The Brigalow Catchment Study: Nitrogen runoff generation rates from pasture legumes and changes since land development

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Abstract

Grazing is the dominant agricultural land use in reef catchments of central Queensland, and despite the rapid and broad-scale inclusion of pasture legumes into grazing systems, there is currently no information available on the loads and impacts of nitrogen on the Great Barrier Reef (GBR) lagoon from legume based pastures.

This paper assesses the risk of nitrogen runoff from legume pastures to water quality in the GBR by comparing runoff water quality from grass pastures with and without nitrogen fixing legumes, namely leucaena and butterfly pea. Furthermore, historical data from the long-term internationally recognised Brigalow Catchment Study (BCS), near Theodore in central Queensland, is used to provide estimations of pre-European nitrogen loads in runoff waters to determine how nitrogen dynamics have changed with land development.

Trends observed in these results indicate that pastures with leucaena and buffel grass pose a smaller threat to water quality in the GBR than both buffel grass only pastures and ley pastures of butterfly pea, as less nitrogen and sediments are exported in runoff waters. Furthermore, based on 20 years of historical data from the BCS, the cumulative effect of grazing on total and oxidised nitrogen was smaller than the effect from cropping and the predicted effect had the native brigalow scrub not been cleared.

1. INTRODUCTION

Grazing is the dominant agricultural land use in reef catchments, accounting for 96% (26.2 million ha) of land use within the Burdekin, Fitzroy and Burnett-Mary catchments (Australian Bureau of Statistics, 2009). In this region of central Queensland, 9.1 million hectares are sown to improved pastures (Australian Bureau of Statistics, 2009). Nitrogen fixing legumes, such as butterfly pea and leucaena, are often introduced into pastures to improve the fertility of the system and increase ground cover. However, runoff is one of many processes that can reduce nitrogen availability in the system, resulting in lower productivity.

Leucaena hedgerows planted with companion pasture grasses are one of the most productive, profitable and sustainable grazing systems in tropical and subtropical Australia (Dalzell *et al*, 2006; Shelton & Dalzell, 2007). In managed agricultural scenarios, leucaena has many reported benefits, including reduced soil erosion, improved runoff water quality, and enhanced soil fertility (Dalzell *et al*, 2006; Shelton & Dalzell, 2007). Beef production on leguminous pastures in central Queensland is becoming more common, as there is an increase in the availability of data that demonstrates greater nutritive value of forage and consequently greater live weight gains of cattle from leucaena-grass paddocks versus grass only paddocks (Elledge & Thornton, 2012; Thornton & Buck, 2011). Although there is a paucity of information on beef production benefits from butterfly pea, interest in this legume as a ley pasture system is becoming more popular in cropping areas as declines in soil fertility limit production (Pengelly & Conway, 2000). Furthermore, there is currently limited research available on water quality from leucaena and butterfly pea pasture systems in Australia.

Despite the rapid and broad-scale inclusion of pasture legumes into grazing systems in central Queensland (Pengelly & Conway, 2000), there is currently no information on the loads and impacts of nitrogen on the GBR from these catchments. This knowledge gap is a weakness in current catchment models, as they do not attribute different nitrogen generation rates to pastures which do or do not have legumes. Thus, the two objectives of this paper are:

1. Assess the quality of water discharging into the GBR by calculating nitrogen loads in runoff waters from three pasture land uses: i) cropping catchment with a grazed butterfly pea ley pasture, ii) grazed buffel grass catchment, and iii) grazed leucaena and buffel grass catchment.

2. Use historical data from the BCS to estimate pre-European nitrogen loads from the cropping and pasture catchments (i and ii above) in order to determine nitrogen dynamic changes with land development.

2. METHODS

2.1. Study Site

This research was conducted on the BCS site near Theodore in central Queensland. The BCS commenced in 1965 and is an ongoing long-term study on the impact of land development on hydrology, resource condition and productivity. This paper compares data from four catchments (Figure 1): 1) native brigalow scrub (*Acacia harpophylla*) which is an uncleared control; 2) butterfly pea (*Clitoria ternatea* cv. Milgarra) paddock that was originally cleared in 1982 and cropped for 27 years before conversion into a grazed ley pasture in 2010; 3) grazed buffel grass (*Cenchrus ciliaris* cv. Biloela) paddock that was originally cleared in 1982 and planted in 1983; and 4) leucaena (*Leucaena leucocephala* cv. Cunningham) and buffel grass paddock that was originally cleared ~1968 and cropped for 10 to 15 years before conversion into a grazed pasture. Leucaena was planted in 1998 on 8 m hedgerows. Soils in all catchments are predominantly grey and black Vertosols with an average slope of 2.5%, and there is no history of fertiliser application.

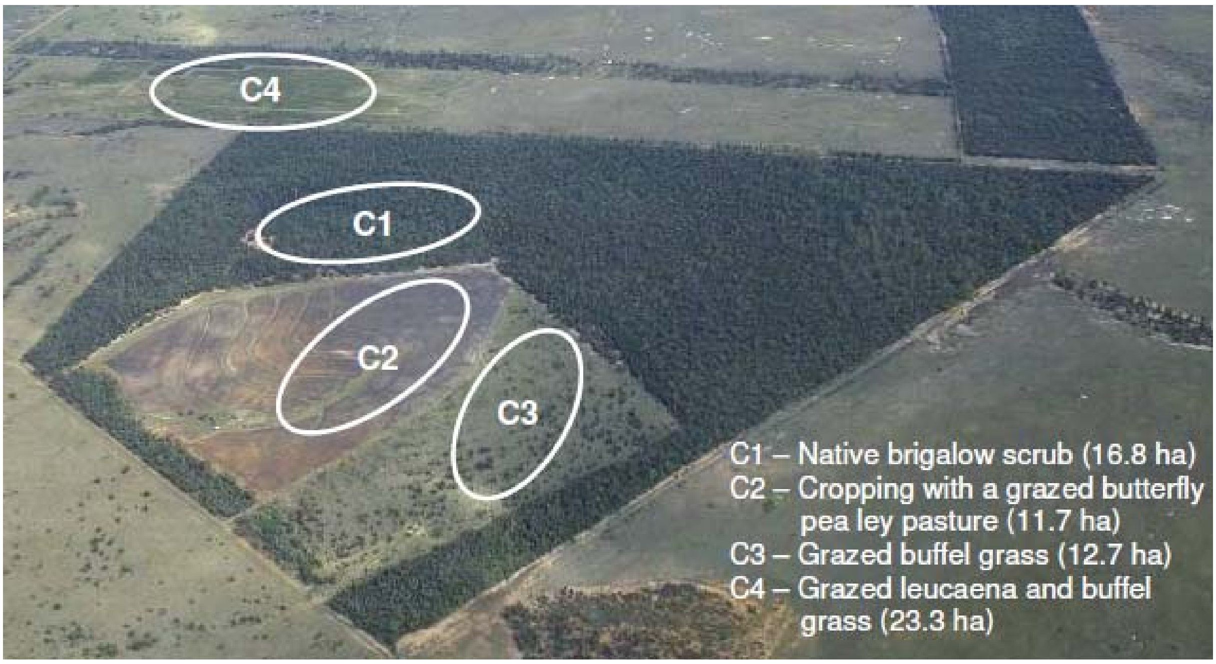

Figure 1. Ariel photo of the Brigalow Catchment Study showing the four catchments compared in this paper.

2.2. Leguminous Pasture Effect on Water Quality

Rainfall and runoff were monitored over a 17 year calibration period (1965 to 1982) from the three catchments referred to elsewhere in this paper as native brigalow scrub (C1), cropping with a butterfly pea ley pasture (C2), and grazed buffel grass only pasture (C3). In their virgin condition, runoff was approximately 5% of annual rainfall for all three catchments. Furthermore, the amount of runoff from C2 and C3 prior to their development was 95% and 72% of runoff from C1, respectively (Thornton *et al*, 2007). Calibration of the leucaena-grass catchment did not occur at this time due to its latter inclusion in the BCS.

Measurement of nitrogen in runoff waters was undertaken for all four land use types for two hydrological years: 2010 and 2011. All catchments were instrumented to measure rainfall and runoff, and to collect event based water quality samples. Total loads and event mean concentrations were calculated for total nitrogen, oxidized nitrogen (nitrate NO_3–N + nitrite NO_2–N), and ammonia (NH_4-N). No samples were collected from the leucaena-grass catchment for water quality in the 2010 wet season. Total rainfalls for the 2010 and 2011 wet seasons were 958 mm and 1009 mm, respectively.

2.3. Land Development Effect on Water Quality

Total nitrogen, oxidised nitrogen and ammonia loads were determined for runoff data for the period 1984 to 2004 in the native brigalow (C1), cropped (C2) and grazed catchments (C3). This was achieved by converting runoff depth (mm) to volume discharge (L), and then calculating load (kg/ha) using event mean concentrations (EMC) for the period 2000 to 2010. EMC data for total nitrogen only covers the period 2004 to 2010 due to a change in laboratories, and thus analytical methods. Loads were calculated for observed data in all three catchments and predicted estimates for the cropped and grazed catchments if they had not been cleared. Predicted estimates were calculated using EMC data from C1 applied to the predicted runoff from C2 and C3 had they not been cleared, as described in Thornton *et al* (2007). The effect of land use on runoff water quality for the cropped and grazed catchments was determined by subtracting their predicted uncleared loads from observed loads.

3. RESULTS

3.1. Leguminous Pasture Effect on Water Quality

For the 2010 wet season, nitrogen and sediment loads from the newly established butterfly pea in the cropping catchment were much higher than results from the pasture catchment with only grass (Figure 2). Loads in the grass only catchment were also lower than results from native brigalow scrub.

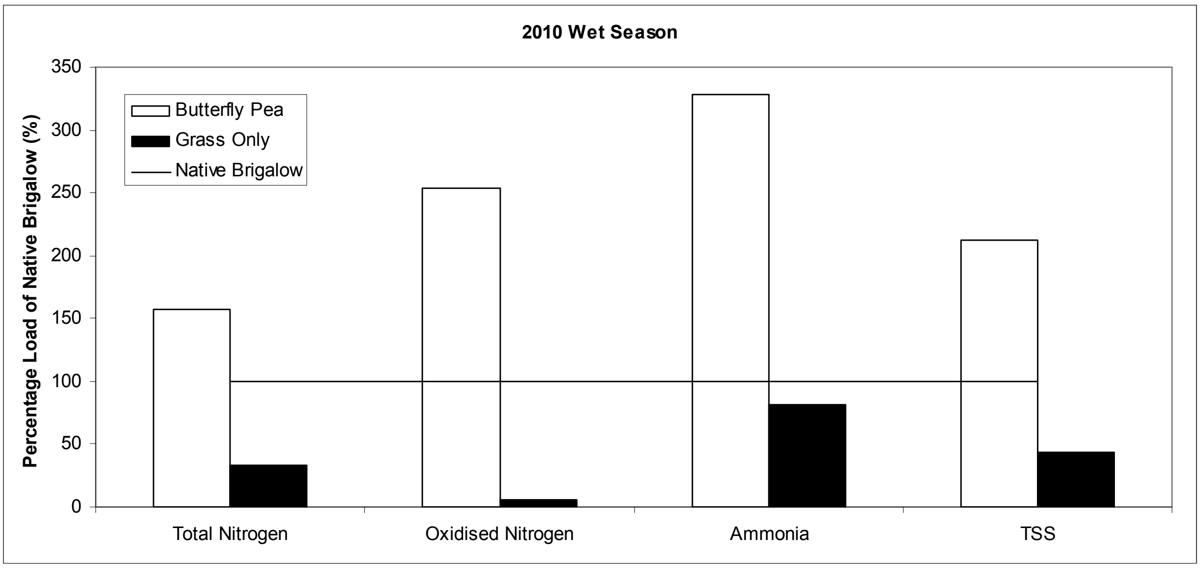

Figure 2. Nitrogen and total suspended sediment (TSS) loads in runoff waters from the butterfly pea and grass only catchments. Values are presented as a percentage of the native brigalow scrub loads.

For the 2011 wet season, nitrogen and sediment loads in all three developed catchments were greater than in the native brigalow scrub (Figure 3). Nitrogen loads were consistently higher in the butterfly pea catchment; and oxidized nitrogen in the grass only catchment was the closest value to the native brigalow scrub. Sediment loads were considerably higher in the butterfly pea and grass only catchments compared to the native brigalow scrub.

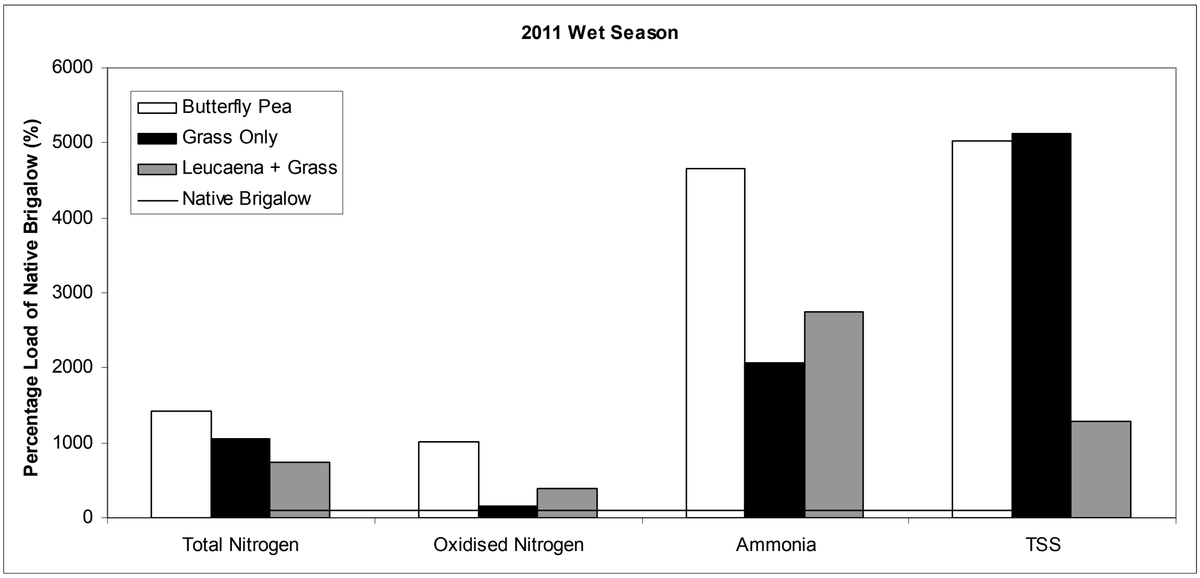

Figure 3. Nitrogen and total suspended sediment (TSS) loads in runoff waters from the butterfly pea, grass only, and leucaena-grass catchments. Values are presented as a percentage of the native brigalow scrub loads.

3.2. Land Development Effect on Water Quality

After 20 years of land development, total and oxidized nitrogen from the cropped catchment were not dissimilar to predicted uncleared native brigalow scrub with only 7 and 8 kg/ha lost in runoff waters, respectively (Figures 6 and 7). In contrast, the grazing catchment exported 55 kg/ha less total nitrogen and 27 kg/ha less oxidized nitrogen than predicted estimates of uncleared land. Both the cropped (1.08 kg/ha) and grazed catchments (0.17 kg/ha) lost ammonia in runoff waters, but loads were considerably higher in the cropped catchment (Figure 8). Loads of total suspended sediments were also considerably higher in the cropped (9603 kg/ha) than grazed catchment (793 k/ha) over the 20 year period.

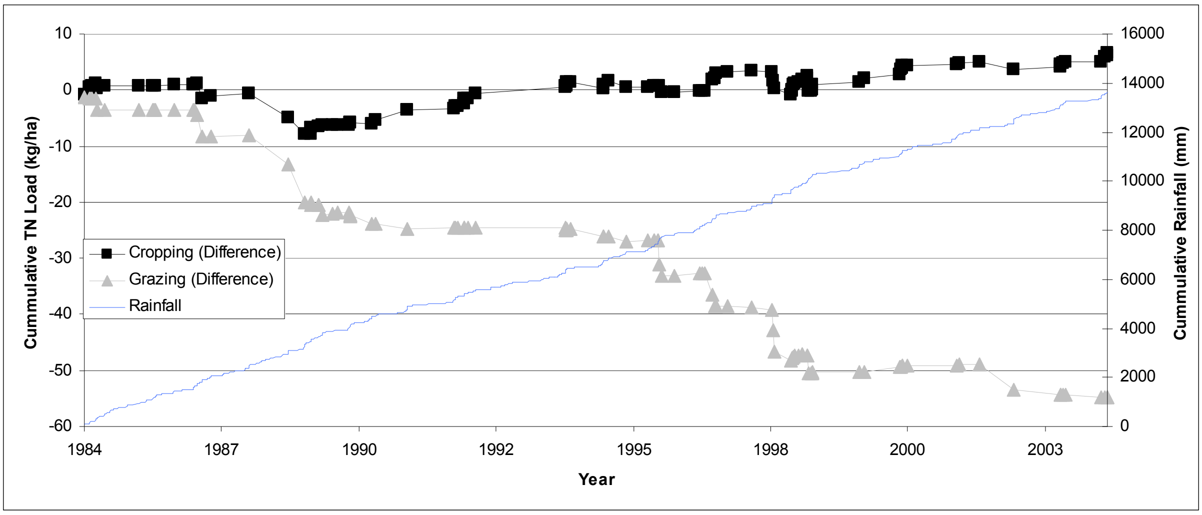

Figure 6. Cumulative total nitrogen (TN) loads from cropping (square) and grazing catchments (triangle), and cumulative total rainfall (line) for the period 1984 to 2004.

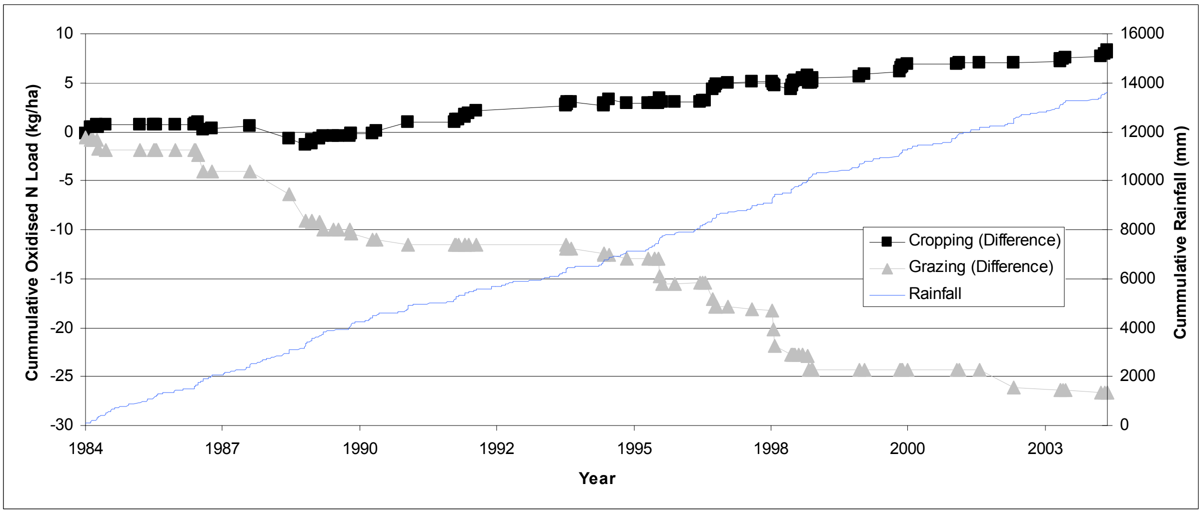

Figure 7. Cumulative oxidised nitrogen (N) loads from cropping (square) and grazing catchments (triangle), and cumulative total rainfall (line) for the period 1984 to 2004.

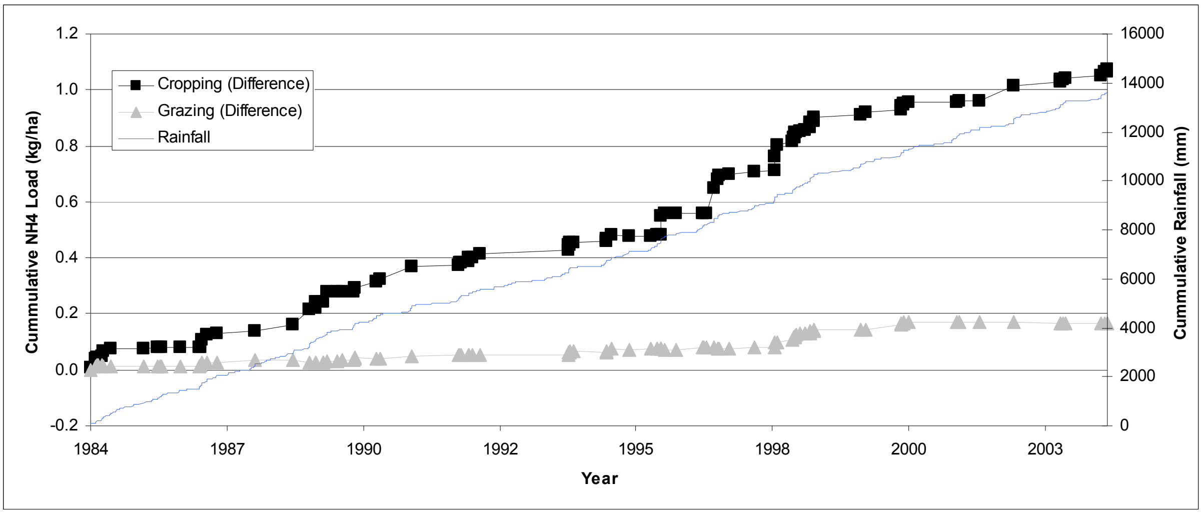

Figure 8. Cumulative ammonia (NH_4) loads from cropping (square) and grazing catchments (triangle), and cumulative total rainfall (line) for the period 1984 to 2004.

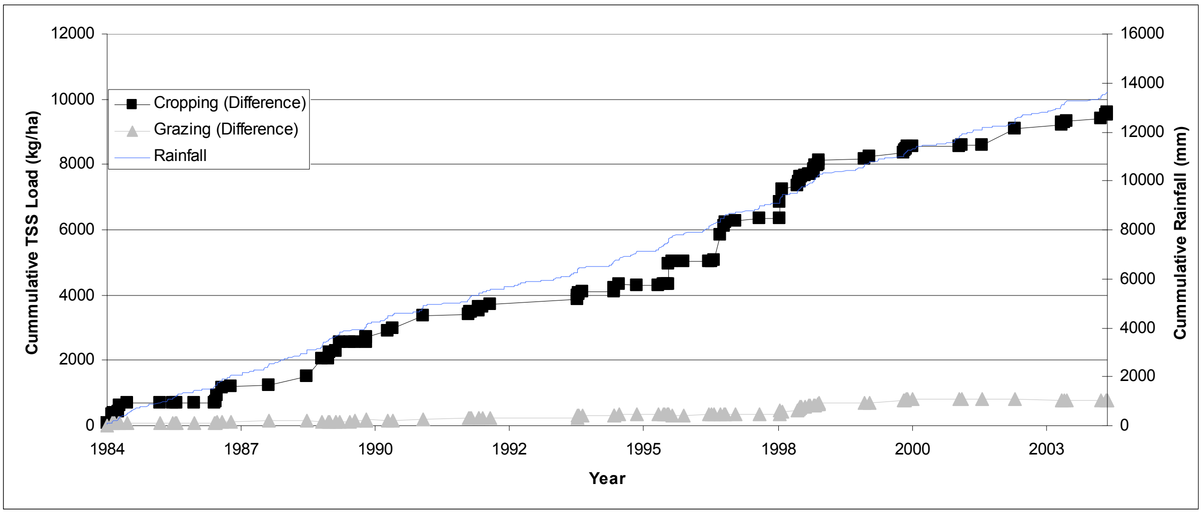

Figure 9. Cumulative total suspended sediment (TSS) loads from cropping (square) and grazing catchments (triangle), and cumulative total rainfall (line) for the period 1984 to 2004.

4. DISCUSSION

Runoff water quality from pastures in the brigalow bioregion of central Queensland varied between years and also the type of legume species present. Catchments with butterfly pea may pose a greater threat to water quality in the GBR than grass pastures with and without leucaena based on higher nitrogen loads in runoff water. In the 2010 hydrological year, the higher nitrogen and sediment loads in the butterfly pea catchment can be partly attributed to the short time since planting, that is, the catchment had a greater risk of nutrient and sediment loss due to recent soil disturbance and reduced ground cover. However, a similar trend was also observed in the second year of the study with higher concentrations of ammonia, total nitrogen and oxidised nitrogen in the butterfly pea catchment.

Although there is only one year of data for the leucaena-grass catchment, to date, our results indicate that this legume exports less nitrogen and sediment in runoff waters than grass pastures with and without butterfly pea. In regards to beef production, the leucaena-grass catchment is able to carry more cattle per hectare than grass only paddocks when stocked according to feed availability (Thornton & Buck, 2011; Thornton *et al*, 2010). The resulting greater live weight gains per hectare in the leucaena-grass paddock can be associated with higher concentrations of crude protein found in the leucaena leaves versus grass leaves (Elledge & Thornton, 2012). Thus, leucaena-grass catchments are able to produce more beef per hectare whilst exporting less nitrogen and sediments in runoff waters than grass only pastures.

Using historical data from the BCS, we found that the cumulative effect of cropping over 20 years on cleared brigalow lands was negligible for total and oxidized nitrogen in runoff waters. However, considerably smaller loads were exported in runoff waters from the grazed catchment compared to its uncleared predictions. Furthermore, grazing resulted in negligible losses of ammonia and sediments compared to if the land had remained uncleared, whereas cropping had considerably higher loads in runoff waters. This is consistent with other literature which demonstrates greater sediment losses from cropping than grazing (Freebairn *et al*, 2009; Murphy *et al*, 2012). Although minimum tillage was initiated at the BCS in 1992, this management effect can not be clearly observed due to the absence of runoff events immediately following the implementation of this practice. These results also support Silburn *et al* (2007), who reported that conservative farming practices generally reduce sediment losses, but concentrations of dissolved nutrients transported in runoff, such as nitrate and ammonia, can be higher in conservative compared versus intensely tilled systems.

Nitrogen and sediment loads were lower from grass pastures in 2010 compared to butterfly pea pastures. In addition, the grazed catchment exported less total and oxidized nitrogen compared to cropped and native brigalow scrub in the 20 year period since land development. There is currently no data for the effect of land development on the leucaena-grass catchment due to the later inclusion of this treatment into the BCS, but it is hypothesized that a similar trend of less nutrient and sediment exporting in runoff waters would be observed to the grass only catchment. Thus, grazing in reef catchments exports less nitrogen and sediments than cropping, and in the case of total and oxidized nitrogen, observed loads from the grazed catchment were lower than predicted loads had the catchment remained uncleared.

5. ACKNOWLEDGEMENTS

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