Appendix 35. Spatial nitrogen surplus relationship to yield in sugarcane

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Introduction

Paddock measured data on nitrogen losses from sugarcane to water are sparse (Armour et al., 2013; Bengtson et al., 1998; Ng Kee Kwong et al., 2002; Prove et al., 1997; Webster et al., 2012) mainly due to the high cost and uncertainty that exists in extrapolating measurements in time and space. To overcome this lack of data, the use of the nitrogen surplus (defined as the difference between the amount of N supplied to the crop in fertiliser, and the amount of N removed in harvested material (Parris, 1998)) has been proposed as a surrogate for nitrogen losses (Thorburn and Wilkinson, 2013). As the nitrogen surplus increases, the potential for nitrogen losses to water from sugarcane production also increase.

To our knowledge the nitrogen surplus at a sub-block scale has not been measured in sugarcane. Yield can vary across short distances in sugarcane production units under uniform management (Appendix 12, 13, 14 of this report). However, due to the variable total uptake of nitrogen by sugarcane (Thorburn et al., 2010) how the nitrogen surplus varies at a sub-block scale is unknown.
In this study we investigate the nitrogen surplus at multiple points within a single block of sugarcane over two years and investigate the relationship between nitrogen surplus and yield to make some assessment of management strategies that could be implemented in a precision agriculture context to reduce nitrogen losses from sugarcane.

Methods

The site was located in the Burdekin sugarcane farming district at Denis Pozzebon's farm, close to latitude 19°40' south. Rainfall at the nearby Bureau of Meteorology 'Ayr DPI' station (5 km to the north east) averages 933 mm per year, with more than 75% of rainfall occurring in the months from December to March (Bureau of Meteorology, 2014a). Maximum temperature averaged 32C in the hottest month (December) and 25.1C in the coolest (July). Minimum temperature averaged 22.8C in the warmest month (February) and 11.7C in the coolest (July) (Bureau of Meteorology, 2014b).

Soil at the site was a very dark grey surface of light clay that has been degraded by cultivation and bed-forming operations. The subsoils were most commonly whole coloured brown light clay to a depth of 60 – 100 cm, below which the light clay - light medium clay deeper subsoils were coarsely mottled brown and grey with many fine ochreous mottles (Coventry, 2012). Percent sand averaged 39 to 45%, silt 24 to 26% and clay 31 to 35% in the top 600 mm.

The trial was established in block 11-2, where sugarcane (Tellus variety) was planted in March 2006, and harvested annually to 2009, then growing for two years (due to inclement weather preventing harvest in 2010), with the 2011 harvest taking place in early July. Immediately after harvest in 2011 the ratooning cane was fertilised with 500 kg/ha of 'urea S', delivering 205 kg/ha of nitrogen. The forth ratoon of sugarcane was harvested in October 2012, before being fertilised again with 500 kg/ha of 'urea S', delivering 205 kg/ha of nitrogen. The fifth ratoon was harvested in September 2013. Prior to harvest each year the standing sugarcane was burnt. In 2012 and 2013 the sugarcane was harvested with machines fitted with yield monitors mounted on the elevator, monitoring hydraulic pressure applied which could then be used to calculate yield on a three second harvesting interval.

At harvest in 2012 and 2013, more than 200 random sites within the block were sampled by taking five sticks of sugarcane and georeferencing the sites with differential GPS. At 22 and 25 of these sites in 2012 and 2013 respectively, the sugarcane mass (fresh and dry weight) was measured and total nitrogen determined by combustion in a Leco analyser. For each of the georeferenced sampled points, nitrogen in harvested cane (kg N/t fresh weight) was calculated and converted to exported nitrogen (kg N/ha). Nitrogen surplus (kg N/ha) was calculated as the difference between applied fertiliser and exported nitrogen.

The yield monitor data was converted into yield maps, and the georeferenced sampling points located on the map. Yield was determined at each of the 22 and 25 sampling points in 2012 and 2013 respectively from the yield maps. The 22 and 25 sampled points from 2012 and 2013 were divided into those that had a higher nitrogen surplus than the average nitrogen surplus, and those that had a lower nitrogen surplus, and plotted separately onto the relevant yield map.

Results

Dry matter of sampled sugarcane averaged 34% (range 23 to 37%) in 2012 and 34% (range 31 to 36%) in 2013. Total nitrogen in sampled sugarcane averaged 2306 mg/kg (range 812 to 3840) in 2012 and averaged 5016 mg/kg (range 2800 to 6400) in 2013.

Harvested fresh sugarcane yield at the 22 sampled sites in 2012 averaged 117 t/ha (range 67 to 146) and at the 25 sampled sites in 2013 averaged 81 t/ha (range 41 to 112) (Figure 35.1). Nitrogen surplus exhibited a wider range, averaging 114 kg N/ha in 2012 (range 54 to 171) and 68 kg N/ha in 2013 (range -7 to 136) (Figure 35.1).

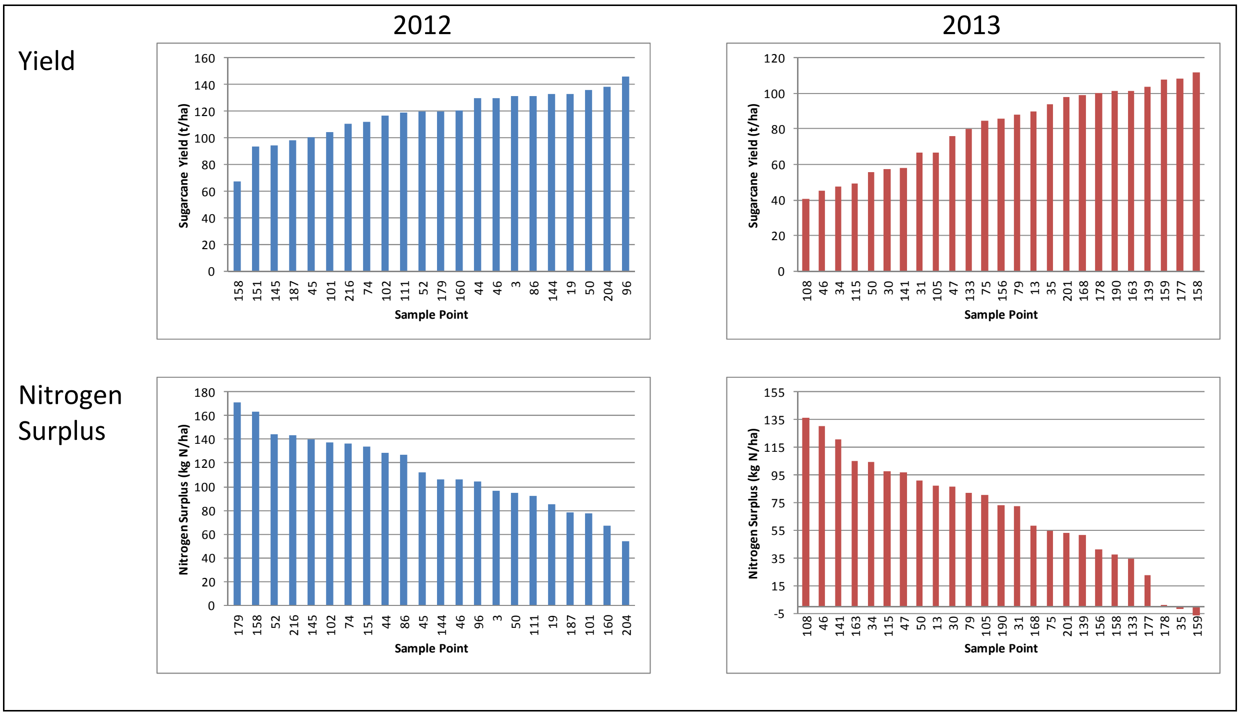

Figure 35.1 Yield (fresh weight tonnes per hectare) and nitrogen surplus (kilograms per hectare) from block 11-2 at 22 random sampling points (2012) and 25 random sampling points (2013) taken at harvest. Average yield was 117 t/ha in 2012 and 81 t/ha in 2013. Average nitrogen surplus was 114 kg N/ha in 2012 and 68 kg N/ha in 2013.

Kilograms of nitrogen in sugarcane, presented as per tonne of fresh sugarcane, averaged 0.78 kg/t in 2012 (range 0.28 to 1.29) and 1.73 in 2013 (range 0.99 to 2.2) (Figure 35.2). There appears to be no relationship between nitrogen in sugarcane and sugarcane yield as evident by the slope of the trend lines being very close to zero in both years (Figure 35.2).

In each year the difference between the nitrogen surplus of each point and the average nitrogen surplus was plotted against the difference between the fresh weight sugarcane yield of each point and the average yield. These plots show a trend that as sugarcane yield increased, nitrogen surplus decreased (Figure 35.3).

The yield maps for 2012 and 2013 exhibited a degree of temporal stability, with a lower yielding zone to the west of the block (Figure 35.4). The 22 and 25 sampled points from 2012 and 2013 were divided into those that had a higher nitrogen surplus than the average nitrogen surplus, and those that had a lower nitrogen surplus. Those with a higher than average nitrogen surplus are plotted in Figure 35.4 (a and b) and those with a lower than average nitrogen surplus are plotted in Figure 35.4 (c and d). The higher than average nitrogen surpluses tended to be associated with lower yielding areas, and the lower than average nitrogen surpluses tended to come from areas of higher yield (Figure 35.4).

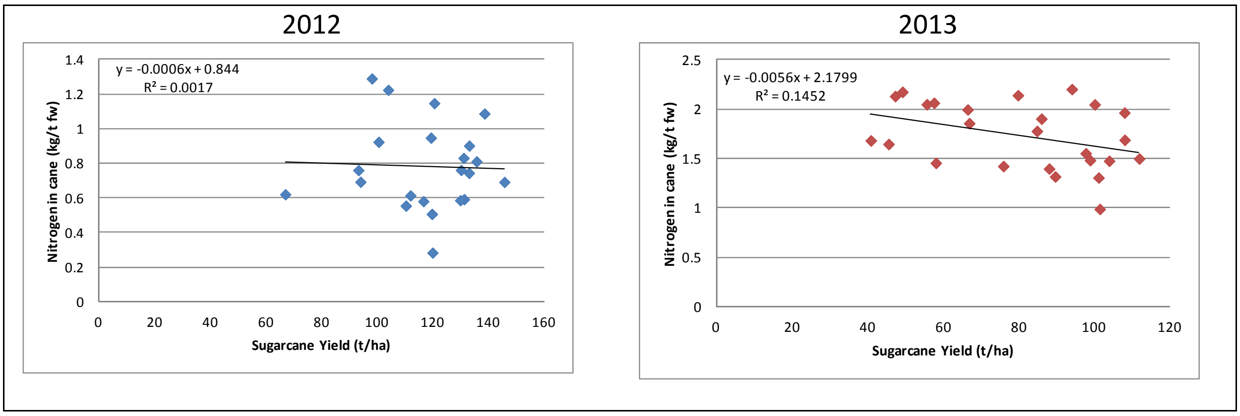

Figure 35.2 Relationship between nitrogen in sugarcane at harvest (kilograms of nitrogen per tonne of sugarcane fresh weight) and sugarcane yield (fresh weight tonnes per hectare) from block 11-2 at 22 random sampling points (2012) and 25 random sampling points (2013) taken at harvest.

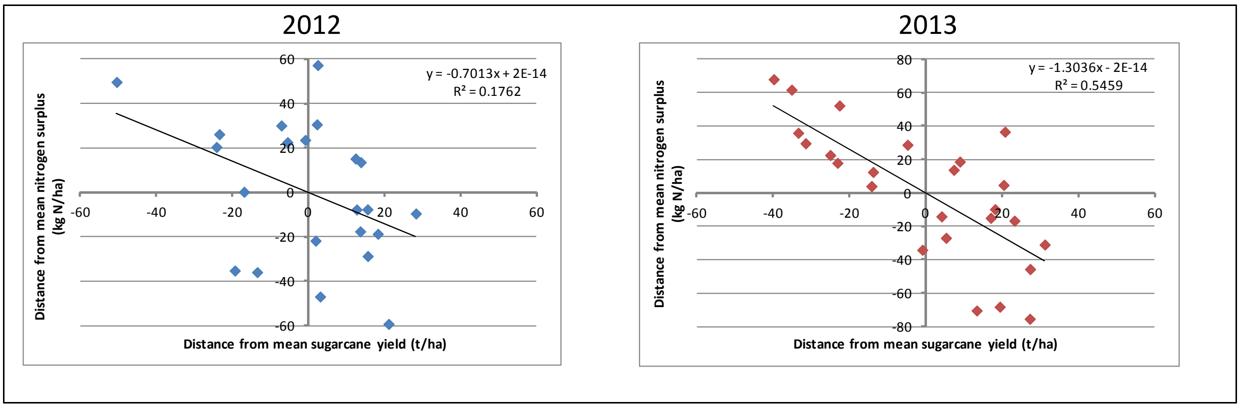

Figure 35.3 Relationship between nitrogen surplus (kilograms of nitrogen per hectare) and sugarcane yield (fresh weight tonnes per hectare) from block 11-2 at 22 random sampling points (2012) and 25 random sampling points (2013) taken at harvest.

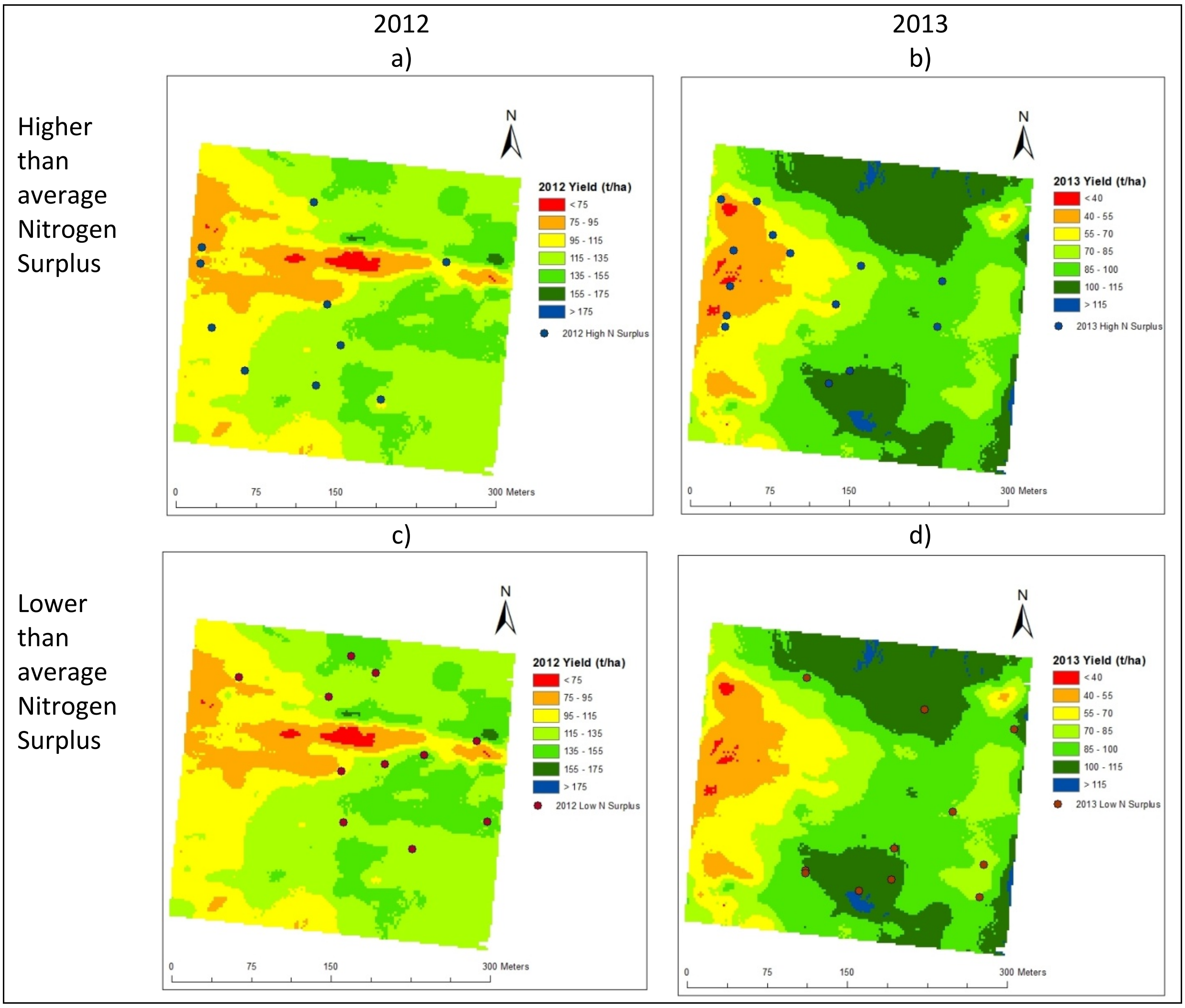

Figure 35.4 Location of random sampling points with higher than the average (a and b) or lower than the average (c and d) nitrogen surplus in 2012 and 2013

The majority of points in 2012 and 2013 lie in the upper left and lower right quadrants (Figure 35.3), supporting the hypothesis that higher than average yields are associated with lower than average nitrogen surpluses, and lower than average yields are associated with higher than average nitrogen surpluses. In 2012 16 of 22 points lie in these quadrants and in 2013 20 of 25 lie in the upper left and lower right quadrants (Figure 35.3).

Discussion

The nitrogen surplus can be used as a surrogate for nitrogen losses in sugarcane at the block scale, as nitrogen surplus increases, so do nitrogen losses to water (Thorburn and Wilkinson, 2013). Routinely measuring nitrogen surplus at a sub-block scale would be time consuming and expensive. The use of yield monitors in sugarcane automates the yield calculation side of the nitrogen surplus equation; however, individual samples of sugarcane need to be analysed for total nitrogen.

Through sampling a block of Tellus sugarcane over two years in the Burdekin sugar milling area we are able to demonstrate there is no relationship between sugarcane yield and nitrogen in sugarcane when expressed as kg N/fresh weight (Figure 35.2). Low yielding areas are just as likely to have the same concentration of nitrogen as high yielding areas. In this uniformly fertilised block of sugarcane there was a relationship between yield and the nitrogen surplus (Figure 35.3). As sugarcane yield increased, nitrogen surplus decreased. Therefore, under uniform management, yield can be an indicator of nitrogen surplus.

Georeferenced sampling points in both 2012 and 2013 where the nitrogen surplus was lower than the average nitrogen surplus of all sampled points (roughly half of the 22 and 25 points) strongly tended to be where the sugarcane yield was higher than the average sugarcane yield (Figure 35.4). Given the relationship between nitrogen surplus and yield, and the propensity for higher nitrogen surpluses to be associated with higher nitrogen losses, this study suggests that the lowest yielding parts of a sugarcane block are likely to be the areas where more nitrogen losses are originating. Management of nitrogen, such as variable rate application, that targets reductions of nitrogen application to lower yielding areas is likely to lead to lower nitrogen losses than reducing applications to higher yielding areas.

How much nitrogen can be reduced is difficult to determine *ex post* using this analysis. The average nitrogen surplus for the five highest yielding points was 89 and 41 kg N/ha respectively in 2012 and 2013. The average nitrogen surplus for the five lowest yielding points was 127 and 112 kg N/ha respectively for 2012 and 2013. The lowest yielding parts of block are not nitrogen limited, as demonstrated by their higher than average nitrogen surpluses. Lowering the nitrogen surplus of the low yielding parts of the block can be achieved by lowering the nitrogen application rate. For the five lowest yielding points measured in the block to achieve the same average nitrogen surplus as the five highest yielding points, nitrogen rates would have to be lowered at these points by 38 kg N/ha in 2012 and 71 kg N/ha in 2013. These rates may be a useful starting point for demonstrating lower nitrogen rates to lower yielding parts of this block.

Conclusion

Nitrogen surplus is correlated with sugarcane fresh weight yield at a sub-block scale. Higher nitrogen surpluses are associated with areas of the block where yield is lowest. As higher nitrogen surpluses are correlated with higher nitrogen losses to water, yield appears to be an indicator of possible nitrogen losses from sugarcane under uniform management – nitrogen losses are more likely from lower yielding areas of blocks. Management actions targeted at lowering nitrogen application rates to lower yielding areas of blocks should reduce nitrogen losses from sugarcane to water.

References

Armour, J.D., Nelson, P.N., Daniells, J.W., Rasiah, V., Inman-Bamber, N.G., 2013. Nitrogen leaching from the root zone of sugarcane and bananas in the humid tropics of Australia. Agriculture, Ecosystems & Environment 180, 68-78.

Bengtson, R.L., Selim, H.M., Ricaud, R., 1998. Water quality from sugarcane production on alluvial soils. American Society of Agricultural Engineers, pp. 1331-1336.

Bureau of Meteorology (2014a). http://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_nccObsCode=136&p_display_type=dailyDataFile&p_stn_num=033002&p_startYear= (accessed August 2014).

Bureau of Meteorology (2014a). http://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_nccObsCode=38&p_display_type=dataFile&p_stn_num=033002 (accessed August 2014).
Coventry, R.J. (2012). Soil profile descriptions from Pozzebon's Mount Kelly Farm, Ayr, Queensland.Technical Report, 2012–11, Soil Horizons Pty Ltd, Townsville (unpublished).
Ng Kee Kwong, K.F., Bholah, A., Volcy, L., Pynee, K., 2002. Nitrogen and Phosphorus Transport by Surface Runoff From a Silty Clay Loam Soil Under Sugarcane in the Humid Tropical Environment of Mauritius. Agriculture, Ecosystems and Environment 91, 147-157.
Parris, K., 1998. Agricultural nutrient balances as agri-environmental indicators: an OECD perspective. Environmental Pollution 102, 219-225.
Prove, B.G., McShane, T.J., Reghenzani, J.R., Armour, J.D., Sen, S., Moody, P.W., 1994. Nutrient loss via drainage from the major agricultural industries on the wet tropical coast of Queensland. Water Down Under, Adelaide, pp. 439-443.
Thorburn, P.J., Biggs, J.S., Webster, A.J., Biggs, I.M., 2010. An improved way to determine nitrogen fertiliser requirements of sugarcane crops to meet global environmental challenges. Plant and Soil.
Thorburn, P.J., Wilkinson, S.N., 2013. Conceptual frameworks for estimating the water quality benefits of improved agricultural management practices in large catchments. Agriculture, Ecosystems & Environment 180, 192-209.
Webster, A.J., Bartley, R., Armour, J.D., Brodie, J.E., Thorburn, P.J., 2012. Reducing dissolved inorganic nitrogen in surface runoff water from sugarcane production systems. Marine Pollution Bulletin 65, 128-135.