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Estimating supply functions for agri-environmental schemes: Water quality and the Great Barrier Reef

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Contributed paper prepared for presentation at the 60th AARES Annual Conference,
Canberra, ACT, 2-5 February 2016

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Estimating supply functions for agri-environmental schemes: Water quality and the Great Barrier Reef

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Abstract

Funding programs to improve water quality into the GBR are difficult to evaluate, and administering agencies typically need to allocate funds without a clear assessment of the cost-effectiveness of proposals. This is particularly the case for agri-environmental schemes where policy makers set targets for improvements in water quality from agricultural lands and then need to identify funds and programs to encourage changes in practices. The priorities for actions are often driven by bio-physical assessments of risks on the natural environment with little information about the opportunity costs and challenges in changing land management. The goal of the research reported in this paper is to develop a supply function for water quality improvements in agricultural lands in the Great Barrier Reef catchments. Costs of supply have been estimated from multiple sources, including modelling, expert opinion, and the analysis of water quality tenders and Reef Rescue grant programs. The study addresses challenges in reconciling cost estimates from different sources, dealing with heterogeneity across industries and catchments, and managing different influences on costs from factors such as risks, adoption issues and transaction costs.

Keywords

Supply costs
Agri-environmental schemes
Great Barrier Reef
Water quality
Modelling

1. Introduction

The Australian and Queensland Governments have allocated significant public funds to improve water quality from agricultural land management in catchments draining into the Great Barrier Reef (GBR) lagoon. Over the past two decades the funds have been allocated across a range of different programs and initiatives, largely through the six Natural Resource Management (NRM) regional bodies. Reef Plan Targets (Australian and Queensland Governments 2013) indicate the following water quality reduction targets to be achieved by 2018.

- At least a 50% reduction in anthropogenic loads end-of-catchment dissolved inorganic nitrogen loads in priority areas;
- At least a 20% reduction in anthropogenic end-of-catchment loads of sediment and articulate nutrients in priority areas; and
- At least a 60% reduction in end-of-catchment pesticide loads in priority areas

Cost effectiveness is a key criteria for judging both the performance of past investments and guiding the allocation of future investments (Pannell 2015). A simple definition of cost-effectiveness is that it is the ratio of water quality improvements (such as reductions in sediment or nutrient loads) to the costs of achieving the change. More cost-effective investments generate larger improvements per allocated dollar of investment. Both Governments are exploring new investment approaches to generate more targeted and effective outcomes, through the creation of programs such as Reef Trust.

There has been limited evidence to date that funds allocation in the GBR has been cost-effective. Initial allocations of funds to programs were driven by science priorities and expert opinion, with multi-criteria analysis used in some cases (Australian and Queensland Governments 2013), while programs have mostly allocated funds through fixed rate grants. Pannell and Roberts (2010) raised concerns that these types of arrangements would lead to inefficient allocations of funds, while at the program level Rolfe and Windle (2011a) demonstrated for the Burdekin catchment that traditional grants mechanisms had the potential to be very inefficient.

The complexity of the GBR system makes prioritisation and evaluation very difficult. Poor water quality from agriculture is an externality problem characterised by asymmetric and incomplete information, and complicated by multiple pollutants, a focus on input measures rather than environmental outcomes, and a complex set of drivers for farmers to make practice changes (Brodie et al. 2013).

There has been substantial attention paid to reporting the outcomes of various GBR programs. The health of the reef is now summarised annually in a Great Barrier Reef Report Card, which also includes estimates of improvements in land management in catchments and the modelling reductions in pollution loads across catchments (GBR Report Card 2014). The outcomes of funding programs such as the Reef Rescue program have been reported by the NRM bodies and the Australian and Queensland governments (e.g. Bass et al. 2013; Australian Government 2014). In addition returns on investment and cost-effectiveness are becoming more explicit in planning for new programs and funding allocations (e.g. Addison and Walshe 2015), in modelling the tradeoffs that farmers face to adopt new management practices (e.g. Star et al. 2013, van Greiken et al. 2013), or from limited trials of water quality auctions and reverse tenders (e.g. Rolfe and Windle 2011b).

A key challenge is to reconcile the differences in cost-effectiveness that can be measured from various programs and modelling. Estimates of cost-effectiveness can be systematically different for several reasons:

- The environmental benefits may not be consistent
- Different components of cost may be included
- Accuracy of estimates for either the costs or environmental benefits may vary
- The mechanisms to select projects or programs for inclusion or funding may differ.

This means that it is often difficult to determine whether variations in the cost-effectiveness of programs and projects are related to variations in efficiency or systematic differences in the way that cost-effectiveness has been assessed.

The purpose of this paper is to summarise and evaluate available data on the cost-effectiveness of improvements in agricultural water quality within GBR catchments, identifying how differences in estimates might be reconciled. The paper is structured as follows. A summary of key concepts relating to cost-effectiveness is provided in the next section, followed by a review of historic data in the next two sections: the Reef Rescue grants in section 3 and competitive tenders in section 4. This is followed by a summary of predictive modelling: the regional Water Quality Improvement Plans are covered in section 5, and the most important of the bioeconomic models in section 6. Final conclusions follow in section 7.

2. Concepts

Identifying the economic tradeoffs involved in improving water quality from agriculture has been an important topic; for example Doole and Pannell (2012) and Doole et al. (2013) review cost-effectiveness associated with dairy impacts in New Zealand and agricultural catchments in Victoria respectively. Cost effectiveness in the context of agricultural water quality improvements in the GBR is the ratio of water quality improvements (such as reductions in sediment or nutrient loads) to the costs of achieving the change. There is normally significant variation (heterogeneity) in the costs of making water quality improvements across different scales and parameters because both costs and emissions are driven by a number of factors that vary between and across catchments, between farms, and within farming operations.

There are a number of complexities in assessing cost effectiveness. These include:

- Variations in the types of benefits involved
- Differences in the scale at which benefits are assessed
- Missing or limited information
- Challenges in modelling or measuring both environmental and cost variables.

Measures of cost-effectiveness focus closely on the damaging environmental **outputs** (e.g. total nitrogen emissions) or **outcomes** (e.g. area of healthy reef) rather than **inputs** (e.g. change in farm machinery) which are the focus of most existing grant approaches. Measures should take account of marginal changes, such as the **additional** costs and reduced pollution emissions associated with a farm management change, rather than the **total** or **average** farm management costs and pollutant emissions. Many grant programs do not assess benefits in these ways, focusing on changes in inputs and grouping farm management into A,B,C,D classifications, making it difficult to assess exactly what improvements in water quality will result.

Problems of information asymmetry also limit information about cost effectiveness. Farming operations are private enterprises, so the information about the costs of making enterprise changes to improve management actions are available to the enterprise managers, not to government and agencies. Similarly, information about the emissions generated on-farm and transferred into waterways and GBR lagoon is typically not available to farmers. Incomplete information about both the costs of enterprise changes and the environmental benefits generated have largely been responsible for a focus on input mechanisms and practice changes that maintain productivity.

There are several approaches available to estimating the costs of a farm management change:

- Farm production models that estimate changes in revenue, costs and profits with management / activity changes, typically based on data of multiple farm operations,
- Incentives paid or required by farmers to make the necessary management changes,
- Expert opinion about the average cost within a sector or industry to make changes.

The modelling and expert opinion approaches typically estimate costs for an average farm operation, so limit heterogeneity in cost estimates. In contrast, information about the incentives paid to farmers, particularly those revealed through competitive tenders, are more accurate in identifying the variation in cost tradeoffs.

In a similar way, there are different approaches to estimating pollutant emissions associated with different management changes:

- Direct measurement: challenging because of logistics and expense, the difficulties of identifying marginal changes, and the variations in climate and other factors.
- Simple models: these are often used to estimate emissions at the farm level where most factors can be held constant.
- Catchment models: these are necessary to make predictions of changes across different types and locations of farming operations, and where it is important to estimate changes in pollutant delivery at end of catchment (rather than end of farm).

These models are typically for an average landtype and farming operation within a catchment area, which have the effect that they limit heterogeneity in estimates of off-farm emissions. As well, the estimates can be for changes in pollutant loads at the farm level or at the end-of-catchment (delivery point to the GBR lagoon).

The cost-effectiveness of management changes can be estimated through bioeconomic models, which link farm production models with pollutant generation and delivery models. These models have the advantage that the interactions between key variables and non-linear effects can be accounted for, but mostly report average costs of emission reductions. However by running bioeconomic models at different scales and enterprise changes, it is possible to generate a cross-section of the potential cost effectiveness of management changes (e.g. van Grieken et al. 2010, 2014).

Modelling and assessment are further complicated by the jointness of many pollutants and corresponding management actions. Assessment and reduction measures in the GBR are focused on the following key pollutants:

- Total suspended solids (TSS), with increasing focus on the fines within this group
- Dissolved inorganic nitrogen (DIN)
- Particulate nitrogen (PN)
- Dissolved inorganic phosphorus (DIP)
- Particulate phosphorus (PP)
- PSII herbicides (PSII)

Agricultural activities and changes in management actions will often affect multiple pollutants (e.g. sediments and phosphorus are closely linked), so modelling needs to take account of these complexities. In some cases environmental benefits are summarised together into an Environmental Benefits Index (EBI) so that the costs of action can be compared to the 'package' of environmental improvements. One example of this approach being applied in a water quality tender in the Burdekin is provided in Rolfe et al. (2011). Alternatively, and more commonly, cost-effectiveness is modelled for each pollutant separately.

It is not only the environmental factors where predictions vary across several dimensions; costs also vary depending on the scope of the tradeoffs being considered. The simplest types of cost estimates focus on changes in enterprise profits or returns (private operating costs). These are often generated by farm production models that focus on partial economic analysis; e.g. changes in gross margins can be estimated by changing the variable costs and production of an operation, holding most factors such as capital, prices and fixed costs constant. Most bio-economic models (e.g. Star et al. 2011, van Greiken et al. 2014) generate estimates of private costs that focus on changes in net economic surplus (net farm profit).

However the full costs of changes in management practices may include additional private and public costs, particularly where management changes are being targeted through programs. These may involve indirect or non-financial costs. Extra components of private costs may involve:

- Capital costs (where not included in the enterprise changes)
- Risk and uncertainty – associated with increased variability or risk of production returns with changes in management
- Transaction and administration costs – the costs of finding and organising new opportunities

Public costs of conducting a program to encourage changes in landholder management may include:

- Direct incentive payments
- Administration costs
- Other costs, such as monitoring and enforcement.

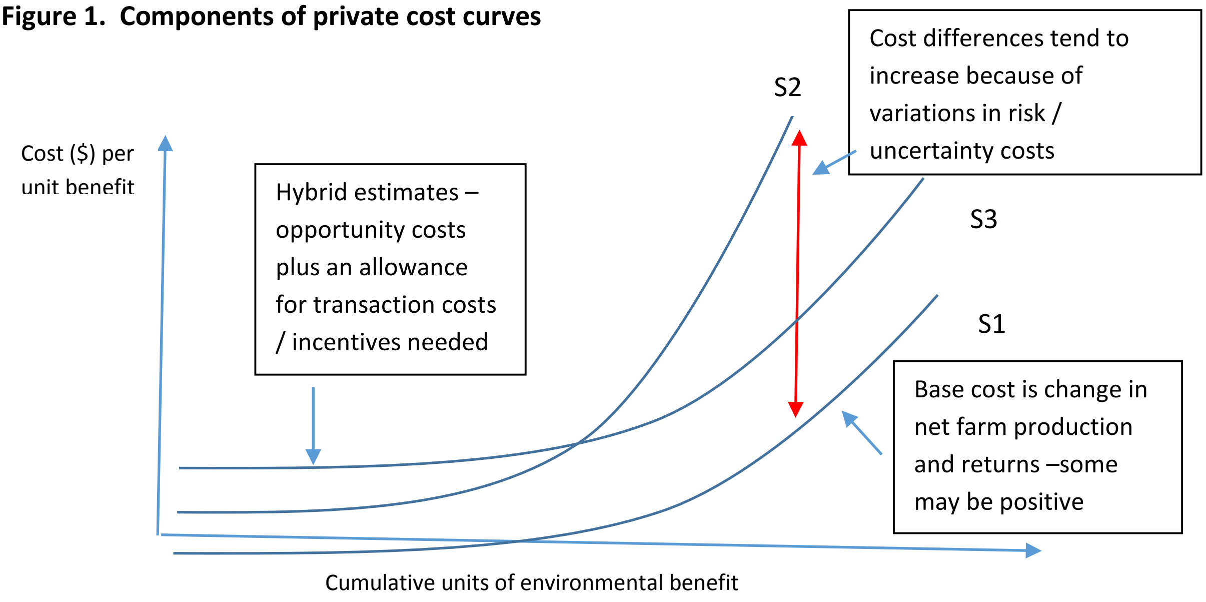
The challenges of estimating private costs is summarized in the figure below, where supply curve S1 represents the net change in enterprise production returns for new management practices, and supply curve S2 represents those same management practices with the additional indirect and involvement costs included. The diagrams show that:

- Costs of making changes increase with the quantity of desired changes
- Some management changes may involve almost zero costs in terms of net production returns
- Additional risk / transaction / administration costs increases the real or perceived private costs of landholders
- The increase in costs can be much higher if there are perceptions of risk or uncertainty in returns.

Farm production models and bioeconomic models tend to measure only net production costs (e.g. curve S1). However costs that are revealed by farmers' involvement in programs (e.g. grant mechanisms) or by farmers setting the cost of management changes (e.g. in water quality tenders) usually incorporate the full costs of involvement (e.g. curve S2). This means that estimates of costs generally vary according to whether they are modelled or revealed, as different components of costs are included.

Mechanisms to predict costs deal with the challenge of estimating indirect costs in different ways. Many grant programs estimate payment rates for actions on the average cost for a practice change and allowing for some nominal administration costs (e.g. Bass et al. 2013); these then become a flat-rate payment irrespective of underlying landholder costs. A similar approach was taken by Pannell (2015); low opportunity costs for practice change were supplemented with (large) allowances for the incentives needed to encourage landholders to change practices ($25/ha/year). These approaches are represented in the diagram as curve S3 (a vertical shift of S1). A comparison shows that costs estimated with the hybrid approach (curve S3) will over-estimate costs for lower levels of environmental change and over-estimate costs for higher levels of change (full costs represented in S2).

Figure 1. Components of private cost curves



Based on this analysis, a matrix of the key options to generate an estimate of cost-effectiveness from a site or regional area can be identified according to whether (a) emissions are estimated at farm boundary or end-of-catchment, (b) costs are estimated as changes in net farm enterprise returns, include all indirect and involvement costs, or some allowance to generate farmer involvement. While estimates may vary by other factors, such as the quality of the modelling and the scale of the environmental improvements involved, Table 1 summarises the key factors that limit the comparison of cost-effectiveness estimates in GBR catchments, and categorises the programs that are reviewed in the report by those key factors.

Table 1. Matrix of cost-effectiveness estimates by key factors

		Predictions of emissions	
		On –farm	*End-of-catchment*
Costs of action	*Operating costs (Curve S1)*	Bio-economic models (various)	Bio-economic models (various)
	Operating + risk & transaction/admin. Costs (Curve S2)	Water quality tenders (various)	
	Operating costs + allowance for admin/incentives (Curve S3)	Local Assessment (Terrain)	Reef Rescue grants WQIP (various)

3. Public funding: grants programs 2008-2013

The Australian and Queensland Governments introduced the Reef Plan in 2003 to improve the quality of water entering the reef and the resilience of the reef to poor water quality (Queensland Audit Office 2015). There have been several programs and funding initiatives to achieve this, most notably after the Reef Plan was revised in 2009 to provide specific targets for best practice adoption in agriculture and reduced emission loads for key pollutants.

The Queensland Government committed $175 million in a five year program to achieve the Reef Plan from 2009 to 2014. Activities have included the industry-led Best Management Practice programs, extension and education activities, catchment monitoring and modelling, and research. The Australian Government invested $200 million in the Reef Rescue Programme (2008-2013) to reduce nutrient, pesticide and sediment discharge into the Great Barrier Reef from broadscale landuse. Funding included $158 million to cover water quality grants for on-ground works, and funding for developing industry partnerships and community participation. In 2015, each Government committed an additional $100 million towards reef protection activities, with the funding still to be specifically committed.

A range of reports have summarized the results and achievements of the Reef Rescue Program, but few sources provide information about load reduction cost estimates where information is provided about both program costs as well as load reductions. For example, the Queensland Audit Office (2015) identified that a small component of Queensland Government expenditure had been on investment programs through the Regional NRM bodies ($4.3 million in 2013-14), but that practice changes are poorly quantified.

The most informative data comes from the analysis of the Australian Government investment into water quality grants, as summarized in the following sub-sections. However the insights provided are limited. One problem is that the available information is limited to averages by NRM region. Ideally data would be available at an individual project level so that funding allocations could be matched to projected reductions in emissions. While there is potential for Paddock to Reef modelling to retrofit emissions predictions to individual grants, this data is not automatically available.

A second problem is that the Reef Rescue grant program, and NRM grants more generally, do not function well as a cost revelation mechanism. This is because the funding levels for particular activities tend to be set in advance through the program design, based either on some expert opinion about average costs of performing an activity and funding levels necessary to attract participation, or some level of cost-sharing. The outcome is that costs tend to be uniform for specific activities, rather than tailored to individual operations. The emphasis on the use of fixed grants to allocate funds has disguised the variations in private costs by landholders.

3.1 Reef Rescue Achievements 2008 – 2013 (Australian Government 2014)

A summary of the Reef Rescue Programme achievements across the regions is provided by the Australian Government (2014). The report provides broad level estimates of the incurred cost of pollutant load reductions over the life of the program. Load reductions were estimated from bio-physical modelling, conducted through the joint Australian and Queensland Government Paddock to Reef Programme, and based on the reported improvements in land management practices collected by the natural resource management (NRM) regions. The modelled Reef Rescue pollutant load reductions and total costs for the five year program were used to estimate approximate costs of sediment, dissolved inorganic nitrogen (DIN) and of photosystem II (PSII) pesticide reductions. The reported costs represented the approximate costs to the Australian Government for the annual average, **end-of-catchment,** load reduction, as follows:

- **Suspended (fine) sediment reduction**: approximately **$130 per tonne per year** from the adoption of improved grazing land management practices.
- **Dissolved inorganic nitrogen (DIN) reduction**: approximately **$63,000 per tonne per year** from the adoption of improved fertiliser management practices in sugarcane.
- **Photosystem II (PSII) inhibiting pesticides reduction:** approximately **$3,500 per kilogram per year** from the adoption of improved pesticide management practices in sugarcane.

These estimates of cost-effectiveness are limited in several ways. First, it is unclear what the cost base is, i.e. total program costs ($200 million), water quality grants ($158 million) or some other variant. Second, not all benefits were included in the modelling, such as improvements from the horticulture and dairy industries. Third, the modelling is underpinned by a number of assumptions about the extent and duration of practice change, which may be over-optimistic; typically model estimates have become more conservative over time as model accuracy has improved[1]. It is also important to note that the grants programs involved generally relied on a fixed cost or subsidy for a mechanism change plus some allowance for administration costs, so did not function as a price revelation system.

The regional level details provided in the program summary reveal considerable regional heterogeneity in the estimated costs of load reductions (Table 2). The cost of sediment reductions

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[1] Comment by Kevin McCosker, Paddock to Reef program.

ranged from $106 per tonne in the Burdekin to $1,343 in the Burnett Mary region, more than a 10 fold increase. The cost of nitrogen reductions varied by a factor of more than 30 and pesticide reduction by a factor of 65.

Table 2. End-of-catchment load reductions and cost estimates by NRM region

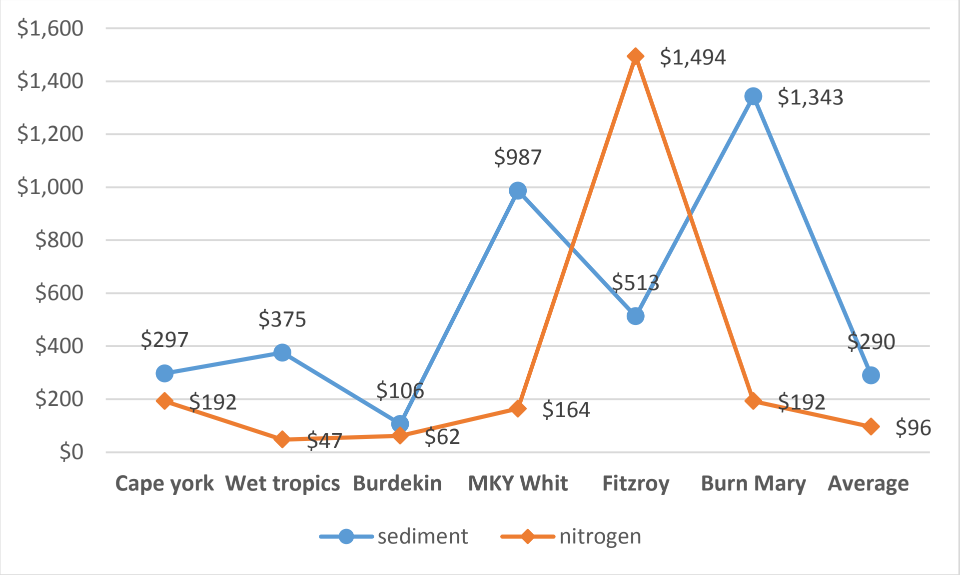
	Funding	**Sediment reduction**			**Nitrogen reduction**			**DIN reduction**			**Pesticide PSII reduction**		
	2008-13	%	tons	**$/ton**	%	tons	**$/kg**	%	tons	$/kg	%	kg	$/kg
Cape York	4.05M	8	13,639	**$297**	8	21	**$192**						
Wet Tropic	33.70M	12	89,792	**$375**	11	710	**$47**	12	237	**$142**	24	2,062	**$16,343**
Burdekin	32.43M	12	306,334	**$106**	9	525	**$62**	14	261	**$124**	13	269	**$120,770**
Mky Whit	32.00M	9	32,421	**$987**	11	195	**$164**	24	204	**$157**	42	1,657	**$19,315**
Fitzroy	30.63M	4	59,717	**$513**	2	21	**$1,494**				5	29	**$1,060,650**
Burn Mary	16.19M	3	12,050	**$1,343**	6	84	**$192**				28	424	**$38,153**

Data sourced from Australian Government (2014).

The costs of achieving a sediment reduction were much higher in the Mackay Whitsunday and Burnett Mary regions, where the main focus has been on nutrient reductions. The lowest cost provider was the Burdekin (Figure 2). The Wet Tropics and the Burdekin were the lowest cost providers of Nitrogen reduction (Figure 2), while the cost of DIN reductions were similar across the three reporting regions (Table 2). The Fitzroy region was not a low cost provider of any pollutant reduction and particularly not for pesticide reductions (Table 2), although these were not program priorities in the catchment. There is an inconsistency between the estimates reported for the whole GBR by the Australian Government (2014) and the average of the NRM costs, even though approximately the same data should be involved:

- Sediments: whole GBR cost ($130/t) < average NRM cost ($290/t)
- Nitrogen: whole GBR cost ($63/kg) < average NRM cost ($96/kg)
- Pesticides: whole GBR cost ($3,500/kg) < average NRM cost ($48, 465) (excludes Fitzroy)

Figure 2. The average cost of sediment ($/t) and nitrogen ($/kg) reduction across the regions



3.3 Local Assessment (Bass et al. 2013)

Terrain NRM conduct their own annual assessment to identify the impacts of the Reef Rescue grants in the Wet Tropics region. In the most recent summary, reporting on the 2011-12 period, Bass et al. (2013) apply the best secondary data estimates available to estimate the load reduction from the different type of activities funded across different industry sectors. However, in some cases load reductions estimates were relatively subjective and attributed to an input with an unpredictable output or outcome. The total **end of paddock** load reduction estimates are reported as 180,575 t of sediment; 315 t of nutrients and 6.9 t of pesticide and **the end of catchment** load reductions as 18,057 t of sediment; 105 t DIN and 201 kg PSII herbicides.

In Bass et al. (2013) the cost of achieving these reductions ($4.6 million) is more precisely defined (compared to the Reef Rescue Achievements report) as the water quality incentive grants to the agricultural industries: dairy, cane, wet and dry grazing, banana, papaw, multicrops, forestry and tree crops. The estimated costs of load reduction are outlined in Table 3 and compared to those reported for the region in Table 2 above. The variations are difficult to reconcile: the end-of-catchment estimates are essentially for the same program so estimates should be closer, while variations between end-of-paddock and end-of-catchment appear unrealistic (farms in the Wet Tropics region are very close to the coast so transmission rates should be high).

Table 3. Cost of pollutant reductions in the Wet Tropics region

	Sediment ($/tonne)	**Nitrogen ($/kg)**	**DIN ($/kg)**	**PSII ($/kg)**
End of paddock (Bass et al. 2013)	$25	$141		$667
End of catchment (Bass et al. 2013)	$255		$438	$22,886
End of catchment (Table 2 [Aus Gov 2014])	$375		$142	$16,343

4. Public funding: Future grants programs

There has been increased attention on predicting the costs and pollution reductions from future grants programs. Concerned that current investment would not meet the Long Term sustainability Plan vision for a sustainable GBR region, Reef Regions (2015) developed an investment plan to provide a realistic estimate of abatement costs, based on nine years of experience and two generations of Water Quality Improvement Plans. It was estimated that continued improvement in agricultural management practices across the Great Barrier Reef would cost $175 million for the period 2015 to 2020. It was predicted that such expenditure would result in the following **end-of-catchment** reductions (incorporating existing achievements (2008 – 2013):

- 15-20% reduction in total suspended solids
- 30-35% reduction in dissolved inorganic nitrogen
- 15-20% reduction in particulate nitrogen
- > 90% reduction in PSII herbicides

The approximate load reduction costs are outlined in **Error! Reference source not found.**, using data from the 2014 GBR Report Card to estimate annual loads. It is not possible to identify how the $175M would be allocated between pollutants, so estimates are based on allocating $175M equally across the three pollutant types (sediment, nutrients and pesticides), or split 50:35:15 (broadly in line with the Reef Catchments Water Quality Improvement Plan (WQIP)).

Table 4. Estimated end-of-catchment abatement costs for the whole GBR 2015-2020

	Sediment	Nitrogen	Nitrogen (DIN)	Herbicide (PSII)
Load reduction %	15-20%	15-20%	30-35%	90%
1% equivalent[1]	54465.34t	162.24t	52.58t	164.28kg
Cost@$58.3M per pollutant	**$61/t**	**$21/kg**	**$34/kg**	**$3,945/kg**
Cost split 50:35:15 by pollutant	**$91/t**	**$22/kg**	**$36/kg**	**$1,775/kg**

[1] Based on information about end of catchment load reduction provided in the GBR Report Card, 2012-2013 (A&QG 2014) and Waters et al. (2014).

The estimates of future program costs in Reef Regions (2015) were based on details from Water Quality Improvement Plans prepared by each of the NRM groups, with reports available from the Wet Tropics (Cairns region), Reef Catchments (Mackay Whitsunday region), Fitzroy Basin and Mary Burnett. Estimates of both costs and emission reductions have been generated through a variety of approaches, including the use of bioeconomic modelling, expert opinion and value transfer.

There is considerable variation in the economic analysis applied in the development of the WQIPs and future funding cost estimates, however most provide estimates of the predicted costs of achieving change and the anticipated percentage change in pollutants at the end-of-catchment. The reported percentage reductions were converted into absolute quantities applying information from the Great Barrier Reef report cards and Waters et al. (2014). The resulting estimates of cost-effectiveness are summarised in Table 5; further details are available in Rolfe and Windle (2016).

Table 5. Summary of cost estimates for future funding (WQIPs)

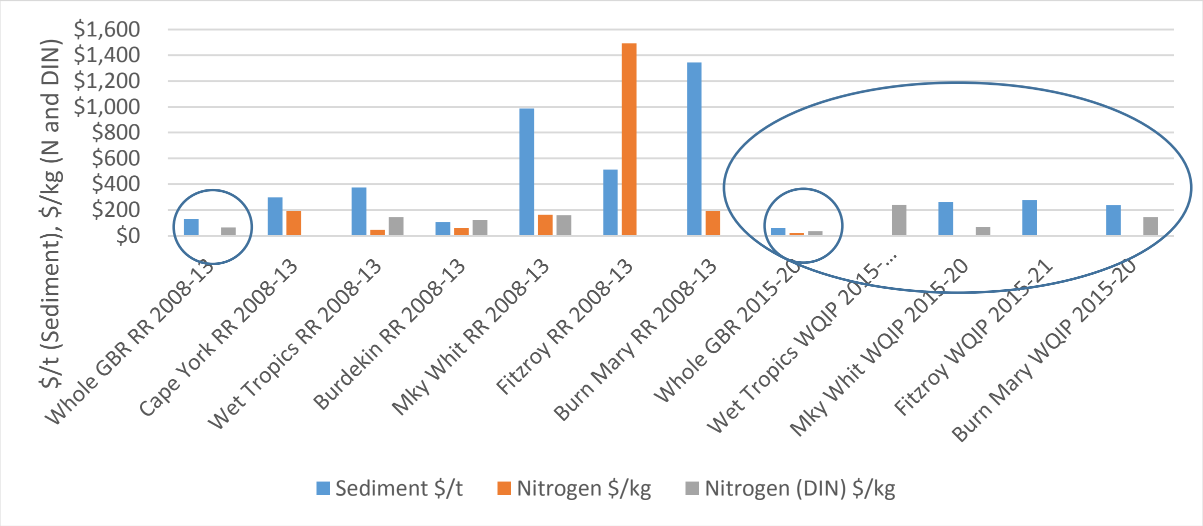
Region	Sediment	Nitrogen	Nitrogen (DIN)	Pesticide (PSII)
End of catchment loads				
Whole GBR (Reef Regions 2015)				
Load reduction	15-20%	15-20%	30-35%	90%
Public Cost @ $175M (equal allocations)	**$61/t**	**$21/kg**	**$34/kg**	**$3,945/kg**
Public Cost @ $175M (50:35:15)	**$92/t**	**$22/kg**	**$32/kg**	**$1,776/kg**
Wet tropics				
Load reduction	na		19%	63%
Public Cost @ $13M			**$239/kg**	**$3,076/kg**
Mackay Whitsunday				
Load reduction	15%		12%	15%
Public Cost @ $46M inc extn	**$263/t**		**$68/kg**	**$10,178/kg**
Burnett Mary				
Load reduction	20%		50%	60%
$32.5M split 50:35:15 by pollutant	**$238/t**		**$142/kg**	**$11,917/kg**
Fitzroy				
Load reduction	20%			
Private cost	**$277/t**			

Results show that cost estimates of emission reductions across the whole Great Barrier Reef (Reef Regions 2015) are systematically about three to five times lower than the average costs from the WQIPs, even though the information base should be the same.

- Sediments : whole GBR cost ($92/t) < average WQIP cost ($259/t)
- DIN : whole GBR cost ($32/kg) < average WQIP cost ($150/kg)
- Pesticides : whole GBR cost ($1,776/kg) < average WQIP cost ($8,390)

The costs estimates from both the past Reef Rescue grants and the future anticipated program costs are summarised in Figure 3 below (future costs are circled). While comparisons are limited, they reveal that heterogeneity in costs is predicted to be lower in future programs than in past ones. Costs in future programs are predicted to be much lower than over past grants (average decreases are 64% in Sediment, 11% in DIN and 46% in PSII); this is despite more accurate modelling generally reducing predictions of pollution changes[2]. The data also illustrates how estimates for costs across the whole GBR are systematically lower than costs at the regional level.

Figure 3. The average cost of sediment ($/t) and nitrogen ($/kg) reduction across regions



5. Public funding: market data from competitive tenders

Information about cost-effectiveness can also be sourced from water quality auctions (also known as competitive tenders, reverse auctions or procurement auctions). These are market based approaches where governments purposefully design allocation mechanisms for public funding, rather than allocating funds through flat-rate grants (Rolfe and Windle 2011a,b). The intention is to engage the competitive power of market processes to improve the efficiency of public funding allocation. Rather than paying a fixed price for a fixed action (as in a flat-rate grant), a tendering mechanism exploits the heterogeneity in both inputs and outputs. Landholders face different

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[2] Comments from Kevin McCosker (Paddock to Reef program)

opportunity costs in providing environmental improvements, and the bio-physical outputs vary across the landscape. In a competitive tender, landholders nominate the management practice changes they are prepared to implement and the price they are prepared to accept to provide the changes.

Water quality auctions provide much more accurate information than grant mechanisms about the private costs of changing management practices, for two key reasons:

- Landholders reveal their individual incentives required, so costs discriminate between landholders, and are net of most private benefits that might be generated
- Landholder costs include all costs of involvement, include considerations of capital costs, risks and transaction costs.

However the estimates of environmental benefits tend to be less accurate, as the primary purpose is to rank proposals. In most water quality tenders, proposals have been evaluated only in terms of end-of-paddock changes.

A number of competitive tenders, designed to achieve water quality improvements, have been implemented in Great Barrier Reef catchments and provide information about the revealed costs of emission reductions (Rolfe and Windle 2011b). The most relevant tenders was a water quality auction conducted in the Burdekin region in 2008 (Rolfe et al. 2008, Rolfe and Windle 2011b), and the Wet Tropics Reverse Auction conducted in 2014 (Whitten et al. 2016) (Table 6).

Table 6. Summary statistics for the water quality tenders (successful bids only)

2015 dollar values **End of paddock reductions**	**Burdekin:** **Cane + Grazing 2008**	**Wet Tropics Reverse Tender** **Cane 2014**
Total cost	$707,850	$1,381,516
Sediment	(grazing only)	
Sediment reduction (tons)	492	
Sediment reduction cost	$91,885	
Av. Reduction cost ($/ton)	$104.39	
Reduction price range ($/ton)	**$34.88 – $244.69**	
Nitrogen	(cane only)	(cane only)
Nitrogen reduction (kg)	96,016	191,912
Nitrogen reduction cost	$512,021	$1,454,797
Av. Reduction cost ($/kg)	$5.34	$8.01
Reduction price range ($/kg)	**$0.76 – $20.46**	**$1.73 - $14.59**
Pesticide	(cane only)	
Pesticide reduction (kg)	55.5	
Pesticide reduction cost	$109,710	
Av. Reduction cost ($/kg)	$1,976	
Reduction price range ($/kg)	**$860 - $19,379**	

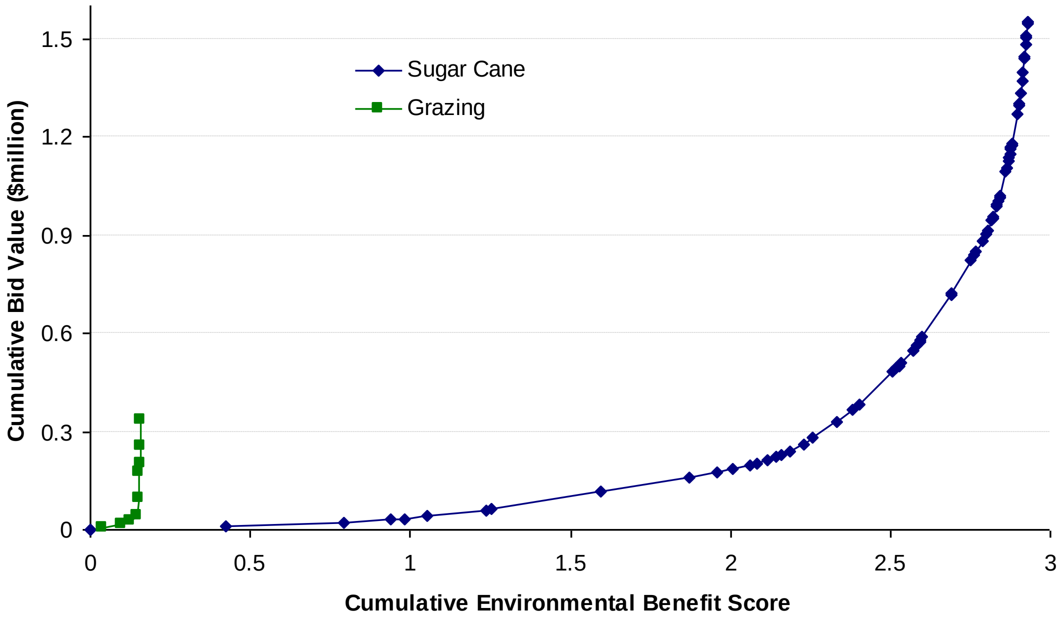
The evidence from the water quality auctions is that reductions in pollutants from agriculture are available at a range of costs, including many very low cost proposals. The schemes that have been implemented appear to be lower cost than flat rate grant schemes. However comparisons with the

Reef Rescue costs are complicated because the tender estimates are end-of-paddock, limited to the length of the contracted arrangement, and estimation of emissions are often simplistic.

As an example, the cost-effectiveness of the Nitrogen emissions from the tenders might be converted to end-of-catchment emissions at a factor of one-third. On this basis, the average end-of-catchment costs of annual change in Nitrogen emissions would be $16/kg in the Burdekin tender and $27/kg in the Wet Tropics tender, which are lower than both the historic and forward NRM cost estimates for the Burdekin and Wet Tropics reported in Tables 2 and 5. This comparison is based on an assumption that both types of allocation mechanisms generate benefits of equal duration and effect; variations in those assumptions will impact on the relative cost-effectiveness of either approach.

Insights into cost heterogeneity are provided from the Burdekin tender in Rolfe et al. (2011), where there were 87 bids submitted in the tender but only 33 funded. In both the sugarcane and grazing sectors there were some very high cost bids that provided little environmental improvement (Figure 4), but also a number of lower cost proposals that generated large environmental benefits. This heterogeneity is essentially hidden in flat-rate grant schemes.

Figure 4. Cumulative bid curve for all bids (87) in the Burdekin tender (Rolfe et al. 2011: Figure 4)



6. Bio-economic modelling: Private farm level costs

The more standard approach in economics to predicting costs of making management changes is to employ bio-economic models. Many of the earlier studies relevant to the GBR have been focused on case studies and end-of-paddock improvements (e.g. Star et al. 2011), but more recent studies have involved broader applications and more detailed modelling. Some of the more sophisticated analyses are summarised in Table 7, together with the key variations in pollutant, catchment and modelling approaches that limit the comparison of estimates. Note that many of the predictions in the WQIPs are based on bioeconomic modelling.

Table 7. Overview of the outputs from bio-economic modelling studies

	Pollutant	Private cost	location	Reported results
Sugarcane				
Poggio et al. 2014	Pesticide **End of paddock**	AEB (10yr @6%)	Tully; Mackay; Burdekin (x2)	-$4,920/kg to +$4,910/kg pesticide reduction across C-B, C-A and B-A class practice change
Van Grieken et al. 2013	DIN **End of catchment**	NPV (gross margins + capital) (10 + 5 yr @ 7%)	Tully Mackay	-$22/kg (5yrs) to +$22/kg (10yrs) -$22/kg (5yrs) to +$22/kg (10yrs) NPV of practice (ABCD) change
Grazing				
Star et al. 2011, 2013, 2015a	Sediment **End of paddock**	NPV (20yr @6%)	Fitzroy Basin	$4/t to $421/t sediment reduction across 5 land types and 3 land condition classes
Star et al. 2015b	Sediment **End of catchment**	Capital + operating	Fitzroy WQIP	$19/t to $9,799/t across land types and land conditions in 93 sub-catchments; average cost to achieve 20% reduction is $277/t
Pannell et al. 2014	n/a	Capital + operating + non-financial	Burnett Mary WQIP	$10 - $160/ha/yr for practice (ABCD) change across different practices, land types & farm size (includes $25/ha for incentives to change practices)

AEB = Annual equivalent benefits (capital costs are included)
ABCD = four classes of management practices, ranging from A = aspirational to D = dated.

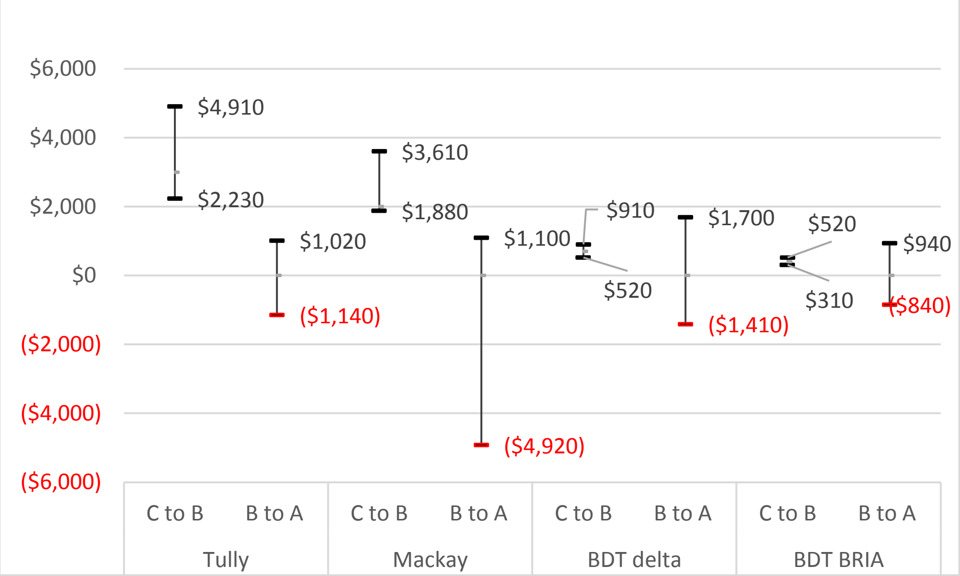
Two important conclusions can be drawn from the bio-economic modelling. First, there are large variations in private costs, confirming that heterogeneity is important. Second, there are many situations where there are potential private returns from improving management practices that also deliver environmental improvements (win-wins); in these situations the financial enterprise costs of making management changes are effectively zero. These conclusions are demonstrated in Figure 5 for the costs of pesticide reduction, where the variation in costs are shown across catchments and practice changes.

A comparison of the bioeconomic modelling results (Table 7) to the previous costs and projected future costs of funding programs (Tables 2 and 5) reveals that the bio-economic modelling estimates of costs are a magnitude lower. For example, the estimates of costs for Nitrogen reduction from van Greiken et al. (2013), which are estimated for end-of-catchment loads in the Tully and Pioneer catchments, range from -$22/kg to +$22/kg, compared to an average of $47/kg and $164/kg for previously funded Reef Rescue projects in the Wet Tropics and Mackay Whitsunday regions (Australian Government 2014), and $185/kg across the GBR for future projects estimated from Reef Regions (2015).

Similarly, the average cost of $277/t to achieve a 20% reduction in sediment in the Fitzroy (Star et al. 2015) is much lower than $513/t for previously funded Reef Rescue projects in the Fitzroy region

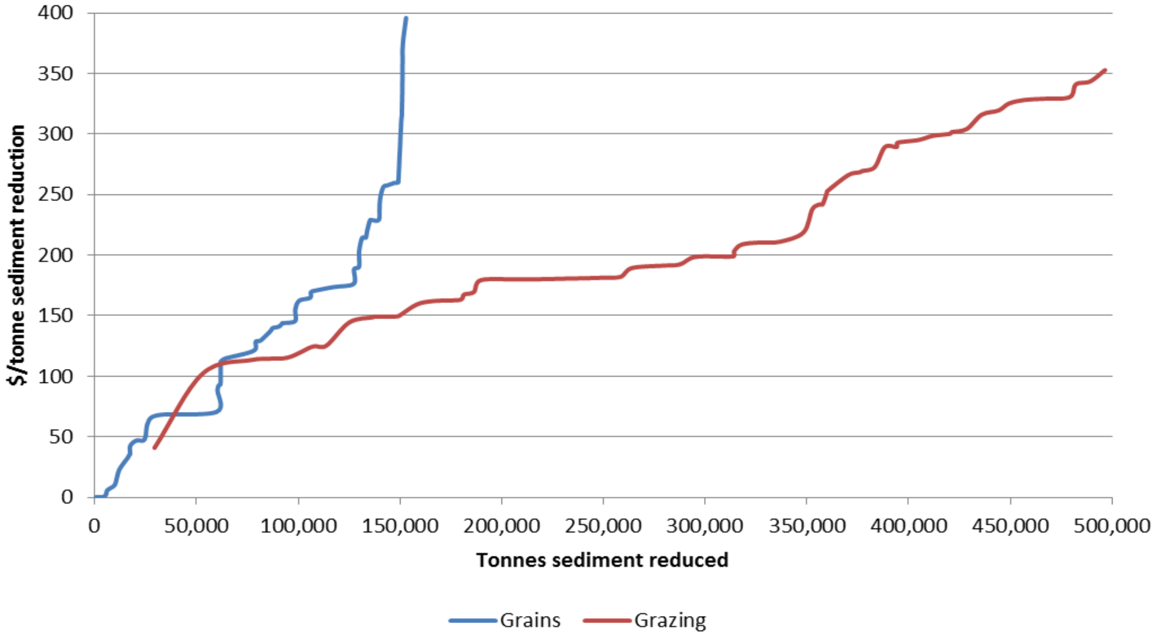
(Australian Government 2014), and $550/t across the GBR for future projects estimated from Reef Regions (2015). The estimated cost curves from Star et al. (2015) are replicated in the Figure below; these capture opportunity costs and an allowance for incentive/transaction costs, so should be directly comparable to Reef Rescue cost and Reef Regions estimates.

Figure 5. Private benefit/cost ($/kg) variation for pesticide reduction from practice change



Data sourced from Poggio et al. (2014).
'C-B' and 'B-A' represent shifts from Common to Best and Best to Aspirational management practices

Figure 6. Costs of sediment reductions in the Fitzroy Basin (Figure 16 in Star et al. 2015)



7. Summary

The estimates of cost effectiveness have been summarised in Table 8, by end-of-catchment and end-of-paddock loads. Results from bioeconomic models that are not captured in the WQIPs have not been included because of the complexity of the data, although it should be noted that those models generally predict much lower costs.

Table 8. Summary of Cost estimates

Region	Sediment $/tonne	Nitrogen $/kg	Nitrogen (DIN) $/kg	Pesticide (PSII) $/kg
End of catchment loads				
Whole GBR				
Achieved: Aust Govt 2014	130		63	3,500
Predicted: Reef Regions 2015	*61*	*21*	*34*	*3,945*
Cape York				
Achieved: Aust Govt 2014	297	192		
Wet tropics				
Achieved: Aust Govt 2014	375	47	142	16,343
Achieved: Bass et al. 2013	255		438	22,886
Predicted: WQIP(70:30 funding split)			*239*	*3,076*
Burdekin				
Achieved: Aust Govt 2014	106	62	124	120,770
Mackay Whitsunday				
Achieved: Aust Govt 2014	987	164	157	19,315
Predicted: WQIP	263		68	10,178
Fitzroy				
Achieved: Aust Govt 2014	513	1,494		1,060,650
Predicted: Star et al. 2015b WQIP	277			
Burnett Mary				
Achieved: Aust Govt 2014	1,343	192		38,153
Predicted: WQIP (50:35:15 funding split)	237		142	11,918
End of paddock loads				
Wet tropics				
Achieved: Bass et al. 2013	25	141		667
Achieved: Wet Tropics Tender 2014		9		
Burdekin				
Achieved: Burdekin Tender 2011	104	5		1,976

The initial research question was to determine if variations in cost components and modelling approaches could explain differences in modelling.

The results of this review reveal significant differences in cost estimates for each of the key pollutant types, with most estimates available at end-of-catchment to facilitate comparison:

- Costs vary across regions (see Table 2 and Figure 2) where cost effectiveness of NRM grants vary by at least a factor of 10 across regions. This indicates that cost-effectiveness can be significantly improved by the allocation of funds across regions.

- Costs vary within regions (see Figures 4, 5 and 6), reflecting significant heterogeneity between landholders and projects. This variation is largely disguised in the grants programs because funding rates are often fixed. This heterogeneity means that cost-effectiveness can be significantly improved by the allocation of funds within regions.
- Projected costs of grant projects appear to be decreasing over time (Figure 3). Costs in future programs are predicted to be much lower than over past grants (average decreases are 64% in Sediment, 11% in DIN and 46% in PSII); this is despite more accurate modelling generally reducing predictions of pollution changes and thus increasing estimates of cost-effectiveness.
- Cost estimates vary by estimation approach, with the economic tools of bio-economic modelling and water quality auctions predicting much lower levels of cost-effectiveness than what is revealed through grant programs. Bio-economic modelling indicates that there are many practice changes that involve little or no opportunity costs; even after making allowances for incentive and transaction costs the costs of making changes is low (Table 7).
- Costs vary by allocation approach, with costs revealed through tenders significantly lower than costs identified with grants programs:
    - For Sediments, average grant costs ($536/t) > five times tenders ($105/t)
    - For Nitrogen, average grant costs ($359/kg) > 51 times tenders ($7/kg)
    - For Pesticides, average grant costs ($39,107/kg > 20 times tenders ($1,976)

  While some of the differences are because of confounding between end-of-paddock (tenders) and end-of-catchment modelling, the size of the differences indicates that allocation methods have an impact on costs.
- Summary estimates of costs at the whole GBR level appear to be systematically lower than when costs are analysed at the regional level.

These results indicate that better information about cost-effectiveness should be used to improve prioritisation of funding allocations and project selection, and that large gains in the effectiveness of public funding are possible.

The research revealed that data on cost-effectiveness was generally difficult to source at the project level, even though estimates of water quality improvements should be a key component of evaluation in each project approval. It is recommended that data on cost-effectiveness should be automatically collated at the project level when predictions of improvements are made and funding is allocated.

Estimates of cost-effectiveness appear to be much higher in grant programs than predicted by bioeconomic modelling or achieved through water quality tenders (noting some confounding between end-of-paddock and end-of-catchment modelling). It is recommended that:

- There should be greater emphasis on cost-effectiveness in project selection.
- Program design should be adjusted away from a reliance on simple grant mechanisms to processes that encourage better price discovery and project selection.

References

Addison, P. and Walshe, T. 2015 *Summary report: the cost-effectiveness protocol used to assist in the prioritisation of the second phase of Reef Trust investment*. Final Report to the Commonwealth Department of the Environment. Australian Institute of Marine Science, Townsville.

Australian Government 2014. *Reef Achievements 2008 – 2013*. Commonwealth of Australia, Canberra.

Australian and Queensland Governments (A&QG) 2013. *Reef Water Quality Protection Plan 2013,* Australian and Queensland Governments, Canberra.

Australian and Queensland Governments (A&QG) 2014. *Reef Water Quality Protection Plan Investment Strategy,* Australian and Queensland Governments, Canberra.

Australian and Queensland Governments (A&QG) 2014. *Great Barrier Reef Report Card 2012 and 2013. Reef Water Quality Protection Plan*, Australian and Queensland Governments, Canberra.

Bass, D., Sing, N., Harrison, D.A., & Blakeney, S. 2013. *Wet Tropics Reef Rescue Impact Report 2012*. Terrain NRM, Innisfail.

Brodie, J., Waterhouse, J., Schaffelke, J., Kroon, F., Thorburn, P., Rolfe, J., Johnson, J., Fabricius, K., Lewis, S., Devlin, M., Warne, M. and McKenzie, L. 2013. 2013 *Scientific Consensus Statement: Land use impacts on Great Barrier Reef water quality and ecosystem condition*, State of Queensland, Brisbane.

Burnett Mary Regional Group (BMRG) (n.d) *Water Quality Improvement Plan for the Burnett Mary Region*. Natural Decisions, Burnett Mary Regional Group and Australian Government.

Coggan, A., van Grieken, M., Boullier, A., Jardi, X. 2013*. Private transaction costs of best management practices (BMP) through Reef Rescue*. Reef Rescue Integrated Paddock to Reef Monitoring, Modelling and Reporting Program. CSIRO: Water for a healthy Country National Research Flagship, Dutton Park, Brisbane.

Doole, G. and Pannell, D.J. (2012). Empirical evaluation of nonpoint pollution policies under agent heterogeneity: regulating intensive dairy production in the Waikato region of New Zealand, *Australian Journal of Agricultural and Resource Economics* 56(1), 82-101.

Doole, G., Vigiak, O., Roberts, A.M. and Pannell, D.J. (2013). Cost-effective strategies to mitigate multiple pollutants in an agricultural catchment in North-Central Victoria, Australia, *Australian Journal of Agricultural and Resource Economics* 57(3), 441-460.

East, M.2010. Estimating the economic implications for grazing properties in the Mackay Whitsunday catchments of practice changes to more sustainable landscapes. Paper presented at the 54th Annual Conference of the Australian Agricultural & Resource Economics Society, Adelaide.

East, M., Simpson, S. and Simpson, J. 2012. Economic implications of changing sugarcane management practices—Mackay Whitsunday region. *Proc Aust Soc Sugar Cane Technol* 34: 1-10.

Edwards, B., Sluggett, R. and East, M. 2013. Informing policy design for water quality improvements in the sugarcane industries adjacent to the Great Barrier Reef: a case study approach. Paper presented at the 57th Australian Agricultural and Resource Economics Society Annual Conference, Sydney.

Folkers, A., Rohde, K., Delaney, K., Flett, I. 2014. *Mackay Whitsunday Water Quality Improvement Plan 2014-2021*. Draft Report. Reef Catchments and Australian Government.

Pannell, D.J., (2015) *Ranking Environmental Projects*, Working Paper 1506, School of Agricultural and Resource Economics, University of Western Australia, Crawley, Australia.

Pannell, D.J. and Roberts, A.M., 2010. The National Action Plan for Salinity and Water Quality: A retrospective assessment. Australian Journal of Agricultural and Resource Economics, 54(4), 437-456.

Pannell, D., Roberts, A. and Park, G. 2014. *Economic analysis of grazing systems for water quality improvement in the Burnett Mary catchment*. Natural Decisions, http://www.naturaldecisions.com.au/

Park, G. and Roberts, A. 2014. *Wet Tropics WQIP – INFFER Assessment. Final Report (draft) to Terrain NRM for the Wet Tropics Water Quality Improvement Plan*, version 25th July 2014. Natural Decisions, http://www.naturaldecisions.com.au/

Poggio, M., Smith, M., van Grieken, M., Shaw, M. & Biggs, J. (2014). *The Economics of Adopting Pesticide Management Practices Leading to Water Quality Improvement on Sugarcane Farms*. Department of Agriculture, Fisheries and Forestry (DAFF), Queensland.

Queensland Audit Office 2015. *Managing Water Quality in Great Barrier Reef catchments*, Report 20 2014 – 15, The State of Queensland, Brisbane.

Reef Regions 2015. *Great Barrier Reef Long Term Sustainability Plan 2050 Investment proposal*. *Water quality, catchment and coastal repair. First edition 200115*. Reef Regions: GBR Natural Resource Management Organisations.

Rolfe, J. & Windle, J. 2011a. Comparing a best management practice scorecard with an auction metric to select proposals in a water quality tender *Land Use Policy,* 28, 175-184.

Rolfe, J. and Windle, J. 2011b. Using auction mechanisms to reveal costs for water quality improvements in Great Barrier Reef catchments in Australia, *Agricultural Water Management,* 98(4):493-501.

Rolfe, J. and Windle, J. 2016. *Benchmarking costs of improving agricultural water management in Great Barrier Reef catchments*, Research report for project 3.10, Tropical Water Quality Hub, National Environmental Science Program, Canberra.

Rolfe J., Greiner R., Windle J. and Hailu A. 2011. Testing for allocation efficiencies in water quality tenders across catchments, industries and pollutants: A north Queensland case study. *Australian Journal of Agricultural and Resource Economics, 55(4): 518-536.*

Star, M., Rolfe, J. and Donaghy, P. 2011. Economically viable land regeneration in Central Queensland and improved water quality outcomes for the Great Barrier Reef. *The Rangeland Journal* 33:267-276.

Star, M., Rolfe, J., Donaghy, P., Beutel, T., Whish, G. and Abbott, B. 2013. Targeting resource investments to achieve sediment reduction and improved Great Barrier Reef health. *Agriculture. Ecosystems and Environment* 180: 148-156 n press (http://dx.doi.org/10.1016/j.agee.2012.03.016).

Star, M., Rolfe, J., Long, P., Whish, G. and Donaghy, P. 2015a. Improved grazing management practices in the catchments of the Great Barrier Reef, Australia: does climate variability influence their adoption by landholders? *The Rangeland Journal* 37 (5): 507–515.

Star, M., Beutel, T., Scrobback, P., Rolfe, J., McCosker, K., Ellis, R. 2015b. *Prioritisation of neighbourhood catchments in the Fitzroy Basin*. Report to Fitzroy Basin Association for the Fitzroy Water Quality Improvement Plan.

Terrain 2015. *Wet Tropics Water Quality Improvement Plan 2015-2020.* Terrain NRM and Australian Government.

Thorburn, P. Rolfe, J. et al. 2013. *Scientific Consensus Statement 2013. Chapter 5: The water quality and economic benefits of agricultural management practices.* The state of Queensland, Reef Water Quality Protection Plan Secretariat.

van Grieken, M., Lynam, T., Coggan, A., Whitten, S. and Kroon, F. 2013. Cost effectiveness of design-based water quality improvement regulations in the Great Barrier Reef. *Agriculture, Ecosystems and Environment* 180: 157-165.

Van Grieken, M.E., Poggio, M.J., East, M., Page, J. and Star, M.2010. *Economic Analysis of Sugarcane Farming Systems for Water Quality Improvement in the Great Barrier Reef Catchments.* Reef Rescue Integrated Paddock to Reef Monitoring, Modelling and Reporting Program. CSIRO: Water for a healthy Country National Research Flagship.

Van Grieken, M.E., Pannell, D. and Roberts, A. 2014a. *Economic Analysis of Farming Systems for Water Quality Improvement in the Burnett Mary Catchment*. A report prepared for the Burnett Mary Regional Group in cooperation with Natural Decisions. CSIRO Water for a Healthy Country Flagship. Brisbane.

Van Grieken, M., Poggio, M., Smith, M., Taylor, B., Thorburn, P., Biggs, J., Whitten, S., Faure, C., and Boullier, A. 2014b. *Cost-effectiveness of management activities for water quality improvement in sugarcane farming.* Report to the Reef Rescue Water Quality Research & Development Program. Reef and Rainforest Research Centre Limited, Cairns.

Waterhouse, J., Flint, N., Johnson, J. 2015. *Fitzroy WQIP Supporting Studies: Key findings, gaps and recommendations*. A report to the Fitzroy Basin Association to support the Fitzroy Water Quality Improvement Plan. November 2015.

Waters, DK, Carroll, C, Ellis, R, Hateley, L, McCloskey, GL, Packett, R, Dougall, C, Fentie, 2014, Modelling reductions of pollutant loads due to improved management practices in the Great Barrier Reef catchments – Whole of GBR, Technical Report, Volume 1, Queensland Department of Natural Resources and Mines, Toowoomba, Queensland (ISBN: 978-1- 7423-0999).

Whitten, S., Rolfe, J., Coggan, A., Thorburn, P., Attard, S. and Windle, J. 2016. Reef Trust Tender: Further development and application of mechanism (Burdekin), CSIRO Report to the Department of the Environment, CSIRO Canberra.