banana yield (t/ha) Range[c]	23.6 19.2 – 28.6 2007-08 to 2013-14	24.4 19.9 – 29.6 2007-08 to 2013-14
Average Production (t) Range[c]	122792 92397 - 155427 2007-08 to 2013-14	92062 69274 - 116530 2007-08 to 2013-14

Source: [a] Australian Government, (2015a).
[b] Australian Government, (2008).
[c] Australian Bureau of Statistics, (2016a).

Three growers will be selected for a case study analysis according to the project selection criteria. Insofar as practical, case study selection will be made according to the following criteria:

1. Growers who are willing participants in the project (i.e. willing to provide production data, economic data and consent for case study publication).
2. Growers who have made a change to Banana BMP's, preferably within the last 5 years.
3. Growers with detailed and accurate knowledge of their past and current farming system.
4. Farms from either Innisfail or Tully regions, ideally representing a cross section of business variability (e.g. farm size, location).

Representative economic analyses will also be undertaken for banana growing enterprises of various sizes for the Tully and Innisfail regions.

7.3 Practice selection

The banana industry BMP framework contains 24 categories and 83 key principles (which then have 'best, okay, improve' classified practices within them – see Appendix 3) and the Terrain NRM ABCD Management Practice Framework has five categories and 23 key principles (which then have 'A, B, C and D' classified practices within them – see Appendix 1). To help identify suitable banana growers for the case studies and narrow down the range of practices that will be modelled in the representative economic analyses, priority rankings from Terrain NRM, Paddock to Reef Program and from DAF extension officers as well as advice from hydrology modellers was used to come up with the list of practices to consider for economic analysis in Table 7 below.

Table 7 Practices to be considered for economic analyses

Key Principle/ Indicator	Practice description by Terrain NRM Practice Description by P2R (in light blue text) where different to Industry BMP/Terrain NRM	Terrain NRM [1] and P2R classes
Soil management – crop destruction **Crop removal**	The banana crop is removed by treating with herbicide and plants are left to break down before cultivation. Banana crop is killed with herbicide and plants are left to break down in the row area before cultivation.	B Moderate to Low Risk
	The banana crop is removed by mechanical practices with minimal soil disturbance e.g. light discing / mulching.	C Moderate Risk
Soil management - Land preparation **Tillage – plant crop**	Pre-formed beds using GPS & zonal-tillage. Crop planted into permanent beds. Row area only receives minimum tillage necessary for establishment.	A Moderate to Low Risk
	The row only is cultivated at the times of the year when the risk of erosion is low. Minimum tillage of whole block area, with row area only subject to more cultivation necessary to establish row profile and plant.	B Moderate Risk
	The whole block is cultivated at the times of the year when the risk of erosion is low.	C
Controlling run-off water - Slowing water	All blocks have been designed to slow surface water and direct it to an appropriate waterway capable of carrying high velocity water. Blocks are laser-levelled where required to prevent water from collecting in the paddock and creating wet areas.	B
	Most blocks have been designed to slow surface water and direct it to an appropriate waterway, although some corrective work is still required.	C
Controlling run-off water – contouring	If the farm has areas under banana production with a gradient over 3%, all blocks have been planted along the contour and include diversion banks and constructed waterways which have been accurately surveyed. For gradient over 3% ALL blocks planted on the contour and incorporating diversion banks and constructed waterways.	B Moderate to Low Risk
	If the farm has areas under banana production with a gradient over 3%, most blocks have been planted along the contour and include diversion banks and constructed waterways. For gradient over 3% MOST blocks planted on the contour and incorporating diversion banks and constructed waterways.	C Moderate Risk
Fallow/Crop rotation	A planted fallow crop is grown between banana crop cycles, on all fallow land for a minimum of 12 months. Fallow crop is planted between banana crop cycles or a volunteer grass fallow is maintained between crop cycles.	A Moderate to Low Risk
	Either a grass fallow or a planted fallow crop is grown between banana crop cycles on all fallow land (for less than 12 months).	B
	A weedy fallow grows between banana crop cycles.	C Moderate Risk
Ground cover	(i) At least 60% living ground cover is achieved in areas such as the inter-row space and headlands, excluding major roadways. OR (ii) In very dry areas only, where inter-row cover would have to be	B Moderate to Low Risk

	watered and where plant waste does not break down readily, greater than 60% inter-row ground-cover is achieved by retention & mulching of banana wastes. Living ground cover is maintained in the inter row space and headlands.	
	At least 60% ground cover is achieved by a combination of living & dead matter in areas such as the inter-row space and headlands. This includes mulching banana plant material in the inter-row space, excluding major roadways. Living or dead, at least 60% cover is maintained in inter-row space and headlands.	C Moderate Risk
Nutrient application method	All fertigation, or a combination of fertigation and banded surface applications is used depending on the weather conditions.	B
	Banded surface fertiliser applications to rows only.	C
Fertiliser application frequency	Aim is to apply fertilizer fortnightly during high growth periods and reduce this during low growth periods such as winter. Weather conditions may mean that this is not always possible.	B
	Aim is to apply fertiliser monthly all year round.	C
Fertiliser program – nutrient budgeting	The fertiliser program **is** based on recommended rates for nitrogen and phosphorus.	B
	The fertiliser program **is not** based on recommended rates for nitrogen and phosphorus.	C
Fertiliser program – nutrient rates	The fertiliser program is supported by soil and leaf testing and yield monitoring. The program is revised annually and checked to ensure targets are updated and actually applied.	B
	The fertiliser program is supported by frequent soil and leaf testing and yield monitoring.	C

Source: compiled from Sing and Barron (2014) and Queensland Government (2015c).

Notes: 1.Terrain NRM code: A: aspirational practice; B: best practice; C: conventional practice and D: dated practice. Terrain NRM management practice classification almost identical to that of the Industry Best Management practice coding of best, okay and improve where Terrain NRM B, C and D class practices often the equivalent to industry best, okay and improve respectively. The P2R code: MR: moderate risk; MLR: moderate to low risk. Practices with no P2R code are not included in the P2R Water Quality Risk Framework.

7.4 Planned extension of results

Extension of results is an integral component of this project, with extension activities and outputs explicitly accounted for throughout the project as results are generated rather than post project completion. The extension of the results of this project will provide the RWQ program, ABGC, extension providers, Panama Taskforce and banana growers with greater confidence as to the likely water quality, profitability and productivity benefits of the various management practice options of the Banana BMP. Extension assists farmers in identifying which practices they may want to implement first or which practices will have the greatest impact on water quality (and incidentally – quarantine) for priority of implementation.

The project will produce the following extension outputs:

Case study results — design of extension material for communication of findings from the case studies will occur as soon as the economic analysis is completed with extension of the case study's findings following shortly afterward. Extension of the economics of the BMP will be disseminated to growers through the National Banana Development and Extension Program, which is run by the ABGC. This includes using existing banana grower networks including BAGMan, NextGen and local grower associations. The program has a national roadshow series planned for June/July 2016 and if there are adequate results available by this time there is the opportunity to make information available at these events. When results are available they will be published in the Australian Bananas Magazine, as well as in e-bulletins and newsletters, to ensure that the information is reaching growers.

Final synthesis report — the results presented in the final synthesis report will be communicated to Wet Tropics banana growers and key industry stakeholders by the project team in two ways: 1) The publication of the technical paper; and 2) Training workshops to extension providers to up-skill their knowledge of economic principals and present findings from the project.

Adoption innovation profile report — this report will identify perceived relative advantage and trialability of management practices, any barriers to adoption and possible mechanisms to improve adoption by growers as well as assisting extension officers in the tailoring of information to particular grower requirements.

Regional summary fact sheets — the findings from the economic and water quality evaluation will be developed into regional summary fact sheets. These fact sheets will be targeted at extension officers and growers.

8 Summary

There are a number of key findings from this initial synthesis report. First, the economic research presented here indicates that over the past decade the banana industry has experienced a number of events that have had negative economic ramifications. The banana growing regions of Tully and Innisfail were severely impacted by tropical cyclones in 2006 and 2011 with many plantations' production severely impacted in the months afterwards. There is also the recent discovery of Panama TR4 in the Tully region which has resulted in significant investment in farm biosecurity measures to prevent pest and disease incursion across the entire Wet Tropics region.

Second, the environmental impact of banana growing practices that contribute to higher than naturally occurring levels of suspended sediments, nutrients and pesticides is of concern to industry, the broader community and government. While the focus in the past has been very much on grazing and sugarcane, the banana industry is coming under increasing scrutiny for their contribution to pollutants entering the GBR lagoon. The banana growing industry has been proactive in developing a BMP guide that specifically includes components addressing the movement of sediment, nutrients and chemicals off-farm and the Terrain NRM Management Practice and Paddock to Reef water quality risk frameworks draw heavily from this guide. While comprehensive, there are still gaps in the BMPs for water quality outcomes, such as alternatives for managing traffic in inter rows to prevent the forming of wheel ruts which contribute to sediment losses. There have been a number of studies looking at the water quality implications of management practices, particularly grassed inter-rows and fertiliser rates and application methods, however, the focus has mainly been on measuring the hydrological impacts and not quantifying the economics of moving to these BMPs for growers.

Third, there is a dearth in studies looking at the economic impacts of changing to management practices with improved water quality impacts. This review was only able to find four studies, only one of which included some estimate of the water quality impacts of implementing best management practices. The approach used by all of these studies was a cost benefit approach, although only one study specified the time frames of the estimated net present values of changing to the selected best management practices for banana growing. These studies were also of particular circumstances (one representative farm 60 ha, one case study farm of 60 ha and two trial plots of undisclosed size) and did not compare the economics of management practices when adopted by banana farms in different areas or of different size of operation. Such heterogeneity may be influential on the economic viability of particular practices and hence their perceived relative advantage over existing practices that produce sub-optimal water quality outcomes.

This project aims to contribute to the body of knowledge by undertaking economic work at the practice level, which integrates water quality data in to the analysis to identify the most cost-effective practices that achieve the desired water quality outcomes. Analysing at a practice level is beneficial in terms of being able to isolate an incremental change in management practice and its resultant impact on farm profitability, water quality and adoption characteristics. In addressing a gap in the existing economic literature on banana BMPs, enterprise heterogeneity will also be taken into account by incorporating the two main regions of banana production in the Wet Tropics, farm sizes, soil type and management practice characteristics.

9 Appendix 1 – Terrain NRM Wet Tropics Banana Management Practices

The ABCD frameworks for bananas cover: nutrient management, soil management, weed management, irrigation and integrated pest and disease management.

Table A1 Wet Tropics Practice Framework R11, Banana

R11 - Bananas	A	B	C	D	N/A
Soil Management					
BS25.0 Cultivation method and timing - crop Destruction	-	The banana crop is removed by treating with herbicide and plants are left to break down before cultivation.	The banana crop is removed by mechanical practices with minimal soil disturbance eg light discing / mulching.	The banana crop is removed by heavy discing green plant material repeatedly.	
BS1.0 Cultivation method and timing - Land Preparation	Pre-formed beds using GPS & zonal-tillage.	The row only is cultivated at the times of the year when the risk of erosion is low.	The whole block is cultivated at the times of the year when the risk of erosion is low.	The whole block is cultivated at any time of the year.	
BS26.0 Controlling run-off water - Contouring	-	If the farm has areas under banana production with a gradient over 3%, all blocks have been planted along the contour and include diversion banks and constructed waterways which have been accurately surveyed.	If the farm has areas under banana production with a gradient over 3%, most blocks have been planted along the contour and include diversion banks and constructed waterways.	The farm has areas under banana production with a gradient over 3% but there are no control structures in place.	The farm does not have areas under banana production with a gradient over 3%.
BS2.0 Fallow/Crop Rotation	A planted fallow crop is grown between banana crop cycles, on all fallow land for a minimum of 12 months.	Either a grass fallow or a planted fallow crop is grown between banana crop cycles on all fallow land (for less than 12 months).	A weedy fallow grows between banana crop cycles.	There is no fallow period between banana crop cycles or bare fallow is left between crop cycles.	
BS27.0 Riparian Vegetation	Native riparian vegetation at 20m wide for creeks and 50m for rivers along 100% of their length.	Native riparian vegetation is present at less than 20m wide for 100% of the length of all creeks and rivers.	Native riparian vegetation is present for at least 50% of the length of all creeks and rivers.	Native riparian vegetation is present for less than 50% of the length of all creeks and rivers.	No natural water ways on farm so no riparian vegetation.
BS28.0 Controlling run-off water - Silt Traps	-	Silt traps have been designed, constructed and located with expert advice and satisfactorily address the targeted sediment issue.	Silt traps have been designed, constructed and located with expert advice. , however some sediment loss indicates further work is still required.	Silt traps have been designed, constructed and located without expert advice.	No silt traps present on farm.
BS29.0 Controlling run-off water - Drains	All constructed drains on-farm (deep or shallow) are vegetated spoon shaped drains.	Most constructed drains on-farm are vegetated-shallow-spoon drains and any box drains have a batter suited to the soil type so they do not erode.	Most constructed drains on farm are box drains with steep batters & little vegetative cover.	-	No constructed drains on farm.
BS30.0 Ground Cover	-	(i) At least 60% living ground cover is achieved in areas such as the inter-row space and headlands, excluding major roadways. (ii) In very dry areas only, where inter-row cover would have to be watered and where plant waste does not break down readily, greater than 60% inter-row ground-cover is achieved by retention & mulching of banana wastes.	At least 60% ground cover is achieved by a combination of living & dead matter in areas such as the inter-row space and headlands. This includes mulching banana plant material in the inter-row space, excluding major roadways.	Areas such as inter-rows and headlands are bare.	
BS40.0 Mulching	-	Harvested heads and leaves are left on the row or in drier areas harvested heads are mulched in the inter-row space providing ground cover.	Harvested heads and leaves are left where they drop.	Harvested heads and leaves are removed from the row and placed in the inter-row space.	

R11 - Bananas	A	B	C	D	N/A
Nutrient Management					
BN31.0 Soil testing - Pre-Plant	-	100% of blocks are soil tested before planting.	Most blocks are soil tested before planting.	Soil testing before planting is infrequent or not done at all.	
BN32.0 Soil testing - Ratoons	Soil tests are taken on all blocks more than once a year.	Soil tests are taken on all blocks once a year.	Soil tests are taken less than once a year or on fewer than all blocks	No or little soil testing.	
BN33.0 Leaf Testing	-	Paired leaf and soil tests are taken on all blocks at least annually.	Paired leaf and soil tests are taken at indicator sites at least annually or tissue tests taken throughout the year but not paired with soil tests.	Leaf tests are taken less than annually or not at all.	
BN34.0 Fertiliser program – selecting nutrient types and amounts (Nutrient rates)	-	The fertiliser program is supported by soil and leaf testing and yield monitoring. The program is revised annually and checked to ensure targets are updated and actually applied.	The fertiliser program is supported by frequent soil and leaf testing and yield monitoring.	There is no planned fertiliser program and/or the rates applied are not based on soil and leaf test results.	
BN35.0 Fertiliser program – nutrient budgeting	-	The fertiliser program is based on recommended rates for nitrogen and phosphorus.	The fertiliser program is not based on recommended rates for nitrogen and phosphorus.		
BN36.0 Fertiliser application frequency	-	Aim is to apply fertilizer fortnightly during high growth periods, and reduce this during low growth periods such as winter. Weather conditions may mean that this is not always possible.	Aims is to apply fertiliser monthly all year round.	Fertiliser is applied less frequently than monthly.	
BN37.0 Fertiliser application method	-	All fertigation, or a combination of fertigation and banded surface applications is used depending on the weather conditions.	Banded surface fertiliser applications to rows only.	Fertiliser broadcast over rows and inter-row spaces.	
BN22.0 Water and fertiliser distribution efficiency	-	Water uniformity and distribution is tested and above 90%.	Water uniformity and distribution is tested and above 80% but below 90%.	Water uniformity and distribution is tested and below 80% or not tested and therefore unknown.	
Irrigation					
BN19.0 Method of Irrigation	-	100% under-tree sprinklers or drip and an automated system.	100% under-tree sprinklers or drip and a manual system.	Some overhead irrigation.	
BN21.0 Soil moisture monitoring	Irrigation schedules are based on capacitance probes and weather stations and are fully automated.	Irrigation schedules are based on capacitance probes or tensiometers and use a manual system.	Scheduling based on subjective tools e.g. feel, inspection of soil, water availability and area.		
Integrated Pest and Disease Management					
BP38.0 Pest & disease Monitoring	-	Pest and disease levels are monitored on a regular and consistent basis by trained staff or service providers. Records are retained and treatment are applied using monitoring information and relevant threshold levels for each pest/disease.	Pest and disease levels are monitored by general observations when doing other activities and control methods applied accordingly.	Pest and diseases are not monitored on a regular basis. Spray treatments are applied on a calendar basis or in response to severe outbreaks.	
BP39.0 Pesticide Resistance	-	A rotation program is in place to ensure products are applied correctly and rotated according to label instructions, to prevent resistance from developing.	Attempts are made to rotate between chemical groups according to label instructions, but there is no effective rotation program in place.	Chemicals are not rotated to avoid resistance.	
General					
BP16.0 Disposal of shed water	Settlement and filtration ponds used to remove all extraneous material including post harvest chemicals before release into local waterways.	Filtration in place to remove fine particles and larger debris before releasing water into local drains or waterways.	Grates in the shed to remove large debris before water is released into local drains or waterways.	No filtration of any sort in place and water from the packing shed is disposed of into adjacent drainage lines or waterways.	
BR23.0 Record keeping	As in B below, but including automated field data collection from tractor-mounted computers/controllers with associated recording and reporting functions.	Detailed computer-based records of field activities, farm inputs, production results and monitoring data (eg soil analyses, weed-survey, water-quality) & any nutrient/weed management plans	Detailed paper-based records of field activities & inputs (eg nutrient rates in kg/ha, types & rates of herbicides etc) as well as production records	Pocket diary of a limited range of farm operations.	

Source: Sing, N., Barron, F., (2014).

10 Appendix 2 – Improved Practices Catalogue

The Improved Practices Catalogue (IPC) provides information to help producers in reef catchments "identify and adopt better land management practices … The aim is to support agricultural profitability while improving the quality of water in the Great Barrier Reef as part of the Reef Plan initiative." There are guides for the Sugarcane, Grazing and Banana growing industries.

There are three categories or guides listed for the banana industry under the IPC:

1. Optimise nutrient rate and application;
2. Optimise pesticide use as part of a pest management plan; and
3. Optimise soil retention and water infiltration.

Under each of these categories are a series of management practices that contribute to overall goal captured in the category heading (see Table A2).

Table A2 Improved Practice Catalogue for Banana Industry

Category	Improved Practices
Optimise nutrient rate and application	1. Regular soil, leaf and/or sap nutrient testing to inform nutrient application (e.g. bananas pre-plant soil test and paired leaf and soil tests at least annually).
	2. Multiple applications timed to irrigation and rainfall, including methods of fertigation, foliar and band application
	3. Regular calibration of fertiliser and/or fertigation equipment, particularly by product type and batch.
Optimise pesticide use as part of a pest management plan	Flexible management strategies based on block monitoring and taking into account:
	1. Weed species, stage of weed and crop growth
	2. Pest threshold numbers, populations of beneficial species and levels of crop damage
	3. Block history, prevailing environmental conditions, chemical options, rate and timing of applications, and selection equipment
	4. Efficient use of residual and knockdown chemicals (e.g. regular calibration of equipment, nozzle selection, band application, product label recommendations).
Optimise soil retention and water infiltration	1. Minimising tillage throughout crop cycle
	2. Maintaining or establish groundcover during high risk periods. E.g. grassed inter-rows and trash placement for bananas
	3. Managing headlands, vegetation buffers, drains and sediment traps to capture and/or filter run-off from the production area (this relates to vegetated headlands that are not highly trafficked by farm equipment).
	4. Mechanically cultivating across the slope
	5. Scheduling irrigation based on soil properties, crop growth requirements, and monitoring of soil moisture and weather forecasts.
	6. Managing fallow with cover or break crop.

Source: Department of Agriculture and Fisheries, (2014).

11 Appendix 3 – ABGC Banana BMP Guideline

The Australia Banana Growers Council Banana BMP Guideline is based on the Freshcare Environmental Code and uses a 'best, okay, improve' criteria (King, N, 2008). This is similar to the ABCD criteria, except for the exclusion of the aspirational practices.

The guidelines have many different categories for the banana industry:

1. Soil structure;
2. Soil erosion;
3. Soil acidity and alkalinity;
4. Pesticides;
5. Banana integrated pest and disease management;
6. Fertiliser and soil additives;
7. Water;
8. Biodiversity;
9. Disease management;
10. Waste;
11. Air;
12. Energy; and
13. Fuel.

Table A3 ABGC Banana BMP Guideline

Practice	Best	Okay	Improve
Soil Structure			
Crop Rotation	Either a volunteer grass fallow or a fallow crop is planted between banana crop cycles.	A weedy fallow grows between banana crop cycles or the block is rotated with another crop.	There is no fallow period between banana crop cycles or bare fallow is left between crop cycles.
Cultivation method and timing - land preparation	The row only is cultivated at the times of year when the risk of erosion is low.	The whole block is cultivated at times of year when the risk of erosion is low.	The whole block is cultivated at any time of year.
Cultivation method and timing - crop destruction	The banana crop is removed by treating with herbicide and plants are left to break down before cultivation.	Practices are implemented to breakdown plants while minimising soil disturbance, for example, using a mulcher or lightly with the discs.	The banana crop is removed by discing green plant material repeatedly.
Which do you use to increase organic matter? Best=6+, Okay=4+, Improve=3 or less. Fallow crops are grown between banana crops, Harvested heads and leaves are left on the row, Products are applied to increase organic matter (such as manures, mulch, compost, mill mud), High nitrogen rates are avoided, Cultivation is reduced, A side-throw slasher or similar is used to put mulch back on the row, Banana waste scraps are spread back onto the rows, Non-competitive companion crops are encouraged around banana plants.			
Soil Erosion			
Ground Cover	Living ground cover is encouraged in areas such as the inter-row space and headlands, excluding major roadways.	Living or dead, at least 60% ground cover is encouraged in areas such as the inter-row space and headlands. This includes mulching banana plant material in the inter-row space. Major roadways are excluded.	Areas such as inter-rows and headlands are sprayed bare.
Which of the practices below do you use to reduce the risk of erosion in plant crops? Best=3+, Okay=2, Improve=1 or less. Planting is confined to low-rainfall times of the year when the risk of erosion is low, Grasses/plants are encouraged as inter-row ground cover in the plant crop, Permanent beds are used, allowing cultivation to be restricted to the row only. If plant blocks are established outside of low-risk rainfall periods, rows are formed early and grass is encouraged as ground cover and only the row or furrow is disturbed at planting.			
Wind Erosion (WA only)	Structures or trees are placed on the southern side of banana blocks to help minimise wind damage and erosion.		No wind breaks of any kind.
Controlling run-off water - slowing water	The farm and blocks have been designed to slow surface water and direct it to an appropriate waterway capable of carrying high velocity water. Blocks are laser-levelled where required to prevent water from collecting in the paddock and creating wet areas.	Most blocks have been designed to slow surface water and direct it to an appropriate waterway, although some corrective work is still required.	Little or no attention is currently given to slowing surface water or directing it to a suitable waterway.
Controlling run-off water - contouring	If the farm has areas under banana production with a gradient of 3% or more, all blocks in these areas have been planted along the contour and designed to include diversion banks and constructed waterways. Advice has been sought for placing these structures correctly. Annual maintenance is carried out to ensure these structures are operating correctly. Blocks are left undeveloped if erosion cannot be managed.	If the farm has areas under banana production with a gradient of 3% or more, most blocks in these areas have been planted along the contour and designed to include diversion banks and constructed waterways. Advice has been sought for placing these structures correctly. Annual maintenance is carried out to ensure these structures are operating correctly. Blocks are left undeveloped if erosion cannot be managed.	The farm has areas under banana production with a gradient of 3% or more, but there are no control structures in place.
Controlling run-off water - silt traps	Silt traps have been designed, constructed and located with expert advice.		Silt traps have been designed, constructed and located without expert advice.
Controlling run-off water - drains	All constructed drains on-farm are vegetated-shallow-spoon drains	Most constructed drains on-farm are vegetated-shallow-spoon drains and any box drains have a batter suited to the soil type, so they do not erode.	Constructed drains on-farm are mostly box drains with straight sides.
Controlling run-off water - roads	All main roadways are either concreted or stabilised with sand or rock. Unless specifically designed the road is not used to direct and carry water. Suitable batters and culverts are used.	Most main roadways are either concreted or stabilised with sand or rock, but some roads still require improvements	Main roadways are not stabilised and water is able to travel along roads that are not designed for this purpose
Controlling run-off water - maintenance	All maintenance of drains, roads and inter-row spaces is carried out during the time of the year when the risk of erosion is low. Maintenance is carried out annually or as required to ensure these structures are working adequately.		Maintenance of drains, roads and inter-row spaces is carried out at any time of the year regardless of rainfall activity or no maintenance is carried out and structures may not be working adequately.

Soil acidity and alkalinity	Soil pH is monitored at least annually and pH amending products are applied as required		Soil pH is not monitored at least annually or pH amending products are applied without testing pH levels
Pesticides			
Integrated pest and disease management	Methods to manage all pests and diseases on-farm include physical (mechanical), biological, cultural and chemical control options. They do not rely only on chemical options.	Methods to manage most pests and diseases on-farm include physical (mechanical), biological, cultural and chemical control options. They do not rely only on chemical options.	Pests and diseases are predominately managed using chemicals and little thought is given to other forms of control.
Monitoring	Pest and disease levels are monitored on a regular and consistent basis by trained staff or service providers. Records are retained and treatments are applied using monitoring information and relevant threshold levels for each pest/disease.	Pest and disease levels are monitored by general observations when doing other activities and control methods applied accordingly.	Spray treatments are applied on a calendar basis or in response to severe outbreaks.
Chemical Rotations	A rotation program is in place to ensure products are applied correctly and rotated according to label instructions, to prevent resistance from developing	Attempts are made to rotate between chemical groups according to label instructions, but there is no rotation program in place.	Chemicals are not rotated to avoid resistance.
Chemical registrations	Key personnel know how to find which products are registered and permitted for use and only these products are used on-farm.	Rely on reseller or consultant advice for product registrations and only registered and permitted products are used on-farm.	Not sure if the products used are registered or permitted for use.
Obtaining chemicals	Chemicals are sourced from an Agsafe-accredited supplier or similar.		Not sure if suppliers are accredited by Agsafe or similar.
Storing chemicals	The chemical storage area is locked and bunded, and is either located in an area where spills will not affect waterways, or measures are in place to ensure potential spills will not affect waterways.		The chemical storage area is not bunded and spills could not be contained.
Handling and applying chemicals	Only appropriately-trained staff handle and apply chemicals. Other staff cannot access or use chemicals.		Measures are not in place that prevent unqualified staff from accessing chemicals.
Disposal of chemicals	Empty chemical drums and unwanted or out-of-date chemicals are disposed of through a DrumMUSTER® or ChemClear® type scheme		Schemes such as DrumMUSTER® or ChemClear® are not used to dispose of empty chemical drums or unwanted or out-of-date chemicals.
Spray Drift chemical treatments	Aerial and ground applications are only made during suitable weather conditions and care is taken to prevent off-target spraying. Vegetative buffer zones are in place around the farm to minimise the risk of drift.	Aerial and ground applications are only made during suitable weather conditions and care is taken to prevent off-target spraying.	Measures are in place to minimise off-target movement of chemicals but improvements are still required.
Maintain and calibrate equipment	Spray equipment is maintained and calibrated regularly to ensure it is working effectively, leaks are avoided and the product is distributed evenly.		Maintenance and calibration of spray equipment could be improved or you need information about calibrating spray equipment.
Banana Integrated Pest and Disease Management			
Nematodes, which of the practices listed below do you use to manage plant-parasitic nematodes? Best=3+, Okay=2+, Improve=1 or less, N/A. Only tissue culture or clean (and dipped) plant material is used, at the end of the crop cycle banana plants are removed with glyphosate to eradicate all living plant material that could harbour plant-parasitic nematodes between crops, A fallow crop identified as a non-host for a particular plant-parasitic nematode is planted in the fallow period, Plant-parasitic nematode levels are monitored using the Root Disease Index (RDI) to determine when economic thresholds are met, N/A.			
Banana weevil borer, Which of the practices listed below do you use to manage banana weevil borer? Best=3+, Okay=2, Improve=1 or less, N/A. Only tissue culture or clean plant material is used, At the end of the crop cycle banana plants are removed using glyphosate to eradicate all living plant material that could harbour banana weevil borer between crops, Banana weevil borer levels are monitored to determine when economic thresholds are met, Desuckering practices that produce broken or cut corm material or excessive stem shatter are avoided, In the subtropics where decay rates are slow the psuedostems are cut in half lengthwise to accelerate the rate of stem decay.			
Spider mites, Which of the practices listed below do you use to manage spider mites? Best=4+, Okay=3, Improve=2 or less, N/A. Using chemicals that disrupt predators is avoided, Spider mite populations are monitored to determine when thresholds are met, Appropriate irrigation management is used to ensure the plants are not water stressed, Excessive applications of nitrogen fertiliser are avoided, Sufficient volume and coverage is applied if spray treatments are used, N/A.			
Leaf diseases, Which of the practices listed below do you use to manage yellow Sigatoka? Best=3+, Okay=2, Improve=1 or less, N/A. A deleafing program is followed and infected leaf material removed (the deleafing program removes all innoculum before the peak infection period), Potential sources of infection are removed by eradicating old crops and feral plants, Leaf disease levels are monitored to determine when disease is present, Plant and soil nutritional status is monitored and maintained at desired levels, N/A.			
Which of the practices listed below do you use to manage leaf speckle and leaf rust? Best=3, Okay=2, Improve=1 or less, N/A. A deleafing program is followed and infected leaf material removed, Leaf disease levels are monitored to determine when disease is present, Ground applications are made of the spray treatment to target the organism, N/A.			

Planting material	Only tissue culture or plant material from the farm is used.		Plant material may be sourced from outside of the farm.
Farm quarantine	All vehicles, machinery and personnel are required to be free of soil before entering and leaving the farm. Staff are required to report any unusual plants to management.		Practices need to be improved to achieve the required standard outlined above
Fertiliser and soil additives			
Soil testing pre-plant	100% of blocks are soil tested before planting		Soil testing before planting is infrequent or not done at all.
Soil testing	Soil tests are taken on all blocks more than once a year	Soil tests are taken on all blocks once a year.	Soil tests are taken less than once a year or on fewer than all blocks.
Leaf testing	Paired leaf and soil tests are taken on all blocks at least annually.	Paired leaf and soil tests are taken at indicator sites at least annually or tissue tests taken throughout the year but not paired with soil tests.	Leaf tests are taken less than annually or not at all.
Fertiliser program	The fertiliser program is supported by soil and leaf testing and yield monitoring. The program is revised annually and checked to ensure targets are actually applied.	The fertiliser program is supported by soil and leaf testing and yield monitoring	There is no fertiliser program and/or the rates applied are not based on soil and leaf test results.
Recommended rates	The fertiliser program is based on recommended rates for nitrogen and phosphorus.		The fertiliser program is not based on recommended rates for nitrogen and phosphorus.
Pre-plant pH adjustments and fertiliser applications	If pH adjustments, calcium, magnesium, potassium and phosphorus applications are required pre-plant, they are applied and incorporated into the soil.		If pH adjustments, calcium, magnesium, potassium and phosphorus are required pre-plant, they are applied to the soil surface
Fertiliser application frequency	The aim is to apply fortnightly applications of fertiliser during high growth periods such as summer and potentially reduce this during low growth periods such as winter. Weather conditions may mean that this is not always possible.	The aim is to apply monthly fertiliser applications all year round.	Fertiliser is applied less frequently than monthly
Fertiliser application method	All fertigation or combination of fertigation and banded surface fertiliser applications depending on the weather conditions.	Banded surface fertiliser applications to rows or in non-mechanised production systems the fertiliser is broadcast by hand to entire root zone.	Fertiliser broadcast over rows and inter-row spaces or in non-mechanised production systems the application is more concentrated by placing it primarily at the base of the plant
Calibration and maintenance of fertiliser application equipment	All spreaders are calibrated on a regular basis and fertigation systems are checked regularly for uniformity.		Improvements are required in the current systems and/or regular calibration of spreaders. Fertigation systems are not checked regularly for uniformity.
Storing fertilisers	The fertiliser storage area is located in an area where spills will not affect waterways, or measures are in place to ensure potential spills will not affect waterways. This includes manures, compost and liquid fertilisers.		Spills could not be contained and/or surface water is not diverted away from the site
Fertiliser application records	Records of all fertiliser applications are kept in a manner that allows the user to easily monitor progress and, if required, easily retrieve information such as total nutrients applied to date and soil and tissue test trends (e.g. electronic).	Records of all fertiliser applications are kept although retrieving information would be time-consuming (e.g. hardcopy).	Not all fertiliser applications are recorded.
Water			
Irrigation emitter type	100% under-tree sprinklers or drip and an automated system.	100% under-tree sprinklers or drip and a manual system.	Some overhead irrigation.
Soil Moisture monitoring	Irrigation schedules are based on capacitance probes and weather stations and are fully automated.	Irrigation schedules are based on capacitance probes or tensiometers and use a manual system.	No scheduling equipment is used to develop an irrigation schedule.

Salinity management	Underground water is tested to monitor salinity levels especially after periods of heavy rain. Where possible water sources are combined to reduce salinity levels or irrigation from tidal reaches is only taken at low tide and tests have been taken to ensure this water is safe for use.		Water sources are not tested to monitor salinity levels.
Check irrigation system performance	Water uniformity and distribution is tested and above 90%.	Water uniformity and distribution is tested and above 80% but below 90%.	Water uniformity and distribution is tested and below 80% or not tested and is therefore unknown.
Protect water quality	Applications of fertiliser and pesticides are timed for suitable weather conditions and all run-off water is filtered through grassed headlands or vegetation before reaching waterways.	Applications of fertiliser and pesticides are timed for suitable weather conditions and most run-off water is filtered through grassed headlands or vegetation before reaching waterways.	Applications of fertiliser and pesticides are not timed for suitable weather conditions and/or run-off water is not filtered through grassed headlands or vegetation before reaching waterways.
Packing shed waste water quality	Filtration removes fine particles and larger debris before releasing water into local drains or waterways.	Grates in the shed remove large debris before water is released into local drains or waterways.	There is no filtration of any sort in place and water from the packing shed is disposed of into adjacent drainage lines or waterways.
Biodiversity			
Regional biodiversity priorities	Management is aware of regional biodiversity priorities and how to source this information if required.		Management is not aware of regional biodiversity priorities or how to source this information if required.
Riparian vegetation	Native riparian vegetation is present for 100% of the length of all creeks and rivers.	Native riparian vegetation is present for at least 70% of the length of all creeks and rivers.	Native riparian vegetation is present for less than 70% of the length of all creeks and rivers.
Native vegetation	Stands of native trees are maintained and protected, and additional native vegetation is established through tree plantings.	Stands of native trees are maintained and protected.	Stands of native trees are not maintained and protected.
Native birds and animals	Native birds and animals are identified and their habitats preserved. Farming practices that minimise impact on native wildlife are selected.		Little thought or consideration of native birds and animals.
Feral animals	Feral animals are controlled through suitable methods to minimise their populations and impact on the environment.		Feral animals are not controlled.
Environmental weeds	Weeds on the property are identified and managed according to relevant legislation.		Weeds are not controlled according to relevant legislation.
Disease management	The business has reviewed the major pest and disease threats to their business and a biosecurity plan is in place. Visitors have a designated parking area and all machinery and vehicles are excluded from entering the farm. Only designated farm machinery is used on site. A perimeter fence is in place to prevent unauthorised access.	The business has reviewed the major pest and disease threats to their business and a biosecurity plan is in place. Visitors have a designated parking area and any personnel, machinery or vehicles entering the farm must be free of soil before entry is allowed.	Threats from potential pests and diseases are not considered and there is no set policy for dealing with visitors to the farm. Vehicles and machinery are not forced to be free of soil before entering the farm.
Waste			
General Waste	Products that allow packaging to be minimised, re-used or recycled are used in preference to those that require disposal, where possible. A formal waste plan is in place.	Products that allow packaging to be minimised, re-used or recycled are used in preference to those that require disposal, where possible, but there is no formal waste plan.	Little thought or consideration is given to waste management and no formal waste plan exists.
Banana bunch covers - number of uses	Bunch covers are re-used as many times as possible.		Bunch covers are single use.
Banana bunch covers - disposal method	Recycled or biodegradable bunch covers are used.	Bunch covers are disposed of at the local dump or through a waste contractor	There is no formal disposal method for bunch covers
Banana bunch covers - farm collection	All bunch covers are removed from the paddock and staff are aware that any bags laying around the farm should be collected and returned to an appropriate collection point.		Bunch covers are often left in the paddock or not collected when seen laying around the farm.

Fertiliser bags and containers	All bulk fertiliser bags and containers are stored in a suitable location until collected by the provider.		Fertiliser bags and containers are rarely returned to the provider.
Waste bananas	Waste bananas and stalks are mulched and spread back onto the banana paddock.	Waste bananas are fed to livestock or disposed of away from waterways and not in a single pile.	Waste bananas are dumped in a single pile or where surface water flows directly into waterways and are not managed.
Removing irrigation	All irrigation pipes are removed from the block before cultivating.		No attempt is made to remove irrigation before cultivating.
Disposing of irrigation	If accepted by the local council, irrigation pipes are taken to the designated waste station.	Local council does not currently accept irrigation pipes, so they are stockpiled at the farm until a solution is found.	No formal disposal method exists.
Disposing of string	String is removed from the paddock and stockpiled in an appropriate manner pending waste collection.		String is not removed from the paddock or string is removed from the paddock but no formal disposal method is in place.
Chemical containers and chemical	All chemical containers are triple-rinsed and collected through the DrumMUSTER® scheme. All chemical that is out of date or no longer required is collected through the ChemClear® scheme.		DrumMUSTER® and ChemClear® type schemes are not used.
Disposing of general waste	All waste material that cannot be re-used (e.g. some plastic) is separated from waste that can be recycled (e.g. paper). Waste is either collected by a local waste contractor or taken to the local waste station.	All waste material that cannot be re-used is either collected by a local waste contractor or taken to the local waste station.	There is no waste management plan in place and not all the waste for disposal is taken by a waste contractor or taken to the local waste station.
Air			
Neighbouring properties	Immediate neighbours are known and contactable at short notice. The impacts of business operations have been discussed with the neighbour/s and reasonable practices to minimise disturbance have been adopted.	Reasonable practices to minimise disturbance to neighbouring properties have been adopted.	Neighbouring properties aren't considered when undertaking farming activities.
Odour management	Raw manures, waste bananas and chemicals are stored and applied in a way that minimises their odour potential. The prevailing wind determines where these products are stored and when they are applied, to minimise disturbance to neighbours and staff.		Raw manures, waste bananas and chemicals are stored and applied with little consideration for reducing their odour potential.
Dust management	Disturbance to neighbours and staff is minimised with action taken to reduce the impact of dust from activities such as liming, cultivation and peak traffic periods along dirt roads.		No action is taken to minimise disturbance to neighbours or staff by reducing the impact of dust from activities such as liming, cultivation and peak traffic periods along dirt roads.
Smoke management	The use of fire is minimal and the prevailing wind is considered when burning to reduce disturbance to neighbouring properties and staff.		No action is taken to minimise the impact of smoke on neighbouring properties and staff.
Noise management	The noise level generated from activities has been considered and, where possible, practices have been altered and improved, or measures are in place to reduce the amount of noise produced.		No action is taken to minimise the impact of noise on neighbouring properties and staff.
Artificial light management	Night activities that require lights have been reviewed and all required practices are implemented to minimise disturbance to neighbouring properties and wildlife.		No action is taken to minimise the impact of light on neighbouring properties and wildlife.
Energy			
Machinery	Only machinery with the right capacity for the job is chosen. Machinery that lacks the capacity or has excess capacity is not used.		No consideration is given for the capacity of the machinery.
Machinery - crop destruction	Practices that minimise the number of passes required to remove the banana crop are incorporated. For example, the banana crop is removed by treating with herbicide and plants are left to break down before cultivation.		Little consideration is given to minimising the number of passes required to remove the banana crop. For example the banana crop is removed by cultivating green plant material repeatedly.

Pump	The pump's most efficient operating zone in terms of head pressure and volume of output is understood and adhered to.		The pump's most efficient operating zone in terms of head pressure and volume of output is not understood or adhered to.
Irrigation efficiency	All irrigation is under-tree, rather than overhead, so that less water needs to be pumped.		There is still some overhead irrigation used on farm, which requires more water to be pumped.
Cold Rooms	Cold rooms are well insulated and protected from direct sunlight. All seals are checked on a regular basis to ensure they are not losing air.		Cold room efficiency could be improved through better insulation, protection from direct sunlight or more regular checks for air loss.
Management practices	Where possible, management practices are implemented that reduce the amount of energy used and energy consumption is monitored.		Little consideration given to the business's energy use and consumption is not monitored.
Maintenance	All machinery, cold rooms, pumps and other equipment are serviced following the service book instructions to ensure they are operating efficiently.		Servicing is not always done on time and there are no systems in place to identify when services are due.
Nitrous Oxide	The loss of nitrates to nitrous oxide is minimised by limiting nitrogen fertiliser applications when soils are at field capacity or saturated and by having good drainage in blocks.		There is no awareness of nitrous oxides or how these are formed.
Carbon farming initiative	Management is aware of the types of projects that can be funded under the carbon farming initiative and where to source this information.		Management is unaware of the types of projects that can be funded under the carbon farming initiative or where to source this information
Fuel			
Storage location	Fuel tanks are stored in an area where spills will not affect waterways, or measures are in place to ensure potential spills will not affect waterways. This includes mobile fuel tanks. Bunding is provided on all petrol tanks and diesel tanks	Fuel tanks are stored in an area where spills will not affect waterways, or measures are in place to ensure potential spills will not affect waterways. This includes mobile fuel tanks. Bunding is not in place on all fuel tanks because tank capacity is less than that requiring bunding (minor storage) and a risk assessment has been performed.	Spills from the current fuel tank location could not be contained and prevented from reaching waterways.
Storage and maintenance	Fuel is only stored in tanks specifically designed for this purpose. Tanks are located in easy-to-reach locations, where filling is easy and access to fuel machinery is easy. All tanks are locked when not in use and systems are in place to reduce the chance of accidental spills and leakage.		Fuel is only stored in tanks specifically designed for this purpose. Tank location could be improved to allow improved access or there are no systems in place to reduce the risk of accidental spills and leakage.

Source: King, N., (2008).

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