Assessing the cost for pollutant load reductions in the Great Barrier Reef: a case study

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Abstract: The slow progress of pollutant reduction towards the Great Barrier Reef water quality improvement plan targets has increased the pressure to achieve more cost effective outcomes. Consistency in how costs are captured for different policy mechanisms from the paddock scale to the catchment scale would allow more robust evaluation of achieving overall pollutant reduction targets. Progress in the Paddock to Reef monitoring and modelling program (P2R) in the areas of landholder adoption, ground cover and monitoring the program have improved decision making. However, the costs involved in current optimization approaches have data paucity, and could be improved with more consistent, and comprehensive data to evaluate investments. This paper provides a framework on how economic data could be collected to integrate into Paddock to Reef program to optimise investments.

Keywords: *Grazing management. Great Barrier Reef, cost-effective, optimisation*

1. INTRODUCTION

In response to the declining health of the Great Barrier Reef the Australian and Queensland governments developed the Reef Water Quality Improvement Plan (Reef Plan 2013) which identified a number of pollutant reduction targets and land management targets. Priority setting under Reef Plan 2013 has been based around pollutant loads, subsequent targets and marine exposure. This has resulted in the selection of priority pollutants relative to specific catchments, with sediment reductions from the grazing industry targeted in the Fitzroy and Burdekin catchments and nutrient reductions from the sugar industry targeted in the Wet Tropics and Burdekin regions (Queensland, 2013). There is a general tendency in conservation to prioritise based on locations or assets without consideration of the overall objectives and the actions required in different locations to conserve the assets.

There have been a number of incentives and extension programs to increase the level of best management practices of landholders. These include: Best Management Practices (BMP) extension programs, Reef Programme and Reef Trust which are on-ground cost-sharing grants. For each of these known actions there is an associated cost and impact on the asset concerned. The cost of each action and policy might reflect the opportunity cost in forgone production (Star et al., 2011a) or information acquisition and planning also known as transaction costs (cost associated with negotiating an economic exchange or establishing conservation contracts) (Coggan et al., 2015). In this case the actions have costs and result in the pollutant reduction. As a result, a number of costing exercises to improve our understanding of specific practices, increased adoption, and meeting pollutant reductions targets have been undertaken (Alluvium, 2016; Kroon et al., 2012; Star et al., 2015a). The analyses have however often been completed for different purposes and often with different audiences (i.e landholder or state government), time scales, and spatial scales within the catchments (paddock, sub catchment, catchment)(Rust and Star, 2016; Star et al., 2017; Van Grieken et al., 2010).

Data limitations have required surrogates to be formed based on environmental data which are then monitored and modelled. The monitoring and modelling program Paddock to Reef (P2R) was designed to monitor the progress toward the targets using surrogate environmental and management indicators. In the P2R program five basic lines of evidence are collected: (1) effectiveness of management practices to improve water quality; (2) prevalence of adoption management practices (defined under the water quality risk frameworks); (3) long-term catchment water quality monitoring; (4) change in catchment indicators are used to evaluate progress towards reef targets; (5) marine monitoring of GBR water quality and reef ecosystem health (Carroll et al., 2012; Shaw et al., 2013). Although initially incorporated into the program, economic data has not been collected across the temporal or spatial scale of the program (East and Star, 2010). Studies have shown that incorporating spatial distributions of benefits and economic costs into planning can achieve up to 10 times more efficient outcomes (Naidoo et al., 2006).

The limited resource of funds, staff and program delivery clearly provide the basis for an optimisation problem where the challenge is to achieve the largest pollutant reductions. Previously, data limitations have resulted in an inability to improve optimisation of outcomes relative to the inputs available. As the P2R monitoring and modelling program expands its data set, the question arises of what data parameters are most useful for optimisation and how economic information can be integrated into a monitoring and modelling program to ensure that improved outcomes are achieved.

This paper presents three key aspects:

1. An overview on the economic data challenges and optimisation approaches that have been undertaken, specifically in the grazing sector.
2. We then note the importance for such data to improve for optimisation and effectiveness purposes by providing a case study where two different data sets have been used.
3. Finally we provide a framework for integration of costs into the P2R program and how the improved information can improve the approaches to optimisation for great reef outcomes.

2. OVERVIEW OF OPTIMISATION APPROACHES

The ability to optimise effectiveness of conservation approaches is becoming increasingly important and widely acknowledged (Cook et al., 2010). Constraints on decision-makers such as resource shortages, and competing priorities of overall conservation funding mean that more cost-effective investments are required. There is a distinction between highest contributors of pollutants (i.e gully erosion processes), effectiveness (i.e marginal change in pollutant reduction by implementing a management action) and cost effectiveness. Cost effectiveness accounts for the cost relative to the reduction in pollutant, ideally a cost benefit would be completed however the marginal reduction in pollutant load and the marginal improvement in reef health are not well understood. Typically conservation priorities are based on optimizing the asset such as the reef, as opposed to priority locations based on biodiversity importance, or based on prioritising actions (Bathgate et al., 2009; Ribeiro et al., 2017).

Currently the targets are set based on the premise of increased loads contributing to the current state of degradation, with sediment, dissolved inorganic nutrient and pesticides contributing to different factors of degradation such as, increased frequency of crown-of-thorns star fish outbreaks, and reduced photosynthesis in seagrass, corals and algae respectively (Brodie et al., 2017). This has then resulted in the formation of targets such as the long term goal to ensure that by 2020 the quality of water entering the reef from broad scale land use has no detrimental impact on the health and resilience of the Great Barrier Reef (Brodie et al., 2017).

The current lines of evidence collected under P2R are reported back in regards to the progress towards the targets. They represent surrogates which can be used to better model the progress towards the targets. The surrogates of ground cover, management practice adoption, and catchment indicators such as ground cover, and riparian extent are integrated into the Source modelling to understand the change relative to the targets with monitoring sites providing insights into the efficacy of the management actions and to allow modelled results to be validated against monitored loads (Carroll et al., 2012).

These surrogates provide challenges when optimising where in the GBR catchments outcomes can be achieved for the key reasons of:

- Lead management practices and time lags of management which lead to degradation (Barbi et al., 2015).
- Time lags for paddock scale actions to be implemented on-ground and take effect.
- Extreme weather events and different temporal impacts (source uses a 28 year average).

These surrogates however are key pieces of data in prioritisation as they have now been consistently collected since 2009, providing a comprehensive data set. A key improvement to allow for more robust economic data to link into the P2R.

Economic costs data based on incentives was initially collected under Paddock to Reef in 2009 and paddock scale analysis to understand the opportunity and capital cost trade-offs with pasture biomass for landholders wanting to regenerate land, or improve land condition (Star et al., 2011b). The costs highlighted the heterogeneity between locations, land types and the importance of climate sequences (Rolfe and Windle, 2016). Following this more catchment scale costings across adoption of a suite of practices was explored with the outcomes of land condition used as the proxy for land management, and many of the paddock scale outcomes extrapolated to catchments (Star et al., 2015b).

The focus on past studies for prioritisation has been to achieve either adoption targets, or achieve pollutant targets through incentives, extension or regulation (Alluvium, 2016). These have been focused on the cost effectiveness of adopting categories of land management and the subsequent pollution reductions both at an end of paddock scale and then end of catchment. There has also been a combination of scale effects where a particular paddock scale, or catchments are prioritised and temporal effects over different time periods based on production cycles. These projects have used paddock scale data developed from under P2R at particular farm scale or representative farm scale and applied across large spatial areas.

The current time dynamics are a complex interaction, the adoption data is collected and monitored relative to the change landholders implemented with the natural resource management group. It is assumed the effects are immediate and are integrated into the overall Source catchments model in this manner. The management practices however represent how the land will respond over time to the management and do not reflect the current state, rather land condition is a measure of current state (Chilcott et al., 2005). The two are operating on different time scales and therefore do not align. For optimisation purposes this creates difficulty in estimating changes in pollutant loads and the costs, as costs from the paddock are often scaled up to the sub-catchment level.

Cumulative costs or interdependencies have not been accounted for, such as management actions of fencing off watering points and cattle stocking rate re-distribution. If undertaken interdependently of each other they may cost more than completing the two management practices at the same time. Likewise the benefits of different combinations of management practices may be more than another two combinations of management practices. Risks have not always been accounted for such as risk of prolonged dry periods which may hinder achieving the benefits of a management practice.

The consideration of what costs are accounted for and where in the paddock to end of catchment scale would also provide improvements to optimisation. To highlight the impact that either using the management practices or land condition a case study was developed below.

3. CASE STUDY

The time dynamics of some parameters present challenges in optimisation (Pressey et al., 2007), as the lines of evidence are relating to a number of catchment indicators are then modelled on average over a 28 year period similar to how the targets are now set (Brodie et al., 2017).

Table 1. demonstrates the difference in the percentage of area that is in the different classifications of A, B, C, D in land condition and then land management. The land condition areas have a smaller area in D condition (5% on average across the neighbourhood catchments) with the majority in A and B (74% of the area) as opposed to 18% in best management practices and 82% in C or D management practices (Table 1). This therefore means that there is a larger area of poor management practices in the catchment which incur a higher cost for pollutant reductions, then if it was costed using the same opportunity for land condition and management based on area size (Figure 1).

Table 1. Proportional areas of management practice and land condition

	Difference in classification across the Fitzroy Basin			
	A	B	C	D
Land condition averaged across all neighbourhood Catchments (Whitten et al 2015)	0.448	0.291	0.210	0.052
Adoption of management practices (FBA WQIP 2015)	0.04	0.14	0.59	0.23

Using the same costings approach the costs for improvements in land condition are less than the costs of management change purely based on the extrapolation over the catchment. This highlights that a consistent approach to managing how costs are accounted for is necessary to inform future investments.

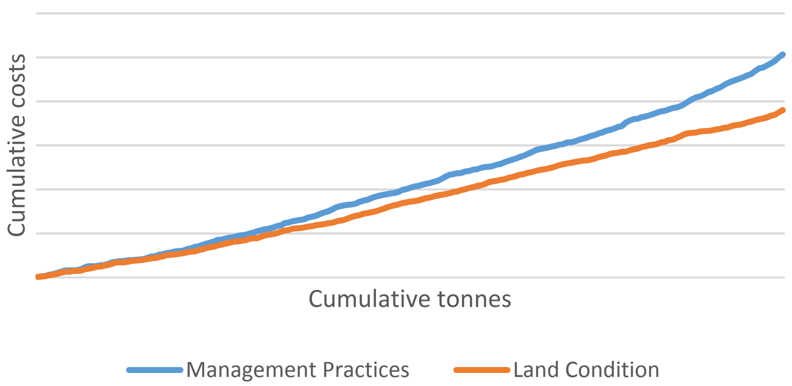

Figure 1. Cost differences between management practices and land condition based only on the land area parameter highlighting the importance of a consistent costing approach.

4. COST FRAMEWORK

Based on the large difference in costs it presents an opportunity to put together a framework to cost changes at a paddock scale, sub-catchment scale and catchment scale. The components described below are summarized in Table 2.

Paddock Scale

Paddock scale costs require consideration of management actions and subsequent changes to production and profitability. This is difficult because production functions are typically complex and non-linear. Additional complications include the heterogeneity of land and water resources, the stochastic impacts of weather variables, varying time lags, and other external forces, such as market conditions.

Management - Production economics helps to make predictions about the impact of natural resource management changes and actions in key inputs. We propose they are captured in farm production models and linked to pollutant reductions or a bioeconomic model. The transition through time and to shift to a new suite of management practices must reflect what is practical for a landholder with current farm infrastructure. A key consideration, particularly in grazing, is the land productivity and the time to implement a change and see a response, these time lags affect both the costs and the realized sediment reductions. Capital cost, depreciation, maintenance and salvage values at the end of the analysis time period must be considered in farm production models. Capital costs can vary significantly based on the considered starting point for the analysis this therefore must be clearly defined at the start of the analysis. These are critical when assessing incentives as it allows evaluation of the public and private trade-offs for adopting the practice change.

Time frames - Similarly the time frame before the on-ground action is implemented and the full benefits are received must also be considered. In grazing the changes over time on particular land types and locations which reflect inherit productivity are extremely variable and this is required to be considered when estimating when the benefits will occur. Properties in a closer proximity to the coast receive more reliable rainfall than those further west however are also more exposed to cyclone damage. There are step changes that also must be considered particularly in grazing which has a temporal element. For example shifting from D management through to A cannot occur through the time period of one year and the shift between D to C is not linear to the shift from C to B or B to A. The time periods selected have a significant impact on the economic outcomes and how the result can be interpreted for future policy approaches.

Risk and Uncertainty - The variability of weather, price and subsequent financial outcomes is a risk for landholders to adopt and to continue to adopt the change. Past work has highlighted the impact of rainfall on financial outcomes (Star et al. 2015) and inability to make long-term decision (Gregg and Rolfe 2015). To consider these facets in the analysis sensitivity testing is required, if possible monte carlo simulation or more sophisticated risk models to capture the variance.

Sub catchment scale

Sub catchment activities are generally extension activities where the local natural resource management groups such as the Fitzroy Basin employs staff to engage with landholders and complete administration for projects. The other aspect is Queensland Department of Agriculture staff who provide technical advice regarding operations. Together both organizations provide a Best Management Practice (BMP) training program.

Management - Estimating the level of extension effectiveness is difficult due to time lags in both landholder adoption and achievement of outcomes. It is likely that there are diminishing returns to extension expenditure, as extension services tend to engage the more willing landholders first and over time working with less willing landholders and therefore more costly to engage with. Another difficult aspect to capture in costing extension is how particular training/education change is related to water quality outcomes. There are a number of training/ extension practices that don't align to the water quality risk frameworks. These costs are also often opaque and difficult to estimate, however improved costings would allow the optimisation process to improve significantly.

The costs of staff that provide group training in a particular region with a number of landholders are extension costs to be accounted for. Generally staff are salary based which captures their cost and the effectiveness is essentially the change in the level of adoption of these landholders. The cost of the landholder project administration is often a transaction cost. It is difficult to estimate transaction costs per landholder or at a paddock scale the learning regarding remediation or changing management is supported and funded through extension. Alternatively, in reef catchments, transaction costs are borne by the field officer who supporting the landholder. Similarly, a landholder may have to incur costs to attend meetings. Coggan et al (2015) estimated that the transaction cost for a cane farm in Mackay is $9,026 which includes extension and field officer time. As the cost is significantly high the impact on optimisation and policy approach will require consideration.

Timeframes - Trial-ability of new management practices is critical to adoption however the timeframe for it to be fully implemented across a whole property can vary depending on the practice or suite of practices. Similarly, the connectivity of landholders and extension staff can promote change along with the time for landholders to complete all training modules for BMP is required to be considered. To date this has been poorly integrated and considered in costings but improved monitoring of progress would allow these costs to be captured.

Risk and Uncertainty Weather risks at the sub-catchment level may mean inability to engage with landholders due to weather events or the person engaged with extension may not have the ability to implement the changes that they have been learning about.

End of catchment scale

At the end of catchment scale there are a number of costs that have not previously been accounted for, such as the program costs for natural resource management groups to administer programs, government administration costs, the time frames between funding allocations and program implementation, and political risks of changed governments which change legislative agendas or program focus. These are extremely hard to capture as they are not transparent and involve multiple layers of administration, departmental aspects and political risks.

Table 2. Framework for integration of economic costs into Paddock to Reef (P2R) program

	Paddock Scale	Sub-catchment scale	End of catchment scale
Management actions	• Opportunity costs based on land condition • Capital costs based on land condition • Private costs and benefits • Maintenance costs, and effectiveness of treatments over the same time period as pollutant reduction is calculated over.	• Extension costs based on management practices • Regulation costs based on management practices • Transaction costs based on management practices • NRM groups catchment management costs	• Program costs • Government administration costs
Time Frames	• Implementation • Land productivity response • Erosion mitigation • Climatic effects	• Learning • Connectivity	• Connectivity
Risks and uncertainties	• Price • Weather • Adoption	• Climate change increased cyclones, drought • Collaboration success	• Political risks

5. CONCLUSIONS

Current reef investment is based on the Great Barrier Reef as a total asset without consideration of the overall objectives and the actions required in different locations to conserve it. The ability to incorporate economic information is critical to achieve more cost effective outcomes, and improve reef health. The information required to be captured must be useful at a paddock, sub catchment and catchment level. This requires capturing the complexities of management, time frames and risk and uncertainties for different management practices. The economic implications are also driven by other catchment indicators or existing P2R lines of evidence however the critical optimization question must first be determined to ensure that the most useful indicators are integrated. This paper provides a framework for critical economic components to be accounted for more precisely to better optimise pollutant reductions.

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