Increasing Profitability & Sustainability of Maize using Site-Specific Crop Management in New Zealand

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Abstract

Precision agriculture (PA) tools and techniques have been used in New Zealand (NZ) since the early 1990's. There has been wide-scale uptake of some PA tools such as autosteer; planter and sprayer section control; and variable-rate irrigation. However, there has been a limited uptake of Site-Specific Crop Management (SSCM) using variable-rate seeding, nutrient and lime applications to different Management Zones (MZ).

This paper outlines examples of the use of SSCM on maize crops, and the effect on whole-paddock profitability of the resulting crop, as well as the sustainability of crop production measured using metrics such as nitrogen leaching.

Hybrid maize seed in NZ is approximately double the price than in North America, and as such the potential benefits to growers using variable-rate seeding (VRS) are significant. However, VRS has not been undertaken in commercial maize crops in New Zealand. Two trials carried out in the 2015/16 growing season showed that the use of SSCM and VRS can provide a relatively simple, practical way of improving maize crop gross margin; in this case by an average of NZ$96 per hectare. Targeting different maize yields to different MZ is a valuable tool to minimise losses due to nutrient over-supply to poor performing zones in maize crops. Nitrogen leaching losses could be reduced from up to 150kg N/ha in parts of the paddock to less than 10 kg N/ha using SSCM.

Spatial clustering analysis of the results established a good basis for site-specific management by identifying MZ. In conjunction with the growers' knowledge, a practical analysis of crop agronomic decisions can be made based on geospatial crop and soil data to inform crop management decisions in the future.

SSCM is a practical tool to help manage variability in New Zealand cropping paddocks to improve profitability and reduce environmental impacts.

Keywords. *New Zealand (NZ); Site-Specific Crop Management (SSCM); Management Zones (MZ); Maize*

Introduction

Precision agriculture tools and techniques have been used in New Zealand since the early 1990's. There has been wide-scale uptake of some PA tools such as autosteer, planter and sprayer section control, and variable-rate irrigation. However, there has been a limited uptake of Site-Specific Crop Management using variable-rate seeding, nutrient and lime applications to different Management Zones. Paddock spatial and temporal variability can have a significant effect on crop development, yield and profitability. Where within-paddock variation exists, precision agriculture has been found to be valuable irrespective of paddock size (Gemtos *et al*. 2005). Adoption of precision agriculture can minimise the impact of variability through efficient input management, resulting in cost reductions, minimisation of the environmental footprint and crop yield improvement (Reichardt and Jürgens 2008).

Background

Worldwide there is an increasing focus on the impact of agriculture on the environment. The OECD, 2004, has said that "*There is a general recognition of the need to improve environmental performance in agriculture, through enhancing the beneficial – and reducing the harmful – environmental effects to ensure the sustainability of resource use".*

Managing optimal crop input rates is one of the many challenges facing New Zealand crop growers. Currently, seeding and fertiliser rates are based on paddock historic yields from several years and crop expectations. This approach has significant flaws especially where spatial variability exists in the paddock, as more nutrients than are required by the crop can be applied in low yielding parts of the paddock, and it is possible that less nutrient than is required by the crop is applied in high yielding parts of the paddock.

One aspect of precision agriculture involves defining homogenous regions of a paddock that possess similar yield limiting characteristics, and then applying similar fertiliser and/or seeding rates within distinct areas (Koch *et al*. 2004). These homogenous areas can be defined as management zones (Doerge, 1999). Management zones (MZ) can have a specific rate of crop input applied using variable-rate (VR) application equipment, leading to Site Specific Crop Management (SSCM). There has been limited work generating MZ in maize crops in New Zealand, with Ekanayake *et al.*, 2015, using a combination of yield data, satellite imagery and farmer knowledge to determine MZ prior to undertaking a variable-rate nitrogen trial. Even though within-paddock yield variation can be attributed to variation in soil chemical and physical properties, cropping history and soil type (Inman et al. 2005; Pierce and Nowak 1999; Sawyer 1994) MZ can be effectively determined using yield maps or knowledge from past experiences (Fleming et al. 2000; Hornung et al. 2006).

Site Specific Crop Management

Horbe *et al.* (2013), found that increasing the seeding rates of maize in more fertile areas led to higher yields while low seeding rates performed better in low productivity areas. Shanahan *et al*. (2004) undertook studies with different seeding rates to investigate the relationship with low, medium and high performing zones in paddocks, concluding that VR Seeding (VRS) could be undertaken with MZ based on site characteristics such as elevation, electrical conductivity and soil brightness obtained from a simple aerial or satellite photo of the soil.

Most maize crops for silage or grain production are harvested with machines that have yield monitors installed that record GPS location, yield and other data every second they are in the paddock. This data can be analysed, and crop yield maps often show considerable variation between areas within a paddock. Managing this variability through the analysis of yield monitor data is used widely internationally to apply variable-rate nutrients, seeding rates, chemicals etc. to increase crop gross margin, and practical guides to carrying out the variable-rate management are available (Jeschke et al, 2017). Modern maize precision planters can change their seeding rate on the go, based on prescription maps developed using GIS mapping programmes to define the population to be planted in different Management Zones in the field, yet the facility is rarely utilised. Some of the anecdotal evidence for slow uptake is due to lack of data or know how to generate precision maps required to create MZ. Empirical evidence to prove the financial benefits of the use of VRS in New Zealand maize crops is also non-existent.

The aims of this work were to:

1. Use existing yield maps to determine within-paddock maize yield variability,
2. Generate different MZ,
3. Identify the highest yielding and most profitable seeding rates across a range of MZ,
4. Generate geospatial nutrient loss maps.

Methods

Data from both sites as shown in Figure 1 was geo rectified and a range of yield maps produced using AgLeader Technology SMS Advanced v17.20.

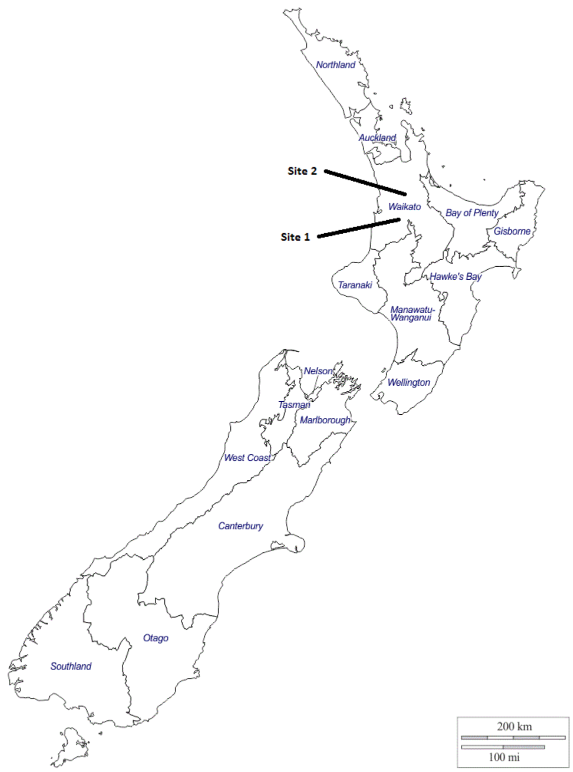

Figure 1 New Zealand map showing trial site locations

Methods

Two long-term maize paddocks (10+ years in maize, with maize grown each year) with historical yield map data were selected in the Waikato Region. Site details are given in Table 1. Starter fertiliser was applied as grower best practice, and the maize was side dressed at approximately V4 stage as grower standard practice. Neither site received irrigation.

Table 1 Site locations and properties

	Site 1	Site 2
Location	Kihikihi, Waikato	Tamahere, Waikato
Coordinates	-38.050598° 175.317530°	-37.835845° 175.372656°
Metres above sea level	38	48
Soil Type	Puniu gley	Horotiu silt loam
Area (ha)	12.0	11.6

Gross Margin was calculated based on the value of maize grain at NZ$380/tonne, and the costs given in Table 2 . No value for the land, crop management or interest on inputs was included.

Table 2 Values used to calculate crop gross margin

	Expenditure
Fixed costs	$1440 per hectare
Grain cartage	$18 per wet tonne
Grain drying	$24 per wet tonne + $2 per % moisture above 20%
Maize seed	$6 per 1,000 seeds

Site 1

Eight years of maize harvest yield data files were obtained for the paddock and analysed for spatial and temporal variability. The multi-year data was normalised and then aggregated to create three MZ: High yield Stable (HS); Low yield Stable (LS) and Unstable yield (US). The normalised yields for the three management zones and their respective areas are shown in Table 3.

Table 3 Average normalized yield and CVs in three management zones

	Unstable	Low Stable	High Stable
Normalized yield (%)	84.8	90.2	114.3
CV (%)	38.1	24.2	19.5
Area (Ha)	0.9	2.9	8.2

Stable zones were defined as having less than 30% coefficient of variance over the six years, while those where the coefficient was greater than 30% were considered unstable. Areas with a normalised yield higher than 100% were defined as high yielding and those with less than 100% of normalised yield were low yielding. The MZ are shown in Figure 2.

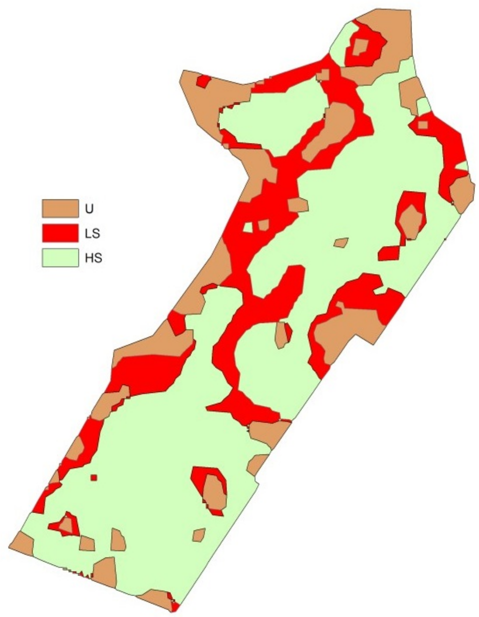

Figure 2 Management Zone map. U = Unstable yield; LS = Low yield Stable; HS = High yield Stable (Site 1)

In 2015, a seeding rate experiment was established in part of the paddock to investigate the effect of four seeding rates (75, 90, 105 and 120 thousand seeds/ha) across the three management zones. The experiment was a completely randomised block design replicated four times.

Plots were eight rows wide (76.2cm row spacing) by approximately 180 metres long. Pioneer® hybrid P0791 (106 CRM) was planted on 5 October 2015. The maize grain crop was harvested using a John Deere combine harvester with GPS and yield monitor on 21 May 2016.

Site 2

In 2016 a Variable-rate Seed trial was established in a paddock at FAR's NCRS research site, to investigate the effect of VRS in the different MZ of the paddock. Four replicated strips of VRS were planted across the three zones established in the paddock, as shown in Table 4. The remainder of the paddock was planted at 100,000 seeds per hectare.

Table 4 Management Zone area and seeding rate (Site 2)

	High Yield	Medium Yield	Low Yield
Area (Ha)	3.7	6.3	1.6
Seeding rate ('000's/hectare)	105	90	75

Results & Discussion

Site 1

The average maize grain yield was 13.3 t/ha, with yields at distinct locations within the paddock ranging from less than 8 t/ha to greater than 18 t/ha. Based on these results, the monetary impact of planting the entire paddock using VRS was calculated. If the entire paddock were planted at 90,000 seeds per hectare, as would be the commercial norm, the total paddock GM would be $30,048. If planted using VRS, the paddock GM would be $31,983, an increase of $161 per hectare over the constant seed rate. Horbe et al. (2013), found a similar result, with the net economic effect of VRS application being a US$113-342/ha increase in margin.

Site 2

The maize grain crop was harvested on 4 June 2017 and the data recorded and analysed for each of the different management zones and seed planting rates. The average grain yield was a low 8.0 t/ha, given a dry 2016/17 growing season. The geospatial variation across the paddock is shown in Figure 3. The yield from the strips of different seed rates was excluded from the whole paddock analysis.

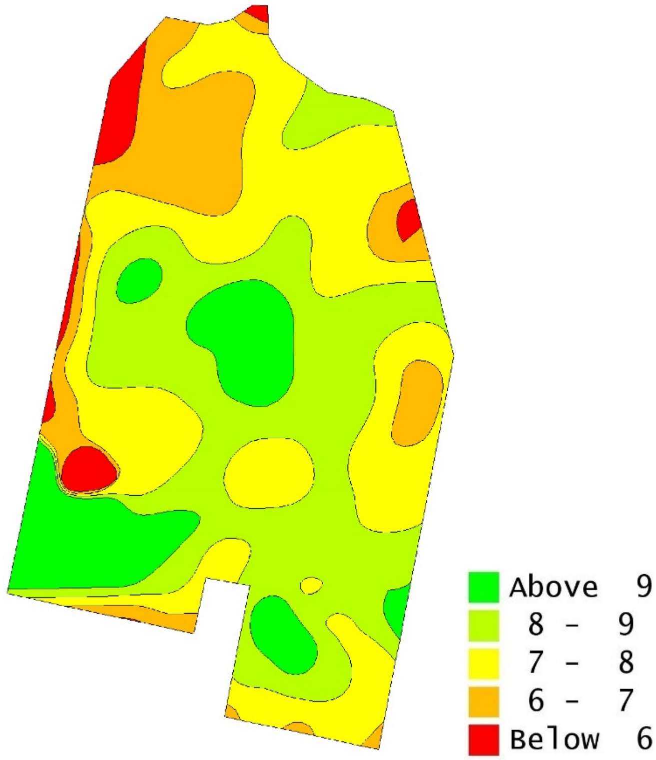

Figure 3 Maize grain yield (t/ha @ 14% moisture) harvest 2017 (Site 2)

From this data, we calculated geospatial Gross Margin (GM) using values given in Table 2. The average GM for the paddock was $489/ha. Using the MZ map, we could calculate what the yield and gross margin (GM) would have been for the different management zones if we had planted using Variable-rate Seeding. Results are given in Table 5 .

Table 5 Seeding rate, yield and Gross Margin calculated from VRS and standard seed rates

	Average seed rate (thousands/hectare)	Yield (t/ha @ 14% moisture)	Gross Margin ($/hectare)
Fixed seed rate	100.1	8.07	$474
Variable seed rate	96.0	8.10	$505
LSD 5%	1.6	0.18 (NSD)	$63 (NSD)

The results above show no significant difference (NSD) between yield and gross margin from the standard and VRS.

If the entire paddock were planted at 90,000 seeds per hectare, the total 11.6 ha paddock gross margin would be $5,498. If planted using Variable-rate Seeding, the paddock gross margin would be $5,858, an increase of $31 per hectare over the constant seed rate.

Nutrient Implications

The detrimental effect of land use on the environment is increasingly being spotlighted worldwide. This is putting pressure on agricultural producers to maximise their input use efficiency by producing the maximum amount of product for the least input of nutrient or water.

In New Zealand, much attention has been placed on leaching losses from farming systems of nitrogen, and this has led to the use of nutrient modelling tool, OVERSEER®, to model the flow of nutrients on farms.

OVERSEER® is best described by Watkins & Selbie, 2015, as *"an agricultural management tool which assists in examining nutrient use and movement within a farm, as an aid to optimize production and to reduce nutrients losses from the farm."*

To date, growers have made fertiliser inputs based on historic yields from a paddock, and expected average yields from the paddock. This approach has significant flaws, especially where spatial variability exists in the paddock. If paddock yield averages are used to plan nutrient programmes, there will be high levels of nutrients not taken up by crops in areas of the paddock where low yields are produced, and possibly inadequate levels of nutrients available at potentially high yielding parts of the paddock.

Using the geospatial harvest data, it is possible to calculate a geospatial map of OVERSEER® modelled N loss based on nutrient inputs and crop production. Figure 9 shows the OVERSEER® modelled N loses from Site 1 based on the harvest in 2017.

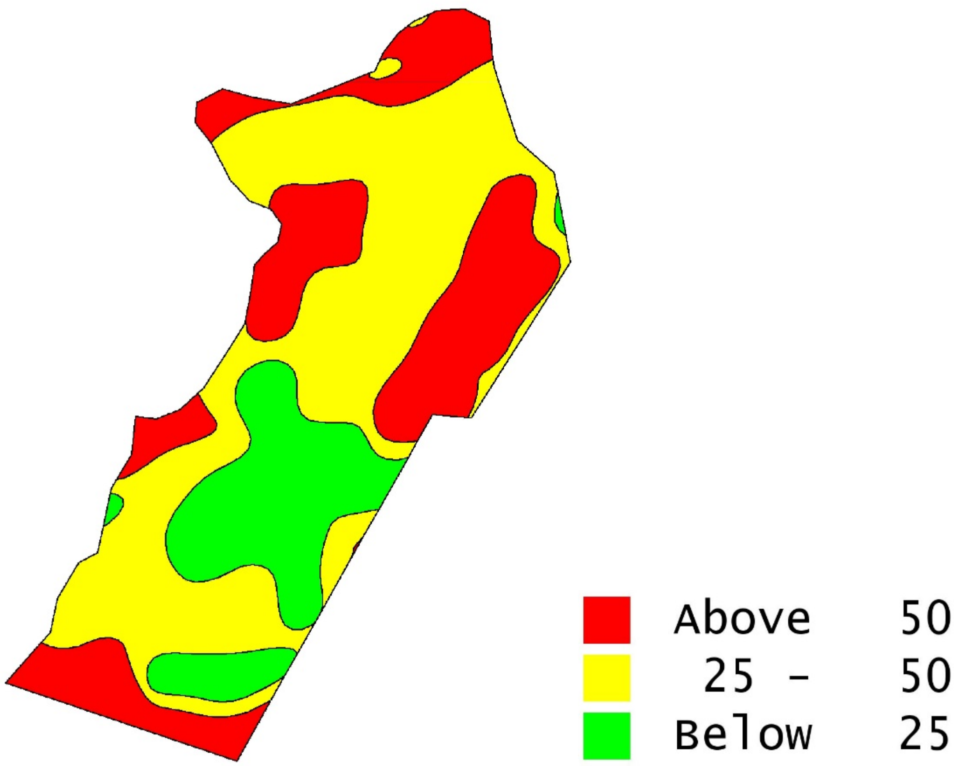

Figure 9 OVEERSEER® estimated N losses from the root zone (kg/ha/year) (Site 1)

Not only does the loss of N, and other nutrients, to the environment cause detrimental environmental effects, but it also represents a financial cost to the grower incurred from the wasted inputs. Figure 10 shows the cost of this excess N to the grower at Site 1, and this trend is similar at Site 2.

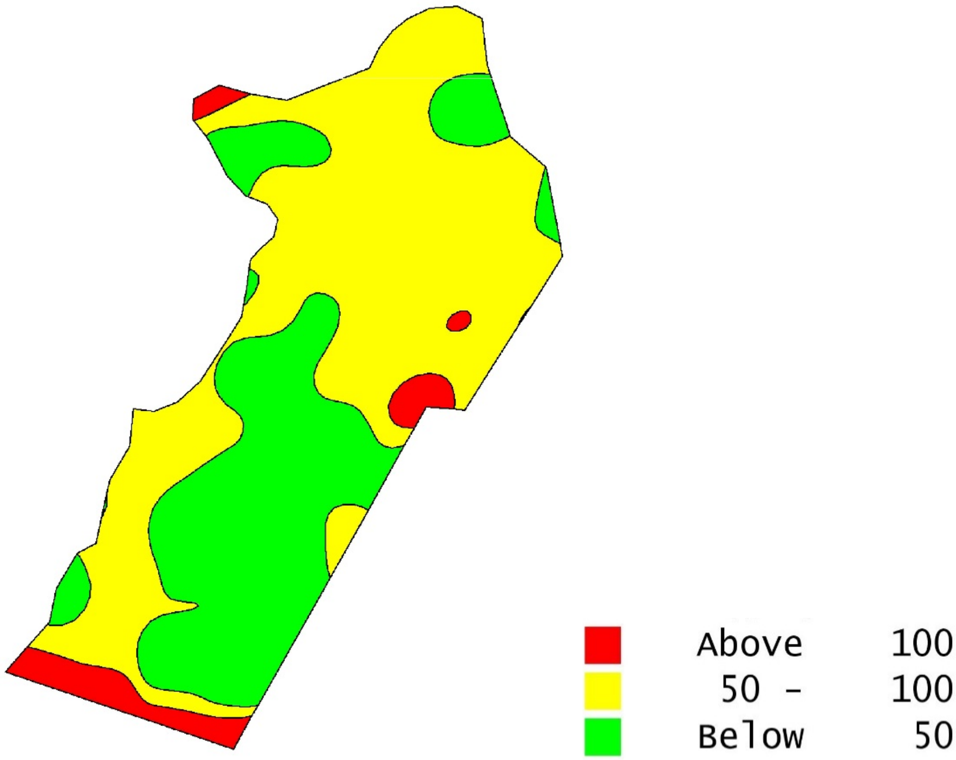

Figure 10 Cost of excess N applied ($/ha) (Site 1)

Conclusion

This work shows that the use of MZ in maize crops can help inform crop management decision making. Spatial clustering analysis has established a good basis for site-specific management by identifying MZ. We are working with growers to identify different MZ in maize paddocks, and then in conjunction with the growers investigating practical ways to improve crop performance by site-specific management techniques.

VRS can provide a relatively simple, practical way of improving maize crop gross margin in a New Zealand paddock. By planting using VRS targeting different MZ, we are effectively targeting different yields in each MZ. Currently, the same rate of fertiliser is applied to each MZ, despite the different yield targets. Tremblay *et al*., (2007), found that the optimal rate of nitrogen fertiliser for different zones within the same paddock in Quebec ranged from less than 50 kg/ha to more than 200 kg/ha. It is practically feasible to target crop nutrients, and other inputs, to the different MZ, leading to more nutrients being available in the High Stable MZ, and less nutrients applied to the Low Stable MZ, reducing the risk of nutrient loss. It is necessary to undertake further work optimizing the seeding rate to MZ in different conditions, as the relationship of yield to seed rate will vary, as claimed by Licht *et al*., (2016); and Woli *et al*., (2014). Optimal seeding rates to maximise Gross Margin will vary based on the value of maize grain and silage, and the price of maize seed.

Given the importance of farmers ensuring the minimization of nutrient loss, we also believe that SSCM is a valuable tool to minimise losses of nutrients because of over-supply to poor performing zones in maize crops. It has also given a practical analysis of crop agronomic decision making that can be made by growers based on geospatial crop and soil data to inform crop management decisions in future.

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