ASSESSING MANAGEMENT OPTIONS TO REDUCE NUTRIENT OUTPUTS FROM CANE PRODUCTION IN THE HERBERT RIVER DISTRICT

By

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Abstract

The northern section of the Australian sugar industry operates in one of the more environmentally sensitive regions of the world, surrounded by World Heritage Wet Tropical Rainforest areas and the Great Barrier Reef Marine Park. Since the release of the Great Barrier Reef Ministerial Council guidelines to reduce nitrogen and phosphorus output from canegrowing catchments draining into the Great Barrier Reef (GBR) lagoon, growers have been concerned about the impact of these restrictions on their farm incomes. The impact of some nutrient management options, for example, restrictions on cane growing on riparian lands and alternative fertiliser application strategies in the Herbert River canegrowing district, has been assessed. The potential area of cane that could be affected in sensitive riparian locations has been estimated using GIS technology and the impact on farmers' incomes has been assessed with the assistance of a caneland allocation model previously used for other studies in the region.

Introduction

The Queensland section of the sugar industry dominates sugar production in Australia, supplying about 95% of the country's 5 million tonne raw sugar output. Most of Australia's sugarcane is grown within 80 km of the coast in the higher rainfall areas across 22 river catchments between Mossman in far north Queensland and Grafton in northern New South Wales (Mallawaarachchi and Jacobsen, 2000).

The Great Barrier Reef situated adjacent to the Queensland coast is the largest reef system in the world. Thus, coastal Queensland is an area of global significance with a number of unique ecosystems and spectacular natural heritage. The Great Barrier Reef Marine Park was proclaimed under the *Great Barrier Reef Marine Park Act 197*5. Although the region hosts a variety of activities including agricultural production, tourism, shipping, and urban settlements, it is a

relatively unspoiled environment. However, the health of the Great Barrier Reef and adjacent lagoon may be at risk from pollutant inputs associated with human settlement and related activities.

Changes in social attitudes and community awareness have resulted in a high level of community interest in the resource allocation strategies of the sugar industry and their impact on the wider environment.

In June 2001, the Great Barrier Reef Ministerial Council noted that activities in the catchments adjacent to the Great Barrier Reef were affecting the quality of water flowing to the Great Barrier Reef World Heritage Area. The Commonwealth Minister for Environment and Heritage directed the Great Barrier Reef Marine Park Authority to develop a Great Barrier Reef Water Quality Action Plan. The objectives of the Plan are shown in the accompanying panel.

Objectives of the GBR Water Quality Action Plan.

1. Identify the major catchment-based threats to water quality in the Great Barrier Reef World Heritage Area.
2. Identify priority catchments and sub catchments in terms of potential risks to the world heritage values of the Great Barrier Reef.
3. Recommend specific targets (including pollution loads and concentrations) for outflow water quality in individual rivers and for reef water quality consistent with the National Standards for Coastal Water Quality Protection.
4. Suggest specific actions which need to be taken to improve the quality of water entering the Great Barrier Reef World Heritage Area and, in particular, actions which need to be taken to meet the targets referred to in objective 3.
5. Suggest for the actions identified in objective 4, a timetable for implementation.
6. Detail arrangements for monitoring, reporting the results of that monitoring and reporting of all information to the community.

Source: GBRMPA (2002)

Sugarcane is by far the most widespread cropping activity in catchments draining into the Great Barrier Reef lagoon and the area of cane within the GBR catchment has increased substantially over the past fifty years. Thus, sugarcane production was identified as a significant threat to water quality within the Great Barrier Reef Marine Park.

Sugarcane cultivation in the Great Barrier Reef catchment is estimated to contribute around 20 000 tonnes of nitrogen per year on average to the Great Barrier Reef lagoon and this represents about 25% of the total load exported from the river systems in the area (Moss *et al*., 1993; Rayment and Neill, 1997).

Meeting the catchment targets established under the action plan proposed by the GBR Ministerial Council will require significant changes to production activities and resource management within the cane industry. In particular, meeting the targets will presumably require a significant decrease in net amounts of nitrogen applied to caneland within the catchments or substantial changes in land management. It is possible that reduced nitrogen application levels will result in lower cane yields and thus create opportunity costs to cane farmers and to the whole sugar industry. Policy makers therefore have to balance the reduced income of profit-maximising farmers against the welfare of society as a whole in order to maximise social welfare.

The objective of policy makers is to encourage resource allocation that achieves a social equilibrium in which private and public benefits and costs are considered and social welfare of the whole community is maximised. It is therefore necessary to consider the externalities created by

cane production as well as the direct economic benefits. In this context, policy makers must consider the impact of nitrogen rich runoff on water quality and, ultimately, the health of the reef. Once externalities are taken into account, profit-maximising levels of fertiliser application may be higher than socially optimal. Theoretically, some level of nitrogen application exists that would result in maximum social welfare. However, determining this value requires quite complex analysis and involves measurement and valuation of intangible goods and services.

Objectives of the study

The objective of the project reported in this paper was to analyse the potential economic and environmental trade-offs associated with some management options designed to reduce the level of nitrogen exported to the GBR lagoon so that the targets proposed by the Great Barrier Reef Ministerial Council are met. In particular, the impact of riparian vegetation and economically optimal rates of nitrogen will be analysed.

This study used GIS technology applied to the Herbert River Catchment to determine areas affected by a policy to restrict canegrowing on riparian lands integrated with a modelling study using the CLAM land allocation model (Mallawaarachchi, 2000) to determine the economic and environmental net benefits of alternative land allocation strategies. In addition to assessing the income from a canegrowing area reduced by the introduction of riparian buffer zones, the opportunity cost of various management strategies that could be employed to meet nitrogen export targets were also evaluated.

Geo-spatial analysis

The GIS analysis enabled riparian zones to be theoretically created around significant hydrological features within the catchment. Three scenarios incorporating riparian zones of different widths were considered in the geo-spatial analysis and this enabled the amount of cane land that would have to be retired under each of these scenarios to be determined.

The area within the riparian zones was calculated to determine the total number of hectares of caneland that would be retired from production under the three different options. Table 1 reports results derived from this analysis.

Table 1—Retired cane area for three alternative widths of riparian buffer.

	Benchmark canegrowing (ha)	Buffer options		
		30 metre buffer (ha)	20 metre buffer (ha)	10 metre buffer (ha
Total area retired	0 (from 52 257 ha)	4 554	1 609	563
Percentage of total		8.7%	3.1%	1.1%

It was assumed that there is no homogeneity between all the land parcels that are retired under these scenarios. Therefore, the land capability or productive potential of the retired land was considered. To do this, the retired caneland areas were overlayed with another GIS coverage that

contained a land suitability index developed for Mallawaarachchi's (2000) study of the whole Herbert River canegrowing area. The scale was therefore considered appropriate to delineate land suitability classes within the riparian areas. The suitability index divided the cane blocks into:

- good caneland;
- average caneland;
- marginal caneland;
- poor caneland; and
- a fifth land suitability category that includes land that is unsuitable for cane production.

Table 2 indicates the total area within the Herbert River catchment according to cane suitability as well as the area of cane blocks within each category.

Table 2—Area of cane by land suitability, Herbert River canegrowing area.

Land class	Total area (ha)	Area within cane blocks (ha)
Good (I)	15 140	9 328
Average (II)	20 613	7 607
Marginal (III)	99 702	33 433
Poor (IV)	19 391	1 297
Unsuitable (V)	164 604	508
Total	319 450	52 173

Introducing caneland suitability into the analysis presumably increased the accuracy of estimates of the opportunity costs of management strategies. The buffers created above were further manipulated to calculate the area of cane retired under each scenario by land class.

The optimisation model used in the second stage of this analysis had the capacity to use only three land classes and the areas of class IV and V land used for sugarcane production in the Herbert River district was very small. Therefore, the area of cane land in land suitability classes III, IV, and V were added together to produce the final figures to be used in the CLAM model. Table 3 indicates the final results of the geo-spatial analysis. It outlines the area within each land suitability class that would be retired if the buffer zones are imposed.

Table 3—Retired cane land by capability class.

Buffer scenario	Benchmark (Total) (ha)	30 metre buffer (ha)	20 metre buffer (ha)	10 metre buffer (ha)
Area good caneland	9 328	1 330	490	202
Area average caneland	7 607	805	281	98
Area of marginal caneland (including a small area of unsuitable land)	35 238	2 420	838	263

These results were used in the optimisation model to predict the impact of the management scenarios on the present value of the net benefits (PVNB) generated in the study area.

Optimisation model

The CLAM model (Mallawaarachchi, 2000) was used to estimate the cost of the riparian buffer options as indicated by a change in the PVNB generated in the lower Herbert catchment from a range of land-use practices.

The model was adapted to suit the needs of this project. All cane expansion activities were deleted from the original model and the area constraints were redefined, such that they represented the potential canegrowing area reduced by the area retired from canegrowing due to the imposition of buffer zones.

All areas used in the analysis were derived from the GIS data, available for the Herbert River catchment (from the Herbert River Resource Information Centre website under an access agreement with The University of Queensland).

The areas indicated in Table 3 were subtracted from the total land area constraints in Table 4. The CLAM model was designed to analyse the allocation of land in the lower Herbert catchment between canegrowing, grazing, and natural activities. While the emphasis in this paper is on the impact of changes in the use of riparian canegrowing land, the other features of the model were retained.

Table 4—Area land-use constraints.

Land class	Land use (ha)		
	Cane area	Grazing	Natural
Good	9328	836	3188
Average	7607	1731	7963
Marginal	35238	14088	35261
Total	52173	16655	46412

The model assumed that cane yields for each land class declined as the suitability decreased. The maximum yields expected from each class of land are listed:

- good caneland: 100 tonnes/ha;
- average caneland: 90 tonnes/ha; and
- marginal caneland: 80 tonnes/ha.

The caneland allocation model has a Mitcherlich production function built into the structure of the canegrowing activities with the capacity to modify the base yield in accordance with the economically optimal fertiliser application rates in each case. The optimal rate of fertiliser application did not change with the imposition of the buffer zones. However, changes in the average pool sugar price do have a bearing on these rates, and thus optimal yields.

Some details of the other parameter values used in the model are given in Table 5. The average pool price of sugar (PPS) was obtained from ABARE and is the estimated return for the 2001–2002 crop (ABARE, 2002)

The model was run over a period of seven years, which represented two crop cycles. Of the available land allocated to cane activities, it was assumed that only a percentage (80%) had cane growing on it at any given time, with the remainder fallowed and producing no income. This area is described as the harvest area in the model.

The net benefits generated in each year were discounted at a rate of 4% in order to derive their present value. In the status quo scenario, the cane area constraints were not modified and the optimal solution was found. The model was then re-run three times with modified constraints to exclude the buffer areas.

Impact on cropped areas, crop yields, and net benefits

The buffer constraints reduced the area available to the model to be allocated to cane production. In Table 5, the total land available for cane production in each of the three land classes is shown. These areas represent the total area in each class in Table 4, reduced by the areas indicated in Table 3 as buffer strips.

Table 5—Cane planted and harvested areas.

PPS – $332/t	**Cane area (ha)**				**Harvested area (ha)**			
	Good	Average	Poor	Total	Good	Average	Marginal	Total
Status quo	9328	7607	35 238	52 173	7462	6086	28 190	41 738
10 m buffer	9126	7509	34 975	51 610	7301	6007	27 980	41 288
20 m buffer	8838	7326	34 400	50 564	7070	5861	27 520	40 451
30 m buffer	7998	6802	32 818	47 618	6398	5442	26 254	38 094

Of the available land specified as ‘cane area’, 20% is fallowed each year. This is recognised as an overestimate since the fallow area for this district is more likely to be 10–15% due to the practice of plough-out replanting. However, the model did not make any distinction between fallow

plant and plough-out replant cane. The values specified as 'harvested area' in Table 5, reflects the actual land area cropped in any given year in the optimal solution of the model.

Once the model has determined the harvested area and optimal yield, the tonnes of cane produced can be calculated. Table 6 indicates the cane produced by land class, for the status quo, and buffer zone options. By subtracting the cane produced under the buffer scenarios from the status quo, the tonnage of cane foregone by introducing the riparian buffer options can be calculated.

Table 6—Cane produced from land classes under buffer options.

PPS – $332/t	**Cane produced (t)**				**Foregone production (t cane)**
	Good	Average	Marginal	Total	
Status quo	847 900	569 750	2 357 400	3 775 050	
10 m buffer	829 540	562 410	2 339 800	3 731 750	43 300
20 m buffer	803 360	548 710	2 301 300	3 653 370	121 680
30 m buffer	727 010	509 460	2 195 500	3 431 970	343 080

These figures for cane production may appear conservative in light of recent production from the Herbert River district but, as noted previously, the model assumed that all plant cane was grown after a fallow while in fact plough-out replanting occurs on part of the area. More importantly, the model was a normative rather than a positive model with an objective of simulating maximum profits from canegrowing in the area, rather than maximum yields. Finally, it is the relativity between yields from the various options that is important rather than the absolute yields themselves in calculating the opportunity cost of the riparian buffers. In order to give the model the flexibility to allocate land among alternative potential uses, the objective function describes the present value of net benefits generated from cane production, cattle production, and natural areas within the lower Herbert catchment However, it is the land allocated to sugarcane production and income generated from it that is of predominant interest in this paper The PVNBs over the seven-year time frame (1996–2002), are as indicated in Table 7.

The PVNB was also determined in the initial year (1996). As can be seen from the Table, the status quo results in a PVNB of approximately $35 million. For subsequent years, the income is the same. However, after discounting the benefit stream declines over time as expected, due to the 4% discount rate. An annuity, indicating the annual increase in PVNB for the seven-year time period is also indicated in Table 7.

Table 7—Present Value of Net Benefits.

PPS–$332/t	PVNB (1996) ($)	PVNB (1996–2002) ($)	PVBN (1996–2002, expressed as an annuity*) $	Opportunity cost (Annual change in PVNB between options) $
Status quo	34 955 000	218 914 811	36 473 312	
10 m buffer	34 550 000	215 667 225	35 932 233	541 079
20 m buffer	33 853 000	211 317 146	35 207 468	1 265 844
30 m buffer	31 870 000	198 938 414	33 320 825	3 152 487

* An annuity is an amount which if set aside each year for the period specified at the appropriate rate of interest would accumulate to be equivalent to the NPV.

The change in PVNB for the various riparian buffer options can be noted from Table 7. The imposition of a 10 metre buffer around the waterways within the catchment reduces the PVNB bymore than $500 000, while the 30-metre buffer reduces regional income by more than $3 million. All of this loss is imposed initially on canegrowers although the flow-on effects also affect other sections of the industry. The extent of the grower's loss equals the reduction in the tonnage of cane harvested, multiplied by the marginal value of the cane but the rest of the industry, harvester crews, millers, and associated support services also suffers from reduced income.)

The optimisation model also calculates the shadow prices for resources in each land-use category which represents the net value of a one hectare change in land area available to canegrowers. That is, the returns from one extra hectare of land, less the variable costs associated with production, and adjusted for the value of any alternative use to which the land may be allocated. This can be described as the marginal value per hectare of the land use activities.

The marginal value for the various land classes when the PPS is $332/t were:

- good – $8 492;
- average – $5 290; and
- marginal – $3 520.

These marginal products when multiplied by the cropped areas foregone with the introduction of riparian buffer strips indicated in Table 3 are an indicator of the opportunity costs (OC) of adopting this policy.

Discussion

Impact of creating buffer zones

The reduction in cane production, due to the creation of buffer zones, will have two effects on the amount of nitrogen potentially reaching the Great Barrier Reef Lagoon. Firstly, the reduction in the area cropped will reduce the actual amount of fertiliser applied in the catchment. Secondly, the buffering of the hydrological network will potentially reduce the level of nutrient rich runoff reaching the streams and creeks. This assumes that the riparian buffers will be planted with appropriate vegetation. In this example, the area allocated to riparian strips has been excluded from

the area modelled and therefore not costed. If the cane along the watercourses is simply replaced by weeds and grass, the riparian buffer may actually be less effective than a crop of cane in filtering sediment and nutrients.

The first aspect of these reductions in cane area can be estimated using the model but we do not have sufficient information to estimate the second part. The model output specifies the optimal fertiliser application rate for each land class. Interestingly, there was no difference in optimal fertiliser application rates. (They were identical for the three land classes: good, 170 kg/ha; average, 169 kg/ha; and marginal, 170 kg/ha, perhaps revealing a deficiency in the Mitcherlich functions built into the model and their inability to specify lower rates on nitrogen for the good land which has a higher natural fertility. However, on the other hand, it does reflect the widespread practice of growers applying similar amounts of nitrogen fertiliser irrespective of soil type and land capability.

At these optimal application rates, the total amounts of nitrogen applied to caneland under the status quo and buffer strip options are presented in Table 8.

Table 8—Total fertiliser applied at optimal rates.

PPS – $332/t	**Fertiliser applied (t)**					
	Good	**Average**	**Marginal**	**Total**	**Change**	**Percent**
Status quo	1270	1026	4780	7075		
10 m buffer	1242	1013	4744	6999	76	1.1
20 m buffer	1203	988	4666	6857	218	3.1
30 m buffer	1089	917	4451	6458	618	8.7

In the Table, the difference between the status quo and the buffer strip options in the total tonnes of nitrogen, in the form of urea, applied to caneland within the Herbert catchment is reported. In effect, the 10 metre buffer reduces the total tonnes of nitrogen applied by 1.1%. A 20 metre buffer results in a 3.1% reduction, and similarly a 30 metre buffer reduces nitrogen applied to the caneland by 8.7%.

According to the Great Barrier Reef Water Quality Action Plan (GBRMPA, 2002), 9800 tonnes of nitrogen (per year) are used within the Herbert catchment. The Action Plan states that of this 1589 tonnes (16.2%) of the nitrogen used is exported to the lagoon. There are differences between these figures and the ones calculated from the model, due to expansion in canegrowing in the district since the GIS data were collected, fertiliser application rates in excess of the optimal rates, and nitrogen sourced from other land uses. Regardless of this, the buffer scenarios go little way to achieving the proposed 50% reduction in nitrogen output from the catchment, and are achieved at significant cost.

The model suggests that for every one percent reduction in nitrogen output, the cost to the cane industry lies between $350 000 and $380,000. A 50% reduction in nitrogen output from the Herbert River catchment, would therefore amount to approximately $18 million per year in foregone revenue.

This analysis, however, fails to take into account two important facts. Firstly, the buffer zone strategy removes the potentially high-risk areas surrounding the waterways from production. The percentage of nitrogen that is exported from these areas is likely to be greater than the

catchment average. Secondly, the model fails to take into account the mitigating properties of the buffer strips, as they filter sediment and reduce runoff originating from the remaining cropped area. Regardless of this, it can be seen that the opportunity costs of water quality targets are considerable.

Despite limitations with the model, it shows the extent of the costs incurred by the industry due to the introduction of riparian zones to buffer the impact of canegrowing on offshore areas adjacent to the Great Barrier Reef.

The model indicates the exponential nature of the opportunity costs associated with an increasing the width of the buffer zones. There is also an exponential decrease in the level of nitrogen reaching waterways and exported to the lagoon as the buffers are increased. However, the model does not provide information on the exact level of the reduction, or the benefits accruing to society from increases in water quality. The problem, therefore, becomes a political one, and is addressed further in the next section.

Implications for management

The model suggests that the creation of buffer zones around the watercourses in the cane-growing part of the Herbert catchment will impose considerable costs on the sugar industry. Some of this cost might be transferred to the wider community since they enjoy the benefits of an increase in the natural areas conserved and water quality leaving the catchment. However, the industry is not able to benefit by cash payments of any kind from any of these benefits accruing to the rest of society.

When the utility gained from improving water quality is ignored, the creation of the buffer zones results in substantial net loss to the canegrowing and sugar milling sections of society. If the community decided that these losses are exceeded by the benefits gained by the wider community from the increased water quality associated with the buffers, then policies to enforce the buffer policy may be warranted from a social viewpoint.

The sugar industry would no doubt seek to be compensated, theoretically to the extent described by the shadow values derived from the model.

Government has a number of options available to achieve the desired policy options (buffer strips). Command and control methods, such as legislation, in effect reduce the growers' property rights, and would be met with strong opposition and demands for compensation.

Regulations have limited capacity to achieve behavioural change in the creation of the desired buffer zones, and will result in a misallocation of resource if enforced with little regard to the site-specific nature of the environment.

Alternative approaches, including market-based instruments (subsidies, taxes, and fines), voluntary codes of practice, and education to change attitudes towards the use of public resources and the environment may be just as effective in producing the desired environmental outcome.

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