Farming practices to improve water quality in the Burdekin region

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Abstract

There is concern about environmental impacts of cropping in catchments of the Great Barrier Reef, especially losses of nitrogen (N) from cropping systems. Sugarcane production in the Burdekin region stands out from other crops/regions because it is fully irrigated and has the highest N fertiliser application rates of any sugarcane producing region in Australia. Few measurements of N losses from farms exist in the region and more complete information is needed to evaluate and develop future management recommendations to reduce environmental impacts of sugarcane production in the region. We measured water and N balances at three sites in different parts of the Burdekin region, covering a range of soil types and irrigation systems. The experimental data were then used to parameterise the APSIM-Sugarcane cropping systems model, and the model used to explore possible management strategies to reduce long-term nitrate losses at the three experimental sites. Measured nitrate losses in runoff (2-14 kg/ha/yr) were smaller than expected. A similar amount of nitrate was leached below the root-zone at sites with fine textured soil, but up to 10 times more was leached at the site with coarser textured soil. APSIM was parameterised to model crop growth, and the water and N balance (including runoff from furrow irrigation). Long-term simulations of different tillage, fallow and N fertiliser managements currently, or potentially practiced in the region identified opportunities for significantly reducing N losses, without reducing profitability, in these fully irrigated sugarcane systems.

Key Words

Nitrogen, runoff, deep drainage, APSIM, Great Barrier Reef, sugarcane

Introduction

Concern about the health of the Great Barrier Reef (GBR) has led to the development of the Reef Water Quality Protection Plan (Anon 2003), which will require industries in catchments draining into the GBR lagoon to meet water quality targets. Agriculture is an important land use in GBR catchments and has been identified as an important source of diffuse pollution in them (Brodie et al. 2003). Thus meeting water quality targets is likely to require changes to the management practices traditionally employed on farms.

The Burdekin is Australia's largest sugarcane producing region with over 70,000 ha of sugarcane harvested annually, yielding ~8 Mt of cane or ~22 % of Australia's total production. In common with other sugarcane producing regions, nitrate is one of the priority water quality contaminants originating from sugarcane cultivation (Mitchell et al. 2007). Sugarcane production in the Burdekin region stands out from other crops/regions in the GBR because; (1) it is fully irrigated, and the irrigation may enhance the losses of pollutants from farms, and (2) it has the highest average nitrogen (N) fertiliser application rates (~220 kg/ha) of any sugarcane producing region. Despite these concerns there have been few measurements of N losses, especially loads (kg/ha), from Burdekin farms. Stewart et al. (2006) reported nitrate-N lost through leaching at one site for a single crop. Other research has focussed on nitrate-N concentrations (rather than loads) in groundwater (Thorburn et al. 2003) or in a small number of runoff events (Ham 2007b). More information, especially on N lost in runoff, is needed to evaluate and develop future N management recommendations to reduce environmental impacts of sugarcane production in the region.

This paper reports N balances, including loss loads, at three sites in different districts of the Burdekin region that have a range of soil types and irrigation managements. From these and other previously published results, potential management strategies to both reduce long-term nitrate-N losses and maintain sugarcane production were examined.

Methods

Determination of N balances

Water and N balances were monitored on three commercial sugarcane farms in the Burdekin region (Table 1), although only the N results are considered in this paper. One site, Delta-f, was in the Delta region, where soils have relatively coarser texture and groundwater is used for irrigation. The other two sites (Mulgrave and Mona Park) were located in the Burdekin-Haughton Water Supply Scheme (BHWSS) district, a more recently developed surface irrigation area with water supplied from the Burdekin Falls dam. Measurements were made at one field (3-12 ha) on each farm, starting in 2004 with the commencement (planting or ratooning) of the crop. During the study sugarcane was the only crop grown, the fields were furrow irrigated and all management operations were performed and recorded by collaborating farmers.

At all sites irrigation water applied, rainfall, crop yields and the N concentration in the above ground crop biomass were measured At the Delta-f and Mulgrave sites runoff was measured with Parshall flumes and runoff samples collected with an ISCO sampler. At the Mona Park site deep drainage was measured with lysimeters and samples of deep drainage water collected. The focus was on deep drainage at this site because the farmer had blocked furrows on this field in an effort to prevent runoff. At the Mulgrave and Mona Park sites soil water contents were measured to 1.5 m depth with EnviroSCAN probes. All data, except water and crop samples were collected electronically. Runoff and deep drainage water samples were collected within 12-24 hours of the runoff or deep drainage event, then kept cool (< 4^{o}C) until analysis for nitrate-N.

The experimental data were used to parameterise the APSIM-Sugarcane cropping systems model (Thorburn et al. 2005) for each site. There was good agreement between predicted and measured water and N balance results (data not shown). The model was then used to predict missing data on N losses, i.e. deep drainage at the Delta-f and Mulgrave sites, thus allowing estimation of whole-of-crop N balances assuming that N losses in runoff and deep drainage were entirely in nitrate form. This is a reasonable assumption as sediment losses from irrigated fields are very low in the Burdekin (Ham 2007a).

N losses from different management practices

APSIM-Sugarcane was used to explore possible management strategies to reduce long-term N losses at the experimental sites. The management strategies were classified according to farming systems and N fertiliser amounts (Table 2). These management classes were determined from consultation with farmer groups and regional extension staff to, as best as possible, categorise the range of management practices in the region. Each class, E to A, combined decreasing tillage intensity with reducing N application rate, both practices being generally promoted in the sugarcane industry. Classes E to C represent practices currently common in the Burdekin region, while Class B is similar to the currently promoted ‘best practice’, with Class A being the possible future best practice that is currently under investigation. Irrigation management (amount applied and scheduling) was kept consistent in all classes, with common irrigation management practice represented in the simulations.

Long term simulations of these management classes were undertaken for the three experimental sites to quantify the potential change in nitrate-N lost through runoff and deep drainage. Stewart et al. (2006) had previously monitored and modelled N dynamics at another site in the Delta region that had coarser textured subsoil (coarse sand) than the Delta-f site. Their site (named Delta-c in our study) was included in the modelling to provide a more comprehensive coverage of soils in the Delta district.

Results

N balances

The greatest amount of N (as nitrate) was lost through deep drainage at the Delta-f site (Table 1), due to the higher permeability of that soil (and hence higher deep drainage, data not shown) compared to the Mulgrave and Mona Park sites. These losses, especially for the 2006 crop, were higher than those reported by Stewart et al. (2006) in a ratoon crop at the Delta-c site (~20 kg/ha), where deep drainage and N losses are likely to have been impeded by a water table at 2.5 m depth. Apart from the fertiliser applied, a legume (Lablab) cover crop grown at the Delta-f site during the 2003-04 fallow would have contributed N to the soil and affected N balances and losses in the plant crop (i.e. harvested in 2005), and possibly even the 2006 first ratoon crop. The N contained in this legume cover crop could also account for N in crop off-take being greater than the fertiliser N applied in the 2005 crop. Surprisingly, nitrate-N lost through runoff was ~ 13 % of that lost through deep drainage (averaged over both crops, Table 1) even though the amount of runoff was higher (~ 74 %) relative to deep drainage (data not shown).

At the Mulgrave site where furrows were open, nitrate-N lost in runoff (Table 1) was a small proportion of N fertiliser applied, as observed at the Delta-f site. This occurred despite runoff being more than double the amount measured at the Delta-f site (data not shown). There was no nitrate-N lost in runoff at the Mona Park site because the blocked irrigation furrows prevented runoff from irrigation events. Blocking the furrows would have also increased deep drainage. However, despite this practice, nitrate-N losses through deep drainage were smaller than from the coarser textured soils at the Delta-f (Table 1) and Delta-c (Stewart et al. 2006) sites, and similar to those from the finer textured soil at the Mulgrave site.

Table 1. Soil texture, nitrogen (kg/ha) applied to, and lost through crop off-take and in runoff and deep drainage (both as nitrate-N, kg/ha) from fields at three sites in the Burdekin region.

	Delta-finer texture		**Mona Park**		**Mulgrave**	
Soil texture: surface soil / subsoil	silty clay loam / light clay		medium clay / medium clay		medium clay / medium clay	
Year of harvest	2005	2006	2005	2006	2005	2006
Cane yield (t/ha)	140	146	138	131	118	96
Fertiliser N applied	149	225	237	247	234	234
Nitrate-N in runoff	14	2	0[A]	0[A]	5	5
Nitrate-N in deep drainage	59[B]	129[B]	9	12	2[B]	12[B]
N in crop off-take[C]	213	103	71	74	77	66
N retained in crop residue	16	18	12	10	12	9

[A] Irrigation furrows blocked at this site to prevent runoff
[B] Not measured at these sites. Data derived entirely from simulations.
[C] N in harvested cane and burnt crop residues

Simulated N losses from different management practices

N losses (as nitrate) in runoff and deep drainage varied across the simulated management classes at all sites, reducing with decreasing tillage intensity and N application rates (Figure 1). Of these two factors, N rate was the most important in determining the amount of N lost (data not shown). In the coarser textured soils of the two Delta sites, N losses were dominated by deep drainage. Conversely, losses were predominantly in runoff in the finer textured soil of the Mona Park and Mulgrave sites. The greatest reduction in N losses occurred between classes E and D. The marginal reduction in N loss declined from classes D to A.

Table 2. Fertiliser and tillage management within management classes

Management class	Fallow and tillage system	N fertiliser management system
E	Bare fallow with high level of tillage for crop destruction and weed control (8 passes), seedbed preparation (6 passes) and crop establishment (6 passes).	330 kg/ha on Plant cane/ 400 kg/ha on Ratoon cane
D	Bare fallow with conventional tillage practice (as for E but number of passes halved, except for weed control).	190-210 kg/ha on Plant cane/ 270 kg/ha on Ratoon cane
C	Bare fallow (crop destruction as for D), then zero tillage (including planting)	Traditional BSES recommendations (Calcino 1994)
B	As for C	'Six Easy Steps' (Schroeder et al. 2005)
A	Legume (containing low N amounts) cover crop in fallow with no tillage following planting, then as for C	'N Replacement' adjusted for legume N input (Thorburn et al. 2007)

At both the Mona Park and Mulgrave sites, N in runoff, deep drainage, crop off-take and retained residues was < 100 kg/ha, substantially less than N fertiliser applications to these crops (Table 1). This difference implies that considerable N was lost through denitrification during these crops. While not an issue for water quality, these losses, if proven correct, represent a significant financial and potential greenhouse gas concern.

Discussion

This study provides the first information on N loads in runoff in the Burdekin region. Runoff has been promoted as an important pathway for pollutants leaving farmlands and impacting the GBR (e.g. Brodie et al. 2003; Mitchell et al. 2007). However there are few data on N losses via runoff from sugarcane production systems and little insight into the response of N in runoff to different farm management practices. While losses were relatively low at the experimental sites (Table 1), there are management systems practiced in the Burdekin region that are predicted to result in high N losses, especially in fine textured soils in the BHWSS district (e.g. the Mona Park and Mulgrave sites; Figure 1). Simulations of the different management classes show that improving practice, especially better matching N fertiliser applications to crop needs, can substantially reduce N lost. This information provides the basis for determining the distribution of practices needed within the Burdekin region to meet the goals of the Reef

Water Quality Protection Plan (Anon 2003). However, there are some practices, such as irrigation management or controlled traffic, not reported in this paper that should affect N losses. Those practices need to be examined to provide more complete information for the Reef Water Quality Protection Plan.

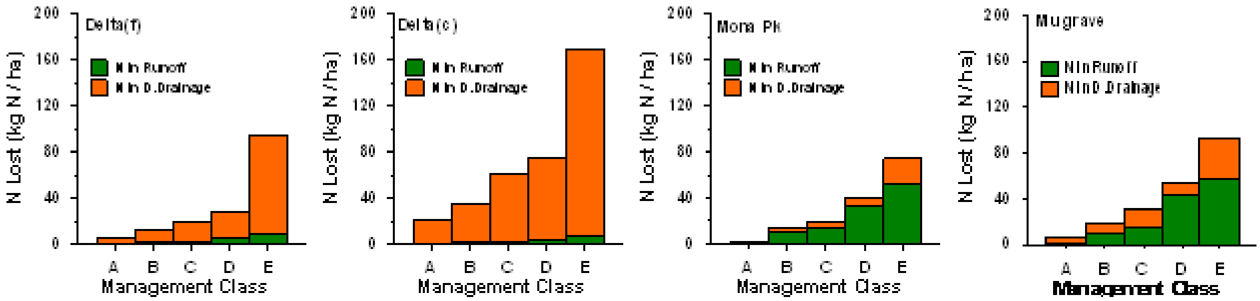

Figure 1. Predicted long-term annual losses of N via runoff and deep drainage at the four sites under a range of management practices defined in Table 2.

The results again highlight the potential for substantial amounts of N to be leached below the root-zone (Table 1, Figure 1). High groundwater nitrate concentrations are a concern in the region (Thorburn et al. 2003), but, except for Stewart et al. (2006), there has been little information connecting management practice to N losses in deep drainage. Apart from the farm economic and human health implications of leached N contaminating groundwater used for drinking, as it is in the Burdekin, N in groundwaters may impact the GBR through interactions between groundwaters and either surface waters and/or the marine environment.

The information on N losses from Burdekin farms from this study shows there are opportunities for reducing N losses that could lead to enhanced profitability and sustainability in sugarcane farming. This study will provide the basis for predicting of whole-of-region impacts of sugarcane on the environment.

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