International Environmental Modelling and Software Society (iEMSs)
2012 International Congress on Environmental Modelling and Software
Managing Resources of a Limited Planet, Sixth Biennial Meeting, Leipzig, Germany
R. Seppelt, A.A. Voinov, S. Lange, D. Bankamp (Eds.)
http://www.iemss.org/society/index.php/iemss-2012-proceedings

Economic incentive-based instruments for the adoption of management options for water quality improvement in heterogeneous sugarcane farming communities

M.E. van Grieken[A], P.C. Roebeling[B], I.C. Bohnet[C], S.M. Whitten[D] and A.J. Webster[C]

A - CSIRO Ecosystem Sciences, GPO Box 2583, Brisbane, QLD 4001, Australia. Email: martijn.vangrieken@csiro.au
B - CESAM, Universidade de Aveiro, 3810-193 Aveiro, Portugal.
C - CSIRO Ecosystem Sciences, PO Box 12139, Earlville BC 4870, Australia.
D - CSIRO Ecosystem Sciences, GPO Box 284, Canberra, ACT 2601, Australia

Abstract: There is growing recognition that coastal water quality is interdependent with agricultural management in coastal catchments. Economic incentive-based instruments can be used to internalize the negative externalities from coastal water pollution. In this paper we assess a performance-based instrument for promoting the adoption of management practices for water quality improvement in heterogeneous sugarcane farming communities in the Great Barrier Reef (GBR) region, with emphasis on regional income and dissolved inorganic nitrogen (DIN) delivery impacts. We combine financial and environmental analyses of farming systems at the paddock scale with a mathematical modelling approach at the farm scale, differentiating for three farm typologies, aggregated to the catchment scale. Management practice adoption rates are assessed by exploring how different types of farmers are likely to respond to economic incentive-based instruments, using a nutrient accounting system to institute both levies and bonuses that, respectively, penalise pollution and provide incentives for reducing DIN export.

Keywords: Adoption; land use; land management; water quality improvement; heterogeneity; farming community; natural resource policy; Great Barrier Reef

1 INTRODUCTION

Coastal and marine ecosystems around the world are threatened by disturbances (e.g. climate change and water pollution) caused by human activity (Brodie et al., 2012). Estuarine and coastal water quality is adversely impacted by extensive eutrophication caused by the agricultural sector (Canfield et al., 2010). For example, (nonpoint source) pollution from agricultural activity is linked to the degradation of coastal ecosystems in the Great Barrier Reef (GBR), Australia (Kroon et al., 2011). Population growth, climate change and the intensification of industrial and agricultural activity are likely to increase eutrophication of estuarine and coastal waters (Rabalais et al., 2009). To address this issue, improved management of resources in coastal catchments is needed (Doney, 2010).

In this study we explore the potential socio-economic consequences of incentive-based instruments that are aimed to increase adoption of management practices for water quality improvement. We therefore model how different types of farmers respond to an economic incentives-based approach where pollution beyond a specified level is taxed, whereas improvement beyond this level is subsidised. This conceptual approach provides information regarding the cost-effectiveness of the instrument, but also likely socio-economic indicators, such as farm enterprise specific adoption rates.

The remainder of the paper is structured as follows; in the next section we provide background information for the research presented in this paper. In the following section we describe the methods used in this research followed by a section where we describe the modelling framework used to investigate the problem. We then present the results in a final section, followed by a discussion and conclusion.

2 BACKGROUND

The World Heritage listed Great barrier Reef (GBR), adjacent to the Queensland coast in Australia, is the largest reef system in the world with over 3,000 reefs covering an area of approximately 350,000 square kilometres, (Haynes and Michalek-Wagner, 2000). Degradation of GBR ecosystems has been linked with increases in land-based pollutant runoff since European settlement (Kroon et al. 2011). Pollutant sources have been identified and include suspended sediment from erosion in cattle grazing areas; nitrate from fertiliser application on crop lands; and herbicides from various land uses (Brodie et al. 2012). Sugarcane dominates agricultural production in the high risk GBR catchment of the Tully-Murray (Armour et al. 2009).

The majority of sugarcane grown in GBR catchments is located on floodplains, close to the end of catchments. This proximity to the end of catchments means water draining from sugarcane farms can reach the GBR lagoon quickly, leaving little opportunity for in-river processes to remove pollutants from the flow (Furnas and Mitchell, 2001). N losses in water from sugarcane production occur through two pathways, leaching via deep drainage below the root zone, or in surface runoff. Webster et al. (2012) reported N losses to both surface water and via deep drainage are reduced when lower nitrogen application rates are applied. They propose that nitrogen rate is the most important determinant of N losses, being more important than other management practices such as surface versus sub-surface fertiliser application.

In 2003, the Queensland state and the Australian Governments jointly launched a voluntary policy instrument, a 10-year commitment to address diffuse source pollution from agriculture to *halt and reverse the decline in water quality entering the GBR*, named the Reef Water Quality Protection Plan (Reef Plan; RWQPP 2003). In addition, in 2008, the Federal Government announced its Reef Rescue Program, including the Water Quality Grants Scheme ($146 million over 5 years) that provides land managers with matching funding to implement land management activities that will improve water quality run-off from properties. Furthermore, on January 2010 the Queensland Government introduced the Great Barrier Reef Protection Amendment Act 2009 (GBRPAA 2009) to regulate a number of specified activities on cattle grazing and sugar cane properties in catchments in the Wet Tropics, Burdekin and Mackay–Whitsunday regions.

3 METHODS

In this paper we use a bio-economic approach that explores the cost-effectiveness of improving catchment water quality via the adoption of prioritized land management practice changes in a heterogeneous farming community. We model how different types of farmers respond to an economic incentives-based approach where pollution beyond a specified level is taxed, whereas improvement beyond this level is subsidised. Adoption rates are estimated by predicting how different farm types are likely to respond to different levels of the levy/bonus system. In addition, farm level profit and environmental consequences of implementing this system are modelled.

3.1 Farm enterprise typology

The research presented in this paper concentrates on the sugarcane growing sector in the Tully-Murray catchment. To develop a classification of sugarcane farmers in the Tully -Murray catchment, qualitative interviews with the widest possible range of sugarcane farmers and land managers were carried out during 2006. The resultant landholder profile comprised three types of sugarcane farming agents, broadly based on farm size (Bohnet, 2008). In the Tully-Murray case study area, the landholder profile is matched with geographical information, through intersection of farm property information from the Digital Cadastral Data Base (DCDB) of Queensland (2006), land use from Queensland Land Use Mapping Program (QLUMP 2004) and soil type data layers (from Roebeling et al. 2009), using the geographical information system software ArcGIS by ESRI. This allows for the identification and characterisation of agents according to their specific objectives, their agricultural production system and socio-economic features and their spatially explicit agro-ecological conditions (e.g. soil typology).

3.2 Management practices for water quality improvement

A range of agricultural management practices have been developed to address water pollutant exports from sugarcane farms while maintaining production (Roebeling et al. 2009; Schroeder et al. 2009; Thorburn et al. 2010). The management practices we use in this research have been adopted from the 'ABCD' framework of farming system classification used by natural resource management (NRM) regions for Reef Rescue (Higham et al. 2008). The 'ABCD' framework describes management practices that range from *degrading* (D), *common* (C), and *best* or industry recommended (B), through to *aspirational*, cutting edge (A) farming systems that would provide the greatest water quality improvement.

Sugarcane input-output data for different management practices were generated using the APSIM (version 7.0) cropping systems model (Keating et al. 2003). The APSIM model was used because it is capable of modelling N cycling in sugarcane production systems (e.g. Thorburn et al. *In press*), and has been used previously in bio-economic modelling in the Tully region (Roebeling et al. 2009; Van Grieken et al. 2011). APSIM was used to predict regional soil type specific productivity (sugarcane yield) and environmental indicators (available DIN; Van Grieken et al. 2011). APSIM provides plot scale DIN in runoff and DIN leached below the root zone for each management practice. In our framework we assume 100% of DIN in runoff reaches the GBR lagoon (Furnas and Mitchell 2001) and 60% of N in deep drainage reaches the GBR lagoon (Webster et al. 2012).

Information on transition costs (e.g. capital investments) and changes in farm gross margins associated with the uptake of management practices has been adopted from financial economic research in various GBR catchments by Van Grieken et al. (2010). To account for variation in farm sizes, the investment quantities provided by Van Grieken et al. (2010) are adjusted accordingly. This analysis furthermore uses a 6 year investment horizon, representing the full sugarcane crop cycle in the Wet Tropics. Future revenues are discounted at a 7% real rate to represent these cash flows in present values (Zerbe and Dively 1994).

3.3 Nutrient accounting system

In this paper we assess the cost-effectiveness of an economic incentive-based policy instrument in promoting the adoption of best management practices to achieve DIN water quality improvement. When landholders pollute beyond a specified performance standard level of DIN exported from the farm (runoff and deep drainage leaching), a tax is charged for each corresponding kg of DIN. However if landholders adopt management that reduces pollution beyond this baseline level, a subsidy will be granted for each corresponding kg of DIN. This may also occur if landholders decide to take their land out of production. This conceptual approach is based on the Mineral Accounting System (MINAS) introduced in 1998 by the Dutch Government, to reduce farm gate nutrient surpluses. MINAS is a nutrient bookkeeping system in which nitrogen and phosphate outputs are subtracted from the inputs. The resulting surpluses are taxed if they exceed a predetermined surplus standard (Ondersteijn et al. 2003). We extend on this approach by, in addition to taxing surpluses; exploring the provision of incentive subsidies for negative surpluses (i.e. outputs are lower than the predetermined standard).

4 FRAMEWORK

To estimate the level of adoption of farming systems by farmers in the Tully-Murray catchment under the levy-bonus system, we use a linear constrained optimisation model. It assesses how different types of sugarcane producers in the Tully-Murray catchment are likely to respond to changes in their decision environment. The model uses production functions to explore the farmers' decision making process.

The farm enterprise will try to maximize their (gross) income, which is defined as the gross value from sugarcane production and on- and off-farm employment, minus the costs related to the use of labour and agricultural inputs, and corrected for private costs and or benefits from policy interventions. The most important constraints faced by each producer or farm type are related to the use of production systems, land, labour and agricultural output. As we estimate short term responses to instruments (1 full crop cycle; 6 years), land use is constrained to the currently available agricultural area. Available farm household labour can be used for on- and off-farm employment, where each farm profile has a specified proportion of off-farm employment. Also, labour can be hired-in for on-farm agricultural production. For the Tully-Murray case study, the model estimates production, income, resource use and employment at the farm and regional level for identified sugarcane farms in the study area. The mathematical optimisation model is solved using GAMS 22.7 (Brooke et al. 1998).

5 RESULTS

To determine the base scenario, against which all scenario results are compared, an initial or pre-base model run was performed where all farms in the region start off operating under C Class management. After this initial run, accounting for farm type specific characteristics such as farm size, gross margins per hectare, investment costs and labour availability, the results determine the base distribution of management across the landscape. The base distribution of management Classes is presented in Table 1. These result have been validated with local experts to ensure a realistic distribution is presented.

5.1 Abatement costs

Net abatement costs are calculated for all farm types, and aggregated to the region. The abatement achieved is presented for a levy/bonus of up to $40 per kg of DIN polluted/abated by farms. For large farms, at a levy/bonus level of $40, the abatement achieved is likely to be just under 15%. This would results to a net cost to the region of just over $9M over the whole crop cycle. For the medium sized farms, the abatement at this levy/bonus level would be just over 19%. The net cost to the region equals just over $10M. At the highest levy/bonus level the potential for abatement for small farms is just under 43%, with associated net costs of just over $24M. For the whole region, this equates to a potential decrease in DIN exports of almost 77%, at a net cost to the region of just under $44M over the crop cycle.

Cost-efficiency of the mineral accounting system for water quality improvement is presented in Table 1. For example, at a levy/bonus of $8 per kg DIN polluted/abated, the total reduction in DIN delivery that can be achieved is 19% compared to the base scenario. The cost-efficiency at this level of levy/bonus is $4.58. In other words, the net cost to the region of a levy/bonus of $8/kg DIN polluted/abated is just under $5 per kg reduction of DIN exported. At a levy/bonus of $40 per kg DIN polluted/abated, the total reduction in DIN delivery that can be achieved is 77% compared to the base scenario. The cost-efficiency at this level of levy/bonus is $19.82.

5.2 Land use and management distribution

Table 1 shows the distribution of land use and management for increasing levy-bonus values from AU$0 (base scenario) to AU$40, in steps of AU$8. In the base scenario, 44% of the land under sugarcane is cultivated using B Class management. C Class management is represented by 42% of the sugarcane land, with sugarcane land cultivated using A Class management only at 14%. With increased levy/bonus levels, management practices shift from C and B Class dominated, to A Class dominated. At a levy/bonus of $8, A Class management is now adopted on 41% of the sugarcane land; however the majority of sugarcane land is still cultivated using B and C Class management (59%). At the highest levy/bonus level ($40), almost all sugarcane land is cultivated using A Class management (97%), where only very little of the land is under C Class management (3%).

Table 1 Cost-efficiency of a mineral accounting system; Management class distribution as a percentage of total land under sugarcane cultivation.

Scenario	Cost-efficiency ($/kg)	DIN delivery (% reduction)	Management Class A (%)	Management Class B (%)	Management Class C (%)
Base	-	-	14%	44%	42%
Levy $8	$4.58	19%	41%	23%	36%
Levy $16	$9.14	38%	67%	7%	26%
Levy $24	$13.57	57%	86%	3%	11%
Levy $32	$15.75	66%	94%	1%	5%
Levy $40	$19.82	77%	97%	0%	3%

The area of land use and specific management for each farm type is calculated separately, as well as aggregated to the region (see Figure 1). With a levy/bonus of $12 all the sugarcane land operated by large farms is operated using A Class management. At a levy/bonus level of $4 the medium sized farms start adopting A Class management, and at a level of $24 all the land is operated using A Class management. At a levy/bonus level of $4, landholders owning small farms start adopting B Class management, and at the level of $12, they commence the adoption of A Class management. At the highest level of levy/bonus ($40) the majority of sugarcane land is managed using A Class practices. A few farms remain under C Class management, and many farms take land out of production.

Figure 1 shows how land use and management as well as sugarcane production changes in the catchment with increased levy/bonus levels. From the first levy/bonus level ($4), limited sugarcane land is taken out of production (4%; Farm type 3). At the highest levy/bonus level, 39% of sugarcane land is taken out of production. With decreased land under cultivation, regional productivity drops in the region. At $40/kg polluted/abated, regional productivity drops with more than 41%.

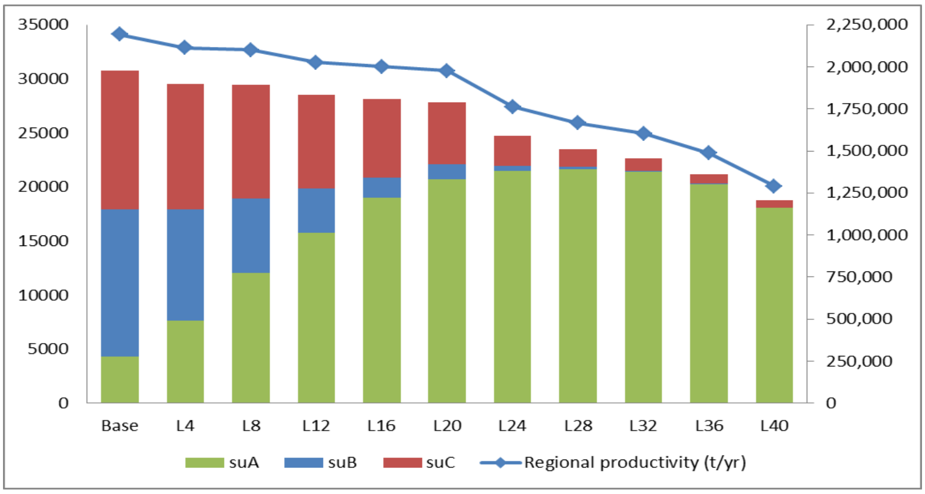

Figure 1 Total regional area under cane production and management with increasing levy-bonus values (X-axis), including regional cane productivity. The left Y-axis represents area (ha) whereas the right Y-axis regional productivity (t/yr).

6 CONCLUSION AND DISCUSSION

In this paper we presented a bio-economic approach that explores the cost-effectiveness of improving catchment water quality via the adoption of prioritized land management practice changes in a heterogeneous farming community. We modelled how different types of farmers respond to an economic incentives-based approach where pollution beyond a predetermined surplus standard is taxed, whereas improvement beyond this level is subsidised. Adoption rates were estimated by predicting how different farm types are likely to respond to different levels of the levy/bonus system. Furthermore, regional socio-economic and environmental consequences of implementing the policy were estimated, such as changes in local income and nitrogen run-off.

Net abatement costs are calculated for all farm types, and aggregated to the region. In the base scenario, the large commercial farms (farm type 1), are already largely operating in management Class B and A. This means their margin for improvement (reducing DIN exports) by changing management is small (given current available technology) in comparison with farm type 2 and farm type 3. The small farms (farm type 3) on the contrary, are largely still operating under management C, leaving substantial margin for water quality improvement by changing management to Class A and B.

With regards to land use and management distribution, in the base scenario, C and B Class management dominate in the region, with some sugarcane land cultivated using A Class management. With increased levy/bonus levels, management practices shift from C and B Class dominated, to A Class dominated. At the highest levy/bonus level almost all sugarcane land is cultivated using A Class management. More specifically, large farms initially operate in a mix of B and A Class management and shift rapidly to A Class management. With a levy/bonus of $12 all the sugarcane land operated by large farms is operated using A Class management. The medium sized farms operate in B Class management and slowly change towards A Class management. At a level of $24 all the land is operated using A Class management. Small farms operate mainly in C Class management, shift to combined A and B Class management, before shifting to mainly A Class management. At a levy/bonus level of $40 the majority of sugarcane land is managed using A Class practices. A few farms remain under C Class management, and many farms take land out of production.

At the highest levy/bonus level, 39% of sugarcane land is taken out of production. Intuitively, with decreased land under cultivation, sugarcane production drops in the region. At $40/kg polluted/abated, regional productivity drops with more than 41%. This raises additional questions not addressed in this research, such as the viability of regional sugarcane mills (see for example Van Grieken et al. 2011).

A number of biophysical and cost related caveats of this study must be mentioned. First, industry water pollution abatement costs are based on the management practices assessed and, thus, do not include any alternative technologies, some of which are currently under development, that may prove cost effective in the future. Second, related to the previous point, industry water pollution abatement costs are based on current land-use patterns and, consequently, gains from land-use change between industries are not taken into account. Third, equivalent production functions are used for all farm types, but this could potentially differ and needs to be investigated further. Small farmers may not be as productive per hectare as their bigger colleagues or they may face differing cost functions or production constraints that we did not explore in this paper. Fourth, in this study it is assumed that labour is freely available for hire – which is not always the case in small towns or during peak labour periods. Fifth, instrument transaction costs are not included in the analyses which could have implications on cost-effectiveness, especially on the adoption and delivery process. Pannell and Wilkinson (2009) for example, found that transaction costs are likely to be higher for small scale (lifestyle) farmers than for larger scale (commercial) farmers. Sixth, it is important to note that a nutrient accounting system as explored in this study may prove difficult in practice as it relies on adequate and proven modelling. It is both difficult and costly to monitor nonpoint emissions with current technology because their diffuse nature. Furthermore, they are impacted by random events such as weather and depend on many site specific factors (Ribaudo 1999). Last, the approach used here is deterministic and is, as a result, does not account for uncertainty. Consequently and self-evidently, care should be taken when using the figures presented in this study for policy and planning purposes.

ACKNOWLEDGEMENTS

We would like to acknowledge the Marine and Tropical Science Research Facility (MTSRF) and the Commonwealth Scientific and industrial Research Organisation (CSIRO) Water for a Healthy Country National Research Flagship for funding this research. For the landholder interviews specifically, we acknowledge a number of projects including: (i) 'Future visions for the Tully-Murray floodplain', funded by CSIRO's Water for a Healthy Country Flagship and Sustainable Ecosystems Division, (ii) 'Community uses and values of waters in the Tully-Murray catchment', funded by terrain NRM Ltd and CSIRO's Water for a Healthy Country Flagship and Sustainable Ecosystems Division, (iii) Project 3.7.5 'Socioeconomic constraints to and incentives for the adoption of land use and management options for water quality improvement', funded by MTSRF and CSIRO Sustainable Ecosystems.

REFERENCES

Armour, J.D., Hateley, L.R., Pitt, G.L. Catchment modelling of sediment, nitrogen and phosphorus nutrient loads with SedNet/ANNEX in the Tully–Murray basin. *Marine and Freshwater Research*, 60, 1091–1096, 2009.

Bainbridge, Z. T., J. E. Brodie, J. W. Faithful, D. A. Sydes and S. E. Lewis. Identifying the land-based sources of suspended sediments, nutrients and pesticides discharged to the Great Barrier Reef from the Tully-Murray Basin, Queensland, Australia. *Marine and Freshwater Research* 60(11): 1081-1090, 2009.

Bohnet, I. Assessing retrospective and prospective landscape change through the development of social profiles of landholders: A tool for improving land use planning and policy formulation. *Landscape and urban Planning* 88, 1-11, 2008.

Brodie, J.E., Kroon, F.J., Schaffelke, B., Wolanski, E.C., Lewis, S.E., Devlin, M.J., Bohnet, I.C., Bainbridge, Z.T., Waterhouse, J. and A.M. Davis. Terrestrial pollutant runoff to the Great Barrier Reef: An update of issues, priorities and management responses. *Marine Pollution Bulletin*, doi: 10.1016/j.marpolbul.2011.12.012, 2012.

Brooke, A., D. Kendrick, A. Meeraus and R. Raman. GAMS User's Guide. Washington, D.C., GAMS development Corporation, 1998.

Canfield, D.E., Glazer, A.N. and P.G. Falkowski. The evolution and future of Earth's nitrogen cycle. *Science* 330, 192–196, 2010.

Doney, S.C. The Growing Human Footprint on Coastal and Open-Ocean Biogeochemistry. *Science* 328, 1512-1516, 2010.

Furnas, M. and Mitchell, A. Runoff to terrestrial sediment and nutrients into the Great Barrier Reef World Heritage area. In: Wolanski, E. (Eds.) Oceanographic processes of coral reefs: Physical and biological links in the Great Barrier Reef. CRC Press, Boca Raton, 37-51, 2001.

Higham, W., J. Drewry and C. Mitchell. Development of 'ABCD' nutrient management framework for water quality improvement at regional scale, Australian Society of Sugar Cane Technologists, 2008.

Keating, B.A., P.S. Carberry, G.L. Hammer, M.E. Probert, M.J. Robertson, D. Holzworth, N.I. Huth, J.N.G. Hargreaves, H. Meinke, Z. Hochman, G. McLean, K. Verburg, V. Snow, J.P. Dimes, M. Silburn, E. Wang, S. Brown, K.L. Bristow, S. Asseng, S. Chapman, R.L. McCown, D.M. Freebairn and

C.J. Smith. An overview of APSIM, a model for farming systems simulation. *European Journal of Agronomy* 18: 267-288, 2003.

Kroon, F.J., Kuhnert, P.M., Henderson, B.L., Wilkinson, S.N., Kinsey-Henderson, A., Abbott, B., Brodie, J.E. and R.D.R. Turner. River loads of suspended solids, nitrogen, phosphorus and herbicides delivered to the Great Barrier Reef lagoon. *Marine Pollution Bulletin*, doi: 10.1016/j.marpolbul.2011.10.018, 2011.

Ondersteijn, C.J.M., Beldman, A.C.G., Daatselaar, C.H.G., Giesen, G.W.J. and R.B.M. Huirne. Farm structure or farm management: effective ways to reduce nutrient surpluses on dairy farms and their financial impacts. *Livestock Production Science* 84, 171-181, 2003.

Pannell, D. J. and R. Wilkinson. Policy mechanism choice for environmental management by non-commercial "lifestyle" rural landholders. *Ecological Economics* 68(10): 2679-2687, 2009.

QLUMP. Queensland Land Use Mapping Program. Department of Natural Resource and Water. http://www.derm.qld.gov.au/science/lump/, 2004.

Rabalais, N.N., Turner, R.E., Díaz, R.J., Justíc, D. Global change and eutrophication of coastal waters. ICES *Journal of Marine Science* 66, 1528–1537, 2009.

Ribaudo, M.O., Horan, R.D., Smith, M.E. Economics of Water Quality Protection from Nonpoint Sources: Theory and Practice. Resource Economics Division, Economic Research Service, U.S. Department of Agriculture, Agricultural Economic Report No. 782, 1999.

Roebeling, P. C., M. E. v. Grieken, A. J. Webster, J. Biggs and P. Thorburn. Cost-effective water quality improvement in linked terrestrial and marine ecosystems: a spatial environmental-economic modelling approach. *Marine and Freshwater Research* 60(11): 1150-1158, 2009.

Schroeder, B. L., A. W. Wood, G. Park, J. H. Panitz and R. L. Stewart. Validating the 'SIX EASY STEPS' nutrient management guidelines in the Johnstone Catchment, Australian Society of Sugar Cane Technologists, 2009.

Thorburn, P. J., A. J. Webster, J. S. Biggs and I. M. Biggs. Nitrogen needs of sugarcane crops: lessons from testing the N replacement concept. *Sugar Cane International* 28(3): 102-108, 2010.

Thorburn, P.J., Biggs, J.S., Attard, S.J. and Kemei, J. Environmental impacts of irrigated sugarcane production: Nitrogen lost through runoff and leaching. *Agriculture Ecosystems and Environment*, doi:10.1016/j.agee.2011.08.003, *in press*.

Van Grieken, M. E., M. Poggio, M. East, J. Page and Star, M. 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, 2010.

Van Grieken, M.E., Thomas, C.R., Roebeling, P.C. and P.J. Thorburn. Integrating economic drivers of social change into agricultural water quality improvement strategies. *Agriculture Ecosystems and Environment*, doi:10.1016/j.agee.2011.06.013

Webster, A.J., Bartley, R., Armour, J.D., Brodie, J.E., Thorburn, P.J. Reducing dissolved inorganic nitrogen is surface runoff water from sugarcane production systems. *Marine Pollution Bulletin* 65, 128-135.

Zerbe, R.O. and D.D. Dively. Benefit-cost analysis in theory and practice. Harper Collins College Publishers, New York, USA. 557 pp, 1994.