Spatial analysis of nitrogen strip trials in sugarcane

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Abstract
Nitrogen losses from sugarcane farms pose a threat to the Great Barrier Reef. Applying differential rates of nitrogen within blocks is one proposed management practice to reduce this threat by matching nitrogen rates to crop demand at the within-block scale. Farmers need practical methods to determine the appropriate nitrogen rate to apply to differing yielding parts of their blocks when employing variable rate application. We implemented a nitrogen strip trial with rates of 37, 132, and 170 kg N/ha in a plant crop of sugarcane and harvested it with a harvester fitted with a yield monitor. From the resultant yield map, yield values were extracted every three metres along the centre line of each strip. Rolling groups of ten extracted yield values were compared for each strip to an adjacent area that received the farmers normal application of 153 kg N/ha via a paired two tail *t*-test. We analysed areas of significantly different yield between adjacent strips in association with the yield map to identify areas where variable application of N could be justified without compromising yield.

Key Words
Precision agriculture, Yield map, Runoff, Great Barrier Reef, Yield monitor

Introduction
In north-eastern Australia, elevated levels of nitrogen originating from agricultural runoff have been detected in rivers draining to the Great Barrier Reef lagoon (Mitchell et al 2009, Bramley and Roth 2002), where excess nitrogen is potentially leading to a degraded reef ecosystem (De'arth and Fabricius 2010). Sugarcane is the dominant cropping system in Great Barrier Reef catchments (~380,000 ha), and is an intensive user of nitrogen fertiliser. There is an immediate need to reduce losses of nitrogen to rivers draining to the Great Barrier Reef (Wooldridge et al 2015), with various strategies recently recommended to increase nitrogen use efficiency and reduce losses (Bell 2014).

Yield of sugarcane within a management unit (or 'block') can be highly variable (Bramley 2009). Under uniform management, lower yielding areas of a block of sugarcane are likely to be nitrogen loss 'hot spots' (Webster et al 2016) and strategies such as variable rate application (VRA) that involve reduced nitrogen application to areas identified as inherently low yielding could reduce nitrogen losses without compromising yield. To implement VRA, farmers need a basis for determining what rates to apply where, to ensure yield is not reduced. The regionally-based fertilizer recommendations do not necessarily provide the right norms for such fertilizer decisions as they derive from trials conducted in small plots that are assumed to be homogenous, albeit often located over a wide geography. Various techniques exist to support VRA, one of these being the spatial analysis of strip trials via a moving *t*-test to identify areas where variable management will achieve a significant change in yield (Lawes and Bramley 2012).

In this study, we apply the moving t-test of Lawes and Bramley (2012) to a number of nitrogen rate treatments in a sugarcane block and interpret the results in conjunction with a yield map to help identify if varying the nitrogen application rate is warranted and to assess the potential utility of the moving t-test method.

Methods
Site description
The experimental site was located in the Burdekin sugarcane farming district, close to 19°40' south, 147°20' east. Rainfall at the nearby Bureau of Meteorology 'Ayr DPI Research Stn' (station number 33002) averages 954 mm per year, with more than 75% of rainfall occurring from December to March (Bureau of Meteorology 2016). Soil at the site is a dark grey vertisol with percent sand averaging 39 to 45%, silt 24 to 26% and clay 31 to 35% in the top 600 mm. Sugarcane (variety Q183) was planted in May 2012, following a break crop of Red Caloona cowpea (planted October 2011 and mulched April 2012). The cowpea returned an

average of 113 kg N/ha in residue. The whole site received 37 kg N/ha via a custom fertiliser blend at planting.

Treatments
Four months after planting, three strips, each nine rows wide, were implemented such that total N application to the strips was either 170, 37, or 132 kg N/ha.. The remainder of the block received fertiliser for a total N application of 153 kg N/ha (Figure 1a). The site was irrigated so that water was non-limiting.

Data collection
The site was harvested on 16th August 2013 after burning. The sugarcane was harvested with a machine fitted with a yield monitor mounted on the elevator, monitoring applied hydraulic pressure (Jensen et al. 2012) which was then used to calculate yield on a three second harvesting interval. The yield monitor data was converted into a yield map following the protocol of Bramley and Jensen (2013). Yield values were extracted from the yield map every 3 metres along the centre line of each treatment strip, and in parts of the block that received the standard 153 kg N/ha adjacent to the treatment strips.

Data analysis
Extracted yield values from each treatment were paired with yield values from a strip parallel to the treatment centre line (approximately 14 metres away) where the standard 153 kg N/ha was applied.

Moving from east to west, the first ten extracted point yields values of a treatment (representing yield along 30 metres of row, approximately double the distance between strips) were compared via a paired two tail *t*-test with the first ten extracted point yields from an adjacent strip approximately 14 metres away, and the *P*-value assigned to the fifth extracted yield value. The *t*-test was performed for the next ten extracted yield values by moving the starting value along one (performing a *t*-test on the 2nd to 11th extracted yield values) and ‘rolled’ until a *t*-test was performed on every paired group of ten extracted yield values over the length of the strip, using the method described by Lawes and Bramley (2012). The *P*-values less than 0.01 were marked on the yield difference plots as zones of significantly different yield.

Results
The overall yield of the block averaged 186 fresh tonnes per hectare, ranging from less than 75 t/ha to greater than 200 t/ha (Figure 1b). Along the entire eastern boundary is a zone of low yielding area, possibly an artefact in converting the raw yield monitor data because the harvester only harvested in an east to west direction and the elevator tends to be idle or slow at the start of rows. This area was excluded from analysis.

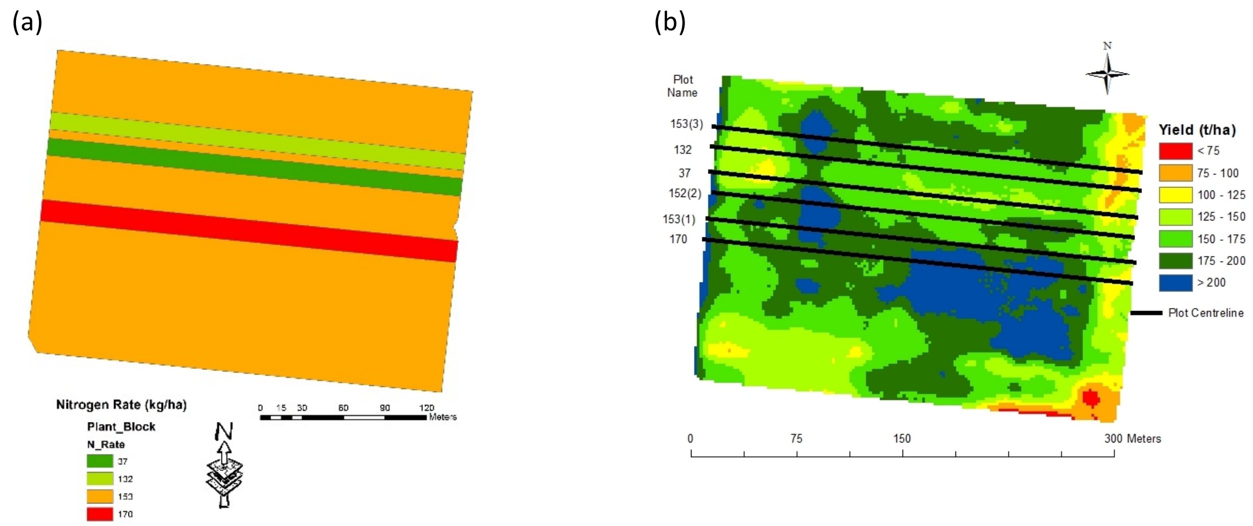

Figure 1. (a) Layout of the treatments within a block of sugarcane, (b) Yield map of whole block and centerlines of treatments

The difference between extracted yield values along adjacent strips (and its significance $P < 0.01$) is plotted in Figure 2. In all of the treatment strip comparisons there are large areas where the yield difference between the two strips is significant. When comparing the 170 kg N/ha strip to an adjacent strip of 153 kg N/ha to the south of the 170 strip (Figure 2a) most of the yield difference along the strip is less than 15 t/ha (except two small areas between 39 to 48 metres and 255 to 261 metres from the eastern boundary). Indeed, a small area on the western boundary has the 170 kg N/ha treatment yielding lower than the 153 kg N/ha application. Almost the entire 37 kg N/ha treatment is significantly lower yielding than a strip to the south which received 153 kg N/ha application, with the difference exceeding 40 t/ha in a number of places, and reaching a maximum of 73 t/ha (Figure 1b). The difference between the 132 kg N/ha treatment and 153 kg N/ha to the north is significant for much of the strip (Figure 2c). However, the yield difference is mostly less than 15 t/ha except for an area between 213 and 270 metres from the eastern boundary.

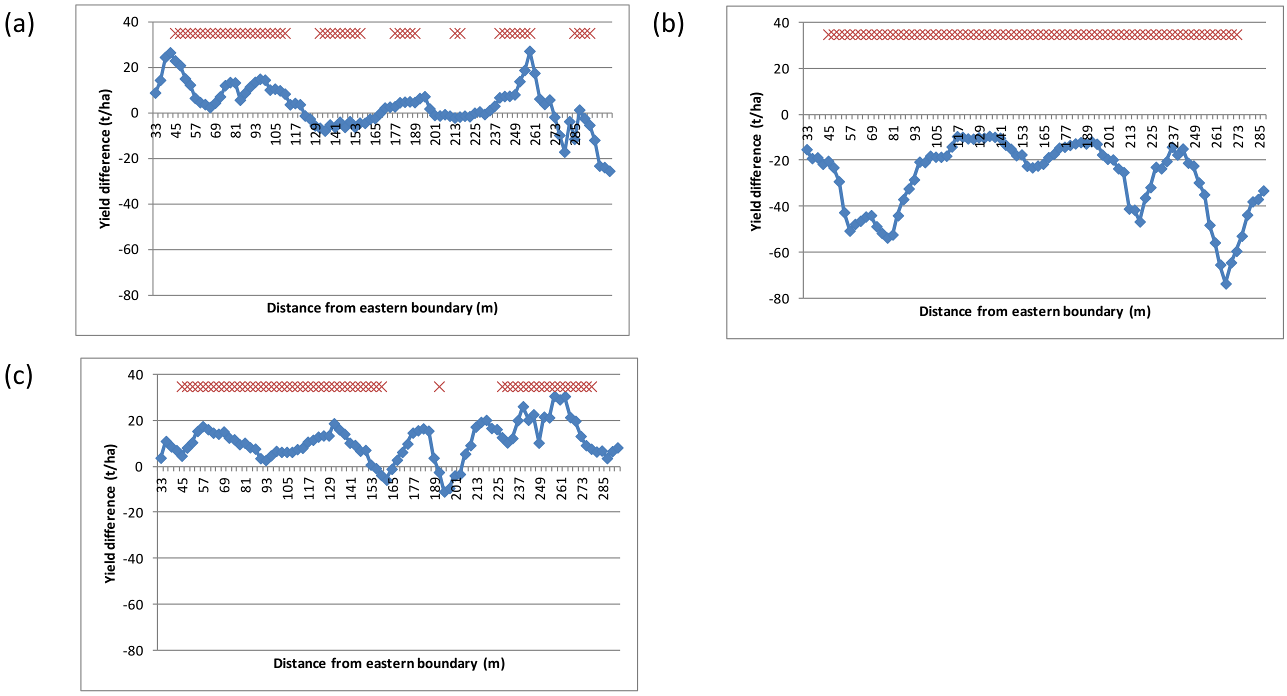

Figure 2. Difference between extracted yield values for treatments compared with 153 kg N/ha. Areas of significance (*P* <0.01) shown with (x). (a) = 170 compared with 153, (b) = 37 compared with 153, (c) = 132 compared with 153

Discussion

The moving window *t*-test, as described by Lawes and Bramley (2012), was initially implemented for use with an 'N-rich' strip (that is, a luxurious N application) to identify areas where response to additional N can be expected. In this instance reduced N treatments are used as 'N limiting' strips, to identify areas where N application is not leading to a response and thus where N rates could be reduced.

The help interpret the moving t-test we consider the yield map (Figure 1b). The yield map reveals large areas where the yield is higher and lower than average, presumably as a consequence of some aspect of underlying variation in the block (Bramley 2009). These areas should be considered when interpreting the significance of yield differences in the moving t-test (Figure 2). For example, the 37 kg N/ha treatment is the only treatment that can be visualized on the yield map (Figure 1b) and is the treatment with the largest yield differences from the normal farmer practice (153 kg N/ha). There are areas of the 37 kg N/ha strip that yield within 10 t/ha of the 153 kg N/ha application, possibly highlighting where N is much less limiting, and worthy of further investigation when considering VRA. Indeed, it is noteable that whilst the 37 kg N / ha strip is the only treatment strip that is identifiable in the yield map, it is only readily identifiable at its lowest yielding parts indicating that this area may be inherently lower yielding. Of course, differences between this strip and the other N rates used also suggest some scope for reducing rates overall.

In this case, and given the long history of N application in the sugar industry targeted at yield maximization, it appears the addition of an N limiting strip and analysis of yield differences between that and 'normal' application may have more potential utility than an 'N rich' strip as described in Lawes and Bramley (2012). Indeed, 'normal' applications of N in the sugarcane industry may already be luxurious (Thorburn et al., 2011) and therefore the use of a strip using N in excess of this may not identify manageable yield differences in a VRA context. It should also be noted that in this preliminary study, we did not have prior knowledge of the variation in crop performance in this block or of the underlying drivers of this. As illustrated in Lawes and Bramley, positioning of strips to cover areas known to be inherently lower and higher yielding should assist in extrapolating the results of such strip trials to the remainder of the block.

Yield maps can be used by practitioners of PA to identify zones of differential management, especially when collected over several seasons (Bramley and Trengove 2013). While yield maps are instructive, the simple tool of analyzing N rich (or N limiting) strips using a moving *t*-test can add value to the interpretation (Lawes and Bramley 2012). Here, we show that short-range variation in sugarcane yield can be marked, as is illustrated by the yield map. We also highlight areas of the 37 kg N/ha treatments (specifically between 54 and 170 metres from the eastern boundary) where nitrogen in excess of 37 kg N/ha is warranted.

Conclusion

In conclusion, in sugarcane, when areas of significantly different yield from an N limited strip are analysed in conjunction with yield maps, more meaningful identification of areas to target future differential management can be made. Analysing yield maps in conjunction with the moving t-test of Lawes and Bramley (2012) is likely to lead to better management decisions on the appropriate rates of N to apply spatially and ultimately lower N losses from N loss 'hot spots'.

References

Bell MJ (2014). A review of nitrogen efficiency in sugarcane. Sugar Research Australia Limited, Brisbane.

Bramley RGV (2009). Lessons from nearly 20 years of Precision Agriculture research, development, and adoption as a guide to its appropriate application. Crop Pasture Science 60, 197-217.

Bramley RGV and Trengove S (2013). Precision Agriculture in Australia: present status and recent developments. Engenharia Agricola 33 575-588..

Bramley RGV and Roth CH (2002). Land-Use Effects on Water Quality in an Intensively Managed Catchment in the Australian Humid Tropics. Marine and Freshwater Research*,* 53, 931-940.

Bureau of Meteorology (2016). http://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_nccObsCode=139&p_display_type=dataFile&p_stn_num=033002 (accessed March 2016).

De'ath G and Fabricius K (2010). Water quality as a regional driver of coral biodiversity and macroalgae on the Great Barrier Reef. Ecological Applications*,* 20, 840-850.

Lawes RA and Bramley RGV (2012). A Simple Method for the Analysis of On-Farm Strip Trials. Agronomy Journal 104, 371-377.

Mitchell A, Reghenzani J, Faithful J, Furnas M (2009). Relationships between land use and nutrient concentrations in streams draining a 'wet-tropics' catchment in northern Australia. Marine and Freshwater Research, 60, 1097-1108.

Thorburn PJ, Biggs JS, Webster AJ, Biggs IM (2011). An improved way to determine nitrogen fertiliser requirements of sugarcane crops to meet global environmental challenges. Plant and Soil, 339**,** 51-67.

Webster T, Bramley R, Jensen T (2016). Spatial analysis of the relationship between nitrogen surplus and yield in sugarcane. Proceedings of the Australian Society of Sugar Cane Technologists 38th Conference, Mackay.

Wooldridge SA, Brodie JE, Kroon FJ, Turner RDR (2015). Ecologically based targets for bioavailable (reactive) nitrogen discharge from the drainage basins of the Wet Tropics region, Great Barrier Reef. Marine Pollution Bulletin*,* 97, 262-272.