Paddock Scale Water Quality Monitoring of Banana and Sugarcane Management Practices

Summary report 2010-2013 Wet Seasons

Wet Tropics Region

Runoff and deep drainage in banana cropping

Project outline

Banana cropping was monitored at the South Johnstone Research Station in the Johnstone catchment. This region receives some of the highest rainfall totals in Australia with an average annual of 3,413 mm. The effect of best management practices (B class) and conventional management practices (C class) on water quality were compared at two sites (Table 1; Figure 1). At each site, sediment and nutrients were monitored in surface runoff, and nutrients in deep drainage at a depth of 1 m (below the root zone) were also monitored. Additionally, runoff and deep drainage were analysed for the pesticides, glyphosate, AMPA and glufosinate-ammonium at Site 2 with Reef Rescue R&D funding. The project was established in conjunction with an existing Department of Agriculture, Fisheries and Forestry (DAFF) experiment, Building Competitive Banana Production Systems for a Competitive Future.

Table 1. Management practice details

Site 1 (B class practice)	Site 2 (C class practice)
Nutrient management	
• N fertiliser applied by fertigation (dissolved in irrigation) • Fortnightly • 343 kg N/year (ratoon) • P applied once a year (surface applied)	• N fertiliser broadcast onto surface (granules) • Monthly • 434 kg N/year (ratoon) • P applied once a year (surface applied)
Inter-row management	
• Groundcover (when possible)	• No groundcover (controlled with Glyphosate 450)
Basta (glufosinate-ammonium) was used to control weeds within rows (i.e. under plants) at both sites.	

Figure 1. Site 1 (top) and Site 2 (bottom)

Key findings

Annual Rainfall

Rainfall over the monitoring period was highly variable from year to year (Figure 2).

The 2010/11 season (including cyclone Yasi) had well above the long-term average rainfall, whilst 2011/12 was slightly above average and characterised by several early rainfall-runoff events (Sept-Nov). The 2012/13 season was considerably below the long-term average.

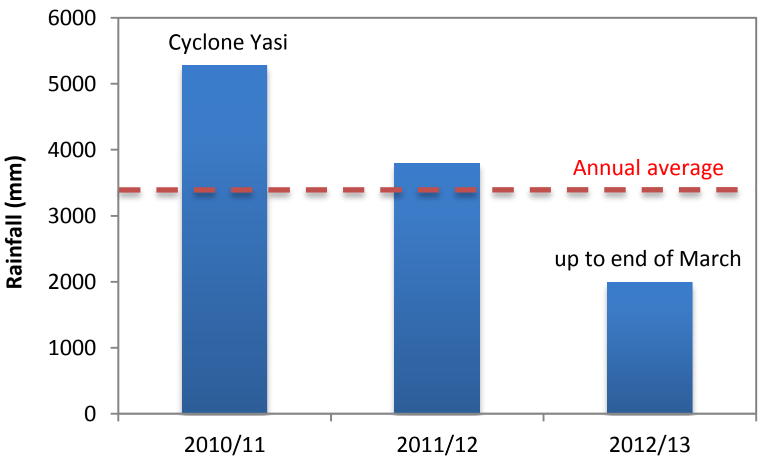

Figure 2. Annual rainfall at South Johnstone Research Station
(note: reporting period finished end of March 2013, rainfall during the 2012/13 season was below average in all months except July and January)

Runoff and deep drainage

Grassed inter-rows reduced runoff volumes and lowered runoff rates, compared to bare inter-rows (25-54% less runoff; Figure 3). Deep drainage (under the row only) accounted for 18-33% of annual rainfall (plus irrigation; Figure 3). The high percentage of drainage below the root zone highlights the importance of sub-surface loss pathways in the Wet Tropics region. Differences in deep drainage between sites were greatest during the driest season (2012/13). This is assumed to be a result of slightly different irrigation schedules.

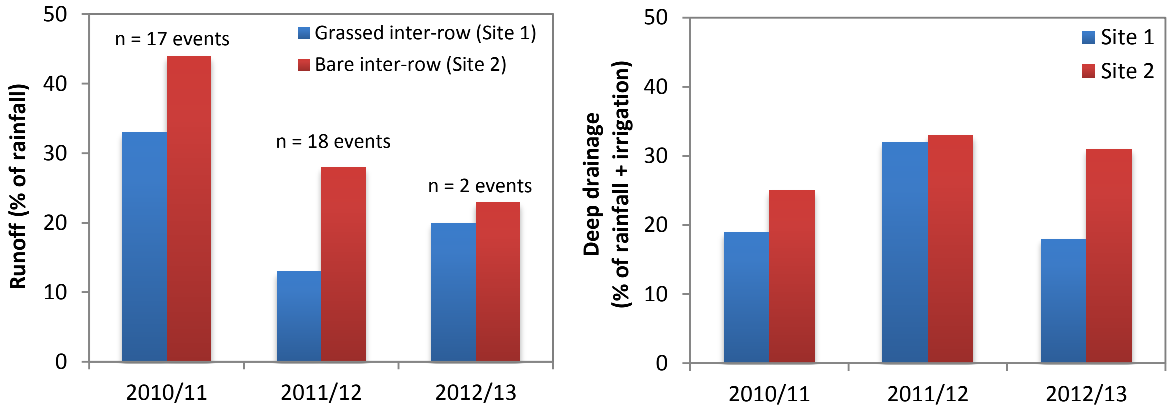

Figure 3. Runoff (left) and deep drainage (right) at Site 1 and 2 over three monitored seasons
(note: deep drainage is calculated from total rainfall + irrigation; runoff is calculated from discrete rainfall events only)

Bare inter-rows and wheel ruts caused high sediment loss

The bare inter-row at Site 2 had high sediment loss during runoff events (0.9-11 t/ha/yr; Figure 4). However, deep wheel ruts were also a critical source of sediment (Figure 5). These formed in the inter-row from excessive traffic during extended wet periods.

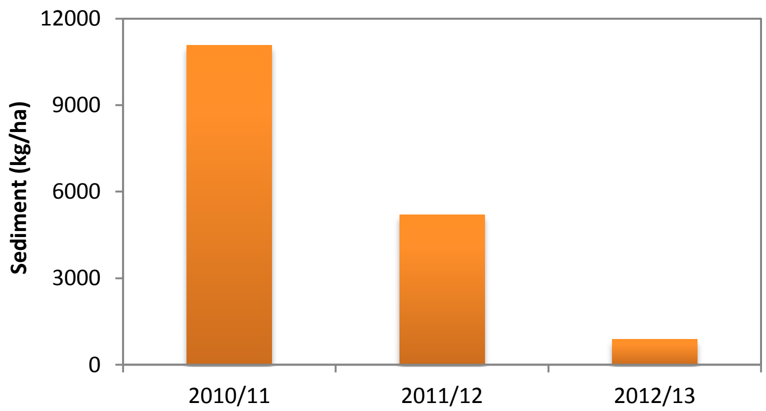

Figure 4. Annual sediment loss for bare inter-row at Site 2
(note: data excludes runoff from cyclone Yasi in 2010/11)

In 2011/12, Site 2 had average event losses of 285 kg/ha. However, Site 1 averaged 292 kg/ha due to the formation of wheel ruts (despite being grassed).

Improving the inter-row management is a significant challenge for the banana industry.

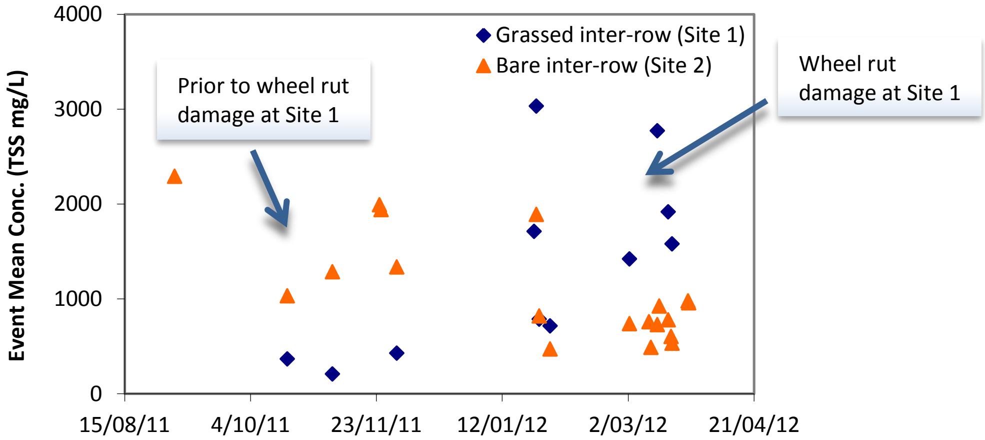

Figure 5. Sediment loss at Site 1 due to inter-row traffic damage

Nitrogen and phosphorous in runoff

Most of the total nitrogen (TN) lost in runoff (3-60 kg N/ha/yr) was in the particulate form (82-91%; Figure 6). Total phosphorus (TP) in runoff ranged from 1.8-26 kg P/ha and was also primarily as particulate P (Figure 6). Thus improved control of sediment will reduce the loss of N and P.

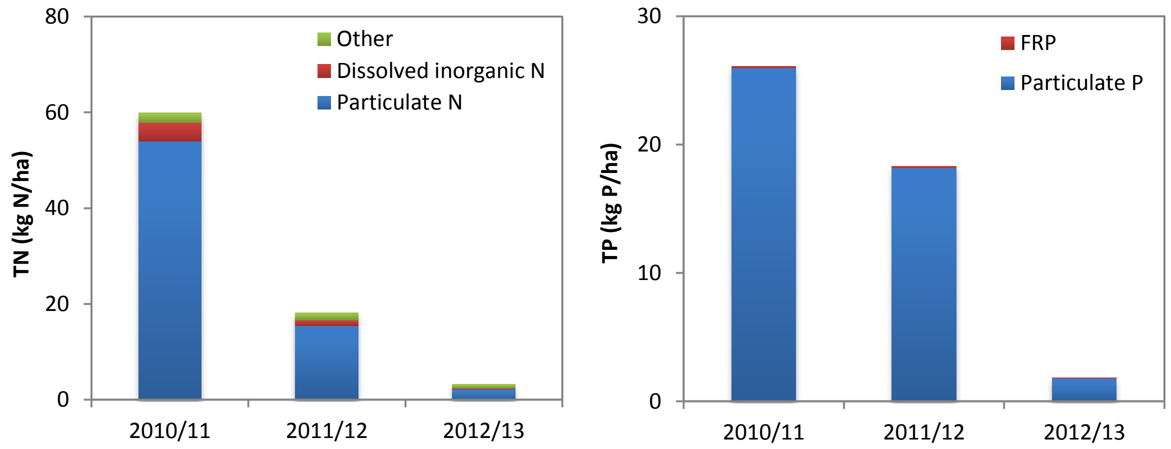

Figure 6. Total N (left) and Total P (right) loads in runoff at South Johnstone Site 2 over three monitored seasons (2010-13)

(Note: data excludes runoff from cyclone Yasi in 2010/11.
Dissolved inorganic N = nitrate and ammonia. FRP = Filterable reactive phosphate, measured mainly phosphate)

Timing of fertiliser application was a critical factor for runoff losses

There were clear increases of nitrate, ammonium and phosphates in runoff events following fertiliser application (within days to weeks). Concentrations then typically declined across following events (e.g. Figure 7).

More research is required to determine the impact of fertigation (Site 1) and broadcast (Site 2) nutrient application methods on N in runoff.

Our understanding is currently incomplete.

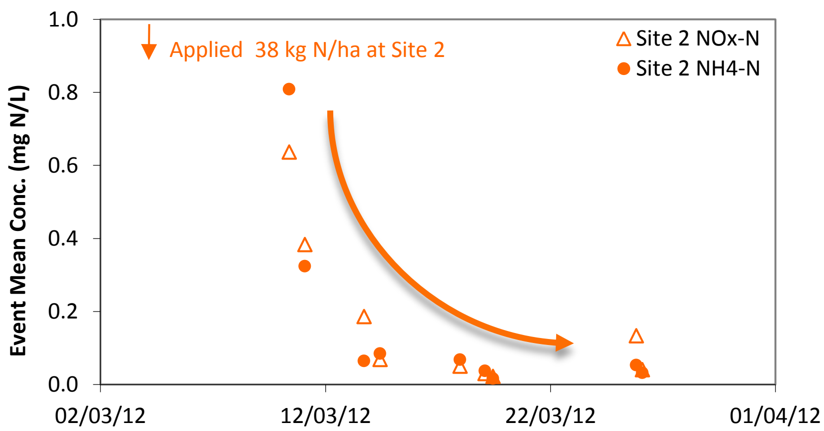

Figure 7. Nitrate (NO_x-N) and ammonium (NH_4-N) increased in runoff events immediately following fertiliser application

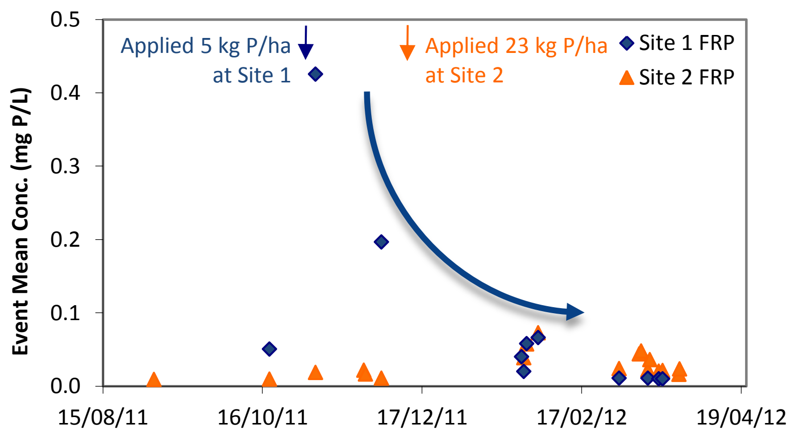

Figure 8. Phosphate (FRP) increased at Site 1 in the runoff events immediately following P fertiliser application

Phosphate increased in concentration at both sites in events a few days after the application of P (e.g. Figure 8).

In contrast to N, banana crops normally only require P once a year. Phosphorous application could be scheduled outside of the wet season to reduce phosphate losses in runoff.

*Glyphosate and glufosinate-ammonium in runoff and deep drainage**

The 'knock-down' herbicides Basta (glufosinate-ammonium) and Glyphosate 450 (glyphosate, and its breakdown product AMPA) were detected in surface water runoff in both 2011/12 (Figure 9) and 2012/13 wet seasons. Glufosinate-ammonium (measured as glufosinate (acid)) had been applied each year within 5-7 days of a rainfall-runoff event (January and February). However, glyphosate had been applied 6 months earlier (June) and was still detected in runoff.

In 2011/12 neither chemical was detected in deep drainage (1 m depth), despite sampling occurring fortnightly throughout the year. In contrast, in the following season glyphosate was detected (0.8-1.1 μg/L) after a 700 mm rainfall event over 4 days. This was after a period of below average rainfall since application in June 2012. Glufosinate-ammonium and AMPA were not detected.

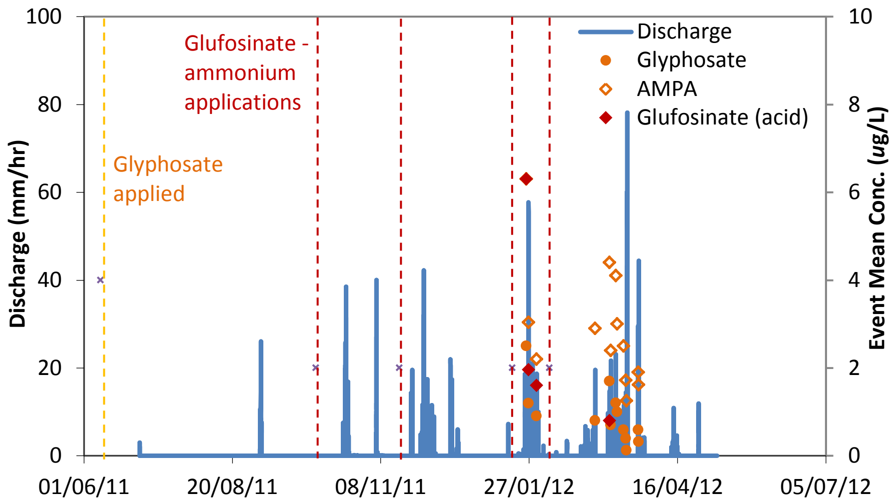

Figure 9. Glufosinate (acid), glyphosate and AMPA in runoff*
(Note: monitoring commenced January 2012)

'Knock-down' products such as glyphosate, have been considered less prone to runoff and therefore the 'safer' alternative.

More investigation on the runoff and drainage transport mechanisms of these chemicals is required.

Nitrogen in deep drainage was low

Concentrations of nitrate and ammonium were relatively low, resulting in low loads of N (<5 kg N/ha/yr; Figure 10) moving below the root zone.

Results from an associated Reef Rescue R&D trial show that the plant phase is a critical loss period for nitrate (Figure 11), due to high soil mineral N from site preparation and a developing root system. This has highlighted the need for monitoring across all phases of a cropping system in order to understand highest risk periods.

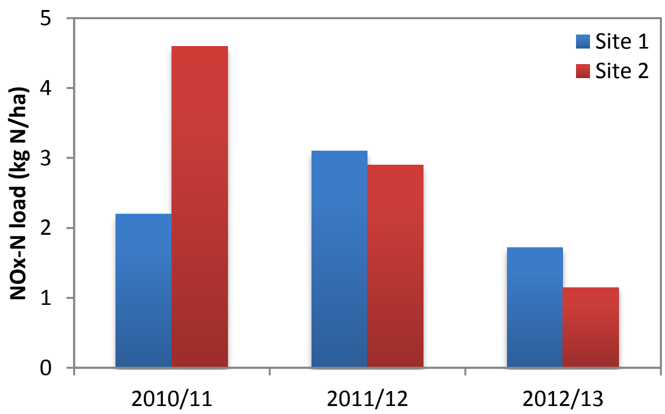

Figure 10. Nitrate (NO_X-N) loads in deep drainage at Site 1 and 2
(Note: intermittent data in 2010/11 due to cyclone Yasi and recovery)

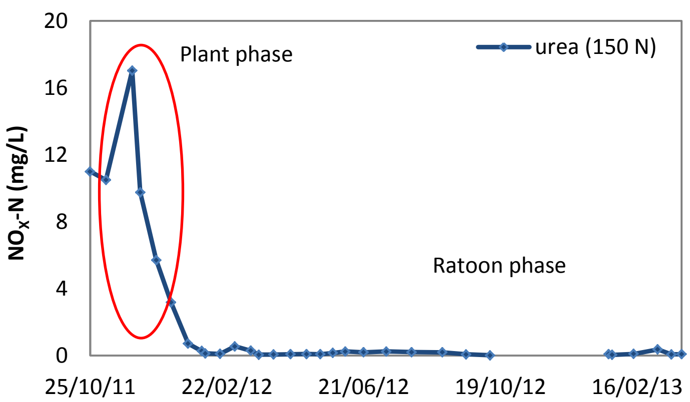

Figure 11. Nitrate (NO_X-N) in deep drainage at the Reef Rescue R&D site*

Management options to capture available nitrate loads from land preparation include:

Incorporating soil mineral N loads at planting into N fertiliser recommendations.

The adoption of minimum tillage practices as decreased cultivation should reduce the loss of N to the environment (permanent bed systems currently account for <10% of banana production in North Queensland).

Runoff and deep drainage in sugarcane farming

Project outline

The effect of various management practices on water quality from the new farming system and conventional or 'current' farming system were compared at two sites (Table 2). At each site, nutrients and pesticides were monitored in surface water runoff, and nutrients and pesticides in deep drainage at a depth of 1 m (below the root zone). These sites were located on two neighbouring farms in the wet-tropical sugarcane growing district of the upper Murray catchment (Tully-Murray catchment; Figure 12). Sugarcane cropping in the area is rain-fed from an average annual total of 1,923 mm. These sites were also part of the Department of Agriculture, Fisheries and Forestry's Demonstration Farms project.

Table 2. Management practice details

Site 1	Site 2
Nutrient management	
• BSES Six Easy Steps • Stool split • Legume fallow	• BSES Six Easy Steps • Stool split • Watermelon rotation & grassy fellow
Row/sediment management	
• New Farming System, 1.9 m wide rows, dual row of cane, controlled traffic	• Current Farming System, 1.6 m rows, single row of cane
Weed/chemical management	
• Integrated weed management plan for entire farm • Residuals in plant cane only. Minimal use of regulated PSII herbicides (possible spot spray). Contact and translocated herbicides used in ratoons. Recommended label rates used.	• Farmer's conventional herbicide use throughout crop cycle, herbicide selection and application dependent on weed pressure. Moving away from regulated PSII herbicides. Recommended label rates used.

Figure 12. Site 1 (top) and Site 2 (bottom)

The pronounced year to year variability in rainfall highlighted climate as one of the dominant drivers affecting farming practices, grower decision-making and associated off-site water quality.

Key findings

Annual Rainfall

Rainfall over the monitoring period was highly variable from year to year (Figure 13).

Rainfall in 2011/12 and particularly the 2010/11 wet seasons (including Cyclone Yasi) was well above the long-term annual average.

Rainfall during the 2012/13 wet season was well below the long-term average.

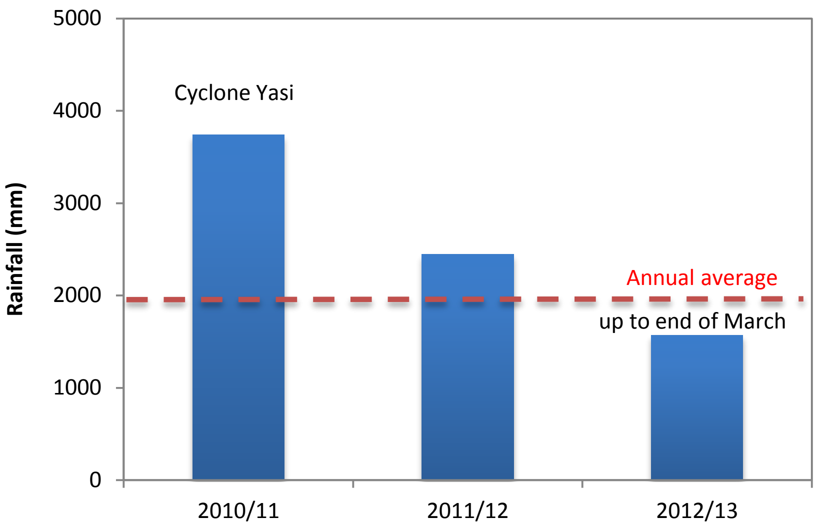

Figure 13. Annual rainfall for the Upper Murray
(note: reporting period finished end of March 2013)

Deep drainage was greater than runoff volumes

There were differences in the hydrology of the two sites, mainly due to impeded drainage at Site 2. During prolonged periods of rainfall, water would remain perched (20-30 cm below the soil surface) and was assumed to be moving laterally to nearby sub-surface drainage systems on the farm. Hence a direct comparison of runoff and deep drainage between controlled traffic and conventional cultivation was not possible.

Overall, runoff accounted for between 6-14% of rainfall at Site 1 and between 7-11% at Site 2 (Figure 14).

Deep drainage, in contrast, accounted for between 23-42% of annual rainfall at Site 1 (Figure 14).

Deep drainage was the main loss pathway of N in water in the permeable soil of the monitored sites.

> Future water quality monitoring needs to incorporate other potentially critical loss pathways, such as lateral flow into drains. In the Tully-Murray catchment alone, there is an estimated 1,100 km of constructed drainage networks.

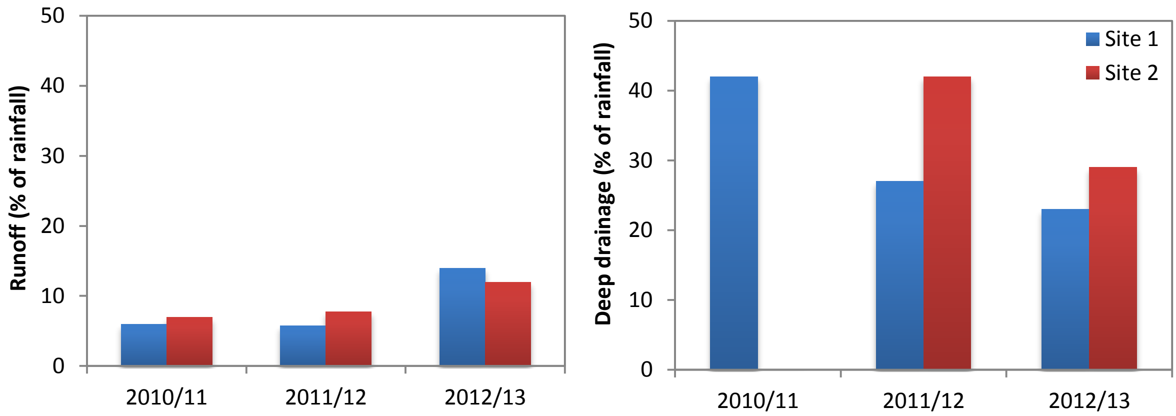

Figure 14. Runoff (left) and deep drainage (right) at Site 1 and 2 over three monitored seasons
(note: Site 2 deep drainage data unavailable for 2010/11 period due to ephemeral aquifer)

Nitrogen in runoff

Particulate N was consistently the dominant form of N export in surface runoff from both sites (25-87% of total N; Figure 15). Total N in runoff was 2-9 kg N/ha/year, of which inorganic N (nitrate and ammonium) was <4 kg N/ha/year. The inorganic N load was equivalent to 3% of N applied with 'Six Easy Steps'.

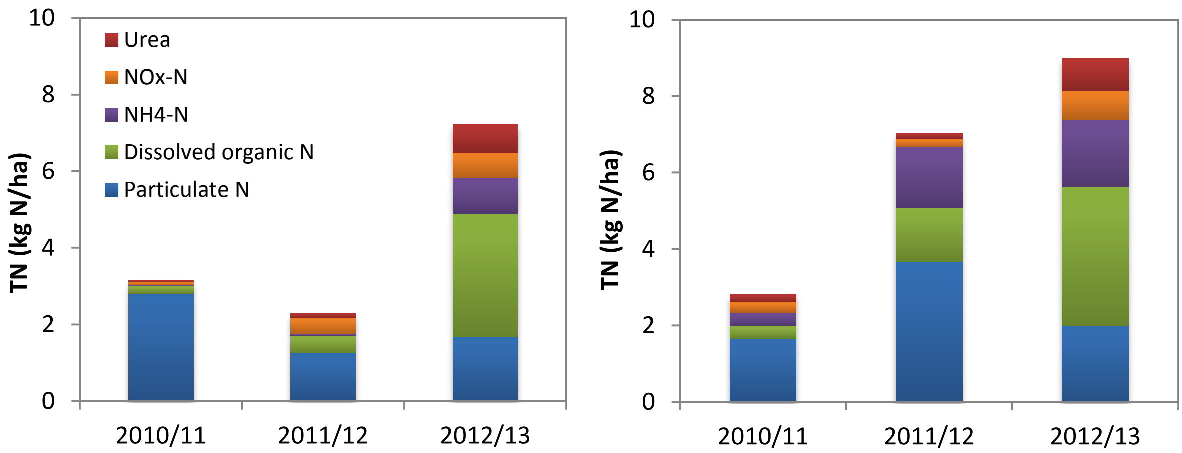

Figure 15. Total N loads in runoff at Tully-Murray sugarcane Site 1 (left) and Site 2 (right) over three monitored seasons (2010-13)
(Note: >90% of runoff in 2012/13 was derived from ~550 mm rainfall over 4 days in January)

Timing of herbicide application was critical

There was a critical relationship between the date of pesticide application, timing of rainfall, and resultant pesticide losses in runoff. This relationship was not specific to one type of chemical. For example, diuron applied early in the season at Site 1 resulted in low concentrations and loads in runoff during substantial December rainfall. In contrast, a late season application at Site 2 resulted in markedly higher losses in the same rainfall event, even though approximately half the rate of diuron was applied (Figure 16). Conversely, high pendimethalin concentrations were measured at Site 1, where it was applied close to rainfall compared to much earlier in the season at Site 2 (both sites received the same rate).

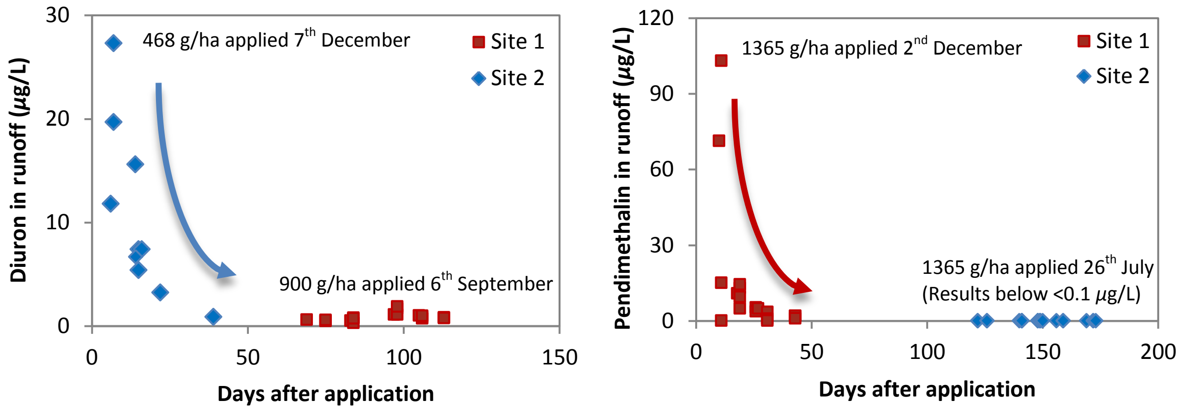

Figure 16. Diuron (left) and pendimethalin (right) in runoff after early and late application, 2010

All herbicides used were susceptible to off-site movement

Substantial amounts of 'non-regulated' or 'alternative' pesticides as well as the regulated PSII chemicals were detected in runoff, and in many cases, deep drainage. In addition to the PSII herbicides diuron, atrazine and hexazinone, 'alternative' herbicides such as pendimethalin, metribuzin, 2,4-D, triclopyr and picloram were detected in runoff (e.g. Figure 17). The insecticide imidacloprid was also commonly detected in runoff (0.02-0.38 µg/L at Site 2) further demonstrating that other pesticides are a potential concern to off-site movement.

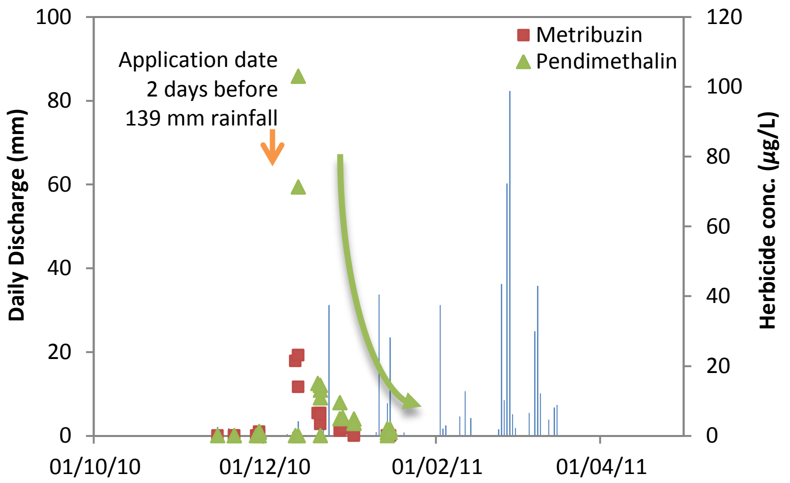

Figure 17. The highest herbicide concentrations and loads lost were in 1-2 events following application

All sugarcane sites had the highest pesticide losses when chemicals were applied late in the year, just before major wet season rainfall events.

Applying longer-lived chemicals early in the year, and shorter-lived chemicals nearing, or within the high risk wet season period, are critical to minimising herbicide losses from cane farms.

In deep drainage, some herbicides were detected for extended periods of time after application, albeit at lower concentrations. For example, diuron (0.002-0.02 µg/L) and imidacloprid (0.02-0.09 µg/L) were detected more than 2½ years after they were applied, highlighting the longevity of some of these compounds in the soil profile.

The increasing use of 'alternative' herbicides instead of the PSII herbicides has been a common response by farmers to address water quality concerns. However, this monitoring demonstrates these are also lost from paddocks at concerning levels, and the likely environmental effect of this off-site movement is yet to be rigorously assessed.

These results need to be communicated to the sugarcane industry and extension agencies in order to avoid sudden broad-scale industry shifts towards unknown pesticide products.

Timing of herbicide application, *as well as product selection*, was overwhelmingly the biggest driver of pesticide losses.

Deep drainage was a major loss pathway for nitrogen

Inorganic N loss (primarily nitrate) was up to 13 kg N/ha/year in deep drainage and was considered the major loss pathway for these sites (Figure 18). Water logging restricted accurate calculation of deep drainage for the wettest season monitored (2010/11).

The fate and time-lags of large volumes of water in deep drainage is still unclear.

Nitrogen loss in deep drainage may be reduced by a lower rate of application, a longer period between application and heavy rain, and possibly controlled release fertilisers. However, this warrants further investigation.

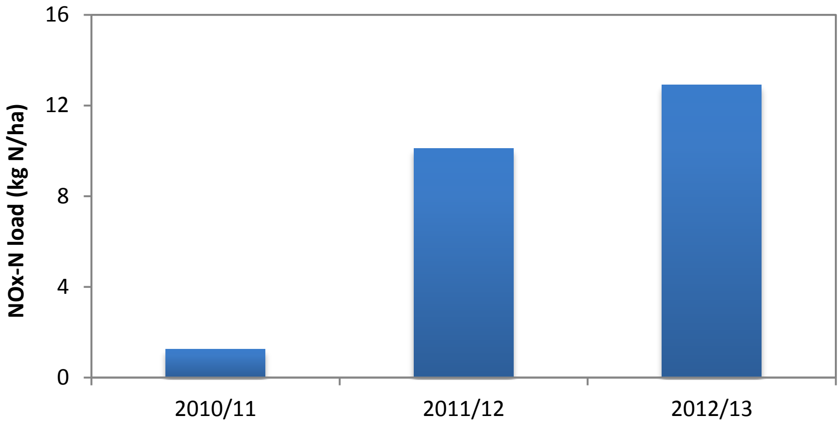

Figure 18. Nitrate (NO_X-N) loads in deep drainage at Site 1 over three monitored seasons
(Note: Site 2 data unavailable for 2010/11 period due to ephemeral aquifer)

While these monitored rates are relatively low from an agronomic perspective, they are considered environmentally important. Catchment modelling has shown that the Wet Tropics contributes 44% of the nitrate load to the Great Barrier Reef, whilst only occupying 5% of the area. This is equivalent to 11 kg N/ha from both sugarcane and banana production. This value is close to the N losses measured in this study.

Authorship

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Funding was provided by Terrain from the Paddock to Reef Integrated Monitoring, Modelling and Reporting Program, and by DNRM and DAFF.
*Additional results presented were funded by Reef Rescue Research and Development projects RRRD038 (Pesticide dynamics in the Great Barrier Reef catchment and lagoon: management practices (grazing, bananas and grain crops) and risk assessments)) and RRRD049 (Minimising off-farm movement of nitrogen in the north Queensland banana industry).

Acknowledgements

We thank Mr A. and S. Crema, Mr B. Boyge and Mr B. Mackay, and the Marina family for allowing access to their property, crop management records and assistance throughout the project. We also appreciate the advice and technical support provided by Jordan Villaruz (TCPSL), and the site management and agronomic measurements by Stewart Lindsay, John Slingo and the team at the South Johnstone Research Station (DAFF).

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