ISSN 1835-9728

Environmental Economics Research Hub Research Reports

Costing water quality improvements with auction mechanisms: case studies for the Great Barrier Reef in Australia

John Rolfe and Jill Windle

Research Report No. 35

August 2009

About the authors

John Rolfe is a Professor in Regional Development Economics in the Faculty of Business and Informatics at CQ University.

Dr Jill Windle is a Research Fellow with the Centre for Environmental Management at CQ University

Environmental Economics Research Hub Research Reports are published by The Crawford School of Economics and Government, Australian National University, Canberra 0200 Australia.

These Reports present work in progress being undertaken by project teams within the Environmental Economics Research Hub (EERH). The EERH is funded by the Department of Environment and Water Heritage and the Arts under the Commonwealth Environment Research Facility.

Crawford School of Economics and Government
THE AUSTRALIAN NATIONAL UNIVERSITY
http://www.crawford.anu.edu.au

Table of Contents

Abstract:

Australian governments continue to commit significant resources to the protection of the Great Barrier Reef, with funding for Reef Rescue aimed at reducing the impacts of agricultural production on water quality. A key challenge for policy makers is to identify where funding can be efficiently allocated, as information about both the costs and benefits of different proposals is limited. While there is adequate information about the costs of different inputs for reducing water quality, there is much more limited information about the costs of achieving different outputs.

The use of water quality tenders to reveal the opportunity costs of changing agricultural practices can help policy makers to understand the potential costs of misallocating public resources and to design better ways of achieving water quality improvements. This role of water quality tenders to reveal opportunity costs is demonstrated by reporting four pilot applications to improve water quality into the Great Barrier Reef in Australia. The results demonstrate the potential for opportunity costs to vary substantially between agricultural producers, and across industries, catchments and pollutants.

Key words: auctions, conservation tenders, market based instruments, water quality

1. Introduction

The Great Barrier Reef (GBR) ecosystem has a complex inter-dependent relationship with the adjacent river catchments (Furnas 2003). Concerns about the impacts of poor water quality from these catchment areas on the health of the GBR have been expressed in a number of recent studies and reports (Furnas 2003; GBRMPA 2008; Haynes et al. 2007; Independent Panel of Scientists 2008; Productivity Commission 2003; Science Panel 2003; SQCA 2003). More than 80% of the GBR catchment area supports some form of agricultural activity. These activities have impacted on water quality through increased erosion, clearing of vegetation, the destruction of wetlands and stream bank vegetation, with the run-off of sediment, fertiliser and chemical residues (GBRMPA 2001).

The Australian Government has invested around $3.7 billion over 11 years through the National Heritage Trust (1997-2008) and the National Action Plan for Salinity and Water Quality (2001-2008), trying to address the problems of land and water degradation, and nature conservation. However, these programs fell a long way short of achieving their stated goals (Pannell 2009) and the Independent Panel of Scientists (2008) believe current management interventions are not effectively solving the problem. Under the new Caring for our Country initiative, the Government will invest a further $2.25 billion over the next five years (2008-2013) with the stated aim of restoring the health of the environment and improving land management practices. Incorporated within the scheme is the Reef Rescue plan (worth $200 million over five years), with the objective to improve water quality in the GBR lagoon by increasing the adoption of land management practices that reduce run-off of nutrients pesticides and sediment from agricultural land.

A key challenge for government is to make the most efficient use of the limited funding to achieve better water quality outcomes in the GBR lagoon. In economic terms, this would be best achieved by matching the costs of supply of mitigating activities to the benefits of the demand for environmental improvements. Little is known about the non-market benefits of environmental improvements in the GBR, although some work is underway (e.g. Rolfe et al. 2008b). Until recently, little was also known about the costs of supplying these improvements. While there is adequate information about the costs of different inputs for reducing water quality, there is much more limited information about the costs of achieving different outputs. To be able to perform a benefit cost analysis effectively, the costs of achieving water quality improvements such as reduced sediments, nutrients and pesticides should be compared with the benefits that would be achieved with these reductions.

Under the National Action Plan for Salinity and Water Quality, a number of water quality incentive schemes were implemented across GBR catchments. The information elicited from four schemes is presented in this report. Three initiatives were designed and implemented as competitive tenders, a market-based incentive approach, with the same metric being applied to assess emission reductions in each case. They were run in the Burnett Mary and Burdekin catchments and involved landholders from the grazing, sugarcane, horticulture and dairy industries. The fourth scheme involved sugarcane growers in the Mackay/Whitsunday region. Although this scheme was not run as a competitive tender, there were sufficient similarities and information available to make a subsequent reassessment of the projects and apply the same water quality metric used to assess emission reductions in the other three tenders.

The data gathered in these four schemes provided details about the quantity of sediment and nutrient emission reductions that can be acquired from a given level of investment, as well as the farm level costs of provision. An assessment of the outcomes from the projects allowed comparisons to be made about the public costs of obtaining reductions in sediment and nutrient emissions, as well as the private costs (prices) of supplying the reductions. Comparisons could be made across the four industry sectors and across two regions within the sugarcane industry. The results suggest there are considerable cost differentials both across and within industry sectors. This means important policy decisions need to be made about the most efficient way of providing improved water quality outcomes in the GBR. The results presented in this report would suggest a more targeted regional approach, rather than a broadscale statewide approach, might provide more efficient outcomes. As well, there is some evidence to suggest that the costs of providing improved water quality outcomes may be less that some assessments suggest.

Gaining more targeted information about the costs of achieving environmental outcomes is important for two key reasons. First, it allows a more direct analysis of the costs required to achieve target outcomes. A cost-effectiveness analysis helps to identify the lower cost options for improving water quality, and can help to ensure that public funding is spent more efficiently. Second, it provides essential data for input into a cost-benefit analysis framework, which has the potential to judge the overall efficiency of investment funding.

The focus of the research reported in this paper is to describe the application of field trials to value the costs of potential supply of water quality improvements. The field trials are a series of water quality auctions designed to protect the environmental health of the Great Barrier Reef in Australia. Information from these tenders can potentially be used to help drive policy formation and fine tune the design of incentive and trading systems. The paper is structured in the following way. In the next section, the relevant case study and policy issues are described, with an overview of market based instruments and water quality tenders in section three. The case study applications are described in section four, and discussion and conclusions then follow.

2. Water Quality issues in the Great Barrier Reef catchments

Australia holds about 15% of the world's coral reefs, and is the only developed nation to have significant areas of reef ecosystems. The Great Barrier Reef is the major reef area in Australia, consisting of over 2,900 individual reefs as a broken maze of coral reefs and cays for over 2,000 kilometres along the Queensland coast (Furnas 2003). The area of approximately 35 million hectares is protected by the Australian and Queensland Governments as a marine park, and has had World Heritage site status since 1981 (Figure 1). A key focus of current protection efforts is to address issues of poor water quality that may be entering the Great Barrier Reef lagoon.

The ecosystem of the Great Barrier Reef has a complex inter-dependent relationship with the adjacent river catchments. A number of rivers discharge into the Great Barrier Reef area, draining 423 070 km^2, which is 25 per cent of the land mass of Queensland (Furnas 2003). Whilst the Reef has been exposed to nutrients and sediment in natural runoff prior to Australian colonisation, agricultural, mining, industry and urban activities are enhancing the movement of sediments, nutrients and pesticide concentrations to the Reef. Approximately 990 fringing and/or inshore reefs are most at risk from these elevated concentrations of sediment and nutrients in catchment run-off (GBRMPA 2001).

Concerns about the impacts of poor water quality on the health of the GBR have been expressed in a number of recent studies and reports (Furnas 2003; Productivity Commission 2003; SQCA 2003, Haynes et al. 2007; Independent Panel of Scientists 2008; GBRMPA 2008). Evidence indicates that over the last 150 years land-based activities within the GBR catchment area have adversely impacted on the water quality entering the GBR, particularly during flood events. In particular, Furnas (2003) suggests that there has been:

a four to nine fold increase in the quantities of sediment entering the GBR;

a three to fifteen fold increase of phosphorus; and

and a two to four fold increase in total nitrogen inputs.

Agricultural practices from grazing, farming and irrigation activities are identified as the key contributors to water quality issues. Improvements in water quality are expected to lead to improved seagrass and reef health, and to increase the resilience of the reef against future environmental pressures (De'ath and Fabricius 2008).

In recent years, the government has made significant investments in trying to address issues of land and water degradation, through programs such as the National Heritage Trust (1997 - 2008) and the National Action Plan for Salinity and Water Quality (2001-2008). These programs have been implemented through a number of regional natural resource management groups and industry bodies, with a strong focus on direct grants to agricultural producers to trial and implement management improvements. However, despite these mitigating measures, the quality of water entering the GBR lagoon is still cause for concern (Independent Panel of Scientists 2008; Vandergragt et al. 2008). Further initiatives are being developed in 2009 under the Reef Rescue plan ($200 million in funding over five years). This is aimed to improve water quality by increasing the adoption of land management practices that reduce run-off of nutrients pesticides and sediment from agricultural land.

With substantial government expenditure directed at achieving better land management practices, the opportunity cost of misallocated resources is substantial (Hajkowicz et al. 2008; Pannell 2009). This potential has been exacerbated by the focus on fixed rate grants to landholders, a focus on supplying inputs (rather than generating outputs), an emphasis on maximising landholder participation (rather than funding effectiveness), and the diversity of environmental factors and management actions involved. This has made it difficult to identify whether the funding has been allocated efficiently, and what the real opportunity costs of improving water quality are for landholders.

Interest in improving funding allocation and generating better information about the opportunity costs involved has led to the application of four separate trials of water quality tenders across different GBR catchments:

a) A tender for recycle pits for sugarcane growers run by the Mackay Whitsunday NRM Group (Rolfe et al. 2007);

b) A dairy water quality tender run by the Queensland Dairy Organisation in the Mary River catchment (Rolfe and Windle 2008);

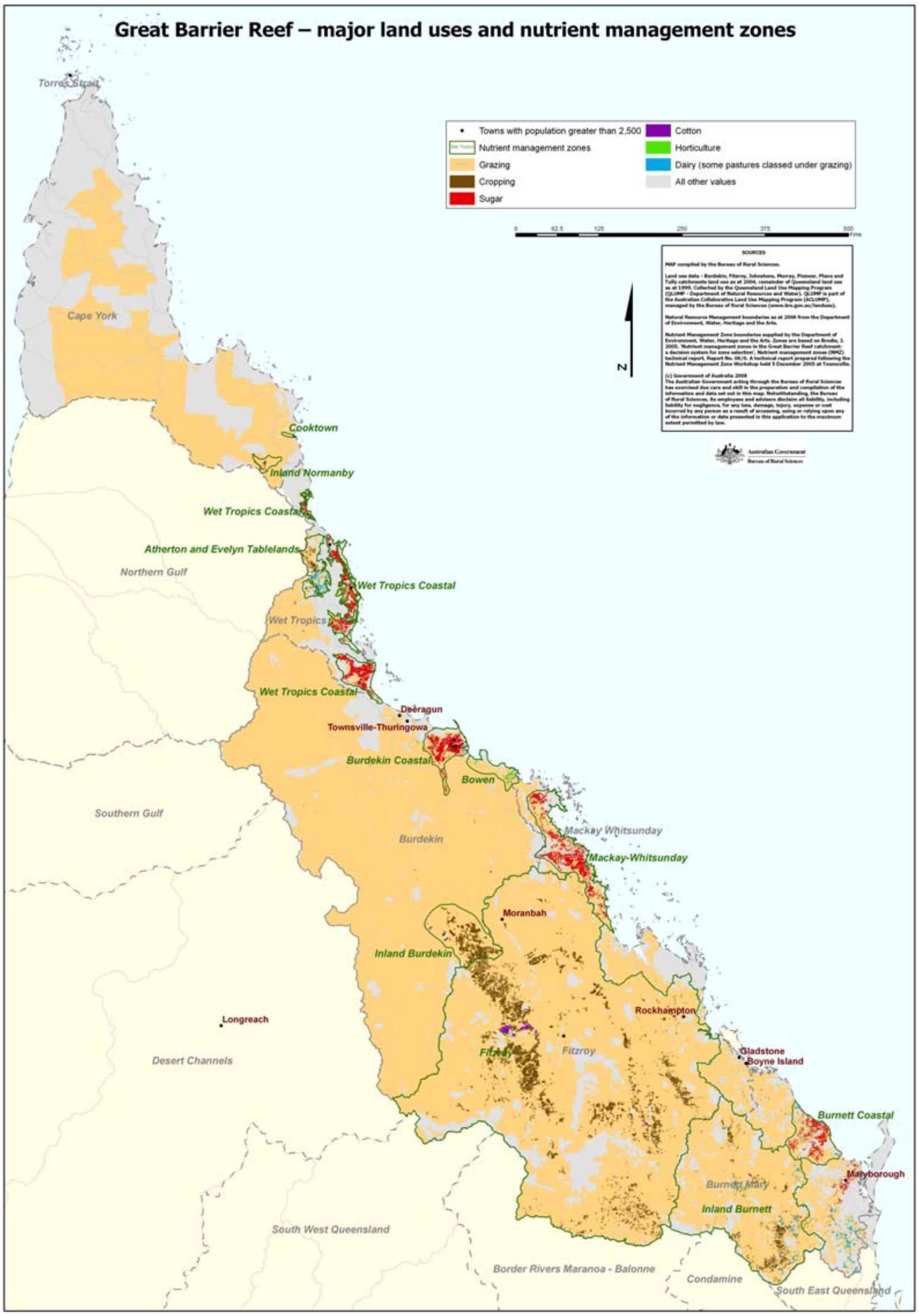
c) A horticultural water quality tender run by Growcom in the Kolan River catchment (Rolfe and Windle 2008); and

d) A sugarcane and beef grazing industry water quality tender run by the Burdekin Dry Tropics NRM group in the lower Burdekin Catchment (Rolfe et al. 2008a).

Figure 1: Great Barrier Reef Marine Park

The water quality tenders were implemented across different industries and catchments within the GBR catchment area. A brief overview of each of the regions and the target water quality improvements are summarised below, with information about catchments and landuses provided in Figure 2.

Figure 2: Catchments and land uses in the GBR region



2.1 The Burdekin region

The Burdekin River catchment covers an area of 133,000km^2 and is the second largest river basin draining into the GBR. The region is subject to climate variability and severe episodic events, generating large variations in river flows. The main source of sediment reaching the coast is from grazing lands, particularly in the higher rainfall grazing areas, while a primary source of nutrient runoff is from irrigated agriculture on the coast, principally sugarcane production (Scheltinga and Heydon 2005). Grazing is the dominant land use occupying over 98% of the area (Productivity Commission 2003).

2.2 The Mackay/Whitsunday region

The Mackay Whitsunday region (referred to as the Mackay region) covers an area of almost 9400km^2. In the coastal and marine areas, there are numerous offshore islands, including the iconic Whitsunday Island group, making issues of water quality a high priority. The region includes several river catchments that are listed in the Reef Water Quality Protection Plan as of being between medium high to high biophysical risk and of medium to high risk to marine industries (SQCA 2003). The key water quality pollutants of concern in the region are dissolved and particulate forms of nitrogen and phosphorus, suspended sediments and herbicides. The majority of these pollutants come from the grazing and sugarcane industries (Drewry et al. 2008).

2.3 The Burnett Mary region

The Burnett Mary region covers approximately 56,000km^2 and is the most southern section of GBR catchment area. There is some variation in rainfall within the region which is reflected in a diversity of farming (cropping, horticulture and dairy) and grazing systems (Vandergragt et al. 2008). The region comprises a number of river catchments, including the Mary and the Kolan Rivers.

3. Market Based Instruments and Water Quality Tenders

There has been growing interest in the application of market based instruments to address environmental problems, where market-like instruments underpinned by regulatory frameworks generate more efficient application of scarce resources than simple regulation or grant programs (Latacz-Lohmann and van der Hamsvoort 1997, 1998; Cason and Gangadharan 2004, Ferraro 2008, Classon et al. 2008). There are two key types of instruments that can be applied to agricultural water quality issues: price based mechanisms and quantity based mechanisms. Price based mechanisms include auction mechanisms for the purchase of environmental services, often with public funds. These are also known as water quality tenders. Quantity based mechanisms include cap and trade mechanisms, offset programs and bubble schemes, which can be grouped into the family of water quality trading mechanisms (Tietenberg 2006).

The key benefits of applying market based instruments such as water quality tenders or water quality trading mechanisms are they can provide land users with more tailored incentives to achieve environmental improvements, the incentives for improvement are dynamic and ongoing, and they provide more flexibility for individual adjustment, helping to ensure that the marginal benefits of abatement equate to marginal costs at the farm level (Windle and Rolfe 2008). Compared to regulatory or direct grant processes, these competitive mechanisms are more likely to indicate the marginal value of the resources being used to produce the environmental service, and to minimise opportunities for rent seeking behaviour (Latacz-Lohmann and van der Hamsvoort 1998).

An attractive outcome of water quality tenders and trading mechanisms is that they reveal the opportunity costs for landholders to provide environmental improvements (Jack et al. 2008). This addresses a key problem of asymmetric information for policy makers (Segerson 1988, Ferraro 2008). Information about the costs of potential supply of water quality improvements are typically needed to first evaluate if it is worthwhile to address an environmental issue. Cost benefit analysis is appropriate for the evaluation stage, where the potential costs of water quality improvements are compared with the public benefits of the environmental outcomes. Once a decision to intervene has been made, detailed information about supply costs is required to design different policy mechanisms (Jack et al. 2008).

There is very limited scope to generate information about potential water quality supply schedules prior to scheme design. Analysis of current water quality markets with similar participants and tradeoffs would be an option for gaining some information about expected supply patterns, but there is a dearth of such schemes in operation, particularly in relation to non-point sources. Bioeconomic modelling is an alternative approach where interactions between production systems models and ecological impact models are used to identify how changes in agricultural management systems may lead to differing amounts of environmental outputs. However, the modelling is difficult to perform accurately, is typically averaged across production units, and rarely captures the individual and farm-level characteristics that drive incentives at the production unit.

Emerging approaches to the estimation of supply information are to use experiments and trials of trading mechanisms. These have developed as ways of 'road testing' auction mechanisms with human interactions (Cason and Gangadharan 2004) and to provide advice into policy formation (Cummings et al. 2004). In the same way that flight engineers use wind tunnels to test airplane design, the experimental economics discipline provides methods to test the economic design of auction methods and confirm whether theoretical predictions are appropriate guides to real human behaviour (Shogren 2004). Information from well designed experiments and competitive tenders can be used to formulate a supply curve for emission reductions, revealing price information about true abatement costs.

There are three broad forms of experimental procedures available. The first are laboratory experiments, usually underpinned by bioeconomic models. In these economic experiments the tradeoffs are tightly controlled and carefully defined to subjects, university students are often involved as participants, and potential monetary payments from the workshop are typically used as incentive mechanisms. The second are field experiments, where simulated farms are used, farmers are involved as participants, and a variety of different incentive mechanisms may be used[1]. The third group are field trials, where exploratory applications may be tested prior to the full roll-out of a conservation auction. Laboratory experiments have advantages of being tightly controlled, and can provide insights into human behaviour when the endowments or rules of engagement are changed (Roth 2002; Cason et al. 2003). Field experiments and trials have more confounding variables involved, but provide more direct feedback on the potential costs of supply and how landholders of interest would behave

[1] A more general bibliography of framed field experiments is provided by John List at http://www.fieldexperiments.com/

if different forms of conservation auctions were introduced (List and Shogren 1998, List and Lucking-Reiley 2002, Rolfe et al. 2009).

Water quality tenders are equivalent to a conservation auction, where a competitive process is used to allocate funds for the purchase of environmental services. Conservation auctions such as the BushTender program in Australia (Stoneham et al. 2003) have been used to identify landholders who can provide on-farm conservation and biodiversity protection actions at lowest cost. Water quality tenders operate in the same way to identify landholders who can generate water quality improvements, and thus environmental benefits, at lowest cost. Under the programs, landholders are invited to submit tenders specifying their proposed actions and compensation (bid) levels, and a subsequent evaluation process identifies the environmental benefits involved and the most cost effective proposals.

Competitive tender mechanisms differ from the more traditional grants programs in a number of ways (Latacz-Lohmann and van der Hamsvoort 1997, 1998). In particular, there is:

- More focus on landholders to propose actions and the level of financial incentives required,
- A focus on the environmental services or improvements (outputs) that will be generated rather than a set of management changes (inputs);
- Variable payment levels relative to the level of environmental improvements gained rather than set payment levels;
- A stronger focus on selection of the most cost-effective proposals from landholders rather than on participation and engagement; and
- Evaluation of proposals by comparing the environmental benefits against the payment required rather than by set criteria or assessment panels.

There are several ways that a water quality tender can be designed, with the auction process typically being tailored to suit the situation in which it is being applied (Klemperer 2002). The application of a tender normally involves a careful planning process to identify if a market can be created and to deal with issues of auction design. There are three key elements in a tender that govern the process and influence the final outcomes:

- Auction design, where the process for conducting the conservation tender and the rules of engagement are specified;
- Metric design, where the mechanism for evaluating the amount of environmental benefit involved in landholder bids is provided; and
- Contract design, where the rules for specifying, monitoring and enforcing agreements are specified.

The auction design specifies the rules for the process and engagement with landholders. Design issues include the selection of the auction type and bidding rules, whether to have sealed or open bids, whether to select on uniform or discriminatory prices, and the number of bid rounds to be run. There are also a number of operational issues to consider, including the entry requirements for bidders, information provision, and the logistics of conducting the tender process.

The purpose of the metric design is to assess the environmental outcomes of each project proposal in a single score that can then be compared against the costs of the proposal. However, defining environmental outcomes such as biodiversity or water quality improvements is complex, and there is no consensus about how a biodiversity objective might be defined or what features need to be optimized. This means that even when there is some agreement on what biodiversity components may be important in a specific situation, there are many plausible scoring functions for a given conservation context (Ferraro 2004). The steps performed in a standard cost-effective metric for water quality tenders can be summarised in the following way:

Assess on-farm reduction in pollutants for each proposal	→	Make adjustments for farm and distribution factors	→	Account for impacts over time	→	Represent impacts in a single index	→	Rank proposals by ratios of index / cost

The purpose of the contract design stage is to ensure that once the preferred proposals have been selected there is an effective process to enter into agreements with landholders and ensure that activities are performed. The contact design stage will normally involve considerations of the type, structure and duration of the agreement, the payment schedule, and the monitoring and enforcement provisions.

4. Case study applications

The water quality tenders in the GBR catchments were designed in part to capture information about the potential variation in opportunity costs within and across agricultural sectors, as well as across different geographic areas. If variations in opportunity costs are very small, then the traditional government approach of using granting mechanisms and allocating funds across industries and areas may be effective. However, if larger variations in opportunity costs exist, then efficiencies can be gained by identifying and selecting the most cost-effective proposals. In this section the performance of the different water quality tenders is reviewed to identify if there is variation in opportunity costs within tenders.

The four water quality tenders in the GBR catchments were performed separately, but there was a substantial degree of commonality in the design and application across the projects. Each involved a call to landholders for proposals relevant to water quality improvements where landholders had to specify the financial incentive they required. In the Mackay sugarcane tender the selection of the proposals followed a simplistic categorisation process, but a subsequent application of a metric as a desktop exercise allows cost-efficiency data to be estimated. The other three tenders in the Mary, Kolan and lower Burdekin catchments were designed and applied as water quality tenders. Key aspects of the tender design and process were common across the case studies. These included:

single bidding round,

sealed bids,

discriminatory pricing,

an (unspecified) reserve price,

multiple bids allowed from landholders,

one year contracts for successful bidders,

simple contracts used to secure agreements, and

simple monitoring and reporting processes.

A similar metric used to assess the cost-effectiveness of proposals was applied in a four step process for each case study. First, an estimate was made of the amount of each type of emission reduction that would result from the management practice change in each proposal. Second, adjustments were made to account for the effectiveness of the different projects and to consider factors that could impact on the net environmental outputs. Third, further adjustments were made to account for the temporal scope of the different projects. Fourth, the estimated emission reductions were converted to proportions of catchment emission targets as outlined in GBRMPA (2001).[2] This allowed the different types of emissions to be represented in the same units and then summed for each proposal into a single environmental benefit index.

Once each proposal had been summarised into an environmental benefits score (EBS), essentially representing the proportional contribution to emission reduction targets, the cost effectiveness could then be calculated as the ratio of the EBS to the cost of the proposal. This relative bid value was then used to rank the proposals in terms of cost effectiveness and select the ones that generated the largest water quality improvements per dollar of investment. As estimates were made of the amount of pollution reductions that would be generated from each proposal that was funded, it is possible to estimate the cost of pollutant reduction for each bid. This allows a comparison of pollution reductions to be performed within schemes and across schemes (Table 1). First, a brief description of the results of each tender is provided below.

4.1 The Mackay cane incentive scheme

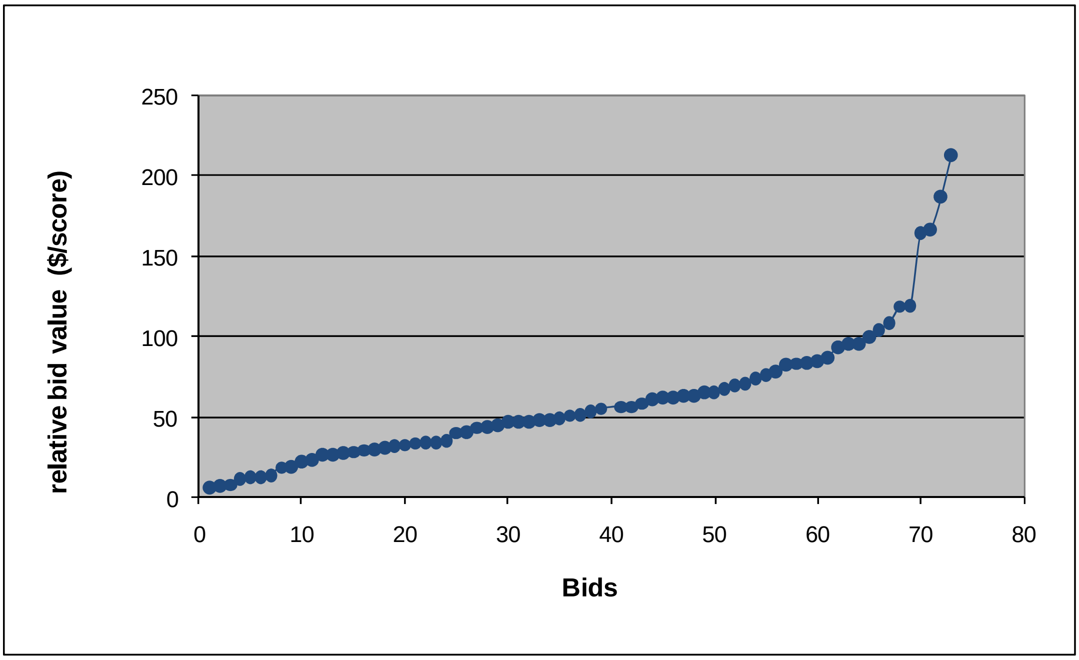
The Sustainable Landscape program implemented in the Mackay region in 2005/2006 was a large incentive scheme focused on sugarcane producers (Rolfe et al. 2007). The call for stormwater management projects within this program was consistent with a competitive tender process, allowing 75 landholder proposals to be subsequently assessed on the amount of sediment and nutrient reductions they provided. There were three types of stormwater management projects that competed for $582,000 in funding:

- eight constructed wetlands;
- 11 sediment detention traps; and
- 56 grassed waterways for irrigation.

A summary of the relative bid values from the proposals (with two outliers removed) is presented in Figure 3.

Figure 3: Relative bid values for stormwater projects in the Mackay cane scheme

[2] At the time all the case studies were conducted, these were the only available catchment targets.

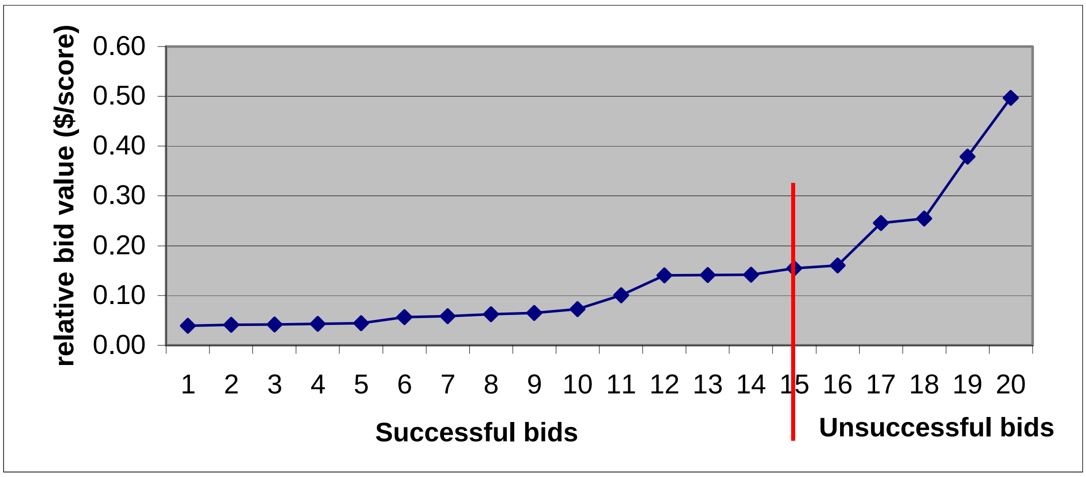


4.2 The Burnett Mary dairy tender

This tender was run in the lower Mary River catchment (at the southern end of the GBR catchments) as a small scale pilot trial in 2006/2007 (Rolfe and Windle 2008). The tender focused on achieving nitrogen and phosphorus reductions, with projects encouraged under two main categories; riparian management (keeping cows out of waterways) and effluent management (preventing effluent from milking areas from entering waterways).

There were 28 producers in the area that were eligible to participate in the tender for a budget of $165,000. A total of 20 bids were received from 14 producers. Fifteen projects were successful (eight riparian management and seven effluent management projects) and five were unsuccessful (Figure 4).

Figure 4. Relative bid values in the Burnett Mary dairy tender



4.3 The Burnett Mary horticulture tender

The horticulture tender was another small scale trial implemented in the Kolan River catchment (north of Bundaberg) with a pool of 45-50 eligible horticultural producers (Rolfe and Windle 2008). The tender was run in 2007 with a funding budget of $100,000. A total of 17 proposals were submitted from eight growers. Thirteen proposals were successful, which included:

seven stormwater management projects (recycle pits);

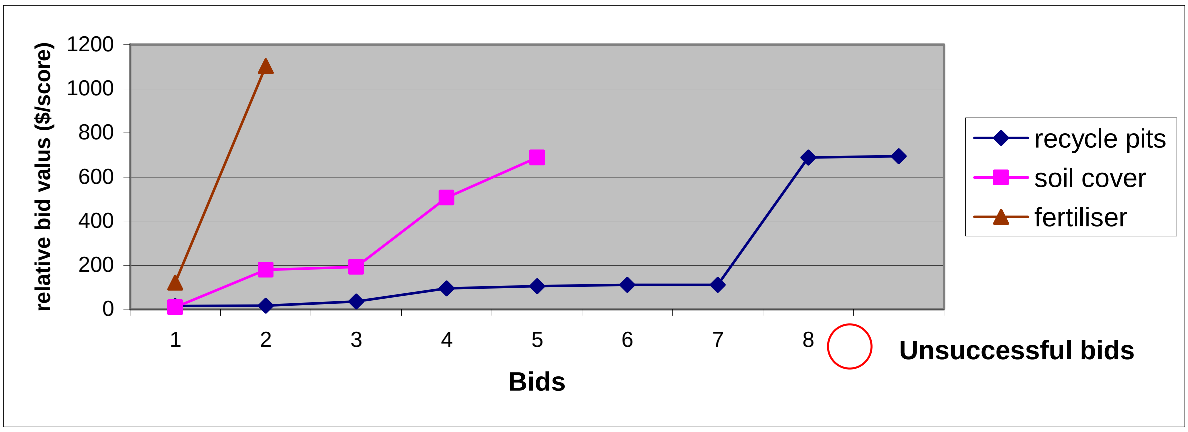
four projects relating to improved soil cover;

one project relating to fertiliser management; and

one project relating to pesticide management.

The environmental benefits of the projects were focused on sediment, nutrient (N and P) and pesticide reductions. The relative bid values by management category are shown in Figure 5.

Figure 5. Relative bid values in the Burnett Mary horticulture tender



Note: the most cost effective bid (pesticide) with a relative bid value of 0.4 is not included.

4.4. The Burdekin cane and grazing tender

The Burdekin water quality tender was implemented in the lower Burdekin and Haughton River catchments in northern Queensland in 2007/2008 (Rolfe et al. 2008a). The tender included both the sugarcane and grazing industries and had a funding budget of $600,000. A total of 87 project proposals were submitted, of which nine came from the grazing industry and 78 from the cane industry. Thirty-three proposals were successful, which included:

five pesticide management projects;

eight water management projects;

nine recycle pit projects;

seven nutrient management projects; and

four grazing management projects.

The lower Burdekin area, where sugarcane is mainly grown, is very flat and soil erosion from cane paddocks is not considered a serious environment issue in the industry. Consequently, emissions of sediments and phosphorus were not estimated for the sugar industry. The reductions in emissions were focused on the following categories:

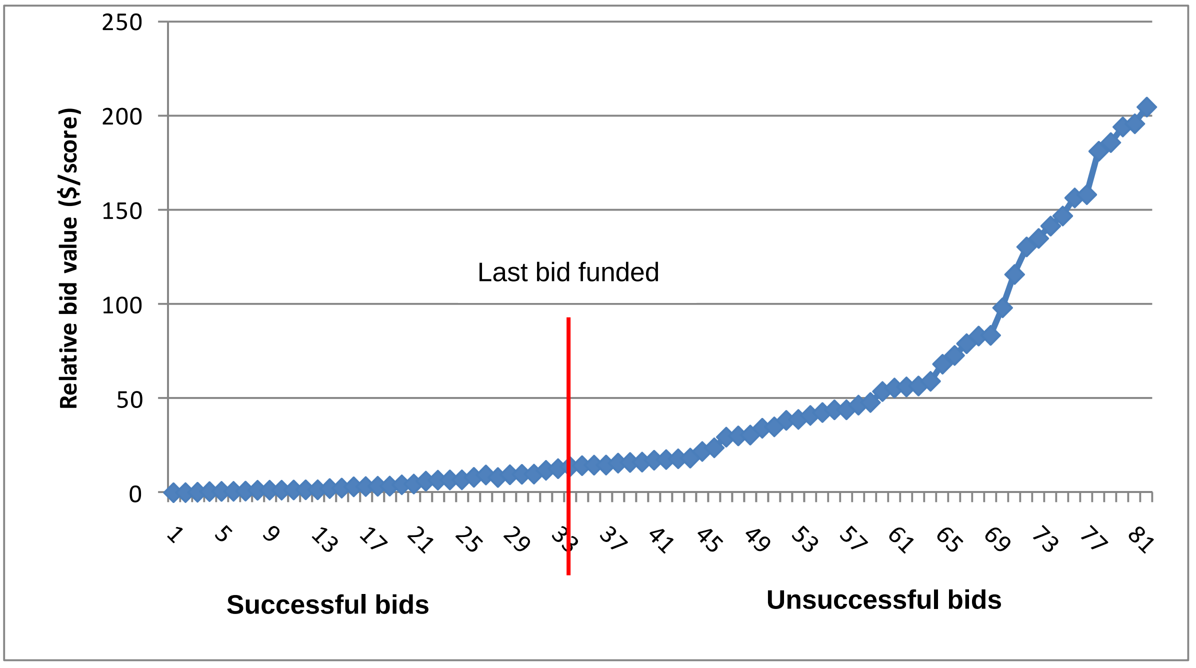
nitrogen reductions (sugarcane projects);

pesticide reductions (sugarcane projects); and

sediment reductions (grazing projects).

The range in cost effectiveness of the sugarcane projects in reducing nitrogen emissions is presented in Figure 6.

Figure 6: Relative bid values in the Burdekin cane tender



4.5. Variations in opportunity costs within tenders

The tender results show that large variation in opportunity costs has been revealed in each tender process, even when they are smaller scale and focused on particular industries and limited geographic areas. Taking the Burdekin tender as an example, the 10 most highly ranked projects cost $180,574 and were modelled to capture 47,510 kgs of nitrogen ($1.70/kg), 51.6 kgs of pesticide ($1,579/kg), and 29.8 tons of sediment ($117.4/ton). In comparison, the 10 lowest ranked projects would have cost $495,808 and were modelled to capture 870 kgs of nitrogen ($290.78/kg), no pesticides and 18 tons of sediment ($13,480/ton). The level of cost-effectiveness varied by more than 100 times between the 10 most highly-ranked projects and the 10 most lowly-ranked projects. This variation in the cost-effectiveness of proposals confirms the potential for competitive tenders to generate improvements in resource allocation. It also indicates that traditional grant approaches, with little evaluation of outputs, may disguise large inefficiencies in funding.

5. Cost-effectiveness across pollutants and tenders

There are wider questions about how resources should be allocated to reducing the emissions of different pollutant types, and whether reduction costs are consistent across catchments. Information on these issues can be gained by identifying within each tender how funding was allocated to reducing different pollutants, and comparing across tenders. Comparisons of reduction costs for the different pollutants across the tenders are reported in this section, using data from only the successful proposals in each water quality tender.

Summary details of the different tenders are presented in Table 1.

Table 1. Summary statistics for the water quality tenders (successful bids only)

	Burnett Mary: Dairy	Burnett Mary: Horticulture	Burdekin: Cane + Grazing	Mackay/ Whitsunday: Cane
Total cost	$165,000	$100,000	$605,000	$582,000
Successful Bids	15	13	4 grazing 29 cane	75
Sediment			(grazing only)	
Sediment reduction (tons)	-	53,661	492	114,300
Sediment reduction cost	-	$86,987	$78,534	$464,000
Av. Reduction cost ($/ton)	-	$1.62	$89.22	$4.06
Reduction price range ($/ton)	-	$0.26 – $6.23 + 1 outlier	$29.81 – $209.14	$0.67 – $14.11 + 2 outliers
Nitrogen			(cane only)	
Nitrogen reduction (kg)	204,980	25,811	96,016	38,303
Nitrogen reduction cost	$91,191	$5,837	$437,625	$53,761
Av. Reduction cost ($/kg)	$0.44	$0.23	$4.56	$1.40
Reduction price range ($/kg)	$0.21 – $0.79 + 1 outlier	$0.03 – $0.65 + 2 outliers	$0.65 – $17.49	$0.14 – $8.64 + 1 outlier
Phosphorus				
Phosphorus reduction (kg)	30,737	3,692	-	5909.23
Phosphorus reduction cost	$73,784	$6,576	-	63,837
Av. Reduction cost ($/kg)	$2.40	$1.78	-	$10.80
Reduction price range ($/kg)	$1.19 – $4.47 + 1 outlier	$0.17 – $3.92 + 2 outliers	-	$0.64 – $81.35
Pesticide			(cane only)	
Pesticide reduction (kg)	-	-	55.5	-
Pesticide reduction cost	-	-	$93,769	-
Av. Reduction cost ($/kg)	-	-	$1,689	-
Reduction price range ($/kg)	-	-	$735 - $16,563	-

There were small differences in the metrics used for the tenders, which slightly confounds some of the comparisons:

No adjustments were made in the Mackay-cane projects or the Burnett-Mary horticulture tender to account for varying effectiveness of different management actions. This meant the benefits of these projects may have been slightly overestimated compared with the other case studies.

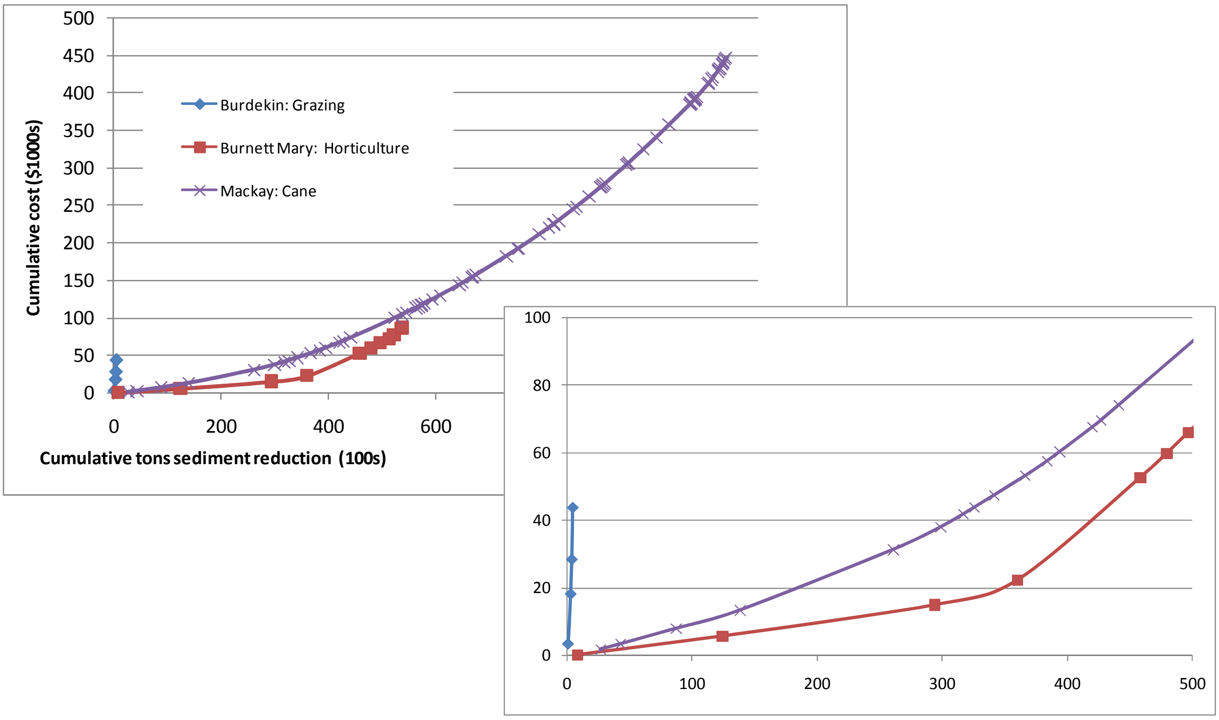
The Burdekin-cane projects were only assessed for their contribution to nitrogen emissions which made them relatively more expensive.

The variation in funding scale in the tenders may also generate some differences, as this can influence the number and types of proposals being offered. The strongest comparisons are between the Burdekin and Mackay tenders (larger scale funding), and between the dairy and horticulture tenders in the Mary-Burnett (smaller scale funding).

5.1 Sediment reductions

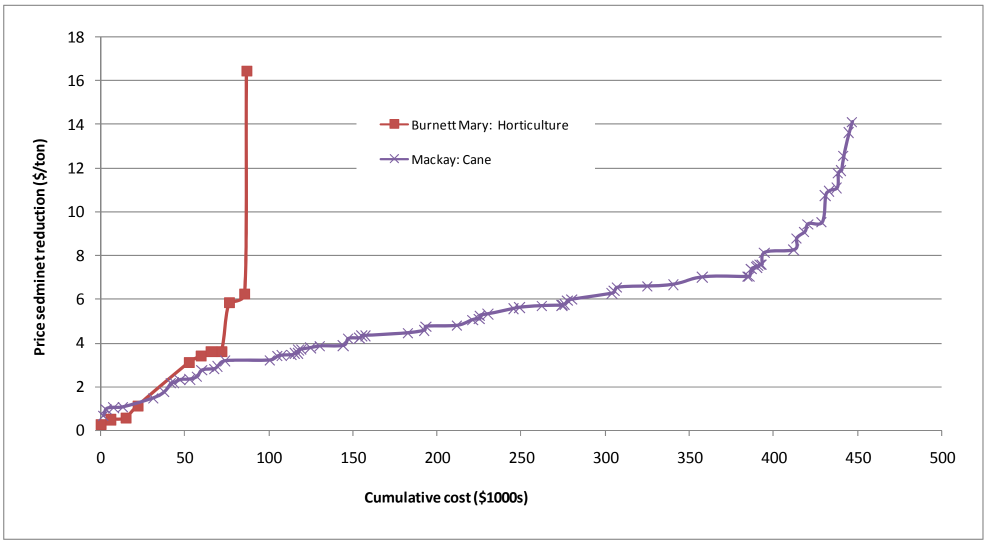
The projects that delivered the most cost effective reductions in sediment emissions came from the Mackay-cane and the Mary-Burnett horticulture sectors, with the latter out-performing the former (Figure 7). If funding had been set at $100,000 (the cap for the horticulture tender), the Mackay-cane projects would only have provided 84% of the sediment reductions compared with the horticulture projects. However, the main benefits in the horticulture sector came from a few very cost effective bids, after which the gains were not so apparent. The Burdekin grazing projects proved to be a very costly means of providing sediment reductions.

Figure 7. Sediment reduction costs



The price per ton of sediment reduction can be compared between the two most cost effective tenders (Figure 8). Apart from the first four projects in the Burnett-Mary horticulture tender, the Mackay-cane projects provided sediment reduction at a lower price ($/ton).

Figure 8. Sediment reduction prices



5.2 Nitrogen reductions

The cost of reductions in nitrogen emissions were calculated from each of the tenders (Figure 9). There are substantial differences in cost-effectiveness, with nearly $446,000 allocated in the Burdekin to reduce 98,000 kgs of nitrogen compared to nearly $200,000 allocated in the Burnett-Mary dairy tender to reduce more than 200,000 kgs of nitrogen.

The dairy sector was able to provide the cheapest reductions (Figure 10). The average price of nitrogen reduction from the dairy sector was $0.44 per kilogram compared with the Burdekin-cane sector which was the most expensive at $4.56 per kilogram of reduction. At funding levels of less than $30,000 the prices of the Mackay and Burdekin projects were very similar, but then projects from the latter become more competitive.

Figure 9. Nitrogen reduction costs

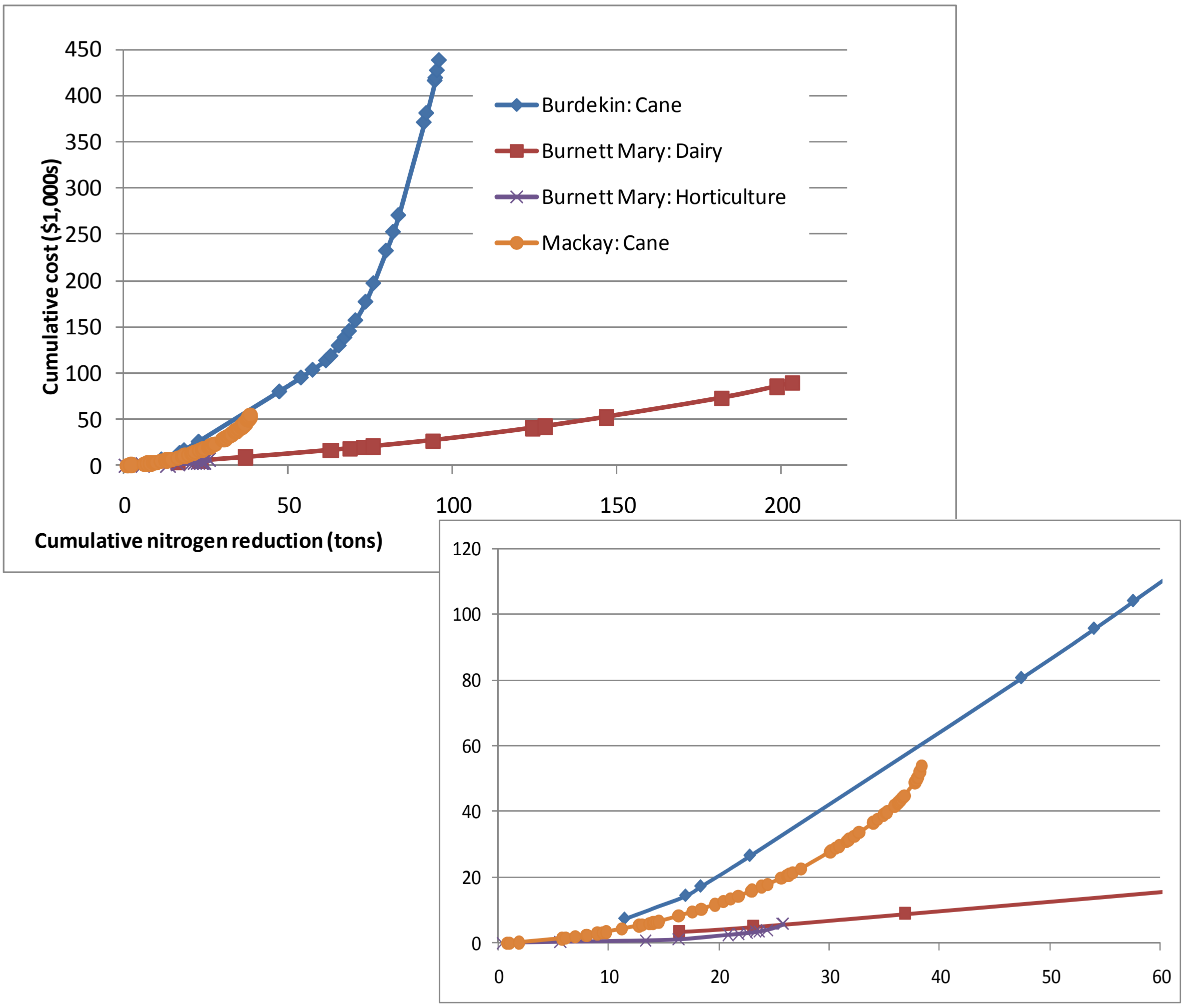
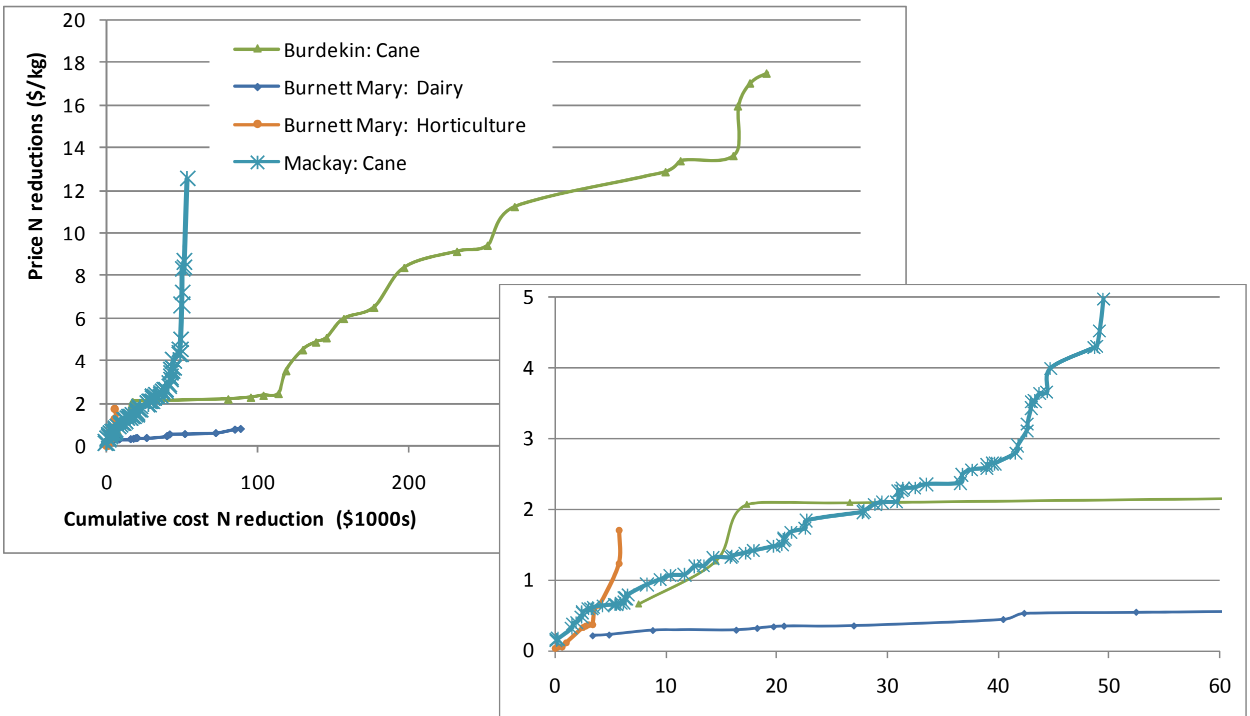


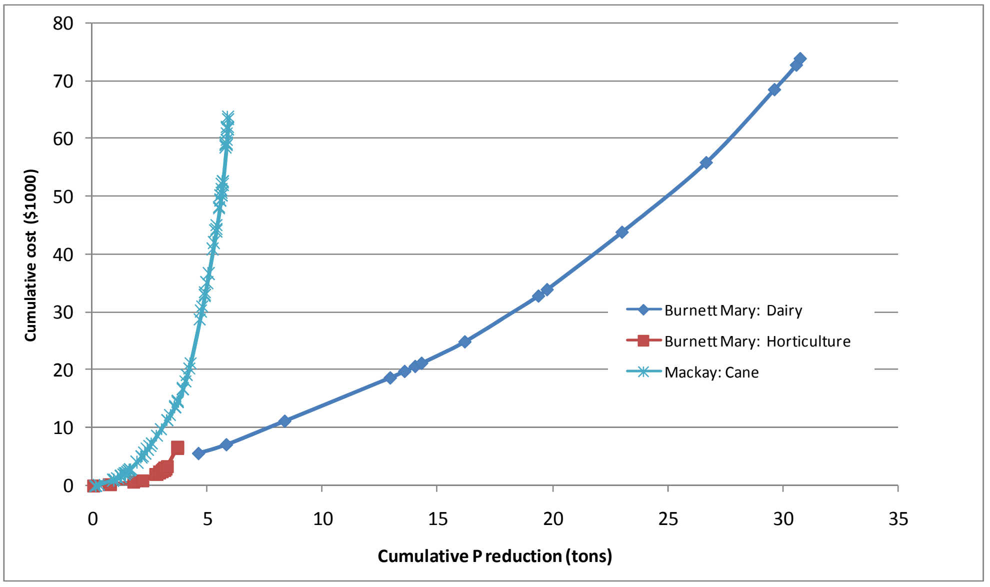
Figure 10. Nitrogen reduction prices



5.3 Phosphorus reductions

The cost of reductions in phosphorus emissions were calculated from three of the tenders (Figure 11). The dairy tender generated more extensive reductions than the horticulture tender, and more cost effective reductions than the Mackay-cane tender. At an expenditure of $60,000, the dairy tender generated more than 5 times the reduction in phosphorus emissions than the Mackay-cane tender.

Figure 11. Phosphorus reduction costs



The dairy sector produced the cheapest reductions in phosphorus emissions (Figure 12). The average price of phosphorus reductions from the dairy sector was $2.40 per kilogram compared with the most expensive in the Mackay-cane sector at $10.80 per kilogram reduced. Again there were some project outliers that act to increase the average price of emission reduction for the overall tender projects. In particular, there was a steep rise in prices in the Mackay-cane projects prices after a funding level of approximately $60,000. Had the funding level been capped at this point, the average price would only have fallen by $0.58 per kilogram of reduction.

5.4 Pesticide reductions

The cost of reductions in pesticide emissions were calculated for funded projects in the Burdekin tender (Figure 13), where $94,000 was allocated to reduce pesticide emissions by 55.5 kilograms, at an average cost of $1,690 per kilogram[3].

[3] The pesticides were calculated in terms of the active constituents of Atrazine, Diuron and 2-4D, which are the key residual pesticides of concern.

Figure 12. Phosphorus reduction prices

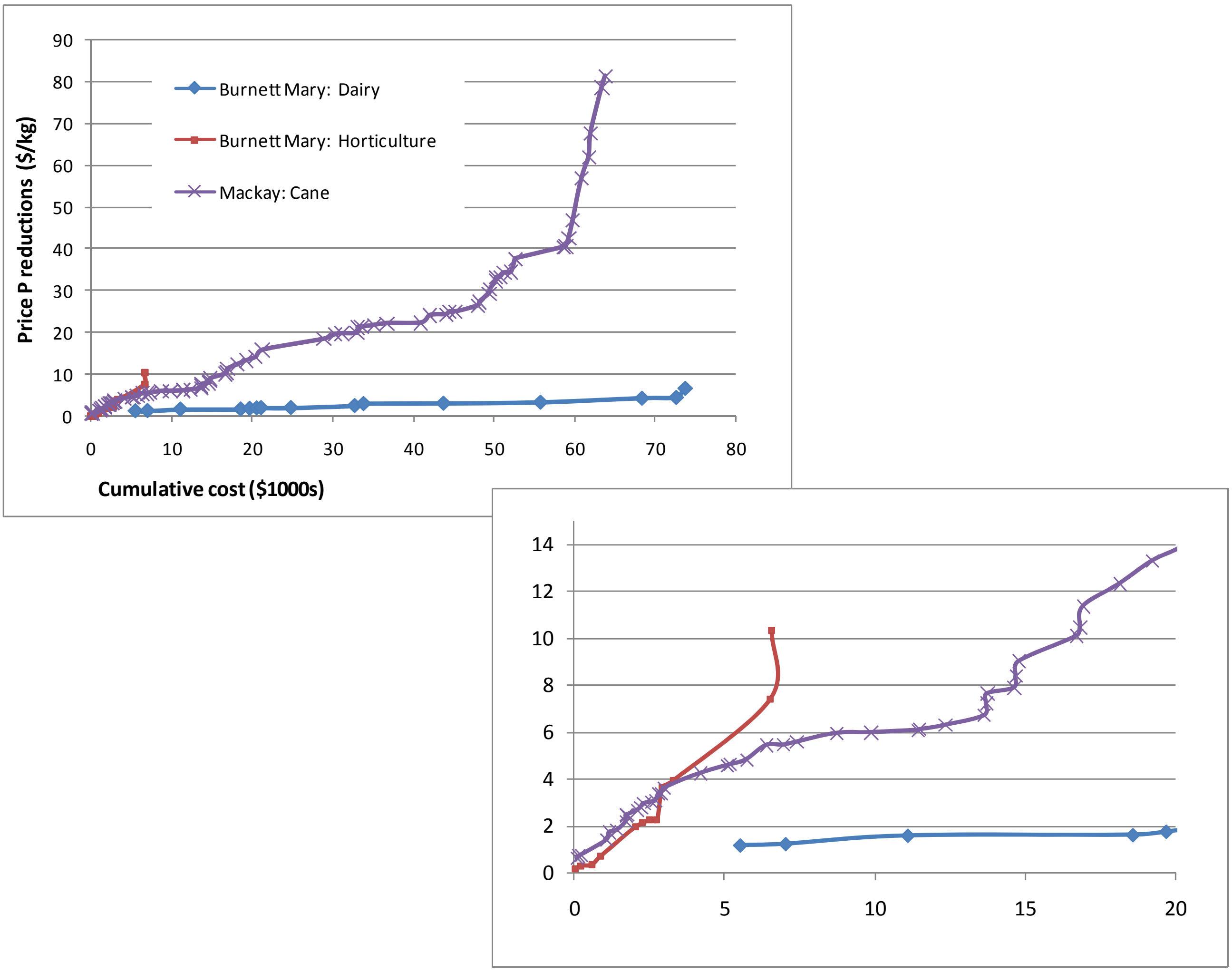
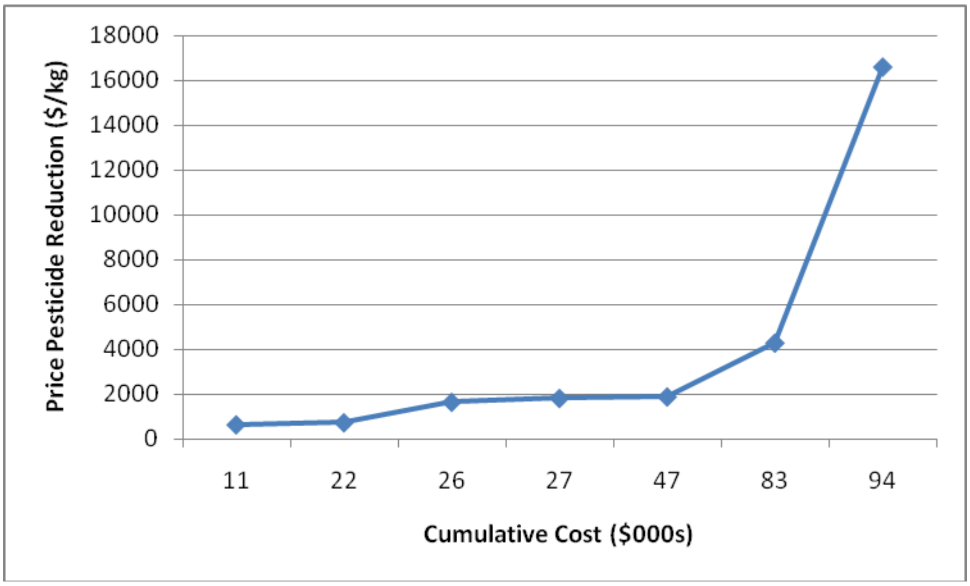


Figure 13. Pesticide reduction prices



5.5 Variations in cost-effectiveness across pollutants and programs

The comparison of the costs of emissions reduction across pollutants and catchments shows significant variations between tender results (Table 2). There are four broad conclusions that can be drawn from the data. First, there are very substantial variations in opportunity costs for achieving a reduction in a pollutant type. The cost of reducing nitrogen emissions in only the funded bids varied from the most efficient price of $0.03/kg to the most expensive price of $17.49/kg, almost 600 times more expensive.

Second, there are significant variations in the cost of achieving pollution reductions between the different agricultural sectors. These results indicate that the most cost-effective water quality improvements may be generated from the horticulture and dairy sectors. However, these industries only account for a very small proportion of land use in GBR catchments (Table 2). In contrast, the opportunity costs of reducing emissions from the cane and grazing industries appear to be higher.

Third, opportunity costs may potentially vary across catchments within the same industry sector. This is demonstrated by the variation in costs to achieve nitrogen reductions from the cane industry in two different regions (Mackay and Burdekin), where reduction costs are approximately three times higher. It is likely that differences in opportunity costs will be lower for catchments that share similar production systems. Rolfe et al. (2008a) reported that there was no significant difference in reduction costs for nitrogen for two sugar cane production areas in adjacent sub-catchments in the lower Burdekin.

Fourth, the difference in opportunity costs between pollutant types raises a number of questions about the relative efficiency of different pollution reductions. The average cost of reducing a kilogram of pesticide emissions in the Burdekin was more than 7,000 times the cost of reducing a kilogram of nitrogen emissions in the Burnett-Mary catchment from the horticulture industry.

Table 2. Average cost of emission reductions (successful bids only)

	Burnett Mary: Dairy	Burnett Mary: Horticulture	Burdekin: Cane + Grazing	Mackay/ Whitsunday: Cane
Total cost	$165,000	$100,000	$605,000	$582,000
Sediment reduction Average price ($/ton)	-	$1.62	$89.22	$4.06
Nitrogen reduction Average price ($/kg)	$0.44	$0.23	$4.56	$1.40
Phosphorus reduction Average price ($/kg)	$2.40	$1.78	-	$10.80
Pesticide reduction Average price ($/kg)	-	-	$1,689	-

6. Conclusions

The case study examples of water quality tenders that are presented in this paper demonstrate the potential for more efficient resource allocation to address water quality issues. The costs of improving water quality through changed agricultural management practices vary substantially: across producers, agricultural sectors, and catchments. In a classic case of information asymmetry, policy makers have been allocating (and continue to allocate) substantial public funding to address water quality issues in the GBR with scant information about the cost efficiencies of different investment options. These results show how important that cost-effectiveness information is.

The reported case studies demonstrate that water quality tenders have an important ability to reveal opportunity costs, and can be used both as an information revelation tool and a resource allocation mechanism for policy makers designing better systems to address water quality problems. The water quality tenders reported in this paper have helped to avoid the allocation of public funding to a number of proposals that would have generated lower levels of environmental benefit. However, an analysis of the results has demonstrated that there are still very large variations in the opportunity costs of achieving reductions across agricultural sectors, across catchments, and between pollutant types.

Some caveats must be noted in any extrapolation of these results. First, there are often efficiencies available in the application of smaller scale tenders because of the ability to work more closely with individual landholders and attract more cost-effective bids. This may help to explain why the emission reduction costs from the two small tenders in the Burnett-Mary catchment were much lower than the larger ones in the Mackay and Burdekin regions. Second, there were some differences in the assessment metrics used, which might have contributed to some variations in opportunity costs. However, these variations are not significant enough to confound the differences in opportunity costs that have been identified.

The results of these case studies allow two types of conclusions to be drawn. The first revolve around the role that market-like mechanisms such as water quality tenders can play in information revelation. Not only do these mechanisms help participants to search out the best opportunities for resource gains, but they reveal to policy makers the previously hidden information about the real opportunity costs of different management strategies. This information can then be used to design better allocation systems. Examples would be using this information to set reserve prices for funding environmental improvements or establishing the scale and scope of future water quality tenders.

The second group of conclusions revolve around implications for improving the efficiency of funding allocation for water quality improvements into the GBR. This can occur in two main ways. First, the effectiveness of public funding can be substantially improved by ensuring that funding is allocated across regions and industries so as to generate similar marginal improvements per dollar of investment. Greater attention to returns on investment and more use of competitive approaches to allocate funds will help to achieve this. Second, the efficiency of public funding should be tested by ensuring that the costs of generating different water quality improvements are lower than the public benefits that are realised. Valuing the benefits of water quality improvements in the GBR will help to identify where investments in improving water quality should be focused.

Acknowledgement

This research has been supported through the Environmental Economics Research Hub, funded by the Australian Department of Environment and Water Heritage and the Arts under the Commonwealth Environment Research Facility.

References

Cason, T.N. and Gangadharan L. (2004) Auction design for voluntary conservation programs, *American Journal of Agricultural Economics*, 86: 1211-1217.

Cason, T.N. and Gangadharan L. Duke C (2003) A laboratory study of auctions for reducing non-point source pollution, *Journal of Environmental Economics and Management* 46: 446-471.

Classon, R., Cataneo, A. and Johansson, R. (2008) Cost-effective design of agri-environmental payment programs: U.S. experience in theory and practice, *Ecological Economics* 65: 737-752.

Cummings, R.G., Holt, C.A. and Laury, S.K. (2004) Using laboratory experiments for policymaking: an example from the Georgia Irrigation Reduction Auction, *Journal of Policy Analysis and Management* 23: 341-363.

De'ath, G. and Fabricius, K.E. (2008) Water quality of the Great Barrier Reef: distributions, effects on reef biota and trigger values for the protection of ecosystem health, Final Report to the Great Barrier Reef Marine Park Authority, Australian Institute of Marine Science, Townsville.

Drewry, J., Higham, W. and Mitchell, C. (2008) *Water Quality Improvement Plan: Final report for Mackay Whitsunday region*, Mackay Whitsunday Natural Resource Management Group, Mackay.

Ferraro, P.J. (2004) Targeting conservation investments in heterogeneous landscapes: A distance function approach and application to watershed management, *American Journal of Agricultural Economics* 86(4): 905-918.

Ferraro, P.J. (2008) Asymmetric information and contract design for payments for ecosystem services, *Ecological Economics* 65(4): 810-821.

Furnas, M. (2003) *Catchments and Corals: Terrestrial Runoff to the Great Barrier Reef*, Australian Institute of Marine Science and CRC Reef Research Centre, Townsville.

Great Barrier Reef Marine Park Authority (GBRMPA) (2001) *Great Barrier Reef Catchment Water Quality Action Plan: A report to the Ministerial Council on targets for pollutant loads*, Great Barrier Reef Marine Park Authority, Townsville

Great Barrier Reef Marine Park Authority (GBRMPA) (2008) *Water quality guidelines for the Great Barrier Reef Marine Park Draft Report*, Great Barrier Reef Marine Park Authority, Townsville.

Hajkowicz , S., Spencer, R., Higgins, A., Marinoni, O. (2008) *Evaluating water quality investments using cost utility analysis*, *Journal of Environmental Management* 88: 1601-1610.

Haynes, D., Brodie, J., Waterhouse, J., Bainbridge, Z., Bass, D. and Hunt, B. (2007) Assessment of the water quality and ecosystem health of the Great Barrier Reef (Australia): Conceptual models, *Environmental Management* 40: 993-1003.

Independent Panel of Scientists (2008) *Synthesis of evidence to support the Scientific Consensus Statement on Water Quality in the Great Barrier Reef*, Queensland Department of Premier and Cabinet, Brisbane.

Jack, K.B., Leimona, B. and Ferraro, P. (2008) A revealed preference approach to estimating supply curves for ecosystem services: Use of auctions to set payments for soil erosion in Indonesia, *Conservation Biology* 23(2): 359-367.

Klemperer, P. (2002) What really matters in auction design, *Journal of Economic Perspectives* 16(1): 169-189.

Latacz-Lohmann, U. and Van der Hamsvoort, C. (1997) Auctioning conservation contracts: a theoretical analysis and application, *American Journal of Agricultural Economics* 79(2): 407-418.

Latacz-Lohmann, U. and Van der Hamsvoort, C. (1998) Auctions as a means of creating a market for public goods from agriculture, *Journal of Agricultural Economics* 49(3): 334-345.

List, J.A. and Lucking-Reiley, D. (2002) Bidding behavior and decision costs in field experiments, *Economic Inquiry* 40: 611-619.

List, J. and Shogren, J. (1998) Calibration of the difference between actual and hypothetical valuations in a field experiment, *Journal of Economic Behaviour and Organization* 37: 193-205.

Pannell, D. (2009) Australian environmental and natural resource policy – from the Natural Heritage Trust to Caring for our Country, Invited Paper presented at the 53rd Annual Australian Agricultural and Resource Economics Society Conference, Cairns.

Productivity Commission (2003) In*dustries, Land Use and Water Quality in the Great Barrier Reef Catchment*, Australian Government, Canberra.

Rolfe, J., Fihue, G., Donaghy, P. and Wake, J. (2007) Evaluating an incentive program for improvement in land management: The sustainable landscape program at Mackay, Paper presented at the 51st Annual Australian Agricultural and Resource Economics Society Conference, Queenstown, New Zealand.

Rolfe, J., Greiner, R., Windle, J., Hailu, A. and Gregg, D. (2008a) *Testing for scope and scale efficiencies in water quality tenders: Final Report*, Using Conservation Tenders for Water Quality Improvements in the Burdekin Research Report 7, Central Queensland University, Rockhampton.

Rolfe, J., Windle, J. and Bennett, J. (2008b) *Designing choice experiments to incorporate tests for geographic scale and scope differences,* Assessing protection values for the Great Barrier Reef research reports, Environmental Economics Research Hub Research Report #3, http://www.crawford.anu.edu.au/research_units/eerh/index.php (accessed 24th March 2009)

Rolfe, J. and Windle, J. (2008) Tendering for water quality improvements in agriculture: lessons from the dairy and horticulture industries in the Burnett Mary region, Queensland, paper presented at the 52nd Annual Australian Agricultural and Resource Economics Society Conference, Canberra.

Rolfe, J., Windle, J. and McCosker, J. (2009) Using field experiments to explore the use of multiple bidding rounds in conservation auctions, *Canadian Journal of Agricultural Economics* 57: 287-303.

Roth, A.E. (2002) 'The economist as engineer: game theory, experimentation, and computation as tools for design economics', *Econometrica* 70(4): 1341-1378.

Scheltinga, D.M. and Heydon, L. (eds) (2005) *Report on the Condition of Estuarine, Coastal and Marine Resources of the Burdekin Dry Tropics Region*, Burdekin Dry Tropics Board, Townsville.

Science Panel (2003) *A report on the study of land-sourced pollutants and their impacts on water quality in and adjacent to the Great Barrier Reef*, Queensland Department of Premier and Cabinet, Brisbane.

Segerson, K. (1988) 'Uncertainty and incentives for non-point pollution control', *Journal of Environmental Economics and Management* 15: 87-98.

Shogren, J.F. (2004) 'Incentive mechanism testbeds: discussion', *American Journal of Agricultural Economics* 86: 1218-1219.

State of Queensland and Commonwealth of Australia (SQCA) (2003) *Reef Water Quality Protection Plan for catchments adjacent to the Great Barrier Reef World Heritage Area*, Queensland Department of Premier and Cabinet, Brisbane.

Stoneham, G., Chaudhri, V., Ha, A. and Strappazzon, L. (2003) 'Auctions for conservation contracts: an empirical examination of Victoria's BushTender trial', *Australian Journal of Agricultural and Resource Economics* 47(4): 477-500.

Teitenberg, T.H. (2006) *Emissions Trading: Principles and Practice*, Resources for the Future, Washington D.C.

Vandergragt, M., Heales, M., Tilden, J., Rissik, D. and Playford, J. (2008) 2007 *Water Quality Report: Great Barrier Reef catchments and inshore ecosystems*, Queensland Environmental Protection Agency, Brisbane.

Windle, J. and Rolfe, J. (2008) 'Exploring the efficiencies of using competitive tenders over fixed price grants to protect biodiversity in Australian rangelands', *Land Use Policy* 25: 388-398.