The economic and environmental impacts of managing soil health

Case study: Alan Lynn (North Queensland)

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

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

Image 1: Alan Lynn

Key findings of the Alan Lynn case study

The practice changes considered in this study resulted in:

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

The findings of this case study are specific to the individual business evaluated and not intended to represent the impact of similar practice changes more broadly.[1]

Economic, biophysical and farm management data before and after practice change were supplied by the grower. Certain implements built by Alan are costed as if bought new. The Farm Economic Analysis Tool (FEAT)[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 Alan progressively over at least 10 years from the base year of 2009. For simplicity, the economic analysis excludes some changes (e.g. trying different bed-forming approaches, legume species, multi-operation implements and extending the cane crop cycle by at least one ratoon) and the Annual Benefit is calculated using a 10 year investment horizon.

[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

Alan shared the following insights when interviewed about his journey:

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

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

What changes were made?

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

Table 1: Main changes to the farming system

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

What does this mean for the business?

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

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

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

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

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

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

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

How much did it cost to make the changes?

To move to a reduced tillage, controlled traffic system with a mixed species legume break crop, Alan purchased a GPS unit and GPS rate controller, built two bed formers (including one from scrap), added boards to a rotary hoe (to allow for light sweeping), and made minor modifications to his boom sprayer. He modified the boom on his high rise and converted it, along with his fertiliser box, to be hydraulically adjustable (for convenience during the transition to a wider row spacing). The total cost of implementation, for various one-off costs, was $96,476 (or $519/ha) when some implements designed and built by Alan are included on the basis of a current market price.[4]

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

Was the investment profitable?

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

Over a ten year investment horizon, Alan's investment has added an additional $7,905 per year ($42/ha/yr) to his bottom line (when the initial investment, required return of 7% and time to transition to the new system is taken into account) (Table 2).[5]

Table 2: Cost of implementation and investment results

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

This analysis is based on cane yields staying the same across Alan's farm after the practice changes.[6]

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

What does this mean for the environment?

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

- Fossil fuel use, an indicator of fossil-fuel resource depletion (MJ) [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 as impacts to the environment that occur *on-farm* (tractor exhaust emissions, gaseous losses of nitrogen, runoff of pesticides and nutrients to water).

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

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

[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 Alan are shown in Figure 2. The practice changes have resulted in substantial environmental improvements for both water quality (eutrophication and eco-toxicity) and carbon footprint.

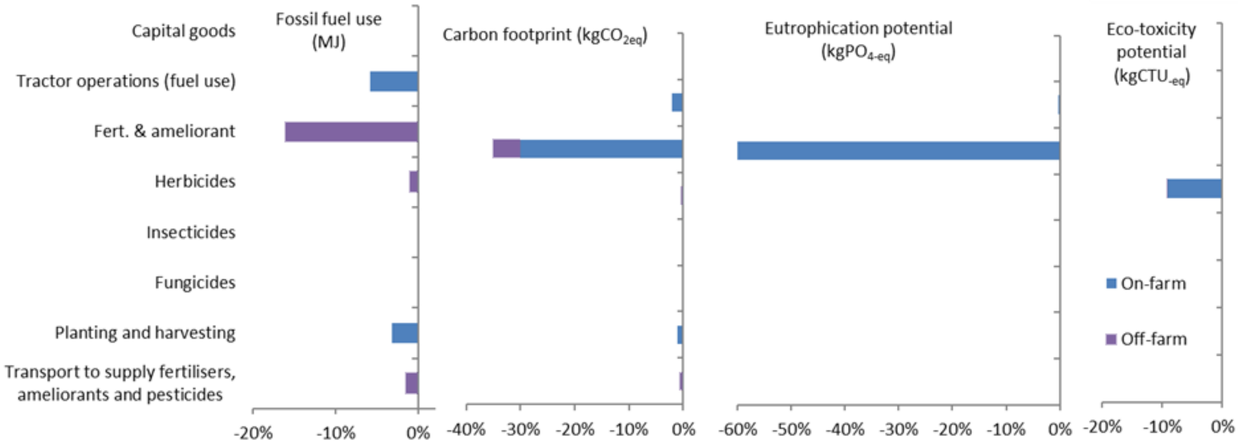

Figure 2: Decrease in environmental impacts after practice changes (% change per t cane) [11]

Fossil fuel use. The practice changes reduced the life-cycle fossil-fuel use (per tonne cane) by 26% per year. This means that around 1,245 GJ per year are saved, which is equivalent to combusting 27 tonnes less diesel fuel per year[12]. The biggest reduction is less off-farm energy use for producing and supplying fertilisers to the farm (especially urea) due to the reductions in fertiliser application. The other large reduction is due to less on-farm diesel use for tractor operations largely resulting from a considerable reduction in tillage operations and the wider row spacing.

Carbon footprint. The practice changes reduced the carbon footprint (per tonne of cane) by around 38% per year. This means around 366 tonnes per year of carbon dioxide emissions are now avoided, which is equivalent to taking 119 cars off the road each year. The dominant reduction sources are the avoided on-farm emissions of nitrous oxide (N_2O), a strong GHG[13], and avoided off-farm emissions of producing fertilisers, due to reduced N fertiliser application rates. There are also avoided emissions from the reduced on-farm combustion of diesel in tractors largely due to reduced tillage and wider row spacing.

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

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

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

[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-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 3.4% before Alan's investment in practice 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.

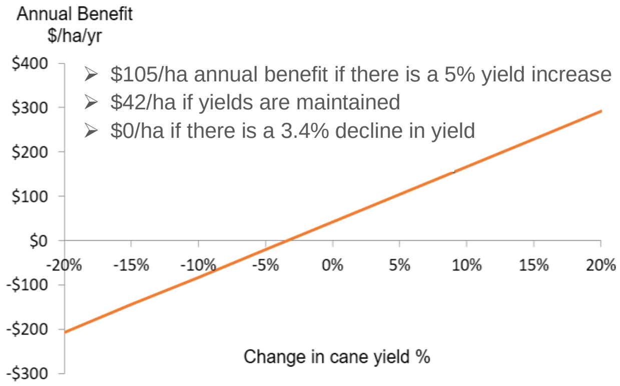

Figure 3: Sensitivity of annual benefit of investment to yield

Conversely, a small improvement in cane yield is expected to result in a substantial economic gain. For example, the yield data for Alan's farm indicates an increase of over 9% in tonnes of cane per hectare (when an average of Alan's yields for the 2005-09 period was compared to the 2015-19 period). [16] The production risk analysis indicates a 9% improvement in cane yield could result in an annual benefit of $155/ha ($28,743). Even if only a proportion of the yield gain were attributed to the practice changes (as in, a 5% yield improvement), an estimated $105/ha/yr ($19,481/yr) would have been added to the bottom line for Alan.

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

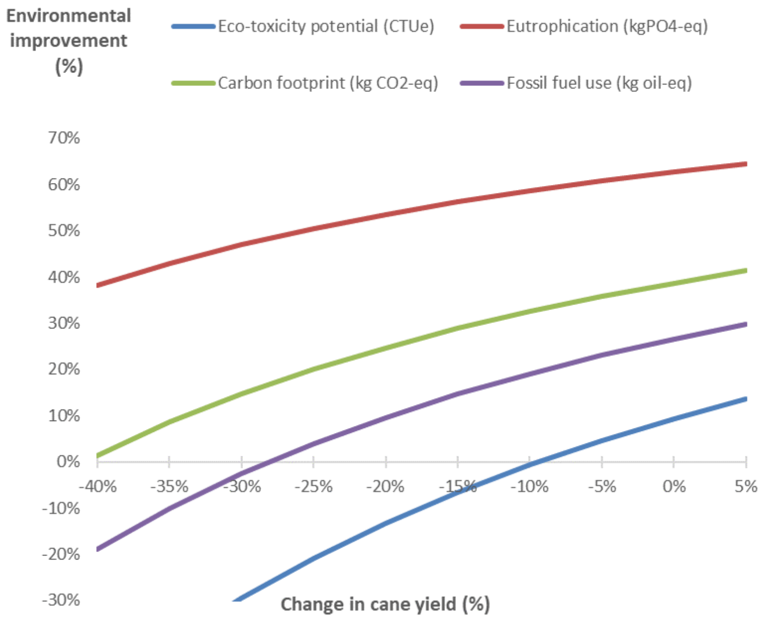

Figure 4: Sensitivity of environmental improvements to yield

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

[15] Such as Smartcane BMP best management practices.

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

What's the bottom line?

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

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

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

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

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

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

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