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.

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.

Image 1: Tony and Mitch Chapman

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.[1]

Economic, biophysical and farm management data before and after practice change 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 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.

[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

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.[4] 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.

[4] 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.

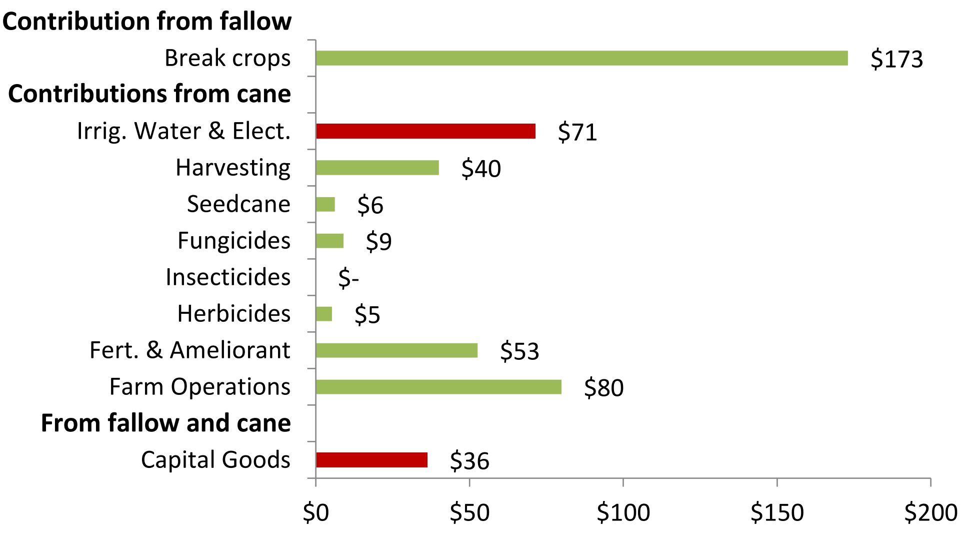

Figure 1: Contributions to the change in farm operating return ($/ha change)

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).[5]

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).[6] 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.[7]

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).[8]

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

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

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

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

[8] 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.[9]. 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).[10]
- Carbon footprint, an indicator of greenhouse gas (GHG) emissions causing global warming over the cane life cycle (kg $CO_{2\text{-}eq}$/t cane).[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 $PO_{4\text{-}eq}$/t cane).[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}/t cane).[13]
- 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.

[9] 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).

[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 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.

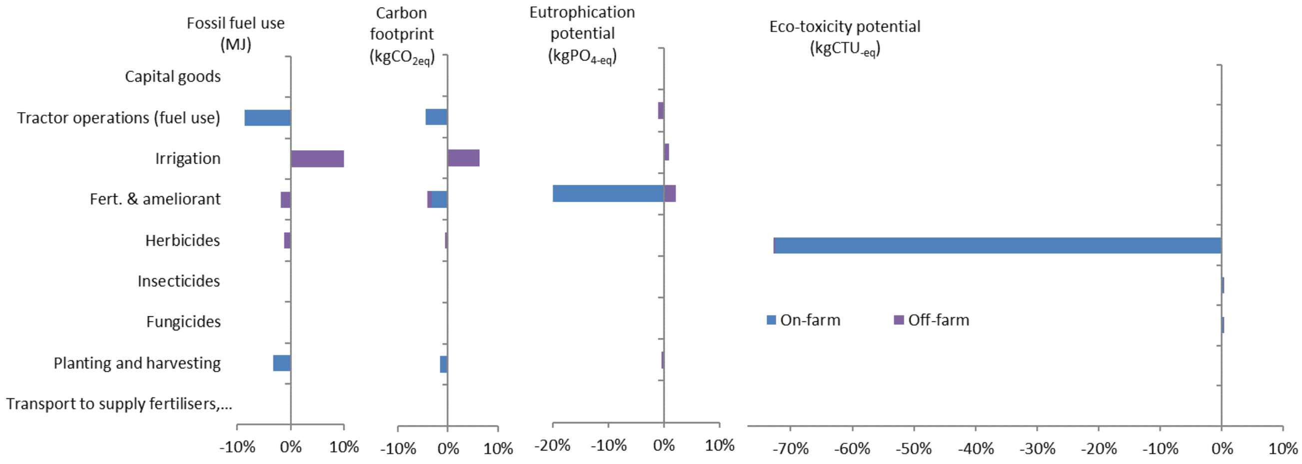

Figure 2: Changes in environmental impacts after practice changes (% change per t cane) [14]

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[15]. 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.

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

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)[16] 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[17] means an adverse impact on cane yield is unlikely.

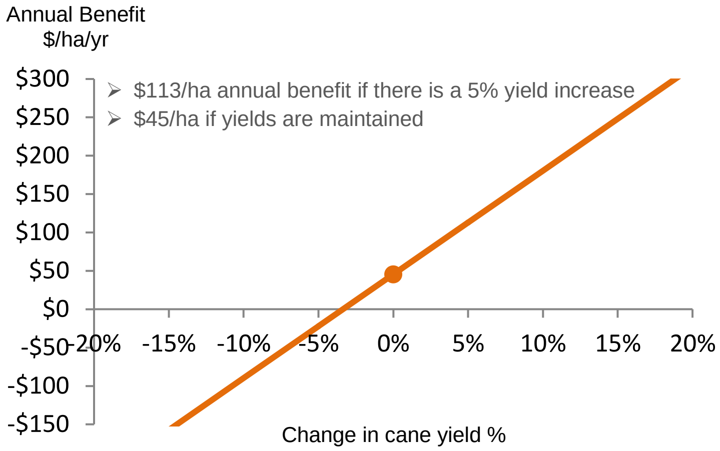

Figure 3: Sensitivity of annual benefit of investment to yield

Conversely, a small improvement in cane yield is expected to result in a substantial economic gain. For example, the yield and CCS data for Tony's farm indicates an increase of over 13.6% in tonnes of sugar per hectare.[18] 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).

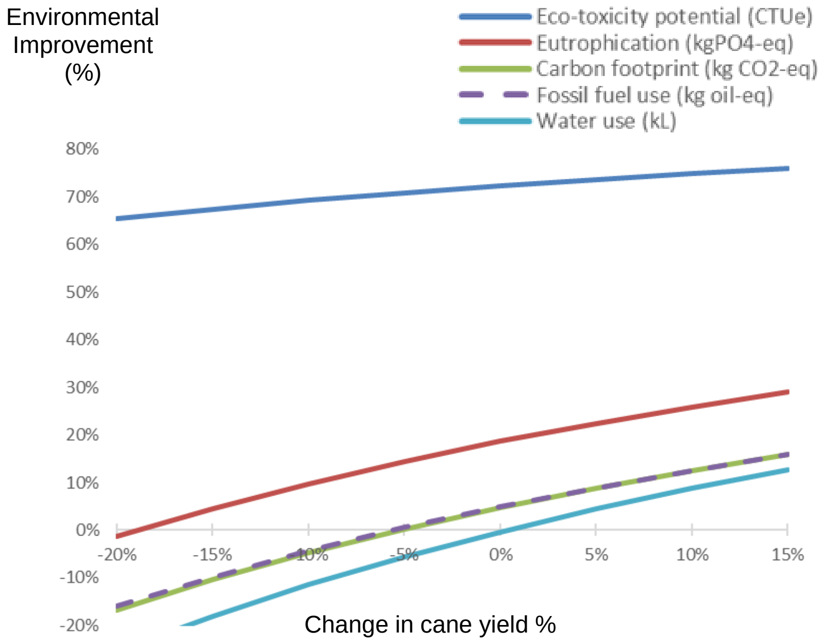

Figure 4: Sensitivity of environmental improvements to yield

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

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

[18] 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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