Marginal Abatement Cost Curves for Sugar Cane and Grazing in the Great Barrier Reef Catchments

Technical Report
Prepared by: Office of the Great Barrier Reef, Department of Environment and Heritage Protection

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Citation

Acknowledgements

This publication combines two studies which were commissioned by the Department of Environment and Heritage Protection at the request of the Great Barrier Reef Water Science Taskforce.

The methods and results presented in this report have been drawn directly from the following works:


Further details are provided in these studies and they are available on request from the Office of the Great Barrier Reef, Department of Environment and Heritage Protection, Brisbane.

* Department of Agriculture and Fisheries
^ Department of Science, Information Technology and Innovation
# Central Queensland University
## Abbreviations and acronyms

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
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<tbody>
<tr>
<td>AE</td>
<td>Adult equivalent</td>
</tr>
<tr>
<td>AEB</td>
<td>Annualised equivalent benefit</td>
</tr>
<tr>
<td>APSIM</td>
<td>Agricultural Production Systems sIMulator</td>
</tr>
<tr>
<td>BRIA</td>
<td>Burdekin River Irrigation Area</td>
</tr>
<tr>
<td>DIN</td>
<td>Dissolved Inorganic Nitrogen</td>
</tr>
<tr>
<td>GBR</td>
<td>Great Barrier Reef</td>
</tr>
<tr>
<td>GRASP</td>
<td>Grass Production Model</td>
</tr>
<tr>
<td>Ha</td>
<td>Hectare</td>
</tr>
<tr>
<td>Kg</td>
<td>Kilogram</td>
</tr>
<tr>
<td>NC</td>
<td>Neighbourhood catchment</td>
</tr>
<tr>
<td>TSS</td>
<td>Total suspended sediment</td>
</tr>
</tbody>
</table>
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Executive summary

The Great Barrier Reef Water Science Taskforce commissioned two studies to understand the costs and effectiveness of moving landholders from one land management practice class to the next. The studies investigated the costs and reduction in dissolved inorganic nitrogen for sugar cane production in the Wet Tropics and Burdekin catchments and the costs and reduction in total suspended solids for the grazing industry in the Fitzroy and Burdekin catchments. As this is the first attempt to undertake this type of analysis at a catchment level for the Great Barrier Reef the approach presented is innovative.

By examining the costs and effectiveness of moving from one land management practice class to the next, the marginal costs of pollution abatement can be determined. Both studies assessed the opportunity costs for landholders. These are the additional costs for landholders to make the required changes.

It is also recognised that there are barriers to the adoption of new practices which are not financial. For example, the complexity of the required changes, the lack of fit with farm operations or owner goals, trialability and observability may limit the uptake of improved practices. Both studies assess the cost and effectiveness of current extension programs.

Alternatively, it may be a regulatory requirement that all landholders reach a certain land management practice class in which case all the opportunity costs will be borne by the landholder. The cost of ensuring compliance with the regulation is the responsibility of government. The costs and effectiveness of regulation was only considered for sugar cane as there are currently no specific regulatory requirements relating to land management practice for grazing.

The studies provide important insights into the variation in opportunity costs depending on location and farm size. For example, the cane study showed that targeting extension and incentives (to cover the opportunity costs) in the Herbert and Tully sub-catchments in the Wet Tropics would result in the highest reduction in loads at the lowest cost. Conversely, in the Burdekin Delta sub-catchment the costs of moving from C class practice to B class nutrient management practice are very high and will only produce a small reduction in loads of dissolved inorganic nitrogen.

The cane study also demonstrated that using regulation to shift landholders from D class practice to C class nutrient management practices is likely to impose few financial costs and may generate significant financial benefits from some land units. Nevertheless other non-financial barriers are likely to remain which may require different supporting measures. Extension combined with incentives is likely to be effective, if properly designed, implemented and targeted, in supporting a large group of landholders in shifting from C class practice to B class practice.

Another important conclusion from the cane study is that even with adoption of best available technology resulting in A class practices, less than 50 per cent of dissolved inorganic nitrogen exports are abated in most of the catchments analysed. Therefore there must be a role for future technology development and implementation if reduction targets are to be achieved for cane farming.

The results from the grazing study indicate that it is possible to reduce 20 per cent of the current load of total suspended sediment from the Fitzroy and Burdekin catchment through a combination of policy mechanisms. This includes moving all current B class land condition to A class land condition at a cost of $164 million and moving all current C class land condition to B class land condition at a cost of $53.3 million.

The spatial distribution of costs and effectiveness was also demonstrated for grazing with a large variance in cost of sediment reduction. Areas with the highest productivity, generally located closer to the coast, should be considered as higher priority for investment in sediment reductions, as these areas typically have higher regeneration times and present lower risk options. Highlighting the importance of maintaining good levels of groundcover at the end of the drought is important to avoid large sediment loss through the development of gully erosion.
Introduction

The Reef Water Quality Protection Plan (2013) and the Reef 2050 Long-Term Sustainability Plan (2015) are Australian and Queensland Government initiatives that focus on halting the decline in the health of the Great Barrier Reef (GBR). These plans state a number of targets for sediment, nutrient and pesticide run-off reduction in the grazing, grains and sugar industries.

Prioritisation processes conducted under the Reef Water Quality Protection Plan 2013 have resulted in the Wet Tropics and Burdekin catchments being rated as “Very High” for nitrogen load reductions, and the Burdekin and Fitzroy catchments being ranked as “Very High” for sediment load reductions. An annual Great Barrier Reef Report Card assesses progress towards targets, and highlights the slow progress as a result of a number of complexities such as climate, existing degree of landholder adoption, and geographical variation. Given these results, there is increased pressure to improve the progress towards the targets.

In response to the declining health of the Great Barrier Reef the Queensland Government has set up the Great Barrier Reef Water Science Taskforce (the Taskforce). The aim of the Taskforce is to provide advice to the Queensland Government on the best possible approach to achieving the 2025 targets for pollution run-off into the Great Barrier Reef.

Within the terms of reference for the Taskforce is the requirement to advise on the best approach to meeting the government's water quality targets, including the effectiveness and cost of robust regulations, incentives, Best Management Practice programs, market-based trading mechanisms and other policy instruments (or a combination thereof) and to identify priority areas for investment of the additional $100 million funding that the government has committed to the GBR.

As part of meeting the terms of reference the Taskforce has requested that a series of marginal cost abatement curves for nutrients (Wet Tropics and Burdekin) and sediment (Burdekin and Fitzroy) for different management classes be produced. The purpose of producing the cost curves is to provide information to estimate the most cost-effective way to allocate $90 million for the GBR over the next four years.

This report includes marginal abatement cost curves for nutrient reduction from the sugar cane industry in the Wet Tropics and Burdekin catchments and sediment reduction from the grazing industry in the Fitzroy and Burdekin catchments. It must be noted that the most current data sets have been utilised in this report, however a number of assumptions have been required to integrate the data and to generate the cost curves.
Objectives

The objective of this report is to produce a series of marginal cost abatement curves for nutrient exports from sugar cane production in the Wet Tropics and Burdekin catchments and for sediment from grazing operations in the Fitzroy and Burdekin catchment regions for different management classes.

This includes:

1. Estimating the marginal cost abatement curves for nutrients for the Wet Tropics and Burdekin catchment regions for different management classes and for sediments based on shifting landholders to an improved state of land condition in the Fitzroy and Burdekin catchments.

2. Adapt marginal cost abatement curves to present the likely program costs in the form of a marginal program cost curve. Program costs for incentives, extension and regulation were considered for cane in the Wet Tropics and Burdekin catchments and for incentives and extension in the Fitzroy and Burdekin catchments.

3. Identify the likely distributional costs attached to the policy program cost curve in order to inform both debate around policy implementation and an understanding of the burden (or benefit) of any required change on taxpayers and industries.

Practice Management frameworks

Classes of practice (ABCD) frameworks for improved practices for water quality have been developed by the Great Barrier Reef (GBR) natural resource management bodies since 2008 (Sing and Barron, 2014). The respective frameworks reflect the differences in farming systems and landscapes between regions, providing a mechanism for land managers to identify where their current system of management sits with respect to water quality outcomes and the options available for improvement.

The Reef Water Quality Protection Plan 2013 Paddock to Reef monitoring program has developed a water quality risk framework¹ to classify and report on the adoption of management practices. Practices are ranked from lowest risk (innovative practices that have the lowest water quality risk) to high risk (superseded practices that have the highest water quality risk) for sugarcane, horticulture and grains. They are ranked from very low soil erosion and water quality risk to moderate-to-high soil erosion and water quality risk for grazing.

For the purposes of the cane study the description of practice is couched in terms of the classes of practice – A, B, C or D – which in general equates to the water quality risk framework (lowest risk to highest risk). For the grazing study classes of land condition were used as the basis for bioeconomic modelling recognising that land condition may not always have a direct correlation to land management practice.

Nutrients – cane

Methods and models

A marginal abatement cost curve illustrates the cost of delivering additional units of pollutant reduction. Typically there will be a number of options available to reduce pollutants. For example, in the case of reducing dissolved inorganic nitrogen (DIN) exported from sugar cane, the technologies can be bundled into the ABCD practice framework which describes a suite of management practices. Each suite of management practices is applied in a particular biophysical and farming operational context which will deliver a different level of effectiveness. In the models for cane, the biophysical and farming operational contexts used are:

- Biophysical parameters: climate, soil and resultant yield response. These are only reported at the aggregate scale representing differences in exports across the sub-catchments.
- Farm size. Farming operations are differentiated into small, medium and large for the purposes of identifying the costs and benefits from adoption.

The conceptual model applied to develop the abatement cost curves integrates the outputs from previous studies of the economic cost of practice change in the Burdekin and Wet Tropics, with the nutrient export model and the rates of practice adoption into a bio-economic model. The bio-economic model combines data to identify costs and payoffs from a defined baseline to facilitate the estimation of abatement cost curves. Note that the model does not estimate the quantity of DIN received by the GBR—rather the quantity reduced at edge of paddock or farm.

The conceptual model is used to deliver two types of financial economic analysis of the relevant costs to landholders of reducing pollutant exports:

- Annual return or gross margin based analysis. This estimates the net change to per hectare cane returns based on yields (and sales) and the impact on variable costs.
- Annualised equivalent benefit (AEB) over a ten year horizon. This builds on the gross margin approach by including the cost of new equipment required to implement practice changes by spreading the cost over a ten year period.

The annualised equivalent benefit is the preferred financial economic analysis because it takes into account the necessity of investing in new equipment to undertake some management practice transitions. Nevertheless the annualised equivalent benefit estimates exclude a number of important factors which are likely to influence both the cost to landholders and the likelihood of practice change adoption even where it is financially beneficial.

These costs and barriers include:

- Risk preferences: landholders tend to be risk averse and the risk of an adverse impact on yield is likely to increase moving from D class practice to A class practice.
- Transaction costs: in broad terms transactions costs arise from the transfer of a good from one agent to another. Some transaction costs are financial, but many others are related to time and effort, and other barriers to adoption. Coggan et al. (2014) estimate first time practice change transaction costs for participants in the Reef Rescue program at an average of $9,000 per participant, but note these are expected to fall for subsequent practice changes by these participants.
- Other barriers to adoption: examples include complexity, lack of fit with farm operations or owner goals, visibility of desired outcomes, observability of impacts, etc.

The combined impact of these barriers, costs and preferences mean that financial costs are an underestimate of the full costs of practice change and that the progress of adoption is likely to be slower or rejected by some landholders.

The consequences of business as usual and three policy scenarios were modelled to estimate the impacts on reducing DIN exports at the paddock scale.
There is an underpinning assumption that existing programs such as Queensland Government extension support and investments by the Australian Government through the Reef Programme and Reef Trust continue to support adoption across business as usual and the three policy scenarios. The three scenarios are defined as follows:

- **Business as usual**: adoption continues on the same trajectory as the previous three years which achieves a further three per cent shift in the suite of practices adopted by landholders from D class practice through to A class practice (i.e. three per cent each from D to C class practice, from C to B class practice, and from B to A class practice).

- **Regulation scenario**: a regulatory program is introduced which will shift all remaining landholders with a suite of D class practices to a C class practice suite. The cost to government of this program has been set at $1 million per year to fund compliance officers that support the practice adoption shift.

- **Extension scenario (inclusive of regulation scenario)**: an expanded extension program is implemented which will double the effectiveness of all current programs to shift a further three per cent of farmers from a suite of C class management practices to B class management. The cost of the program is estimated at $1.6 million per year for eight additional extension officers, which is a doubling of current resources.

- **Incentives scenario (inclusive of extension and regulation scenario)**: an expanded incentive program shifts all landholders with modelled abatement costs of changing from a C class suite of practices to a B class suite of practices at less than $0/kg AEB. This program would cost around $8.9 million per year or about $10/kg DIN lost at the farm scale. This amount is about 50 per cent higher than average price paid in recent Wet Tropics tender (and Reef Rescue). Note that the exact structure could be varied (e.g. grants or tenders) and prices could be higher or lower.

The modelling approach and scenarios are depicted in Figure 1.

### Bio-economic model – baseline for policy scenarios

- **Abatement** = \( \Delta \text{Adoption} \times \text{Area available} \times \Delta \text{ Loads} \)
- **Financial cost** to shift differentiated by:
  - Practice change (D to C to B to A)
  - Sub-catchment (Burdekin BRIA & Delta, WT by 5 major)
  - Farm size (small = 50ha, medium = 150ha, large = 250ha)

1. **Regulations**:
   - All D shifted to C
   - $1m/yr

2. **Extension (+regs)**:
   - 3% of all farmers shift C to B
   - $1.6m/yr (+$1m regs)

3. **Incentives (+extn +regs)**:
   - All AEB <$0/kg shift C to B @ $10/kg
   - ~$8.7m/yr (+1.6 extn +$1m regs)

**Figure 1. Policy scenarios modelled**

**Data Sources**

Biophysical data was sourced from various parts of the Queensland Government. Nutrient export loads were generated using an updated Agricultural Production Systems sIMulator (APSIM) modelling approach across the modified 2015 ABCD framework. Cane farming practice data (2015) was sourced from Queensland Department of Agriculture and Fisheries (DAF).

Basic catchment parameters identifying the area of land under cane production were sourced from the Wet Tropics and Burdekin Water Quality Improvement Plans (WQIPs). Economic performance under alternative management actions was sourced from the economic modelling supporting the WQIPs and from van Grieken et al (2010).
Economic modelling for the Burdekin WQIP was undertaken using both previous CSIRO and DAF data and additional elements. Economic modelling for the Wet Tropics was undertaken by DAF and based on van Grieken et al. (2013) and Poggio et al. (2014). Costs of D class management were adjusted to 2015 dollar values from van Grieken et al. (2010).

All modelling was undertaken in Microsoft Excel. Graphical analysis was undertaken using Abate.

Results – cane

The modelling output comprises a summary of DIN exports at the paddock/farm scale and cost of abatement for the business as usual, and three policy scenarios. These results are also presented as an abatement cost curve. Additional data also details the potential cost to government in the form of program costs.

A summary of the overarching results of the business as usual scenario is presented in Table 1. Positive numbers indicate that the modelling shows a positive financial outcome on average, negative numbers indicate a cost. In total, just over 2,500 tonnes of DIN are exported from cane farms across the Burdekin and Wet Tropics. Major exporting regions are the Mossman and Herbert catchments despite having few or no D class farmers. The annualised equivalent benefit (AEB) cost per tonne abated is modelled as ranging from an increase in profits of around $15,000 per tonne abated from D to C class management in the Burdekin River Irrigation Area (BRIA) to a cost of $289,000 per tonne abated from C to B class management in the Delta region of the Burdekin. The high cost in the Delta region is due to the very small amount of DIN abated (0.4kg/ha) and abatement costs between $44 and $320/ha depending on farm size.

Table 1. Summary of nutrient abatement available by cost and quantity

<table>
<thead>
<tr>
<th>Practice package change</th>
<th>Sub-catchment</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BRIA</td>
<td>Delta</td>
</tr>
<tr>
<td>BAU DIN exports in tonnes (farm scale, current farming system)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>4.1</td>
<td>2.2</td>
</tr>
<tr>
<td>B</td>
<td>5.4</td>
<td>3.1</td>
</tr>
<tr>
<td>C</td>
<td>116.4</td>
<td>59.7</td>
</tr>
<tr>
<td>D</td>
<td>66.7</td>
<td>46.6</td>
</tr>
<tr>
<td>Total</td>
<td>192.5</td>
<td>111.6</td>
</tr>
<tr>
<td>Total tonnes of DIN which can be abated at farm level by practice suite shift</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D to C</td>
<td>53.9</td>
<td>40.0</td>
</tr>
<tr>
<td>C to B*</td>
<td>31.8</td>
<td>8.9</td>
</tr>
<tr>
<td>Average cost of abatement tonne of DIN abated (AEB) at farm level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D to C</td>
<td>$14,822</td>
<td>$13,426</td>
</tr>
<tr>
<td>C to B*</td>
<td>$30,747</td>
<td>-$289,428</td>
</tr>
</tbody>
</table>

Notes: Tablelands catchment not included due to very small size.
- Positive numbers indicate modelling shows a positive financial outcome on average, negative numbers indicate a cost.
* C to B includes all farms previously in D. B to A are not relevant as there was no significant abatement modelled for this transition.
The effect of farm size on the cost of abatement is shown in Figure 2 and Figure 3 for the annualised equivalent benefit analyses.

Figure 2. Effect of farm size on DIN abatement costs – annualised equivalent benefit analysis.

These costs are the per hectare impact. The following conclusions can be drawn from these:

1. **Changing from a D class to C class suite of management practices should not be financially costly.** In all instances the models show an increase in profits. The increase is clearly larger for landholders in the Burdekin. Increases are largest for large farmers (at around $500 per hectare). They are negligible for small farmers in the Wet Tropics. The fact that landholders have not shifted suggests other barriers to change are present or that there are unobserved costs. That is, changing will impose other challenges on remaining D class management practice landholders.

2. **Changing from C class practice to B class practice should be a low financial cost for many landholders.** Our models suggest low to negligible annualised equivalent benefit financial costs for large farmers in the BRIA and Wet Tropics. For small landholders the change from C class practice to B class practice will impose a cost in all instances.

3. **Shifts to A class practices are not a viable option because they impose significant costs with few to no modelled DIN reductions.**

**Combined abatement costs**

A summary of the results of the three policy scenarios is shown graphically in Figure 3. The figure illustrates that the benefits are lower and costs are higher for increasing levels of practice management and especially for the C to B transition. Note that in the real world a large variation in costs would be expected within classes which is not shown here due to the differential nature of cost structures and barriers on individual enterprises. Evidence of this is apparent in the distribution of costs for Reef Trust Tender Wet Tropics in which offers varied from less than $2/kg DIN abated/year to more than $25/kg DIN abated/year, with similar large variations in Reef Rescue attributed costs per kilogram abated.
Figure 3. Adjusted DIN abatement annualised equivalent benefit costs by sub-catchment and farm size.
Policy scenarios

The summary results of the three policy scenarios are shown in Table 2 and graphically in Figure 4. The ‘Regulation scenario’ would achieve approximately 98 tonne of DIN abated at the farm scale at a cost of between $7-$10/kg in the Burdekin catchment to over $40/kg in the Herbert sub-catchment. However, it is anticipated that other catchments will achieve all C class practice or better under business as usual within five years in the absence of regulations. Regulations remove the D to C class practice segment of the abatement curve when considering further policies and are estimated to increase financial returns to landholders although landholders clearly face other barriers to change or they would already have shifted their practice.

The ‘Extension scenario’ abates a further 28 tonne of DIN at approximately $50/kg DIN. The high marginal cost per unit of additional DIN reduced under this scenario reflects two factors. First, extension programs in isolation appear to have relatively low effectiveness in delivering high rates of practice change as evidenced by the slow rate of change over recent years. Nevertheless extension programs are likely to be essential in reducing transaction costs and assisting in overcoming some other barriers to practice change and therefore are likely to reduce the costs of abatement under both regulations and incentive programs.

Table 2. Comparison of policy scenario to business as usual approach.

<table>
<thead>
<tr>
<th>Practice package change</th>
<th>Policy scenario</th>
<th>Extension (includes regulations)</th>
<th>Incentives (includes regulations and extension)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Regulation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DIN abatement at the farm scale</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D to C</td>
<td>98.1 t</td>
<td>98.1 t</td>
<td>98.1 t</td>
</tr>
<tr>
<td>C to B</td>
<td>0</td>
<td>32.2</td>
<td>32.2</td>
</tr>
<tr>
<td>B to A</td>
<td>0</td>
<td></td>
<td>870</td>
</tr>
<tr>
<td>Cost to government of policy scenario</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D to C</td>
<td>$1m per year</td>
<td>$1m per year</td>
<td>$1m per year</td>
</tr>
<tr>
<td>C to B</td>
<td>$1.6m per year</td>
<td></td>
<td>$1.6m per year</td>
</tr>
<tr>
<td>B to A</td>
<td></td>
<td></td>
<td>$8.7m per year</td>
</tr>
<tr>
<td>Qualitative estimate of cost to landholders of policy scenario</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nature of costs and benefits to landholders</td>
<td>Financial returns may increase for many but other barriers remain. Will have a mix of non-financial and potentially indirect financial impacts on landholders.</td>
<td>Assists in overcoming some barriers to change but is not effective where landholders are exposed to additional risk or financial costs. Only likely to support adoption in the absence of significant financial costs.</td>
<td>Supports landholders directly in overcoming financial impediments.</td>
</tr>
</tbody>
</table>

Finally the ‘Incentive scenario’ was applied to support practice changes where our modelled financial costs are at most $0/ha AEB could deliver as much as 870t in DIN abatement per year. That is, incentives are offered to support landholders even though modelled financial costs to landholders of making practice changes are zero or less because transaction costs and other barriers are not included in our financial models. This approach is consistent with research such as Coggan et al. (2015) who estimate significant transaction costs associated with change, to incentivise risk management or as a financial incentive to assist in overcoming other barriers to adoption. Nevertheless, assuming all landholders modelled as low cost actually adopt changes to practices under the ‘Incentive scenario’ is likely to be overly optimistic, while actual costs would likely be higher than $10/kg for at least some landholders.
The DIN abatement and modelled financial cost to landholders by sub-catchment is shown in Table 3. These results indicate there are likely to be considerable benefits from targeting. For example, there are likely to be few profitable opportunities in the Delta region of the Burdekin catchment for shifting farmers to B class practices, and indeed losses are low. The BRIA region in the Burdekin is also a poor target as profits alone should drive change and there is relatively little reduction in total losses.

The message across the Wet Tropics is similar. These results suggest targeting extension and incentives towards the Herbert and Tully sub-catchments as these areas have a combination of high loads and low cost per unit reduction, although the entire Wet Tropics region meets this objective. Note that Wet Tropics economics data is from Tully and may differ in other sub-catchments, with variations in cost per unit driven by average load per hectare from APSIM modelling.

Caution should be used when interpreting the modelled increase in financial returns to landholders. These results indicate that before transaction costs and other barriers are considered, implementation of the combined regulatory, extension and incentive policies is estimated to increase returns to landholders by $3.5 million. We do not model inclusion of transaction costs, however were we to include these at the amount estimated by Coggan et al. (2015) for just 25 per cent of Burdekin and Wet Tropics landholders, transaction costs would exceed $4 million. That is, landholders are likely to face transaction costs, shifts in risk exposure and other barriers in making changes which are not included in the modelling and these will impact their financial returns from practice adoption. Nevertheless, larger modelled financial benefits clearly indicate that any incentive payment required should be lower. This conclusion may be testable with the results of the Burdekin Reef Trust Tender expected in early 2016.
Table 3. Summary of nutrient abatement available by cost and quantity.

<table>
<thead>
<tr>
<th>Policy scenario</th>
<th>Sub-catchment</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BRIA</td>
<td>Delta</td>
</tr>
<tr>
<td>Regulations</td>
<td>53.9</td>
<td>40.0</td>
</tr>
<tr>
<td>Extension</td>
<td>1.0</td>
<td>0.3</td>
</tr>
<tr>
<td>Incentives</td>
<td>26.4</td>
<td>0.0</td>
</tr>
<tr>
<td>Total</td>
<td>81.3</td>
<td>40.3</td>
</tr>
</tbody>
</table>

*Incremental reduction in DIN exports in tonnes from business as usual (farm scale, current farming system)*

<table>
<thead>
<tr>
<th>Policy scenario</th>
<th>Regulations</th>
<th>Extension</th>
<th>Incentives</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$798,558</td>
<td>$32,196</td>
<td>$1,410,702</td>
<td>$2,241,456</td>
</tr>
<tr>
<td></td>
<td>$537,407</td>
<td>-$84,946</td>
<td>$0</td>
<td>$452,461</td>
</tr>
<tr>
<td></td>
<td>none</td>
<td>-$582</td>
<td>$40,860</td>
<td>$40,277</td>
</tr>
<tr>
<td></td>
<td>$84,553</td>
<td>-$14,885</td>
<td>$382,703</td>
<td>$452,371</td>
</tr>
<tr>
<td></td>
<td>none</td>
<td>-$6,714</td>
<td>$78,895</td>
<td>$72,181</td>
</tr>
<tr>
<td></td>
<td>none</td>
<td>-$13,805</td>
<td>$101,334</td>
<td>$87,529</td>
</tr>
<tr>
<td></td>
<td>none</td>
<td>-$1,343</td>
<td>$218,107</td>
<td>$216,764</td>
</tr>
<tr>
<td></td>
<td>$1,420,518</td>
<td>-$90,077</td>
<td>$2,232,600</td>
<td>$3,563,041</td>
</tr>
</tbody>
</table>

*Total modelled financial cost to landholders*~

<table>
<thead>
<tr>
<th>Policy scenario</th>
<th>Regulations</th>
<th>Extension</th>
<th>Incentives</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$14.82</td>
<td>$30.75</td>
<td>$53.46</td>
<td>$27.57</td>
</tr>
<tr>
<td></td>
<td>$13.43</td>
<td>-$289.43</td>
<td>n/a</td>
<td>$11.22</td>
</tr>
<tr>
<td></td>
<td>n/a</td>
<td>-$0.49</td>
<td>$0.45</td>
<td>$0.44</td>
</tr>
<tr>
<td></td>
<td>n/a</td>
<td>-$0.96</td>
<td>$0.95</td>
<td>$0.93</td>
</tr>
<tr>
<td></td>
<td>n/a</td>
<td>-$1.87</td>
<td>$0.91</td>
<td>$0.80</td>
</tr>
<tr>
<td></td>
<td>n/a</td>
<td>-$3.46</td>
<td>$1.12</td>
<td>$0.93</td>
</tr>
<tr>
<td></td>
<td>n/a</td>
<td>-$0.21</td>
<td>$1.27</td>
<td>$1.21</td>
</tr>
<tr>
<td></td>
<td>$14.48</td>
<td>-$2.80</td>
<td>$2.57</td>
<td>$3.57</td>
</tr>
</tbody>
</table>

~ Positive numbers indicate modelling shows a positive financial outcome on average, negative numbers indicate a cost
Managing DIN from cane beyond improved practices

The total load that could be abated if all farms reached A class management practices was also assessed. Table 4 illustrates the total loads if all landholders achieve A class management, and as a proportion of business as usual DIN exports. In most catchments less than 50 per cent of current loads can be abated. The Herbert sub-catchment delivers the most DIN but the Mossman sub-catchment exports twice as many kilograms from every hectare of cane grown at over 20kg per ha per year. The Burdekin catchment is an order of magnitude lower in terms of DIN contribution with few savings available either in aggregate or per hectare.

Table 4. Remaining DIN exports when all land at A class management.

<table>
<thead>
<tr>
<th>Sub-catchment</th>
<th>Remaining DIN exports (all A class)</th>
<th>Proportion of business as usual DIN exports</th>
<th>Average Kg of DIN per hectare exported at ‘A class’ practice level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burdekin River Irrigation Area</td>
<td>101</td>
<td>53%</td>
<td>2.12</td>
</tr>
<tr>
<td>Burdekin River Delta</td>
<td>55</td>
<td>49%</td>
<td>2.18</td>
</tr>
<tr>
<td>Mossman</td>
<td>128</td>
<td>55%</td>
<td>22.35</td>
</tr>
<tr>
<td>Herbert</td>
<td>461</td>
<td>49%</td>
<td>9.05</td>
</tr>
<tr>
<td>Russell-Mulgrave</td>
<td>177</td>
<td>62%</td>
<td>15.20</td>
</tr>
<tr>
<td>South Johnstone</td>
<td>199</td>
<td>61%</td>
<td>12.81</td>
</tr>
<tr>
<td>Tully-Murray</td>
<td>312</td>
<td>62%</td>
<td>11.71</td>
</tr>
<tr>
<td>Total</td>
<td>1432</td>
<td>55%</td>
<td>7.81</td>
</tr>
</tbody>
</table>

Conclusion – cane

A summary of the results from this analysis is shown in Figure 5. Regulation is likely to result in a relatively low financial cost in shifting the remaining landholders to C class practice management. Nevertheless other non-financial barriers are likely to remain. Extension combined with incentives is likely to be effective, if properly designed, implemented and targeted, in supporting a large group of landholders in shifting from C class practice to B class practice. Steps should be taken in implementing any incentive oriented program to avoid higher cost changes such as those shown to the right in Figure 5. Finally, even with adoption of best available technology (A class practices), less than fifty per cent of DIN exports are abated in most catchments analysed. Therefore there must be a role for future technology development and implementation if reduction targets are to be achieved alongside of cane farming.

Figure 5 also clearly illustrates that steps should be taken to avoid higher cost changes such as those shown to the right when implementing any incentive oriented program. This is reinforced by the distributional analysis indicating that incentives should not be required in the BRIA sub-catchment, and there are only small and high cost DIN abatement options available in the Burdekin Delta sub-catchment once landholders are shifted out of D class practice management.

Figure 5 illustrates the implications, showing a cluster of primarily D to C transitions which may increase profits, a cluster of low cost C to B transitions, and finally a cluster of more expensive C to B transitions before the high cost, low abatement B to A transitions. Note that the figure shows costs for practice transitions for Burdekin BRIA and Delta sub-catchments, and the five major Wet Tropics catchments, split into small, medium and large farms in each. The horizontal axis shows total tonnes abated at farm scale. Within each class costs are likely to vary due to transaction costs, risk, adoption barriers and unobserved factors with the possible range illustrated by the large bracket as an example.
Figure 5. Adjusted DIN abatement AEB costs by sub-catchment and farm size – generic conclusions.
Sediments – grazing

Methods and models

The scale of analysis used for the marginal abatement costs curves for sediments was at the neighbourhood catchment level which is the scale used by the respective Natural Resource Management (NRM) regions in the Burdekin and Fitzroy catchments. The neighbourhood catchments boundaries are based on smaller scale catchments and comprise a varying number of landholders. Fitzroy Basin Association has a total of 192 neighbourhood catchments, and the Burdekin has 51. The scale allows the various parameters to take account of the specific geographic features of the region. Then different levels of data were integrated to best identify the costs per tonne of sediment reduced.

Different approaches were used to estimate the opportunity cost and extension cost curves as provided below.

Opportunity costs curve

The opportunity cost curve (used for the incentive mechanism) estimates the value of the opportunity cost of landholders reducing stocking rate to improve land condition, over a five year period. To estimate this across the catchment allows an understanding of the reduction in stocking rate required and an estimate of the ceiling for future market based instruments. The method to estimate this involved a number of different datasets integrated for each of the neighbourhood catchments to allow for spatial heterogeneity to be considered. Each of these components has various complexities.

The approach and models are illustrated in Figure 6.

Figure 6. Process and data implemented for the opportunity cost curve.

Productivity, land type and condition

The first step in the estimation of the opportunity cost curves is assessing the proportion of land currently in A, B, C and D condition. Accounting for the variation in land condition provides information on the proportions of land that are able to be improved and the scope of change required. It also allows an estimation of the stocking rates currently being used by landholders. Land condition has been used on the premise that low risk management practices will maintain or improve land condition. Therefore understanding the areas in the catchments with the greatest capacity for improvement, and the associated cost per tonne of sediment reduction is important to understand the costs involved in meeting the management practice standard.

Land condition was assessed through information provided by remotely sensed ground cover measurements which have been undertaken as part of the Reef Water Quality Protection Plan and associated programs since 2009. The groundcover data sets produce seasonal (four/year) estimates of ground cover in 30 mega pixel resolution for about 95 per cent of Queensland (Tindal et al. 2014).
The measurement of productivity was based on Adult Equivalent (AE)/Ha. This is the hypothetical number of 400kg cattle that can be sustainably supported per hectare according to the Grass Production Model (GRASP) model (McKeon et al 2000). GRASP takes into account rainfall, land type, tree cover and land condition to determine this long term carrying capacity.

**Bio-economic modelling**

Identifying the most dominant land types present in each of the neighbourhood catchments was also critical. Land types reflect the inherent productivity of the land and therefore the possible grazing enterprises able to be undertaken on properties. There are 42 land types described in the grazing land management descriptions but for the purposes of modelling these 42 have been condensed into five broad category groupings.

It is from these broad groupings that the gross margin based of the enterprise has been estimated, with the herd structure, animal production and animal input costs determined by the Beef Cooperative Research Centre templates (2009) and the prices received updated for 2015 prices. The gross margins per AE ranged from $312.55 down to $182.32 reflecting that highest productivity grouping was turning off heavier Jap Ox and the lowest productivity grouping turning off light store cattle. The different productivity groupings and gross margins are provided in Table 5.

**Table 5. Gross margins per AE of productivity groupings.**

<table>
<thead>
<tr>
<th>Productivity grouping</th>
<th>Beef CRC template</th>
<th>2015 GM$/AE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>R322 Central QLD Brigalow</td>
<td>$312.55</td>
</tr>
<tr>
<td>2</td>
<td>R313E Basalt (Dalrymple, Flinders) and Downs (Flinders, Richmond, McKinlay)</td>
<td>$241.98</td>
</tr>
<tr>
<td>3</td>
<td>R313C Goldfields (eastern half or Dalrymple Shire)</td>
<td>$199.30</td>
</tr>
<tr>
<td>4</td>
<td>R332B Lower Burdekin and Bowen</td>
<td>$197.43</td>
</tr>
<tr>
<td>5</td>
<td>R331 Coastal speargrass</td>
<td>$182.32</td>
</tr>
</tbody>
</table>

A critical aspect for each of the land type productivity groupings was to estimate the reduction in stocking rate required to improve the land condition. This requires consideration of the optimal level of production for the current land condition. Data from past grazing trials and previous bio-economic modelling was reviewed, which included a number of land types and ranges of productivity. The difference in stocking rates between the current and the economic optimal from the bio-economic modelling results was then calculated and averaged for each of the five land type productivity categories.

The reductions in productivity are essentially a proportion of the whole neighbourhood catchment and it is assumed that collectively the change occurs across the area. Table 6 represents the percentage reduction in stocking rate that would be required to occur for five years to produce an improvement or shift in land condition.

**Table 6. Percentage reduction in stocking rate needed to shift land condition over five years.**

<table>
<thead>
<tr>
<th>Productivity grouping</th>
<th>Change in productivity from C to B</th>
<th>Change in productivity from B to A</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.26</td>
<td>0.19</td>
</tr>
<tr>
<td>2</td>
<td>0.30</td>
<td>0.27</td>
</tr>
<tr>
<td>3</td>
<td>0.35</td>
<td>0.31</td>
</tr>
<tr>
<td>4</td>
<td>0.32</td>
<td>0.23</td>
</tr>
<tr>
<td>5</td>
<td>0.35</td>
<td>0.31</td>
</tr>
</tbody>
</table>
The marginal changes in stocking rate for each of the neighbourhood catchments was then multiplied by the current gross margin, for the duration of five years and at a seven per cent discount rate to bring everything back into today’s dollars.

Levels of adoption

The level of adoption for the different management practices classes has been derived from the information collected under the Paddock to Reef (P2R) Water Quality Risk frameworks for the 2013-14 Great Barrier Reef Report Card.

There is a suite of specific management systems defined under the water quality risk framework relevant to hillslope management, gully management or streambank management in grazing systems. Currently only 22 per cent and 30 per cent of land managers in Fitzroy and Burdekin respectively have best management practices or A or B management for hillslope (Table 7). Similarly, 35 per cent and 62 per cent are managing for streambank and 20 per cent and 26 per cent are managing for gully erosion processes.

<table>
<thead>
<tr>
<th>Area</th>
<th>Hillslope</th>
<th>Streambank</th>
<th>Gully</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fitzroy</td>
<td>22</td>
<td>35</td>
<td>20</td>
</tr>
<tr>
<td>Burdekin</td>
<td>30</td>
<td>62</td>
<td>26</td>
</tr>
</tbody>
</table>

Extension cost curve

The extension cost curve estimates the costs of achieving reductions in sediment based on landholder improvements in management practices instigated through government provided extension services.

Figure 7 shows an overview of the method used to calculate the extension cost curve.

The first step in the extension cost curve estimation process is to obtain an understanding of the proportion of land currently in A, B, C and D condition. This step is exactly the same as described for the opportunity cost curve estimation.

Estimating the level of extension effectiveness is difficult as there may be significant time lags in both landholder adoption and achievement of outcomes. The one-on-one extension program run by the Department of Agriculture and Fisheries (DAF) which includes a landholder survey was aligned to the Paddock to Reef management framework to evaluate the extension cost curve estimation.

The aligned of the DAF management practice survey to the Paddock to Reef framework showed that 11 per cent of landholders had shifted from a C to B level of management. It is likely that there were many other landholders who may have taken smaller steps towards improved management practices; however these small changes are impossible to quantify. Therefore for estimation of the extension cost curve, 11 per cent of landholders were used to provide an indication of the potential outcomes that may be expected from future expenditure on extension, based on the past DAF extension investment.
The number of properties per sub-catchment was derived from property mapping for the study area. Properties were included in the counts where they covered >200ha of grazing land. Each property was only counted in one sub-catchment to avoid double counting properties that straddle multiple sub-catchments. In these cases the property was assigned to the sub-catchment in which it had the largest proportion of its area.

For each neighbourhood catchment 11 per cent of properties were used, combined with the average property size for that neighbourhood catchment, to understand the hectares of change likely to occur. The estimated DAF extension cost per property was then extrapolated out across the catchment, with the average tonnes per hectare then used to understand the dollars per tonne per hectare.

**Approach for marginal sediment reductions**

Tonnes of fine sediment from hillslope, gully and streambank sources were calculated from the most recent version of the Source Catchments model (October 2012) used in the Paddock to Reef modelling program. It is estimated that the total load attributed to grazing across the three erosion processes is 4,046,700 tonnes. To achieve a 20 per cent reduction in load (assuming that grazing is the only industry) would equate to a reduction of 809,340 tonnes.

The current loads of sediment were then estimated based on the Paddock to Reef lookup table with the reductions in fine sediment relative to C for hillslope erosion (Table 8). For example a shift from C to B land condition would result in a 30 per cent reduction in sediment. Given the process linkages to gully and streambank erosion from increased cover, smaller quantities were also reduced from gully and hillslope following the approach of Thorburn and Wilkinson (2013). For example, for a shift from C to B the hillslope erosion reduction was a 30 per cent change (Table 8) and the subsequent reductions in gully and streambank erosion were 10 per cent and 20 per cent respectively (Table 9).

**Table 8. Total reduction in sediment depending on land condition shift.**

<table>
<thead>
<tr>
<th>Grazing practice change</th>
<th>D</th>
<th>C</th>
<th>B</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative hillslope erosion rate (%) *</td>
<td>1.8</td>
<td>1</td>
<td>0.3</td>
<td>0.05</td>
</tr>
</tbody>
</table>

\* - Median values of GRASP example table. USLE based values are 1.5, 1, 0.55, 0.10.

**Table 9. Relative changes (per cent) in hillslope and gully erosion rates associated with improvements in vegetation cover, and in bank erosion from riparian revegetation and destocking, applied to all Great Barrier Reef regions.**

<table>
<thead>
<tr>
<th>Reductions in sediment as land condition improves</th>
<th>D to C</th>
<th>C to B</th>
<th>B to A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gully erosion</td>
<td>0.61</td>
<td>0.1</td>
<td>0.3</td>
</tr>
<tr>
<td>Streambank erosion reduction</td>
<td>0.71</td>
<td>0.2</td>
<td>0.2</td>
</tr>
</tbody>
</table>
Results – grazing

Opportunity cost curve

The results of the opportunity cost curve of shifting land from B condition to A condition highlight the complexity of achieving efficient sediment reduction outcomes delivered to the reef. Figure 8 shows the costs ranging from $11.23 per tonne (Burdekin Delta) through to $478,247 per tonne (above the dam, Nogoa neighbourhood catchment) reflecting the characteristics of the neighbourhood catchment and the sediment reduced. The spatial distribution for cheaper sediment reductions was in a mix of areas from the Bowen and Broken River catchments ($21 and $24 per tonne) but also neighbourhood catchments in the Connors and Isaacs catchments ($40 and $201 per tonne).

The total sediment that can be reduced in this modelling scenario is limited by the area of land currently in B condition. Therefore, even if all B condition land shifted to A condition land in all neighbourhood catchments, the targeted reduction of 809,000 tonnes would still not be achieved, but rather only 657,114 tonnes at a total opportunity cost of $164 million. The results are demonstrated in Figure 8.

![Figure 8. Shifting 70 per cent of land managers from B to A condition.](image)

The results of the opportunity cost curve of shifting land managers from C condition land to B condition land resulted in a different mix of neighbourhood catchments again based on the area of land in C condition, the productivity of the dominant land type and the sediment load reaching the reef. The costs ranged from $7.50 per tonne (Burdekin delta) to $540,000 per tonne (Nogoa above the dam) (Figure 9).
There are a number of cheaper options with 27 neighbourhood catchments having costs per tonne under $50 (Figure 10) however again these were spatially varied, highlighting the importance of considering where in the landscape the capacity is to achieve sediment outcomes. Although the target reduction is 809,000 tonnes, shifting 70 per cent of landholders will only achieve approximately 320,000 tonnes and will cost approximately $53.5 million (Figure 9).
The spatial variation in costs is illustrated in Figure 11 which shows the costs per tonne of shifting from C to B land condition.

**Figure 11. Spatial distribution of costs per tonne from shifting from C to B condition.**
Extension cost curve

The extension cost curve was based on the ability of extension to shift landholders from C land condition to B land condition. The costs per tonne ranged from $17.52 per tonne to $216,000 per tonne which was a reflection of the loads delivered, the number of properties and the scale. As result of the effectiveness ratio being calculated as 11 per cent of land managers, the cheapest areas for reductions came from large catchments which had larger properties such as Glenmore Creek and Rosella Creek which delivered significant loads. The larger costs per tonne were driven by neighbourhood catchments which occurred above Fairburn Dam which again had very low rates of sediment that are actually delivered to the reef. Again due to the effectiveness of extension at 11 per cent, a total of 95,000 tonnes are reduced at a total cost of $69,205,714. There are 13 neighbourhood catchments that are greater than $100,000 per tonne due to their location behind the dam and this must be considered along with export ratios when selecting projects.

Figure 12. The cumulative cost curve for shifting 11 per cent of landholders from C to B condition.
Conclusion – grazing

To improve the understanding of different policy mechanisms two cost curves have been developed focusing on opportunity costs and extension. Developing the cost curves has contributed to the policy debate in four main ways. First, a target of 20 per cent sediment reduction can be achieved through further investment into reducing sediment loads from the grazing industry. Second, the interaction of policy mechanisms is critical to achieve the most cost effective outcomes. Thirdly, spatial consideration and understanding of risk in achieving outcomes is paramount. Fourthly, it is important to understand if the total sediment reductions can be achieved, particularly in the context of current climatic conditions.

The results highlight there is scope to achieve a 20 per cent reduction in sediment through a combination of policy mechanisms and the mix is critical to support such changes. The limitation of both landholder adoption and the area of land in different land condition classes results in it being essential for the mix of policy mechanisms to complement each other to achieve required outcomes. Past work has highlighted the difficulty in getting adoption or engaging landholders through extension if regulation is introduced.

There is currently a unique window of opportunity for extension to achieve improvements in land management practices with associated sediment load reductions. The current drought conditions and on-going El Nino climate pattern, combined with the current strong market condition for the sale of cattle present attractive options for landholders to de-stock. Extension services could actively educate landholders about the environmental benefits and private benefits of reduced stocking rates, allowing landholders time to experiment and learn during the enforced period of lower stocking associated with the current seasonal conditions. If successful, when seasonal conditions improve and landholders are seeking to re-stock, they will only re-stock to levels relating to their long-term carrying capacity, which will continue to provide both economic and environmental benefits.

Extension staff require a strong technical background and the ability to offer support and develop solutions with the landholder as the learning progresses. This may require up-skilling a number of existing extension officers and providing soil conservation training to existing staff. There is currently limited existing extension staff across these regions, in both private companies and in State agencies with this technical knowledge and this is a critical deficiency to be addressed. In addition, extension staff must be credible and have good interpersonal skills to develop the required relationships with landholders leading to acceptance of the extension advice.

Spatial considerations must also be considered with a large variance in the cost of sediment reductions reflecting the geographical and inherent landscape implications. Given the state of the current El Nino climate, areas which have a relatively high level of productivity should be considered as a higher priority for investment in sediment reductions, as typically these have higher regeneration times and present lower risk options. Landholders should be encouraged to develop strategies to improve or maintain ground cover. This is particularly the case as results of past LiDAR work have identified that larger gullies may have been driven by episodic or event-based rainfall events, which were possibly exacerbated by low ground cover. Highlighting that maintaining good ground cover at the end of a drought or the break of dry season is important to avoid large sediment loss through the development of gully erosion (Tindal et al 2014).

Some limitations of the study should also be noted. The inference that ABCD land management practice leads to ABCD land condition had not yet been correlated due to time lags. The bio-economic modelling has not captured all the biophysical factors, such as site-specific effects, while the biological models may not have adequately reflected cumulative and threshold effects (Wu and Skelton-Groth 2002). Furthermore, the potential for multiple environmental benefits has not been recognised. The approach is simplistic in assuming that a neighbourhood catchment consists of only one land type and therefore that landholders would be operating one particular enterprise. The assumptions that landholders are always profit-maximising and have perfect knowledge should also be noted as not fully realistic. All sediment reductions have been estimated outside of the Source Catchments model which assumes linear reductions and does not account for the complexity of the issue. For improved understanding of sediment reductions the proposed changes should be modelled through Source Catchments.

The approach however does highlight that the required sediment reduction is achievable if a tailored mix of policy mechanisms is implemented and considerations of the current climate cycle are factored into where in the landscape projects are implemented.
References


Commonwealth of Australia 2015, Reef 2050 Long-Term Sustainability Plan.


