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 1: 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.[1]

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

[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/

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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™ 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™ 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[4] 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).

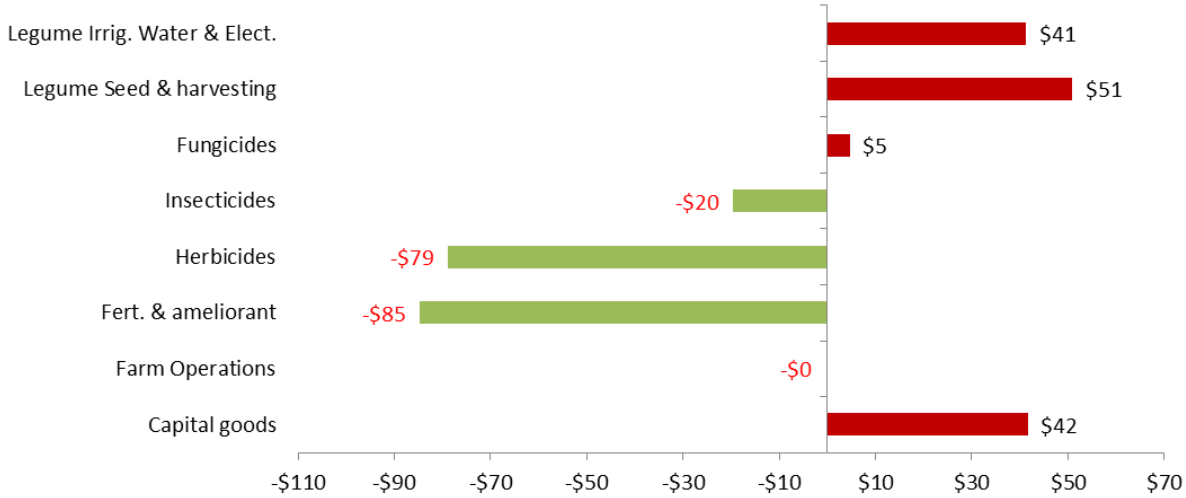

Figure 1: Contribution to change in farm operating costs ($/ha change)*

* 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).

[4] 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.[5]

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) [6]
- Carbon footprint, an indicator of greenhouse gas emissions causing global warming (kg $CO_{2\text{-eq}}$)[7]
- 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 $PO_{4\text{-eq}}$)[8]
- 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})[9]

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).

[5] 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.

[6] MJ = megajoules of fossil fuel energy

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

[8] 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)

[9] 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.

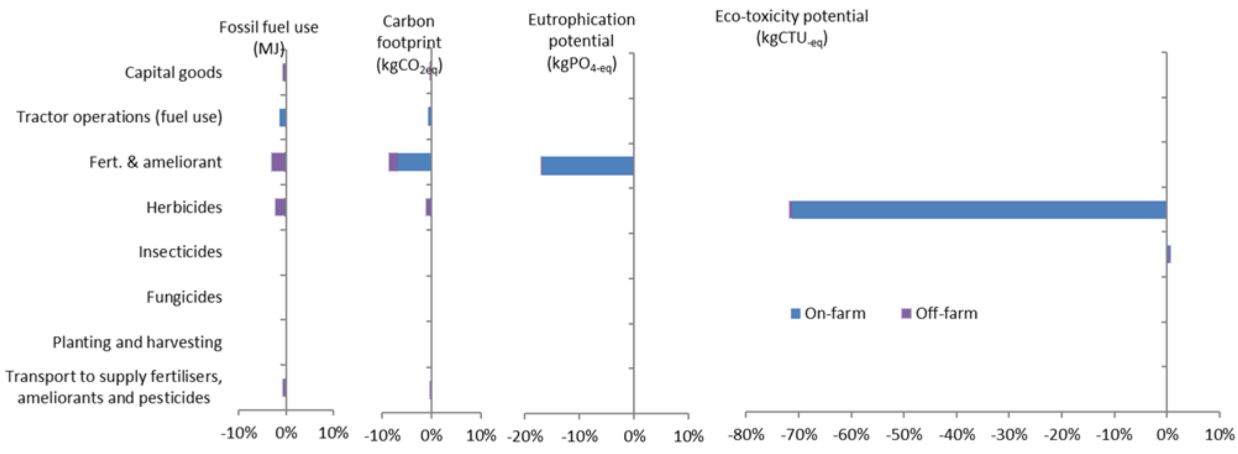

Figure 2: Decrease in environmental impacts after practice changes (% change per t cane) [10]

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[11]. 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[12], 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.

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

[11] 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.

[12] 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.

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

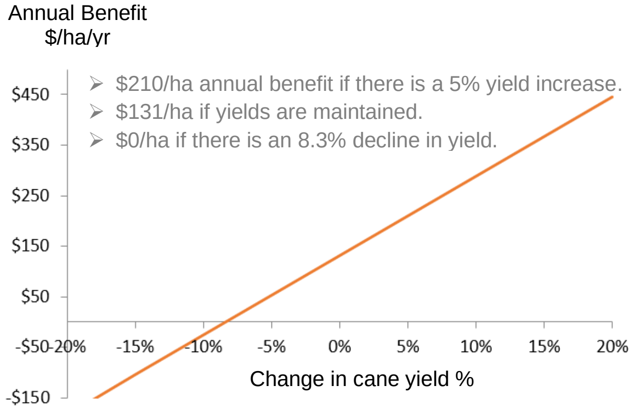

Figure 3: Sensitivity of annual benefit of investment to yield

Conversely, a small improvement in cane yield 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.

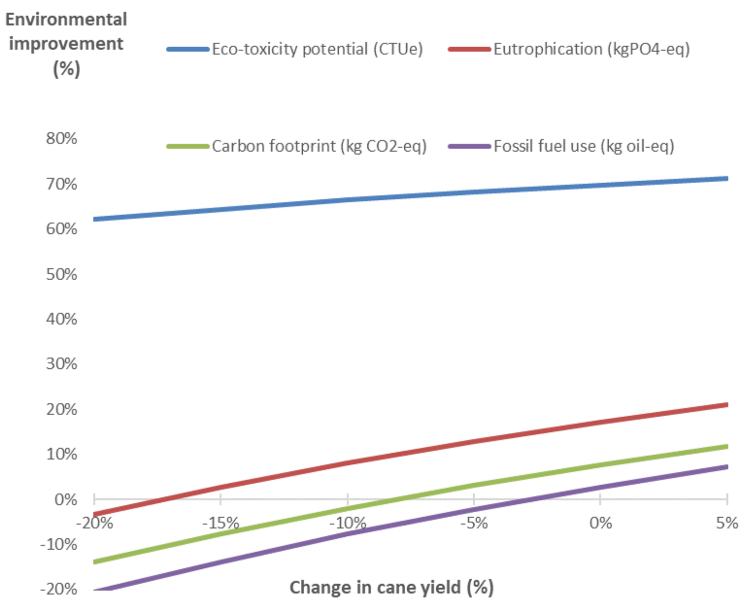

Figure 4: Sensitivity of environmental improvements to yield

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

[14] 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.

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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.