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.

Image 1: Charlie Cacciola

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.

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.[1]

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)[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.

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[1] 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).

[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/

QUT
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Queensland Government

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).

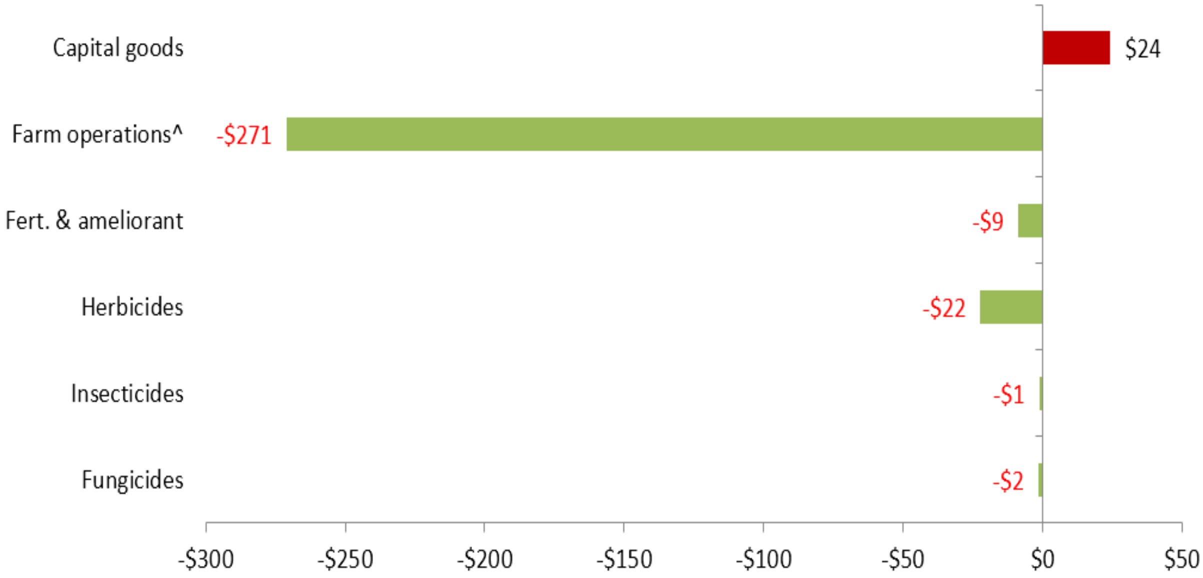

Figure 1: Contribution to change in farm operating costs ($/ha change)*

* 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.[4]

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[4] 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).[5]

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.[6]

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) [7]
- Carbon footprint, an indicator of greenhouse gas emissions causing global warming (kg $CO_{2\text{-eq}}$)[8]
- 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 $PO_{4\text{-eq}}$)[9]
- 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})[10]

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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[5] 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.

[6] 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).

[7] MJ = megajoules of fossil fuel energy

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

[9] 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)

[10] 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.

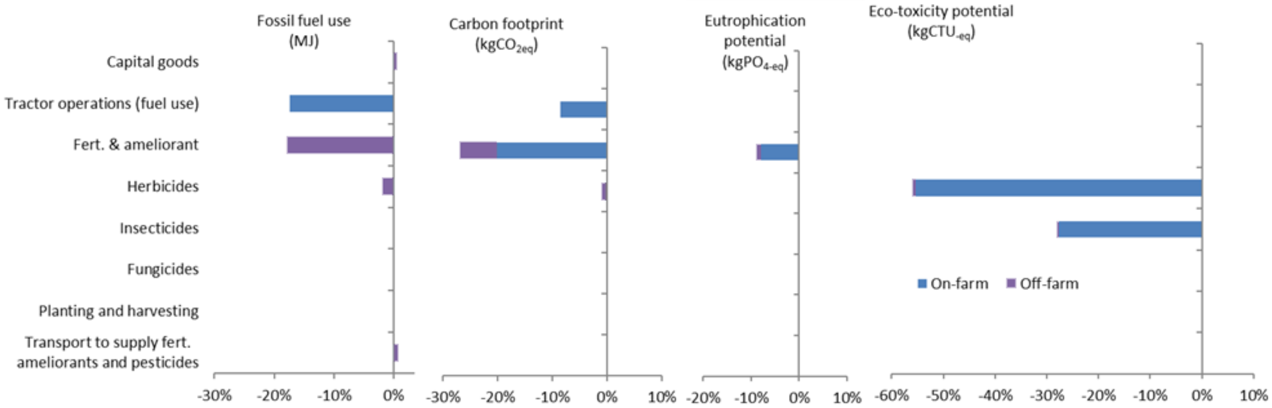

Figure 2: Decrease in environmental impacts after practice changes (% change per t cane) [11]

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[12]. 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[13], 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™ 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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[11] A negative % change represents a decrease in environmental impact, and a positive % value represent an increase in environmental impact.

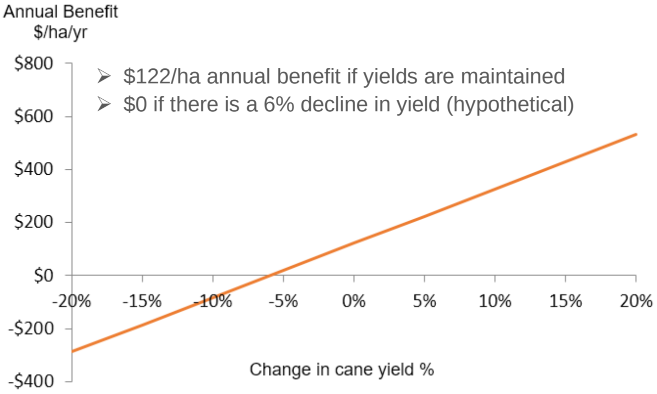
[12] This includes fossil fuel use over the life cycle of the cane growing, includes not just on-farm diesel consumption but also off-farm use of fossil fuels in the production of fertilisers, pesticides, diesel, lime, electricity, and in transport for delivering inputs.

[13] 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)[14] 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,[15] means an adverse impact on cane yield is unlikely.



- $122/ha annual benefit if yields are maintained
- $0 if there is a 6% decline in yield (hypothetical)

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.

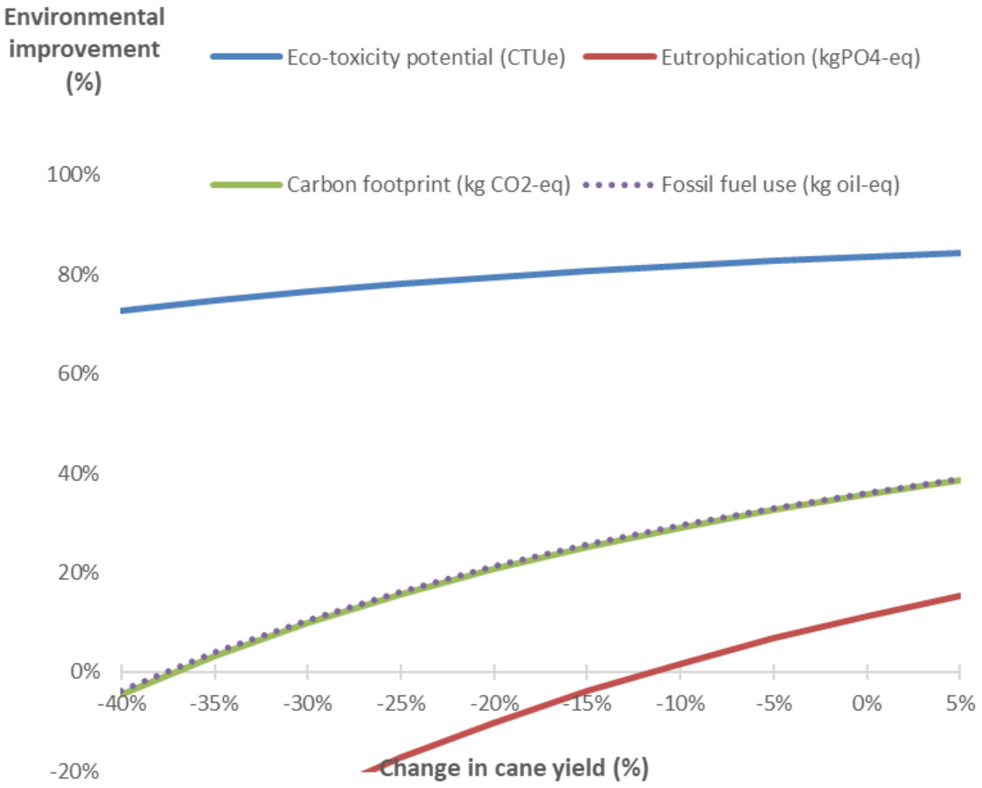


Figure 4: Sensitivity of environmental improvements to yield

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

[15] 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.