Smart Technologies for Sustainable Agriculture

Symposium Handouts

Session I: Agricultural Automation and Robotics – Fiction or reality?
Moderator: Sven Peets
Panelists:

- Simon Blackmore (Harper Adams University)
- ViacheslavAdamchuk (McGill University)
- Qumar Zaman (University of Dalhousie)
- Jordan Boyle (University of Leeds)

Session II: Sensing of Soil and Crop – Satellite, drone, or sensing on-the-go?
Moderator: Viacheslav Adamchuk
Panelists:

- Toby Waine (Cranfield University)
- Asim Biswas (McGill University)
- Vladimir Stoiljkovic (Satellites Application Catapult)
- Alex Melnitchouck (Bayer CropScience Canada)
- Abdul Mouazen (Cranfield University)

Session III: Fertilizer and other agro-inputs – Varying for profitability or environment?
Moderator: Richard Godwin
Panelists:

- Paul Miller (National Institute of Agricultural Botany)
- Bernie Zebath (Agriculture and Agri-Food Canada)
- Nicolas Tremblay (Agriculture and Agri-Food Canada)
- Shamal Mohammed (GeoInfo Fusion Ltd.)
- Bill Deen (University of Guelph)

Session IV: Irrigation, drainage and soil management
Moderator: Paul Miller
Panelists:

- Mark Else (East Malling Research)
- Chandra Madramootoo (McGill University)
- Jean Caron (Université Laval)
- Richard Godwin (Harper Adams University)

Towards Robotic Agriculture

Prof Simon Blackmore

Developed agriculture uses massive amounts of energy in a myriad of forms, from the energy associated with chemicals used to control pests and diseases, through fertilisers, to the tractors themselves and the fuel to power them. This energy is often wasted as it goes off-target, is expensive and will become more so in the future.

Smarter machines should use the minimum amount of energy to turn the natural environment into useful agriculture thus cutting out wasted energy and reducing costs. As agricultural engineers we are continually looking to find ways of making the crop and animal production processes more efficient and have developed the concept of Precision Farming, where we recognise the natural variability found on our farms and change the management and treatments to suit. This variability takes both spatial and temporal forms. Spatial variability can be understood and managed by creating yield maps and soil maps. Temporal variability is often fundamentally linked to changes in weather over time resulting in the need for real-time management.

In industry, we used to have a production line mass producing one item and are now moving over to flexible manufacturing, where each item is developed individually. In agriculture we can see a similar approach by reducing the scale of treatments from farm scale, to field scale, to sub-field scale and even individual plant treatment.

Currently tractors and associated machines are increasing in size due to economies of scale. If you pay someone for an hour then it makes sense to have them work 20 hectares rather than 10 hectares. This leads to the machines getting bigger but as the machines get bigger the opportunity to work the fields gets smaller due to the fragile nature of the soil when wet. This cycle can only be broken by making the machines significantly lighter so as not to damage the soil and thus expand the available operational weather windows.

Let me give an example of how the current system uses too much energy. I estimate that up to 90% of the energy going into traditional cultivation is needed to repair the damage caused by the machines in the first place. Chamen (1984) estimates that between 60 and 70% of tillage energy is not needed without trafficking. If we include the 20-30% that is used for occasional deep loosening of the soil, we can see that there should be significant saving by not compacting the soil in the first place. Each kilonewton of draft (horizontal) requires a kilonewton vertically for traction, which is causing the problem. If we can find a way to stop dragging metal through the soil we can nullify the problem.

There are many other examples like this.

How do we overcome all of these problems and take advantage of new technologies? One way is to improve the current system and the other is to develop a completely new system.

Currently we are seeing new technologies being introduced into agricultural machines. Most new large tractors have autosteer systems that allow much more accurate positioning and driving to avoid overlap and skip of the field treatments. This saves on average 10-15% of time, fuel, treatment costs and wages. Many tractors now not only use a CAN bus for internal system management but also an ISOBUS to communicate with the attached implements. Instead of the tractor controlling the implement, it is now the implement controlling the tractor as it is the implement that is doing the task and not the tractor. For example, when a baler needs to drop a bale, it can command the tractor to stop and when the bale has been dropped it tells the tractor to continue. Telemetry is another innovation that allows new levels of management. New combine harvesters are X-by-wire so a lot of data about the machine is digitally available. Some manufacturers can now transmit this information back to the factory for analysis. If the machine starts to operate outside normal tolerances, say, a belt starts to slip then the driver can be alerted via mobile phone before a problem becomes a disaster.

An alternative way would be to start with a new paradigm that deals with many of these issues. We recognise that farmers today have many conflicting pressures. New legislation, environmental protection, variability of world prices, single payment scheme to name but a few. All of the drivers push towards more efficient production and the reduction of input costs. Combine this with the opportunity from new technologies leads to designing a new mechanisation system based on plant needs that addresses all the drivers which in turn leads to agricultural robotics.

Can we develop a new system of machines that can assess variability in real time and only introduce the minimum amount of energy to support crop development? The answer is clearly yes. We have not yet fully answered all the questions or developed all the technologies needed but many of them have now been prototyped and we can start to visualise a complete new mechanisation system.

Management of these technologies is fundamental to economic viability and environmental sustainability. They are tools that used in the right way can benefit both, used in the wrong way could be detrimental. If the management is sensitive to both economic and environmental drivers both can be improved by using smart management and smart machines. Sustainable intensification can be achieved through increased efficiency in the food production systems.

My vision for the future is one where small smart machines move around the field establishing, tending and selectively harvesting the crops. Ten years ago I developed an autonomous tractor that could mechanically remove weeds, thus achieving 100% chemical reduction. Even then the tractor was too big and used more energy than was needed. Now one of my old PhD students has developed a laser weeding system that probably uses the minimum amount of energy to kill weeds, by using machine vision to recognise the species, biomass, leaf area and position of the meristem (growing point). A miniature spray boom of only a few cm wide can then apply a microdot of herbicide directly onto the leaf of the weed thus saving 99.9% by volume of spray. Alternatively a steerable 5W laser can heat the meristem until the cells rupture and the weed becomes dormant. These devices could be carried on a small robot no bigger than an office desk and work 24/7 without damaging the soil or crop.

Another example is called selective harvesting. Currently many vegetable crops are harvested by hand, which is expensive even when using 'cheap' labour. Between 20 and 60% of the harvested crop is not saleable to the supermarkets as it may not have the desired quality attributes. This may range from too small, too large, incorrect cutting, blemishes etc. Selective harvesting envisages a robot assessing all of the quality requirements and only harvesting produce that has 100% saleable characteristics. If some plants are too small they can be left until later until they grow to the correct size. As we know the position, size and expected growth rates we can schedule a more accurate second or third harvest regime.

By looking at all the operations needed to establish, care for and harvest crop plants and identify ways to minimise inputs, we can see how a new mechanisation system can evolve. If we stop defining what we now do by the way we have done it in the past and look at the fundamental requirements we can identify new techniques that not only meet the economic, environmental and legislative drivers but also do a better job of looking after the plants.

Simon Blackmore Prof Simon Blackmore
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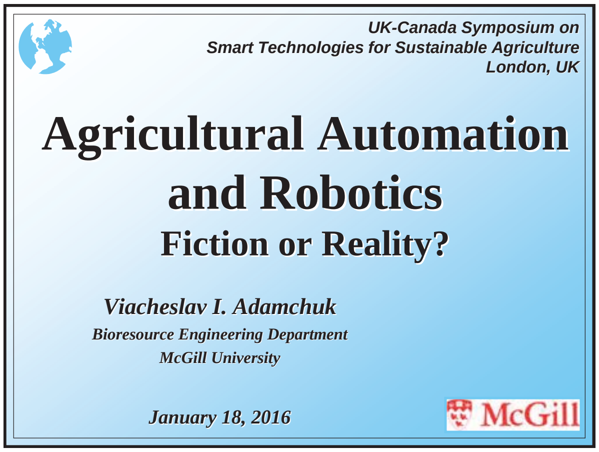
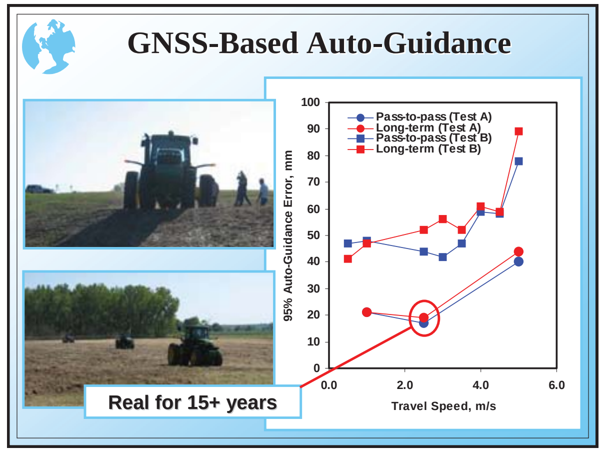
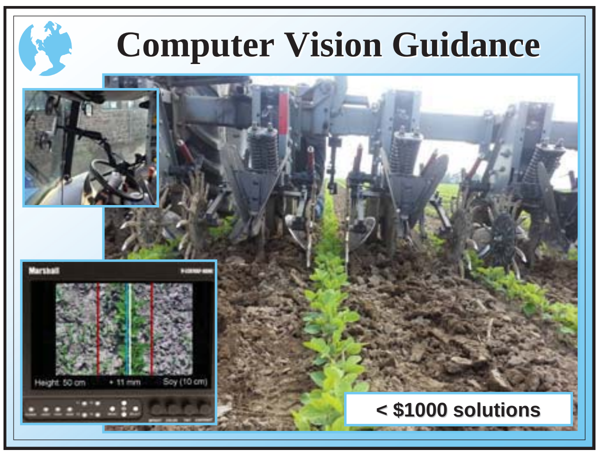
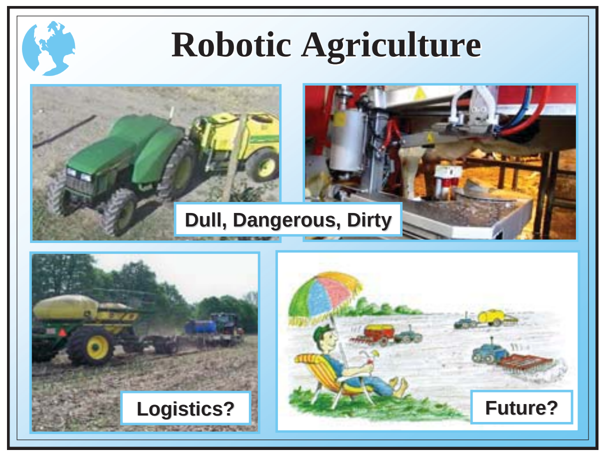
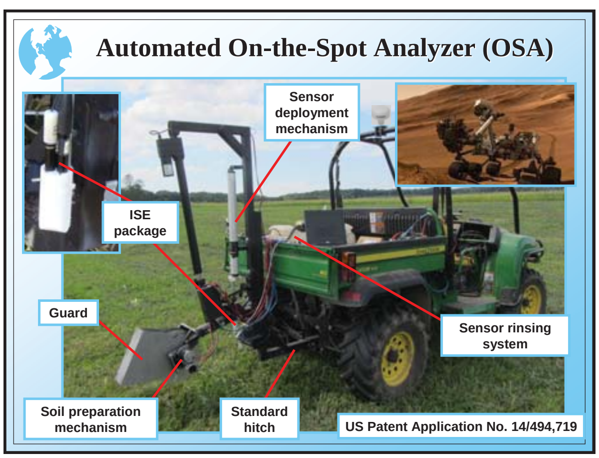
Twitter: ProfSBlackmore

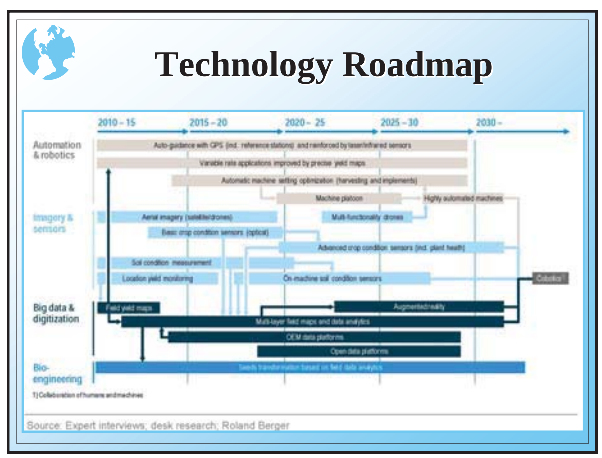

UK-Canada Symposium on
Smart Technologies for Sustainable Agriculture
London, UK
Agricultural Automation and Robotics
Fiction or Reality?
Viacheslav I. Adamchuk
Bioresource Engineering Department
McGill University
January 18, 2016
McGill


GNSS-Based Auto-Guidance
Pass-to-pass (Test A)
Long-term (Test A)
Pass-to-pass (Test B)
Long-term (Test B)
95% Auto-Guidance Error, mm
Travel Speed, m/s
Real for 15+ years


Computer Vision Guidance
< $1000 solutions


Robotic Agriculture
Dull, Dangerous, Dirty
Logistics?
Future?


Automated On-the-Spot Analyzer (OSA)
Sensor deployment mechanism
ISE package
Guard
Sensor rinsing system
Soil preparation mechanism
Standard hitch
US Patent Application No. 14/494,719


Technology Roadmap
2010 – 15
2015 – 20
2020 – 25
2025 – 30
2030 –
Automation & robotics
Auto-guidance with GPS (incl. reference stations) and reinforced by laser/infrared sensors
Variable rate applications improved by precise yield maps
Automatic machine setting optimization (harvesting and implements)
Machine platoon
Highly automated machines
Imagery & sensors
Aerial imagery (satellite/drones)
Multi-functionality drones
Basic crop condition sensors (optical)
Advanced crop condition sensors (incl. plant health)
Soil condition measurement
Location yield monitoring
On-machine soil condition sensors
Big data & digitization
Field yield maps
Augmented reality
Multi-layer field maps and data analytics
OEM data platforms
Open data platforms
Bio-engineering
Source: Expert interviews; desk research; Roland Berger

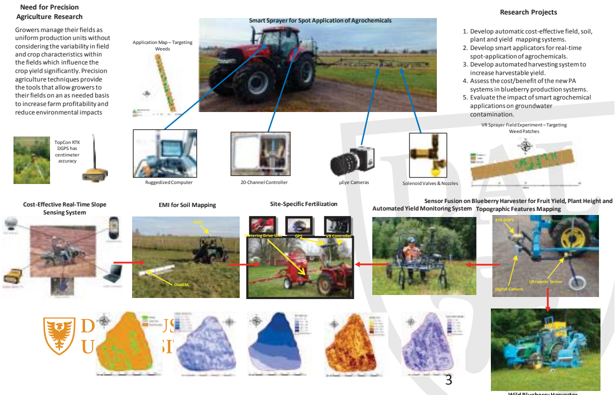
Agricultural Automation and Robotics – Fiction or reality?

Qamar Zaman, PhD
Professor and Precision Agriculture Research Chair
Dalhousie University, Nova Scotia, Canada

Precision Agriculture: Technology for Wise Use of Agricultural Resources

DALHOUSIE UNIVERSITY

Our Solution – Automation of Agri. Machinery
Precision Agriculture Research Program, Dalhousie University



Objectives

Reduce the amount of inputs required to grow crops and increase harvestable crop yield = LOWER COSTS

Increase the efficiency of agrochemical applications
= LOWER ENVIRONMENTAL IMPACT

Automate and log farm operations
= DATA ANAYSIS, EFFICIENCY & CONVENIENCE

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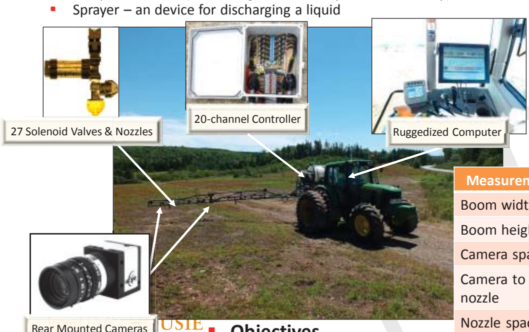
Smart Sprayer

- Smart – operating as if by human intelligence by using automatic computer control *(World English Control Systems Dictionary)*
- Sprayer – an device for discharging a liquid



Measurement	m
Boom width	13.7
Boom height	1.2
Camera spacing	1.52
Camera to nozzle	0.15
Nozzle spacing	0.5

- **Objectives**
  - Technology that automatically senses weeds
  - Real-time detection versus GPS-guided prescription maps
  - Activates nozzles only when necessary

Zaman et al. (2014)-Canadian Patent No: 2,740,503 C
Zaman et al. (2013)-US Patent No: 8488874 B2

Technology Advantage

- Easy user-friendly setup on a touch screen monitor
- Accurate placement of agrochemical
- Real-time detection versus GPS-guided prescription maps
- Agrochemical savings
- Less environmental impacts
- Time and Energy saving
- Reduce chemical residual effect
- Cost effective (Trimble, Topcon, Greenseeker)
- Applicable to other cropping systems such as high bush blueberry, vegetables, small fruit crops, tree crops, grassland.

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EPSRC National Facility
for Innovative Robotic Systems

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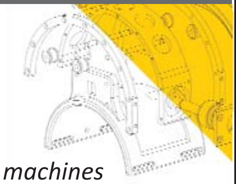

Free-Range Robotics:

Could biologically-inspired *living machines* address long term threats to food security?

The bio-inspired approach

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Identify a real-world problem that needs an engineered solution

Find a biological system that's solved a similar problem

Study it and figure out how it works

Adapt and implement the solution

Nature has invested millions of years in R&D and never filed a patent!

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Mobile robots and animals have similar requirements

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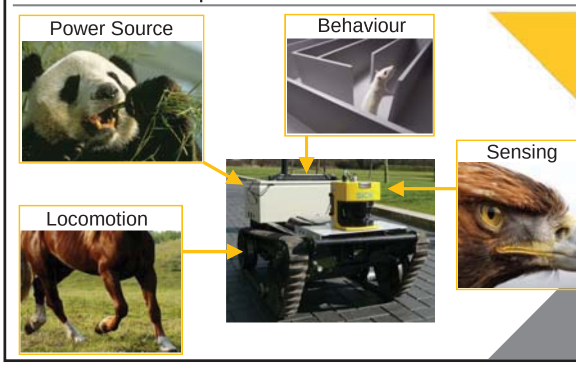

Free-Range Robotics

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My long-term vision is to develop **self-sufficient robots** that can “live” and operate in complex, uncontrolled environments over **timescales of a year or more**, totally **independent of human intervention**.

Applications of Interest

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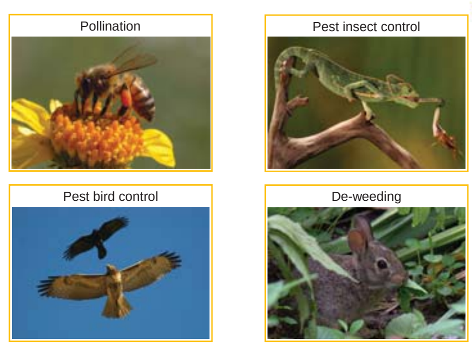


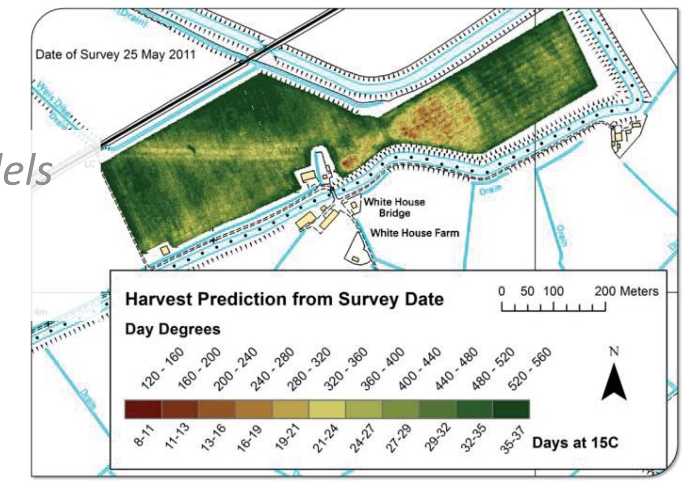
High spatio-temporal data systems for Agriculture – Dr Toby Waine

Cranfield UNIVERSITY

The issue: The assumption in modern agricultural production systems is that ever higher resolution spatial and temporal data will lead to significant improvements in production efficiencies. *Is this true and is there an optimum?*

The approach:

Calibrate models with remote sensing data



Parameterise

Mechanistic Yield Models

Obtain high spatial and temporal datasets: e.g. soil, water, nutrient, canopy, weeds, disease, weather

Data mining using calibration data for yield prediction scenarios

Current challenges of sensing soil using on-the-go sensors

Asim Biswas

Department of Natural Resource Sciences, McGill University, Canada asim.biswas@mcgill.ca

To meet the demand of ever increasing population, we need to improve our crop production system. This provides an enormous pressure on our natural resources including soil and water. For example, the use, overuse and abuse of our natural resources make them more vulnerable and threaten the soil security, water security and thus the food security. Additionally, the realm of changing climate make the whole situation more challenging. Therefore, along with increasing production, we need to make the system more sustainable for future use through optimized use of limited resources available on this planet. Precision agriculture has been adopted to improve our production system while conserving the natural or input resources. Precision agriculture is basically the optimized use of our resources in the production system while maintaining environmental quality.

Soil is the foundation of crop production system as it stores and provides water and nutritional requirement for crop growth and production. Variation in the soil properties creates highly variable soil functionality and creates a highly variable production system. In the highly variable soil system, traditional uniform application of input resources may create situation with over- or under-application and thus the resource utilization. While under-application directly affect the production, over-application may lead to environmental pollution. The need based application of resources tend to increase production while maintaining the environmental quality. Therefore, knowing the variability in the soil properties and thus the production is paramount for the success of precision agriculture.

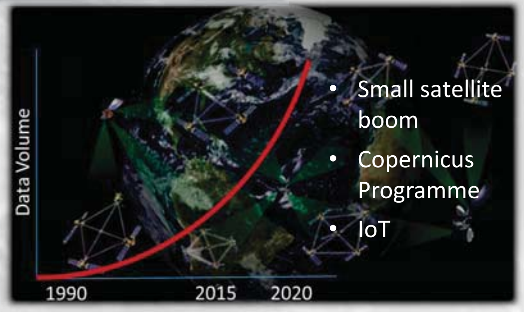
Traditional soil collection and analysis is not at all sufficient and suitable for generating information that can help adopt precision agriculture. High data requirement led us to develop various sensors for measuring soil properties and resources available for crop production. A small sensor can be used to measure or quantify soil properties in large number over a short time. However, these point based measurements using sensors often may not produce enough data or density of the data to adopt precision agriculture with better success. Technological developments introduced on-the-go sensors that are being used to collect data continuously while performing other agricultural operation. However, the question arises on the validity of the measurement. Additionally, a large number of challenges are faced while adopting on-the-go sensors including the speed of measurement and contact issues between soil and sensors as well as sensitivity of the probes or the reaction time or measurement time creating a question regarding the quality of the data collected. Additional questions regarding the repeatability and reproducibility of the sensors are not avoidable also. More often than not, on-the-go sensors suffers from durability issues owing to the toughest field conditions. Additionally, technological advances allowed us to integrate a number of sensors on a single platform. All these sensors can collect data simultaneously sometimes for same property. Now these on-the-go sensors mainly collect soil information at the surface layers or sometimes up to certain depth in contrast to some point sensors that can go much deeper depth. Once the data collected in high resolution, the meaning of the data (or numbers) are often mind boggling to growers. Often the question remains on the usability of those information by growers in terms of decision making. Saying these, I would like to introduce the following questions for discussion.

- Is it possible to get helpful information with on-the-go sensors? How good the data is?
- How repeatable and reproducible the sensor measurements are?
- What to compromise: data quality vs amount of data?
- How much does it cost vs the information we generate: How adoptable they are?
- How to deal with the durability of the sensors? Can new smart materials provide flexibility in developing sensors?
- Can information from remote sensing, point based sensors and on-the-go sensors be integrated?
- How to convert the data into information for developing management decisions by growers?
- How to handle data from multiple sensors? Is sensor data fusion feasible?

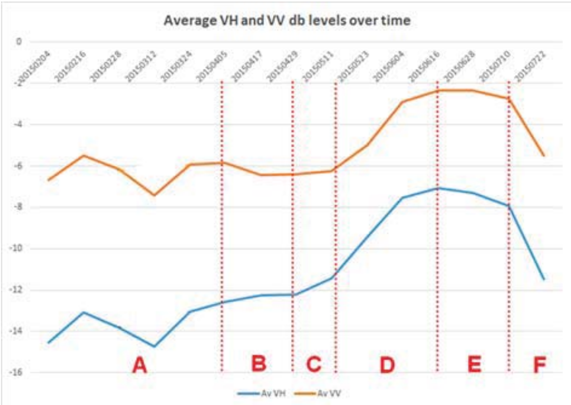
Unprecedented access to data

- As recently as 2013, 4 million square kilometres of imagery collected daily
- The Copernicus programme will obtain about 25 petabytes of EO data in the next five years
- Increased variety of imaging capability and increased temporal coverage from EO satellites
- More capable on-board storage, faster downlink and better reliability are characteristics of satellites being built today

"To create massive business opportunities for European companies, in particular SMEs, to boost innovation and employment in Europe"
- Copernicus



Winter Oil Seed Rape (reproductive growth stages)



A - Over wintered green leaf mass reaches a peak in early February and then bottom leaves drop off by the end of the month.
During March new growth is put on and the plant starts to extend it's main stem. By the end of the month the plant is at the green bud stage (1 on the photo key)
B - Early flowering stages (1 to 3 on the photo key) when rapid stem extension occurs and main stem flowering reaches perhaps 60% with first pods visible.
C - Mid flowering stages (4 to 6 on the photo key) when main stem flowering completes and pods form, whilst the side shoots extend and start to flower.
D - Late flowering stages (7 to 9 on the photo key) during which the main stem pods grow in size and the seeds within change from translucent to opague green.
The sideshoots complete flowering and by 9 all the pods are formed.
E - A long period of increase in seed size and change of remaining pods to opaque.
F - The start of the ripening process as seeds start to colour mottled brown and then brown.

CATAPULT Satellite Applications

Science For A Better Life

Alex Melnitchouck, Ph.D., P.Ag.
Digital Farming Technology Lead - Global
Bayer CropScience

January 2016

"We are trying to plan our future believing that it is going to be like today…but it will be different!" ©

1959

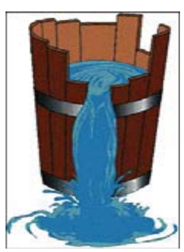
1965

2016

What is yield?

- Varieties/Hybrids
- Crop rotation
- Tillage
- Agronomy
- Fertilizer
- Crop protection
- Machinery

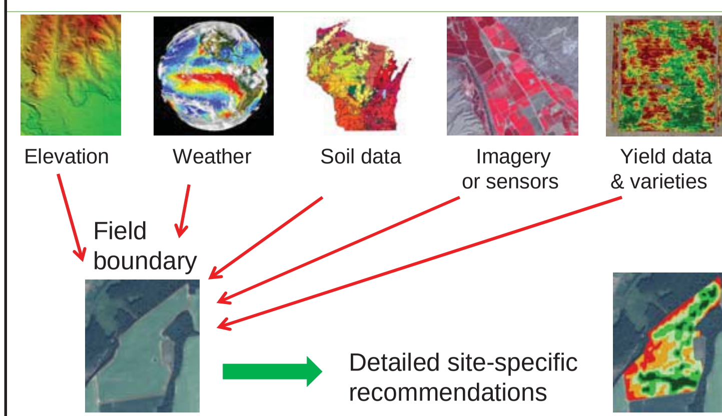
etc.



- Soil OM
- N, P, K, S
- H_2O
- Ca
- Mg
- Micronutrients
- pH
- GDD
- Slope
- Wind speed & direction
- PAR

…>140 factors

How to extract the info for one field from global data?

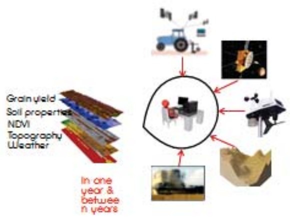


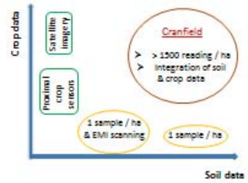
The role of multi-sensor and data fusion for site specific fertilisation

Cranfield UNIVERSITY

Abdul Mouazen
Cranfield Soil and AgriFood Institute
Cranfield University

Core competency & innovation





-1-

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On-line sensing

On-line multi-sensor platform (Mouazen, 2006)

Mouazen, A.M. (2006). Soil Survey Device. International publication published under the patent cooperation treaty (PCT). World Intellectual Property Organization, International Bureau. International Publication Number: WO2006/015463; PCT/BE2005/000129; IPC: G01N21/00; G01N21/00.

- High resolution data (1500 – 2000 reading per ha).
- Readings can be taken from any depth between 5 – 50 cm.
- The sensor can also be fit on different soil equipment e.g. tillage, planters, and seeding machine.
- The system is particularly successful for the measurement of organic carbon moisture content, total nitrogen, clay and organic matter.
- Other properties can also be measured with less accuracy e.g. pH, phosphorous, calcium cation exchange capacity and Magnesium.

-2-

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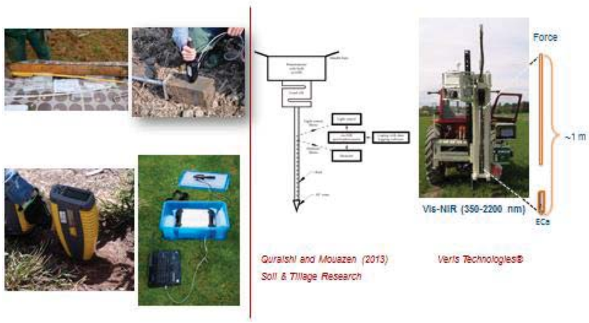
Portable soil sensing



Quraishi and Mouazen (2013) Soil & Tillage Research

Veris Technologies®

-3-

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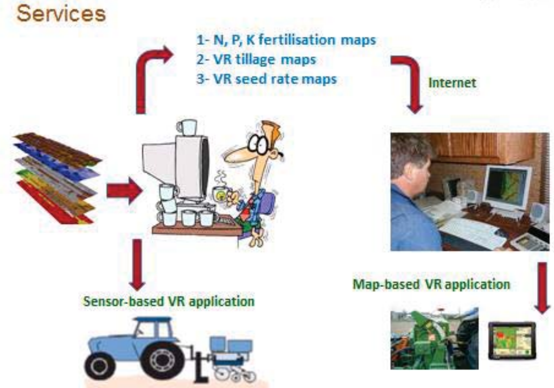
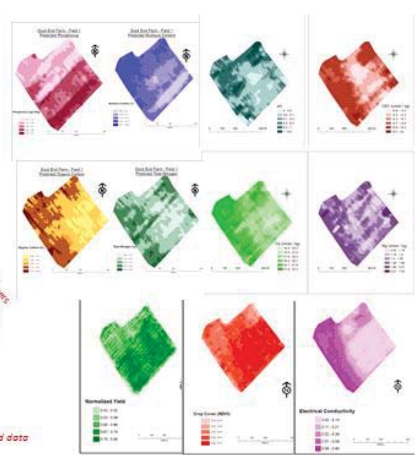
Services



-4-

Map-based site specific N application



Farming Truth – ESA – Unpublished data

-5-

Sensor–based site specific P fertilisation

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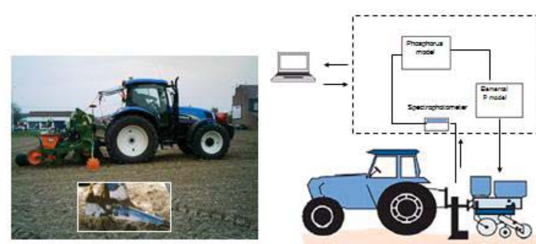

After: Maleki et al. (2008) – Biosystems Engineering

-6-

Application of Plant Protection Products (1)

- Current state-of-the art
  - ➢ Sophisticated machines now developed and commercially available
    - ❖ computer controlled with wide range of sensors including for boom height control
    - ❖ Up to 42 m wide
    - ❖ Using nozzle arrangements for wide turn-down ratio (e.g. clusters or twin-fluid designs)
  - ➢ Strong awareness of drift risks and methods for drift control
    - ❖ drift-reducing nozzles (e.g. air-induction)
    - ❖ boom height and attitude control
  - ➢ Ability to treat spots, patches and an inter-row strip
    - ❖ Using specialised machines.

Application of Plant Protection Products (2)

- Research requirements
  - ➢ New nozzle designs/nozzle performance classification
    - ❖ for targeted applications – to minimise risk of crop and off-target contamination
    - ❖ to give a wide turn-down ratio for variable rate application over a wide range of boom widths and forward speeds
    - ❖ improved "classification" of drift-reducing designs to encourage inclusion on label statements, regulatory acceptance and wider use
    - ❖ studies to quantify product, tank mix and nozzle design interactions
  - ➢ Improved control systems
    - ❖ to improve the uniformity of treatment over a wide range of operating conditions – improved dose control systems, boom height control and accounting for properties of the tank mix
      - ▪ with important links to traceability

Application of Plant Protection Products (3)

- Research requirements – continued
    - ❖ to account for crop and weather conditions and so give:
      - ▪ Improved deposition and product efficacy at minimum doses
      - ▪ Reduced risks to non-target organisms (including human safety)
  - ➢ Better systems for loading chemicals and recording field applications
      - ▪ traceability

Application of fertilisers (1)

- Current state-of-the-art
  - ➢ Standard recommendation tables (RB209 – revised)
  - ➢ Variable rate applicators
  - ➢ Use of canopy sensors to adjust rates
    - ❖ ground-based with active light source
    - ❖ from satellites/aerial platforms
  - ➢ Using yield maps
    - ❖ based on off-take
  - ➢ Using soil data

Application of fertilisers (2)

- Research requirements
  - ➢ Improved systems for canopy characterisation
    - ❖ using multiple sensors
  - ➢ Better predictions of required dose
    - ❖ factors influencing input vs yield prediction
    - ❖ application timings
    - ❖ interactions between inputs (e.g. SDHI fungicides and green area effects)
  - ➢ Improved application systems
    - ❖ turn-down ratio
    - ❖ application distribution
    - ❖ liquids vs solids

Decision support systems

- State-of-the-art
  - ➢ Programs well developed for farm management

➢ Research need
  - ➢ System for helping farmers decide which components will give cost/benefits

SMART TECHNOLOGIES IN POTATO PRODUCTION IN ATLANTIC CANADA

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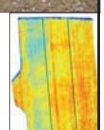
ISSUES AND GOALS

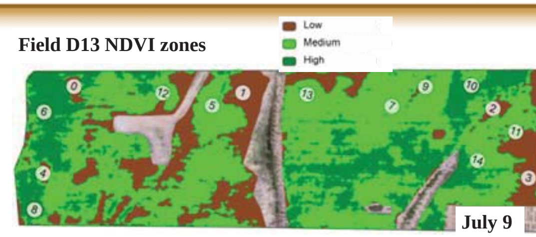
- Issue:
  - Potato production is central to the agricultural economy of Atlantic Canada
  - Intensive crop production occurs on shallow soils overlying permeable deposits in sloping landscapes where extreme precipitation events are frequent
  - Elevated risk of surface and groundwater contamination by sediments and nutrients and loss of soil productivity
- Goal is to apply SMART technologies to:
  - Identify areas of low yield within fields and apply appropriate mitigation practices
  - Use variable within-field management of crop inputs to increase efficiency and productivity

MAP VARIATION IN CROP



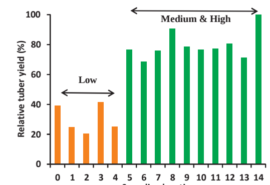
- UAV (drone):
  - Map commercial fields with drone (eBee from SenseFly) and multiSPEC 4C camera with incident light sensor
  - Comparison with fixed-wing aircraft
  - Yield monitor and hand-measured yield
- Novel diagnostic tools:
  - Plant gene-expression based diagnostic tools for abiotic stresses
- Mitigation practices:
  - Compost; nurse crops; fall-seeded cover crops; furrow de-compaction; fumigation

Field D13 NDVI zones



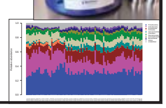
% of field

Field D13	
Low	24%
Medium	51%
High	25%



MAP SOIL VARIATION

- Map soil properties:
  - Map commercial fields
  - Compare instruments: Veris MSP, Dualem, ground penetrating radar, Trimble Soil Information System (SIS), Veris P4000
  - Compare with bare soil imagery from UAV
- Soil health/quality:
  - Spatial variation of soil properties, indices of soil quality/health, indices of mineralizable N
  - Assess soil microbial communities using next generation sequencing



THE FUTURE

- How do we map soil variability?
  - What is the right tool, what does it measure, when and how should we use it?
- How do we map crop variability?
  - What properties can we map, when and how do we map them?
  - Can we monitor individual plants to assess yield/quality parameters?
- Once we map variability, then what?
  - How do we translate information on the spatial variation in soil and crops into recommendations for intervention or management?
  - How do we integrate this into practical tools for end users?

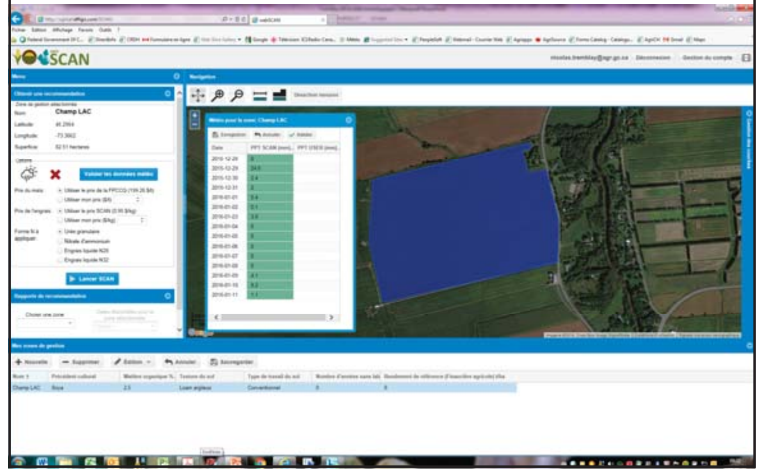
Agriculture and Agri-Food Canada / Agriculture et Agroalimentaire Canada

Crop Nutrition and Management Group

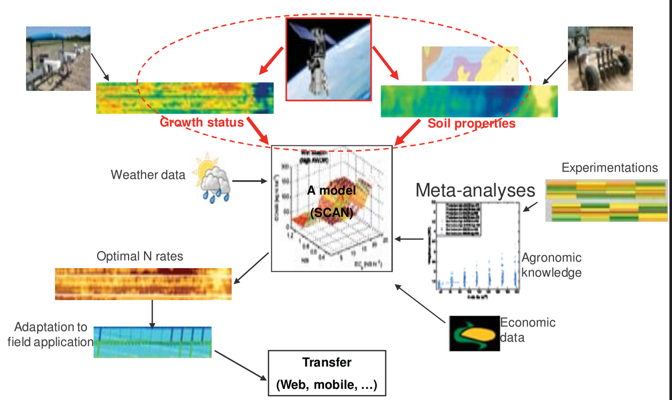
Nicolas Tremblay et al.
Saint-Jean-sur-Richelieu

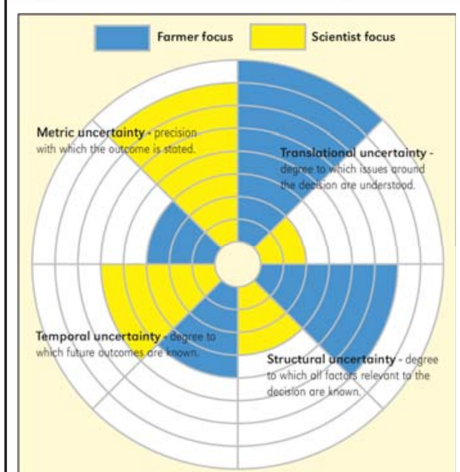
Canada

WebSCAN for corn sidedressed N rate



Approach for Precision Agriculture





- PA performances not up to expectations
- Weather to focus on
- Fisher's statistics and « conventional innovation »
- Data Sharing (open)
  - Research Data Alliance
  - Big Data
- Mechanistic models are out
- Computational Intelligence for Knowledge-Based Systems Design [Hüllermeier, Kruse, Hoffmann (Eds.)]

Smart Technologies for Sustainable Agriculture, UK-Canada Workshop

London, 18-19 January 2016

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Director
GeoInfo Fusion

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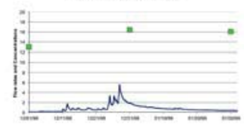
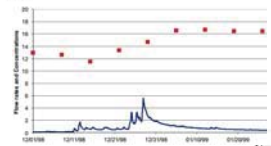
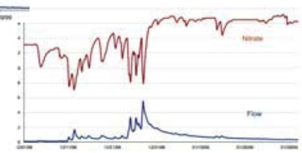
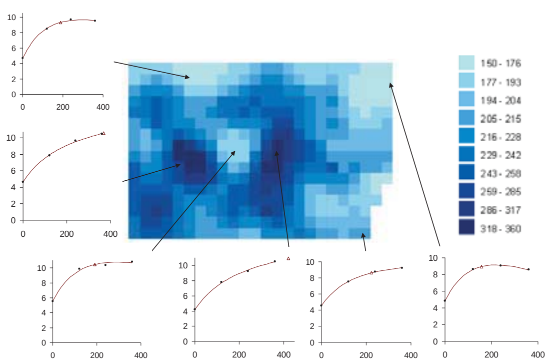






How can we move from **fixed measurement** of input requirements to **continuous measurements**?

Spatial variability of N optima



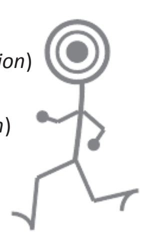
Gaps

- Data Ag Scientist and Data Ag Analytic courses / Teaching
- Development of cheap and small sensors to enable continuous data recording / R&D
- Development of specific input indices to quantify input requirement with reasonable accuracy (beyond NDVI)
- Automating data collection, processing and analysis and intelligent generation / R&D

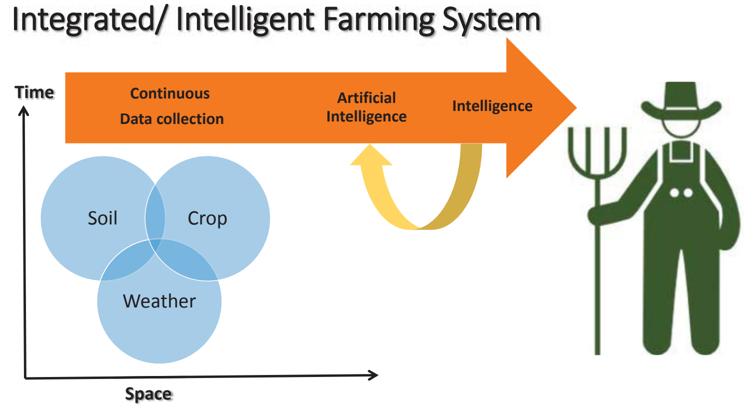
Moving Targets

- Input requirements changes constantly both in Space and Time
- The challenge is to get the all **4Rs** Right

Right Input
Right Time (*This is highly important for Agro-Chemical application*)
Right Place (at right scale)
Right Amount (*This is highly important for Fertiliser application*)



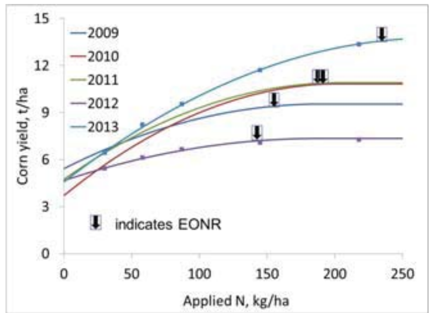
Integrated/ Intelligent Farming System



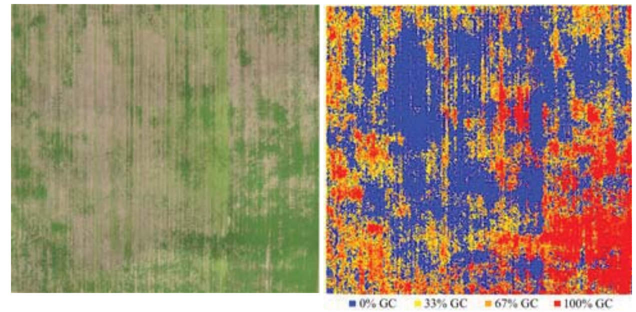
Long-term N-rate trial

- University of Guelph, Elora Research Station
- UAN side-dressed at 8 lf stage
- Continuous corn
- Moldboard plowed

- 100 kg N ha^{-1} variation in N requirement across years
  - Not explained by just NDVI, soil nitrate, green index or OMAFRA general recommendations
  - Correlated with precipitation July-August
  - Decision support tool must integrate various inputs including plant available water
  - Delayed N application?



- Red clover underseeded to wheat benefits - 70 kg N ha-1 credit (Meyer-Aurich et al, 2006a; Meyer-Aurich et al 2006b; Munkholm et al 2012; Munkholm et al, 2013; Gaudin et al, 2013; Gaudin et al. 2014; Gaudin et al. 2015, Wyngaarden et al, accepted)



- Figure 8: The aerial image of the area of interest (left), and the mapping of RCGC (right) using a kNN classifier with blue, yellow, orange, and red representing class 0, class 1, class2, and class 3, respectively. Best viewed in colour. Ammar M. Abuleil, Graham W. Taylor, Medhat Moussa, Ralph C. Martin, Bill Deen

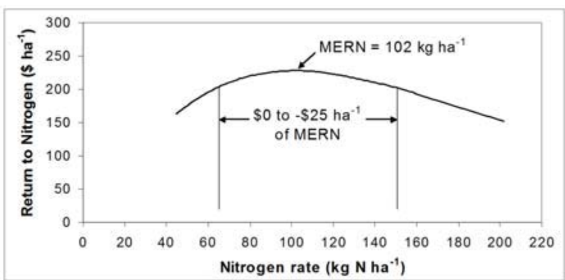


Figure 1: Effect of nitrogen rate on returns for winter wheat, average of 12 Ontario locations, 2006. (N @ 1.00 $Cdn kg-1, wheat @ 114 $Cdn t-1)

Limited economic incentive for producers to "fine tune N rates spatially or across years

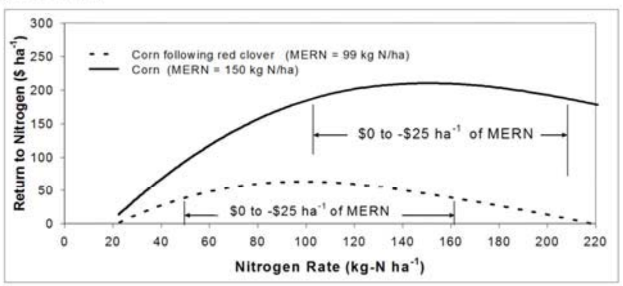
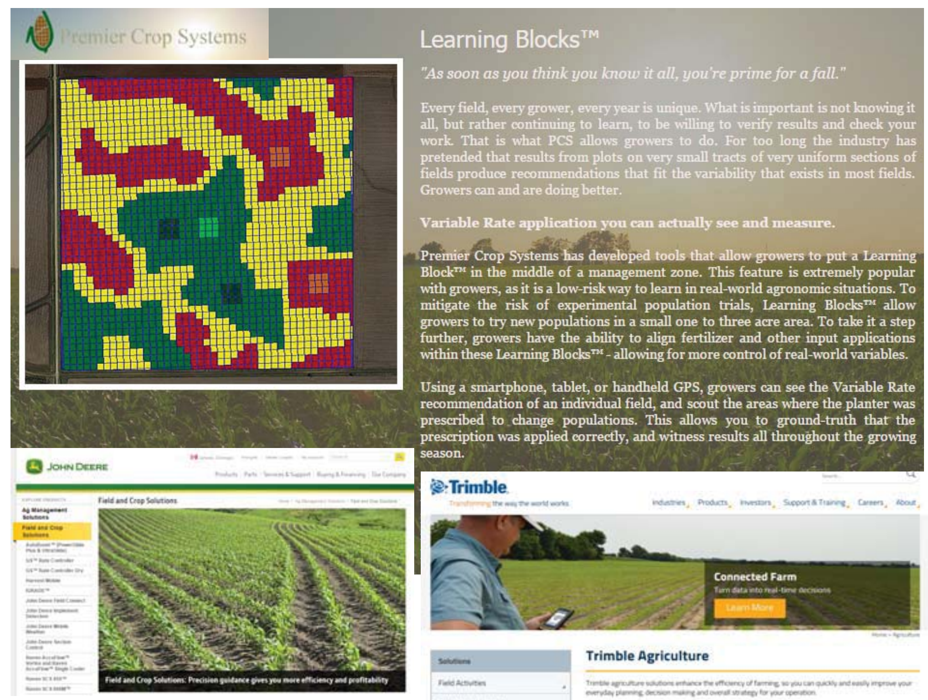


Figure 2: Effect of nitrogen rate on returns for corn, average of 19 pair-wise comparisons between 1990-99. (N @ 1.00 $Cdn kg-1, corn @ 100 $Cdn t-1)



Improving resource use efficiency, marketable yields and quality of fresh produce quality and shelf-life of fresh produce using precision and deficit irrigation techniques

Dr Mark A. Else

East Malling Research, New Road, East Malling, Kent ME19 6BJ, UK
Email: **mark.else@emr.ac.uk**

UK horticulture continues to invest heavily in science and technology and significant increases in marketable yield have been achieved in recent years, due to more intensive plantings of new, high-yielding varieties with improved organoleptic qualities. However, further increases are possible if agronomy can be optimised for these varieties to improve resource partitioning and consistency of cropping and to minimise pre- and post-harvest losses. A better understanding of how to predict and manage the influence of environmental variables on the timing and intensity of cropping will also help to improve accuracy of crop yield forecasts, thereby ensuring higher product pricing and improved grower margins. Research in my science programme aims to develop and deliver new approaches, tools and technologies to help the industry achieve consistently higher yields of first class, phytonutritious produce with an assured shelf-life, whilst ensuring that resources such as water, fertiliser, energy and light are used more effectively and efficiently.

Producing a consistent supply of high quality, phytonutritious fruit with an assured shelf or storage life is difficult, and significant losses of marketable and harvested fruit occur each year due to small size and disorders such as mis-shapes, rots, bruising, blemishes and a poor shelf-life. An improved ability to supply high quality fruit consistently throughout the year is vital to the future success of the industry but this must be achieved against a background of current and impending legislation aimed at reducing the effects of intensive horticulture on the environment.

A first step towards achieving this goal is to identify the agronomic and environmental factors that affect fruit quality. An oversupply of irrigation water and fertiliser can led to excessive vegetative growth which, in turn, reduces light penetration and increases the risk of disease, and during changeable weather can result in soft fruit with poor organoleptic qualities. We have developed precision irrigation scheduling system that match demand with supply to help improve resource use efficiency, marketable yields and consistency of quality. In addition to delivering the anticipated 20-40+% savings in water and fertiliser inputs, our experiments at EMR and on-farm have shown that marketable yields can be increased by 20% and fruit quality can be improved if excessive fertigation is avoided. Exploiting plant responses to environmental stresses offers further opportunities to improve resource acquisition and product quality in perennial and herbaceous crops, and the potential to use stress-induced ethylene induced by a transient loss of shoot turgor to improve berry phytonutrient concentration is being investigated.

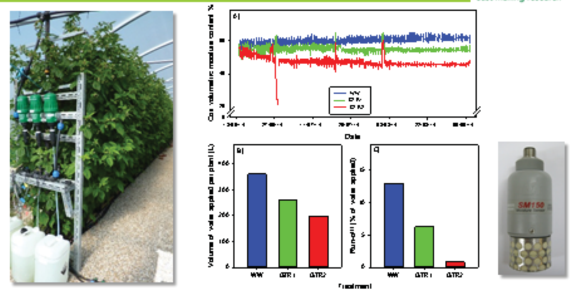
The duration and intensity of such ‘beneficial stresses’ must be regulated carefully to avoid losses in yield and quality. New sensors and associated technologies are being developed to ensure that the benefits demonstrated in scientific experiments can be achieved in commercial intensive production systems. In tandem, novel imaging systems are being developed to ease the integration of these low-input approaches into commercial practice, so that consistency of cropping, plant performance and crop responses to abiotic and biotic stresses can be monitored and measured in real time to inform and improve on-farm decision making.

Benchmarking Water Productivity

Crop	Water applied		Marketable yield		Irrigation productivity	
	M³ / hectare		Tonnes / hectare		M³ / tonne	
	Average	Range	Average	Range	Average	Range
Raspberry						
Soil	1,080	543 - 1,523	10	7 - 17	114	87 - 134
Substrate	1,509	650 - 2,600	13	10 - 20	111	43 - 166
Strawberry						
Soil	1,437	244 - 2,400	19	5 - 34	79	58 - 99
Substrate	2,495	1,275 - 3,942	32	18 - 45	82	49 - 108

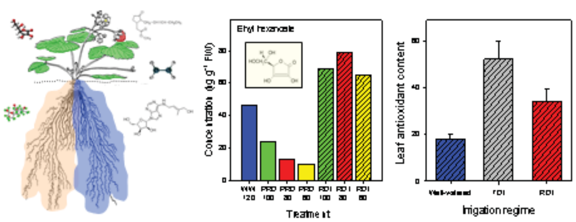
- 'Water conscious' growers recognise the link between irrigation and fruit quality
- Effective irrigation scheduling will improve consistency of fruit quality
- Need to improve irrigation water productivity, yields and fruit quality

Optimising yield potential using precision automated fertigation control



- Fertiliser and water savings of between 14 and 45%
- Floricane - marketable yields of 1.7 Kg per cane (5 Kg per plant)

Exploiting stress signals to improve flavour, firmness and shelf-life



- 'Beneficial stresses'
- Improved flavour, firmness, antioxidant capacity, shelf-life
- Resource partitioning – higher dry matter content
- Stress pre-conditioning to improve crop resilience

Scaling up - high value horticulture

- Precision automated fertigation
- Weather probability forecasting to inform irrigation scheduling decisions
- Environmental metrics (e.g. GDH) to forecast first and peak harvests
- Multi-detector imaging systems to manage risks

Outputs from our research

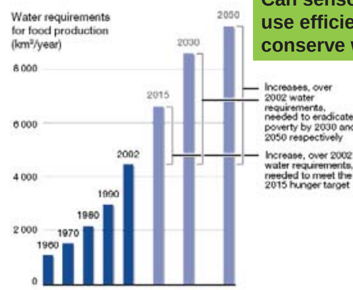
- Increased resource use efficiency
- Higher yields
- Consistent quality
- Assured shelf life
- Reduced waste
- 'Best practice' guidelines
- Improved resilience
- Commercial roll-out
- Sustainable intensification

Delivering impact-driven research

- EMR links scientific research with commercial horticulture

Smart Technologies for Sustainable Agriculture
Irrigation, Drainage and Soil Management


Professor Chandra A. Madramootoo Eng.
Department of Bioresource Engineering
Faculty of Agricultural and Environmental Sciences
McGill University

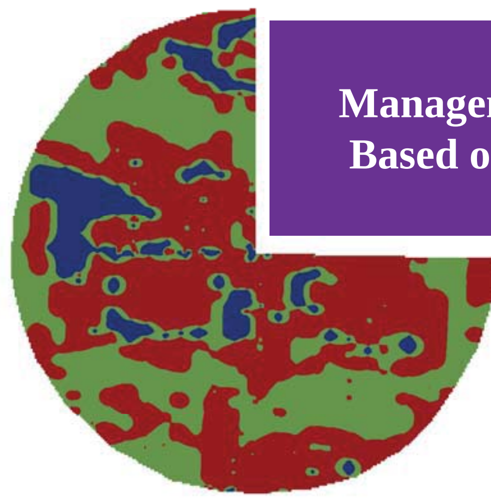



Can sensor technology be used to increase water use efficiency, manage soil and water salinity, and conserve water to achieve food security?

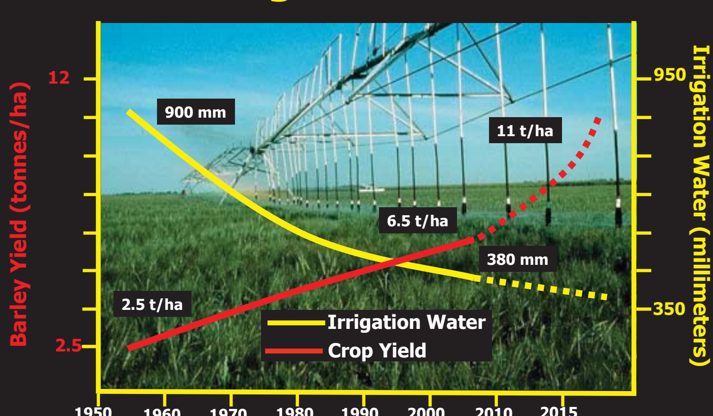
What is Digital Agriculture?

- ICT and data ecosystems to support the development and delivery of timely, targeted information and services to make the agri-food sector profitable and sustainable.
- Leveraging digital technologies (cloud, mobile, remote sensing, sensors, bioinformatics and systems biology – and others) to support demand-driven innovation of sustainable and equitable interventions for ecological intensification of modern food systems.

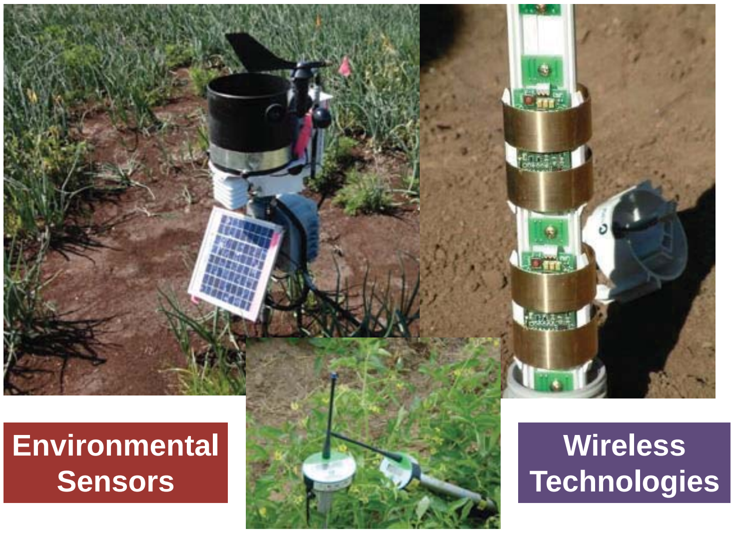
Creation of Management Zones Based on Elevation and EC

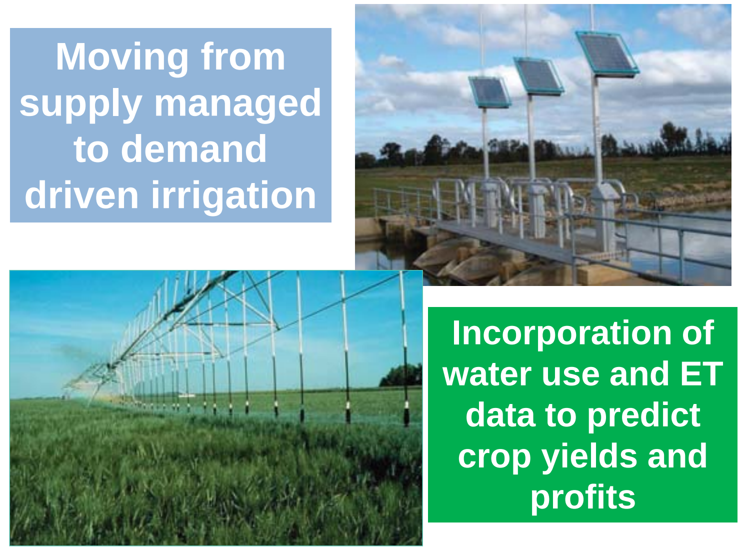


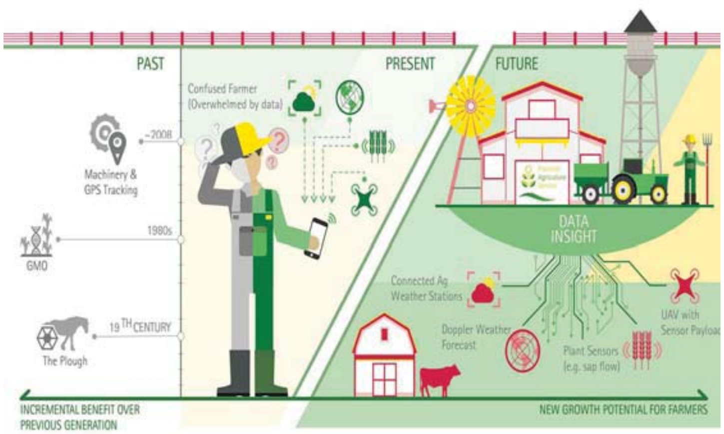
Increasing the Productivity of Irrigation Water



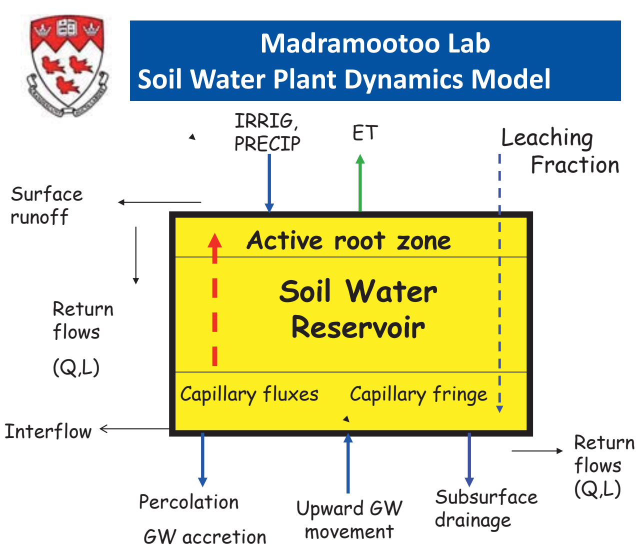
Application of precision irrigation







Ref: Accenture Precision Agriculture Services



Jean Caron, member of the panel on irrigation, drainage and soil management
Professor, Chair in precision irrigation
Soil Science and Agrifood Engineering Department
Université Laval, Québec, Canada
Jean.caron@fsaa.ulaval.ca

Own experience

- Many published papers on water, gases and solute transport in soils and in geostatistics and professor in those fields
- Extensive research on characterization methods of soil hydraulic and storage properties
- Co-founder of Hortau and Hortau Corp. (www.hortau.com), a North American leading company in wireless soil sensors used in precision irrigation (70 employees)

Initiatives with the best success

- Research on irrigation management and technology gave the best success when trying to match real time soil capacity to supply water with plant water demand

- On the soil side, unsaturated hydraulic conductivity (described by K_{sg} and α) is extremely difficult to characterize in situ and determines the onset of stress (critical irrigation setpoints h_c) for the different rooting depths (L) and crop evapotranspiration (S_0) through
-

$$h_c = \frac{1}{\alpha^*}\left(\ln\left\{ \frac{1}{\alpha^* K_{sG}} \left[\begin{array}{l} K_{sG} e^{-\alpha^*(-h_1+z)}\alpha^* + q_0\alpha^* e^{-\alpha^* z} \\ -q_0\alpha^* + S_0 e^{-\alpha^* z}\alpha^* L + S_0 e^{-\alpha^* z} \\ -S_0\alpha^* L + S_0\alpha^* z - S_0 \end{array} \right] \right\} \right) \quad [$$

- Extensive research has shown a typical quadratic yield response curve in which aeration is limiting on the wet (soil matric potential close to zero) and soil plant water transfer (unsaturated hydraulic conductivity) are limiting crop yield on the dry end side

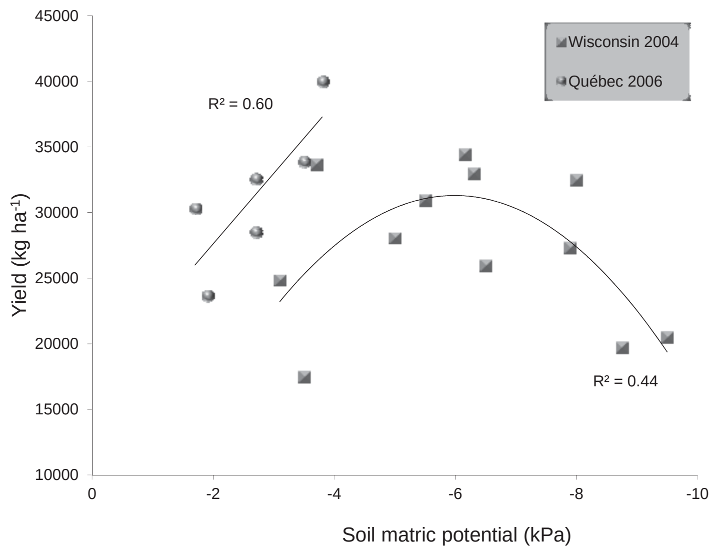
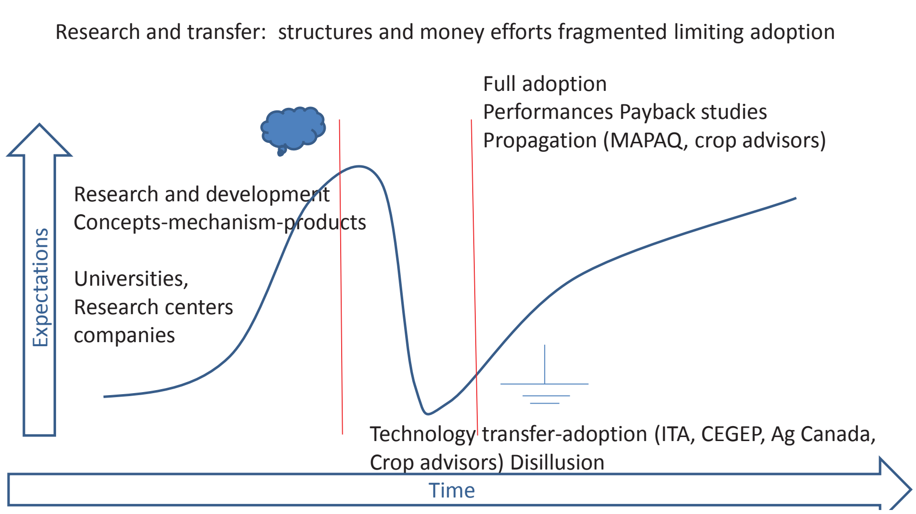


Figure 1. Soil matric potential during the growing season and cranberry yield relationship

- When working on irrigation, spatial variability investigation reveals important drainage and compaction issues limiting crop yield, as important as irrigation needs.

Possible research and business development initiative

- Challenge to derive adequate soil characterization in situ and in real time with important focus on hysteresis
- To achieve the full potential and implement technological changes, common action plans should be put in place with different groups of interest and stakeholders (companies, growers, researchers, advisors, universities and research centers) to avoid disillusion associated with the introduction of technology from universities and large companies



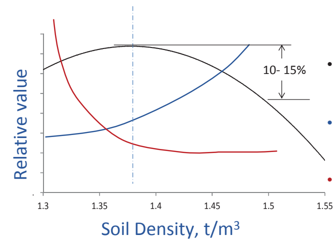
Precision Agriculture

Soil Management

Richard John Godwin FREng

Visiting Professor - Harper Adams University
Emeritus Professor - Cranfield University
Honorary Professor – Czech University of Life Sciences

The effects of soil compaction



- Reduces crop yield from optimum *(Negi & McKyes, 1978)*
- Increases draught forces *(Godwin, 1974; Chamen et al, 1992)*
- Reduces infiltration rates *(Chamen 2011; Chyba, 2012)*

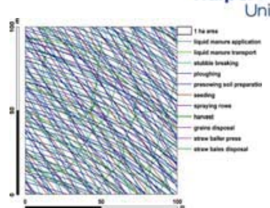
Economic cost in England and Wales : approaches £1bn/annum

(Morris et al - Cranfield University, 2011)

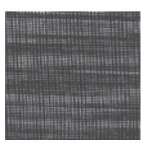
Random Traffic Problems

Extensive areas of the field are exposed to trafficking

- Random Traffic + plough = 85% covered
- Minimum Tillage = 65% covered
- Direct Drilling = 45% covered



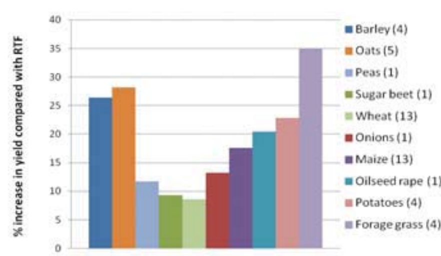
Winter wheat – Czech Republic
Kroulik et al., 2009



Potato planting – UK: 84% cover

Kroulik , Misiewicz, White and Godwin, 2012

Average yield benefit from CTF



The average yield benefit from CTF compared with random traffic farming. Numbers in parenthesis indicate the number of studies reported.
(After: Chamen, 2011)

Results from recent traffic system research and the implications for future work*

- The data show that in comparison to "conventional farming practice" numerous studies have shown benefits from alternative traffic management practices.
- In particular in the Tillage x Traffic Study at Harper Adams shows: -
  - The CTF/Shallow tillage treatment with a 30% traffic lane area showed a significant (p<0.10) 15% (1.1t/ha) increase in winter wheat yield, and
  - The estimated CTF/Shallow tillage with a 15% traffic lane area showed a 19% (1.39t/ha) increase in winter wheat yield.
  - The Low Ground Pressure/Shallow tillage treatment showed a significant (p<0.10) 9% (0.64t/ha) increase in winter wheat yield.
- Managing traffic lanes is critical especially with Zero-tillage in wet conditions.
- CTF and Zero Tillage should be good companions if we can improve traffic lanes conditions – there is more work to be done. Recent studies look more promising.

** Godwin et al., 2nd International CTF Conference Prague, 2015*

Soil Management Challenges

- Reduce compaction, increase crop yield, increase infiltration, reduce runoff, erosion and flooding.
  - Wider range of crop/soil studies.
  - Extension messages to politicians/civil servants, farmers, agronomists & equipment suppliers.
  - Wheel track width matching for tractors/trailers, sprayers and harvesters. More dialogue with manufactures.
- Compaction Sensing
  - Further development of non-contact and contact techniques.
  - Wheel-mark tracking software to guide loosening equipment.