Canadian Agri-Science Cluster for Horticulture 3

Update to Industry

2019-2020

Activity title: Enhancement of Canadian Potato Industry through Smart Agriculture

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Activity Objectives (as per approved work plan)

The overall objective is to develop and evaluate smart farming (precision agriculture: PA) practices suitable for application in several major potato production areas of Canada. Specifically, this project will: 1) characterize soil spatial variability and evaluate methods for mapping this variability; and 2) develop and evaluate precision agriculture strategies most relevant to each production region.

The main objective for the province of Quebec is to assess the benefits of a precision N management approach based on management zones in terms of yield and N-use efficiency as compared to uniform N management. The precision N management approach proposed will be based on soil management zones and in-season N status.

In Prince Edward Island, the main objective is to assess the benefits of precision agriculture approach based on soil management zones and variable rate application (VRA) of fertilizer, pesticides, irrigation, plant density as compared to uniform rate application on the basis of tuber yield and quality, nutrient leaching and economic benefits. The VRA implementation will be based on spatio-temporal soil and crop property maps.

Activity 14A Precision Agriculture in QC

Research Progress to Date:

In agreement with the work plan, activities were pursuit during the years 2019-2020. In spring 2019, a VERIS® equipped with a GPS (Trimble®) were used to measure elevation, soil pH and apparent soil electrical conductivities (ECa) at 0.3 m and 1.0 m (i.e. Shallow: $EC_{Shallow}$ and Deep: EC_{Deep}) in 4 fields to study their spatial variabilities and their potential to delineate management zones (MZs) suitable for nitrogen fertilization experiment. Finally, a 14 ha field under commercial potato production (i.e. Doris field) was chosen to implement the nitrogen fertilization experiment. However, since the EC_{Deep} measurements produced negative, unusable data, this parameter was discarded from our spatial analysis. Maps of the spatial variability of the elevation, $EC_{Shallow}$ and pH were performed with the *Geostatistical tools* of the ArcGIS software (Figure 1).

(a) Elevation	(b) pH	(c) $EC_{Shallow}$

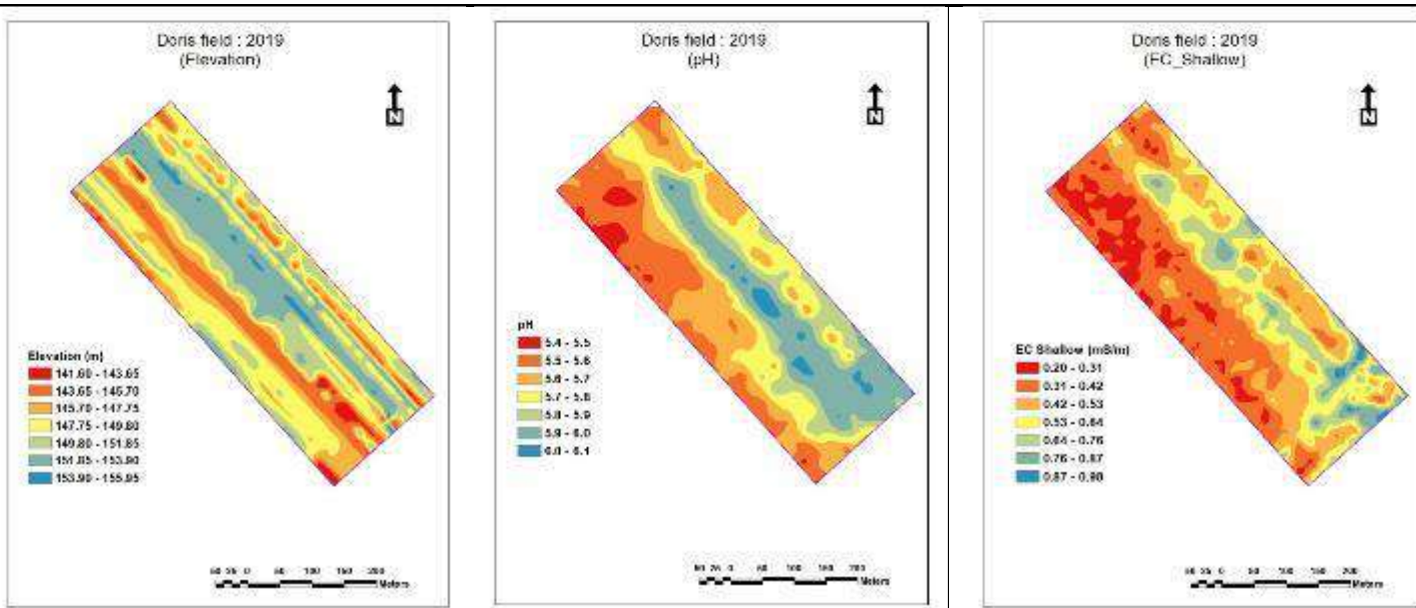


Figure 1 : Interpolated (krigged) maps for the spatial variability of (a) elevation, (b) pH and (c) $EC_{Shallow}$.

Field delineation into three MZs was performed using $EC_{Shallow}$ and pH maps with a non-supervised classification algorithm (ArcGIS's *ISO Cluster Unsupervised Classification)* (Figure 2). Mean $EC_{Shallow}$ and pH values for $MZ_{Low\_EC\_pH}$, $MZ_{intermediate\_EC\_pH}$ and $MZ_{high\_EC\_pH}$ were 0.32 mS/m and 5.52, 0.49 mS/m and 5.73, and 0.63 mS/m and 6.03 respectively (Table 1).

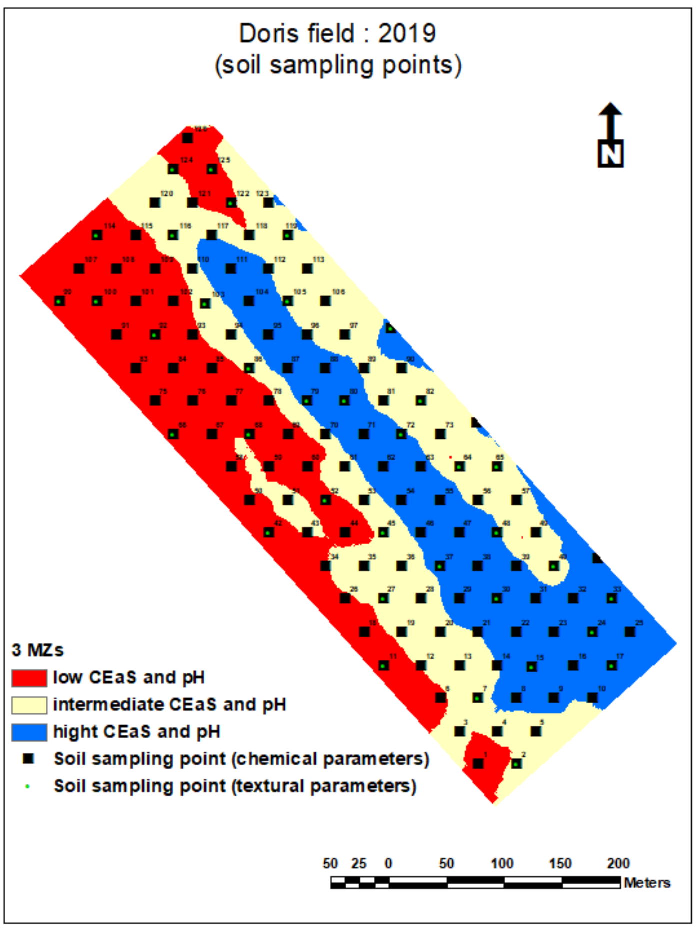


Figure 2 : MZs delineation and soil sampling points on Doris field.

Table 1 : Descriptive statistics for the field subdivided in 3 MZ (on the basis of $EC_{Shallow}$ and pH).

Parameter	MZ_{EC_pH} [a]		N [b]	Min [c]	Max [d]	Mean [e]	SD [f]	CV (%) [g]
	1	Low	1858	0.2	0.6	0.32	0.08	25.0
$EC_{Shallow}$	2	Intermediate	3100	0.2	1.0	0.49	0.13	26.5
	3	High	1770	0.2	1.0	0.63	0.15	23.8
	1	Low	124	5.37	5.79	5.52	0.10	1.8
pH	2	Intermediate	281	5.37	6.06	5.73	0.16	2.8
	3	High	190	5.37	6.24	6.03	0.12	2.0

[a] MZ_{EC_pH} : MZ group number ; [b] N : number of measured points in the field with the Veris;
[c] Min : minimum value; [d] Max : maximum value
[e] Mean : mean value; [f] SD : standard deviation; [g] CV : coefficient of variation

A grid sampling of 33 m x 33 m was implemented to locate 126 georeferenced sampling points (c.f. Figure 2) in order to analyze 13 selected soil chemical parameters (pH_{water} and pH SMP, P, K, Ca, Mg, Al, Cu, Fe, Zn, Mn extracted with Mehlich-III solution , total C and total N). Also, considering the subdivision of the field in three MZs, 12 georeferenced points for each MZ was selected for soil texture analysis (% clay, % loam, % sand) for a total of 36 sampling points. Geostatistical analysis and mapping was also performed on these parameters.

Russet Burbank cultivar potato was planted on the field (Day after planting, DAP=0, May 16th). At planting, N fertilizers were banded for the entire field at the rate of 106 kg N ha^{-1}. Then, an experimental design of four strip treatments (six rows X length of the field) were distributed in a randomized complete block design (RCBD) with four replicates (180, 210, 240, and 270 kg N ha^{-1}) and went through all the MZs. For each of the three MZ and four treatments MZs, 72 georeferenced sampling points were positioned on the field (Figure 3).

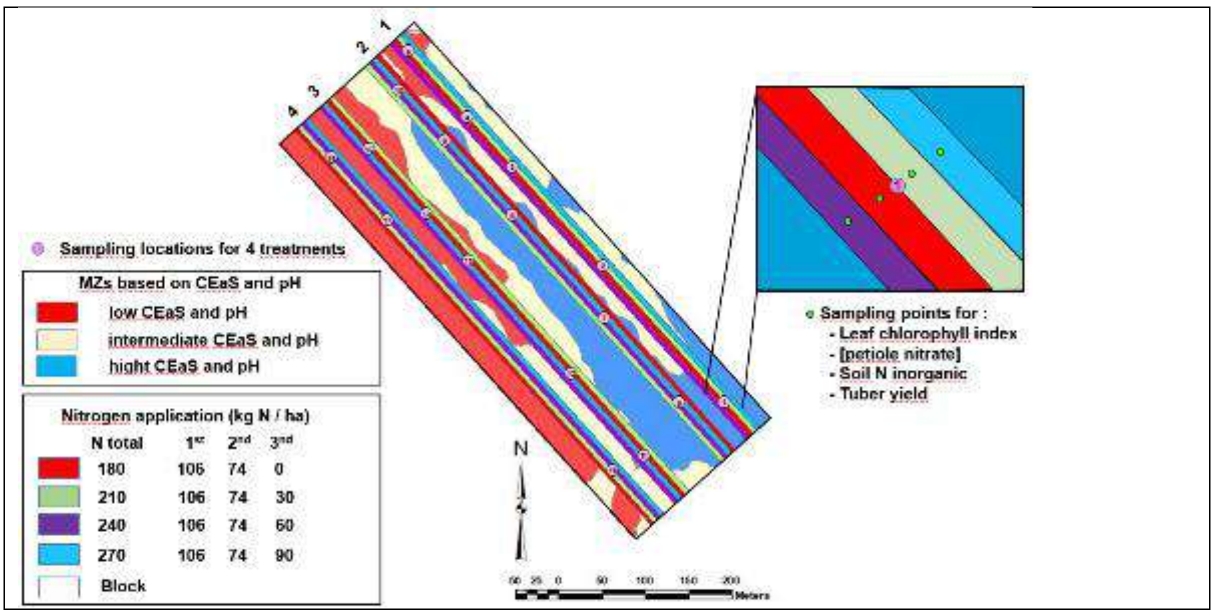


Figure 3 : Management zones and the N strip treatments implemented in spring 2019.

The 2nd N application was also banded at 34 DAP in all the 16 strip treatments at the uniform rate of 74 kg N ha^{-1}. Just before hilling period (48 DAP), at the 72 georeferenced sampling points, many plant parameters [i.e., vegetation indices from hyperspectral and multispectral images acquisition using drone, petiole nitrate concentration (PNIT), leaf chlorophyll index (LCI)] were measured. The soil surface nitrate concentration was also measured at the same time on the same sampling points. At hilling, the 3rd N application was banded according to the specific N rate (0, 30, 60, or 90 kg N ha^{-1}) in each strip treatments. About two to three weeks later, (harvest period: DAP 138), total and marketable yield as well as residual soil nitrate were measured at the 72 sampling points. Potatoes harvest was made manually. After the harvest, potatoes were sorted in different categories and washed in order to perform a quality examination (specific weight, diseases). Finally, from mid-September to mid-October, the VERIS were used to measure ECa in 10 fields in order to find the best field for season 2020. Two of them were retained as possible experimental fields for season 2020.

Preliminary results (SAS® software) showed that the main effects of MZ and N rates on total and marketable yield (Figure 4) for the season 2019 indicated significant difference between MZ_{HighEC_pH} and $MZ_{Low\_EC\_pH}$ or $MZ_{intermediate\_EC\_pH}$ but no significant difference between the four N treatments (N180, N210, N240, N270). The marketable yield of the $MZ_{Low\_EC\_pH}$ and $MZ_{intermediate\_EC\_pH}$ showed higher yield of 10 t ha^{-1} compared to the one measured in the $MZ_{high\_EC\_pH}$ (total yield 48.3 t ha^{-1}). The interaction between MZ x N treatments (i.e. M*N rate) indicated no significant difference between N treatments for the same MZ. However, this indicate that the lower N rate (N180) gave the higher yield in MZs. All other soils, plants, petioles and drone, hyperspectral and multispectral images are under analyzed and will be completed by March 31st 2020.

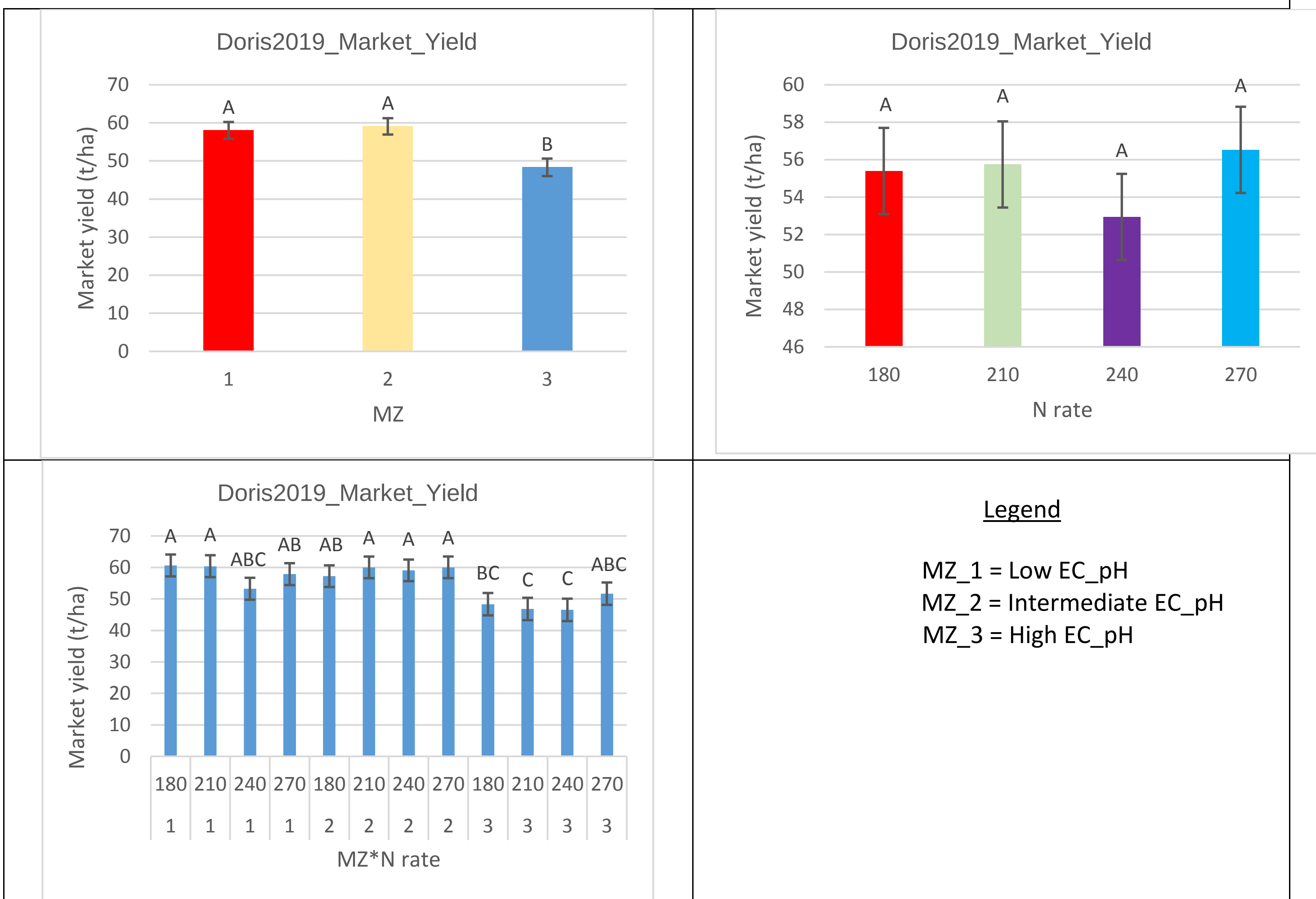


Figure 4: Statistical analysis of market yields for the season 2019.

Activity 14B Precision Agriculture in PEI
Research Progress to Date:

FIELD ACTIVITIES

Two potato fields were selected in Bedeque and Souris, Prince Edward Island, Canada to be referred to as Fields 1 and 2, respectively from here onward (Figure 1). The objective was to assess the spatial variability in soil properties, crop characteristics, field conditions, and crop yield to develop MZs for site-specific nutrient management. A real-time kinematics global positioning system (RTK-GPS) (Benchmark, 6132 Bow Crescent NW Calgary, AB Canada, T3B 2B9) was used to take coordinate and to map boundaries of the selected fields (Figures 2a). The selected fields were under commercial management over the past decade and received traditional management practices (conventional fertilizer, weed and disease management). The soil at the experimental sites were examined and classified for texture. Field activities were performed throughout the growing season.

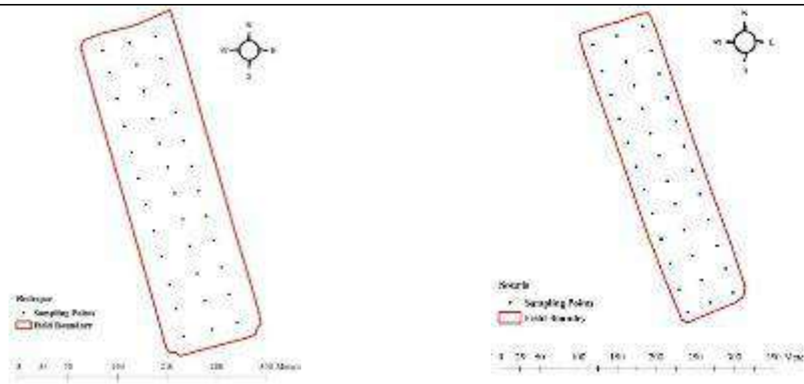


Figure 1: Boundary and sampling grids of experimental Fields 1 (Bedeque) and 2 (Souris) of PEI used for 2019 growing season.

Ground conductivity surveys were accomplished using the DualEM-II instrument coupled with a RTK- GPS behind an all-terrain vehicle (ATV) to collect intensive and manual data (Figures 2b and 2c). The horizontal co- planer geometry (HCP) and perpendicular co-planer geometry (PRP) geo-referenced data, retrieved from the DualEM-II instrument (DUALEM Inc., Milton ON, Canada) were utilized to develop a sampling strategy to collect soil, crop, and yield samples within selected sites. The collected data were analyzed using geostatistics to evaluate the spatial variation, which exits within the selected sites. Various models of semivariogram (gaussian, exponential, linear, and spherical) were fitted to quantify overall spatial variation. The regression model with highest coefficient of the determination (R^2) and minimum residual sum of squares (RSS) will be selected. The grid size to collect samples was established based on the range of the influence from semivariogram. Kerry and Oliver (2003) suggested that the grid pattern for sampling is one third or half of the range of variability. Based on the range of the variability, a grid size was selected for monitoring sites. The grid sampling based on the range of variability from DualEM-II reduces the labor and cost of analyzing these samples.

(a) (b) (c)

Figure 2: Measurement of ground conductivity using DualEM-II instrument and mapping of selected fields with RTK-GPS.

The use of electromagnetic induction sensor DualEM-II is one of the examples of non-destructive estimation of soil properties. It was used to determine ECa in the selected fields. The ECa measurements were made in bare soil and in soils having a potato vegetative cover. The HCP and PRP readings were recorded using the DualEM-II instrument at each sampling location. Soil water moisture content was recorded by inserting TDR-300 probes 15 cm below the soil surface. All these sensors were calibrated and validated with actual attributes prior to sense/estimate the attribute of interest.

Soil samples were collected twice during the growing season and were analyzed for macro and micronutrients from the PEI Analytical Laboratory. Four samplings (physical and sensors) were performed during the monitoring period to capture the spatial variations and to assess the prediction potential of the DualEM-II sensor in delineating MZs for site-specific nutrient management. The normalized difference vegetation index (NDVI) was also collected using a calibrated NDVI meter from each sampling points with selected fields to assess the relationship of crop health with productivity. The slope of each sampling location was also measured to assess the role played by the topography in explaining the spatial variability in yields.

The geo-referenced crop yield samples were collected manually from each sampling location within selected fields. The 3 m strips were harvested at each sampling location to acquire a representative yield sample. This yield data from each sampling location was be regressed against soil property and sensor data to assess the adequacy of the DualEM-II sensor based MZs. Geo-referenced manual yield data collection is presented in Figure 3. Yield monitoring is one of the key variables to be considered in developing MZs. However, its accuracy in representing the yield variations within a field is very important. In order to assess the accuracy of the yield monitoring system in estimating potato crop yield, two of the yield monitors were calibrated in Prince Edward Island. The monitoring data from a selected yield monitor were collected and compared with the actual yield data to develop calibration and validation models.

Figure 3: Geo-referenced yield data collection to match with spatial soil variability within selected field.

STATISTICAL ANALYSIS

The collected soil, crop, slope, yield and sensor data from selected fields over the growing seasons were gleaned and organized for statistical, geo-statistical and GIS analysis. Classical statistics was used to calculate minimum, maximum, mean, standard deviation, coefficient of variation (CV) and skewness using Minitab 17 (Minitab Inc., New York, N.Y.). Classical statistics provides the overall variability of the soil properties, crop characteristics, tuber yield and slope; however, it does not provide the spatial trend. Therefore, the geo-statistical analysis was performed using GS+ Geo-statistics for the Environmental Sciences Version 9 software (Gamma Design Software, LLC, Plainwell, Mich.) to characterize the spatial variability in soil properties, crop characteristics, crop yield and slope. The semivariogram was produced for each attribute to using GS+ software.

The correlation coefficient, linear and multiple regression analysis between soil properties, crop characteristics, tuber yield and slope were performed to identify the relationships. The regression analysis was performed to calibrate and validate the sensors (DualEM, TDR, accelerometers, and yield monitoring system). The sensor data were regressed with the soil, crop and yield attributes to identify their potential in estimating/sensing the significant factors affecting crop yield. The RMSE was calculated using actual and predicted data. The sensor predictions with highest R^2 and minimum RMSE were proposed for estimation of attribute of interest significantly correlated with tuber yield. Sensor data can easily be measured and used for developing MZs to allocate site-specific applications. Geo-statistics combined with GIS were applied to generate detailed maps in ArcGIS 10.4 (ESRI, Redlands, Cal., USA) software to analyze the spatial variability in soil properties; crop characteristics, slope and crop yield visually. All the parameters were interpolated using ordinary IDW interpolation technique. The maps were produced at the same scale and equal number of classes in order to allow easier comparison. Results of regression analysis were compared with the maps to verify pattern of variation.

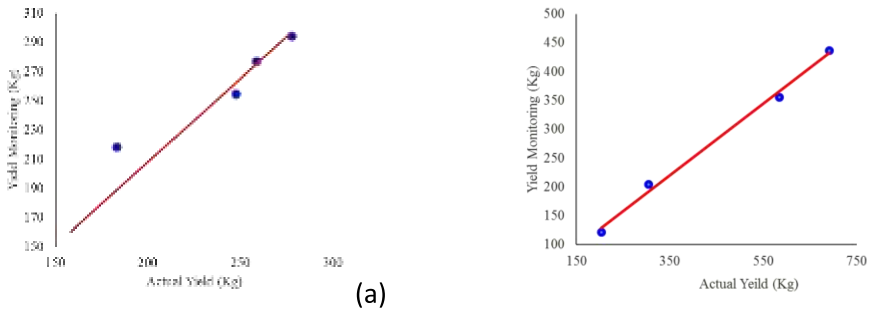
After the significant factors were identified and spatial variations were determined, the cluster analysis was performed to observe the spatial patterns of natural productivity groups aiming to minimize within- cluster variance and maximize between cluster variance to develop MZs. The cluster analysis will produce dendrograms. After cluster analysis, the natural grouping of the data was extracted and organized based on clusters (zones). The analysis of variance (ANOVA) was performed and the means were compared with least significant difference (LSD) at 5% level of significance using PROC GLM (SAS Institute, Cary, N.C.) for different clusters.

The clustered data based on the class membership (zones) were imported in ArcGIS 10.4 software to develop the MZs. Based on the variation in soil, crop, yield and nutrient attributes among various clusters, different agrochemical application rates were proposed to optimize crop productivity with the aided advantage of reduced production cost. This soil, crop, yield, slope, and sensor data will be collected for multiple years to ensure stability of data over time, which is a pre-requisite for delineating MZs to implement site-specific applications. Significantly correlated attributes with crop yield and easily predictable factors via sensors (HCP, PRP, TDR, slope, yield monitoring) were proposed for delineating MZs to optimize crop production. Delineating MZs with the help of sensors will eliminate the cost of sample collection and laboratory analysis. Different fertilizer application rates (kg ha^{-1}) can be assigned based on developed MZs (low to high productivity) to provide optimal availability of nutrients for plant uptake to improve crop yield. In the next phase of this project, these MZs will be incorporated into VR applicators to perform VR applications to ensure economic and environmental sustainability.

RESULTS AND DISCUSSION

Calibration of Yield Monitoring System and Mapping in GIS

Two yield monitors were selected and calibrated in selected fields. Results of regression analysis suggested that the accuracy was about 66 to 90% for selected yield monitors (Figures 4a,4b). Results showed over 9% error in actual and predicted yield for the data of Field 1 with RMSE = 18.1 kg and 8% error in actual and predicted yield for the data of Field 2 with RMSE = 20.1 kg. Yield monitoring is one on the key variables, if predicted accurately, can be used to develop MZs for site-specific nutrient management to improve soil health and productivity. Means of Fields 1 and 2 were 236 and 446.2 kg, respectively.



(a) (b)

Figure 4: Calibrations of yield mo for data of (a) Boundary and (b) S fields.

Descriptive Statistics of Soil Properties and Potato Yield

The coefficient of variation (CV) is a first approximation of field heterogeneity. Soil properties are least variable if the CV < 15%, moderate if CV is between 15% and 35%, and most variable if CV > 35%. Summary statistics of soil properties for selected fields showed that slope of the Field 1 had high variability (CV=52.33%) Yield, moisture content, HCP, PRP, copper, zinc, sulpher, calcium, and manganese had moderate variability (Table 1). The rest of the soil properties of Field 1 had least variability (CV<15%). For Field 2, moisture content and slope had high variability (CV > 35%). Yield, HCP, potash, copper, zinc, calcium, magnesium, sulphur, and manganese had moderate variability, and the rest of soil properties had least variability (Table 1).

The variation in potato yield and soil properties may be due to several factors including natural variations in soil, and crop management practices. In addition, the effect of temporal dynamics due to sampling at various times during the study should not be ignored. Overall, summary statistic revealed moderate to high variability within selected field.

Table 1: Descriptive statistics for data of Field 1 (Bedeque, PEI) and Field 2 (Souris, PEI)

Parameters	**Mean**	**Min**	**Max**	**CV (%)**	**Mean**	**Min**	**Max**	**CV (%)**
xperimental Fields	**1**				**2**			
ield (cwt/Acre)	448.33	320.11	545.9	32.03	382.8	565.6	468.8	20.2
Ioisture Content (%)	18.74	13	24	23.84	4.9	18.0	10.8	36.7
lope (%)	1.56	0.2	3.43	52.33	0.1	5.0	2.1	63.7
ICP (mS/m)	6.96	4.93	10.7	33.2	4.0	7.4	5.2	27.0
Organic Matter (%)	2.13	1.6	2.5	10.15	1.8	2.6	2.4	8.0
RP (mS/m)	4.02	2.1	7.13	24.35	3.3	5.7	4.6	14.7
odium (ppm)	14.92	12	20	11.6	15.0	23.0	19.8	10.4
hosphate (ppm)	703.9	594	905	9.15	406.0	687.0	557.0	11.5
otasium (ppm)	222.97	169	284	11.32	99.0	288.0	163.3	27.3
opper (ppm)	3.06	1.6	5.3	30.39	1.3	2.9	2.0	20.2
inc (ppm)	2.38	1.5	3.5	24.14	4.2	11.1	6.4	25.2
ulphur (ppm)	20.17	15	32	16.53	64.0	164.0	109.6	28.5
alcium (ppm)	823.9	386	1643	26.08	406.0	831.0	565.2	19.0
Ianganese (ppm)	43.89	26	79	28.57	46.0	122.0	70.9	20.7
EC (meq/100g)	9.53	8	12	9.87	10.0	13.0	11.9	6.0
luminum (ppm)	1844.4	1642	2091	6.02	942.0	1542.0	1326.8	8.6

Spatial Variation of Soil Properties and Potato Yield

Semivariogram analysis for potato yield from Bedeque field showed the range for some of the soil properties including soil organic matter was > 50 m, whereas, the other properties including HCP was less than 50 m. Literature suggests that variability is non-random at distances shorter than 20 to 50 m. The similar results were observed for other sampling fields. There was an impact of soil variability on yield as described with regression analysis (Figure 5). Significant relationships between HCP and potato yield were observed with R^2 = 0.68 (Field 1) and R^2 = 0.69 (Field 2). The other soil properties had significant relationships among each other for both fields.

Significant relation of DualEM-2 data (HCP) with tuber yield suggested the potential of DualEM-2 equipment to be used as a tool for delineating MZs within potato fields. These findings can be used in development of MZs based on the variation of affecting parameters and yield to increase farm profitability and reducing environmental risks. Selected significant relationships are presented in Figure 5. Significant relationship of potato tuber yield with HCP (R^2 ~ 68%) revealed that the ground conductivity can be used to develop MZs in potato production system to achieve site-specific nutrient management.

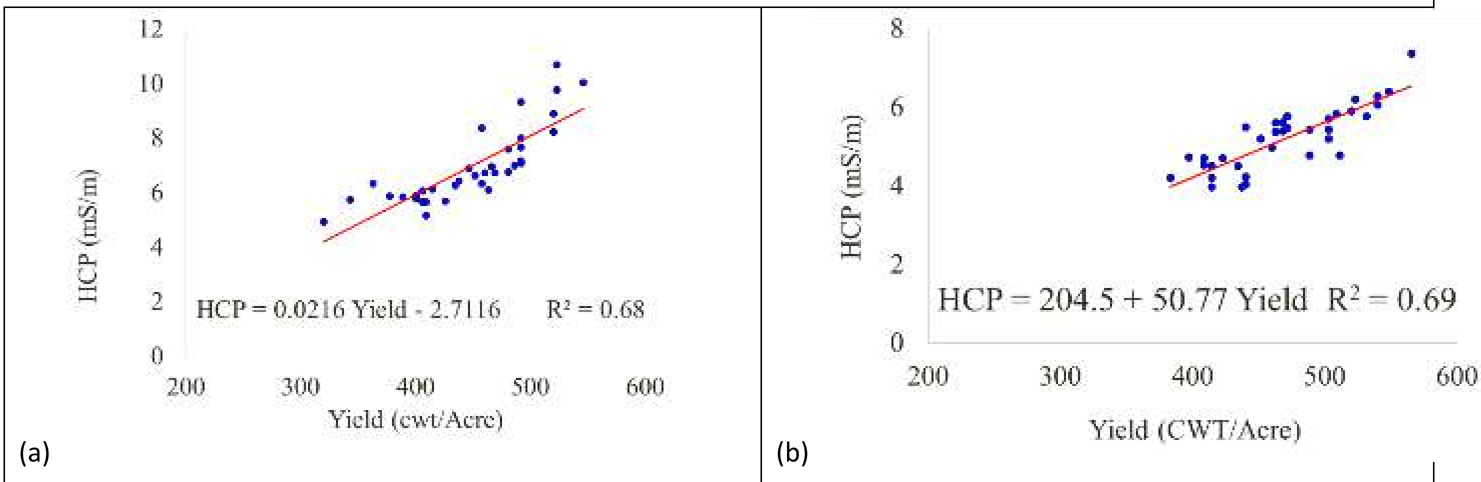


Figure 5: Relationships between HCP and potato tuber yield for (a) Field 1 (Bedeque, PEI) and (b) Field 2 (Souris) in PEI.

Mapping of Soil Properties

The maps of soil properties were created using kriging and/or IDW interpolation to show the spatial variation of values across the experimental fields. The interpolated maps showed substantial variability within selected fields (Figure 6), which was in agreement with the finding of summary statistics and geo-statistical analysis. The variability within fields was random and spatially different suggesting its management using innovative tools for site-nutrient management to ensure uniform productivity across fields. The interpolated map had variable pattern of variation. High yielding and HCP areas were located in the same areas of the monitoring site. These results are in agreement with significant positive correlation between these parameters. The interpolated maps of soil electrical conductivity components, soil water content, slope, SOM, soil pH and cation exchange capacity (CEC) showed similar pattern of variation for the two selected field. Due to shortage of space interpolated maps of Souris field (Field 2) are not presented here.

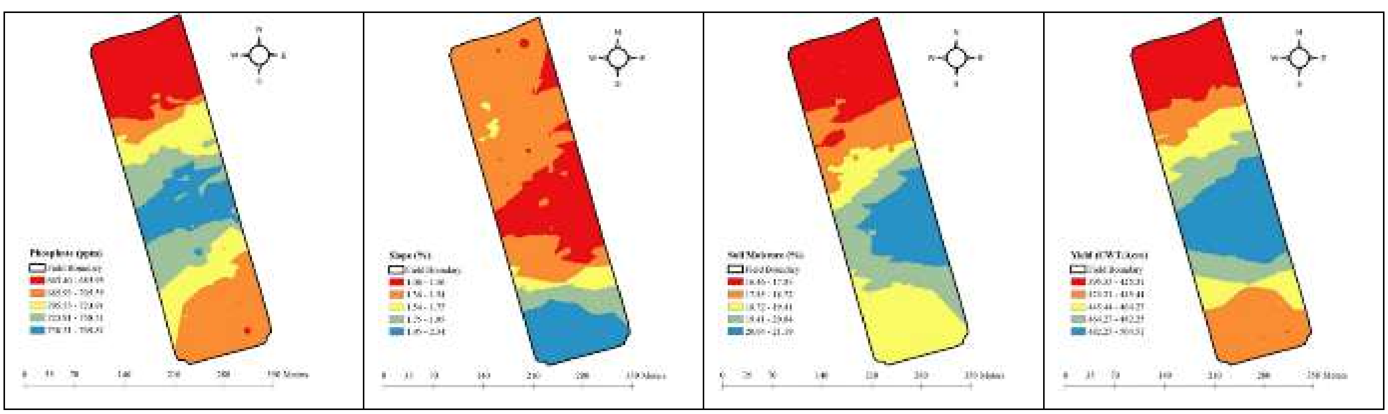
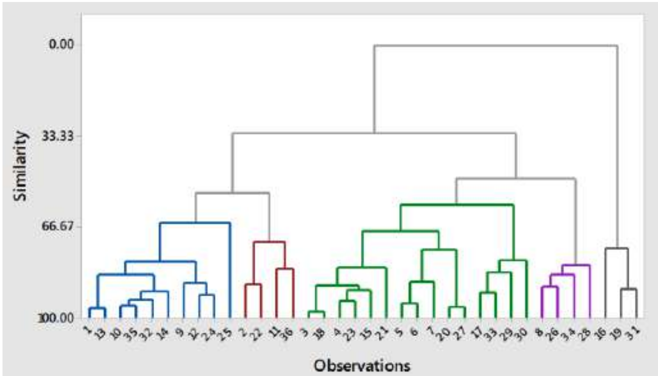


Figure 6: Sample interpolated maps of selected soil variables within Fields 1 (Bedeque, PEI)

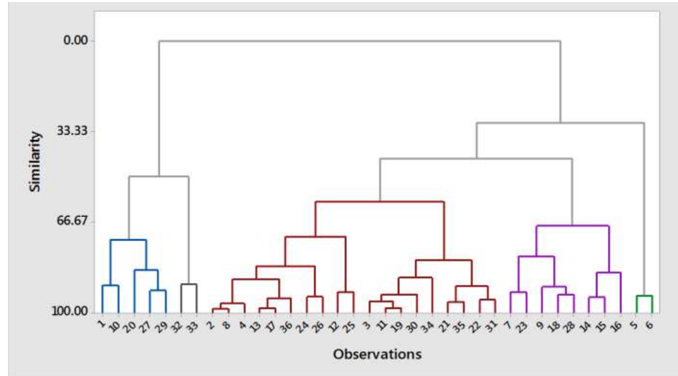
Delineation of Management Zones using Cluster Analysis

The results discussed in previous sections and spatial variability of yield and soil properties indicated the need for development of MZs for each site. The soil properties extracted from the stepwise regression equations and yield were clustered using Minitab 19 statistical software to group the potato yield and soil properties. The results of cluster analysis could differentiate the areas with different fertility status within fields. Figure 7a and 7b show the cluster observations dendrograms for the Fields 1 and 2, respectively. Each color cluster is internally homogeneous and externally heterogeneous. These colors represent Excellent, Very Good, Good, Poor, and Very Poor MZs based on their yield data.



(a)

Yield Mean (cwt/acre)
Black: Excellent: 491.60
Purple: Very Good :486.60
Green: Good: 481.31
Blue: Poor: 403.57
Red: Very Poor: 365.80



(b)

Yield Mean (CWT/Acre)
Purple: Excellent: 528.42
Green: Very Good: 495.58
Blue: Good: 487.86
Maroon: Poor: 443.78
Black: Very Poor: 395.60

Figure 7: Cluster observations dendrogram for (a) Field 1 (Bedeque, PEI) and (b) Field 2 (Souris, PEI). Each color cluster is internally homogeneous and externally heterogeneous.

The results of cluster analysis of data from Fields 1 and 2 exhibited that HCP in combination with potato yield can be used to develop MZs for site-specific fertilization in potato fields. The clustered data based on their class membership were imported in ArcGIS and IDW/krigging interpolation was applied to produce detailed maps representing MZs. Eventually, Figures 8 shows the MZs of a Fields 1. Due to shortage of space MZs of Field 2 are not presented here. The MZs map represented various levels of productivity across the site, which shows the need for proper management of agricultural practices in each zone. The comparison of potato yield and HCP map shows that the higher potato yield was produced in the area indicated as HCP and vice versa. The close resemblance in the trend of variation in tuber yield and HCP can be used to draw MZs based on readings of DualEM-2. The high HCP areas can be named as excellent MZ and the low HCP areas can be named as poor MZ as the tuber yield varied accordingly in these areas. Non-destructive mapping with DualEM-2 sensor can help to save sample analysis cost and to manage nutrient application based on soil and crop needs. These results could be used to apply proper rate of nutrients to improve farm productivity and reduce the environmental risks.

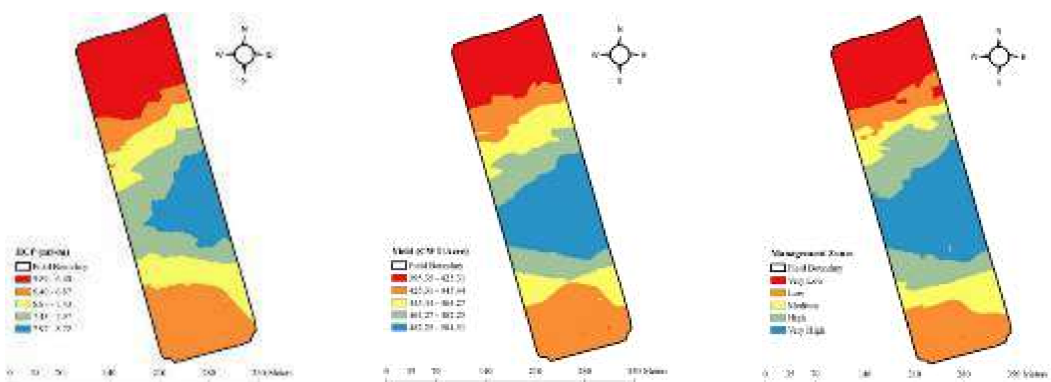


Figure 8: Visual compar of HCP with tuber yield examine its adequacy f constructing manageme zones for Field 1.

Fertility Maps and Application of Management Zones

Once the adequacy and accuracy of the DualEM-2 sensor in developing MZs was established and scientifically tested and evaluated, ground conductivity surveys were conducted in selected fields to develop fertility maps for fall potash application in site-specific fashion. The following methodology was adopted to prepare fertility maps (Figure 9). This was done to perform the fall potash application using the DualEM-2 sensor based MZs. We will be comparing the productivity benefits from these activities during next year.

- The field was split into sub-fields for treatments of application of fertilizer at uniform and variable rates separately.
- In variable treatment fields DualEM-2 sensor continuous survey was conducted for recording ECa each second while walking in straight lines. The distance between lines was approximately 10 to 15 m.
- Each ECa reading in line was geo-tagged with WGS 1984 system. Then these values were interpolated into a surface map using inverse distance weighting technique of the ArcGIS 10.5 software.

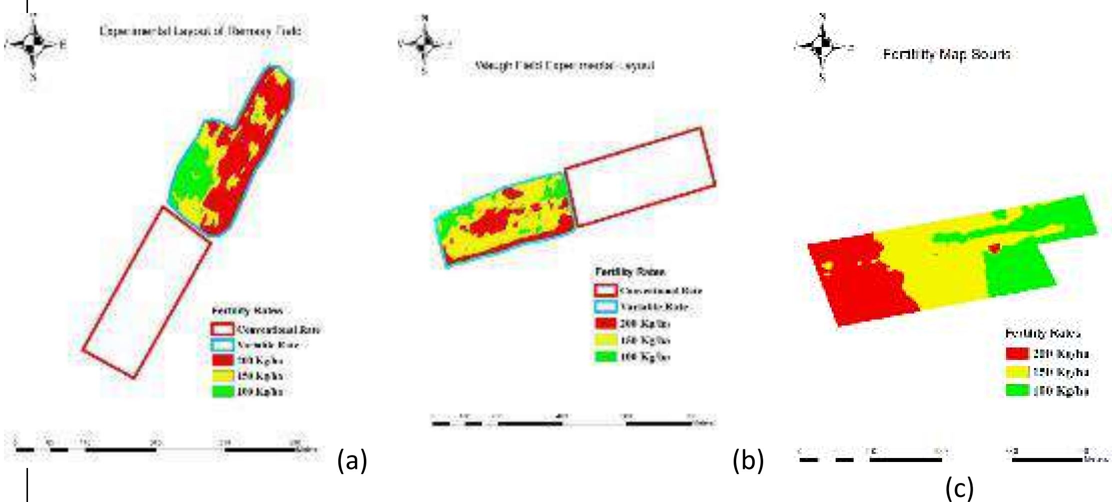


Figure 9. Experimental layouts, proposed fertility rates for (a) Hamilton (b) Waugh and (c) Souris field prepared based on ECa values. Fields in (a) and (b have been divided into tw sections to experiment uniform and variable rate treatments. The field in (c has only variable rate treatment due to small siz

- During the next year, these maps will be used to apply fertilizer rates. In variable treatment, nutrients will be applied based on prescription as shown in the maps. In conventional treatments, nutrients will be uniformly applied. At the end of next growing season, yield will be compared of both treatments to assess the accuracy and efficiency of the sensor based MZs.
- The Souris field had very small area (Figure 9c). Therefore, no conventional treatment (uniform application) is being suggested. This whole field would have variable rate treatment only.

All the three fields were in their rotation year. These fields were additional and separate from those plotted in Figure 1 to preform experimentation in relation to delineation of MZs.

Extension Activities (presentations to growers, articles, poster presentations, etc.):

Related to Activity 14A

Published article in peer-reviewed journal:

Zebarth, B.J., Monirul Islam, M., **Cambouris, A.N.,** Perron, I., Burton, D.L., Comeau, L.P., Moreau, G. 2019. Spatial variation of soil health indices in a commercial potato field in Eastern Canada. Soil Sci. Soc. Amer. J. 83 : 1786-1798. doi:10.2136/sssaj2019.03.0087.

Scientific presentations at international conference

Cambouris, A.N., Zebarth, B.J. , Perron, I. 2019. Delineated Soil Management Zones with Proximal Soil Sensors to Effectively Characterize the Soil Variability under Potato Production in Eastern Canada. Pages 9-14 in the Proceedings of 5th Global Workshop on proximal soil sensing, Columbia, Missouri, USA, May 28th to 31st , 2019. K.A. Sudduth, N.R. Kitchen and K.S. Veum. (Oral presentation).

Cambouris, A.N., Zebarth, B.J. , Perron, I. 2019. Soil Management Zone Delineation using Proximal Soil Sensors for Potato Production in Eastern Canada. Oral presented at 2019 ASA-CSSA-SSSA International Annual Meeting “Embracing the Digital Environment”. San Antonio, Texas, USA. Nov 10th-13th 2019. (Oral presentation).

Technology transfer to the sector

Charbonneau, C. and **Cambouris, A.N.** 2019. Analyse comparative entre les données de pH prises avec le VERIS-MSP et en laboratoire. Workshop with MaxiPlant and Cantin & Fils Farm at Ste-Catherine-de-la-Jacques-Cartier, Quebec, December 16th. (Oral presentation, 7 people).

Duchemin, M., **Cambouris, A.N.** and Baillargeon, A.D. 2019. Analyse géostatistique des données issues du VERIS. Workshop with MaxiPlant and Cantin & Fils Farm at Ste-Catherine-de-la-Jacques-Cartier, Quebec, December 16th. (Oral presentation, 7 people).

Published proceedings with peer review:
Cambouris, A.N., Zebarth, B.J. , Perron, I. 2019. Delineated Soil Management Zones with Proximal Soil Sensors to Effectively Characterize the Soil Variability under Potato Production in Eastern Canada. Pages 9-14 in the Proceedings of 5th Global Workshop on proximal soil sensing, Columbia, Missouri, USA, May 28th to 31st , 2019. K.A. Sudduth, N.R. Kitchen and K.S. Veum.

Related to Activity 14B
Published an article in peer-reviewed journal:
Farooque, A.A., Zare, M., Abbas, F., Bos, M., Esau, T., Zaman, Q. (2019) Forecasting potato tuber yield using soil electromagnetic induction. *European Journal of Soil Science.* https://doi.org/10.1111/ejss.12923.
Khan, H., Acharya, B., **Farooque, A.A.**, Abbas, F., Zaman, Q.U., Esau, T. (2020) Soil and crop variability induced management zones to optimize potato tuber yield. *Applied Engineering in Agriculture*. (Revised)
Transfer technology Presentation:
Hussain, N., **Farooque, A.A.**, Schumann, A.W., Afzaal, H., Zaman, Q.U., Acharya, B. (2019). Development of a Smart Sprayer for Targeted Applications of Agrochemicals. Demonstration of technology during 2019 Regional Conference on Precision Agriculture held at University of Prince Edward Island, Charlottetown, PEI on August 22, 2019.
Published proceedings with peer review:
Khan, H., Acharya, B., **Farooque, A.A.** (2019) Site-specific Nutrient Management to Improve Soil Health and Productivity for Potato Tuber. Proceedings 2019 International Annual Meeting of ASABE held on July 07-10, 2019 in Boston, MA, USA

Early Outcomes (if any) or Challenges:
Delineation of MZs using yield dataset from yield monitor reduce the spatial variability of yield data and seems to have a good potential for delineation of productivity MZs. Adding the soil ECa measurements will probably improve the delineation of the MZ for site specific application in the QC province.
DualEM-II sensor used in PEI province showed a strong potential to be used as a mapping tool to tailor the best management practices. We will be repeating the experiments this year to have a sense of stability of data over time for temporal variations (if any). Nutrient management based on soil and crop needs can ensure economic viability and environmental safety.

Key Message(s):

- Develop map/sensor-based precision agriculture systems for Québec and Atlantic Provinces Canada's potato industry based on proper characterization and quantification of variability.
- Identify sensor-based options to perform mapping and tailor management practices to reduce labor and sample analysis cost.
- Apply nutrients based on need to evaluate the productivity benefits.
- Evaluate environmental benefits of the variable rate nutrient management.
- Develop user-friendly protocols for farmers/industry use.
- Train HQP and industry personnel in the emerging area of precision agriculture.

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