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Variable Rate Nutrient Application on Sugarcane Farms in the Mackay Whitsunday Region[1]

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Abstract

Variable rate nutrient application (VRA) has the potential to improve farm profitability by improving the overall use of fertiliser inputs on-farm. In addition, VRA nutrient application is potentially a viable option for the reduction of dissolved inorganic nitrogen (DIN) in farm water runoff as a consequence of the associated reduction in overall nitrogen application. Agricultural runoff, in particular DIN from sugarcane production in the Mackay Whitsunday region, enters into the Great Barrier Reef lagoon affecting water quality. In this study we investigate the impact on the economics of the farm business due to a shift from the conventional sugarcane farming practice, using the industry's 'Six Easy Steps' (6ES) nutrient application rate, to variable rate within block. The conventional 6ES rate is based on the district yield potential in conjunction with the soil mineralisation index and organic carbon content of soils on a particular block in a given region. VRA of nutrients aims to match the nutrient application rate to the historical block yield potential and the physical and chemical properties of the soil. Where there is significant variation within-block in terms of yield or crop variation, topography, climate and soil characteristics, nutrients can be varied to match zone yield targets. We find that the VRA system has the capacity to improve farm gross margins and reduce the overall nutrient application on one trial farm (by 14 percent). However, after the capital outlay required for the system was accounted for, we find that the VRA system reduced the profitability of the overall farming enterprise. Consequently, we explore the conditions under which the VRA system adds value to the trial farm, and also the minimum farm size (on land with similar yield variation to the trial property) needed for the capital outlay to breakeven.

Key words: Great Barrier Reef, variable rate, precision agriculture, sugar cane.

Introduction

Variable rate nutrient application (VRA) involves changing the rate of fertiliser applied within a field to target nutrients into high yielding soil areas. VRA has the potential to improve farm profitability

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by reducing the overall use of fertiliser. In addition, farmers are coming under increasing pressure to improve the quality of farm water runoff. Water quality in agricultural areas surrounding the Great Barrier Reef (GBR) is receiving increasing attention as an important determinant of environmental health. In particular, the runoff of Dissolved Inorganic Nitrogen (DIN) from agricultural cropping land has been identified as a contributory source of pollution for the GBR (Brodie et al., 2012; Joo et al., 2012; Kroon et al., 2012; Reef Water Quality Protection Plan Secretariat, 2013; Thorburn, Wilkinson and Silburn, 2013). Agricultural runoff from sugar production in the Mackay Whitsunday region, an intensive sugar growing area in northern Australia, is a key source of DIN pollution affecting the health of the GBR (Reef Water Quality Protection Plan Secretariat, 2013).

The adoption of precision agriculture techniques, in particular intra-block VRA, is seen by many as a viable management approach for the reduction of overall nitrogen application rates and a consequent decrease in the nutrient content of water runoff from farms (Coventry and Hughes, 2011; Markley and Hughes, 2013b). Extension work undertaken in sugarcane farming has demonstrated the potential to reduce nitrogen use without significantly altering yields through the application of VRA techniques within sugarcane blocks (Markley and Hughes, 2013a). Analyses of these intra-block management techniques have shown that poor yielding areas in cane fields are often associated with poor subsurface drainage exacerbated by low-lying areas within the block as well as variation in the soil's chemical and physical properties (Coventry and Hughes, 2011; Markley and Hughes, 2013b). By reducing nitrogen application rates in areas that consistently yield less sugarcane, the potential exists to reduce the overall level of nitrogen applied to the field. In other crop-production systems, substantial reductions in nutrient application as a result of the implementation of VRA techniques have been observed (Robertson, Carberry and Brennan, 2009). However, the impact of VRA on the rate of nutrient application will depend critically on the propensity and capacity of the existing growers to take up the technology. Amongst other things, the profit potential of the VRA system for an individual grower will depend on the amount of intra-block yield variability on their farm.

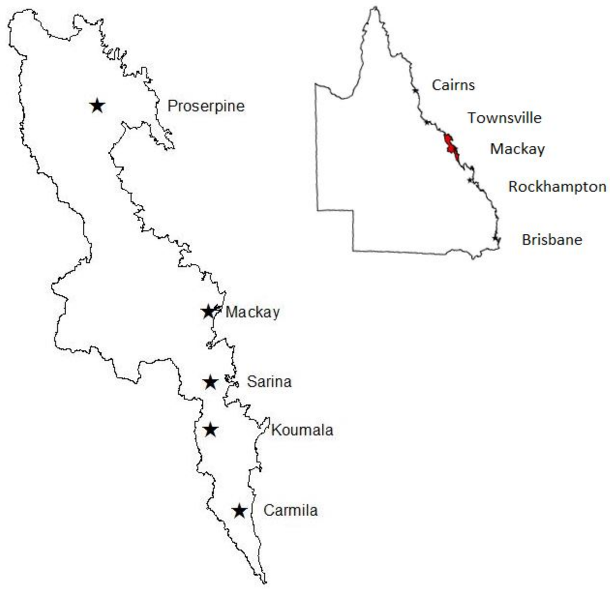
The use of VRA has the potential to improve farm efficiency through more targeted application of nutrient inputs (Markley and Hughes, 2013a). The conventional sugarcane farming practice has been to apply uniform rates of nutrient to the whole farm area as specified by the Six Easy Steps (6ES) programme, which is based on the district yield potential (DYP) that applies to that farm's local mill area and the soil properties, which are determined by soil testing (Schroeder et al., 2009). By targeting the application of nutrient inputs, site-specific methods have the potential to reduce overall nitrogen use and improve farm profitability and efficiency. In this paper we investigate the net economic benefit to sugarcane growers of a shift from conventional sugarcane farming, based on the industry recommended 6ES rate of fertiliser application, to a VRA system. The aim of the VRA system is to improve the targeted delivery of nutrient to the paddock. The VRA system varies the rate of nitrogen application across the field depending on a combination of soil type and historical yield data to achieve a refined block yield target (BYT), which measures the yield potential of the area over which the VRA system applies (the entire farm in this case), and a specific zone yield target (ZYT), which measures the yield potential of each of the defined management zones. We use data from an agricultural trial conducted on a sugarcane farm in the Mackay Whitsunday region in central Queensland, Australia.

In addition to measuring the improvement in farm gross margin, we undertake an investment appraisal to estimate the on-farm value of purchasing a variable rate applicator and associated on-costs. We undertake our analysis for a farm that is already operating at a 'high' level of management, i.e. with GPS guidance for at least some farm operations. Using the change in farm gross margin per hectare, from the agricultural trial results, we investigate the breakeven farm size for the net present value of that investment. Using this analysis we examine the minimum area of sugarcane farming land that may be required for the formation of cooperative or grower groups providing a dedicated contracting service for VRA nutrients.

Background

As shown in Figure 1, sugarcane in the Mackay Whitsunday region is grown from Carmila to Proserpine and as far west as the Nebo range. According to the 2014-15 Rural Environment and Agricultural Commodity Survey (Australian Bureau of Statistics, 2016), the total gross value of sugarcane production in the Mackay Whitsunday region is approximately $349 million.

Figure 1: Geographic location of the Mackay Whitsunday region

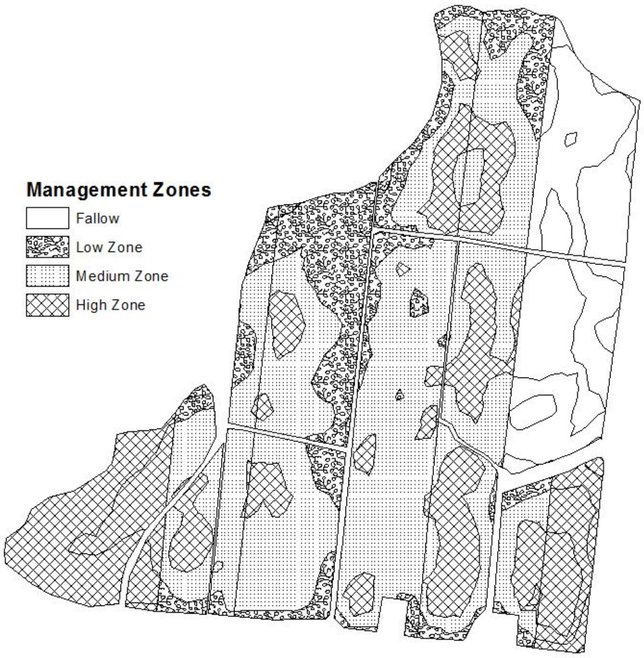


Historically, there has been a one-size fits all management approach to growing sugarcane even though high levels of spatial and temporal variation exist between regions (Bramley, 2009; Davis, Baillie and Schmidt, 2009; Lawes et al., 2004). The annual rainfall in this region averages 1,555 mm and is summer dominant (Australian Bureau of Meteorology, 2015). There are a number of other prominent physical parameters that vary throughout the region, including soil structures and textures, maximum and minimum temperatures and solar radiation.

Trial Design

This farming system trial was established to investigate the performance of an entire sugarcane farm under VRA, compared with the uniform rate recommended in the 6ES programme. The trial builds on previous sugarcane innovation trials undertaken by Farmacist Mackay which, among other things, link yield variation with heterogeneous soil properties (Coventry and Hughes, 2011; Markley and Hughes, 2013a). Analysis of the soil and historical yield data for the trial farm has identified three distinct yield zones which are not contiguous, and which are stable over time. Consequently, a three zone nutrient management system (i.e. high, medium and low) has been established for the trial. A management zone map for this system is shown in Figure 2, which identifies the different rates of fertiliser that are applied in each yield zone. The high zone has the highest rate of nutrient application and the low zone has the lowest.

Figure 2: Management zone map of VRA trial property



The management zone map shown in Figure 2 is based on the BYTs and ZYTs as previously defined. These targets are identified from a statistical analysis of historical yield data which is cross referenced with recent soil tests (Markley and Hughes, 2013a). Nitrogen application rates in each of the management zones were determined by multiplying the applicable ZYT by 1.4 kg N/ha for each tonne of sugarcane up to 100t/ha, and then adding 1 kg N/ha for every tonne of sugarcane over 100 t/ha (Markley and Hughes, 2013a). The application rate in the high zone has been rounded up from 158 kg N/ha to 160 kg N/ha. This nitrogen was delivered using Gargett Ratooner fertilizer, which contains by weight: 26 percent nitrogen, 2 percent phosphorus, 16 percent potassium and 2 percent sulphur. The zonal application rates for Gargett Ratooner were: 625kg/ha for the high zone, 540kg/ha for the medium zone and 425kg/ha for the low zone. The nutrient was applied using a stool splitter fertiliser bin, and in the case of the VRA system, a variable rate controller. Being in fallow, a section of the farm totalling 5 ha did not receive any fertiliser over the trial period.

Table 1 presents a summary of the key trial characteristics that have been discussed in this section, and compares the VRA trial with the conventional 6ES based management practice for the farm. The table also reports the total nitrogen use under each of the management practices, based on the area of land under each of the management zones in the VRA trial. While the VRA system in this trial has involved varying the application rate of other macronutrient under each of the yield zones, advice from the project agronomist has indicated that nitrogen was the limiting factor for sugarcane growth during this period. The result shows a net reduction in nitrogen application under the VRA system of 14 percent.

Investment Analysis

To indicate if the switch in management to a VRA system is economically viable an investment analysis was completed. This analysis determines whether the stream of gross margin benefits that is due to the farm changing from its historical nutrient application regime (i.e. before), to the VRA system (i.e. after) is sufficient to cover the initial capital and on-going costs, when discounted back to today’s dollars.

Table 1: Comparison of sugarcane parameters in the trial

Practice	Conventional Nutrient Application (Before)	Variable Rate Nutrient Application (After)
Fertiliser	Gargett Ratooner N:26; P:2; K:16; S:2	Gargett Ratooner N:26; P:2; K:16; S:2
Fertiliser rate kg/ha and area under each zone	625kg/ha =37ha Nil 0kg/ha = 5 ha	High 625kg/ha = 10 ha Med 540kg/ha = 21 ha Low 425kg/ha = 6 ha Nil 0kg/ha = 5 ha
Total nitrogen for each yield zone (kg N/ha)	160	High = 160 Medium = 140 Low = 110
Total nitrogen applied (Ratoons kg/ha)	5120	4420 (14% reduction)
Implement	Stool Splitter with manual rate control	Stool Splitter with variable rate controller

This is achieved through the calculation of a net present value (NPV) for the investment. In this case, the farmer's historic nutrient application is based on the 6ES programme, and we have not considered the famer's choice to invest in GPS technology (due to the wide range of precision farming techniques these systems enable in addition to the VRA system considered here). Our investment analysis has been done for the first decade of operating the VRA system on the farm.

Calculating the change in farm gross margin between the 'before' and 'after' scenarios is the first step in assessing the value added by capital investment. The gross margin analysis for this trial was undertaken using the Farm Economic Analysis Tool (FEAT), a tool developed by the Queensland Department of Agriculture and Fisheries for analyses in sugar production. The assumptions for our gross margin analysis are presented in Table 2.

Table 2 indicates the total farm area was 42 ha. At the time of the trial, 5 ha of this was in bare fallow and received no fertiliser, and a further 5 ha was under plant cane, and received a uniform rate of nutrient application. The ratooning sugarcane, which accounted for the remaining 76 percent of farm area, was fertilised according to the VRA specification. The analysis assumes an international commodity price for sugar of $435.00 per tonne. The price for molasses and clean fibre were assumed to be $119.20 and $3.23 per tonne, respectively. The total harvest costs, including fuel and transport, were estimated at $7.20 per tonne of sugarcane, and the analysis also accounted for levies charged by the industry research organisation, peak bodies, local productivity services and others, totalling $0.70 per tonne of sugarcane. The farm operates on 1.83 metre row spacing, and carries cane through to the sixth ratoon.

Table 2: Assumptions of VRA trial

Assumption	Conventional Nutrient Application (Before)	Variable Rate Nutrient Application (After)
Farm area (ha)	42.00	42.00
Sugar price ($/t)	435.00	435.00
Molasses price ($/t)	119.20	119.20
Clean Fibre price ($/t)	3.23	3.23
Total harvest costs (incl. fuel and transport) ($/t)	7.20	7.20
Levies ($/t)	0.70	0.70
Row spacing (m)	1.83	1.83
Number of ratoons	6.00	6.00

The investment analysis assumptions for our study are shown below in Table 3. The total cost of capital equipment required for the VRA system was $12,835.50, and this mainly relates to the purchase of a variable rate controller for the delivery of granular fertiliser. We assume a zero salvage value for this equipment after ten years. In order to maintain an up to date management zone map for the property, it was further assumed that agronomic advice totalling 10 hours per year would be required, at a cost of $100 per hour, for total of $1,000.00 per year. Other on-going annual costs associated with the VRA system were: soil samples ($500.52), satellite imagery ($125.13) and Electrical Conductivity mapping ($1,459.85). We have undertaken our NPV calculation using a seven percent real discount rate, and over a 10 year time horizon (i.e. assumed life for the VRA equipment). Finally, the analysis presented here has not considered the benefits of transitioning from no GPS guidance to GPS guidance for the farm.

In our analysis we also assume a base case for which there is no long-term change in yield as a result of switching to the VRA system. The long-term yield implications of such zonal management systems are not well established for the region, and this is in large part due to a lack of empirical data. We therefore test the yield assumptions in a sensitivity analysis for our NPV results.

Results

In this section we present our economic analysis of the results from the agronomic trial discussed in the previous section. The economic analysis of the trial results is shown in Table 4. These results indicate changes in both farm gross margin and the value added from the purchase of capital required for the VRA system. The results show an improvement in total farm gross margin of six percent or $2,859.78, which equates to $77.82 per hectare of the farm under cane.

Table 3: Investment analysis assumptions

Assumption	Value
Capital Costs	
Variable rate controller (assumed that the grower already has RTK Guidance; this analysis did not consider benefits obtained from adoption of GPS)	$12,835.50
Salvage Value after 10 years	$0.00
On-going Costs	
Agronomic consultancy per year (10 hrs @$100 per hour)	$1,000.00
Soil sampling per year	$500.52
Satellite imagery per year	$125.13
EC mapping per year	$1,459.85
Real discount rate	7.00%
Other	
Time horizon	10 years

The NPV analysis using a seven percent per annum real discount rate, shows reduced total farm value of -$14,420 for the enterprise. This is a result of the small size of the trial farm (42 ha) and the additional on-cost of the associated services. The trial analysis assumes a higher level of management and the farmer is already using precision agriculture technics, such as GPS controlled traffic and minimum tillage, which have not been taken into consideration. Because of the additional on-cost of associated services, cash flow in the out years is negative and the investment has no payback period. Table 4 indicates that the VRA system has led to a reduction in applied nitrogen of 14 percent.

Table 4: Economic trial results

Total farm gross margin change	6%
Whole farm NPV	-$14,420
Pay Back Period (years)	∞
Total reduction nitrogen application	14%

Table 5 presents a sensitivity analysis of the NPV with respect to the change in yield (i.e. after the adoption of the VRA system), the real discount rate and the price of sugar. The results show that the NPV of investing in the VRA system is negative for yields at or below the pre-VRA harvest, regardless of the sugar price. The NPV is at positive levels for a 10 percent improvement in yield. Reduced nutrient availability for weed growth, and potential improvements in soil health, may contribute to such an outcome. For the assumed sugar price of $435 per tonne, the positive NPVs ranged from $43,838 (at nine percent per annum real discount rate) to $55,355 (at five percent per annum real discount rate).

Table 5: Sensitivity of NPV with respect to cane yield, price and discount rate

		Net present value		
Yield	Real discount rate %	Cane price ($/t)		
		385	435	485
-10%	5	-$75,219	-$84,509	-$93,796
	7	-$69,579	-$78,028	-$86,476
	9	-$64,683	-$72,404	-$80,123
0	5	-$14,575	-$14,577	-$14,577
	7	-$14,418	-$14,420	-$14,419
	9	-$14,282	-$14,283	-$14,283
+10%	5	$46,068	$55,355	$64,643
	7	$40,742	$49,189	$57,638
	9	$36,120	$43,838	$51,558

Figure 3 shows a breakeven analysis for the NPV of the VRA system compared with the farm size in hectares. This analysis has been based on the change in farm gross margin on the trial property and assumes that the spatial variability of the land does not change at large property sizes, so that the proportion of the farm under each management zone remains constant as the property expands.

The results in Figure 3 show that the viability of the VRA system depends on the scale of the farming enterprise. The breakeven point, i.e. where the NPV is $0.00, is illustrated in the graph by the closed point at 72 ha. This is for advanced practice farmers, i.e. those already undertaking activities under GPS guidance prior to the adoption of a VRA system. This breakeven point is comfortably below the typical farm size of 125 ha for the region (Queensland Government, 2016).

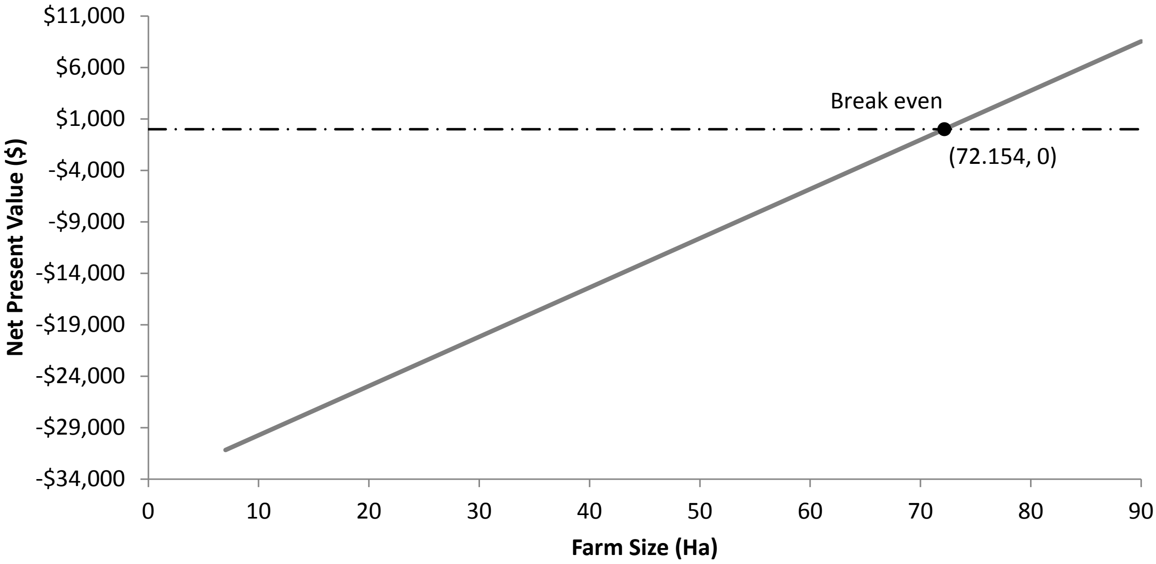
Conclusion

Minimising nutrient application rates and reducing the environmental impact of farming practices is important for the sustainability of agriculture into the future (Brodie et al., 2013; Reef Catchments, 2015; Reef Water Quality Protection Plan Secretariat, 2013; Thorburn, Wilkinson and Silburn, 2013; Thorburn et al., 2003). The water runoff from farming practices is an important factor affecting the ecology of both inland and coastal waters in the Mackay Whitsunday region. Nitrogen runoff from cropping activity in this region continues to impact significantly on the health of the GBR (Reef Water Quality Protection Plan Secretariat, 2015). Where there is substantial variation in yield, the VRA system has the potential to reduce nutrient application and improve water runoff from farms.

The analysis presented in this paper has demonstrated the capacity of the VRA system to deliver economic and environmental benefits through reduced fertiliser application on sugarcane ratoons. The results show that the system has achieved a reduction in total nitrogen application of 14 percent on the trial property in the Mackay Whitsunday region.

Our analysis of the NPV has revealed a risk to small-scale growers in deciding to implement the system. The investment appraisal we have undertaken in this paper shows that the NPV of the VRA equipment is negative (i.e. -$14,420) even for small farms that already operate at a high level of management such as the trial property (i.e. with GPS-guided equipment). For these farmers, the VRA system would have to generate an improvement in yield to be a viable investment choice.

Figure 3: Breakeven analysis for the NPV of the VRA system based on the change in farm gross margin per hectare from on the trial property as a result of the shift to variable rate application



Economies of scale are common to on-farm investments, where benefits are reaped on a per hectare basis across a large area of land, but investment outlays are required up-front for the new farming practice to begin. As the farm size increases, the total benefit from adoption of the system increases because it is employed over a larger number of hectares. Our analysis of the investment required to adopt the VRA system on the trial property suggests a minimum farm area of 72 ha is necessary for the system to be economically viable (on similar land to that of the trial property with respect to yield variability). This area is less than a typical farm size in the Mackay Whitsunday region, i.e. 125 ha (Queensland Government, 2016), so that granular VRA systems are potentially viable on farms in the region that already operate under GPS guidance. In the case of VRA systems for liquid fertilisers, no upfront investment is required since contractors exist to apply such products according to zonal management practices (Damian Baxter of Wilmar BioEthanol AgServices, *per. comm.*).

This study has demonstrated the capacity of a granular VRA system to reduce nutrient application and improve farm gross margins on properties with sufficient spatial variation in yield. However, for a small farming operation (42 ha) we found that the VRA system represented a reduction in the total value of the farming enterprise after capital investment is taken into account. On this property, the granular system must generate an improvement in yield or recoverable sugar in order to justify the additional upfront and ongoing costs. For properties already operating under GPS guidance, our analysis has also calculated a minimum farm size required to justify the investment in equipment for the VRA system. GPS guidance is required for a range of precision agriculture techniques, and is an essential element to the continued growth and development of these practices in the region. The majority of farms in the Mackay Whitsunday area will exceed the breakeven size, and for these properties a granular VRA system has the potential to generate economic benefits where there is sufficient yield variation.

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