

# The Global Digital Revolution and Canadian Agriculture and Mining

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# The digital opportunity

- *Key Questions*
  - How does the diffusion of digital technology contribute to the overall dynamism and competitiveness of Canadian agriculture and mining?
  - Does it change value capture in our portion of the global production network?
  - Does it change the focus, speed and impact of innovation in our product areas?
  - Are we ready?

# The industrial context

% distribution of GDP, 2014

| Industry                     | Canada | AB          | SASK        | MB   |
|------------------------------|--------|-------------|-------------|------|
| All industries               | 100    | 100         | 100         | 100  |
| Agriculture & FFH            | 1.7    | 2.0         | <b>11.0</b> | 4.2  |
| Mining, quarrying, oil & gas | 8.2    | <b>23.1</b> | <b>24.2</b> | 4.1  |
| Utilities                    | 2.5    | 1.6         | 1.9         | 2.3  |
| Construction                 | 7.2    | 10.9        | 7.6         | 6.5  |
| Manufacturing                | 10.4   | <b>7.3</b>  | <b>6.4</b>  | 11.3 |
| Services                     | 69.9   | <b>55.1</b> | <b>48.9</b> | 71.7 |

# Labour Productivity Growth (annual average 1997-2010)

| Sector                              | Canada      | AB          | SASK        | MB          |
|-------------------------------------|-------------|-------------|-------------|-------------|
| <b>Market Sector</b>                | <b>1.29</b> | <b>0.57</b> | <b>1.79</b> | <b>1.88</b> |
| Agriculture & FFH                   | 4.55        | 8.75        | 5.46        | 5.59        |
| Mining and Oil and Gas Extraction   | -1.56       | -2.98       | -4.52       | 2.05        |
| Manufacturing                       | 1.65        | 0.78        | 0.99        | 0.75        |
| Wholesale Trade                     | 3.24        | 2.47        | 4.59        | 5.12        |
| Transportation and Warehousing      | 1.21        | 2.32        | 1.54        | 1.06        |
| Information and Cultural Industries | 1.73        | 4.33        | 3.97        | 0.63        |
| FIRE                                | 1.46        | 1.15        | 3.50        | 1.84        |
| Professional, S&T Services          | 1.11        | 2.32        | 2.43        | 0.03        |

Source: <http://www.csls.ca/data/mfp2012.asp> •

# Capital Productivity Growth (annual average 1997-2010)

| Sector                              | Canada       | AB           | SASK         | M B          |
|-------------------------------------|--------------|--------------|--------------|--------------|
| <b>Market Sector</b>                | <b>-0.47</b> | <b>-4.22</b> | <b>-2.46</b> | <b>-0.62</b> |
| Agriculture & FFH                   | 1.91         | 2.80         | 0.08         | 2.51         |
| Mining and Oil and Gas Extraction   | -5.10        | -6.90        | -6.57        | -2.72        |
| Manufacturing                       | 1.03         | -1.77        | -1.45        | -0.37        |
| Wholesale Trade                     | -0.85        | -3.45        | 2.84         | 2.23         |
| Transportation and Warehousing      | -0.98        | -3.63        | -1.05        | -1.53        |
| Information and Cultural Industries | 2.06         | 0.52         | -2.50        | -0.47        |
| FIRE                                | 0.09         | -2.01        | -0.45        | -1.60        |
| Professional, S&T Services          | -2.38        | -5.51        | -6.11        | -1.53        |

Source: <http://www.csls.ca/data/mfp2012.asp>.

# Multifactor Productivity Growth (annual average 1997-2010)

| Sector                              | Canada       | AB           | SASK         | MB          |
|-------------------------------------|--------------|--------------|--------------|-------------|
| <b>Market Sector</b>                | <b>-0.24</b> | <b>-2.22</b> | <b>-1.17</b> | <b>0.46</b> |
| Agriculture & FFF                   | 2.44         | 4.07         | 1.01         | 2.87        |
| Mining and Oil and Gas Extraction   | -4.64        | -6.10        | -6.36        | -1.11       |
| Manufacturing                       | 0.60         | -0.53        | -1.00        | 0.03        |
| Wholesale Trade                     | 1.49         | 0.29         | 3.58         | 3.85        |
| Transportation and Warehousing      | -0.22        | -0.38        | 0.24         | 0.11        |
| Information and Cultural Industries | 1.34         | 2.11         | 0.91         | -0.09       |
| FIRE                                | -0.11        | -0.52        | 1.21         | -0.32       |
| Professional, S&T Services          | -0.12        | 0.30         | 0.43         | -0.04       |

Source: [Http://www.csls.ca/data/mfp2012.asp](http://www.csls.ca/data/mfp2012.asp)

# AGRICULTURE

# 12 disruptive technologies with \$125T gross value and agricultural relevance

(McKinsey Global Institute)

- **Internet of Things (\$40T)**
- **Mobile internet (\$26T)**
- 3D printing (\$11T)
- **Automation of knowledge work (\$9T)**
- **Advanced Robotics (\$8T)**
- **Next-generation genomics (\$8T)**
- **Cloud Technology (\$5T)**
- **Autonomous and near autonomous vehicles (\$4T)**
- Advanced oil and gas exploration and recovery (\$4T)
- Renewable energy \$4T)
- Energy storage (\$3T)
- Advanced materials (\$1T)

# The Digital Revolution in Agriculture

R&D

- **The Virtual Seed, Plant and Animal:** genomics, phenotyping, visualization, big data mining, Cloud based networks

DATA

Farm

- **Precision Farming:** GSP and geomapping, sensors and drones, scripting, biologicals, computer assisted production

DATA

Market

- **Just Right Foods:** integrated supply and demand ; traceability; demand fro provenance

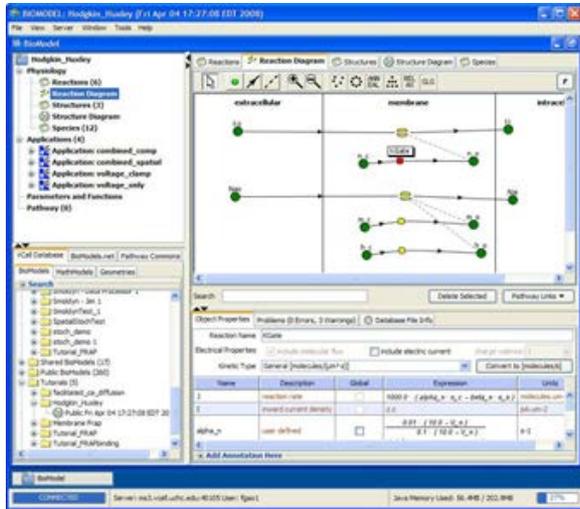
DATA

# The history—anchoring image



# The reality—the virtual ?

## vCell 1997-



## vLab for Plants 2012-

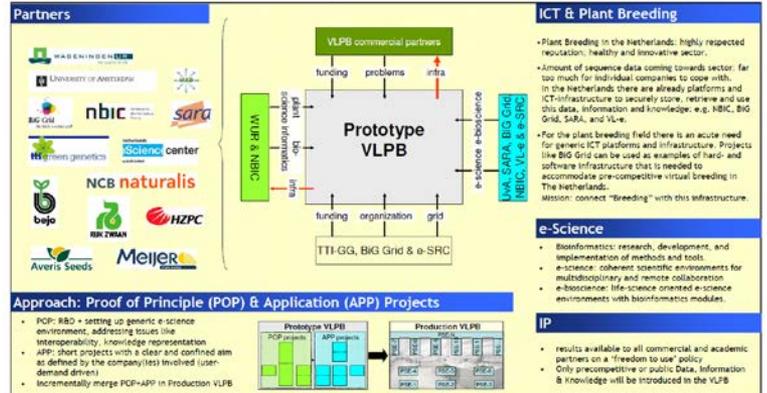
### The Virtual Lab for Plant Breeding (VLPB)

H. Rauwerda<sup>1</sup>, R. Finken<sup>1</sup>, M. Kuzak<sup>1</sup>, R. Ursom<sup>1</sup>, H. Huits<sup>1</sup>, G. Heeselmans<sup>1</sup>, G. Beers<sup>1</sup>, J. de Haas<sup>1</sup>, T.M. Breit<sup>1</sup>, R. Vissers<sup>1</sup>, W. Spink<sup>1</sup>, B. de Gaus<sup>1</sup>, R. Dirks<sup>1</sup>, University of Amsterdam<sup>1</sup>, Wageningen UR<sup>2</sup>, Rijkswaarden<sup>3</sup>, Bejo Zaden BV<sup>4</sup>, NCOB Naturalis<sup>5</sup>, HZPC<sup>6</sup>, TTI-Drosna Genetics<sup>7</sup>.

High-throughput sequencing of public germplasm collections of stock centres, combined with appropriate bioinformatics tools, will become very important in the process of finding new elite alleles "in silico". Hence, it will be possible to forecast which genotype from which accession from which related species will be a promising candidate for a specific breeding project.

The objective of this project is to set up a Virtual Lab for Plant Breeding in which this vision is realized in the context of pre-competitive public-private partnership consisting of plant-breeding companies and knowledge institutes

| Aim & Objectives  | Rationale   |
|---|---|
| <p>Driven by clearly defined biological questions, (generic) problem-solving environments will be developed to efficiently mine and use genome-associated information and other resources.</p> <p><b>Objectives</b></p> <ul style="list-style-type: none"> <li>Develop a pre-competitive public-private partnership consisting of plant-breeding companies and knowledge institutes, with strong ties to institutes in the domains of e-bioscience, bioinformatics and ICT infrastructure</li> <li>Create a sustainable pre-competitive day-to-day research infrastructure securing innovation in the plant-breeding industry and associated knowledge infrastructure</li> <li>Secure real-life use by end users via a demand-driven development strategy.</li> </ul> | <p>Due to rapid developments in genomics research, the breeding approach is changing quickly. In the last 3 decades, all kinds of molecular markers have been used, eventually resulting in the ultimate detection platform for "single nucleotide polymorphisms" (SNPs). Until now, the development of such markers was quite cumbersome. In the last 2 years, DNA sequencing technology and development of bioinformatics tools and methodologies have soared. For several crops a complete core genome sequence is available (maize, rice, tomato, potato, cucumber, watermelon, melon, cabbage...) and many more species are on the verge of being sequenced.</p> <p>This sequence information can be used for "in silico" mining of interesting gene/alleles in these accessions. In essence, this reverses the original workflow: first "virtual" analysis and on the basis of the outcome, followed by dedicated crosses. In principle this can lead to faster and easier development of commercially interesting varieties.</p> |



## vPlant 2009-



### Example: Tooling for Allelic Variation Visualization

**Background**  
It is anticipated that within the near future the full-genomes of many (100+) non-cultivar tomato strains will become available. In order to introduce this new information into the breeding approach of Rijkswaarden and Bejo Zaden, a new e-bioscience infrastructure that allows easy data exploration is needed.

**Aim & deliverable: Allelic Variation PSE (AV-PSE)**  
A problem-solving environment (PSE) to identify for target genes the naturally-occurring single-nucleotide polymorphisms (SNPs) in next-generation DNA sequencing data. By organizing the SNP combinations in haplotype blocks, new defined as a specific combination of nucleobases on a given stretch of DNA, the size of the search space will be strongly reduced.

**Functionality**  
Show the haplotype blocks per annotated target gene  
Cluster the haplotype blocks by similarity

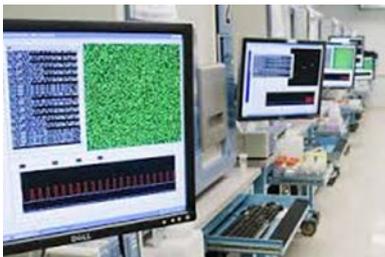
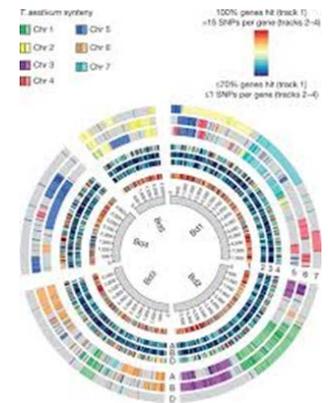
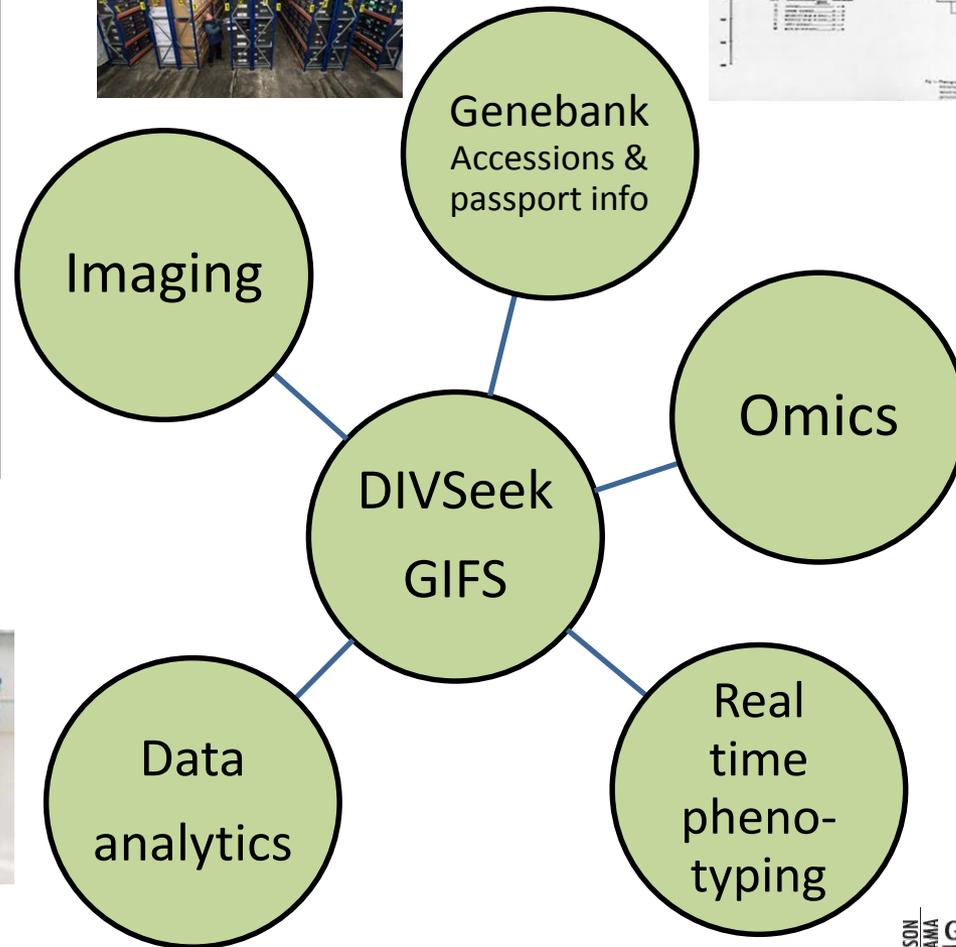
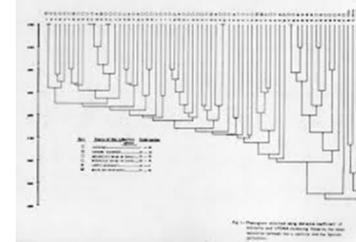
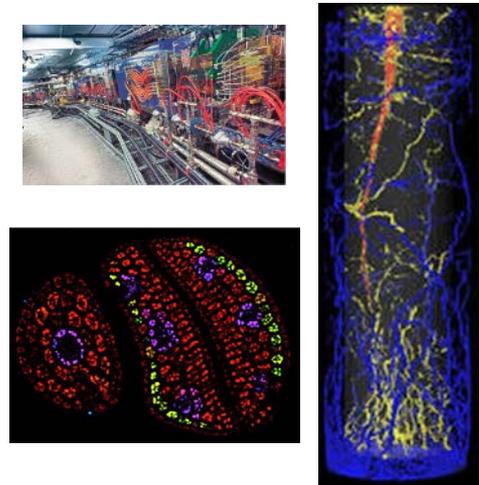
- Display the amount of strains with the specific haplotype
- Generate a list of strains for each haplotype block
- Indicate per haplotype block and with respect to the reference strain which SNPs are coding, silent, stopcodon introducing.
- Indicate per gene / DNA stretch if strains are not covered
- Assign a p-value to each haplotype block based on
  - p-value of the SNP giving the probability that the SNP is falsely called on the basis of the strain
  - p-value of the SNP giving the probability that the SNP is falsely called on the basis of the population of strains and visualize these per-SNP p-values per haplotype block.
- Export the sequences in a haplotype block, together with a stretch upstream and downstream of the block with the SNPs inside square brackets

**Mockup:**

**Sequence structure:** Heterozygous overlapping base, Allelic Variation Explorer, Haplotype priority matrix.

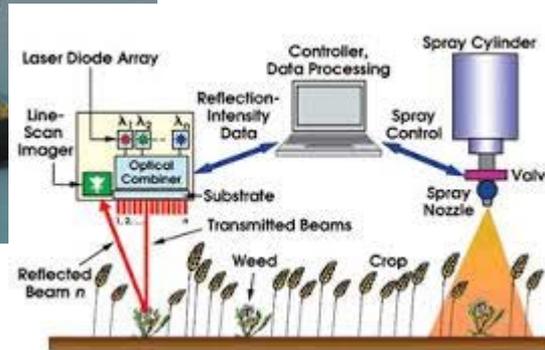
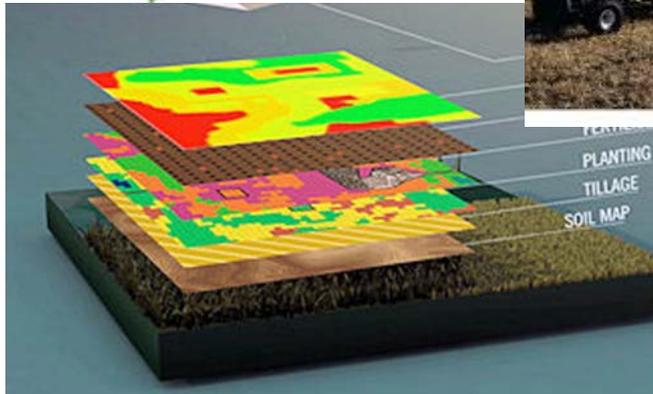
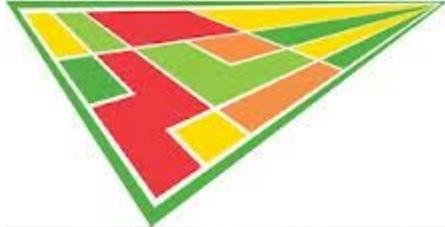
**Haplotype matrix:** Haplotypes (basis with first SNPs (anchor))

# Endgame 2—designed crops



# Endgame 2: on-farm scripted, precision ag

## FieldScripts<sup>SM</sup>



**6% gains = ~+100% gross margin**

# Preparedness

## ICT penetration into Agriculture

| Type of ICT service expense            | Any outlays on ICT in past 3 years | Software as a service | Web site design or hosting | Data processing services | Database services |
|--|------------------------------------|-----------------------|----------------------------|--------------------------|-------------------|
| <b>Private sector</b>                  | <b>51.5</b>                        | <b>18.3</b>           | <b>31.4</b>                | <b>7.5</b>               | <b>17.8</b>       |
| <b>Ag Production Network</b>           |                                    |                       |                            |                          |                   |
| Scientific R&D services [5417]         | 66.4                               | 25.9                  | 38.8                       | 8.2                      | 21.6              |
| Chemical manufacturing [325]           | 79.1                               | 17.5                  | 61.1                       | x                        | x                 |
| Machinery & equip wholesale-dist[417]  | 74.2                               | 31.4                  | 48.9                       | 9.2                      | 26.1              |
| Insurance and related activities [524] | 75.9                               | 19.4                  | 47.7                       | 16.2                     | 43.2              |
| Management, S&T consulting [5416]      | 47.3                               | 16.9                  | 22.3                       | 4.8                      | 15.5              |
| Agriculture (& FFH) [11] (1)           | 29.9                               | 3.3                   | 19.3                       | 6.1                      | 11.9              |
| Securities & commodity contracts [523] | 28.0                               | 12.3                  | 16.0                       | 3.6                      | 12.9              |
| Farm product wholesale-distrib. [411]  | 23.7                               | 2.0                   | 18.5                       | 3.5                      | 7.7               |
| Truck transportation [484]             | 24.9                               | 6.6                   | 7.1                        | 0.7                      | 6.6               |
| Food manufacturing [311]               | 58.7                               | 14.8                  | 33.7                       | 10.5                     | 22.7              |
| Accounting, tax prep, books (5412)     | 58.4                               | 21.0                  | 22.2                       | 0.7                      | 11.1              |

# AG Digital technology and Internet use

Capital expenditures on types of ICTs by NAICS, 2012 (%)

|   | Firm size | Private sector | Agriculture & FFH |
|---|-----------|----------------|-------------------|
| Any capital expenditures on ICT in the past three years | Total     | 51.3           | <b>36.7</b>       |
|   | Large     | 85.5           | <b>83.1</b>       |
|   | Medium    | 76.5           | <b>73.0</b>       |
|   | Small     | 48.2           | <b>34.0</b>       |
| Computer hardware                                       | Total     | 47.4           | <b>34.3</b>       |
|   | Large     | 84.7           | <b>59.1</b>       |
|   | Medium    | 73.8           | <b>69.6</b>       |
|   | Small     | 44.2           | <b>31.8</b>       |
| Customized computer software                            | Total     | 15.6           | <b>4.3</b>        |
|   | Large     | 52.5           | <b>33.8</b>       |
|   | Small     | 12.5           | <b>2.1</b>        |
| Network Operating Systems or Equipment                  | Total     | 18.3           | <b>13.9</b>       |
|   | Large     | 65.7           | <b>66.3</b>       |
|   | Small     | 14.6           | <b>11.6</b>       |
| Off-the-shelf software                                  | Total     | 32             | <b>27.1</b>       |
|   | Large     | 62.6           | <b>50.6</b>       |
|   | Medium    | 50.3           | <b>61.4</b>       |
|   | Small     | 29.6           | <b>24.6</b>       |

# Barriers to use of ICT, 2012

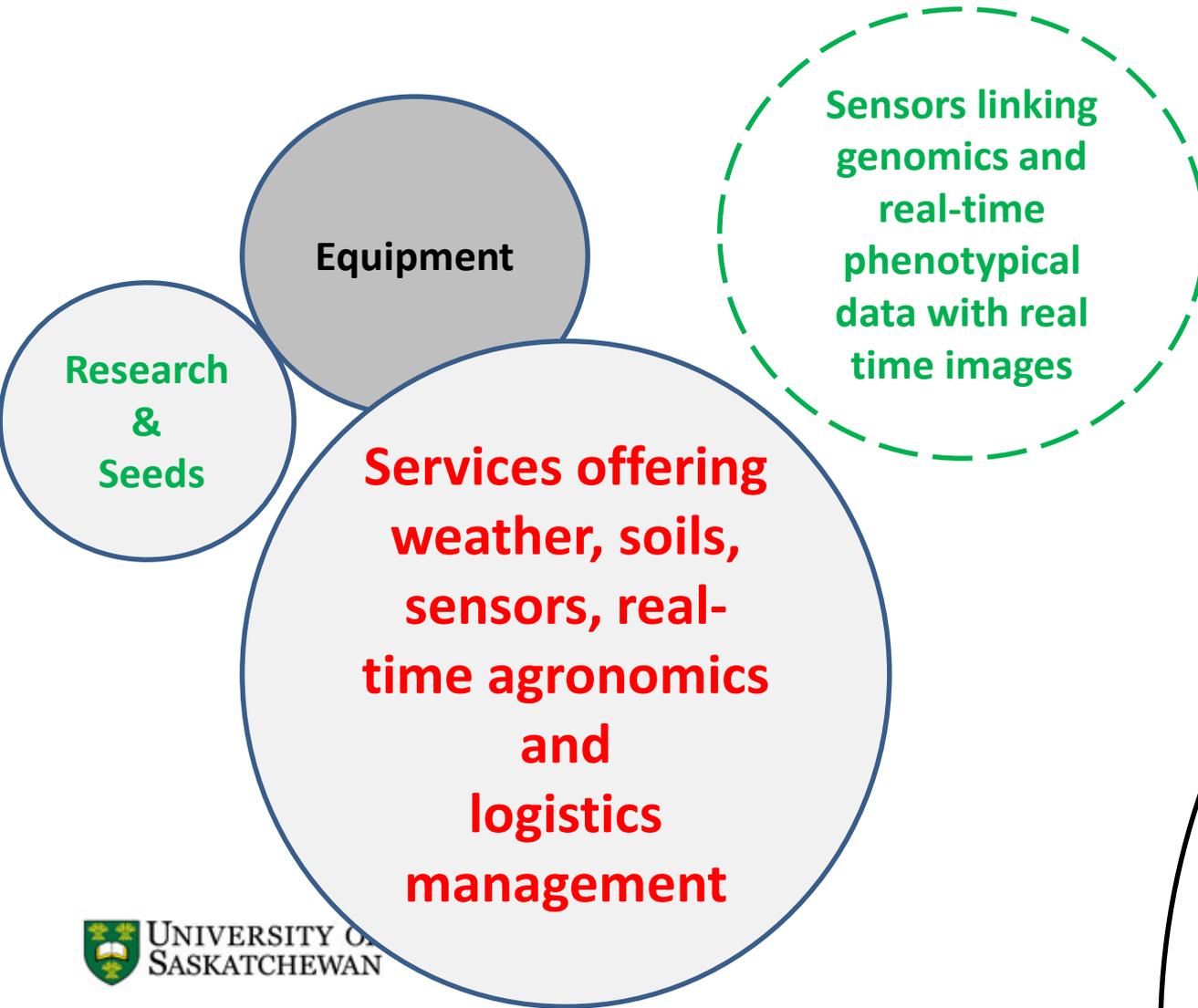
| BARRIER  | Firm Size    | Private sector | Agriculture +FFH |
|--|--------------|----------------|------------------|
| Cost of technology and implementation are too high         | <b>Total</b> | <b>30.1</b>    | <b>22.2</b>      |
|  | Small        | 28.6           | 19.2             |
|  | Large        | 40             | 72.9             |
| Employee resistance to introduction of new technology      | <b>Total</b> | <b>9.6</b>     | <b>11.5</b>      |
|  | Small        | 8.3            | 9.5              |
| Lack of technical expertise and skilled personnel in-house | <b>Total</b> | <b>29.5</b>    | <b>54.5</b>      |
|  | Small        | 29.3           | 53.7             |
|  | Medium       | 35.3           | 65.5             |
| New systems will not be compatible with existing systems   | <b>Total</b> | <b>9.8</b>     | <b>20.4</b>      |
|  | Large        | 18             | 61.8             |
| Not enough evidence of a strong return on investment       | <b>Total</b> | <b>21.8</b>    | <b>17.1</b>      |
|  | Large        | 22.4           | 11.9             |
| Security and/or privacy concerns                           | <b>Total</b> | <b>18.7</b>    | <b>30.9</b>      |
|  | Small        | 18.1           | 32.9             |
| Unaware of what technologies exist in the marketplace      | <b>Total</b> | <b>16.4</b>    | <b>20.1</b>      |

# Hypothesized impacts

|               | <b>Designed crops</b>  | <b>Precision ag</b>              |
|---------------|--|----------------------------------|
| Cost          | High fixed; lower variable costs   | Lower costs generate all returns |
| Benefits      | New traits; more differentiation   | Lower risk and uncertainty?      |
| Timing        | Faster   | ?                                |
| Discount rate | Lower due to more predictability?<br>But also differentiated by uptake and use |                                  |
| Location      | Canada? Germany?   | US first? Then ...?              |
| Diversity     | Capital intensive but open and transferable?                                   | Bias to larger farms             |

# The policy challenge

## Guesstimated Data Value



*While there is hardware value (drones, sensors etc), the emerging fight is to control data and exploit its value*

### **UNKNOWNNS**

**Challenges of farmer skills, data ownership & mgt; cost v benefits**

# John Deere Wants To Be Able To File Copyright Claims Against The Way You Use Your Tractor

By **Kate Cox** April 22, 2015



<http://consumerist.com/2015/04/22/john-deere-wants-to-be-able-to-file-copyright-claims-against-the-way-you-use-your-tractor/>

(**Matt McGee**)

# MINING

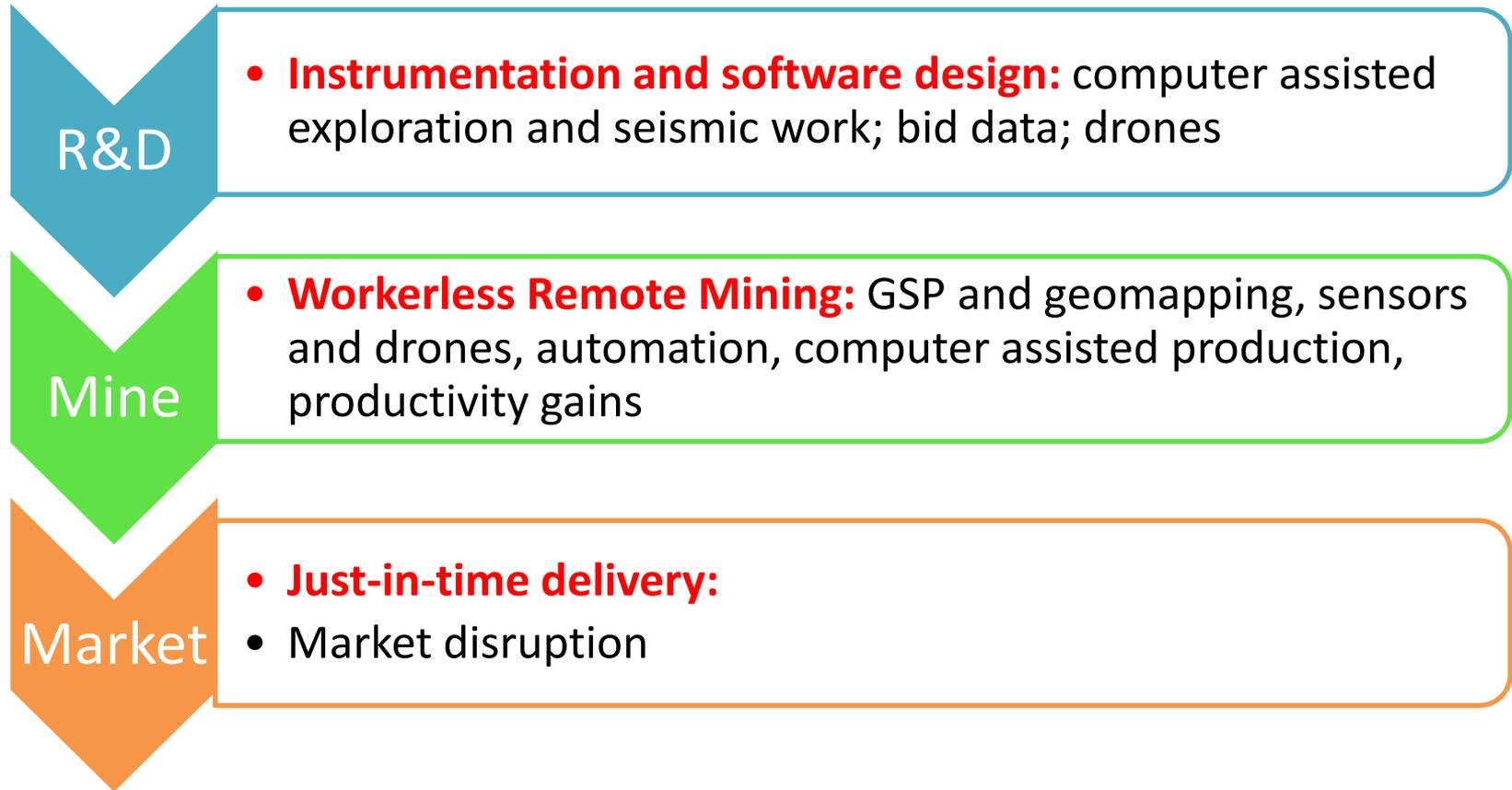
(NOT OIL & GAS)

# 12 disruptive technologies with \$125T gross value and mining relevance

(McKinsey Global Institute)

- Internet of Things (\$40T)
- Mobile internet (\$26T)
- 3D printing (\$11T)
- Automation of knowledge work (\$9T)
- Advanced Robotics (\$8T)
- Net-generation genomics (\$8T)
- Cloud Technology (\$5T)
- Autonomous and near autonomous vehicles (\$4T)
- Advanced oil and gas exploration and recovery (\$4T)
- Renewable energy (\$4T)
- Energy storage (\$3T)
- Advanced materials (\$1T)

# The Digital Revolution in Mining



# The Future Happened Yesterday —in Australia



# Digital impact on mining

- Mining software and technology industry \$150b global industry (Aust has 60%)
- Autonomous haul trucks (Rio Tinto alone has 63)
- Autonomous ore trains (start operation in 2015)
- Robotic drills (just beginning)
- Komatsu has no spare 'autonomous capacity'
- BHPBilton working with Caterpillar
- Remote centres of control (1500km+)
- Job shift to much higher qualifications

# Expenses on ICT services

| Type ICT service expense                             | Size of firm | Private sector | Mining, quarrying, and oil and gas extraction |
|--|--------------|----------------|---|
| Any expenditures on ICT services in the past 3 years | Total        | 51.5           | <b>51.6</b>                                   |
|  | Large        | 88.7           | <b>99.2</b>                                   |
|  | Medium       | 80.1           | <b>83.6</b>                                   |
|  | Small        | 48.1           | <b>46.5</b>                                   |
| Data processing services                             | Total        | 7.5            | <b>1.6</b>                                    |
| Database services                                    | Total        | 17.8           | <b>13.1</b>                                   |
|  | Large        | 54.7           | <b>91.1</b>                                   |
| No ICT service expends                               | Small        | 32.2           | <b>34.4</b>                                   |
| Other ICT services                                   | Total        | 12.2           | <b>24.7</b>                                   |
|  | Large        | 32.4           | <b>6.3</b>                                    |
| Software as a service                                | Total        | 18.3           | <b>25.7</b>                                   |
|  | Large        | 44.3           | <b>79.4</b>                                   |
|  | Medium       | 29.9           | <b>50.9</b>                                   |
|  | Small        | 16.7           | <b>20.3</b>                                   |
| Web site design or hosting                           | Large        | 69.3           | <b>93.4</b>                                   |

Table 358-0202 Survey of digital technology and Internet use, expenses on types of ICT services, by NAICS and size of enterprise, occasional.

# Capital outlays on ICT

| Type of capital expenditure on Information and Communications Technology (ICT) | Size of enterprise | Private sector | Mining, quarrying, oil & gas extraction |
|--|--------------------|----------------|---|
| Any capital expenditures on ICT in the past three years                        | Total              | 51.3           | <b>46.4</b>                             |
|  | Large              | 85.5           | <b>96.1</b>                             |
|  | Medium             | 76.5           | <b>75.5</b>                             |
|  | Small              | 48.2           | <b>41.2</b>                             |
| Computer hardware  | Total              | 47.4           | <b>42.1</b>                             |
|  | Large              | 84.7           | <b>95.7</b>                             |
|  | Medium             | 73.8           | <b>74.7</b>                             |
|  | Small              | 44.2           | <b>36.5</b>                             |
| Customized computer software   | Large              | 52.5           | <b>23.3</b>                             |
| Network Operating Systems or Equipment   | Total              | 18.3           | <b>26.1</b>                             |
|  | Large              | 65.7           | <b>87.6</b>                             |
| Off-the-shelf software   | Total              | 32             | <b>22.9</b>                             |
|  | Large              | 62.6           | <b>90.7</b>                             |

Source: Stats Can 358-0201

# Investments in training

| Enterprises investing in ICT training             | Size of firm | Private sector | Mining, quarrying, oil & gas extraction |
|---|--------------|----------------|---|
| Businesses with ICT/IT specialists as of Dec 2013 | Total        | 13.4           | <b>27.2</b>                             |
| Businesses with ICT/IT specialists as of Dec 2013 | Large        | 74.7           | <b>96.9</b>                             |
| Businesses with ICT/IT specialists as of Dec 2013 | Small        | 10.1           | <b>12.7</b>                             |
| Training for ICT/IT specialists                   | Large        | 73.5           | <b>95.3</b>                             |
| Training for other staff using ICTs               | Large        | 77.8           | <b>95.4</b>                             |

Table 358-0233 Survey of digital technology and Internet use, enterprises investing in Information and Communications Technology (ICT) training, by North American Industry Classification System (NAICS) and size of enterprise, occasional

# Barriers to ICT use

| BARRIER  | SIZE  | Private sector | Mining, quarrying, and oil and gas extraction |
|--|-------|----------------|---|
| Cost of technology and implementation are too high         | Large | 40             | <b>8.6</b>                                    |
| Employee resistance to introduction of new technology      | Total | 9.6            | <b>17.6</b>                                   |
| Lack of technical expertise and skilled personnel in-house | Total | 29.5           | <b>12.6</b>                                   |
| Lack of technical expertise and skilled personnel in-house | Large | 18.4           | <b>6.8</b>                                    |
| New systems not compatible with existing systems           | Large | 18             | <b>5.5</b>                                    |
| Security and/or privacy concerns                           | Total | 18.7           | <b>6.9</b>                                    |
| Unaware of what technologies exist in the marketplace      | Total | 16.4           | <b>5.8</b>                                    |

# Interim Hypotheses for Theme 3

## investigations of Agriculture and Mining

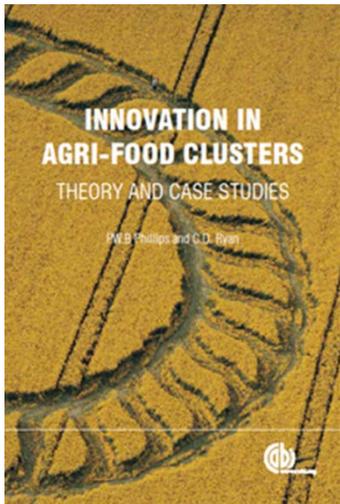
- Canadian ag and mining industries vulnerable – also affecting rural & First Nations people
- The global landscape is changing rapidly
- Transformative technologies have significant potential to change related GPNs and GINs
- Firms and farms are prepared but may need more focus to realize benefits
- If fail to secure critical role in digital world, value will migrate from Saskatchewan/Canada and R&D and innovation may work against Canadian interests

# Existing Data Misleading

- Existing data on this topic of which we have shown some is actually worse than useless – it is actually fundamentally misleading.
- Existing ICT statistics are predicated on standalone expenditure. ICT as a discrete thing.
- The IOT and software-ization of everything is predicated on the concept that everything will have some ICT in it. We need a worldview shift

# Theme 3 Methods (so far)

| Method                             | Ag  | Mining                                  |
|------------------------------------|---|---|
| Map ICT penetration in GPN and GIN | Secondary Data; producer survey; case studies | Secondary Data; tbc                     |
| Survey for ICT readiness           | Stats Can and industry data; interviews       | Stats Can and industry data; interviews |
| Policy readiness                   | GEM survey 2015; interviews                   | GEM survey 2016; interviews             |
| Specific policy issues             | On farm data management; case studies         | Geospatial data management              |



# The Global Digital Revolution and Canadian Agriculture and Mining

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