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 1: 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.[1]

Economic, biophysical and farm management data before and after changes were supplied by the grower. The Farm Economic Analysis Tool (FEAT)[2] was used to determine the impact of these changes on business performance. The CaneLCA Eco-efficiency Calculator (CaneLCA)[3] was used to determine the impact of the practices changes on the environment.

[1] 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.
[2] 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/
[3] 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).[4] 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.

[4] 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™ 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™ 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.[5] 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),[6] are partially offset by an increase in fixed water charges ($14/ha).[7] 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).

[5] '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).
[6] 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.
[7] Based on an extra $48/ha being charged on areas classified as "other crops" according to the relevant water charge scheme.

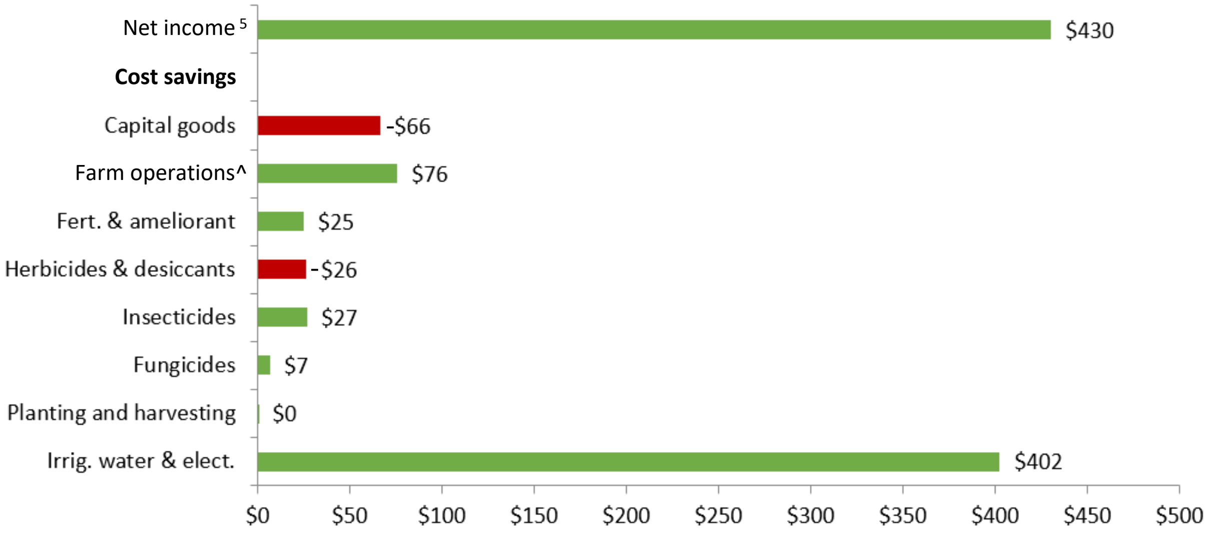

Figure 1: Contributions to change in farm operating return ($/ha change)*

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).[8] 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. [9]

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.[10]

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.[11]

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

[9] 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.

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

[11] 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.[12]

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).[13]
- Carbon footprint, an indicator of greenhouse gas emissions causing global warming (kg $CO_{2\text{-eq}}$).[14]
- 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 $PO_{4\text{-eq}}$).[15]
- 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}).[16]
- 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).

[12] 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.

[13] MJ = megajoules of fossil fuel energy.

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

[15] 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).

[16] 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.

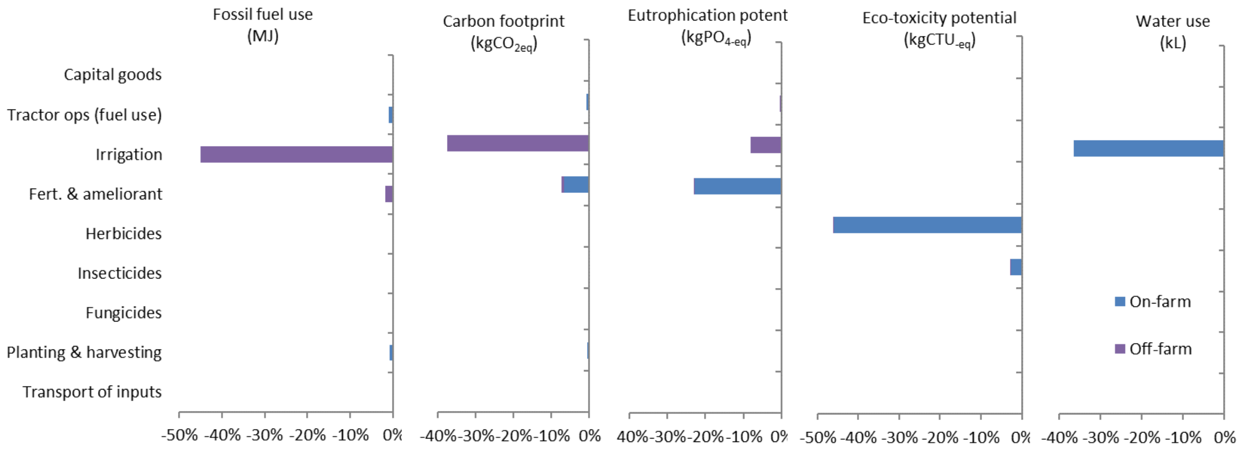

Figure 2: Decrease in environmental impacts after practice changes (% change per t cane)[17]

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.[18] 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™ 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.

[17] A negative % change represents a decrease in environmental impact, and a positive % value represents an increase in environmental impact.
[18] 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).[19] However, the adoption of practice changes that have been scientifically validated, means that such an adverse impact on cane yield is unlikely.[20]

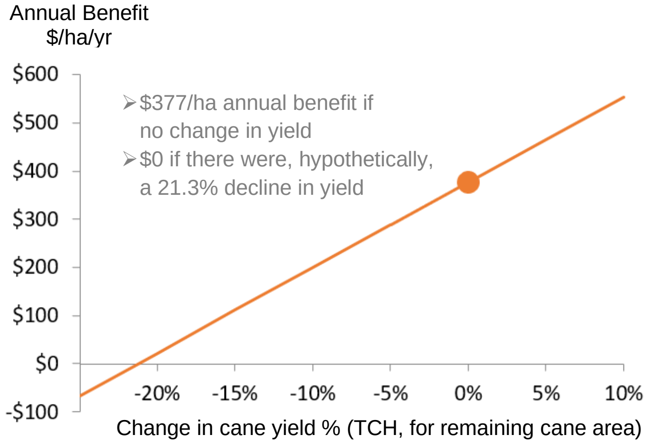

Figure 3: Sensitivity of annual benefit of investment to yield

If cane yields increased, this would be expected to result in an increase in the annual economic benefit of the practice changes (Figure 3).[21]

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.

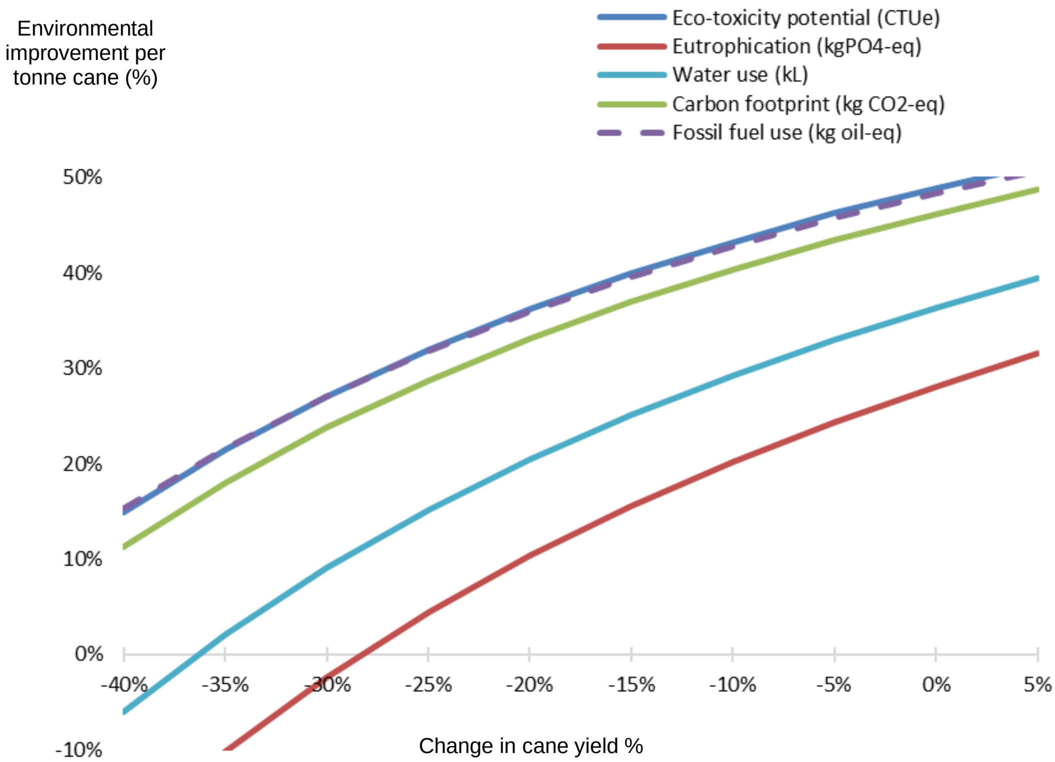

Figure 4: Sensitivity of environmental improvements to yield

[19] The production risk analysis (Figure 3) explores yield only, with CCS and the sugar price, of $428.60/t Net IPS, held constant.
[20] As in, scientifically validated practices that align with Smartcane BMP principles.
[21] 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.

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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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