# The economic and environmental impacts of innovative practice changes and improved irrigation delivery

## Case Study: Andrew and Melissa Deguara (Central Queensland)

The following case study (2021) evaluates the economic and environmental impacts of practice changes adopted by a sugarcane grower (aligned with Smartcane BMP principles). The study also considers the impact of improving irrigation infrastructure and the yield response required for repayment of the investments.

Andrew and Melissa Deguara currently farm 341 ha of cane land (including fallow crops) and 150 breeders (cattle) in the Mackay region, Central Queensland. Over the past 10 years, they have continued to make farming system changes following the introduction of controlled traffic by Andrew's father in 2003. With the aim to improve longer-term yields and soil health, they have introduced additional fallow crops and reduced tillage (pre-formed beds) to enhance soil structure. They have also increased the planting rows for soybeans to improve weed control and, more recently, have introduced variable rate fertiliser application on a portion of their farm. Since 2016, they have been investing in irrigation infrastructure upgrades and solar technology to reduce electricity usage and increase the delivery of water and number of irrigation events (allowing for improved scheduling options for full allocation utilisation). This with the aim to reduce energy costs and improve production.

***Image 1: Andrew and Melissa Deguara***

## Key findings of the Deguara case study

The practice changes considered in this study resulted in:

- An annual benefit of $10,027 ($29/ha) from investments aligned with Smartcane BMP, indicating they were worthwhile. Cost increases relating to irrigation and mixed species legumes were offset by revenue improvements due to a cane yield increase (from additional irrigation).
- With the introduction of solar energy, there was an additional annual benefit improvement of $2,742 per annum ($8/ha) indicating solar investments were also profitable.
- Greenhouse gas emissions reduced by 32 tonnes per year, equivalent to taking 10 cars off the road. This is a reduction of 11% per tonne of harvested cane.
- Fossil fuel use also reduced by 170 GJ of energy use per year, equivalent to burning 4 tonnes less diesel fuel (both on-farm and off-farm through energy for fertiliser manufacturing etc.). This is a reduction of 10% per tonne of harvested cane.
- A slight improvement in water quality related aspects could be expected due to reduced overall eco-toxicity potential of the applied herbicide active ingredients (AI) and a reduction in the nutrients potentially lost to water from the farm by 80kg of nitrogen equivalent per year.
- The practice changes included increased irrigation to improve cane productivity, which contributed to the improved environmental performance per tonne of cane. The trade-off of more water extraction is likely to be minor since the region is not particularly constrained in terms of water availability.

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]

[1] Various management practice changes were made by the Deguaras' progressively over the past 6 years from the base year of 2016. For simplicity, the economic analysis excludes some changes (e.g. controlled traffic/row spacing changes, due to this taking place while ownership resided with Andrew's father before 2016, and cattle grazed on some of their fallow area). The Annual Benefit is calculated using a 10-year investment horizon.



QUT

Queensland Government

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 practice changes on the environment.

## Grower insights

Andrew and Mel shared the following insights when interviewed about their journey:

*"My dad laid a great foundation by introducing controlled traffic in 2003 that included widening the row spacing from 1.5 to 1.86 metres. We have continued to build on this by planting to dual row pre-formed beds that have helped with weed control through improved ground cover. It has also made planting easier with an improved pull-through for our zonal tillage disc opener."*

*"The introduction of an extra mixed species cover crop is motivated by our drive to reduce soil pathogens for improved long-term soil health and biology. Reducing soil movement and sun exposure also helps with this."*

*"For us energy is expensive. It is our main consideration behind the continued roll-out of solar energy on our property. This along with various system improvements on our centre pivots and soft hoses have helped reduced the overall costs per ML of irrigation water. It has also helped us deliver more to our crop which has improved overall yields for the farm."*

*"We have become increasingly aware of the need to reduce the level of toxic chemicals we use on-farm. We are also constantly trying to reduce overall chemical use where possible, but this continues to be a challenge."*

## What changes were made?

Details of changes to the Deguaras' farming system considered in this study are summarised in Table 1. To reduce soil compaction, the Deguaras' introduced pre-formed beds with reduced tillage. To reduce soil pathogens, they introduced a second fallow of mixed species which is also planted in three rows for better canopy closure (less weed competition) and improved soybean yields. They have reduced their BioDunder application from 160 to 149 kg N/ha in their ratoons and are also applying it at a variable rate on 50ha of cane area (under investigation) through the use of prescription mapping.

The investment into irrigation upgrades and solar technology has improved delivery rates (flow rates) and offset a significant amount of electricity usage. This has not only reduced operational costs per ML, but also significantly improved cane yields. The changes considered follow the earlier adoption of controlled traffic and wider row spacing (not considered in this study) and reflect the Deguaras' drive for continued practice and system improvements.

[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/

***Table 1: Main changes considered in this study***

| | Before | After |
|---|---|---|
| **Soil Health Management** | • Heavier tillage (e.g. with rotary hoe and offsets)<br>• Single legume (cash crop) in fallow period | • Reduced/Zonal tillage (e.g. with wavy disc and planting with disc opener) and pre-formed beds<br>• Double legume (cash crop and mixed species) for a better managed fallow period |
| **Nutrient Management & Ameliorant** | • Grower determined nutrient rate (higher rate on ratoons) | • Following SIX EASY STEPS® guidelines to reduce inorganic fertiliser application (and with variable rate application on 50ha, 15% of total area)<br>• Increased soil testing |
| **Weed, Pest and Disease Management** | • Standard pesticide A.I.'s (e.g. 2,4-D)<br>• Double row legume (cash crop) | • Changes to pesticide A.I.'s with lower environmental toxicity (e.g. MCPA)<br>• Triple row legume for improved weed control (cover) and cash crop yield |
| **Irrigation & Drainage Management** | • Long chains (for soft hoses)<br>• Narrow pipes (lower flow rates) | • Shorter chains (for soft hoses) to improve energy efficiencies<br>• Wider pipes and added motors (increased flow rates) for increased irrigation events (improved allocation utilisation and scheduling) |
| *Additional Changes* | | |
| **Energy Source (per ML)** | • 81% electricity, 19% diesel | • 73% electricity, 11% diesel, 16% solar energy (130kW) |

## What does this mean for the business?

The economic analysis shows the Deguaras' operating return has increased by $138/ha ($47,089, excluding solar), largely due to the increase in the cane and legume yields which added $309/ha[4] of net income (based on a conservative yield improvement). The largest cost increase was from harvesting and levies ($66/ha) linked to improved production (Figure 1). The second largest increase came from the more frequent irrigation events and additional irrigation required for the added mixed species fallow ($53/ha, excluding solar). Other cost increases included capital goods ($20/ha), herbicides ($16/ha) and seed ($14/ha).

There was a saving in fungicide costs (-$3/ha) due to a product change but the largest cost saving came in the form of solar energy (-$32/ha) taking the operating return improvement to $170/ha ($58,106). Overall, the yield improvement (largely due to the increase in irrigation, from 2ML to 3ML/ha) outweighed the cost increases giving an overall improvement in operating return.

[4] This is the total income less post-harvest and haulage costs (levies, freight, etc.) per hectare across the full farm area which includes $281/ha from the cane operation (using a sugar price of $429/t for an 8t/ha increase in yield) and $27/ha from the soybeans (using a farm gate price of $650/tonne for a 0.3t/ha increase in yield).

Farm operational costs include fuel, oil and labour for tractor operations. Overall, there was a marginal increase in this category, but there were cost savings in fuel and oil for the cane system (-$4/ha) with increased labour costs in both the fallow ($7/ha) and cane ($5/ha).

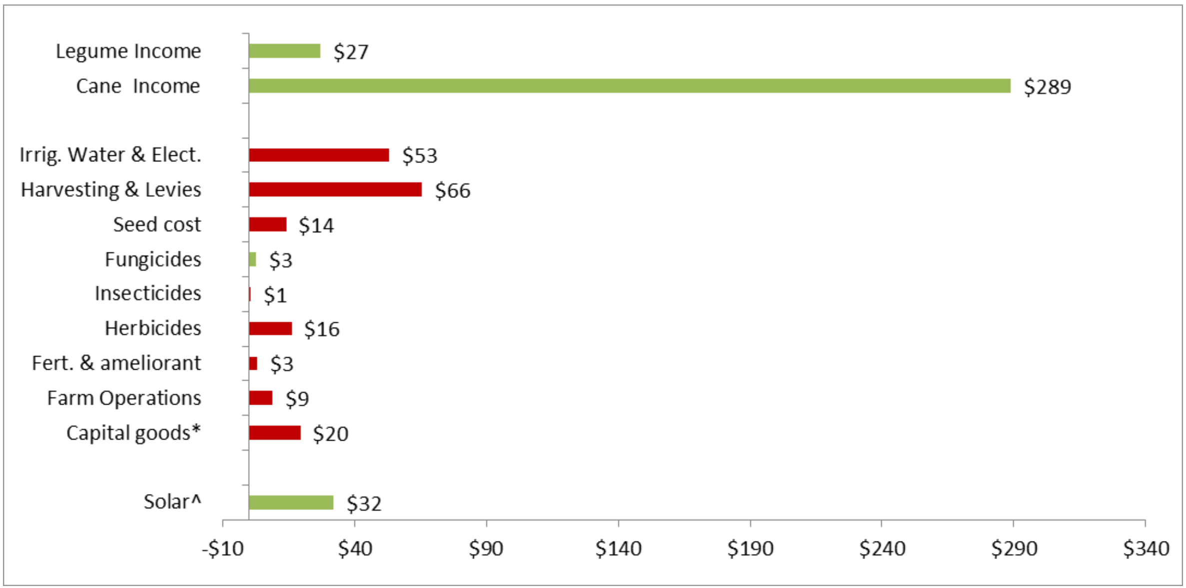


***Figure 1: Contributions to the change in farm operating return ($/ha change)***
*Note: Green bars denote increases in operating return, red bars denote decreases.*
*This includes depreciation of equipment.
^This includes $41/ha in electricity savings and $9/ha depreciation on the solar panel infrastructure.

Seed and harvesting cost increases were due to the mixed species added to the fallow period and higher cane yields respectively. There were increases in overall irrigation costs per hectare but the cost per ML reduced following improvements in delivery efficiencies (i.e. wider pipes, increased area under centre pivots, and a move to solar energy).

## How much did it cost to make the changes?

In moving to preformed beds and zonal tillage, the Deguaras' purchased various implements including wavy discs, a single row ripper, wheelie rake, plant cane cultivator and new seed spreader. They also built up a bed former and modified their planter. These investments resulted in an implementation cost of $102,000. They spent an additional $95,000 on irrigation system upgrades including pipe replacement, pivot refurbishments, additional mains, pipes and pumps. The cost of implementing all these changes is estimated at $578/ha ($197,000). A further $62,899 was spent on solar panel infrastructure bringing the total to $763/ha ($259,899).

## Was the investment profitable?

Results of an investment analysis show the practice changes were a worthwhile investment based on a conservative yield increase (8t/ha from 1ML/ha of added irrigation). Accounting for both the added revenue and higher costs, it would take 10 years to repay the $197,000 (or $578/ha) invested by the Deguaras' in making the changes (which is a similar payback period for when the solar panel investment is included).

Over a 10-year investment horizon, the Deguaras' investment (excluding solar) added an additional $10,027 per year ($29/ha/yr) to their 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 improving by 8t/ha (8.7%) across their farm following the practice changes.[5]

When the solar panel investment and energy cost savings are included the annual benefit is $12,769 per year ($37/ha/yr).

***Table 2: Cost of implementation and investment results (excluding and including solar)***

| | Excl. solar | Incl. solar |
|---|---|---|
| Cost of Implementation | $578/ha | $763/ha |
| Discounted Payback Period | 10 yrs | 10 yrs |
| Annual Benefit | $29/ha/yr | $37/ha/yr |
| Internal Rate of Return | 11% | 11% |
| Investment Capacity | $785/ha | $1,026/ha |

Investment capacity is the maximum amount of money that can be spent before an investment becomes unprofitable. The Deguaras' could have invested up to $267,425 ($785/ha) before the cost savings made by the practice changes would be insufficient to provide the required (7%) return on investment when solar is excluded. When solar is factored into the analysis, the investment capacity is $349,580 ($1,026/ha).

## 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) [6]
- Carbon footprint, an indicator of greenhouse gas (GHG) emissions causing global warming over the cane life cycle (kg $CO_{2\text{-eq}}$/t cane)[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 $PO_{4\text{-eq}}$/t cane)[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 $CTU_{eq}$/t cane)[9]
- 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

[5] From historical cane yield data, a 10% improvement in yield/ha was identified for the 2016-20 seasons (most recent 5-years), when compared to the period 2011-15. However, yields in the analysis are only increased by 8.7% (8t/ha) which is in line with literature from the past two decades (e.g. Baillie & Raine, 2014; Attard et al., 2009; Ballie, 2000; Ridge & Hillyard, 2000; Inman-Bamber et al., 1999; etc.). The yield increase is also supported by discussions with various growers, previous DAF agronomist (J. Hughes), Canegrowers and Mackay Agricultural Productivity Services. A marginal increase in soybean yield was also included at 0.3 t/ha (within a 0.6 t/ha increase based on recent yields). This was largely due to the change in rows planted to the preformed beds. It is anticipated the results of the study conservatively reflect economic benefits of the practice changes. The findings of this case study are specific to the individual business evaluated and is not intended to represent the impact of practice changes more broadly. As noted previously, various aspects of this case study have been simplified.

[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.

impacts of growing break crops, a fraction of which is assigned to the cane production. The reduced use of mains electricity for irrigation due to the introduction of PV solar power was excluded from the analysis. However the effects of this on fossil fuel use and carbon footprint are shown separately.

The percentage changes in environmental impacts per tonne of harvested cane are shown in Figure 2. There has been a decrease in all the environmental impacts per tonne cane (i.e. negative values on the graph), except for water use. Irrigation of the cane crops was increased from 2.2 to 3.3 ML/ha, and irrigation of the break crops was increased from 1 to 1.4 ML/ha. This was done to boost cane productivity by 8t/ha. The higher cane yields contributed to lowering environmental impacts per tonne of cane because more cane is produced from the applied inputs.

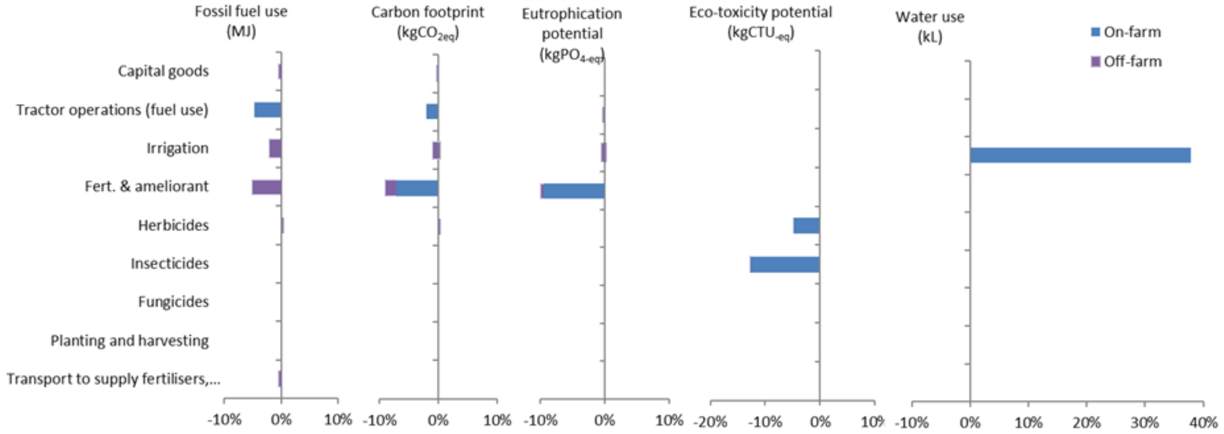


***Figure 2: Changes in environmental impacts after practice changes (% change per t cane)*** [10],[11]

**Fossil fuel use**. The practice changes reduced the life-cycle fossil-fuel use by around 170 gigajoules (GJ) per year (including both on-farm and off-farm energy use), which is equivalent to combusting 4 tonnes less diesel fuel per year[12]. This reduction was due to less diesel use in tractors from fewer cultivations and less energy used for fertiliser production due to a reduced amount of urea-N applied overall. The reduced energy demand combined with the cane yield increase meant that the life-cycle fossil-fuel use per tonne of harvested cane reduced by 10%. If the solar contribution is factored into the analysis, the reductions would be 250 GJ or 5 tonnes diesel fuel per year, and a 12% reduction per tonne of cane.

**Carbon footprint**. The practice changes also led to an overall reduction in life-cycle greenhouse gas emissions by around 32 tonnes of carbon dioxide emissions per year, which is equivalent to taking 10 cars off the road each year. This is partly due to the above-mentioned reduction in fossil fuel use, but there is also a decrease in emissions of nitrous oxide ($N_2O$), a strong greenhouse gas[13] due to less N being applied. Reduced total emissions combined with the greater cane yield meant that the carbon footprint per tonne harvested cane reduced by 11%. If the solar contribution is factored into the analysis, the reductions would be 41 tonnes of carbon dioxide emissions per year or 13 less cars, and a 12 % reduction per tonne of cane.

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

[11] The unshaded bars for irrigation show the reduced fossil fuel use and carbon footprint that would be expected if the solar power was also considered, which reduces use of mains electricity.

[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 $CO_{2-e}/kgN_2O$.

**Eutrophication potential**. The changed nutrient management regime slightly reduced the total amount of N potentially lost to water from the farm per year, in the order of about 80 kg of N-equivalent per year. This combined with the cane yield increase meant that fertiliser-N application reduced from 1.7 to 1.5 kg N/t cane. This has reduced slightly the potential for nutrient-related water quality impacts.

**Eco-toxicity potential**. The amount of pesticide active ingredients (AI) applied has increased slightly due to the introduction of an additional break crop, by around 5kg per year. However, because there has been a slight shift in the types of AIs applied, the over toxicity potential has decreased overall. This will translate into a slightly reduced potential for toxicity-related water quality impacts. This combined with the cane yield increase means that eco-toxicity potential per tonne harvested cane has reduced by about 18%.

**Water use.** There has been an increase in the amount of irrigation water used by around 300ML/yr across the farm, which has enabled greater productivity. As noted for the other impact categories, the increased productivity has contributed to reduced environmental impacts per tonne of harvested cane. The trade-off of water extraction is likely to be minor as the region is not particularly constrained in terms of water availability.

## 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 risk analysis was completed to explore the impacts from a productivity change due to the new practices, excluding solar (Figure 3).[14] This shows overall yields (across plant and ratoon cane crops) would need to increase by 6.9%, when solar is excluded, before the Deguaras' investment in the practice changes becomes profitable (or 6.4% inclusive of solar).

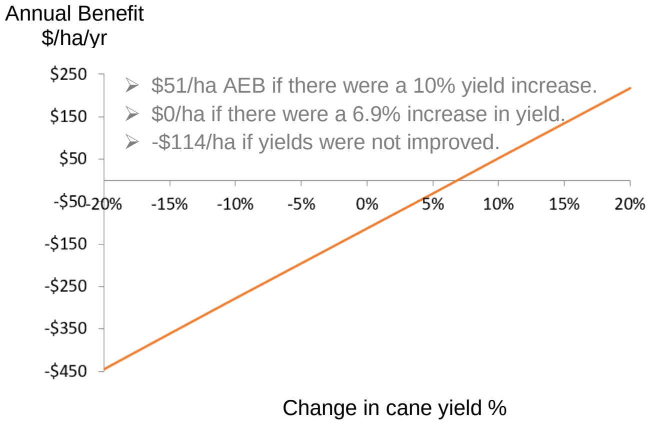


***Figure 3: Sensitivity of annual benefit (AEB) of investment to cane yield (excluding solar)***

Historical production data and past research indicate that the 8.7% (8t/ha) yield improvement used in the analysis to account for added irrigation is conservative (for an annual benefit of $29/ha/yr, excluding solar). In relation to the other practices, such as reduced tillage, yields are assumed to be unaffected (as these practices are aligned with scientifically validated Smartcane BMP principles).

From an environmental perspective, the improvements are relatively sensitive to changes in cane yields (Figure 4). As noted above, the cane yield was assumed to increase by 8.7% which led to reductions in environmental impacts per tonne of cane in the order of 10-17% across all impact categories, except water use. If there had been no yield increase, then environmental impact reductions (per tonne of cane) would be 3-10%. Cane yields would have to increase a lot more than the assumed 8.7% for there to be no net increase in water use per tonne harvested cane. So there will always be a trade-off in terms of water use for productivity gains and the positive influence this has on the other environmental aspects.

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

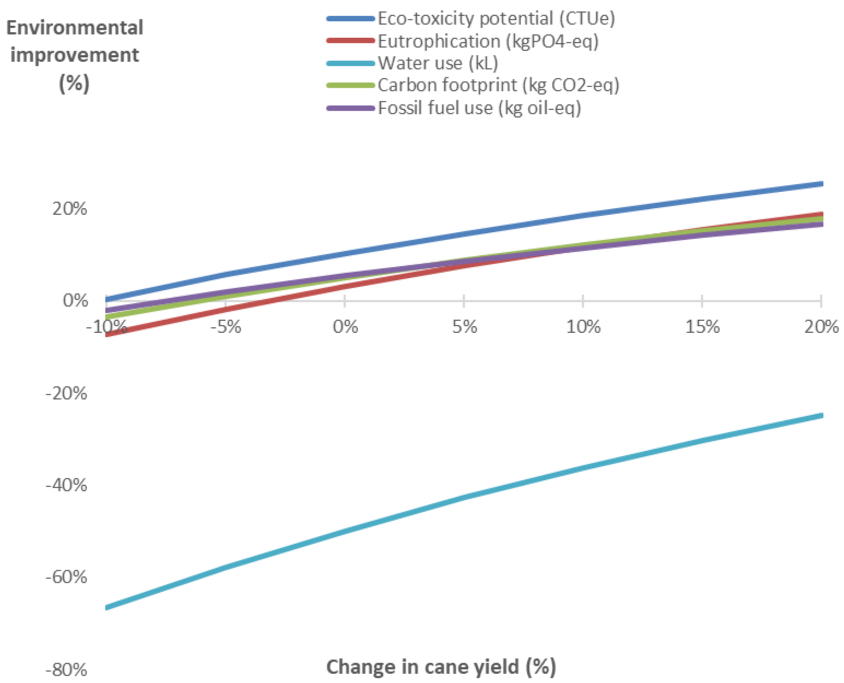


***Figure 4: Sensitivity of environmental improvements to yield (excluding solar)***

## What's the bottom line?

This case study has evaluated the economic and environmental impacts of various practice changes for a farm in the Mackay region. Following on from progress made by Andrew's dad, the Deguaras' have continued to adopt incremental changes. These have improved their profitability and environmental performance.

Results of the economic analysis indicate the recent changes implemented by the Deguaras' have resulted in increased costs per hectare, largely due to increased irrigation and additional legume costs. These additional costs, however, were outweighed by greater income from yield improvements (conservatively estimated) due to increased irrigation events. Overall, the Deguaras' investment in new equipment and infrastructure has been worthwhile within a 10-year payback period. Cane yields (across plant and ratoon crops) would need to increase by 6.9% (6.5% when considering solar investments) before investment in the practice changes becomes profitable.

The practice changes have resulted in slight reductions in environmental impacts per tonne of cane, which have been facilitated by the increases in cane productivity due to increased water application. An interesting aspect of the case study is that the energy needs for the additional water pumping has been met by renewable solar electricity. Therefore there has been no energy trade-off for the productivity gain. There has, however, been a productivity/water-use trade-off in terms of extracting more water overall. This trade-off is minor as the region has a relatively low water stress.

Each farming business is unique in its circumstances and therefore the parameters and assumptions used in this case study reflect the Deguaras' 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.

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.

Thanks to Mackay Sugar for the provision of historical production data.

For further information on this integrated case study please contact the Townsville DAF office on 13 25 23. This is an updated version of the case study.

FEATOnline
FARM ECONOMIC ANALYSIS TOOL



QUT

Queensland Government