DEVELOPING MANAGEMENT ZONES FOR
SITE SPECIFIC NUTRIENT MANAGEMENT
IN POTATO PRODUCTION

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Introduction

- An increase in yield requires precise agricultural inputs – NOT UNIFORM

- Complex interactions among soil, topography, climate, cultivation, crop, and agricultural inputs

- Substantial variability in soil and crop - YIELD VARIABILITY

- Management of agricultural inputs based on soil and crop variability - FARM PROFITABILITY and ENVIRONMENTAL PROTECTION
1. An alternating current is generated in the transmitting coil.

2. This creates a primary magnetic field ($H_p$).

3. Small currents are generated due to the time-varying $H_p$.

4. A secondary field ($H_s$) is generated due to conductive materials in the soil.

5. The receiver coil detects $H_s$ together with $H_p$ and EC is calculated.
Objectives

- Characterize and quantify variability - soil, crop, topography and yield,

- Identify the significant factors affecting potato productivity,

- Calibrate yield monitoring system testify its potential to be used as factor to develop MZs,

- Sensors for an accurate prediction of the attributes of interest explaining significant variability

- Develop MZs for site-specific application of agricultural input – Ensure economic and environmental sustainability.
PARAMETERS - DETERMINED

**Soil Sampling/Analysis**
- Ph
- EC
- Lime Index
- Moisture Content
- Soil Chemical Properties
- SOM
- (P, K, Ca, Mg, Cu, B, Zn, Al, Mn, Na, CEC, Fe,..)

**Sensors Data**
- HCP
- PRP
- Slope Sensor
- NDVI
- TDR

**Potato Yield**
- Calibration of yield monitor
- Geo-referenced yield collection

| 4 Samplings over the growing season |
Data Collection
Data Collection
Site Selection 2017
Site Selection 2018

Souris Field
- Boundary
- Sampling Points

Oleary Field
- Boundary
- Sampling Points

Taylor Road Field
- Boundary
- Sampling Points

Hamilton Field
- Boundary
- Sampling Points
Results 2017
Multiple Regression – Summerside PEI

HCP = 2.0838 + 0.01926 Yield \[ R^2 = 54.5\% \]
Multiple Regression – Souris PEI

Yield (cwt/acre) = 2420 + 8.81 HCP + 10.0 PRP (mS/m) + 0.39 Moisture Content - 9.8 Slope + 30.4 Organic Matter (%) + 20 pH + 0.159 Phosphate + 0.101 Potash + 0.114 Calcium - 0.197 Magnesium + 128 Boron - 9.5 Copper - 1.30 Zinc - 9.46 Sulfur + 1.117 Manganese + 0.064 Iron - 0.72 Sodium + 0.122 Aluminium - 381 Lime Index - 2.54 % P/AI + 2.1 CEC (meq/100g) + 1.98 Total % Base Saturation

Stepwise Regression:

Yield (cwt/acre) = 206.5 + 9.36 HCP - 14.88 Slope + 40.0 Organic Matter (%) + 0.1724 Phosphate + 0.327 Potash + 0.1417 Calcium - 10.41 Sulfur + 0.1109 Aluminium - 3.37 % P/AI

R² = 90.03%

R² = 88.38%

HCP = -2.4193 + 0.02086 Yield    R² = 62.7%
Multiple Regression - O’Leary PEI

Yield (cwt/acre) = \(-3684 + 52.9 \text{HCP} - 10.8 \text{PRP} + 0.41 \text{MC} - 2.1 \text{Slope} + 72.2 \text{OM} + 0.574 \text{Phosphate} - 0.206 \text{Potash} + 0.060 \text{Calcium} + 1.129 \text{Magnesium} - 6 \text{Boron} - 6.8 \text{Copper} + 21.0 \text{Zinc} + 0.475 \text{Sulfur} + 0.69 \text{Manganese} + 0.12 \text{Iron} - 0.85 \text{Sodium} + 0.490 \text{Aluminium} + 446 \text{Lime Index} - 0.7 \% \text{P/AI} - 28.6 \text{CEC} - 2.10 \% \text{Total Base Saturation}

Stepwise Regression

Yield (cwt/acre) = \(-3273 + 44.76 \text{HCP} + 86.1 \text{OM} + 0.735 \text{Phosphate} + 1.493 \text{Manganese} + 0.545 \text{Aluminium} + 270.9 \text{Lime Index}

R\(^2\) = 92.15%

R\(^2\) = 90.08%

HCP = 0.49505 + 0.01046 Yield    R\(^2\) = 53.9%
Cluster Analysis – Souris PEI

Cluster Observation Dendrogram

Observations

Similarity

Excellent: Blue 539.50
Very Good: Purple 535.43
Good: Gray 507.00
Poor: Green 426.00
Very Poor: 365.25 Red
Management Zones – Hamilton PEI
Management Zones – Summerside PEI
Zonal Analysis – PEI

Graphs showing data distribution across different management zones for various parameters:
- Yield (cwt/acre)
- PRP (mS/m)
- Moisture Content (%)
- Slope
- Organic Matter (%)
- pH

Each parameter is represented by a bar graph with categories: Excellent, Very Good, Good, Poor, Very Poor.
Results 2018
Yield Monitoring

Summerside PEI
$R^2 = 0.80$

Taylor Road
$R^2 = 0.79$
## Summary Statistics

### Descriptive Statistics, Hamilton, PEI

<table>
<thead>
<tr>
<th>Variable</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>CV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield (cwt/ac)</td>
<td>237.87</td>
<td>532.72</td>
<td>379.88</td>
<td>31.23</td>
</tr>
<tr>
<td>HCP</td>
<td>3.70</td>
<td>7.90</td>
<td>5.71</td>
<td>34.21</td>
</tr>
<tr>
<td>PRP</td>
<td>2.40</td>
<td>4.30</td>
<td>3.36</td>
<td>22.12</td>
</tr>
<tr>
<td>MC</td>
<td>6.04</td>
<td>11.40</td>
<td>8.62</td>
<td>23.66</td>
</tr>
<tr>
<td>Slope</td>
<td>0.34</td>
<td>3.10</td>
<td>1.62</td>
<td>41.26</td>
</tr>
</tbody>
</table>

CVs < 15% - Least Variable

CVs 15 – 35% - Moderately Variable

CV> 35% Highly Variable

The field showed moderate to high variability in collected data

<table>
<thead>
<tr>
<th>Variable</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>CV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potash</td>
<td>78.00</td>
<td>320.00</td>
<td>184.48</td>
<td>29.47</td>
</tr>
<tr>
<td>Calcium</td>
<td>560.00</td>
<td>1044.00</td>
<td>790.80</td>
<td>17.82</td>
</tr>
<tr>
<td>Alumina</td>
<td>70.00</td>
<td>132.00</td>
<td>99.80</td>
<td>16.94</td>
</tr>
<tr>
<td>Sulfur</td>
<td>13.00</td>
<td>20.00</td>
<td>16.00</td>
<td>10.69</td>
</tr>
<tr>
<td>Manganese</td>
<td>21.00</td>
<td>53.00</td>
<td>34.13</td>
<td>23.19</td>
</tr>
<tr>
<td>Iron</td>
<td>107.00</td>
<td>204.00</td>
<td>139.25</td>
<td>14.21</td>
</tr>
<tr>
<td>Sodium</td>
<td>21.00</td>
<td>42.00</td>
<td>30.05</td>
<td>15.99</td>
</tr>
<tr>
<td>Aluminum</td>
<td>1511.00</td>
<td>1833.00</td>
<td>1627.50</td>
<td>4.57</td>
</tr>
<tr>
<td>Lime Index</td>
<td>6.60</td>
<td>7.10</td>
<td>6.80</td>
<td>1.91</td>
</tr>
<tr>
<td>% P/Al</td>
<td>7.75</td>
<td>14.10</td>
<td>10.39</td>
<td>16.38</td>
</tr>
<tr>
<td>CEC</td>
<td>5.00</td>
<td>10.00</td>
<td>7.88</td>
<td>17.77</td>
</tr>
<tr>
<td>Total % Base Sat</td>
<td>41.20</td>
<td>99.00</td>
<td>68.50</td>
<td>23.99</td>
</tr>
</tbody>
</table>
Geostatistical Analysis

HCP

Slope

OM

Calculates spatial variability in terms of distance (in meters).
## Geostatistical Analysis

### Souris PEI

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Range (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCP (mS m(^{-1}))</td>
<td>18.31</td>
</tr>
<tr>
<td>PRP (mS m(^{-1}))</td>
<td>18.83</td>
</tr>
<tr>
<td>Moisture Content (%)</td>
<td>30.80</td>
</tr>
<tr>
<td>Slope</td>
<td>12.10</td>
</tr>
<tr>
<td>Organic Matter (%)</td>
<td>30.80</td>
</tr>
<tr>
<td>pH</td>
<td>33.30</td>
</tr>
</tbody>
</table>

Spatial variability is 1/3 of the range of variability.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnesium (ppm)</td>
<td>26.40</td>
</tr>
<tr>
<td>Boron (ppm)</td>
<td>53.40</td>
</tr>
<tr>
<td>Copper (ppm)</td>
<td>223.80</td>
</tr>
<tr>
<td>Zinc (ppm)</td>
<td>41.60</td>
</tr>
<tr>
<td>Sulfur (ppm)</td>
<td>30.80</td>
</tr>
<tr>
<td>Manganese (ppm)</td>
<td>190.87</td>
</tr>
<tr>
<td>Iron (ppm)</td>
<td>45.55</td>
</tr>
<tr>
<td>Sodium (ppm)</td>
<td>103.69</td>
</tr>
<tr>
<td>Aluminium (ppm)</td>
<td>66.60</td>
</tr>
<tr>
<td>Lime Index</td>
<td>23.56</td>
</tr>
<tr>
<td>% PAI</td>
<td>77.94</td>
</tr>
<tr>
<td>CEC (meq/100g)</td>
<td>30.90</td>
</tr>
<tr>
<td>Total % Base Saturation</td>
<td>103.69</td>
</tr>
</tbody>
</table>
## Correlation Analysis - Hamilton PEI

<table>
<thead>
<tr>
<th></th>
<th>HCP</th>
<th>PRP</th>
<th>Organic Matter</th>
<th>pH</th>
<th>K$_2$O</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRP</td>
<td>0.565***</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organic Matter</td>
<td>0.024$^{NS}$</td>
<td>0.10$^{NS}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>-0.133$^{NS}$</td>
<td>0.24$^{NS}$</td>
<td>0.015$^{NS}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K$_2$O</td>
<td>0.521*</td>
<td>0.28*</td>
<td>0.192$^{NS}$</td>
<td>0.126$^{NS}$</td>
<td></td>
</tr>
<tr>
<td>CEC</td>
<td>-0.311*</td>
<td>-0.338*</td>
<td>0.274*</td>
<td>0.043$^{NS}$</td>
<td>0.175$^{NS}$</td>
</tr>
</tbody>
</table>

Significance of correlation indicated by *, ** and *** are equivalent to $p=0.05$, $p=0.01$ and $p=0.001$. Where NS is non-significant at $p=0.05$. 


**Correlation Analysis – Souris PEI**

<table>
<thead>
<tr>
<th></th>
<th>HCP</th>
<th>PRP</th>
<th>Organic Matter</th>
<th>pH</th>
<th>K$_2$O</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRP</td>
<td>0.687***</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organic Matter</td>
<td>-0.149$^{NS}$</td>
<td>0.057$^{NS}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>-0.347*</td>
<td>-0.197$^{NS}$</td>
<td>0.091$^{NS}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K$_2$O</td>
<td>0.433**</td>
<td>0.463**</td>
<td>0.136$^{NS}$</td>
<td>0.119$^{NS}$</td>
<td></td>
</tr>
<tr>
<td>CEC</td>
<td>0.25*</td>
<td>0.153$^{NS}$</td>
<td>0.113$^{NS}$</td>
<td>-0.324*</td>
<td>0.222$^{NS}$</td>
</tr>
</tbody>
</table>

Significance of correlation indicated by *, ** and ***, are equivalent to $p=0.05$, $p=0.01$ and $p=0.001$. Where NS is non-significant at $p=0.05$. 
Interpolation and Mapping – Souris, PEI
Multiple Regression

\[ \text{Yield (kg/ha)} = 122270 + 819 \times \text{HCP} + 334 \times \text{PRP} + 1262 \times \text{MC} - 461 \times \text{Slope} + 3077 \times \text{NDVI} + 2876 \times \text{OM} + 792 \times \text{pH} + 81.8 \times \text{Phosphate} + 26.3 \times \text{Potash} + 0.37 \times \text{Calcium} - 6.9 \times \text{Magnesium} + 1159 \times \text{Boron} - 851 \times \text{Copper} + 198 \times \text{Zinc} - 50.2 \times \text{Sulfur} - 11.4 \times \text{Manganese} - 253 \times \text{Iron} + 1167 \times \text{Sodium} - 16.78 \times \text{Aluminum} \]

Regression Analysis - Hamilton PEI

\[ \text{HCP} = 0.3953 \times \text{Yield} + 1.0059 \quad R^2 = 67.89\% \]
Regression Analysis - O’Leary PEI

HCP = 0.4202Yield + 0.4851  \quad R^2 = 0.7014
Regression Analysis - Souris PEI

HCP = 0.4002Yield - 1.245  \( R^2 = 0.5839 \)
Regression Analysis - Taylor Road PEI

HCP = 1.1405Yield - 5.2785 \quad R^2 = 0.6213

\text{Yield} = -5.63 + 0.459 \times \text{HCP A VG} + 0.685 \times \text{PRP A VG} + 0.342 \times \text{Moisture A VG} + 1.771 \times \text{Organic Matter (\%)} + 0.01005 \times \text{Phosphate P}_2\text{O}_5 (\text{ppm}) + 0.00559 \times \text{Potash K}_2\text{O (ppm)} - 5.39 \times \text{Boron B (ppm)} + 0.00307 \times \text{Aluminum Al (ppm)} - 0.4212 \times \text{CEC (Meq/100g)}

\text{Stepwise Regression}

\text{Yield (kg/ha)} = 4908 + 1201 \times \text{HCP} + 1168 \times \text{MC} + 4096 \times \text{OM} + 64.69 \times \text{Phosphate} - 1316 \times \text{Zinc} - 1315 \times \%P/Al - 396 \times \text{CEC}

R^2 = 92.05 \%

R^2 = 90.15 \%
Cluster Analysis, Hamilton, PEI

Yield (cwt/ac) Mean
Excellent: Gray 491.30
Very good: Green 437.60
Good: Purple 395.43
Poor: Red 377.81
Very poor: Blue 285.80
Management Zones – O’Leary, PEI
Management Zones – Tayler Road, PEI
Management Zones - Souris, PEI
Yield Comparison With thermal Imagery, Oleary

Yield (Kg/Sample)

- Boundary
- 11.2 - 11.6
- 11.7 - 12
- 12.1 - 12.3
- 12.4 - 12.7
- 12.8 - 13.1
Conclusions

- The CVs showed moderate to high variability

- Range of influence and geo-referenced mapping in GIS showed substantial spatial variability.

- The HCP was found to explain > 60% of variability in tuber yield within selected fields

- The DualEM showed significant potential to be used for delineation of MZs
Future Steps

- Repeat experiments (2 fields for calibrations and 2 for mapping)
- Apply nutrient based on developed MZs using map based VR spreader to evaluate the productivity benefits.
- Include fall sampling prior to potato production to examine the impact of rotation on developing MZs.
- Evaluate environmental benefits of the variable rate nutrient management based on prescription maps
- Develop user friendly protocols for farmers/industry use
- Train HQP and industry personnel
Ongoing Research Projects

✓ An autonomous robotic system for precision agriculture and environmental protection.

✓ Enhancement of Canadian potato production through precision agriculture technologies.

✓ SpudNik-1: A CubeSat-based high resolution imaging system for precision agriculture.

✓ Development of precision agriculture (PA) technologies to improve crop productivity and mitigate environmental risks: A pathway to sustainable agriculture production.

✓ Intelligent nutrient management practices: A pathway to environmental sustainability.

✓ Evaluating the water balance in Prince Edward Island: Sustainability prospective.
Ongoing Research Projects

✓ Development of map based variable rate technology for site-specific nutrient management in potato cropping system.

✓ Development of sensor based management zones to improve farm profitability and lower environmental risks in potato cropping systems.

✓ Delineating management zones for site-specific application of agrochemicals in potato cropping system.

✓ Improving wild blueberry crop productivity using precision agriculture technology.

✓ Development of VR sprayer for integrated weed management in soybean.

✓ Automation of commercial wild blueberry harvester to improve harvestable berry yield and minimize operator stress.

✓ Integrated harvesting technologies to improve berry recovery and quality.
Collaborators/Funding Agencies

Black Pond Farms
Oyster Cove Farms
Willard Waugh & Sons
MacLennan Properties
NB Growers

Precision Agriculture Research Group – UPEI
Ryan Barrett
Khalil Al Mughrabi
THANK YOU FOR YOUR ATTENTION

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