Development of Management Zones for Site-Specific Nutrient Application: A Sustainable Approach

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Introduction

In agricultural fields, there are high variations in soil properties, topography, crop yield, land cover, precipitation and evapotranspiration. All these variables combine with agricultural inputs to establish highly complex interactions in the soil. To increase yield, precise agricultural inputs are required, on a need basis.

Potato fields with minimal to severe topography emphasize the need for precise site-specific crop management zones (MZs). Detailed georeferenced maps would be useful to treat different field areas according to their specific need, rather than treating the whole field uniformly.

Electromagnetic induction (EMI) methods are gaining popularity due to their non-destructive nature and rapid response assessment of the soil moisture content, water table depth, and salinity. The Dual EM-2 can perform EMI by simply walking it through a field. These measurements are quick, inexpensive and can be easily integrated onto mobile platforms like tractors or ATVs .

The objective of this study was to characterize and quantify the spatial variability of soil properties, and to compare the variability of those properties with the variability of crop yield. Finding correlations between spatial variability of yield and other variable would allow for proper delineation of management zones.

Material and Methods

- Seven potato fields were selected in Prince Edward Island (4) and New Brunswick (3), Canada to map and quantify spatial variability of the soil.
- A grid pattern of sampling points was established at each experimental (Fig. 1) site based on geostatistical results from a Dual EM-2 survey to record volumetric moisture content (Θ_v) and ground conductivity (HCP).
- The sampling coordinates for grid points were recorded using a Topcon Real-Time Kinematics Global Position System (GPS).
- Slope, moisture content, and normalized difference vegetation index were measured and mapped manually for each point at all fields.
- Soil samples were taken periodically at all grid points and were analyzed by the PEI Analytical Lab.
- A drone was flown over two PEI fields to take geothermal imaging, which is directly correlated with moisture content and plant stress.
- A combination of classical statistics and geostatistical techniques were used to determine the spatial variability of the soil properties (Fig. 2).
- The maps were developed using kriging interpolation in Arc GIS 10.4 for HCP and volumetric soil moisture content (Θ_v).

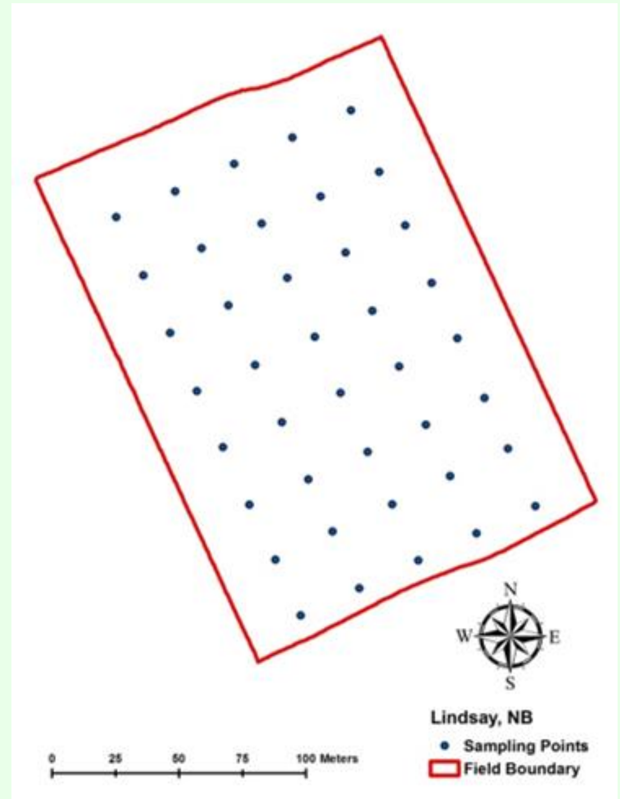

Fig. 1 Grid points to record moisture and HCP readings for Lindsay, NB

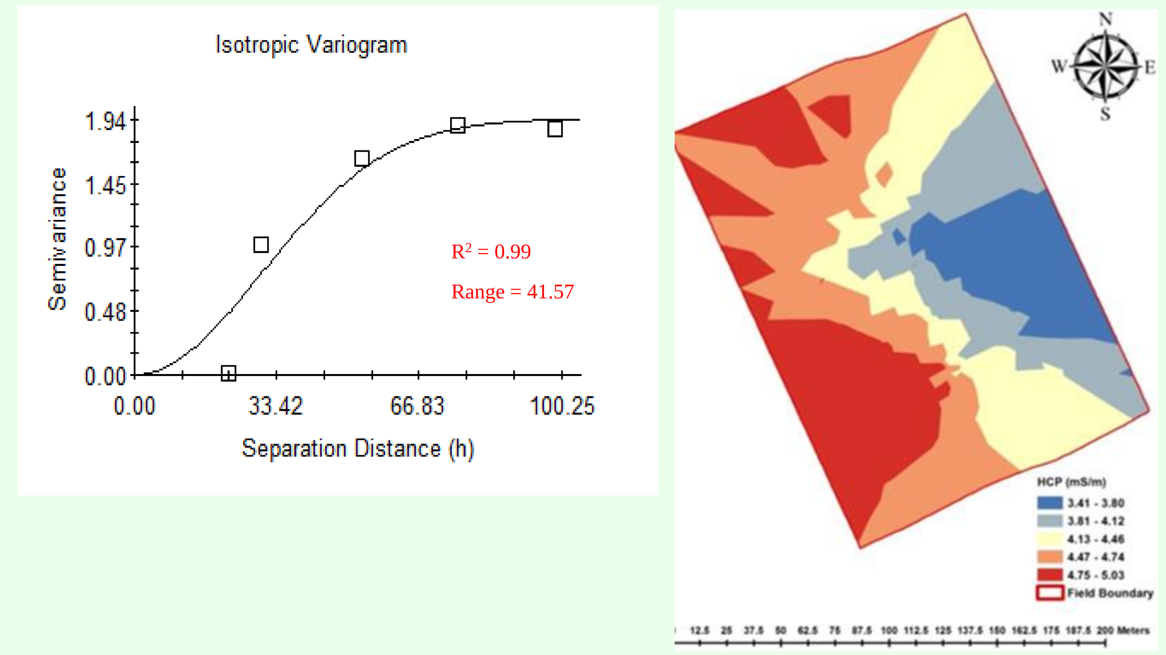

Fig. 2 Isotropic variogram for HCP and extrapolated variable zones


Fig. 3 Data collection of HCP using the Dual EM-2


Fig. 4 Data collection of moisture, slope and NDVI

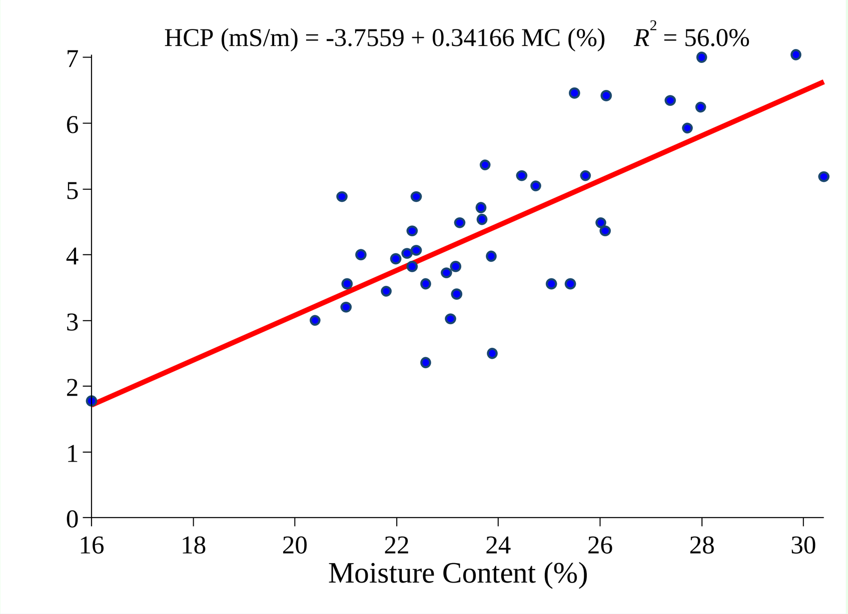

Fig. 5 Relationship between HCP and moisture

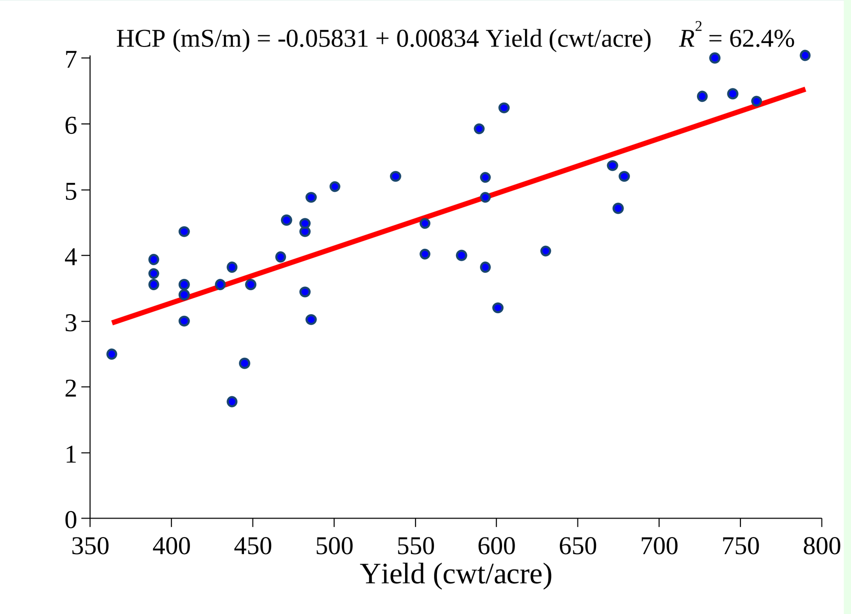

Fig. 6 Relationship between HCP and yield

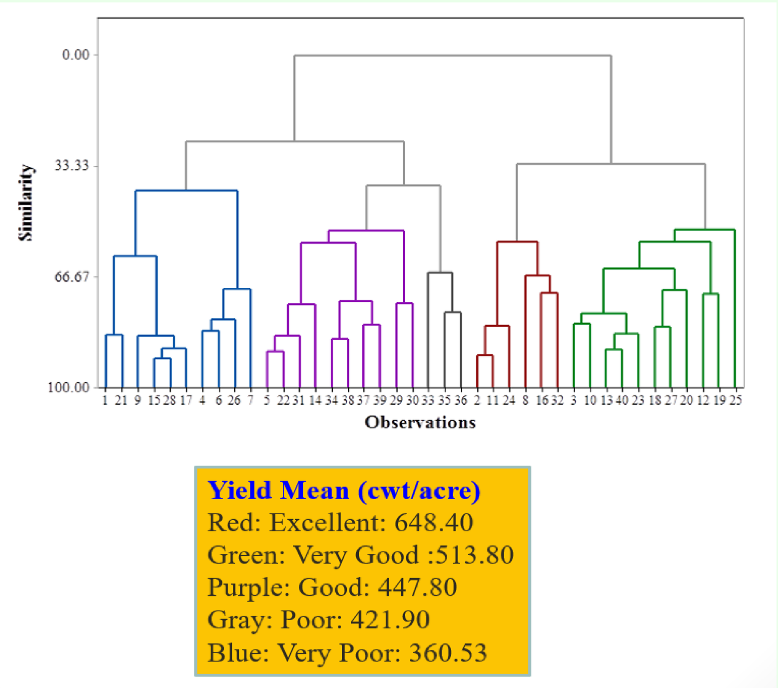

Fig. 7 Cluster Analysis of grid points Lindsay, NB

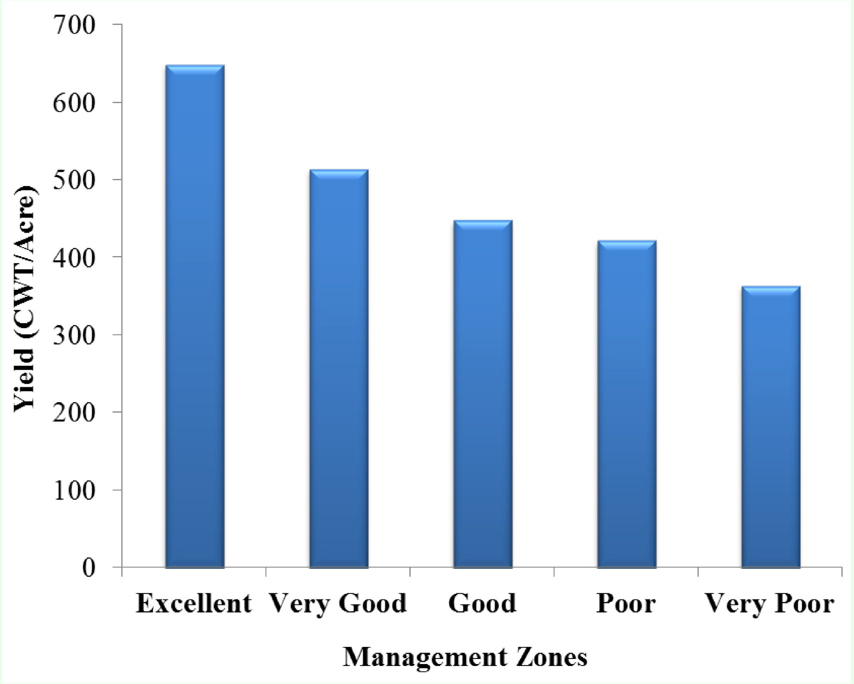

Fig. 8 Zonal Analysis of Yield

Fig. 9 Zonal Analysis of HCP

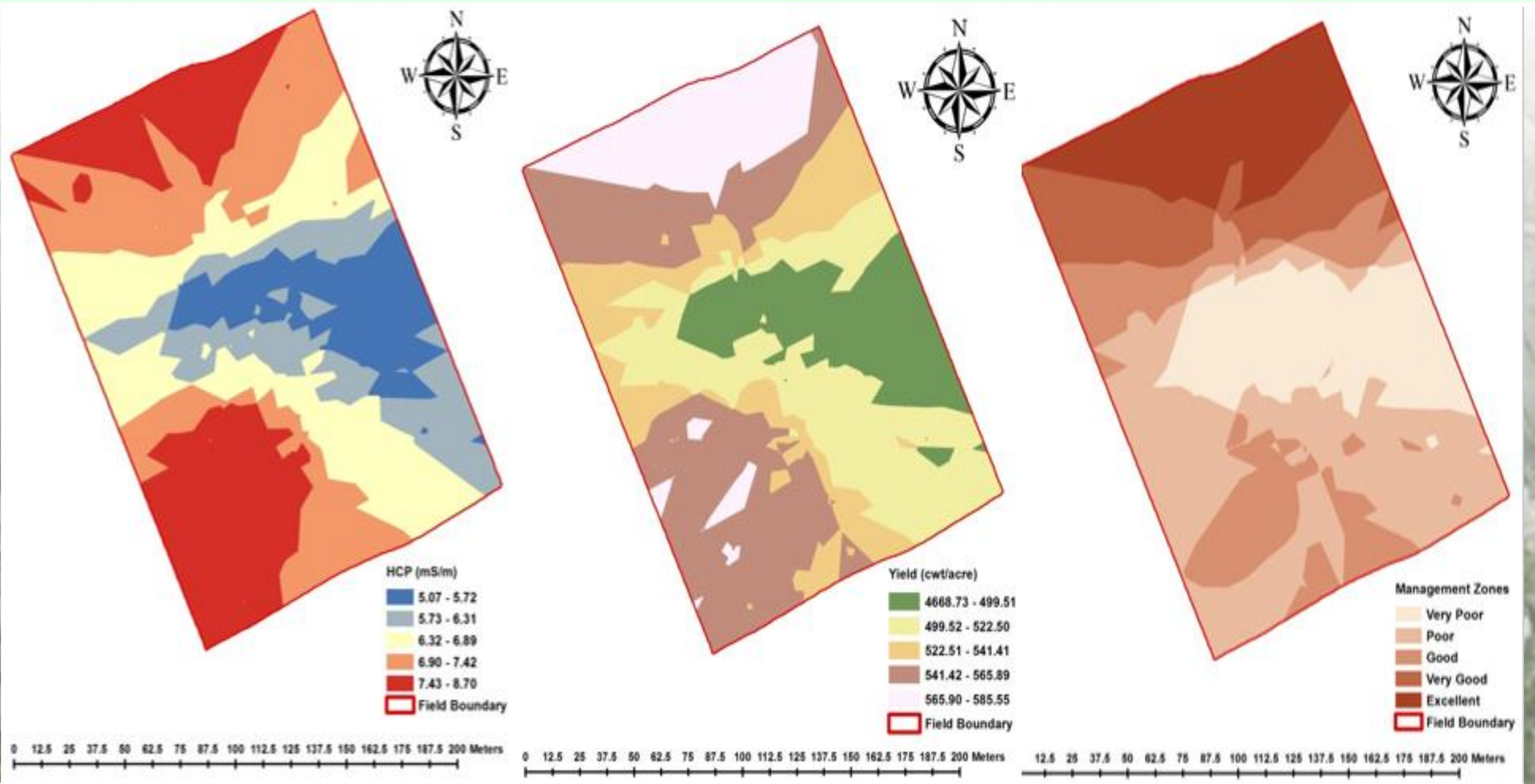
Fig. 10 Management zones based on HCP, that are significantly correlated with yield

Results and Discussion

The grid size for sampling was decided as 3 m x 0.36 m based on the geostatistical range of influence to record moisture content (Θ_v) and HCP values at each grid point.

The geostatistical results suggested that the Θ_v and HCP were highly variable with the range of influence less than 45 m (Fig. 2), but were also highly correlated with yield for the Lindsay, NB field. The ground conductivity was significantly correlated with the Θ_v. The relationship between HCP and Θ_v for this field is shown in Fig. 5. The ground conductivity was also significantly correlated with the yield (cwt/acre). Fig. 6 shows this relationship, with an R^2 of 0.62.

All the data was clustered to make groups with internal homogeneity and external heterogeneity. Clustered data (Fig. 7) was imported in GIS to develop management zones (Fig. 10). The zonal statistics function of Arc GIS 10.4 also suggested significant positive correlation, indicating higher moisture content values where the HCP values were higher, and vice versa. The zonal statistics also suggested that higher moisture content would occur in low lying areas as indicated by the sloped zones.

The significant correlation between HCP and yield means that fields can be broken into different MZs based on the measured HCP values (Fig. 10). Zones with lower HCP values can be expected to produce less crop and therefore should have a different management strategy. Examples of treatment include different rates of fertilizer, different rates of irrigation, different rates of seeding, different rates of insecticides and herbicides. Creating different MZs will allow for better crop management based on individual need of each zone, rather than uniform treatment of the entire field. Having variable rates specific to each zone, will also provide environmental benefits.

Conclusions

✓Significant correlation between HCP and moisture content suggests that electromagnetic induction methods are suitable to measure and map moisture content variability efficiently and reliably.

✓Moisture content maps could be used to access drainage requirements, as well as for scheduling site-specific irrigation within fields.

✓Significant correlation between HCP and yield suggests that electromagnetic induction methods can be used to predict yield and to create site-specific management zones, using conductivity for delineation.

Future Research:

- Repeat experiment for 2-3 years to cover temporal variability and confirm correlation between HCP, moisture and yield.
- Develop more automated, real time sensor platforms for measuring soil properties. Use drone geothermal and multi-spectral imaging for data collection.
- Apply nutrients based on developed management zones to increase yield at poor management zones.
- Evaluate environmental benefits of variable rate nutrient application based on management zone maps.