Department of Agriculture and Fisheries

Celebrating innovation

in farm management practices on Queensland sugarcane farms through case studies that highlight:

Economic wins

operating return
investment capacity
annual benefit
payback period
internal rate of return

through investment analyses and the **farm economic analysis tool (FEAT)**

Eco-efficiency wins

nutrients
pesticides
fossil fuel
greenhouse gases
water

through rapid assessments with the **CaneLCA eco-efficiency tool**

and grower insights

about their innovation journeys

via six grower case studies

exploring innovations from 1984 to 2021

in the Bundaberg, Mackay, Burdekin, Herbert regions

that complement past studies

exploring innovations from 2000 to 2017

in the Cairns, Innisfail, Tully, Herbert regions

Queensland Government

Measuring the profitability and environmental implications of sugarcane management practices

Results from an economic and environmental study into the impacts of adopting practices to improve soil health (aligned with Best Management Practice[1] principles) are detailed below. The research was based on practices adopted at six sugarcane farms in Queensland, located in the Herbert, Burdekin, Mackay and Bundaberg regions (Image 1). Farms ranged in size from 91 to 341 ha and each grower made a number of practice changes over time relating to soil health, nutrient and pesticide management (including drainage and layout improvements at some farms) (Table 1).[2] The economic and environmental performance of the farms before and after the changes were evaluated using the Farm Economic Analysis Tool and the CaneLCA eco-efficiency calculator, based on farm management information provided by the growers.

Table 1—Examples of changes

Soil health: Reduced tillage, matching row spacing to machinery, changes in fallow management
Nutrient management: Following SIX EASY STEPS® guidelines to optimise inorganic fertiliser application, increased soil testing
Weed, pest and disease management: Changes in the types of herbicide active ingredients applied, reduced herbicide applications and more precise applications
Irrigation and drainage management: laser levelling and changes in practices (e.g. after infrastructure/piping upgrades)

Image 1: Farm locations

Were the investments profitable?

Income and costs before and after practice changes were identified for each case study farm. Investment analyses showed the overall practice changes improved profitability for each farming business. The annual benefit after the changes ranged between $29 and $337 per hectare per year (Table 2).[3]

Table 2—Investment analyses results

	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6
Farm size	200 ha	220 ha	91 ha	215 ha	341 ha	186 ha
Cost of implementation	$96,476	$26,828	$138,600	$620,250	$267,425	$637,440
Discounted payback period	8 years	7 years	7 years	10 years	10 years	7 years
Annual benefit per year	$42/ha	$122/ha	$131/ha	$45/ha	$29/ha	$377/ha
Reference year before changes:	2009 -	1984 -	2003 -	2000 -	2016 -	1999 -
Reference year after changes:	2019	2019	2019	2020	2021	2021

Results for each farm in Tables 2 and 3 are not intended to be directly compared, as practice changes and parameters vary between case studies. Please refer to individual case studies for further details.

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[1] BMP, as defined by Smartcane BMP https://www.smartcane.com.au/.

[2] Each case study focuses on key changes that aligned with BMP principles. Please refer to individual case studies for details, such as matters that were out of scope or the subject of supplementary analysis (e.g. the case study for farm 5 includes a supplementary analysis exploring the use of solar electricity).

[3] Net present values (NPV's) were calculated by taking into account initial investment costs and the discounted annual change in gross margin aggregated over a 10-year period (and the residual value for investments at the end of that period). Each NPV is then presented as an annualised equivalent benefit (annual benefit).

What does this mean for the environment?

The environmental evaluations considered four main indicators of environmental impacts over the life cycle of cane production. These relate to water quality protection, fossil fuel use, greenhouse gas emissions and water use for irrigated farms. These indicators were calculated over the 'cradle to farm gate' life cycle of cane growing, including both *on-farm* impacts (tractor exhaust emissions, gaseous losses of nitrogen, runoff of pesticides and nutrients to water) and *off-farm* impacts (production of fertilisers, pesticides, diesel, electricity, lime etc.).

The results (Table 3) show that in most cases the practice changes reduced impacts across all indicators. One exception was Farm 5, in which the amount of water applied in irrigation increased to boost productivity, but the increased productivity led to reduced impacts per tonne of cane for other environmental aspects. So this is a case where there were both benefits and trade-offs. The nature of the environmental improvements varied between farms. For most farms, water quality risks were significantly reduced, while some also had significant reductions in fossil fuel use and GHG emissions.

Table 3—Changes in environmental impacts for the case study farms
(*negative values are reduced impacts, positive values are increased impacts*)

	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6
Eutrophication potential from nutrient losses to water - $PO_{4\text{-}eq}$ /t cane	-62%	-5%	-17%	-19%	-11%	-28%
Eco-toxicity potential from pesticide losses to water - CTUe /t cane	-9%	-80%	-70%	-72%	-18%	-50%
Fossil fuel use - MJ /t cane	-26%	-37%	-7%	-5%	-12%	-49%
Greenhouse gas emissions - $CO_{2\text{-}eq}$ /t cane	-38%	-36%	-10%	-5%	-12%	-46%
Water use – kL/t cane	NA	NA	NA	0%	+38%	-36%

Please note that environmental indicators in this study are focused on cane production, whereas economic indicators (e.g. 'annual benefit') factor in all crops (e.g. legume cash crops for some farms).

What's the bottom line?

Case studies follow past research outcomes and provide further examples of the joint economic and environmental benefits of cane-growing innovations being adopted by the Queensland sugarcane industry. It provides further information for growers considering the adoption of such practices and adds to a growing positive narrative about the industry's efforts to improve sustainability.

Note: Results should not be used for the purposes of comparing farms with before and after practice changes different for each farm. As each farming business is unique, individual circumstances must be considered before applying the case study findings to one's own situation.

For more information

This factsheet was produced to summarise the results of a Department of Agriculture and Fisheries project: Combined Economic and Environmental Evaluations of Practice Adjustments. For further information please call **13 25 23** or visit: www.publications.qld.gov.au/dataset/sugarcane-economics.

It is acknowledged that information in some case studies is based on data collected through the Herbert and Burdekin Soil Health Project (SRA Project 2017/005 - Measuring soil health, setting benchmarks and supporting practice change in the sugar industry). Further info on Sugar Research Australia's (SRA's) soil health program is available at www.sugarresearch.com.au/soilhealth.

The economic and environmental impacts of managing soil health

Case study: Alan Lynn (North Queensland)

This case study is part of a series that evaluates the economic and environmental impacts of practice changes adopted by sugarcane growers aimed at improving soil health on their farms.

Alan Lynn farms 200 hectares in the Herbert region, North Queensland, and uses contractors for cane planting and harvesting. Over a 10-year period he has implemented a range of practice changes on his sugarcane farm. These include reduced tillage, an increase in row spacing width, more targeted fertiliser and mill mud application, and the introduction of a mixed species break crop (on all of his fallow area, in rotation with sugarcane where possible).

Image 1: Alan Lynn

Key findings of the Alan Lynn case study

The practice changes considered in this study resulted in:

- An annual benefit of $7,905 ($42/ha) for Alan's investment, indicating it was worthwhile. Cost savings were largely due to reduced fuel and labour costs from less tillage and lower fertiliser costs.
- Greenhouse gas emissions reduced by 38% (366 t of avoided greenhouse gases per year), which is equivalent to taking 119 cars off the road each year.
- Fossil fuel use reduced by 26% (1,245 GJ of avoided energy use), which is equivalent to burning 27 tonnes less diesel fuel per year (on-farm and off-farm through energy for fertiliser manufacturing etc).
- Potential water quality improvements due to reductions in nutrient losses (reduced by 4.3 tonnes of nitrogen (N) equivalent each year) and pesticide active ingredients (A.I.'s) application (reduced by 230 kg each year).

The findings of this case study are specific to the individual business evaluated and not intended to represent the impact of similar practice changes more broadly.[4]

Economic, biophysical and farm management data before and after practice change were supplied by the grower. Certain implements built by Alan are costed as if bought new. The Farm Economic Analysis Tool (FEAT)[5] was used to determine the impact of these changes on business performance. The CaneLCA Eco-efficiency Calculator (CaneLCA)[6] was used to determine the impact of the practices changes on the environment.

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[4] Various management practice changes were made by Alan progressively over at least 10 years from the base year of 2009. For simplicity, the economic analysis excludes some changes (e.g. trying different bed-forming approaches, legume species, multi-operation implements and extending the cane crop cycle by at least one ratoon) and the Annual Benefit is calculated using a 10 year investment horizon.

[5] FEAT is a tool that considers sugarcane farm production systems from an economic perspective, allowing users to analyse the revenues and costs associated with their farming enterprises. https://featonline.com.au/

[6] CaneLCA is a Microsoft Excel® based tool that calculates 'eco-efficiency' indicators for sugarcane growing based on the life cycle assessment (LCA) method. It streamlines the complex LCA process to make it more accessible to researchers, agricultural advisors, policy makers and farmers. https://eshop.uniquest.com.au/canelca/

Grower insights

Alan shared the following insights when interviewed about his journey:

“Around 2008 I began looking at management issues in heavy clays. I tried out different ways to address them but everything was new to me. Attending workshops and bouncing ideas past other growers helped me make plans and reinforced the direction I was heading in. I was encouraged to continue thinking about adjustments to how I do things, like getting more soil testing. Now, I see soil tests like a tape measure for how my farm is going from year to year. They improve my ability to redirect funds better, rather than paying for blanket applications of fertiliser or mill mud. I also try to make the jobs I don’t like doing as easy as possible, by using GPS for example.”

“Because I feel good about how my soil health is progressing, I’m more confident to keep on trying things to suit my particular situation. The way I see it, if I improve my soil health, this will help or improve my long term production, viability and lifestyle. So long as I know my farm’s soil health is on the right track, I don’t really mind if the organic matter on my farm looks a bit messy after legumes to other people. And when I do legumes, it’s not so much about how much nitrogen it’ll give to my cane crop – for me, it’s more about how it’ll improve soil health.”

What changes were made?

Details of the main changes to Alan’s farming system considered in this study are summarised in Table 1. To reduce compaction and improve soil health, he widened his row spacing from 1.625m to 1.8m, fitted one tractor with GPS guidance, another with a GPS rate controller, and reduced his tillage. He also transitioned from a bare fallow to a mixed species legume fallow. Fertiliser and mill mud application rates were adjusted to be in line with the SIX EASY STEPS$^{\text{TM}}$ guidelines, and application rates of many pesticides were reduced and / or swapped to A.I.’s with lower environmental toxicity. Over the years Alan has tried different bed-forming approaches, legume species, various multi-operation implements and extended his cane crop cycle by at least one ratoon. However, those additional adjustments are not the focus of this study.

Table 1: Main changes to the farming system

	Before	After
Soil health management	• 1.625m row spacing • No GPS guidance for machinery operations • Conventional planting • Heavy tillage / machinery operations (discing, ripping, hilling up, and heavy rotary hoeing on a routine basis) • Bare fallow	• 1.8m row spacing • GPS guidance for machinery operations • Bed forming and conventional planting • Reduced tillage/machinery operations by using implements that can combine operations in a single pass (e.g. bean planter – ripper - renovator) and light rotary hoeing only when necessary • Mixed species legume fallow
Nutrient management & ameliorant	• Grower determined nutrient rate, with no adjustment to P application rates after applying mill mud • Applying same fertiliser and ameliorant rate across all blocks, with limited soil tests	• Following SIX EASY STEPS guidelines to reduce inorganic fertiliser application and adjusting P application rates after applying mill mud • Targeting fertiliser and ameliorant rates on a block by block basis, with soil tests across all blocks
Weed, pest and disease management	• Standard spraying/calibration	• Reduced application rates of some pesticide A.I.’s and changes to A.I.’s with lower environmental toxicity

What does this mean for the business?

The economic analysis indicated Alan's annual operating return has increased by $104/ha ($19,739) after the practice changes, due to a lower average operating cost. The biggest contributors to reducing operating costs were: fuel, oil and labour costs from farm operations ($66/ha), fertiliser and ameliorant costs ($52/ha), and herbicides ($5/ha). There has been an increase in planting costs ($10/ha), capital goods costs ($7/ha) and fungicide costs ($2/ha) (Figure 1).

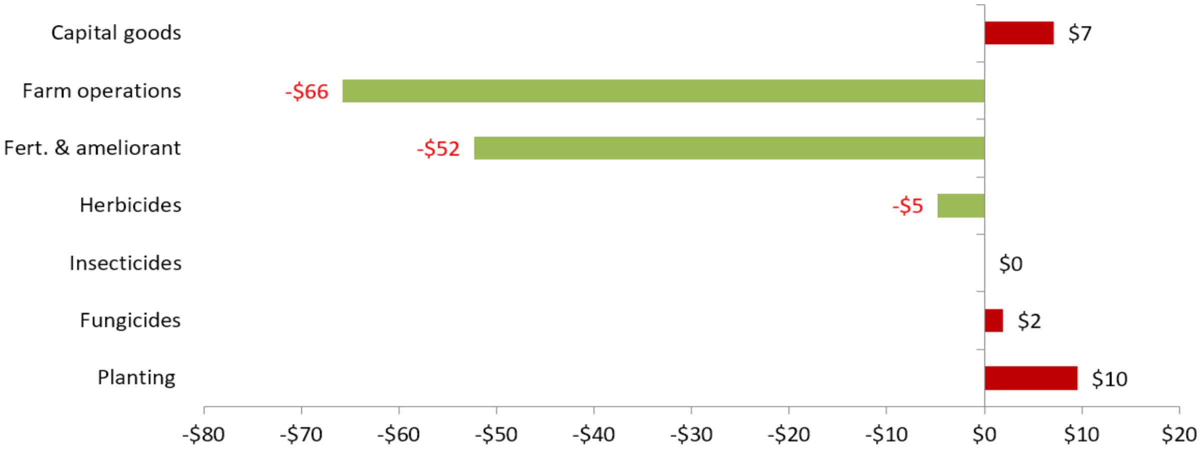

Figure 1: Contribution to change in annual farm operating costs ($/ha change)*

* Transport costs to supply fertilisers, ameliorants and pesticides are embodied in product costs.

Alan has reduced his cane planting rate after widening his row spacing. However, his overall 'planting' cost increased due to planting legumes in the fallow period. The planting operation is combined with his bed-forming operation (which is accounted for under farm operation costs in Figure 1).

Farm operation costs include fuel, oil and labour costs. Reduced tillage has made a large contribution to cost savings. Wider row spacing reduced the total number of rows (and distance travelled) and, together with GPS guidance, contributed to cost savings and reductions in tractor hours.

Alan increased his soil testing, resulting in a negligible increase in costs of $2/ha/yr on average. He introduced a mixed species legume break crop to all of his fallow areas (where possible) and began to adjust nutrient application rates to account for nitrogen from legumes and phosphorous from mill mud. Reductions in fertiliser rates for the plant and ratoon crops have resulted in substantial cost savings.

Capital goods refers to the cost of repairs, maintenance and depreciation of machinery and equipment (Figure 1). After the practice changes, repairs and maintenance costs decreased as a result of reduced tractor hours. However, depreciation increased due to new equipment purchased and this resulted in an overall increase in capital goods costs.

How much did it cost to make the changes?

To move to a reduced tillage, controlled traffic system with a mixed species legume break crop, Alan purchased a GPS unit and GPS rate controller, built two bed formers (including one from scrap), added boards to a rotary hoe (to allow for light sweeping), and made minor modifications to his boom sprayer. He modified the boom on his high rise and converted it, along with his fertiliser box, to be hydraulically adjustable (for convenience during the transition to a wider row spacing). The total cost of implementation, for various one-off costs, was $96,476 (or $519/ha) when some implements designed and built by Alan are included on the basis of a current market price.[7]

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[7] The cost of implementation includes Alan's 'half share' of his investment in the High Rise with his neighbour. Alan was also successful in applying for a number of grants. However, any grant amounts are disregarded in the analysis.

Was the investment profitable?

Results of an investment analysis show the practice changes were a worthwhile investment. Given the lower costs, it would take Alan 8 years to recover the $96,476 (or $519/ha) invested.

Over a ten year investment horizon, Alan's investment has added an additional $7,905 per year ($42/ha/yr) to his bottom line (when the initial investment, required return of 7% and time to transition to the new system is taken into account) (Table 2).[8]

Table 2: Cost of implementation and investment results

Cost of Implementation ($/ha)	$519
Discounted Payback Period	8 years
Annual Benefit ($/ha/yr)	$42
Internal Rate of Return	15%
Investment Capacity ($/ha)	$817

This analysis is based on cane yields staying the same across Alan's farm after the practice changes.[9]

Investment capacity is the maximum amount of money that can be spent before an investment becomes unprofitable. Alan could have invested up to $151,995 ($817/ha), before the cost savings made by the practice changes would be insufficient to provide the required (7%) return on investment.

What does this mean for the environment?

Four indicators of environmental impacts were calculated using the CaneLCA tool to see how much the practice changes influenced environmental impacts. These indicators are:

- Fossil fuel use, an indicator of fossil-fuel resource depletion (MJ) [10]
- Carbon footprint, an indicator of greenhouse gas emissions causing global warming (kg $CO_{2\text{-eq}}$)[11]
- Eutrophication potential, an indicator of water quality impacts caused by the release of eutrophying substances (nitrogen, phosphorus, sugar) to waterways via surface runoff and infiltration to groundwater (kg $PO_{4\text{-eq}}$)[12]
- Eco-toxicity potential, an indicator of water quality impacts caused by the loss of toxic substances to waterways, such as pesticides but also heavy metals (kg CTU_{eq})[13]

Impacts are calculated over the 'cradle to farm gate' life cycle of cane growing (up to and including the haulout of harvested cane to the siding, but not including transport to mill). They include the environmental impacts of *off-farm* production and supply of inputs (fertilisers, pesticides, diesel, electricity, lime etc.) as well as impacts to the environment that occur *on-farm* (tractor exhaust emissions, gaseous losses of nitrogen, runoff of pesticides and nutrients to water).

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[8] Changes are factored in gradually over several years across areas under fallow, plant crop and ratoons.

[9] It is Alan's personal view that yields were (at least) maintained after making practice changes, and this view is informed by Alan's review of his production records from 2005-19 and comparisons of his farm's production data to productivity zone data. The findings of these case studies are specific to the individual businesses evaluated and are not intended to represent the impact of practice changes more broadly (and it is noted that some aspects of the analysis have been simplified).

[10] MJ = megajoules of fossil fuel energy

[11] kg $CO_{2\text{-eq}}$ = kilograms of carbon dioxide equivalent, the reference substance for representing greenhouse gases (carbon dioxide, nitrous oxide, methane)

[12] kg $PO_{4\text{-eq}}$ = kilograms of phosphate equivalent, the reference substance for representing the eutrophication of water due to eutrophying substances (nitrogen, phosphorus, sugar)

[13] kg CTU-eq = kilogram of equivalent critical toxicity units, a measure of the eco-toxicity effects in freshwater due to releases of toxic substances (pesticide A.I.'s, heavy metals). Pesticide A.I.'s usually originate from the on-farm agricultural activities, and heavy metals usually originate from the off-farm activities producing the electricity, machinery, etc used on the farm.

The estimated changes in environmental impacts after the practice changes were adopted by Alan are shown in Figure 2. The practice changes have resulted in substantial environmental improvements for both water quality (eutrophication and eco-toxicity) and carbon footprint.

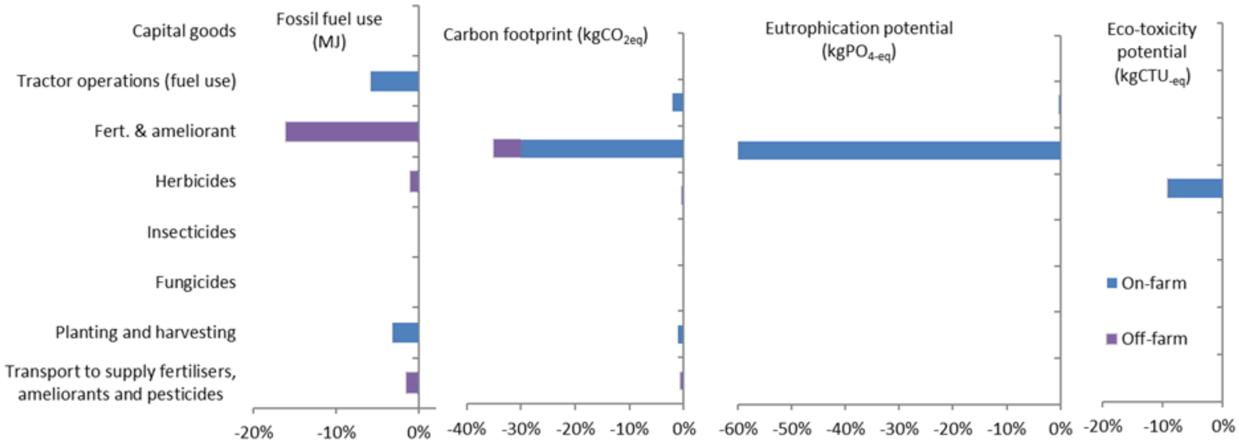

Figure 2: Decrease in environmental impacts after practice changes (% change per t cane) [14]

Fossil fuel use. The practice changes reduced the life-cycle fossil-fuel use (per tonne cane) by 26% per year. This means that around 1,245 GJ per year are saved, which is equivalent to combusting 27 tonnes less diesel fuel per year[15]. The biggest reduction is less off-farm energy use for producing and supplying fertilisers to the farm (especially urea) due to the reductions in fertiliser application. The other large reduction is due to less on-farm diesel use for tractor operations largely resulting from a considerable reduction in tillage operations and the wider row spacing.

Carbon footprint. The practice changes reduced the carbon footprint (per tonne of cane) by around 38% per year. This means around 366 tonnes per year of carbon dioxide emissions are now avoided, which is equivalent to taking 119 cars off the road each year. The dominant reduction sources are the avoided on-farm emissions of nitrous oxide (N_2O), a strong GHG[16], and avoided off-farm emissions of producing fertilisers, due to reduced N fertiliser application rates. There are also avoided emissions from the reduced on-farm combustion of diesel in tractors largely due to reduced tillage and wider row spacing.

Eutrophication potential. The largest environmental improvement has been reduced potential for nutrient-related water quality impacts by around 62% per year. Changes in fertilisation practices to align with SIX EASY STEPS guidelines reduced N application (in fertilisers and mill mud) from 3.4 kg N/t cane to 1.9 kg N/t cane and also reduced P application. This means an avoided loss to waterways of around 4.3 t N equivalent each year.

Eco-toxicity potential. The practice changes reduced the potential for toxicity-related water quality impacts by about 9% per year. This has been due to a 230 kg reduction in pesticide active A.I.'s applied each year (e.g. Dimethylamine, Glyphosate and Paraquat). There has also been a shift away from using AIs with high toxicity potential (e.g. Diuron, Hexazinone).

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[14] A negative % change represents a decrease in environmental impact, and a positive % value represent an increase in environmental impact. All the changes resulted in decreased environmental impact.

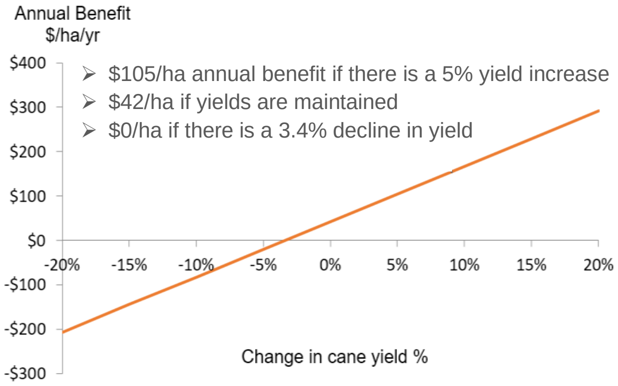
[15] This includes fossil fuel use over the life cycle of the cane growing, includes not just on-farm diesel consumption but also off-farm use of fossil fuels in the production of fertilisers, pesticides, diesel, lime, electricity, and in transport for delivering inputs.

[16] The assessment assumes a generic nitrous oxide (N_2O) emission factor of 1.99% of applied N lost as nitrous oxide N, which is based on the latest Australian greenhouse gas inventory methodology. The global warming potential is 298 kg $CO_{2\text{-}e}/kgN_2O$.

What about risk?

When adopting any management practice change, economic outcomes can vary with changes in key profitability drivers, such as yield, and depend on how effectively the practice is implemented.

A production risk analysis (Figure 3)[17] shows overall cane yield (across plant and ratoon crops) would need to decline by 3.4% before Alan's investment in practice changes would become unprofitable. However, the adoption of practice changes that have been scientifically validated,[18] means an adverse impact on cane yield is unlikely.



- $105/ha annual benefit if there is a 5% yield increase
- $42/ha if yields are maintained
- $0/ha if there is a 3.4% decline in yield

Figure 3: Sensitivity of annual benefit of investment to yield

Conversely, a small improvement in cane yield is expected to result in a substantial economic gain. For example, the yield data for Alan's farm indicates an increase of over 9% in tonnes of cane per hectare (when an average of Alan's yields for the 2005-09 period was compared to the 2015-19 period).[19] The production risk analysis indicates a 9% improvement in cane yield could result in an annual benefit of $155/ha ($28,743). Even if only a proportion of the yield gain were attributed to the practice changes (as in, a 5% yield improvement), an estimated $105/ha/yr ($19,481/yr) would have been added to the bottom line for Alan.

From an environmental perspective, most improvements are not sensitive to changes in cane yields (Figure 4). Cane yield would need to reduce by 30-40% across plant and ratoons before there was no net reduction in fossil fuel use or carbon footprint (per tonne cane), and by 10% for the eco-toxicity benefits. Because the N-related water quality improvements were so large, they are not sensitive to cane yield changes.

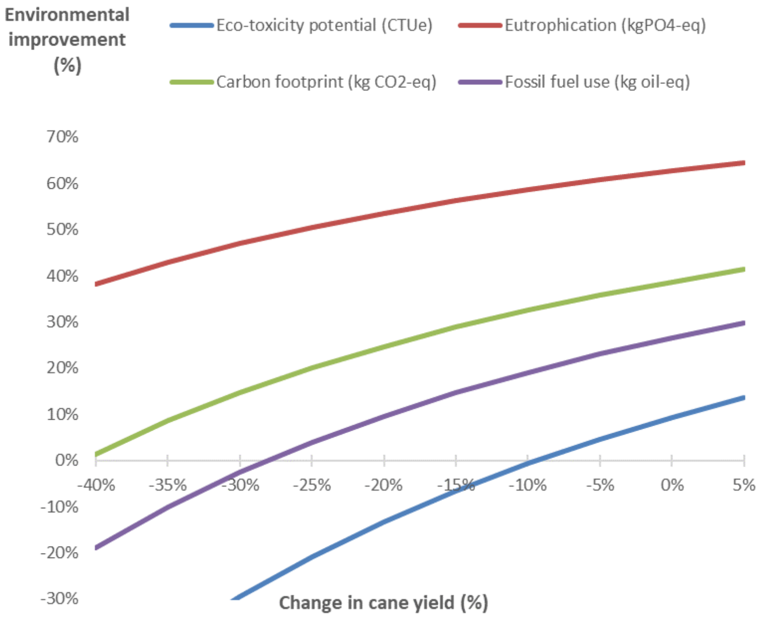


Figure 4: Sensitivity of environmental improvements to yield

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[17] The economic production risk analysis (Figure 3) explores yield only, with CCS and the sugar price held constant.

[18] Such as Smartcane BMP best management practices.

[19] Production records were adjusted for two years of the dataset to account for clean seed sales. CCS is assumed constant.

What’s the bottom line?

This case study has evaluated the economic and environmental impacts of various practice changes, including those aimed at improving soil health, for a farm in the Herbert region.

Results of the economic analysis indicate that the changes resulted in cost savings for Alan, largely due to reduced fuel, oil, labour and fertiliser costs. The average amount he spends on pesticides has also reduced. Alan’s investment in purchasing or building new technology has been worthwhile. Overall cane yields (across plant and ratoon crops) would need to decline by 3.4% before investment in the practice changes becomes unprofitable (and small improvements in cane yield are expected to substantially increase the economic gain).

The practice changes have resulted in reductions in the risk of water quality impacts, especially in relation to eutrophication risks due to reduced nitrogen application. There has also been the added bonus of reduced fossil fuel use and carbon footprint (due to less fertiliser production and use, and less machinery use).

Each farming business is unique in its circumstances and therefore the parameters and assumptions used in this case study reflect Alan’s situation only. Consideration of individual circumstances must be made before applying this case study to another situation.

For further information on this integrated case study please contact the Townsville DAF office on 13 25 23. For further information about project activities in the Herbert, please contact Herbert Productivity Services Limited on (07) 4776 5660.

The economic components of this case study were originally produced as a separate report and formed part of the Herbert and Burdekin Soil Health Project (SRA Project 2017/005 - Measuring soil health, setting benchmarks and supporting practice change in the sugar industry). This project is supported by Sugar Research Australia, Herbert Cane Productivity Services Ltd, Burdekin Productivity Services, Wilmar, Queensland Department of Agriculture and Fisheries, The University of Queensland and University of Southern Queensland. The environmental assessment was performed by the Centre for Agriculture and the Bioeconomy at Queensland University of Technology.

The environmental components of this case study were originally produced as a separate report in a DAF project: Combined Economic and Environmental Evaluations of Practice Adjustments. The environmental assessment was performed by the Centre for Agriculture and the Bioeconomy at Queensland University of Technology.

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The economic and environmental impacts of managing soil health

Case study: Charlie Cacciola (North Queensland)

This case study is part of a series that evaluates the economic and environmental impacts of practice changes by sugarcane growers aimed at improving soil health on their farms.

Charlie farms 220 hectares of sugar cane in the Burdekin region, North Queensland, and uses contractors for planting and harvesting. Since taking on the farm, he has implemented a range of adjustments to his farming system. For example, he has significantly reduced tillage, increased his row spacing, targeted his fertiliser application and reduced pesticide use. Charlie has also installed a recycle pit, tried different planting methods and recently begun growing legumes during his fallow period, however these additional adjustments are not the focus of this study.

Image 2: Charlie Cacciola

Key findings of the Charlie Cacciola case study

The practice changes considered in this study resulted in:

- An annual benefit of $26,828 ($122/ha) for Charlie's investment, indicating it was worthwhile. Cost savings were largely due to reduced fuel and labour costs from less tillage.
- Greenhouse gas emissions reduced by 36% (529 t of avoided greenhouse gases per year), which is equivalent to taking 172 cars off the road each year.
- Fossil fuel use also reduced by 37% (3,700 GJ of avoided energy use), which is equivalent to burning 81 tonnes less diesel fuel per year (on-farm and off-farm through energy for fertiliser manufacturing etc.).
- Potential water quality improvements due to reductions in nutrient losses (reduced by 0.4 tonnes of nitrogen (N) equivalent each year) and pesticide active ingredients (A.I.'s) application (reduced by around 1 tonne each year).

The findings of this case study are specific to the individual business evaluated and are not intended to represent the impact of similar practice changes more broadly.[20]

Economic, biophysical and farm management data before and after changes were supplied by the grower. Certain implements built by Charlie are costed as if bought new. The Farm Economic Analysis Tool (FEAT)[21] was used to determine the impact of these changes on business performance. The CaneLCA Eco-efficiency Calculator (CaneLCA)[22] was used to determine the impact of the practices changes on the environment.

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[20] Various management practice changes were made progressively from a base year of 1984 until 2019. Charlie was an early adopter of various practices, so in some instances the changes considered in this study, such as reductions in tillage, go back as far as the base year. For simplicity, the analysis excludes some changes that were not directly aimed at improving soil health (e.g. investment in a recycle pit) and the Annual Benefit is calculated using a 10 year investment horizon. Some recent changes are also not considered in the analysis (e.g. minor adjustments to row spacing and growing legumes in fallow).

[21] FEAT is a tool that considers sugarcane farm production systems from an economic perspective, allowing users to analyse the revenues and costs associated with their farming enterprises. https://featonline.com.au/

[22] CaneLCA is a Microsoft Excel® based tool that calculates 'eco-efficiency' indicators for sugarcane growing based on the life cycle assessment (LCA) method. It streamlines the complex LCA process to make it more accessible to researchers, agricultural advisors, policy makers and farmers. https://eshop.uniquest.com.au/canelca/

Grower insights

Charlie shared the following insights when interviewed about his journey:

"Soil health has been a top priority and I've gotten lots of value from reaching out to the help on offer from agronomists, extension staff and researchers so I can achieve my goals. For example, when I first started thinking about adjusting my farming system, research and mill staff, like Dr. Lisa McDonald, provided me with support. I would also exchange ideas with other growers, looking for different ways to achieve an effective, low-cost farming system, with solutions that are economical and practical for my farm."

"Things are always a work in progress for me and I take one step at a time and allow for trial and error. By saving time and money in one area of my business I've had freedom to try other things like installing a recycle pit and including legume break crops in my cane farming system."

What changes were made?

Details of the changes to Charlie's farming system considered in this study are summarised in Table 1. With a view to reducing compaction and improving soil health, Charlie substantially reduced his cultivation operations and purchased or customised implements for his farm (such as a bed-former, zonal ripper, custom hill-up boards). He also introduced a trash splitter and custom furrow cleaning rakes to aid in irrigation. Charlie widened his row spacing to better match his machinery and uses GPS guidance for most operations. Fertiliser application rates were also decreased in line with the SIX EASY STEPS^{TM} guidelines and he converted his fertiliser box to a stool splitter. He also purchased a gypsum applicator to apply relatively low rates of product (banded) several times during each crop cycle. Application rates of several pesticides were reduced and/or swapped to A.I.'s with lower environmental toxicity. Charlie also fitted a spray tractor with flow rate control.

Table 1: Main changes to the farming system

	Before	After
Soil health management	• Heavy tillage / machinery operations (discing, ripping, scarifications) without GPS • 1.5m row spacing • Conventional planting	• Reduced tillage/machinery operations (e.g. zonal ripping, and limited discing) and using GPS for most operations • 1.83m row spacing (with furrow cleaning operations to assist irrigation) • Bed forming and conventional planting
Nutrient management & ameliorant	• Grower determined nutrient rate • Applying lime (in bulk, during plant crop)	• Soil testing and following SIX EASY STEPS™ guidelines to reduce inorganic fertiliser application • Applying mill mud (Charlie also applied gypsum with his own implement using a 'less but more often' approach)
Weed, pest and disease management	• Standard spraying/calibration	• Reduced application rates of some pesticide A.I.'s, changes to A.I.'s with lower environmental toxicity, spraying with flow rate control.

What does this mean for the business?

The economic analysis found Charlie's operating return has increased by $281/ha/yr ($61,742/yr total), after the practice changes, due to a lower average operating cost. The biggest contributors to reducing operating costs were: farm operation costs (fuel, oil, labour and contracted sprays) ($271/ha), herbicides ($22/ha) and fertiliser and ameliorant costs ($9/ha). These costs savings were partially offset by increases in capital goods costs ($24/ha) (Figure 1).

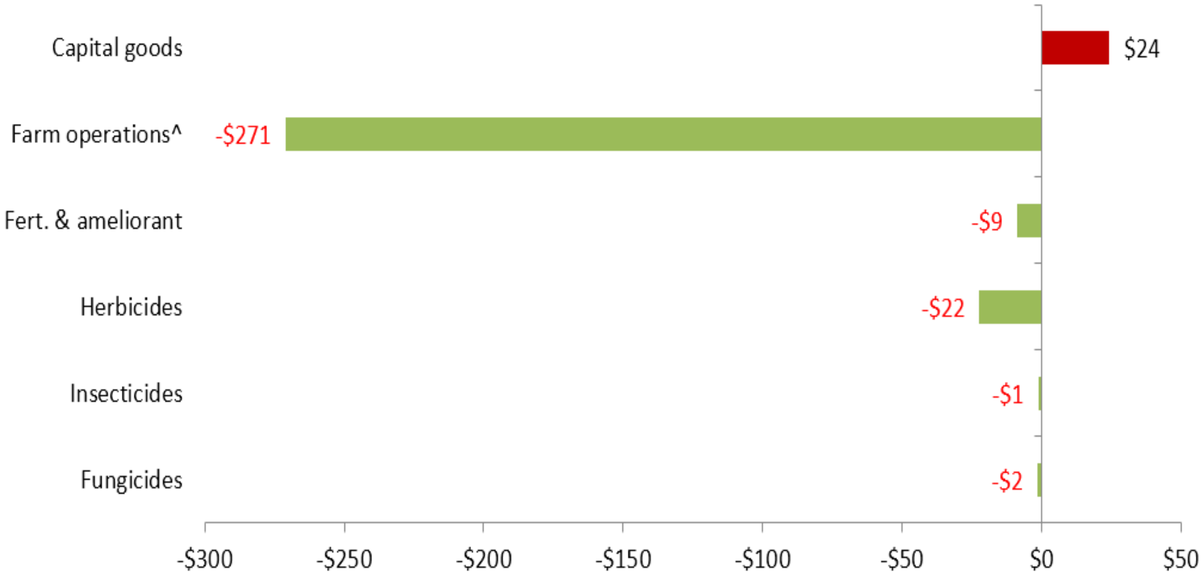

Figure 1: Contribution to change in farm operating costs ($/ha change)*

* Transport costs to supply fertilisers, ameliorants and pesticides are embodied in product costs.

^ Farm operations category includes fuel, oil, labour costs for tractor operations and any contracted spray costs.

Reduced tillage has made the largest contribution to cost savings (reducing fuel, oil and labour costs). Wider row spacing reduced the total number of rows (and distance travelled) and, together with GPS guidance, contributed to cost savings and reductions in tractor hours.

Capital goods (Figure 1) refer to the cost of repairs, maintenance and depreciation of machinery and equipment. After the practice changes, repairs and maintenance costs decreased as a result of reduced tractor hours. However, depreciation increased due to new equipment purchased.

How much did it cost to make the changes?

In moving to a reduced tillage system with controlled traffic, Charlie acquired or customised a bed-former, zonal ripper, custom hill-up boards, trash splitter, custom furrow cleaning rakes, a gypsum applicator and guidance systems with real-time kinematic positioning (RTK) on two tractors for convenience. He also added flow rate control with another guidance system (non-RTK) to a spray rig, converted his fertiliser box to a stool splitter and widened machinery wheel spacings to match row width. The total cost of implementation, for various one-off costs, was $235,200 (or $1,069/ha) when some implements designed and built by Charlie are included on the basis of a current market price. [23]

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[23] The cost of implementation includes Charlie's 'half share' of his investment in the gypsum spreader with his neighbour. Charlie was also successful in applying for a number of grants. However, any grant amounts are disregarded in the analysis.

Was the investment profitable?

Results of an investment analysis indicate the practice changes were a worthwhile investment. Given the lower costs, it would take Charlie 7 years to recover the $235,200 (or $1,069/ha) invested.

Over a ten year investment horizon, Charlie's investment has added an additional $26,828 per year ($122/ha/yr) to his bottom line (when the initial investment, required return of 7% and time to transition to the new system is taken into account) (Table 2).[24]

Table 2: Cost of implementation and investment results

Cost of Implementation ($/ha)	$1,069
Discounted Payback Period	7 years
Annual Benefit ($/ha/yr)	$122
Internal Rate of Return	18%
Investment Capacity ($/ha)	$1,926

This analysis is based on cane yields staying the same across Charlie's farm after the practice changes.[25]

Investment capacity is the maximum amount of money that can be spent before an investment becomes unprofitable. Charlie could have invested up to $423,630 ($1,926/ha) before the cost savings made by the practice changes would be insufficient to provide the required (7%) return on investment.

What does this mean for the environment?

Four indicators of environmental impacts were calculated using the CaneLCA tool to see how much the practice changes influenced environmental impacts. These indicators are:

- Fossil fuel use, an indicator of fossil-fuel resource depletion (MJ) [26]
- Carbon footprint, an indicator of greenhouse gas emissions causing global warming (kg $CO_{2\text{-eq}}$)[27]
- Eutrophication potential, an indicator of water quality impacts caused by the release of eutrophying substances (nitrogen, phosphorus, sugar) to waterways via surface runoff and infiltration to groundwater (kg $PO_{4\text{-eq}}$)[28]
- Eco-toxicity potential, an indicator of water quality impacts caused by the loss of toxic substances to waterways, such as pesticides but also heavy metals (kg CTU_{eq})[29]

Impacts are calculated over the 'cradle to farm gate' life cycle of cane growing (up to and including the haulout of harvested cane to the siding, but not including transport to mill). They include the environmental impacts of *off-farm* production and supply of inputs (fertilisers, pesticides, diesel, electricity, lime etc.) as well impacts to the environment that occur *on-farm* (tractor exhaust emissions, gaseous losses of nitrogen, runoff of pesticides and nutrients to water).

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[24] Rather than assuming in the economic analysis that all practice changes are adopted immediately across the whole farm, changes are factored in gradually instead (with proportions of the farm under fallow, plant crop, ratoons) over several years.

[25] It is Charlie's personal view that yields were (at least) maintained after making practice changes, and this view is informed, in part, by Charlie's review of his farm production data relative to his production zone data from 2005-19. The findings of these case studies are specific to the individual businesses evaluated and are not intended to represent the impact of practice changes more broadly (and it is noted that some aspects of the analysis have been simplified).

[26] MJ = megajoules of fossil fuel energy

[27] kg $CO_{2\text{-eq}}$ = kilograms of carbon dioxide equivalent, the reference substance for representing greenhouse gases (carbon dioxide, nitrous oxide, methane)

[28] kg $PO_{4\text{-eq}}$ = kilograms of phosphate equivalent, the reference substance for representing the eutrophication of water due to eutrophying substances (nitrogen, phosphorus, sugar)

[29] kg CTU-eq = kilogram of equivalent critical toxicity units, a measure of the eco-toxicity effects in freshwater due to releases of toxic substances (pesticide A.I.'s, heavy metals). Pesticide A.I.'s usually originate from the on-farm agricultural activities, and heavy metals usually originate from the off-farm activities producing the electricity, machinery, etc used on the farm.

The estimated changes in environmental impacts after the practice changes were adopted by Charlie are shown in Figure 2. The practice changes have resulted in substantial environmental improvements for both water quality (eutrophication and eco-toxicity), fossil energy use and carbon footprint.

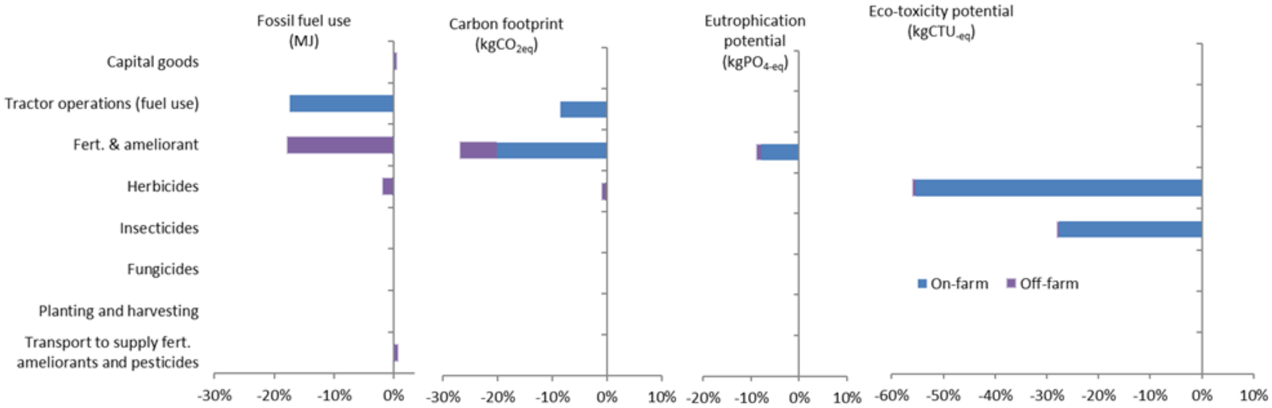

Figure 2: Decrease in environmental impacts after practice changes (% change per t cane) [30]

Fossil fuel use. The combined effect of all practice changes was estimated to reduce the life-cycle fossil-fuel use (per tonne harvested cane) by 37% per year. This means that around 3,700 GJ of energy are saved per year, which is equivalent to combusting 81 tonnes less diesel fuel per year[31]. This reduction is due to i) less off-farm energy use for producing and supplying fertilisers (especially urea) due to the decreased fertiliser application rate, and ii) less on-farm diesel use for tractor operations largely due to a considerable reduction in tillage operations and wider row spacing.

Carbon footprint. The combined effect of all practice changes was estimated to reduce the life-cycle greenhouse gas emissions (carbon footprint) by around 36% per year. This means around 529 tonnes per year of carbon dioxide emissions are now avoided, which is equivalent to taking 172 cars off the road each year. The dominant source of reductions is avoided on-farm emissions of nitrous oxide (N_2O), a strong GHG[32], due to reduced N fertiliser application rates. There are also avoided emissions from the reduced on-farm combustion of diesel in tractors largely due to reduced tillage and wider row spacing.

Eutrophication potential. The practice changes have also reduced potential nutrient-related water quality impacts by 5% each year. Changes in fertilisation practices to align with SIX EASY STEPS^{TM} guidelines reduced N application from 3.0 kg N/t cane to 2.0 kg N/t cane. However, increased phosphorus (P) application means the potential for loss of P to waterways has partially offset the benefits of reduced N application. Overall (for nitrogen and phosphorus), the assessment indicates an avoided loss to waterways of around 0.4 tonnes N equivalent each year.

Eco-toxicity potential. The largest environmental improvement has been reduced potential for toxicity-related water quality impacts by about 80% each year. This has been due to very substantial changes in pesticide practices. There has been a shift away from the use of Ametryn, Hexazinone Chlorpyrifos and Atrazine, and a general reduction in application rates. Compared to previous practices, there has been a 1 tonne per year reduction in application of pesticide A.I.'s.

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[30] A negative % change represents a decrease in environmental impact, and a positive % value represent an increase in environmental impact.

[31] This includes fossil fuel use over the life cycle of the cane growing, includes not just on-farm diesel consumption but also off-farm use of fossil fuels in the production of fertilisers, pesticides, diesel, lime, electricity, and in transport for delivering inputs.

[32] The assessment assumes a generic nitrous oxide (N_2O) emission factor of 1.99% of applied N lost as nitrous oxide N, which is based on the latest Australian greenhouse gas inventory methodology. The global warming potential is 298 kg $CO_{2\text{-}e}$/kgN_2O.

What about risk?

When adopting any management practice change, economic outcomes can vary with changes in key profitability drivers, such as yield, and depend on how effectively the practice is implemented.

A production risk analysis (Figure 3)[33] shows overall cane yield (across plant and ratoon crops) would need to decline by 6% before Charlie's investment in the changes would become unprofitable. However, the adoption of practice changes that have been scientifically validated,[34] means an adverse impact on cane yield is unlikely.

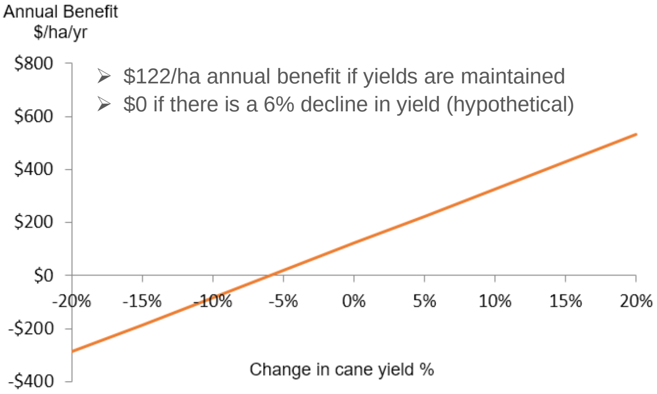

Figure 3: Sensitivity of annual benefit of investment to yield

Conversely, a small improvement in cane yield is expected to result in a substantial economic gain.

From an environmental perspective, most improvements are not sensitive to changes in cane yields (Figure 4). For there to be no net reduction in carbon footprint and fossil energy use (per tonne of cane), cane yields across plant and ratoons would need to decline by 40%. Because the eco-toxicity potential improvements were so large, they are not sensitive to cane yield changes. Eutrophication is the only aspect moderately sensitive to yield changes, needing a 10% reduction in cane yields before that particular environmental improvement is lost.

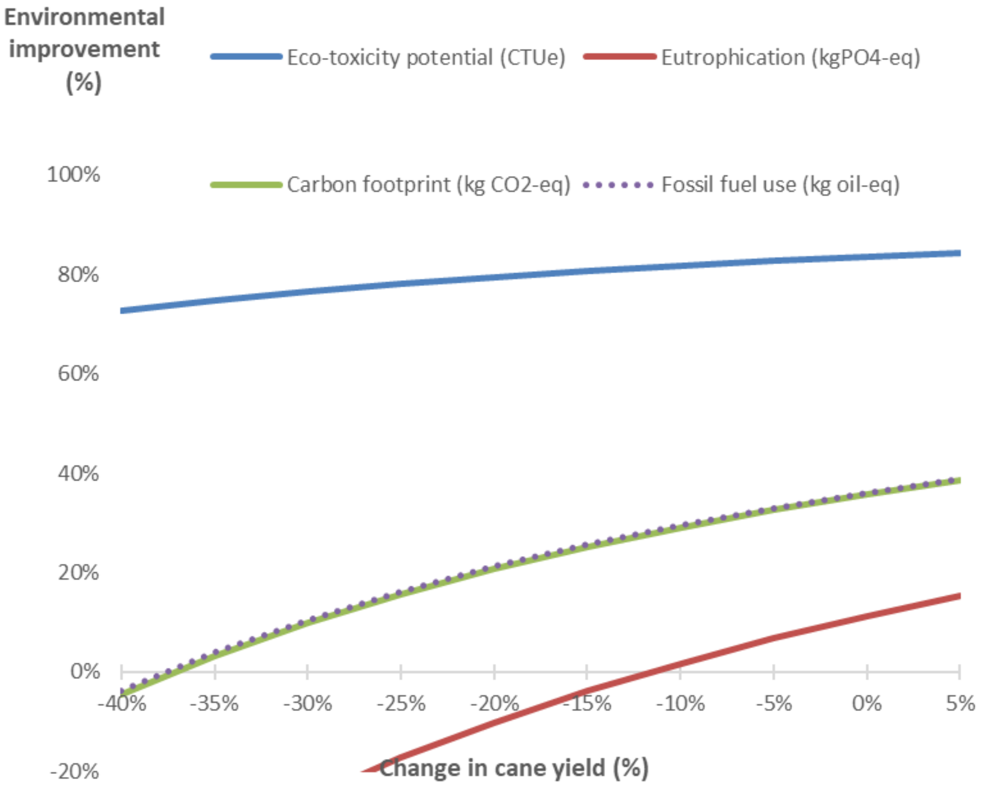

Figure 4: Sensitivity of environmental improvements to yield

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[33] The production risk analysis (Figure 3) explores yield only, with CCS and the sugar price held constant.

[34] Such as Smartcane BMP best management practices.

What's the bottom line?

This case study has evaluated the economic and environmental impacts of various practice changes, including those aimed at improving soil health, for a farm in the Burdekin region.

Results of the economic analysis indicate the changes resulted in cost savings for Charlie, largely due to reduced fuel, oil and labour costs (especially for cultivations) and reduced pesticide costs. Charlie has made substantial investments in new technology and this has been a worthwhile. Overall cane yields (across plant and ratoon crops) would need to decline by 6% before investment in the practice changes becomes unprofitable (and small improvements in cane yield are expected to substantially increase the economic gain).

The practice changes have resulted in reductions in the risk of water quality impacts, especially in relation to eco-toxicity risks due to changes pesticide practices. There has also been an additional bonus of reduced fossil fuel use and carbon footprint (due to less fertiliser production and use, and less machinery use).

Each farming business is unique in its circumstances and therefore the parameters and assumptions used in this case study reflect Charlie's situation only. Consideration of individual circumstances must be made before applying this case study to another situation.

For further information on this integrated case study please contact the Townsville DAF office on 13 25 23. For further information about project activities in the Burdekin, please contact Burdekin Productivity Services on (07) 4783 1101.

The economic components of this case study were originally produced as a separate report and formed part of the Herbert and Burdekin Soil Health Project (SRA Project 2017/005 - Measuring soil health, setting benchmarks and supporting practice change in the sugar industry). This project is supported by Sugar Research Australia, Herbert Cane Productivity Services Ltd, Burdekin Productivity Services, Wilmar, Queensland Department of Agriculture and Fisheries, The University of Queensland and University of Southern Queensland. The environmental assessment was performed by the Centre for Agriculture and the Bioeconomy at Queensland University of Technology.

The environmental components of this case study were originally produced as a separate report in a DAF project: Combined Economic and Environmental Evaluations of Practice Adjustments. The environmental assessment was performed by the Centre for Agriculture and the Bioeconomy at Queensland University of Technology.

The economic and environmental impacts of managing soil health

Case Study: Ray Abela (Central Queensland)

This case study is part of a series that evaluates the economic and environmental impacts of practice changes adopted by sugarcane growers aimed at improving soil health on their farms.

Image 3: Ray Abela

Ray currently farms 91 ha of cane land (including fallow) in the Mackay region, Central Queensland. Over the past 20 years he has made a number of farming system changes with the aim to improve soil health. To reduce soil compaction, he introduced a GPS controlled traffic system, downsized his machinery and reduced tillage. He also increased his rotational crops to a double fallow (most commonly mung beans followed by soybeans). Under opportune conditions, Ray will sometimes introduce a third crop of a mixed species fallow, but this is less common and is excluded from the analysis. Other important changes include multiple applications of superfine lime (on all crop classes), reduced fertiliser application rates and adjustments in herbicide / insecticide practices.

Key findings of the Ray Abela case study

The practice changes considered in this study resulted in:

- An annual benefit of $11,946 ($131/ha) for Ray's investment, indicating it was worthwhile. Cost savings were largely due to reduced fertiliser and herbicide costs, and reduced tillage operations for cane crops. An extra legume crop also provided additional legume grain income (that is partially offset by the cost of added legume operations).
- Greenhouse gas emissions reduced by 10% (37 tonnes of avoided greenhouse gases per year). This is equivalent to taking 12 cars off the road each year.
- Fossil fuel use also reduced by 7% (90 GJ of avoided energy use), which is equivalent to burning 2 tonnes less diesel fuel per year (on-farm and off-farm through energy for fertiliser manufacturing etc.).
- Potential water quality improvements due to reductions in nutrient losses (reduced by 0.3 tonnes of nitrogen (N) equivalent each year) and herbicide active ingredient (A.I.) application (reduced by 390 kg each year).

The findings of this case study are specific to the individual business evaluated and are not intended to represent the impact of similar practice changes more broadly.[35]

Economic, biophysical and farm management data before and after practice changes were supplied by the grower. The Farm Economic Analysis Tool (FEAT)[36] was used to determine the impact of these changes on business performance. The CaneLCA Eco-efficiency Calculator (CaneLCA)[37] was used to determine the impact of the practices changes on the environment.

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[35] Various management practice changes were made by Ray progressively over at least 17 years from the base year of 2003. For simplicity, the economic analysis excludes some changes (e.g. multi-species fallow and micro-nutrient adjustments, e.g. Boron) and the Annual Benefit is calculated using a 10 year investment horizon.

[36] FEAT is a tool that considers sugarcane farm production systems from an economic perspective, allowing users to analyse the revenues and costs associated with their farming enterprises. *https://featonline.com.au/*

[37] CaneLCA is a Microsoft Excel® based tool that calculates 'eco-efficiency' indicators for sugarcane growing based on the life cycle assessment (LCA) method. It streamlines the complex LCA process to make it more accessible to researchers, agricultural advisors, policy makers and farmers. *https://eshop.uniquest.com.au/canelca/*

Grower insights

Ray shared the following insights when interviewed about his journey:

“Soil health has become increasingly important to me over the years, and I believe that caring for the soil has long-term benefits for both the environment and crop. This analysis has confirmed for me that my system changes this past decade have not only benefited me financially but have also reduced my farm’s environmental impact. Change is often the product of difficult times. With the current pressure on grower margins, doing things differently has been a necessity for me to stay in business over the long-term.”

“Diversification has become an important source of revenue to me as well as it being beneficial for my soil. I’ve had to learn to adjust my approach to nutrition given how sensitive my fallow crops are to both macro and micro-nutrient imbalances. I have found making system changes in my business exciting and to a large extent this has helped reinvigorate my interest in farming over the past decade. My son has also shown more interest since the incorporation of new crops and farming practices which bodes well for our future as a farming family.”

“It is good to know I’ll leave my farm in a better position to when I first took it over. Although the economic comparison includes the cost of a GPS, today most growers already have this in place and would likely not need a huge capital investment to make similar changes. I want to keep moving forward while taking on board experiences from the past.”

What changes were made?

Details of the changes to Ray’s farming system considered in this study are summarised in Table 1. To reduce compaction and improve soil health, Ray widened his row spacing to match his machinery tracks and introduced GPS guidance for most operations. Ray also reduced his cultivations and purchased or customised implements to reduce their weight (e.g. smaller implements with a narrower width of pass for ripper and rotary hoe operations, while no longer discing under the current system). He also introduced a second fallow crop while lowering fertiliser rates in line with the SIX EASY STEPS^{TM} guidelines. Where possible, other steps were taken to reduce chemical use and/or swap to A.I.’s with lower environmental toxicity. For his liming operation, he now uses a lime spreader to apply lower rates of product on a more regular basis (in increments, i.e., on each crop class).

Table 1: Main changes considered in this study

	Before	**After**
Soil Health Management	• Heavier tillage / machinery operations (discing, ripping, hoeing) without GPS • 1.65m row spacing (single rows) • Single legume crop (e.g. soybeans) with 2 rows per bed, planted with precision planter	• Lighter tillage / machinery operations (ripping, hoeing, no discing) with the use of GPS for most operations • 1.93m row spacing (dual rows) • Double legume crop (e.g. soybeans and mung beans) with 4 rows per bed, planted with air-seeder
Nutrient Management & Ameliorant	• Grower determined nutrient rate • Applying agricultural lime (average of 3t/ha applied once a crop cycle)	• 50% increase in soil tests and following the SIX EASY STEPS^{TM} guidelines to reduce inorganic fertiliser application • Applying superfine lime (in increments, e.g., 430kg/ha in plant and four ratoons)
Weed, Pest and Disease Management	• Standard spraying/calibration	• Reduced application rates of some A.I.’s and changes to products with lower environmental toxicity

What does this mean for the business?

The economic analysis showed Ray's operating return increased by $305/ha ($27,773) due to lower operating costs of the new practices and an increase in grains net income of $268/ha[38] due to the added mung bean crop. The biggest savings included reduced fertiliser and ameliorant costs ($85/ha), herbicide costs ($79/ha) and insecticide costs ($20/ha). There were, however, increases in capital goods costs ($42/ha), irrigation ($41/ha) and seed/harvesting costs ($51/ha) (Figure 1).

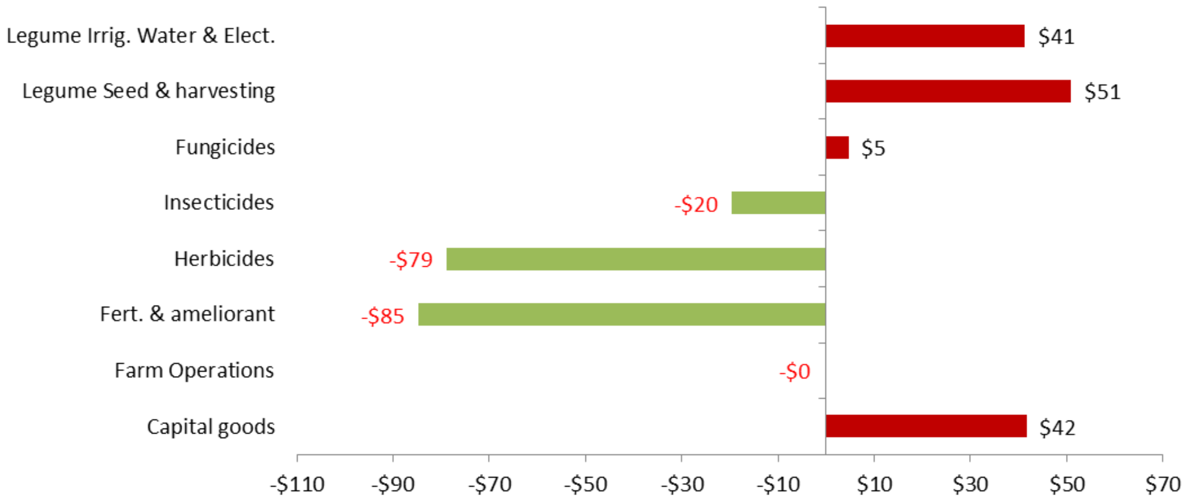

Figure 1: Contribution to change in farm operating costs ($/ha change)*
* Transport costs to supply fertilisers, ameliorants and pesticides are embodied in product costs.

Farm operational costs include fuel, oil and labour for tractor operations. Overall, there was no cost change in this category, but there were cost savings in fuel and oil for the cane system ($13/ha) with increased labour costs in the added fallow ($14/ha).

Capital goods refer to the cost of repairs, maintenance and depreciation of machinery and equipment (Figure 1). Depreciation was the biggest driver behind the cost change in this category, due to new equipment purchases. Repairs and maintenance costs were very similar between practices.

Irrigation and seed/harvesting costs increased due to the added fallow (mung beans). These did not change in the cane crop. There were substantial savings in overall pesticide costs in the cane crop, particularly herbicides (partially offset by the cost of additional sprays on the mung bean crop).

How much did it cost to make the changes?

In moving to a double fallow and reduced tillage system with controlled traffic, Ray acquired a GPS system and narrower 2-legged ripper. He also acquired parts for and built up a roller (for the ripper), a rotary hoe, air-seeder (for the fallow crops) and lime spreader. The total cost of implementing all these changes today is estimated at $1,520/ha ($138,600).

Note: Investment costs mentioned above focus on the full cost of implementing practice changes by Ray. However, moving to the new system has enabled Ray to downsize his tractor and implements (which offset investments in new equipment). The value of all machinery and equipment used in the new system is only $253/ha ($32,200) more when compared to the machinery and equipment used in the old system (at 2021 pricing).

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[38] This is the total income less post-harvest costs (freight, etc.) per hectare across the full farm area which is derived from $1,609 per hectare on the mung bean area (using a farm-gate price of $900/tonne and yield of 1.8 tonnes/ha).

Was the investment profitable?

Results of an investment analysis show the practice changes were a worthwhile investment. Given the lower costs, it would take seven years to repay the $138,600 (or $1,520/ha) invested by Ray in making the changes.

Over a 10-year investment horizon, Ray's investment has added an additional $11,946 per year ($131/ha/yr) to his bottom line (when the initial investment, required return of 7% and time to transition to the new system is taken into account) (Table 2). This analysis is based on cane yields staying the same across Ray's farm after the practice changes.[39]

Table 2: Cost of implementation and investment results

Cost of Implementation ($/ha)	$1,520
Discounted Payback Period	7 years
Annual Benefit ($/ha/yr)	$131/ha
Internal Rate of Return	16%
Investment Capacity ($/ha)	$2,440

Investment capacity is the maximum amount of money that can be spent before an investment becomes unprofitable. Ray could have invested up to $222,503 ($2,440/ha) before the cost savings made by the practice changes would be insufficient to provide the required (7%) return on investment.

What does this mean for the environment?

Four indicators of environmental impacts were calculated using the CaneLCA tool to see how much the practice changes influenced environmental impacts. These indicators are:

- Fossil fuel use, an indicator of fossil-fuel resource depletion (MJ) [40]
- Carbon footprint, an indicator of greenhouse gas emissions causing global warming (kg $CO_{2\text{-eq}}$)[41]
- Eutrophication potential, an indicator of water quality impacts caused by the release of eutrophying substances (nitrogen, phosphorus, sugar) to waterways via surface runoff and infiltration to groundwater (kg $PO_{4\text{-eq}}$)[42]
- Eco-toxicity potential, an indicator of water quality impacts caused by the loss of toxic substances to waterways, such as pesticides but also heavy metals (kg CTU_{eq})[43]

Impacts are calculated over the 'cradle to farm gate' life cycle of cane growing (up to and including the haul-out of harvested cane to the siding, but not including transport to mill). They include the environmental impacts of *off-farm* production and supply of inputs (fertilisers, pesticides, diesel, electricity, lime etc.) as well impacts to the environment that occur *on-farm* (tractor exhaust emissions, gaseous losses of nitrogen, runoff of pesticides and nutrients to water).

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[39] From historical yield data, a 12.8% improvement in yield/ha was identified for the 2016-20 seasons (most recent 5-years), when compared to the 2008-12 seasons. However, yields are held constant in the analysis and therefore conservatively reflect economic benefits of the practice changes. The findings of these case studies are specific to the individual businesses evaluated and are not intended to represent the impact of practice changes more broadly. As noted previously, various aspects of this case study have been simplified and modelled.

[40] MJ = megajoules of fossil fuel energy

[41] kg $CO_{2\text{-eq}}$ = kilograms of carbon dioxide equivalent, the reference substance for representing greenhouse gases (carbon dioxide, nitrous oxide, methane)

[42] kg $PO_{4\text{-eq}}$ = kilograms of phosphate equivalent, the reference substance for representing the eutrophication of water due to eutrophying substances (nitrogen, phosphorus, sugar)

[43] kg CTU-eq = kilogram of equivalent critical toxicity units, a measure of the eco-toxicity effects in freshwater due to releases of toxic substances (pesticide active ingredients, heavy metals). Pesticide active ingredients usually originate from the on-farm agricultural activities, and heavy metals usually originate from the off-farm activities producing the electricity, machinery, etc used on the farm.

The estimated changes in environmental impacts after the changes made by Ray are shown in Figure 2. The practice changes have resulted in environmental improvements, particularly for water quality (eutrophication and eco-toxicity) but also for fossil energy use and the carbon footprint.

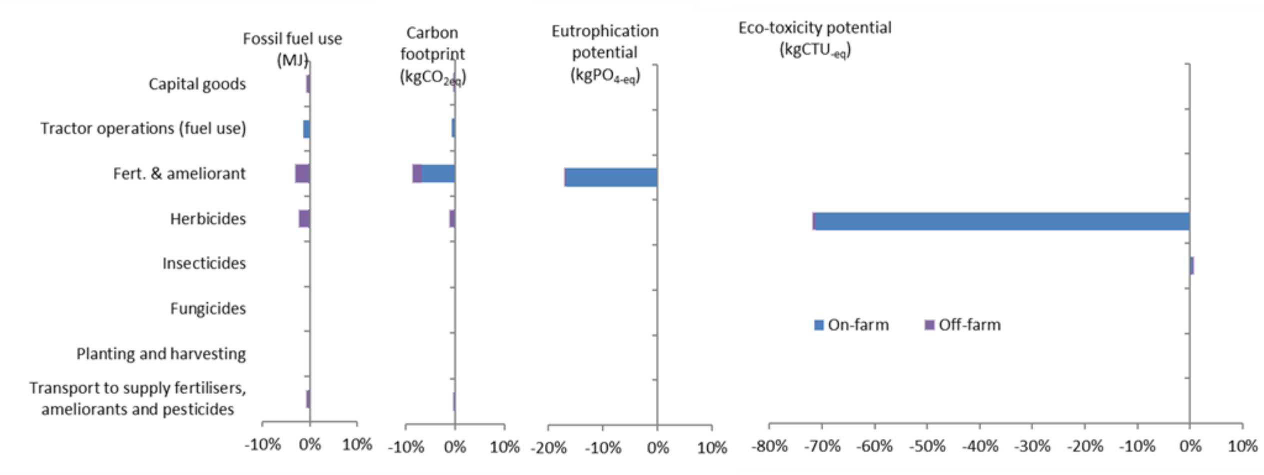

Figure 2: Decrease in environmental impacts after practice changes (% change per t cane) [44]

Fossil fuel use. The combined effect of all the practice changes reduced the life-cycle fossil-fuel use (per tonne harvested cane) by 7% per year. This means that around 91 gigajoules (GJ's) of energy are saved per year, which is equivalent to combusting 2 tonnes less diesel fuel per year[45]. This reduction is mostly due to less off-farm energy use for producing and supplying fertilisers and herbicides due to the decreased application rates. Ray's new farming system actually has more tractor operations due to the additional legume crops, but this has been largely offset by improved fuel efficiencies of smaller tractors with lighter implements. Overall there is very little change in the fuel use for tractor operations.

Carbon footprint. The combined effect of all the practice changes reduced the life-cycle greenhouse gas emissions (carbon footprint) by around 10% per year. This means around 37 tonnes per year of carbon dioxide emissions are now avoided, which is equivalent to taking 12 cars off the road each year. The dominant source of reductions is avoided on-farm emissions of nitrous oxide (N_2O), a strong GHG[46], due to reduced N fertiliser application rates.

Eutrophication potential. The practice changes have also reduced potential for nutrient-related water quality impacts by 17% each year. The changed fertilisation practices reduced fertiliser-N application from 1.8 kg N/t cane to 1.5 kg N/t cane after the changes. This is expected to translate to an avoided loss to waterways of around 0.3 tonnes N equivalent each year.

Eco-toxicity potential. The largest environmental improvement has been reduced potential for toxicity-related water quality impacts by about 70% each year. This has been primarily due to the changes in herbicide practices for the cane crop. There were some changes in insecticide practices but the eco-toxicity significance of these were very minor in comparison. There has been a shift away from the use of Atrazine and MSMA, and a reduction in application rates of Diuron, Fluroxypyr, Hexazinone and Paraquat. Compared to previous practices, there has been a 390 kg per year reduction in application of herbicide A.I.'s.

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[44] A negative % change represents a decrease in environmental impact, and a positive % value represent an increase in environmental impact.

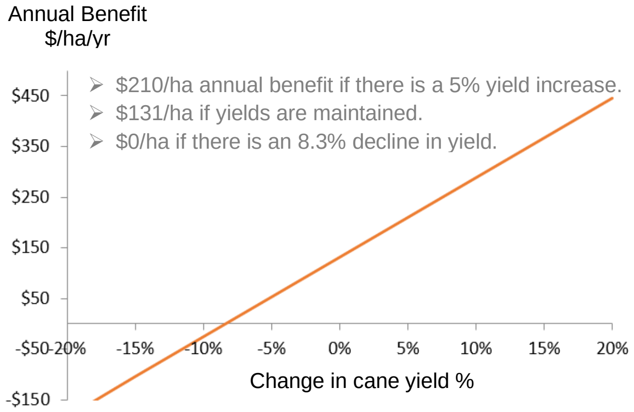
[45] This includes fossil fuel use over the life cycle of the cane growing, includes not just on-farm diesel consumption but also off-farm use of fossil fuels in the production of fertilisers, pesticides, diesel, lime, electricity, and in transport for delivering inputs.

[46] The assessment assumes a generic nitrous oxide (N_2O) emission factor of 1.99% of applied N lost as nitrous oxide N, which is based on the latest Australian greenhouse gas inventory methodology. The global warming potential is 298 kg $CO_{2\text{-e}}$/kgN_2O.

What about risk?

When adopting any management practice change, economic outcomes can vary with changes in key profitability drivers, such as yield, and depend on how effectively the practice is implemented.

A production risk analysis (Figure 3) [47] shows overall yields (across plant and ratoon cane crops) would need to decline by 8.3% before Ray's investment in the practice changes would become unprofitable. However, the adoption of practice changes that have been scientifically validated[48] means an adverse impact on cane yield is unlikely.



- $210/ha annual benefit if there is a 5% yield increase.
- $131/ha if yields are maintained.
- $0/ha if there is an 8.3% decline in yield.

Figure 3: Sensitivity of annual benefit of investment to yield

Conversely, a small improvement in cane yield could result in a substantial economic gain. For example, historical yields made available by the mill show a yield improvement of 12.8% per hectare from the earliest records (2008-2012) to the most recent (2016-2020). Even if only a proportion of that yield gain (e.g., a 5% yield improvement) were attributed to the system change, an estimated $210/ha/yr ($19,110/yr) would have been added to the bottom line for Ray.

From an environmental perspective, most improvements are not sensitive to changes in cane yields (Figure 4). Cane yield would need to reduce by 17% across plant and ratoons before there would be no net reduction in eutrophication benefit per tonne cane. Similarly, if cane yields were to reduce by 4-8% there would be no net improvement in fossil fuel use or carbon footprint per tonne cane. Because the eco-toxicity improvements were so large, they are not sensitive to cane yield changes.

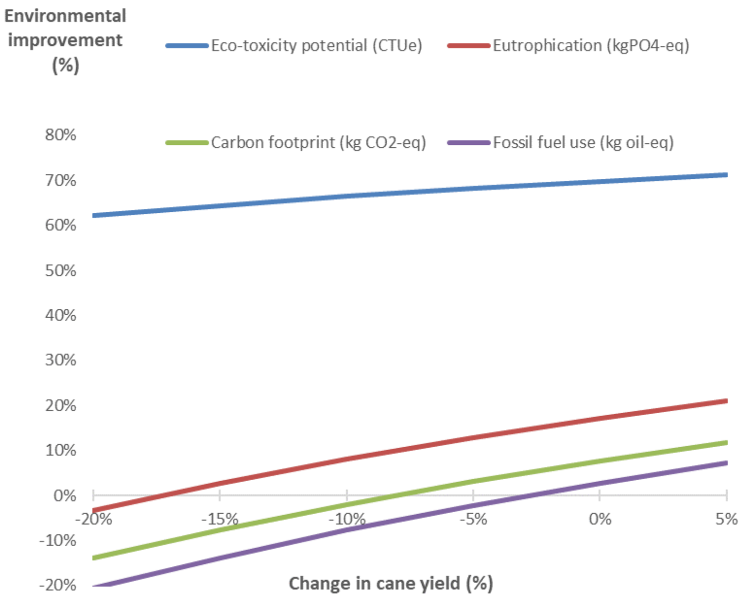


Figure 4: Sensitivity of environmental improvements to yield

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[47] The economic production risk analysis (Figure 3) explores yield only, with CCS and the sugar price held constant.

[48] Such as Smartcane BMP best management practices.

What's the bottom line?

This case study has evaluated the economic and environmental impacts of various practice changes, including those aimed at improving soil health, for a farm in the Mackay region.

Results of the economic analysis indicate the changes have resulted in cost savings for Ray, largely due to reduced fertiliser, herbicide, fuel and oil costs. Ray's investment in purchasing or building new equipment has been worthwhile. Overall cane yields (across plant and ratoon crops) would need to decline by 8% before investment in the practice changes becomes unprofitable (small improvements in cane yield are expected to substantially increase the economic gain).

The practice changes have resulted in reductions in the risk of water quality impacts, especially in relation to eco-toxicity due to changes in herbicide practices. The reduced use of fertilisers and reduced row spacing also means Ray has been able to introduce a second legume crop without any net increase in fossil fuel use or carbon footprint.

Each farming business is unique in its circumstances and therefore the parameters and assumptions used in this case study reflect Ray's situation only. Consideration of individual circumstances must be made before applying this case study to another situation.

The Soil Health Project - Central is supported by the Department of Agriculture, Water and the Environment through funding from Australian Government's National Landcare Program, Sugar Research Australia and the Queensland Government with assistance from Farmacist Pty Ltd, Plane Creek Productivity Services Ltd, Sugar Services Proserpine Ltd, Central Queensland Soil Health Systems, Wilmar Sugar, Queensland Department of Agriculture and Fisheries, The University of Queensland and University of Southern Queensland.

Farmacist, through funding from the Soil Health Project – Central, provided support for this case study by introducing the grower to DAF agricultural economists and being involved in the case study review process.

This case study is an output of the DAF project: Combined Economic and Environmental Evaluations of Practice Adjustments. The economic analysis was completed by DAF agricultural economists. The environmental assessment was performed by the Centre for Agriculture and the Bioeconomy at Queensland University of Technology.

For further information on this integrated case study please contact the Mackay DAF office on 13 25 23. This is an updated version of the case study.

FEATOnline
FARM ECONOMIC ANALYSIS TOOL

The economic and environmental impacts of managing soil health

Case Study: Tony Chapman (Bundaberg)

This case study is part of a series that evaluates the economic and environmental impacts of practice changes adopted by sugarcane growers aimed at improving soil health on their farms.

Image 4: Tony and Mitch Chapman

Tony Chapman farms 215 hectares in the Bundaberg region and he also provides contract cane planting for other growers. For over 20 years (from 2000 to 2020) he has implemented a range of practice changes on his farm.

Key changes include creating a total farm plan (grouping areas into management zones), changing farm layout (as in, row directions) to increase row length and efficiency, reduced tillage, additional fallow cropping and converting from furrow to (mainly) low-pressure boom irrigation. He has also trialled compost applications on part of his farm.

Key findings of the case study

The key practice changes considered in this study resulted in:

- An annual benefit of $9,760 ($45/ha) indicating Tony's investment was worthwhile. Increased revenue came from added legume break crops. Cost savings were largely due to increased tractor and harvest efficiency, and due to reduced fuel and labour costs from less tillage.
- In cane, greenhouse gas emissions reduced by 5% (40 tonnes of avoided greenhouse gases per year). This is equivalent to taking 13 cars off the road each year.
- Fossil fuel use also reduced by 5% (320 GJ of avoided energy use), which is equivalent to burning 7 tonnes less diesel per year (on and off-farm through energy for fertiliser manufacturing etc.).
- Substantial water quality improvements are also expected in cane due to reduced application of herbicide active ingredients (A.I.) (by 600 kg per year), and a net reduction in the potential for nutrient losses (by 410 kg nitrogen (N) equivalent per year).

The findings of this case study are specific to the individual business evaluated and not intended to represent the impact of similar practice changes more broadly.[49]

Economic, biophysical and farm management data before and after practice change were supplied by the grower. The Farm Economic Analysis Tool (FEAT)[50] was used to determine the impact of these changes on business performance. The CaneLCA Eco-efficiency Calculator (CaneLCA)[51] was used to determine the impact of the practices changes on the environment.

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[49] Various management practice changes were made by Tony progressively over at least 20 years (from a base year of 2000 to 2020). For simplicity, the economic analysis excludes some adjustments (e.g., over the years Tony has tried different tillage methods, legume species and composting) and the annual benefit is calculated using a 10-year investment horizon.

[50] FEAT is a tool that considers sugarcane farm production systems from an economic perspective, allowing users to analyse the revenues and costs associated with their farming enterprises. https://featonline.com.au/

[51] CaneLCA is a Microsoft Excel® based tool that calculates 'eco-efficiency' indicators for sugarcane growing based on the life cycle assessment (LCA) method. It streamlines the complex LCA process to make it more accessible to researchers, agricultural advisors, policy makers and farmers. https://eshop.uniquest.com.au/canelca/

Grower insights

Tony shared the following insights about his journey:

"When my son Mitch was about 5 years old, I remember starting to relook at how we were farming. We had some of the Sugar Yield Decline Joint Venture projects on our farm, which got us thinking. It took a while to implement, but it all started with developing a whole farm plan. This involved changing the plantings so we could separate the farm into 5 distinct zones. All the plant cane was now in one area, covering multiple blocks, with the same for each ratoon. We changed some row directions, and laser levelled to improve drainage. This extended the run length of each operation, meaning less time turning around at each headland and improved fuel and time efficiency.

And it also meant we had a set area to work with in each fallow, with a standard ratoon cycle, which enabled us to focus on what was occurring in the fallow. We wanted to get something growing in the soil the whole time to keep the biology alive. So we started looking at a variety of crops to grow, some planted in winter on early plough out blocks, some for the summer months, and a third crop planted in autumn to last until the cane was replanted in spring. And we're still looking for other rotation crops to better fit the plan.

A major change has been to reduce the amount of tillage operations to a minimum, both in terms of area (zonal) and number of passes. I believe that this reduction, and the break in the cane monoculture, with a constant ground cover, has improved the health of our soil, and the microbes within it. This is shown by the consistency of our third ratoon crop. It may be that we could now extend into a 4th ratoon, but that doesn't currently fit the farm plan.

The other aspect that has made a big difference is focussing on soil structure. The roots need uncompacted ground to grow in, and we have seen disaster zones where trucks have driven over the seedbed and crushed all the air out, which lasts for years. So we ask the harvester to use GPS and train the haul-out drivers on being extra careful not to drive on the rows. All the crops are grown on the same wheel spacing, and that has also meant we can get in and spray on time due to firmer tracks, while leaving the seedbed friable. And as the seedbeds aren't so compacted to start with, we have been able to really reduce our cultivations which is good for the soil, good for our cheque book, and gives us more time to contract out our machinery.

Our yields aren't the best in the district, and we are constantly learning, but I am relatively happy with our cost of production and sustainability. Mitch is now working with me in the business. We believe that what we have done to look after the health of the soil and improve the efficiency of operations is a good foundation. We need to be ready to keep changing as we keep learning what works for our soils and our situation. Our motto is: Never stand still - where to next?"

What changes were made?

The main changes to Tony's farming system are summarised in Table 1.[52] To improve tractor efficiency, he increased row lengths where practical, reduced tillage and aligned machinery to row spacing (to reduce compaction and improve soil health).

He also transitioned from a single legume fallow to multiple rotation crops, including a mixed species cover crop, and cash crops such as soybeans, peanuts and field peas. To help with growing these rotation crops, he converted much of his irrigation from flood to low-pressure boom, which also required investing in irrigation infrastructure such as underground pipes.

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[52] Over the years Tony has tried different tillage methods, legume species and composting. However, those additional adjustments are not the focus of this study.

Table 1: Main changes to the farming system considered in this study

	Before	After
Soil health management	Heavy tillage (discing, ripping and rotary hoeing on a regular basis) Single summer legume break crop, with periods of bare fallow	Substantially reduced tillage (less operations/passes and zonal tillage) Multiple fallow crops (mainly harvested). Rows were realigned and plantings grouped by management zones to enable longer runs and easier planning
Nutrient management & ameliorant	Fertiliser applied as a side-dressing in one application (in ratoons)	Fertiliser banded on crop and watered in via boom, with urea fertigated as a split application (in ratoons)
Weed, pest and disease management	Limited spray windows (either waiting for wheel tracks to dry or creating ruts when wheel tracks wet) Standard spraying/calibration	Improved timeliness of sprays (better suited to legume crops) due to firmer wheel tracks (from less cultivation) and less tracks required per block (from a wider spray boom) Reduced application rates and changes towards pesticide A.I.'s with lower environmental toxicity
Irrigation and drainage management	Flood and winch irrigation with poor uniformity of water distribution	Mainly low-pressure boom irrigation with improved uniformity. Provides the ability to fertigate (urea) and grow multi-row fallow crops.

What does this mean for the business?

The economic analysis indicated Tony's annual operating return has increased by $262/ha ($56,369) after the practice changes, due largely to increased revenue in the legumes following the introduction of soybeans and peanuts.

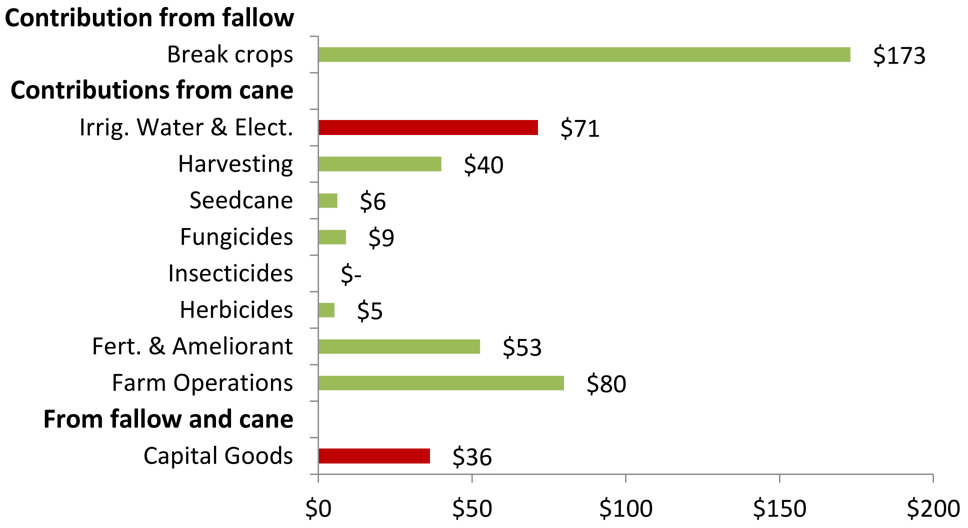

Figure 1: Contributions to the change in farm operating return ($/ha change)

Note: Green bars denote increases in operating return, red bars denote decreases.

The ‘Break Crops’ category (Figure 1) accounts for income from harvested legumes and operations occurring during the cane fallow period. It captures cost changes for all categories except repairs and maintenance (which is assigned to the ‘capital goods’ category). After shifting from a single cover crop to multiple fallow crops (mainly harvested), the gross margin for the fallow area improved by $850/ha, equivalent to an average of $173/ha across the full farm area (including cane area).[53]

The cane operation changes also reduced the overall average farm costs substantially. Cost savings relate to fuel, oil and labour from farm operations ($80/ha), fertiliser and ameliorants ($53/ha), cane harvesting ($40/ha), and other minor cost savings ($10/ha) (Figure 1). The only substantial cost increase was for irrigation electricity ($71/ha), because of different operating pressures between systems when shifting away from furrow irrigation to more overhead boom irrigators. This was done to maximise production in the rotation crops. Note that all values in Figure 1 have been averaged across 5 crop classes (including plant cane, three ratoons and one fallow).

Farm operation costs include fuel, oil and labour costs (for operations performed by the grower), and the reduced tillage has made a large contribution to cost savings. Longer runs per row have also contributed to cost savings during harvest and helped to minimise tractor hours in all crops.

Capital goods refers to the cost of repairs, maintenance and depreciation of machinery and equipment (Figure 1). After the practice changes, depreciation increased due to new equipment purchased, but repairs and maintenance costs decreased because of reduced tractor hours. The net effect was a minor increase in cost as the increase in depreciation was higher than the savings.

How much did it cost to make the changes?

To move to a reduced tillage system with multiple legume break crops, Tony converted a rotary hoe for zonal tillage ($250 in labour) and built up a zonal cultivator ($25,000). He also purchased a sprayer with a wider boom ($40,000) to cope with extra legume sprays. To produce the legume crops, he bought a portion share with neighbours in a vacuum planter ($8,333 for his share) and peanut digger ($6,667 for his share). He converted his irrigation system to include low-pressure booms ($200,000) with new underground piping and bore renovations ($300,000).[54] He laser levelled and changed the directions of selected rows ($25,000) and equipped tail water dams with a mobile pump ($15,000). The total cost of implementation, for various one-off costs, was $620,250 (or $2,885/ha).

Was the investment profitable?

Results of an investment analysis show the practice changes were a worthwhile investment. Given the lower costs and improved revenues, it would take Tony 10 years to recover the $620,250 (or $2,885/ha) invested.[55]

Over a ten-year investment horizon, Tony’s investment has added an additional $9,766 per year ($45ha/yr) to his bottom line. The analysis factors in the initial capital investment, a required return of 7%, time to transition to the new system, and the residual value of the capital investments (Table 2).[56]

To be conservative, this analysis is based on cane yields remaining the same across Tony’s farm after the practice

Table 2: Cost of implementation and investment results

Cost of Implementation ($/ha)	$2,885
Discounted Payback Period	10 years
Annual Benefit ($/ha/yr)	$45/ha
Internal Rate of Return	8.6%
Investment Capacity ($/ha)	$3,204

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[53] The single cover crop had a $533/ha cost and the multiple fallow crops had a positive average gross margin of $317/ha.

[54] Tony was successful in applying for several grants. However, any grant amounts are excluded in the analysis.

[55] This payback period applies if residual capital values are realised at the end of the ten-year investment horizon.

[56] Changes are factored in gradually over several years across areas under fallow, plant crop and ratoons. The Annual Benefit and Internal Rate of Return are calculated over a 10-year timeframe. When calculating the Annual Benefit, the residual value of Tony’s investment is included in the analysis after 10 years.

changes.[57]. Production differences over time can be related to factors such as seasonal conditions and different varieties, rather than management practice changes. However, actual Mill results from his farm show increases in cane yield and CCS, resulting in a 13.6% increase in sugar production.

Investment capacity is the maximum amount of money that can be spent before an investment becomes unprofitable. Tony could have invested up to $688,801 ($3,204/ha), before the cost savings made by the practice changes would be insufficient to provide the required (7%) return on investment.

What does this mean for the environment?

Five indicators of environmental impacts were calculated using the CaneLCA tool to see how much the practice changes influenced environmental performance per tonne of harvested cane. These indicators are:

- Fossil fuel use, an indicator of fossil-fuel resource depletion over the cane life cycle (MJ/t cane).[58]
- Carbon footprint, an indicator of greenhouse gas (GHG) emissions causing global warming over the cane life cycle (kg $CO_{2\text{-eq}}$/t cane).[59]
- Eutrophication potential, an indicator of water quality impacts caused by the release of eutrophying substances (nitrogen, phosphorus, sugar) to waterways via surface runoff and infiltration to groundwater (kg $PO_{4\text{-eq}}$/t cane).[60]
- Eco-toxicity potential, an indicator of water quality impacts caused by the loss of toxic substances to waterways, such as pesticides but also heavy metals (kg CTU_{eq}/t cane).[61]
- Water use, an indicator of water resource depletion over the cane life cycle (kL/t cane).

Impacts are calculated over the ‘cradle to farm gate’ life cycle of cane growing (up to and including the haul-out of harvested cane to the siding, but not including transport to mill). They include the environmental impacts associated with the *off-farm* production and supply of inputs (fertilisers, pesticides, diesel, electricity, lime etc.) as well as those that occur *on-farm* (tractor exhaust emissions, gaseous losses of nitrogen, runoff of pesticides and nutrients to water). They also account for the impacts of growing break crops, a fraction of which may be assigned to the cane production. In this case, as many of the break crops are grown as cash crops, most impacts in the fallow period were assigned to the break crops and around 20% were assigned to cane production.

The estimated changes in environmental impacts per tonne of harvested cane after the practice changes were adopted by Tony are shown in Figure 2. There has been a net decrease in all of the environmental impacts (i.e., negative values on the graph that show environmental improvements). The largest reductions (environmental improvements) are for ecotoxicity potential (from pesticide losses to water). Water use remained the same for cane, and hence is not reported in Figure 2.

Please note that environmental indicators in this study are focused on cane production, whereas economic indicators (e.g., ‘annual benefit’) factor in all crops.

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[57] It is Tony’s personal view that yields were (at least) maintained after making practice changes, and this view is informed by DAF’s review of his production records from 2000-20 and comparisons of his farm’s production data to productivity zone data. The findings of these case studies are specific to the individual businesses evaluated and are not intended to represent the impact of practice changes more broadly (and it is noted that some aspects of the analysis have been simplified).

[58] MJ = megajoules of fossil fuel energy.

[59] kg $CO_{2\text{-eq}}$ = kilograms of carbon dioxide equivalent, the reference substance for representing greenhouse gases (carbon dioxide, nitrous oxide, methane).

[60] kg $PO_{4\text{-eq}}$ = kilograms of phosphate equivalent, the reference substance for representing the eutrophication of water due to eutrophying substances (nitrogen, phosphorus, sugar).

[61] kg CTU-eq = kilogram of equivalent critical toxicity units, a measure of the eco-toxicity effects in freshwater due to releases of toxic substances (pesticide active ingredients, heavy metals). Pesticide active ingredients usually originate from the on-farm agricultural activities, and heavy metals usually originate from the off-farm activities producing the electricity, machinery, etc used on the farm.

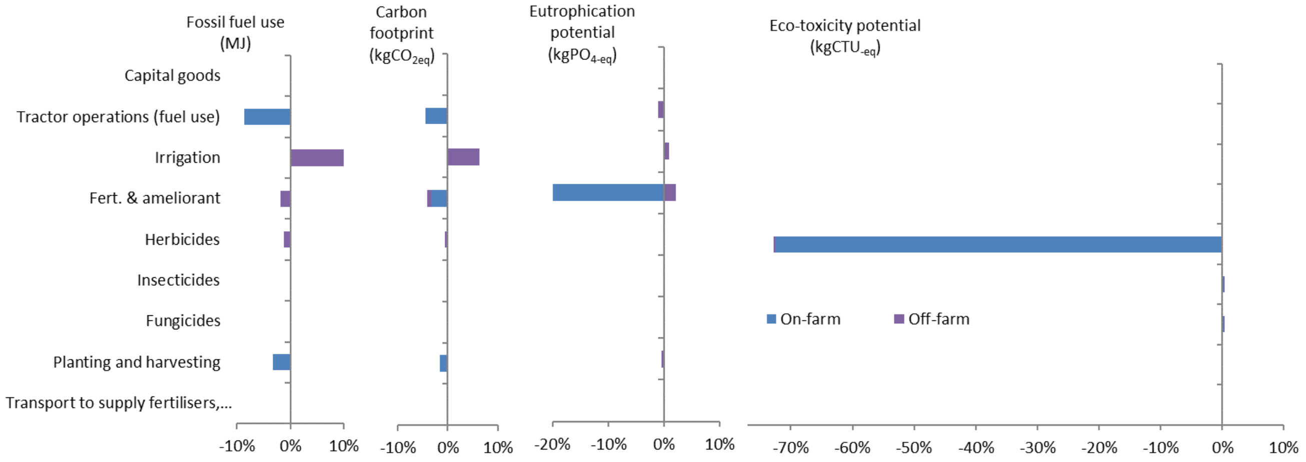

Figure 2: Changes in environmental impacts after practice changes (% change per t cane) [62]

Fossil fuel use. The combined effect of all the practice changes reduced the life-cycle fossil-fuel use by 5% per tonne of harvested cane. This means that around 320 gigajoules (GJ's) less fossil energy is consumed per year for the farm's operations (both on-farm and off-farm), which is equivalent to combusting 7 tonnes less diesel fuel per year[63]. There were reductions in diesel use in tractors and harvesters due to fewer and more efficient tractor operations and improved harvesting efficiency. However these energy savings were offset by increased electricity use for irrigating cane due to the change from furrow to travelling boom. The overall change in fossil fuel use was a modest decrease.

Carbon footprint. The changes in the carbon footprint mostly mirror the changes in fossil fuel use discussed above. There are less greenhouse gas (GHG) emissions due to less diesel use for tractor and harvester operations, but increased GHG emissions associated with electricity use for irrigation. There has also been a reduction in the amount of nitrous oxide (N_2O) emitted due to less nitrogen fertiliser being applied to the ratoon crop. Overall, the GHG emissions (carbon footprint) reduced by 5% per tonne harvested cane. This means around 40 tonnes per year of carbon dioxide emissions are now avoided for the farm's operation, which is equivalent to taking 13 cars off the road each year.

Eutrophication potential. The reduced application rate of fertiliser nitrogen to the ratoon crops reduced the potential for on-farm nutrient-related water quality impacts. This was offset slightly by the off-farm eutrophication effects from producing the additional mineral fertilisers applied to the break crops, and the extra electricity for irrigation pumping (due to N gases emitted when coal is burnt to produce electricity). Overall eutrophication potential is estimated to reduce by 19%, which is reduced loss of nutrients to water by 410 kg of N-equivalent per year.

Eco-toxicity potential. The stand-out environmental improvement has been the reduction in the potential for toxicity-related water quality impacts by about 72% per tonne harvested cane. This has been due to a 600 kg per year reduction in the amounts of herbicides applied, but also changes in the types of herbicide active ingredients. There has been a shift away from the use of Diuron, Glyphosate, Pendimethalin and Picloram, and a reduction in application rates of 2,4-D and Paraquat.

Water use. There has not been a change in the overall amount of water used on the farm per tonne of cane, hence it is not included in Figure 2. There has been more water applied to irrigate the introduced break crops, but as many of these are harvested as a cash crop, most of this additional water use was assigned to the cash crops rather than to the cane.

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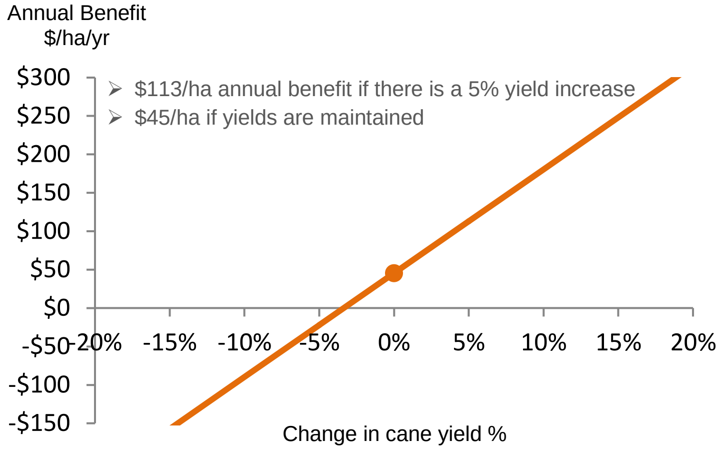
[62] A negative % change represents a decrease in environmental impact, and a positive % value represent an increase in environmental impact.

[63] This includes fossil fuel use over the life cycle of the cane growing, includes not just on-farm diesel consumption but also off-farm use of fossil fuels in the production of fertilisers, pesticides, diesel, lime, electricity, and in transport for delivering inputs.

What about risk?

When adopting any management practice change, economic outcomes can vary with changes in key profitability drivers, such as yield, and depend on how effectively the practice is implemented.

A production risk analysis (Figure 3)[64] shows overall cane yield (across plant and ratoon crops) would need to decline by 3.4% before Tony's investment in practice changes would become unprofitable. However, the adoption of practice changes that have been scientifically validated[65] means an adverse impact on cane yield is unlikely.



- $113/ha annual benefit if there is a 5% yield increase
- $45/ha if yields are maintained

Figure 3: Sensitivity of annual benefit of investment to yield

Conversely, a small improvement in cane yield is expected to result in a substantial economic gain. For example, the yield and CCS data for Tony's farm indicates an increase of over 13.6% in tonnes of sugar per hectare.[66] If a 5% yield gain were attributed to the practice changes (with CCS held constant), the estimated annual benefit would increase from $45/ha/yr to $113/ha/yr ($24,287/yr).

Tony has been making low-cost compost on farm and applying this to part of the plant cane crop. This was not a focus of this case study, but if all the costs associated with making, loading, and applying the compost were included, his cane yields would need to improve by 5.7% to arrive at the same annual benefit identified in this study (of $45/ha).

An additional production risk analysis shows the sensitivity of environmental improvements to yield (Figure 4).

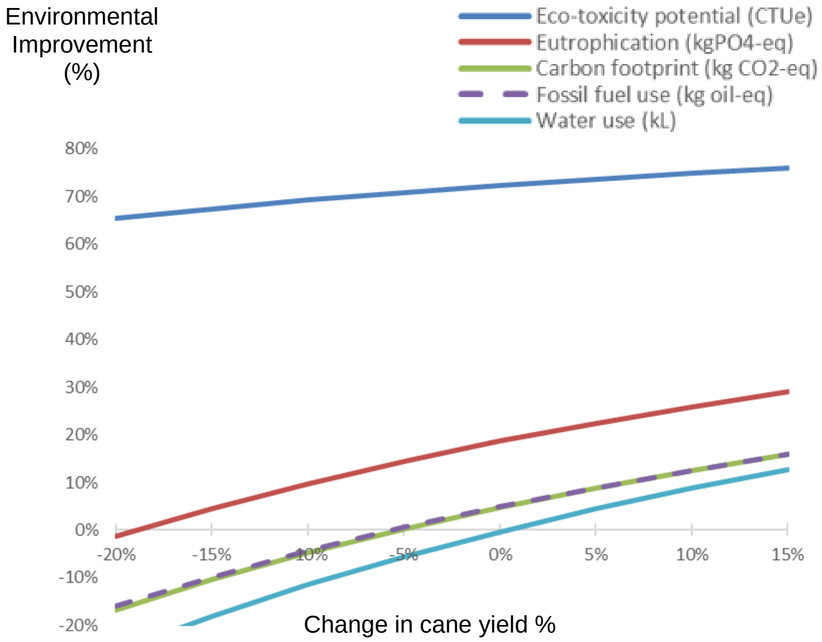


Figure 4: Sensitivity of environmental improvements to yield

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[64] The economic production risk analysis (Figure 3) explores yield changes only, with CCS and the sugar price held constant.

[65] Such as practices aligned with Smartcane BMP (best management practice) principles.

[66] When an average of Tony's yields for the 2000-04 period was compared to the 2016-20 period. This 13.6% increase is a conservative figure. Production records for two years were adjusted to account for probable water restrictions.

The reductions in fossil fuel use and carbon footprint are slightly sensitive to changes in cane yield (Figure 4). If cane yields reduced by 5% or more across plant and ratoons there would be no net reduction in the fossil fuel use or carbon footprint per tonne of cane. For eutrophication potential, it would need to drop by 18% or more for there to be no improvement. As eco-toxicity improvements were so large, they are not sensitive to cane yield changes. Any increase or reduction in cane yield would change the water use efficiency per tonne of cane.

What's the bottom line?

This case study has evaluated the economic and environmental impacts of various practice changes, including those aimed at improving soil health, for a farm in the Bundaberg region.

Results of the economic analysis indicate that the changes resulted in additional income from harvested fallow cash crops that outweighed costs increases during the fallow period. For Tony's cane operations, cost savings were largely due to reduced fuel, oil, labour and fertiliser costs, as well as improved harvesting efficiency. Tony's investment in purchasing, or building, new equipment has been shown to be worthwhile, particularly in respect to reducing land preparation costs and increasing legume revenues. Overall cane yields (across plant and ratoon crops) would need to decline by 3.4% before investment in these practice changes becomes unprofitable (and any improvements in cane yield associated with these changes would be expected to increase the economic gain).

The practice changes have resulted in reduced environmental impacts, especially eco-toxicity due to changes in herbicide use, but also less fossil fuel use, a lower carbon footprint and less risk of nutrient-related water quality impacts.

Each farming business is unique in its circumstances and therefore the parameters and assumptions used in this case study are intended to reflect Tony's situation only. Consideration of individual circumstances must be made before applying this case study to another situation.

We wish to thank the participating growers for providing their time and operational data required to complete the analyses. Thanks to Bundaberg Sugar and Isis Central Mill for the provision of historical production data.

This case study is an output of the DAF project: Combined Economic and Environmental Evaluations of Practice Adjustments. The economic analysis was completed by DAF agricultural economists. The environmental assessment was performed by the Centre for Agriculture and the Bioeconomy at Queensland University of Technology.

For further information on this integrated case study please contact the Bundaberg DAF office on 13 25 23.

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FARM ECONOMIC ANALYSIS TOOL

The economic and environmental impacts of innovative practice changes and improved irrigation delivery

Case Study: Andrew and Melissa Deguara (Central Queensland)

The following case study (2021) evaluates the economic and environmental impacts of practice changes adopted by a sugarcane grower (aligned with Smartcane BMP principles). The study also considers the impact of improving irrigation infrastructure and the yield response required for repayment of the investments.

Andrew and Melissa Deguara currently farm 341 ha of cane land (including fallow crops) and 150 breeders (cattle) in the Mackay region, Central Queensland. Over the past 10 years, they have continued to make farming system changes following the introduction of controlled traffic by Andrew's father in 2003. With the aim to improve longer-term yields and soil health, they have introduced additional fallow crops and reduced tillage (pre-formed beds) to enhance soil structure. They have also increased the planting rows for soybeans to improve weed control and, more recently, have introduced variable rate fertiliser application on a portion of their farm. Since 2016, they have been investing in irrigation infrastructure upgrades and solar technology to reduce electricity usage and increase the delivery of water and number of irrigation events (allowing for improved scheduling options for full allocation utilisation). This with the aim to reduce energy costs and improve production.

Image 5: Andrew and Melissa Deguara

Key findings of the Deguara case study

The practice changes considered in this study resulted in:

- An annual benefit of $10,027 ($29/ha) from investments aligned with Smartcane BMP, indicating they were worthwhile. Cost increases relating to irrigation and mixed species legumes were offset by revenue improvements due to a cane yield increase (from additional irrigation).
- With the introduction of solar energy, there was an additional annual benefit improvement of $2,742 per annum ($8/ha) indicating solar investments were also profitable.
- Greenhouse gas emissions reduced by 32 tonnes per year, equivalent to taking 10 cars off the road. This is a reduction of 11% per tonne of harvested cane.
- Fossil fuel use also reduced by 170 GJ of energy use per year, equivalent to burning 4 tonnes less diesel fuel (both on-farm and off-farm through energy for fertiliser manufacturing etc.). This is a reduction of 10% per tonne of harvested cane.
- A slight improvement in water quality related aspects could be expected due to reduced overall eco-toxicity potential of the applied herbicide active ingredients (AI) and a reduction in the nutrients potentially lost to water from the farm by 80kg of nitrogen equivalent per year.
- The practice changes included increased irrigation to improve cane productivity, which contributed to the improved environmental performance per tonne of cane. The trade-off of more water extraction is likely to be minor since the region is not particularly constrained in terms of water availability.

The findings of this case study are specific to the individual business evaluated and are not intended to represent the impact of similar practice changes more broadly.[67]

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[67] Various management practice changes were made by the Deguaras' progressively over the past 6 years from the base year of 2016. For simplicity, the economic analysis excludes some changes (e.g. controlled traffic/row spacing changes, due to this taking place while ownership resided with Andrew's father before 2016, and cattle grazed on some of their fallow area). The Annual Benefit is calculated using a 10-year investment horizon.

Economic, biophysical and farm management data before and after practice changes were supplied by the grower. The Farm Economic Analysis Tool (FEAT)[68] was used to determine the impact of these changes on business performance. The CaneLCA Eco-efficiency Calculator (CaneLCA)[69] was used to determine the impact of the practice changes on the environment.

Grower insights

Andrew and Mel shared the following insights when interviewed about their journey:

"My dad laid a great foundation by introducing controlled traffic in 2003 that included widening the row spacing from 1.5 to 1.86 metres. We have continued to build on this by planting to dual row pre-formed beds that have helped with weed control through improved ground cover. It has also made planting easier with an improved pull-through for our zonal tillage disc opener."

"The introduction of an extra mixed species cover crop is motivated by our drive to reduce soil pathogens for improved long-term soil health and biology. Reducing soil movement and sun exposure also helps with this."

"For us energy is expensive. It is our main consideration behind the continued roll-out of solar energy on our property. This along with various system improvements on our centre pivots and soft hoses have helped reduced the overall costs per ML of irrigation water. It has also helped us deliver more to our crop which has improved overall yields for the farm."

"We have become increasingly aware of the need to reduce the level of toxic chemicals we use on-farm. We are also constantly trying to reduce overall chemical use where possible, but this continues to be a challenge."

What changes were made?

Details of changes to the Deguaras' farming system considered in this study are summarised in Table 1. To reduce soil compaction, the Deguaras' introduced pre-formed beds with reduced tillage. To reduce soil pathogens, they introduced a second fallow of mixed species which is also planted in three rows for better canopy closure (less weed competition) and improved soybean yields. They have reduced their BioDunder application from 160 to 149 kg N/ha in their ratoons and are also applying it at a variable rate on 50ha of cane area (under investigation) through the use of prescription mapping.

The investment into irrigation upgrades and solar technology has improved delivery rates (flow rates) and offset a significant amount of electricity usage. This has not only reduced operational costs per ML, but also significantly improved cane yields. The changes considered follow the earlier adoption of controlled traffic and wider row spacing (not considered in this study) and reflect the Deguaras' drive for continued practice and system improvements.

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[68] FEAT is a tool that considers sugarcane farm production systems from an economic perspective, allowing users to analyse the revenues and costs associated with their farming enterprises. https://featonline.com.au/

[69] CaneLCA is a Microsoft Excel® based tool that calculates 'eco-efficiency' indicators for sugarcane growing based on the life cycle assessment (LCA) method. It streamlines the complex LCA process to make it more accessible to researchers, agricultural advisors, policy makers and farmers. https://eshop.uniquest.com.au/canelca/

Table 1: Main changes considered in this study

Before		After
Soil Health Management	• Heavier tillage (e.g. with rotary hoe and offsets) • Single legume (cash crop) in fallow period	• Reduced/Zonal tillage (e.g. with wavy disc and planting with disc opener) and pre-formed beds • Double legume (cash crop and mixed species) for a better managed fallow period
Nutrient Management & Ameliorant	• Grower determined nutrient rate (higher rate on ratoons)	• Following SIX EASY STEPS® guidelines to reduce inorganic fertiliser application (and with variable rate application on 50ha, 15% of total area) • Increased soil testing
Weed, Pest and Disease Management	• Standard pesticide A.I.'s (e.g. 2,4-D) • Double row legume (cash crop)	• Changes to pesticide A.I.'s with lower environmental toxicity (e.g. MCPA) • Triple row legume for improved weed control (cover) and cash crop yield
Irrigation & Drainage Management	• Long chains (for soft hoses) • Narrow pipes (lower flow rates)	• Shorter chains (for soft hoses) to improve energy efficiencies • Wider pipes and added motors (increased flow rates) for increased irrigation events (improved allocation utilisation and scheduling)
Additional Changes		
Energy Source (per ML)	• 81% electricity, 19% diesel	• 73% electricity, 11% diesel, 16% solar energy (130kW)

What does this mean for the business?

The economic analysis shows the Deguaras' operating return has increased by $138/ha ($47,089, excluding solar), largely due to the increase in the cane and legume yields which added $309/ha[70] of net income (based on a conservative yield improvement). The largest cost increase was from harvesting and levies ($66/ha) linked to improved production (Figure 1). The second largest increase came from the more frequent irrigation events and additional irrigation required for the added mixed species fallow ($53/ha, excluding solar). Other cost increases included capital goods ($20/ha), herbicides ($16/ha) and seed ($14/ha).

There was a saving in fungicide costs (-$3/ha) due to a product change but the largest cost saving came in the form of solar energy (-$32/ha) taking the operating return improvement to $170/ha ($58,106). Overall, the yield improvement (largely due to the increase in irrigation, from 2ML to 3ML/ha) outweighed the cost increases giving an overall improvement in operating return.

Farm operational costs include fuel, oil and labour for tractor operations. Overall, there was a marginal increase in this category, but there were cost savings in fuel and oil for the cane system (-$4/ha) with increased labour costs in both the fallow ($7/ha) and cane ($5/ha).

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[70] This is the total income less post-harvest and haulage costs (levies, freight, etc.) per hectare across the full farm area which includes $281/ha from the cane operation (using a sugar price of $429/t for an 8t/ha increase in yield) and $27/ha from the soybeans (using a farm gate price of $650/tonne for a 0.3t/ha increase in yield).

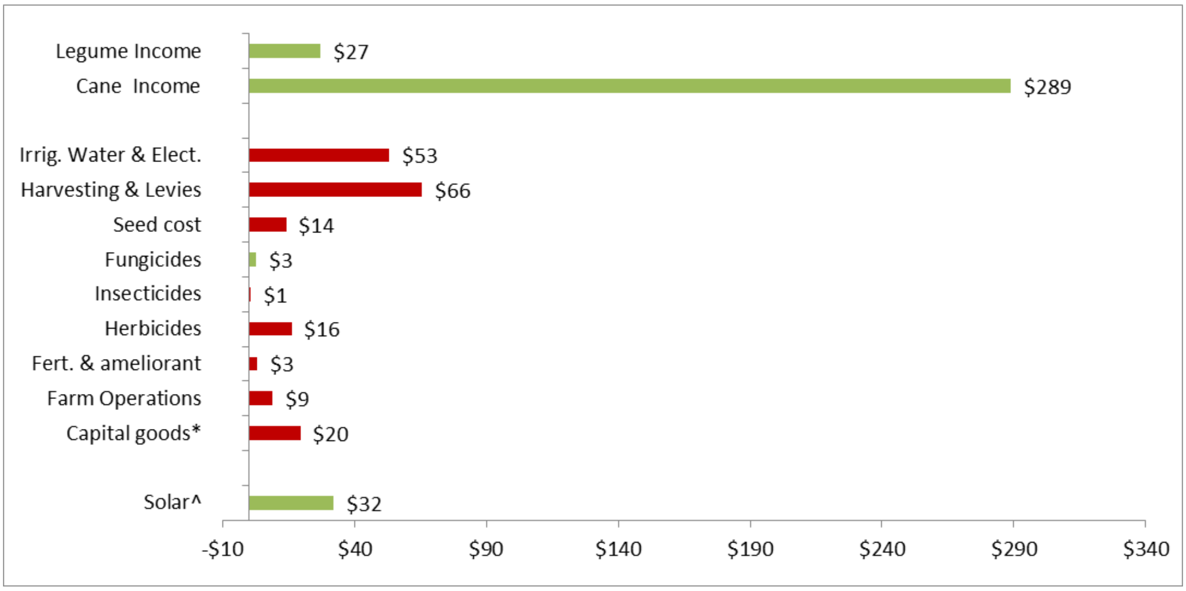

Figure 1: Contributions to the change in farm operating return ($/ha change)
Note: Green bars denote increases in operating return, red bars denote decreases.
*This includes depreciation of equipment.
^This includes $41/ha in electricity savings and $9/ha depreciation on the solar panel infrastructure.

Seed and harvesting cost increases were due to the mixed species added to the fallow period and higher cane yields respectively. There were increases in overall irrigation costs per hectare but the cost per ML reduced following improvements in delivery efficiencies (i.e. wider pipes, increased area under centre pivots, and a move to solar energy).

How much did it cost to make the changes?

In moving to preformed beds and zonal tillage, the Deguaras' purchased various implements including wavy discs, a single row ripper, wheelie rake, plant cane cultivator and new seed spreader. They also built up a bed former and modified their planter. These investments resulted in an implementation cost of $102,000. They spent an additional $95,000 on irrigation system upgrades including pipe replacement, pivot refurbishments, additional mains, pipes and pumps. The cost of implementing all these changes is estimated at $578/ha ($197,000). A further $62,899 was spent on solar panel infrastructure bringing the total to $763/ha ($259,899).

Was the investment profitable?

Results of an investment analysis show the practice changes were a worthwhile investment based on a conservative yield increase (8t/ha from 1ML/ha of added irrigation). Accounting for both the added revenue and higher costs, it would take 10 years to repay the $197,000 (or $578/ha) invested by the Deguaras' in making the changes (which is a similar payback period for when the solar panel investment is included).

Over a 10-year investment horizon, the Deguaras' investment (excluding solar) added an additional $10,027 per year ($29/ha/yr) to their bottom line (when the initial investment, required return of 7%

and time to transition to the new system is taken into account) (Table 2). This analysis is based on cane yields improving by 8t/ha (8.7%) across their farm following the practice changes.[71]

When the solar panel investment and energy cost savings are included the annual benefit is $12,769 per year ($37/ha/yr).

Table 2: Cost of implementation and investment results (excluding and including solar)

	Excl. solar	Incl. solar
Cost of Implementation	$578/ha	$763/ha
Discounted Payback Period	10 yrs	10 yrs
Annual Benefit	$29/ha/yr	$37/ha/yr
Internal Rate of Return	11%	11%
Investment Capacity	$785/ha	$1,026/ha

Investment capacity is the maximum amount of money that can be spent before an investment becomes unprofitable. The Deguaras' could have invested up to $267,425 ($785/ha) before the cost savings made by the practice changes would be insufficient to provide the required (7%) return on investment when solar is excluded. When solar is factored into the analysis, the investment capacity is $349,580 ($1,026/ha).

What does this mean for the environment?

Five indicators of environmental impacts were calculated using the CaneLCA tool to see how much the practice changes influenced environmental performance per tonne of harvested cane. These indicators are:

- Fossil fuel use, an indicator of fossil-fuel resource depletion over the cane life cycle (MJ/t cane) [72]
- Carbon footprint, an indicator of greenhouse gas (GHG) emissions causing global warming over the cane life cycle (kg $\mathrm{CO_{2\text{-eq}}}$/t cane)[73]
- Eutrophication potential, an indicator of water quality impacts caused by the release of eutrophying substances (nitrogen, phosphorus, sugar) to waterways via surface runoff and infiltration to groundwater (kg $\mathrm{PO_{4\text{-eq}}}$/t cane)[74]
- Eco-toxicity potential, an indicator of water quality impacts caused by the loss of toxic substances to waterways, such as pesticides but also heavy metals (kg $\mathrm{CTU_{eq}}$/t cane)[75]
- Water use, an indicator of water resource depletion over the cane life cycle (kL/t cane).

Impacts are calculated over the 'cradle to farm gate' life cycle of cane growing (up to and including the haul-out of harvested cane to the siding, but not including transport to mill). They include the environmental impacts associated with the *off-farm* production and supply of inputs (fertilisers, pesticides, diesel, electricity, lime etc.) as well as those that occur *on-farm* (tractor exhaust emissions, gaseous losses of nitrogen, runoff of pesticides and nutrients to water). They also account for the

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[71] From historical cane yield data, a 10% improvement in yield/ha was identified for the 2016-20 seasons (most recent 5-years), when compared to the period 2011-15. However, yields in the analysis are only increased by 8.7% (8t/ha) which is in line with literature from the past two decades (e.g. Baillie & Raine, 2014; Attard et al., 2009; Ballie, 2000; Ridge & Hillyard, 2000; Inman-Bamber et al., 1999; etc.). The yield increase is also supported by discussions with various growers, previous DAF agronomist (J. Hughes), Canegrowers and Mackay Agricultural Productivity Services. A marginal increase in soybean yield was also included at 0.3 t/ha (within a 0.6 t/ha increase based on recent yields). This was largely due to the change in rows planted to the preformed beds. It is anticipated the results of the study conservatively reflect economic benefits of the practice changes. The findings of this case study are specific to the individual business evaluated and is not intended to represent the impact of practice changes more broadly. As noted previously, various aspects of this case study have been simplified.

[72] MJ = megajoules of fossil fuel energy

[73] kg $\mathrm{CO_{2\text{-eq}}}$ = kilograms of carbon dioxide equivalent, the reference substance for representing greenhouse gases (carbon dioxide, nitrous oxide, methane)

[74] kg $\mathrm{PO_{4\text{-eq}}}$ = kilograms of phosphate equivalent, the reference substance for representing the eutrophication of water due to eutrophying substances (nitrogen, phosphorus, sugar)

[75] kg CTU-eq = kilogram of equivalent critical toxicity units, a measure of the eco-toxicity effects in freshwater due to releases of toxic substances (pesticide active ingredients, heavy metals). Pesticide active ingredients usually originate from the on-farm agricultural activities, and heavy metals usually originate from the off-farm activities producing the electricity, machinery, etc used on the farm.

impacts of growing break crops, a fraction of which is assigned to the cane production. The reduced use of mains electricity for irrigation due to the introduction of PV solar power was excluded from the analysis. However the effects of this on fossil fuel use and carbon footprint are shown separately.

The percentage changes in environmental impacts per tonne of harvested cane are shown in Figure 2. There has been a decrease in all the environmental impacts per tonne cane (i.e. negative values on the graph), except for water use. Irrigation of the cane crops was increased from 2.2 to 3.3 ML/ha, and irrigation of the break crops was increased from 1 to 1.4 ML/ha. This was done to boost cane productivity by 8t/ha. The higher cane yields contributed to lowering environmental impacts per tonne of cane because more cane is produced from the applied inputs.

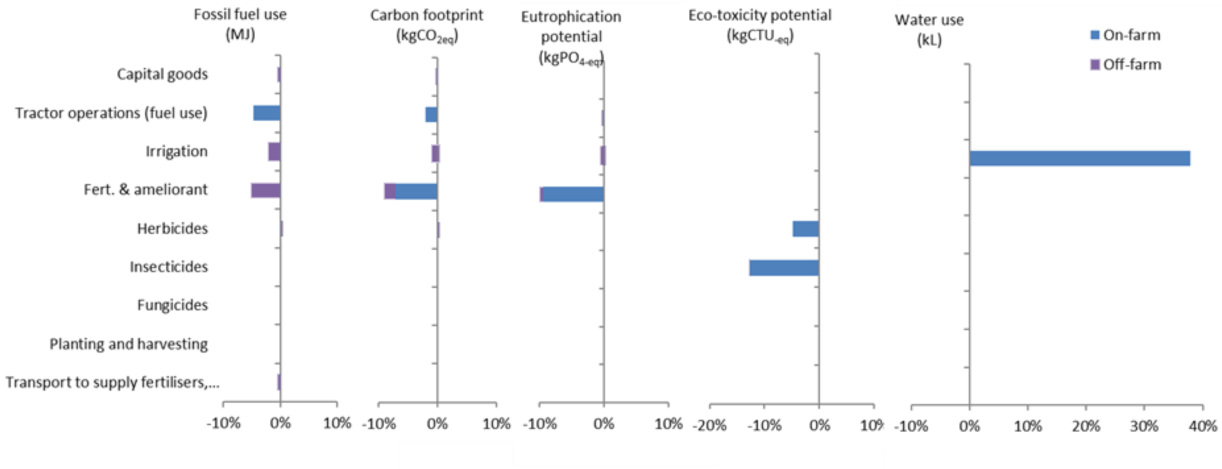

Figure 2: Changes in environmental impacts after practice changes (% change per t cane) [76],[77]

Fossil fuel use. The practice changes reduced the life-cycle fossil-fuel use by around 170 gigajoules (GJ) per year (including both on-farm and off-farm energy use), which is equivalent to combusting 4 tonnes less diesel fuel per year[78]. This reduction was due to less diesel use in tractors from fewer cultivations and less energy used for fertiliser production due to a reduced amount of urea-N applied overall. The reduced energy demand combined with the cane yield increase meant that the life-cycle fossil-fuel use per tonne of harvested cane reduced by 10%. If the solar contribution is factored into the analysis, the reductions would be 250 GJ or 5 tonnes diesel fuel per year, and a 12% reduction per tonne of cane.

Carbon footprint. The practice changes also led to an overall reduction in life-cycle greenhouse gas emissions by around 32 tonnes of carbon dioxide emissions per year, which is equivalent to taking 10 cars off the road each year. This is partly due to the above-mentioned reduction in fossil fuel use, but there is also a decrease in emissions of nitrous oxide (N_2O), a strong greenhouse gas[79] due to less N being applied. Reduced total emissions combined with the greater cane yield meant that the carbon footprint per tonne harvested cane reduced by 11%. If the solar contribution is factored into the analysis, the reductions would be 41 tonnes of carbon dioxide emissions per year or 13 less cars, and a 12 % reduction per tonne of cane.

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[76] A negative % change represents a decrease in environmental impact, and a positive % value represent an increase in environmental impact.

[77] The unshaded bars for irrigation show the reduced fossil fuel use and carbon footprint that would be expected if the solar power was also considered, which reduces use of mains electricity.

[78] This includes fossil fuel use over the life cycle of the cane growing, includes not just on-farm diesel consumption but also off-farm use of fossil fuels in the production of fertilisers, pesticides, diesel, lime, electricity, and in transport for delivering inputs.

[79] The assessment assumes a generic nitrous oxide (N_2O) emission factor of 1.99% of applied N lost as nitrous oxide N, which is based on the latest Australian greenhouse gas inventory methodology. The global warming potential is 298 kg CO_{2-e}/kgN_2O.

Eutrophication potential. The changed nutrient management regime slightly reduced the total amount of N potentially lost to water from the farm per year, in the order of about 80 kg of N-equivalent per year. This combined with the cane yield increase meant that fertiliser-N application reduced from 1.7 to 1.5 kg N/t cane. This has reduced slightly the potential for nutrient-related water quality impacts.

Eco-toxicity potential. The amount of pesticide active ingredients (AI) applied has increased slightly due to the introduction of an additional break crop, by around 5kg per year. However, because there has been a slight shift in the types of AIs applied, the over toxicity potential has decreased overall. This will translate into a slightly reduced potential for toxicity-related water quality impacts. This combined with the cane yield increase means that eco-toxicity potential per tonne harvested cane has reduced by about 18%.

Water use. There has been an increase in the amount of irrigation water used by around 300ML/yr across the farm, which has enabled greater productivity. As noted for the other impact categories, the increased productivity has contributed to reduced environmental impacts per tonne of harvested cane. The trade-off of water extraction is likely to be minor as the region is not particularly constrained in terms of water availability.

What about risk?

When adopting any management practice change, economic outcomes can vary with changes in key profitability drivers, such as yield, and depend on how effectively the practice is implemented.

A risk analysis was completed to explore the impacts from a productivity change due to the new practices, excluding solar (Figure 3).[80] This shows overall yields (across plant and ratoon cane crops) would need to increase by 6.9%, when solar is excluded, before the Deguaras' investment in the practice changes becomes profitable (or 6.4% inclusive of solar).

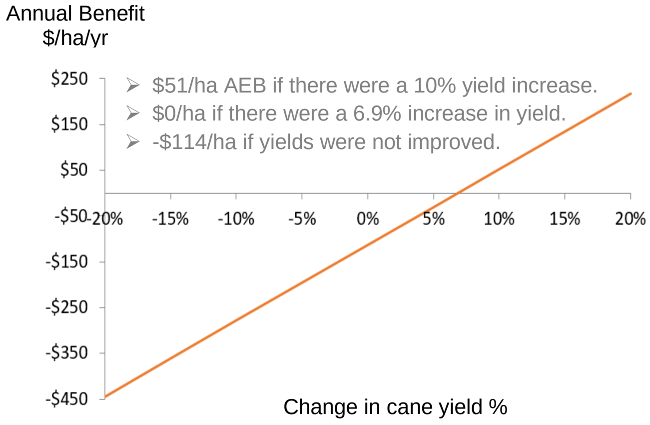

Figure 3: Sensitivity of annual benefit (AEB) of investment to cane yield (excluding solar)

Historical production data and past research indicate that the 8.7% (8t/ha) yield improvement used in the analysis to account for added irrigation is conservative (for an annual benefit of $29/ha/yr, excluding solar). In relation to the other practices, such as reduced tillage, yields are assumed to be unaffected (as these practices are aligned with scientifically validated Smartcane BMP principles).

From an environmental perspective, the improvements are relatively sensitive to changes in cane yields (Figure 4). As noted above, the cane yield was assumed to increase by 8.7% which led to reductions in environmental impacts per tonne of cane in the order of 10-17% across all impact categories, except water use. If there had been no yield increase, then environmental impact reductions (per tonne of cane) would be 3-10%. Cane yields would have to increase a lot more than the assumed 8.7% for there to be no net increase in water use per tonne harvested cane. So there will always be a trade-off in terms of water use for productivity gains and the positive influence this has on the other environmental aspects.

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[80] The economic production risk analysis (Figure 3) explores yield only, with CCS and the sugar price held constant.

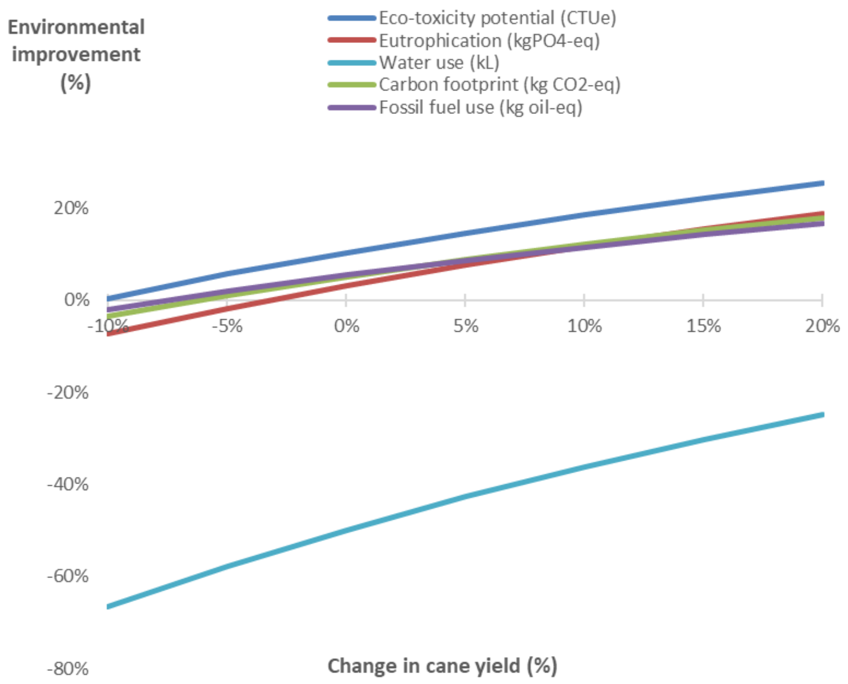

Figure 4: Sensitivity of environmental improvements to yield (excluding solar)

What's the bottom line?

This case study has evaluated the economic and environmental impacts of various practice changes for a farm in the Mackay region. Following on from progress made by Andrew's dad, the Deguaras' have continued to adopt incremental changes. These have improved their profitability and environmental performance.

Results of the economic analysis indicate the recent changes implemented by the Deguaras' have resulted in increased costs per hectare, largely due to increased irrigation and additional legume costs. These additional costs, however, were outweighed by greater income from yield improvements (conservatively estimated) due to increased irrigation events. Overall, the Deguaras' investment in new equipment and infrastructure has been worthwhile within a 10-year payback period. Cane yields (across plant and ratoon crops) would need to increase by 6.9% (6.5% when considering solar investments) before investment in the practice changes becomes profitable.

The practice changes have resulted in slight reductions in environmental impacts per tonne of cane, which have been facilitated by the increases in cane productivity due to increased water application. An interesting aspect of the case study is that the energy needs for the additional water pumping has been met by renewable solar electricity. Therefore there has been no energy trade-off for the productivity gain. There has, however, been a productivity/water-use trade-off in terms of extracting more water overall. This trade-off is minor as the region has a relatively low water stress.

Each farming business is unique in its circumstances and therefore the parameters and assumptions used in this case study reflect the Deguaras' situation only. Consideration of individual circumstances must be made before applying this case study to another situation.

We wish to thank the participating growers for providing their time and operational data required to complete the analyses.

This case study is an output of the DAF project: Combined Economic and Environmental Evaluations of Practice Adjustments. The economic analysis was completed by DAF agricultural economists. The environmental assessment was performed by the Centre for Agriculture and the Bioeconomy at Queensland University of Technology.

Thanks to Mackay Sugar for the provision of historical production data.

For further information on this integrated case study please contact the Townsville DAF office on 13 25 23. This is an updated version of the case study.

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The economic and environmental impacts of managing soil health and improving irrigation

Case Study: Willy Lucas (Burdekin)

The following case study evaluates the economic and environmental impacts of practice changes adopted by a sugarcane grower with the aim of improving soil health and irrigation.

Willy Lucas farms 186 hectares in the Burdekin (Delta) region, North Queensland and uses contractors (from his group) for harvesting sugarcane. Since 1999 he has implemented a range of adjustments to his farming system. He has transitioned to an extended fallow with cash crops, reduced his tillage, introduced GPS and a controlled traffic system, optimised his fertiliser and pesticide applications and improved his irrigation and drainage. Willy has also tried irrigation automation, various crop rotations and installed a recycle pit for a portion of his farm. However, these additional adjustments are not the focus of this study.

Image 6: Willy Lucas

Key findings of the case study

The practice changes considered in this study resulted in:

- An annual benefit of $70,084 ($377/ha), indicating Willy's investment was worthwhile. Harvesting break crops in an extended fallow period introduced additional income. Cost savings were largely due to a reduction in electricity costs (after substantial changes to improve irrigation and drainage) and due to reduced fuel and labour costs from less tillage.
- In cane, greenhouse gas emissions reduced by 46% (1,110 t of avoided greenhouse gases per year), which is equivalent to taking 360 cars off the road each year. Fossil fuel use also reduced by 49% (11,000 GJ of avoided energy use per year), equivalent to burning 240 tonnes less diesel per year (on and off-farm through energy for fertiliser manufacturing etc.).
- Potential water quality improvements due to reductions in nutrient losses (reduced by 1.1 tonnes of nitrogen (N) equivalent each year) and pesticide active ingredients (A.I.'s) application (reduced by around 11 kg each year) in cane. Water use efficiency per tonne of cane, in terms of water applied, also improved by 36%.

The findings of this case study are specific to the individual business evaluated and are not intended to represent the impact of similar practice changes more broadly.[81]

Economic, biophysical and farm management data before and after changes were supplied by the grower. The Farm Economic Analysis Tool (FEAT)[82] was used to determine the impact of these changes on business performance. The CaneLCA Eco-efficiency Calculator (CaneLCA)[83] was used to determine the impact of the practices changes on the environment.

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[81] Various management practice changes were made progressively from a base year of 1999 until 2021. Some of Willy's practice changes, such as herbicide / irrigation practice changes, began shortly after Willy took on the farm. For simplicity, the analysis excludes some changes and trials (e.g. transition from plough out replant to short fallow for parts of the farm, investment in a recycle pit, trialling irrigation automation, cane variety trials, adjustments in planting practices) and the Annual Benefit is calculated using a 10 year investment horizon. Certain implements built by Willy are costed as if bought new.

[82] FEAT is a tool that considers sugarcane farm production systems from an economic perspective, allowing users to analyse the revenues and costs associated with their farming enterprises. *https://featonline.com.au/*

[83] CaneLCA is a Microsoft Excel® based tool that calculates 'eco-efficiency' indicators for sugarcane growing based on the life cycle assessment (LCA) method. It streamlines the complex LCA process to make it more accessible to researchers, agricultural advisors, policy makers and farmers. *https://eshop.uniquest.com.au/canelca/*

Grower insights

Willy shared the following insights about his journey:

My wife and I officially took on the farm from Dad in 1999 after I'd done ag college, hauling out and spray contracting. Dad would do a late plant on some blocks and I had been keeping an eye on the late plant yields put out each year in bulletins. So I moved away from this and made sure all blocks had a fallow with a cover crop like lab lab. Since then I've tried different types of extended fallows with cash crops and, at the moment, my farm is based around having 18 month fallows. This gives me some flexibility to include fallow crops that have good prices at the time. Something I've found is that it's important to use the right varieties of seed and manage the fallow crops well.

In the past, Dad used to water every second (cane) drill, then change cups and water the other drill. I experimented with watering every drill and found it used less water for my particular soils. I started watering every 7 days, not 14, and used less water each irrigation. I began to only work my ratoons if I had to, and noticed big differences in water use in my permeable soils. Then the water moved too quickly down the drill and wouldn't go sideways into the bed so I began a light cultivation which kept some compaction, but slowed the water down enough to get soakage. These days I still juggle this and may use a custom drill renovator and try to keep the right level of trash. I still have a few things I'd like to try. As our farm has expanded, I put pipes in to send water between farms. It was a big cost but made life easy. I laser levelled some additional blocks, since I noticed it could help irrigation. After talking with advisors I decided to make the drills shorter and this proved to be a major benefit.

I have found that using GPS has helped me stick to set zones each year. When I didn't have my own GPS units it was more of a hassle. For example, I might have had to work the whole paddock and then get a contractor in to mark out with his GPS. In more recent years, I've tried a wider row spacing that matched my machinery to see if it would help with better wet weather access. I started doing this on part of the farm (through DAF trials) and then rolled it out across other blocks and found ways to make it work for me. I've also tried different ways of cane planting and had times when I barely had to work my ground. Trial, error, and flukes have shown me I can try different things to drop my costs.

I talk ideas through with my mates, grower groups and agronomists. I've also gotten advice from being involved in projects with BPS, Farmacist, SRA, NQ Dry Tropics and DAF. Going through Smartcane BMP accreditation has also helped me think about how to make practices suit my farm.

What changes were made?

Details of key changes to Willy's farming system considered in this study are summarised in Table 1. He changed the layout of some farm blocks and invested in piping and laser levelling (resulting in more consistent gradients, paddock shapes, run lengths and row directions). He also changed his tillage/trash management practices. These changes were implemented to improve irrigation and drainage and, in particular, to optimise the flow of water down the drills in a farm with permeable soils and a flood irrigation system).[84] He shifted to an extended fallow and, in this study, the example of changing from a short fallow to an extended fallow is considered (with a rotation of cash crops including mung bean, maize and soybean crops).

To improve machinery access after wet weather and reduce soil compaction, Willy widened his row spacing to better match his machinery and uses GPS guidance for his tractors (with variable rate control for his fertiliser operations). Willy reduced his cultivation operations and purchased or customised implements for his farm (including a bed former and bed renovator, a vacuum planter and mulcher for fallow crops, and a drill renovator to clean out furrows for irrigation). He purchased a flipper roller for harvesting on a wider row spacing and modified his fertiliser box.

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[84] Willy made many changes while expanding his farm to include neighbouring blocks. An area of 186ha (the combined area of multiple 'farms' including new ones) is held constant for the analysis.

Fertiliser and ameliorant application rates were optimised in line with the SIX EASY STEPS^{TM} guidelines. Applications were targeted according to soil testing results and findings from EM mapping.

The application rates of several pesticides used in Willy's cane crop were reduced and/or swapped to active ingredients (A.I.'s) with lower environmental toxicity.

Table 1: Main changes to the farming system considered in this study

	Before	After
Soil health management	• Short fallow with legumes (e.g. lab lab). • Heavier tillage / machinery operations (discing, ripping, marking out) without GPS. Operations were partially zonal (in plant crop) and ratoons were worked with a trash incorporator. • 1.524m row spacing (5 foot). • Conventional planting.	• Extended fallow with multiple harvested crops (e.g. mung beans, maize, soybeans). • Reduced tillage / machinery operations (e.g. limited discing) and using GPS. Drill renovator used in fallow and occasionally in a later ratoon to clean furrows for irrigation. • 1.83m row spacing (6 foot). • Bed forming and conventional planting.
Nutrient management & ameliorant	• Nutrient rates determined by blanket BSES recommendations.	• Following SIX EASY STEPS^{TM} guidelines to reduce inorganic fertiliser application, with soil tests (and also informed by instances of EM mapping). Adjusting fertiliser application rates after applying mill mud.
Weed, pest and disease management	• Well managed sprays, with flow rate control (due to Willy's background as a spray contractor before taking on the farm).	• Reduced application rates of some pesticide active ingredients, changes to active ingredients with lower environmental toxicity in cane crop. Some additional pesticides are applied in his extended fallow.
Irrigation and Drainage Management	• Inconsistent gradients, paddock shapes, run lengths and row directions (resulting in irrigation challenges and issues with water reaching the end of rows).	• Invested in laser levelling and piping on portions of the farm. Changed farm layout to enable more consistent runs. As mentioned above, changed tillage/trash management practices.

What does this mean for the business?

The economic analysis found the operating return has increased by $162,507/yr ($874/ha/yr), after the practice changes Willy made. This is partly due to additional net income of $80,025 ($430/ha when averaged across the entire farm area including cane and fallow crops) after transitioning to an extended fallow with harvested cash crops.[85] The practices Willy implemented also resulted in a lower average operating cost ($444/ha cost saving). The main cost savings came from irrigation water and electricity ($402/ha). Reduced irrigation electricity costs ($416/ha),[86] are partially offset by an increase in fixed water charges ($14/ha).[87] Other key savings come from farm operations costs ($76/ha). These cost savings were partially offset by increases in capital goods costs ($66/ha) and in herbicide and desiccant costs ($26/ha) (Figure 1).

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[85] 'Net income' refers to income minus levies (for cane) or income minus transport costs (for fallow crops). Net prices used (after transport paid) are: $570/t for soybeans (yield 4t/ha); $960/t for mung beans (yield 1.5t/ha); and $320/t for maize (yield 10t/ha).

[86] To ensure that economic calculations are conservative, only a portion of water reductions and electricity cost savings are factored into the analysis (and associated labour, repairs and maintenance, fluming and cup cost savings are excluded). Reductions in water applied to cane crops outweigh additional water applied to fallow crops.

[87] Based on an extra $48/ha being charged on areas classified as "other crops" according to the relevant water charge scheme.

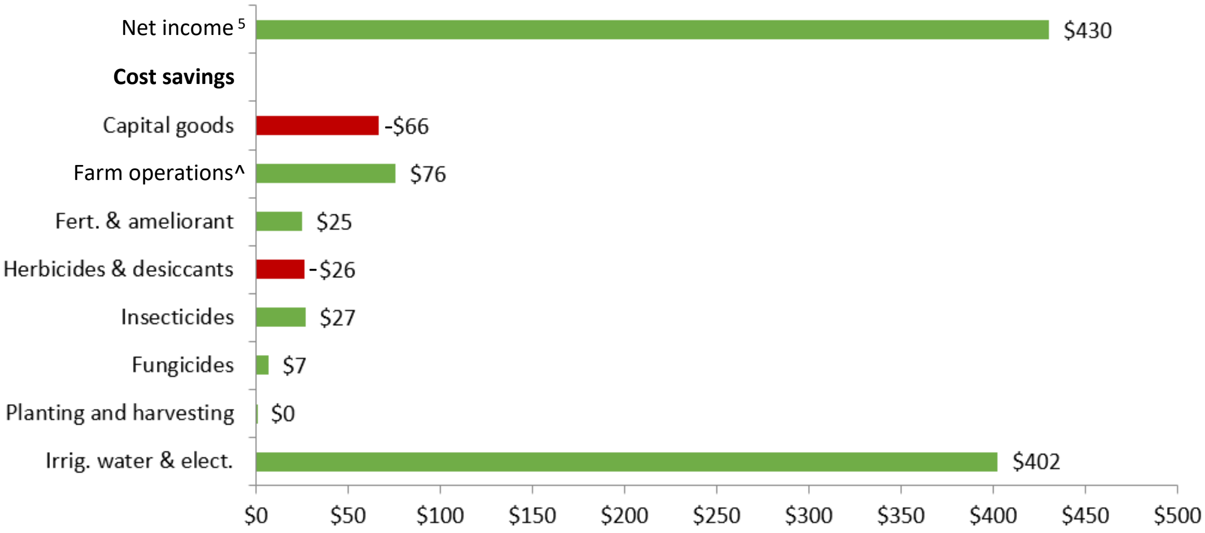

Figure 1: Contributions to change in farm operating return ($/ha change)*

Note: Green bars denote increases in operating return, red bars denote decreases.

* Transport costs to supply fertilisers, ameliorants and pesticides are embodied in product costs.

^ The farm operations category includes fuel, oil, labour costs for tractor operations and GPS fees.

Reduced tillage has contributed to an overall cost saving in the farm operations category, with overall reductions in fuel, oil and labour ($78/ha). Wider row spacing reduced the total number of rows (and distance travelled) and together with GPS guidance, contributed to cost savings and reductions in tractor hours. Savings in the farm operations category were partially offset by additional GPS base station fees a($3/ha).[88] Cost savings from planting and harvesting a smaller area of cane are offset by additional seed and harvesting costs associated with soybean, maize and mung bean cash crops. [89]

As the average area under cane decreased and Willy changed his cane insecticide applications to be more targeted, overall insecticide and fungicide costs decreased (despite additional insecticide sprays to cash crops in fallow). Although Willy applied additional fertiliser for maize during the fallow period, overall fertiliser and ameliorant costs decreased after applications across the farm were optimised.[90]

Capital goods (Figure 1) refer to the cost of repairs, maintenance and depreciation of machinery and equipment. Repairs and maintenance costs decreased as a result of reduced tractor hours ($15/ha). However, depreciation increased due to new equipment purchased ($81/ha).

How much did it cost to make the changes?

In moving to a reduced tillage system with controlled traffic and an extended fallow with cash crops, Willy acquired or customised various items. These included a bed former ($20,000), bed renovator ($20,000), vacuum planter ($40,000), mulcher ($40,000), drill renovator for furrow cleaning ($5,000), harvester flipper roller ($7,000) and 3 GPS units installed across his fleet ($91,000, as not all vehicles were GPS ready). He modified his fertiliser box ($7,000) and completed EM Mapping ($7,440).

Willy also made substantial investments in laser levelling and earth works ($300,000) and piping ($100,000). He addressed the gullies on the farm and changed his farm layout to have shorter runs on most blocks, which helped to improve irrigation efficacy. The total cost of implementation was $637,440 (or $3,427/ha), when some implements or modifications are included at a market price.[91]

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[88] As in, $500/year in additional GPS fees, for the benefit of 186ha.

[89] The analysis is based on a transition from a short to extended fallow, with an extra 22 hectares under fallow on average. Contract rates are used for harvesting and planting of cane, and harvesting of fallow crops. Fallow planting is completed by the grower and captured under the 'farm operations' category.

[90] Fertiliser savings would be more substantial if recent price increases (esp. in 2021/2022) were included in the analysis.

[91] The harvester flipper roller was purchased by a harvesting group but has been included in the analysis to be conservative. Willy has been successful in applying for a number of grants. However, any grant amounts are disregarded in the analysis.

Was the investment profitable?

Results of an investment analysis show the practice changes were a worthwhile investment. Given the improved operating return, it would take Willy 7 years to recover the $637,440 (or $3,427/ha) invested.

Over a ten year investment horizon, Willy's investment has added an additional $70,084 per year ($377/ha/yr) to his bottom line (Table 2). The analysis factors in the initial capital investment, a required return of 7%, time to transition to the new system, an expanded fallow area and a reduction in total farm cane tonnage.[92]

Table 2: Cost of implementation and investment results

Cost of Implementation ($/ha)	$3,427
Discounted Payback Period	7 years
Annual Benefit ($/ha/yr)	$377
Internal Rate of Return	17.5%
Investment Capacity ($/ha)	$6,074

Investment capacity is the maximum amount of money that can be spent before an investment becomes unprofitable. Willy could have invested up to $1,129,681 ($6,074/ha) before the additional income and cost savings made by the practice changes would be insufficient to provide the required (7%) return on investment.

What does this mean for the environment?

Indicators of environmental impacts were calculated using the CaneLCA tool to see how much the practice changes influenced environmental impacts associated with cane crops. These indicators are:

- Fossil fuel use, an indicator of fossil-fuel resource depletion (MJ).[93]
- Carbon footprint, an indicator of greenhouse gas emissions causing global warming (kg $CO_{2\text{-eq}}$).[94]
- Eutrophication potential, an indicator of water quality impacts caused by the release of eutrophying substances (nitrogen, phosphorus, sugar) to waterways via surface runoff and infiltration to groundwater (kg $PO_{4\text{-eq}}$).[95]
- Eco-toxicity potential, an indicator of water quality impacts caused by the loss of toxic substances to waterways, such as pesticides but also heavy metals (kg CTU_{eq}).[96]
- Water use, an indicator of water resource depletion over the cane life cycle (kL/t cane).

Impacts are calculated over the 'cradle to farm gate' life cycle of cane growing (up to and including the haul out of harvested cane to the siding, but not including transport to mill). They include the environmental impacts of *off-farm* production and supply of inputs (fertilisers, pesticides, diesel, electricity etc.) as well as those that occur *on-farm* (tractor exhaust emissions, gaseous losses of nitrogen, runoff of pesticides and nutrients to water).

The estimated changes in environmental impacts per tonne of harvested cane after the practice changes were adopted by Willy are shown in Figure 2. The practice changes have resulted in substantial environmental improvements across all of the impact categories – fossil fuel use, carbon footprint, water quality (eutrophication and eco-toxicity) and water use.

Investment costs for general upgrades that are not critical to implementation of the practice changes are excluded (e.g. new discs, upgraded sprayers, grain silo). Willy's purchase of a grain header and cane planter are also excluded (and these operations are included in the analysis on a contracted basis).

[92] In the economic analysis, rather than assuming that all practice changes are adopted immediately across the whole farm, changes are factored in gradually (with proportions of the farm under fallow, plant crop, ratoons being transitioned over several years). For the annual benefit and cash flow calculations, investment costs for all items are included from the beginning of the 10 year investment horizon. At the end of that period, residual values for investments are included. Regarding production, it is Willy's personal view that yields (TCH) were (at least) maintained after making practice changes (1999 - 2021). Linear trends in historical production data indicate that TCH was maintained from 2005-2021 and that CCS and TSH increased.

[93] MJ = megajoules of fossil fuel energy.

[94] kg $CO_{2\text{-eq}}$ = kilograms of carbon dioxide equivalent, the reference substance for representing greenhouse gases (carbon dioxide, nitrous oxide, methane).

[95] kg $PO_{4\text{-eq}}$ = kilograms of phosphate equivalent, the reference substance for representing the eutrophication of water due to eutrophying substances (nitrogen, phosphorus, sugar).

[96] kg CTU-eq = kilogram of equivalent critical toxicity units, a measure of the eco-toxicity effects in freshwater due to releases of toxic substances (pesticide A.I.'s, heavy metals). Pesticide A.I.'s usually originate from the on-farm agricultural activities, and heavy metals usually originate from the off-farm activities producing the electricity, machinery, etc used on the farm.

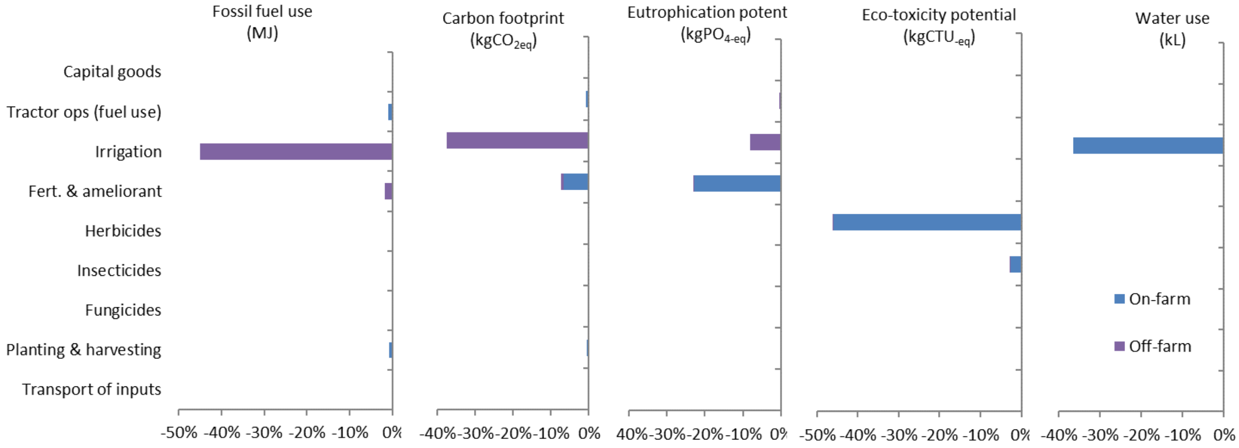

Figure 2: Decrease in environmental impacts after practice changes (% change per t cane)[97]

Fossil fuel use. The combined effect of all practice changes was estimated to reduce the life-cycle fossil-fuel use (per tonne of harvested cane) by 49% per year. This means that around 11,000 GJ of energy are saved per year, which is equivalent to combusting 240 tonnes less diesel fuel per year.[98] This reduction is mostly due to substantially improved water use efficiency, which means that substantially less water is being pumped using electricity.

Carbon footprint. The combined effect of all practice changes was estimated to reduce the life-cycle greenhouse gas emissions (carbon footprint) in cane by around 46% per year. This means around 1,110 tonnes per year of carbon dioxide emissions are now avoided, which is equivalent to taking 360 cars off the road each year. The dominant source of reductions is the substantially reduced consumption of electricity for irrigation due to less water being appplied. There are also avoided emissions of nitrous oxide (N_2O) due to the reduction in nitrogen application rates.

Eutrophication potential. The practice changes have also reduced potential nutrient-related water quality impacts by 28% each year. The estimated avoided nutrient loss to waterways is around 1.1 tonnes N equivalent each year. Optimising fertiliser application in line with SIX EASY STEPS^{TM} guidelines reduced N application from 2.2 kg N/t cane to 1.7 kg N/t cane, which means less risk of N loss to water. The substantially reduced electricity use for irrigation also reduces losses of N to the environment, because the combustion of coal to produce electricity releases gaseous N species to atmosphere.

Eco-toxicity potential. Changed pesticide practices have also reduced the potential for toxicity-related water quality impacts by about 50% each year for cane. This has been due to a shift away from the use of Atrazine to other active ingredients with lower toxicity potential and also a lowering of application rates for 2,4-D, bifenthrin, and imidacloprid. Compared to previous practices, there has been an 11 kg per year reduction in application of pesticide A.I.'s.

Water use. Irrigation improvements have resulted in an improvement in water use efficiency (in terms of water applied per tonne of cane) by 36%. This is a good outcome for freshwater conservation, but it also translates into substantial reductions in electricity use (since less water is pumped). Water savings are due to various changes Willy has made to optimise water use on his permeable soils.

Please note that environmental indicators in this study are focused on cane production, whereas economic indicators (e.g. 'annual benefit') factor in all crops.

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[97] A negative % change represents a decrease in environmental impact, and a positive % value represents an increase in environmental impact.

[98] This includes fossil fuel use over the life cycle for cane growing (and includes both on-farm diesel consumption and off-farm use of fossil fuels in the production of fertilisers, pesticides, diesel, lime, electricity, and in transport for delivering inputs).

What about risk?

When adopting any management practice change, economic outcomes can vary with changes in key profitability drivers, such as yield, and depend on how effectively the practice is implemented.

A production risk analysis shows cane yields (TCH, across areas remaining under plant and ratoon cane crops) would need to decline by a large amount (21.3%) before Willy's investment in the changes would become unprofitable (Figure 3).[99] However, the adoption of practice changes that have been scientifically validated, means that such an adverse impact on cane yield is unlikely.[100]

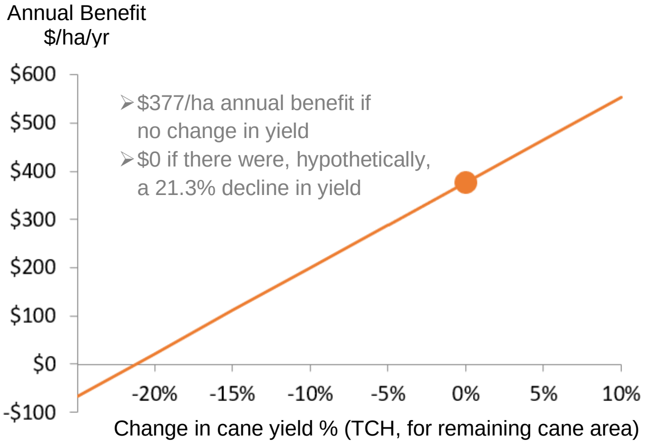

Figure 3: Sensitivity of annual benefit of investment to yield

If cane yields increased, this would be expected to result in an increase in the annual economic benefit of the practice changes (Figure 3).[101]

The environmental improvements are not sensitive to changes in cane yields (Figure 4), across all impact categories. As the scale of environmental improvements were so large, cane yields across plant and ratoons would need to decline by a very large amount before there was no net environmental gain.

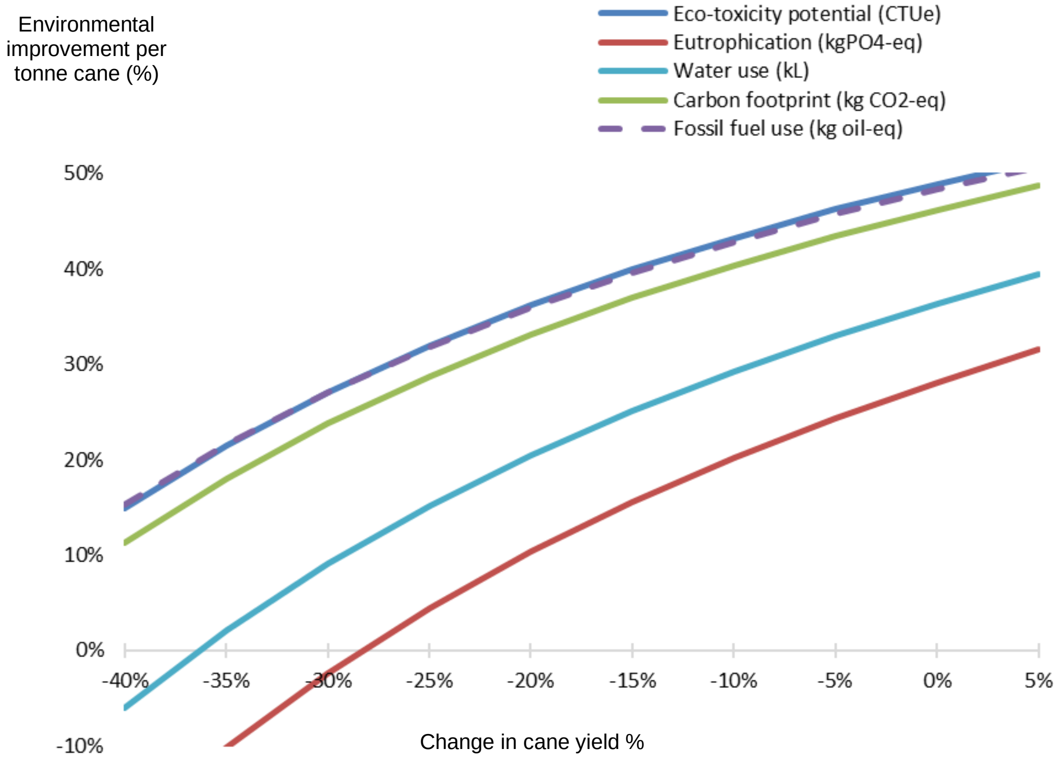

Figure 4: Sensitivity of environmental improvements to yield

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[99] The production risk analysis (Figure 3) explores yield only, with CCS and the sugar price, of $428.60/t Net IPS, held constant.

[100] As in, scientifically validated practices that align with Smartcane BMP principles.

[101] If changes in other parameters were factored into the analysis (e.g. changes in fertiliser costs, chemical costs, and sugar price), they could also impact the annual economic benefit of the practice changes.

What's the bottom line?

This case study has evaluated the economic and environmental impacts of various practice changes, including those aimed at improving soil health and irrigation, for a farm in the Burdekin (Delta) region with permeable soils.

Results of the economic analysis show the changes resulted in additional income from harvested cash crops in an extended fallow. Cost savings were largely due to irrigation electricity savings. The amount of water applied to the farm (with permeable soils and a flood irrigation system) has reduced after laser levelling, changing the farm layout to allow for shorter drills, and adjusting tillage and trash management practices to optimise the flow of water down the drills. Cost savings were also made after reducing fuel, oil and labour costs due to reduced tillage.

Willy has made substantial investments in new machinery and infrastructure to enable the changes on his farm, and this has been worthwhile. Cane yields (TCH) would need to decline substantially (by 21.3%) across areas remaining under cane before Willy's investment becomes unprofitable. On the other hand, any improvements in cane yield associated with the practice changes would increase the economic gain.

The practice changes have resulted in very large environmental improvements associated with cane, with 30-50% reductions in environmental impacts across all categories. This has been largely due to improved water use efficiency with reductions in electricity use (since pumping less water) and in the amount of nitrogen and pesticides applied, which results in water quality benefits (less eutrophication and eco-toxicity risks).

The findings in this case study are influenced by the characteristics for Willy's farm, including soil types and the period over which practice changes were made. Each farming business is unique in its circumstances and therefore the parameters and assumptions used in this case study reflect Willy's situation only. Consideration of individual circumstances must be made before applying this case study to another situation.

For further information on this integrated case study please contact the Townsville DAF office on 13 25 23.

The environmental and economic components of this case study have been produced as outputs in a DAF project: Combined Economic and Environmental Evaluations of Practice Adjustments. The environmental assessment was performed by the Centre for Agriculture and the Bioeconomy at Queensland University of Technology. The investment analysis was performed by DAF economists who aimed to complete it on a conservative basis. Please note that the annual benefit associated with the practice changes considered in this study may be higher than stated.

Some information in this case study is based on data collected through the Herbert and Burdekin Soil Health Project (SRA Project 2017/005 - Measuring soil health, setting benchmarks and supporting practice change in the sugar industry). That project is supported by Sugar Research Australia, Herbert Cane Productivity Services Ltd, Burdekin Productivity Services, Wilmar, Queensland Department of Agriculture and Fisheries, The University of Queensland and University of Southern Queensland.

Willy Lucas is a Smartcane BMP accredited grower. For more information on Smartcane BMP please visit www.smartcane.com.au.

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