# MANAGEMENT ZONE DELINEATION IN ARABLE CROP SYSTEMS

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## 1. Introduction

Precision Agriculture (PA) is the management of variable spatial and temporal factors affecting crop yield and quality across the fields. This is achieved by site-specific application of crop inputs such as plant nutrients, seeds, pesticides, water and tillage through Variable Rate Application (VRA) (Ortega et al., 2007; Doerge, 1999). VRA could lead to reduced inputs, costs and adverse environmental effects or improved yield and quality (Gemtos et al., 2011). Identification of sub-field regions defined by field boundaries is required for a special type of site-specific crop management in PA. These unique management units are referred to as “Management Zones” (MZ) (Fridgen et al., 2004). A Management Zone is a “sub-region of a field that consists of functionally similar combination of yield limiting factors to allocate single rate of a specific crop input”. Management Zone Delineation (MZD) is a method of classifying the spatial variability within a field based on quantitative, qualitative and intuitive/historical site characteristics (Doerge, 1999). There are many approaches for delineating MZ as categorized in Table 1, used by researches (Khosla et al., 2010; Galambošová et al., 2014).

However, research work on the concept of MZD for arable cropping systems in New Zealand is in its initial stage and rare. The aims of the present study are; (i) to discuss some methods available for delineating MZ and their potential applicability in New Zealand scenario and (ii) to design On-Farm experiments to identify suitability of derived MZ for site-specific VRA-N on maize paddocks.

### *1.2 Previous work on MZ for maize*

The benefits of applying PA for large-scale maize farmers and contractors were presented using yield data, soil survey information and aerial images to adopt VRA of fertilizer, seeds and agrochemicals by conducting case studies. They demonstrated that VRA of fertilizer and agrochemical are economical while VRA of seeds has no obvious economic benefits (Pratt et al, 2005). Moreover, a preliminary study was carried out using an active light N sensor and SPAD chlorophyll meter data to see the possibility of delineating yield zones in maize cropping systems. The maps derived based on Simple Ratio (Erdle et al., 2001) and Water Index (Peñuelas et al., 1997) were suggested as being logical for zoning (Fourie et al., 2014). Crop sensors namely Greenseeker$^{TM}$, CropCircle$^{TM}$ and CropSpec$^{TM}$ were compared for developing methods and algorithms for N management of arable crops (Craigie, 2013).

## 2. Materials and Methods

### *2.1 MZD methods*

A literature survey was carried out to discuss some methods available for MZD. The data sources used in each method for delineating MZ, the level of data demand (low, medium and high) and their use in VRA were the parameters considered when assessing the potential applicability in New Zealand conditions (Table).

### *2.2 Delineating MZ and field experiment design*

Two rain-fed maize fields from Waikato located at TeKawa and Cambridge and one pivot-irrigated maize field from Canterbury located at Rakaia were selected for field experiments. Maize-silage yield data were only available for TeKawa field since the Cambridge field was used for maize grain production during last two years. No maize-silage yield data was available for the Rakaia field. Soil electrical conductivity survey maps (EM38/ECa) were not available for any of those fields.

The presented work in the poster is related to the field in TeKawa. Georeferenced maize-silage yield and elevation data in 2013 and 2014 collected with a John Deer 7050 Series Self-Propelled Forage Harvester were used to analyse and create yield maps in ArcGIS 10.2.2. (Esri) software. The data was interpolated using local variogram estimation with an exponential model followed by block kriging in VESPER 1.6 (Australian Centre for PA). The interpolated data was then imported into ArcGIS and three MZ with low, medium and high yield potential were derived in the final map. Satellite images of selected fields available in the Google Earth Archive and farmer knowledge were also used to delineate field boundaries and management zones and eventually to accommodate the experimental plots (Figure1).

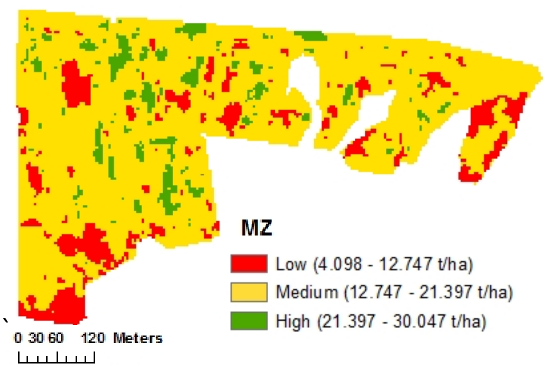


Figure1. MZ derived based on yield map and satellite images

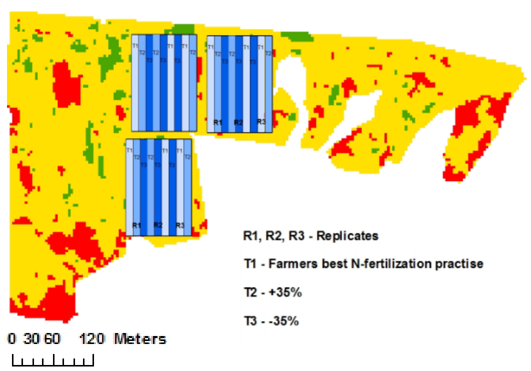


Figure 2. Strip-plot design for TeKawa maize paddock

A strip-plot experimental design with 3 replicates was allocated across management zones at each field. Three treatment levels of N fertilizer: farmer's best N-fertilization practice in 2015 (180 kgN/ha for Waikato fields and 165 kgN/ha for Canterbury field), 135%of farmer's best

N-fertilization practice and 65% of farmer's best N-fertilization practice were applied using calculated N-fertilizer demand prescription maps with an 8- row VRA fertilizer spreader. The field experiments commenced in October 2014 and their initial stages of setting up the experiment were carried out (Figure 2).

## 3. Discussion

MZD is a way of managing field variability. In most cases, 3-6 MZ are suggested appropriate for its practical applicability (Aggelepoulou et al, 2011; Galambošová et al., 2014). The optimum number of MZ of a field can be varied from year to year based on the weather and the crop planted (Fraisse et al., 2001; Galambošová et al., 2014).The questions of, information to be used to create MZ of a field, procedures for classification of selected information and the optimum number of MZ of the field should be addressed in developing site-specific crop management (Fridgen et al., 2004). The work of Ortega et al. (2007) showed adopting an appropriate MZD method timely and spatially demands proper identification of yield limiting variables and practical applicability by evaluating available methods. VRA of crop inputs is achieved by two methods; i) prescription maps prepared ii) sensors which are capable of adjusting the application rates on the go. Sensors are more popular among farmers (Gemtos et al., 2011).

The major limitation encountered at the initial MZD stage for setting up the field trials is the scarcity of suitable data sources, such as soil data and yield data, to develop MZ. Farmer knowledge and satellite imagery may be readily available for a manual first step in MZD. Maize-silage yield data 2014 was used as the data layer in deriving the MZ in ArcGIS. The use of yield monitors connected to harvesters is an efficient way of collecting yield data. Collecting and analysing several years of yield data would identify the real MZ (Ortega et al., 2007). Inclusion of more maps on soil variability would be advantageous in New Zealand for more precise MZD. S-mapOnline provides useful information on soil classification, soil drainage, soil depth and soil moisture in New Zealand, although this information is of limited use at an individual farm scale. Additionally information is missing in S-mapOnline for some areas in New Zealand (S-mapOnline, 2015). A soil electrical conductivity survey will be carried out in the experimental fields after harvest in order to obtain accurate soil data at the experimental fields.

In future work aerial images, soil electrical conductivity survey maps, yearly yield data and topography would be included to validate the coarse data sources in this experiment. Further on-farm research is needed to develop and validate MZD methods in New Zealand scenario and to access the economic benefits of VRA on MZ.

Management Zone Delineation Methods (A draft developed by the authors based on literature and expert knowledge)

| MZD Method | Data Sources | VRA | Data Demand | New Zealand Applicability |
|---|---|---|---|---|
| 1. Manual delineation | • Aerial photos<br>• Yield maps<br>• Soil maps (S-map)<br>• Farmer knowledge and experience | • Fertilizer<br>• Seeds<br>• Irrigation | Low | ++[1] |
| 2. Yield maps (Galambošová et al., 2014) | • Yield maps from several seasons | • Fertilizer<br>• Manure<br>• Seeds<br>• Irrigation | Medium | +/-[3] |
| 3. Aerial photography (Fleming et al., 2000) | • Bare soil aerials images<br>• Landscape position<br>• Farmer's management experience<br>• EM38 maps | • Fertilizer<br>• Seeds<br>• Irrigation | High | +[2] |
| 4. Soil and/or relief information (Galambošová et al., 2014) | • Topographic maps<br>• Direct soil sampling<br>• Soil electrical conductivity surveys | • N fertilizer | High | + |
| 5. Combinations of several methods | • Topography<br>• Aerial photography<br>• Satellite imagery<br>• Soil electrical conductivity maps<br>• Yield data | • Fertilizer<br>• Seeds | High | + |
| 6. Estimation of Soil Index based on<br>• Principle Component Analysis (PCA)<br>• Coefficient of Variation (CV) of each data layer(Ortega, 2007) | • Soil sample tests – pH in suspension, EC in suspension, organic matter, available N, P, K<br>• Software – FarmGPS, Mapinfo Professional version | • N, P, K fertilizer | High | +/- |

| MZD Method | Data sources | VRA | Data Demand | New Zealand Applicability |
|---|---|---|---|---|
| 7. Cluster analysis procedures<br>• Non-hierarchic cluster analysis – Fuzzy k-mean method<br>• Hierarchic cluster analysis – Fuzzy k-mean method (Galambošová et al., 2014) | • Farmer previous knowledge<br>• Software<br>• Yield data<br>• EM38 data<br>• Satellite imagery | • Fertilizer<br>• Seeds | High | +/- |
| 8. Segmentation methods<br>• Object-based image segmentation (Oliveria et al., 2013)<br>• Watershed segmentation (Roudier et al., 2008) | • Median yield of multi-year yield data<br>• Biomass at flowering of wheat | • Fertilizer<br>• Seeds<br>• Irrigation | High | +/- |
| 9. Software for MZD<br>• Management Zone Analyst (Fridgen et al, 2004)<br>• ZoneMap web application (Zhang et al., 2009) | • Soil $EC_a$<br>• Elevation<br>• Slope<br>• Satellite imagery<br>• Images from airborne sensors | • Fertilizer<br>• Seeds<br>• Irrigation | High | +/- |

[1]Highly applicable, [2]Applicable, [3]Applicable with some limitations

## 4. Conclusions

There are many methods available for Management Zone Delineation (MZD) and a suitable workflow can be developed based on the data and other necessary resources availability for a selected field. A farmer who intends to develop MZD for the first time can easily go for manual delineation on-screen or on-paper with his knowledge and experience and gradually add available resources such as public available aerial images or soil maps etc. Soil electrical conductivity maps, specific remote sensing aerial images and yield data from years may be included later to improve the analysis of the yield variation and effectiveness of the derived MZ. We followed this approach in a maize field experiment and started with reduced input at an initial stage. More information layers will be provided from data collection on the bare field, once the maize silage is harvested.


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