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Integrated Analysis of Multilayer Proximal Soil Sensing Data

N. Dhawale
V. Adamchuk
H. Huang
W. Ji
S. Lauzon
Department of Bioresource Engineering
McGill University

A. Biswas
Department of Natural Resource Sciences
McGill University

P. Dutilleul
Department of Plant Science
McGill University

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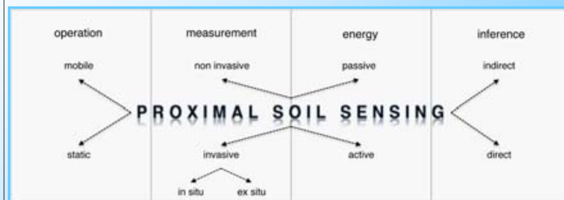
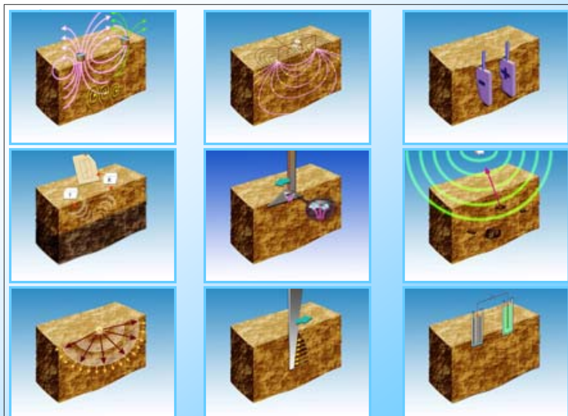
McGill

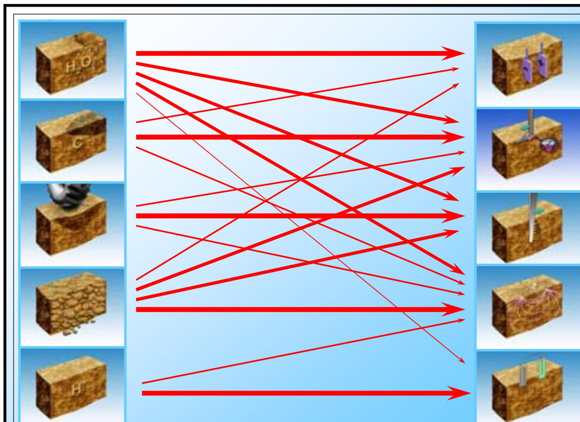
Proximal Soil Sensing

Proximal Soil Sensing (PSS) is a set of technologies developed to measure the physical, chemical and biological properties of soil when placing the sensor in contact with, or at a proximal distance (less than 2 m) to, the soil being characterized



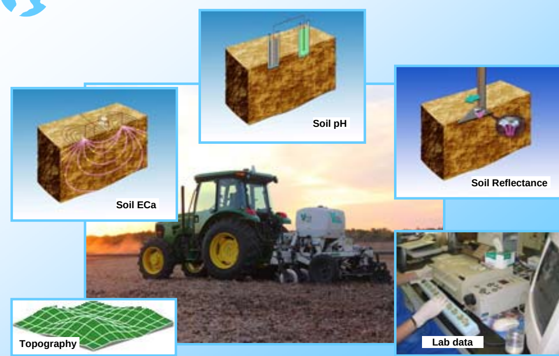
Advances in Agronomy 113: 237-283





Typical Field Mapping

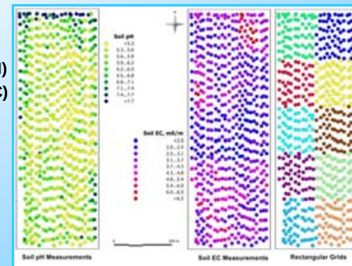
Sensor Fusion



Site Specific Data Calibration

$$OF = \sqrt[5]{S_{opt} \cdot D_{opt-pH} \cdot D_{opt-EC} \cdot H_{cr-pH} \cdot H_{cr-EC}}$$

- S-optimality
- D-optimality (soil pH)
- D-optimality (soil EC)
- H-criteria (soil pH)
- H-criteria (soil EC)



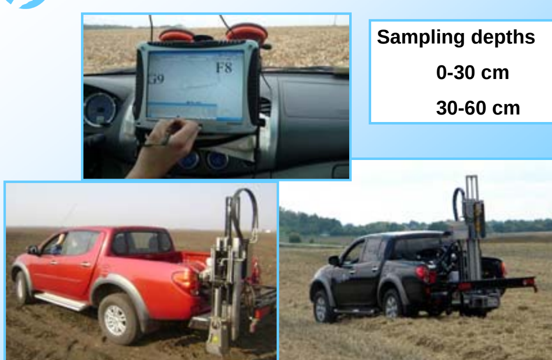
Geoderma 163:63-73

Georeferenced Soil Sampling

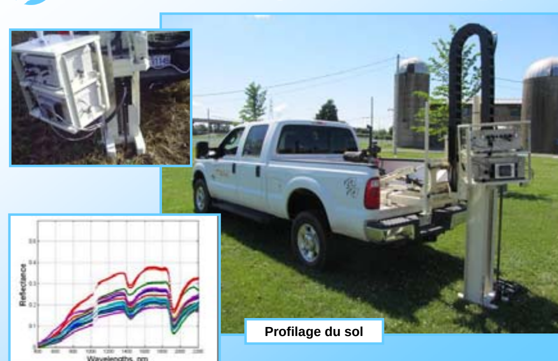
Sampling depths

0-30 cm

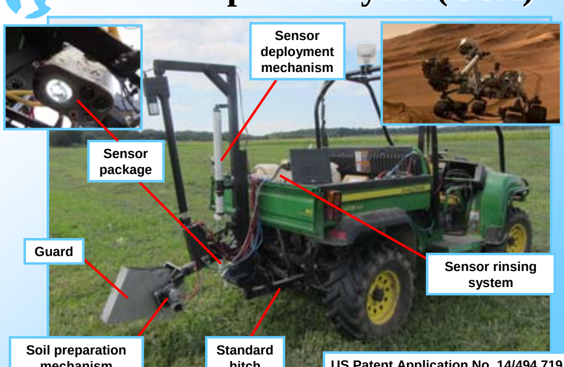
30-60 cm



Soil Profiling (Spectroscopy)



On-the-Spot Analyzer (OSA)



Objective

- To develop a robust algorithm that could handle multilayer PSS data and produce an unspecified number of spatially contiguous field partitions while relying **solely** on the information embedded within the specified PSS dataset
- To locate one **representative** location for each partition for point-based analysis

Objective Function

OR (×) vs. **~~AND (+)~~**

$$OF = \prod_{k=1}^{K} R_k^2$$

$$R_k^2 = 1 - \frac{MSE_k}{FDV_k}$$

$$MSE_k = \frac{\sum_{j=1}^{m}\sum_{i=1}^{n_j}\left(X_{ij} - \bar{X}_j\right)^2}{N - m}$$

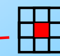
$$FDV_k = MSE_k\,(m = 1)$$

X_{ij} **= sensor value**
N **= the total number of data elements**
m **= the number of groups**
n_j **= the number of dta elements within the** ***j_{th}*** **group**
K = the number of data layers ***k***

Objective Function

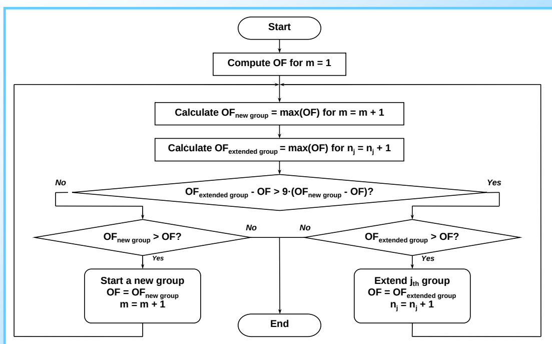
$$R_k^2 = 1 - \frac{MSE_k}{FDV_k} \rightarrow R_{k\,\max}^2 = 1 - \frac{SDV_k}{FDV_k}$$

$$SDV_k = \frac{1}{w}\sum_{j=1}^{w}\sum_{i=1}^{9}\frac{\left(X_{ij} - \bar{X}_j\right)^2}{8}$$

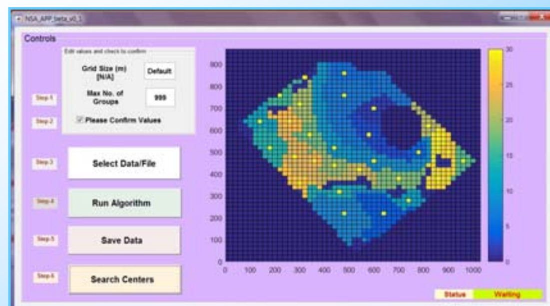


$$OF = \prod_{k=1}^{K} {R_k^2}^{\,R_{k\,\max}^2} = \prod_{k=1}^{K}\left(1 - \frac{MSE_k}{FDV_k}\right)^{\left(1 - \frac{SDV_k}{FDV_k}\right)}$$

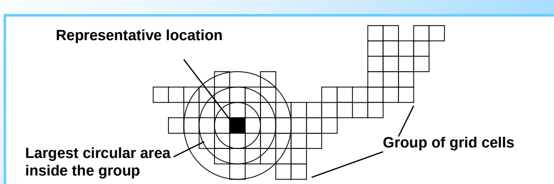
Neighbourhood Search Analysis (NSA)



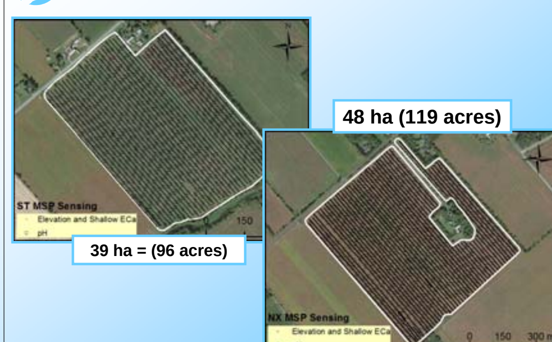
NSA Interface

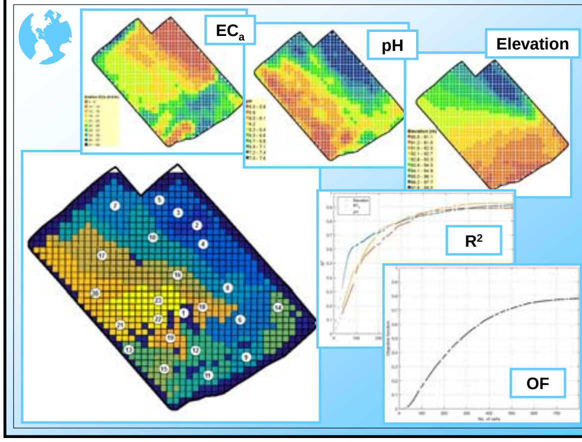


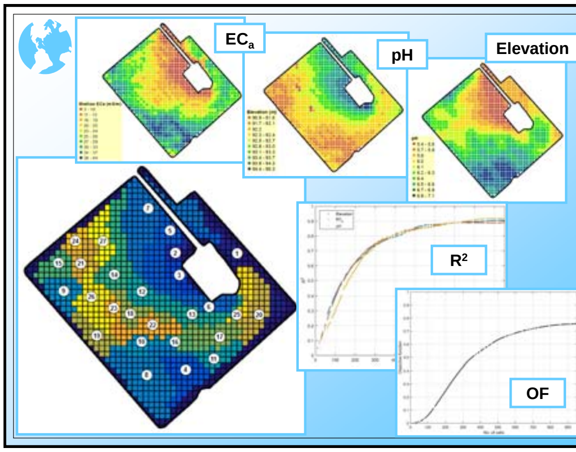
Circular Area Search Method



Field Examples







D-Optimality Comparison

Data layers	NX field (27 locations)			ST field (23 locations)		
	Elevation	Shallow EC$_a$	pH	Elevation	Shallow EC$_a$	pH
	D-optimality = $\lvert(X'X)^{-1}\rvert$					
NSA (max OF)	0.003008	$1.631 \cdot 10^{-5}$	0.005292	0.004048	$2.211 \cdot 10^{-5}$	0.011186
Random (max)	0.004108	$1.246 \cdot 10^{-4}$	0.040810	0.024190	$8.890 \cdot 10^{-5}$	0.325400
Random (median)	0.000480	$2.224 \cdot 10^{-5}$	0.006441	0.005007	$2.432 \cdot 10^{-5}$	0.015570
Random (min)	0.000188	$6.458 \cdot 10^{-5}$	0.003617	0.001372	$8.944 \cdot 10^{-6}$	0.006450
	Ranking (from 0 to 100) with respect to 5000 random selections					
NSA ranking	7	20	19	25	35	28

Summary

- **The spatial clustering algorithm developed in this study is based on a neighbourhood search analysis method and seeks to minimize variance inside each group of interpolated grid pixels corresponding to an unlimited number of sensor-based data layers.**

- **The circular area search method was implemented to define representative locations within each delineated group of grid cells.**

- **Preliminary testing of the algorithm was illustrated using field elevation, shallow EC$_a$ and soil pH PSS data layers obtained from two agricultural fields.**

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http://adamchukpa.mcgill.ca
E:mail: viacheslav.adamchuk@mcgill.ca