2013 ASABE Annual International Meeting
Kansas City, Missouri

Smart Tractor Approach to Variable Rate Technology

Viacheslav Adamchuk
Frederic Rene-Laforest
Trevor Stanhope
Maria Mastorakos
Yue Su
Department of Bioresource Engineering
McGill University

James Lenz
JD Technology Innovation Center

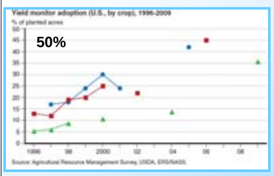
Philipp Münch
European Technology Innovation Center
John Deere

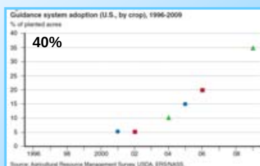
July 24, 2013

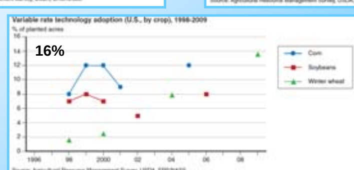
Background

- One of the main objectives of smart farming is to optimize crop production and reduce the environmental footprint by using new digital technologies
- In comparison to the wide-spread use of global navigation satellite system (GNSS) based guidance of field machinery and yield monitors, the adoption of variable rate technology has been somewhat limited and has yielded mixed results

Precision Agriculture Technologies Adoption







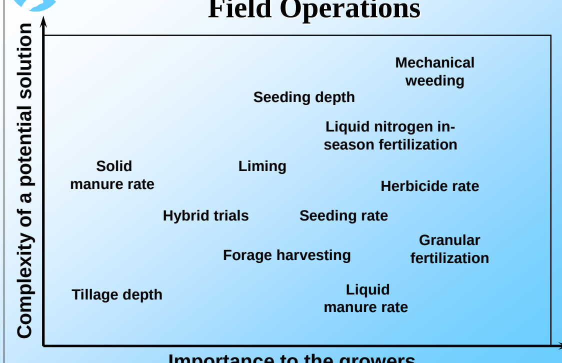
Problem Definition

- Lack of robust decision support mechanisms has been a major limitation when it comes to varying fertilization and seeding rates according to local needs
- The capital costs involved in this technology prevented a number of small and medium farmers from adopting its use
- Many producers understand the need for non-uniform field treatments
- Many farmers can identify distinct field areas where uniform application rates would not be optimal due to the limited, or excessive, crop productivity potential

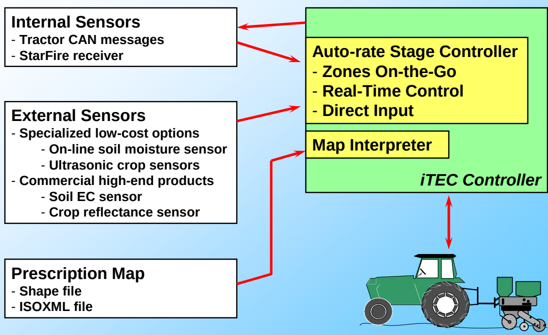
Objectives

- To equip farmers with a technology that would match tractor operation parameters with local conditions according to the rules established by the operator
- The tractor will recognize the operator-defined conditions using internal or external sensors and it will replicate appropriate operation settings across the field when conditions are similar

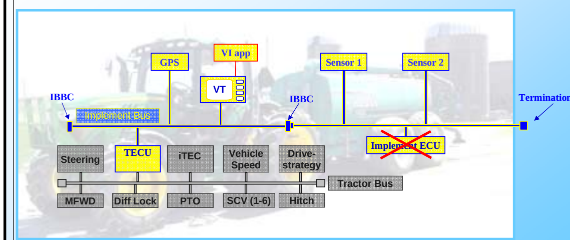
Prioritization of Variable-Rate Field Operations



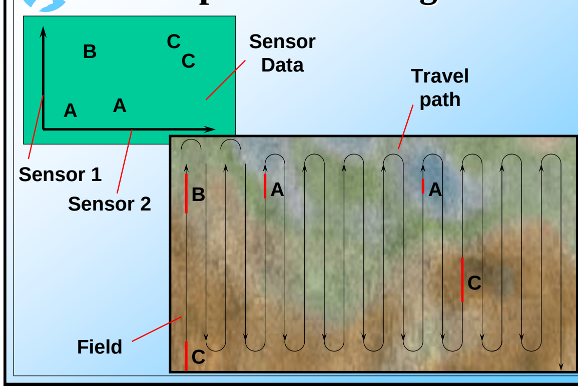
The Concept of JD ASC



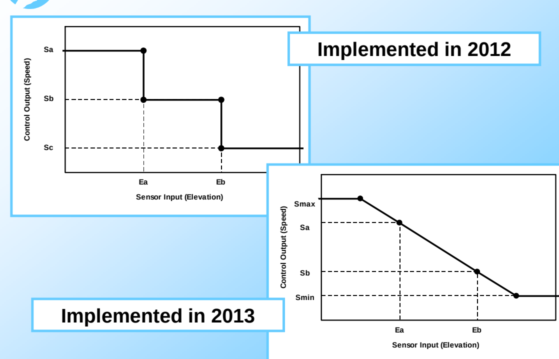
ISOBUS Implementation



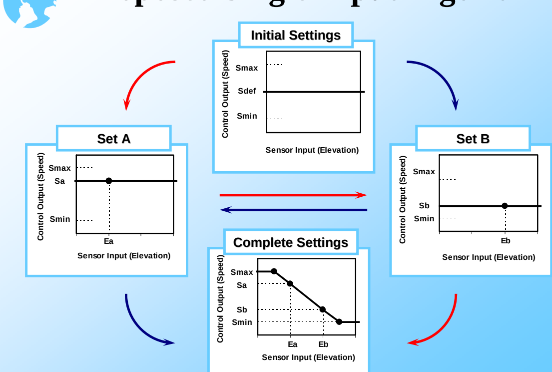
Principle of ZOG Algorithm



Single-Input Algorithms

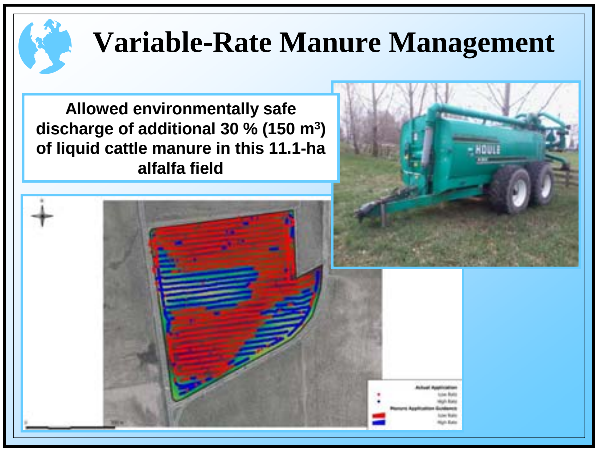


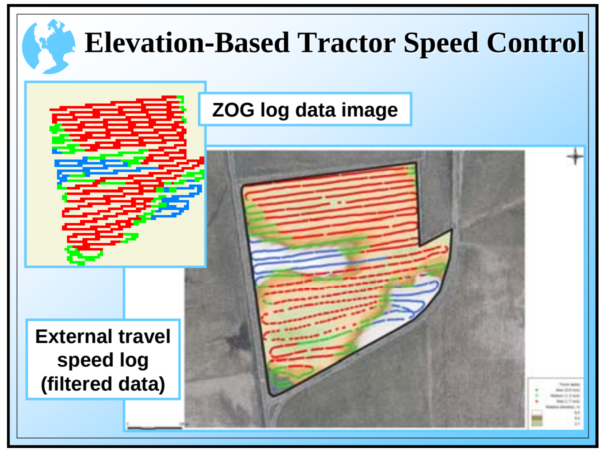
Proposed Single-Input Algorithm

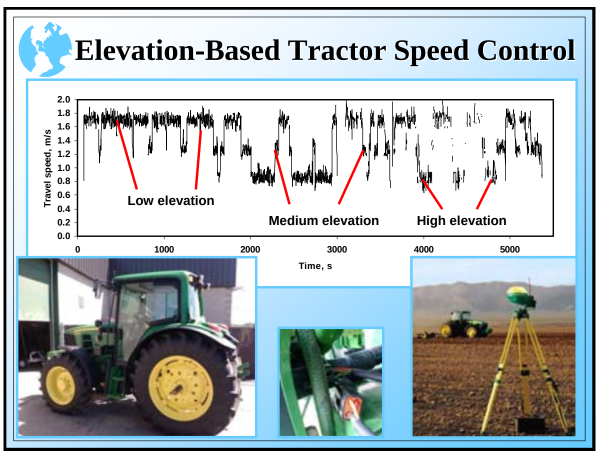


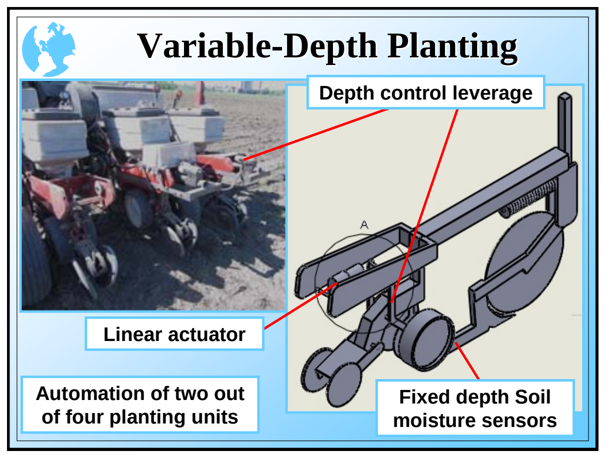
Targeted Applications

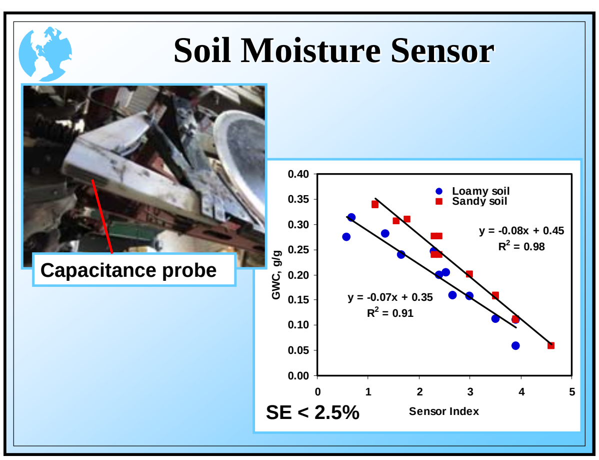
- Variable rate liquid manure management according to landscape positioning
- Variable depth planting according to surface soil water content
- Variable speed of operation while harvesting a forage crop according to biomass
- Variable rate herbicide management according to the degree of weed pollution

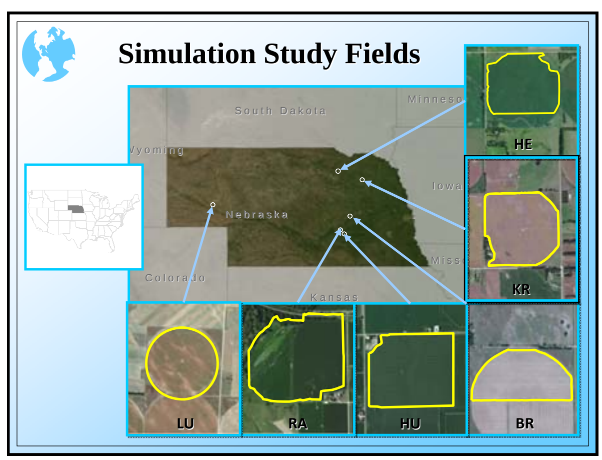

Variable-Rate Manure Management
Allowed environmentally safe discharge of additional 30 % (150 m³) of liquid cattle manure in this 11.1-ha alfalfa field
HOULE

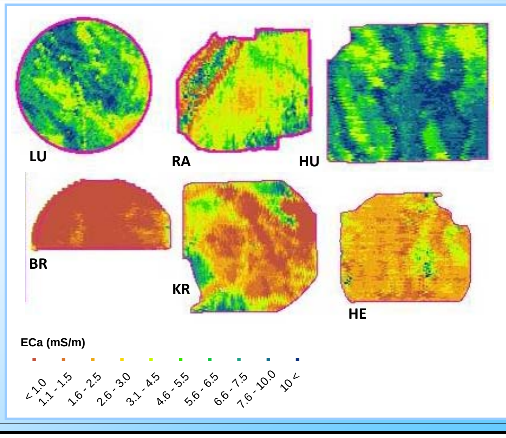

Elevation-Based Tractor Speed Control
ZOG log data image
External travel speed log (filtered data)


Elevation-Based Tractor Speed Control
Travel speed, m/s
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
1000
2000
3000
4000
5000
Time, s
Low elevation
Medium elevation
High elevation


Variable-Depth Planting
Depth control leverage
Linear actuator
Automation of two out of four planting units
Fixed depth Soil moisture sensors
A


Soil Moisture Sensor
Capacitance probe
Loamy soil
Sandy soil
y = -0.08x + 0.45
R² = 0.98
y = -0.07x + 0.35
R² = 0.91
GWC, g/g
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
1
2
3
4
5
Sensor Index
SE < 2.5%

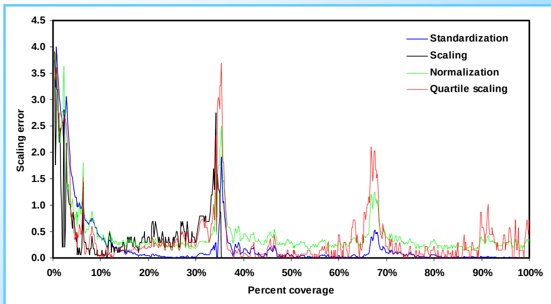

Simulation Study Fields
South Dakota
Minneso
Wyoming
Iowa
Nebraska
Colorado
Miss
Kansas
HE
KR
LU
RA
HU
BR



Scaling Methods

- **Standardization** $$ec_i = \frac{EC_i - average(EC_1 : EC_i)}{stdev(EC_1 : EC_i)}$$
- **Scaling** $$ec_i = \frac{EC_i - \min(EC_1 : EC_i)}{\max(EC_1 : EC_i) - \min(EC_1 : EC_i)}$$
- **Normalization** $$ec_i = \frac{EC_i}{median(EC_1 : EC_i)}$$
- **Quartile scaling** $$ec_i = 0.25 + \frac{EC_i - quartile(EC_1 : EC_i, 1)}{2 \cdot (quartile(EC_1 : EC_i, 3) - quartile(EC_1 : EC_i, 1))}$$
- **First pass scaling** $$ec_i = rank(EC_A) + \frac{EC_i - EC_A}{EC_B - EC_A}(rank(EC_B) - rank(EC_A))$$

Absolute Error Series Example



Simulation Study Summary

Field ID	RMSE/SD for the entire field				
	Standardization	Scaling	Normalization	Quartile scaling	First pass scaling
BR - forward	0.22	0.53	0.19	0.28	0.20
BR - backward	0.31	0.48	0.31	0.53	0.28
RA - forward	0.16	0.15	0.12	0.13	0.09
RA - backward	0.21	0.72	0.15	0.24	0.10
KR - forward	0.22	0.58	0.25	0.25	0.54
KR - backward	0.17	0.59	0.22	0.20	0.12
LU - forward	0.18	0.15	0.30	0.24	0.02
LU - backward	0.32	0.12	0.34	0.40	0.06
HU - forward	0.37	0.46	0.49	0.40	0.04
HU - backward	0.22	0.38	0.17	0.23	0.12
HE - forward	0.16	1.53	0.25	0.28	0.09
HE - backward	0.14	1.74	0.13	0.13	0.04
Average	0.22	0.62	0.24	0.28	0.14

Summary

- Medium-size farm operators frequently resist adopting variable rate technology due to the cost of the equipment and the extra time required to learn the new technologies
- Many operators intuitively understand the need for differentiating their operations within a field in accordance with local needs
- Some operators have implemented what can be classified as VRT using manual control
- What can be called a “smart tractor” concept will enable farmers to implement their intuitive practices in a more replicable and ergonomic way
- A combination of real-time sensor-based and map-based operations will add versatility
- The concept is similar to the principles of auto-guidance and will remove the gap between the use of traditional machinery and farming machinery equipped with high-end controllers and actuators

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