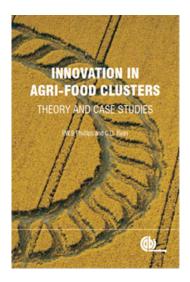


GenomePrairie





The Global Digital Revolution and Canadian Agriculture and Mining

Peter W.B. Phillips, Ph.D. Distinguished Professor of Public Policy

Brian Wixted, Ph.D. Adjunct Professor

Johnson-Shoyama Graduate School of Public Policy Saskatoon, Canada





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	11.0	4.2
Mining, quarrying, oil & gas	8.2	23.1	24.2	4.1
Utilities	2.5	1.6	1.9	2.3
Construction	7.2	10.9	7.6	6.5
Manufacturing	10.4	7.3	6.4	11.3
Services	69.9	55.1	48.9	71.7



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Labour Productivity Growth (annual average 1997-2010)

Sector	Canada	AB	SASK	MB
Market Sector	1.29	0.57	1.79	1.88
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
Market Sector	-0.47	-4.22	-2.46	-0.62
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

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



Multifactor Productivity Growth (annual average 1997-2010)

Sector	Canada	AB	SASK	MB
Market Sector	-0.24	-2.22	-1.17	0.46
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



GRADUATE SCHOOL OF

AGRICULTURE





12 disruptive technologies with \$125T gross value and agricultural relevance (McKinsey Global Institute)

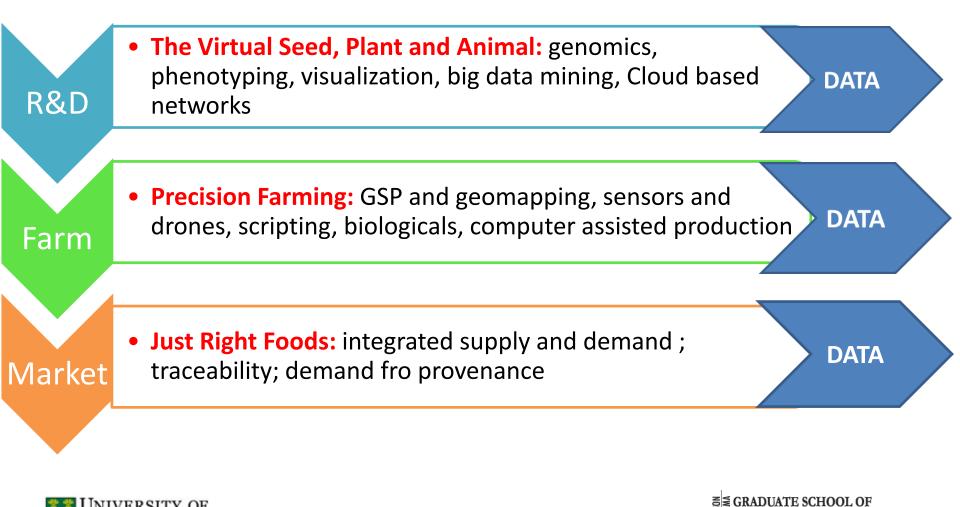
- Internet of Things (\$40T)
- Mobile internet (\$26T)
- 3D printing (\$11T)
- Automation of knowledge work (\$9T)
- Advanced Robotics (\$8T)
- Next-generation genomics (\$8T)

- 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)

DUATE SCHOOL OF



The Digital Revolution in Agriculture





The history—anchoring image







The reality—the virtual

vCell 1997-

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vPlant 2009-



UNIVERSITY OF SASKATCHEWAN

vLab for Plants 2012-

The Virtual Lab for Plant Breeding (VLPB)

H. Rauwerda¹, R. Finkers³, M. Kuzak¹, R. Ursem³, H. Huits⁴, G. Heselmans³, G. Beers⁸, J. de Haas⁷, T.M. Breit¹, R. Visser³, W. Spek⁴, B. de Geus⁸, R.Dirks³ ¹University of Amsterdam, ²Wageningen UR, ²RijkZwaan, ⁴Bejo Zaden BV, ⁴C.Meijer BV, ⁴NCB Naturalis, ¹HZPC, ⁸TTI-Groene Genetica

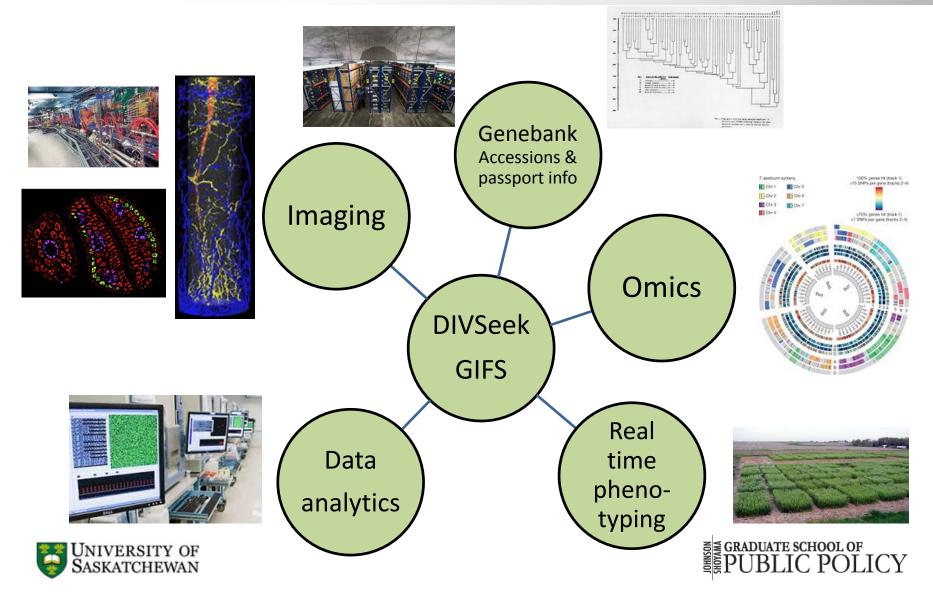
High-throughput sequencing of public germplasm collections of stock centres, combined with appropriate bioinformatics tools, will become very important in the process of finding new elite alleles "in silico". Hence, it will be possible to forecast which genotype from which accession from which related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

Rationale Aim & Objectives Driven by clearly defined biological questions, (generic) problem-solv environments will be developed to efficiently mine and use genome-Due to rapid developments is genomics research, the breeding approach is changing quickly. In the last 3 decades, all isnds of molecular markers have been used, eventually resulting in the ultimate slem-solving associated information and other resources. detection platform for "single nucleotide polymorphisms" (SIPs). Until now, the development of such cerection pations for single nucleotoe poymorphisms (24-3), unit now, the development of sour markers wa quite cumbersome. In the last 2 years, 10% aquencing technology and development of bondomastic stools and methodologies have spared. For several crops a complete core genome sequence its available (marker, new tented, postar, ocumber, watermelon, melon, cabbage...) and many more species are on the verge of being sequenced. Objectives Develop a pre-competitive public-private partnership consisting of plant Develop a pre-competitive public-private partnersing or public breeding comparies and involvidge institutions, with strong tests to initiative in the domains of e-bioscience, bioinformatics and ICT-infrastructure Create a sustainable pre-competitive, dry-lab research infrastructure securing innovation in the plant-breeding industry and associated This sequence information can be used for "in silico" mixing of interventing generialileles 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 essier development of commercially interesting varieties. knowledge infrastructure. Secure real-life use by end-users via a demand-driven development strategy. ICT & Plant Breeding Partners VLPB con Plant Breeding in the Netherlands: highly respected reputation; healthy and innovative sector. -----Amount of sequence data coming towards sector: fa ding problems 001 too much for individual companies to cope with. in the Netherlands there are already platforms and ICT-infrastructure to securely store, retrieve and use this data, information and knowledge: e.g. NBIC, BIG Grid, SAR4, and VL-e. sara nbic Prototype For the plant breeding field there is an acute need **VLPB** for generic ICT platforms and infrastructure. Project like BiG Grid can be used as examples of hard- and Science center software infrastructure that is needed to accommodate pre-competitive virtual breeding in The Netherlands. NCB naturalis Ψ Mission: connect "Breeding" with this infrastructure 6 HZPC funding organization grid e-Science Exotoformatics: research development and TTI-GG, BiG Grid & e-SBC Meijer Averis Seeds implementation of methods and tools. e-science: coherent scientific environments for multidisciplinary and remote collaboration e-bioscience: life-science oriented e-science environments with bioinformatics modules Approach: Proof of Principle (POP) & Application (APP) Projects PCP: R&D + setting up generic e-science ofvice VLPB Production VLPE environment, addressing issues like interoperability, knowledge representation APP: short projects with a clear and confined atm as defined by the company(les) involved (user-PICA · results available to all commercial and academic partners on a "freedom to use" policy Only precompetitive or public Data, Information PET demand driven) Incrementally merge PCP+APP in Production VLPB & Knowledge will be introduced in the YLPB PTR.1 Example: Tooling for Allelic Variation Visualization background It is anticipated that within the near future the full-genomes of many (100-) non-cultiver tomato strains will become available. In order to introduce this new information into the breeding approach of Rijk Zwaan and Bejo Zaden, a new e-bioscience infrastructure that allows easy data exploration is needed. Nim & 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, here defined as a specific combination of nucleotides 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 Allelic Variation Fundame 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

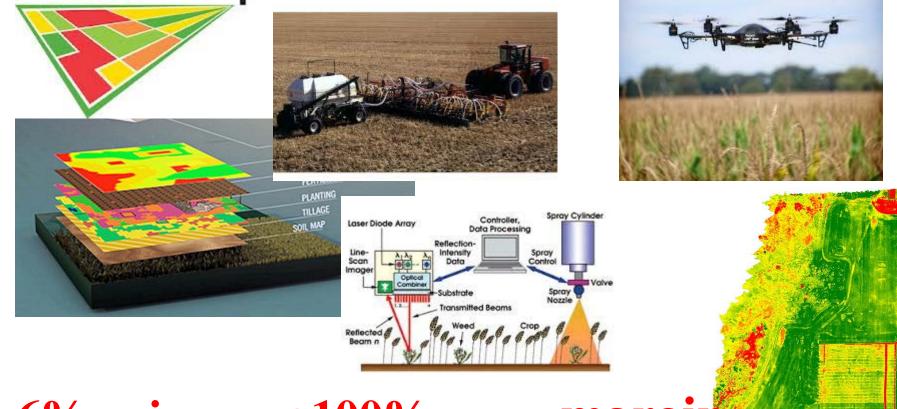
- strain which SNPs are coding, silent, stopcodon introducing. Indicate per gene / DNA stretch if strains are not covered
- Assign a p-value to each haplotype block based on
 - p-value of the SNP giving the probability that the SNP is falsely called on the basis of the strain p-value of the SNP giving 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 ride reiren brackets
- Haploypes (bars) with and SNPS (prd) Ł

Endgame 2—designed crops



Endgame 2: on-farm scripted, precision ag

FieldScripts.



6% gains = ~+100% gross margin



Preparedness

ICT penetration into Agriculture

	Any				
	outlays on	Software	Web site	Data	
	ICT in past	as a	design or	processing	Database
Type of ICT service expense	3 years	service	hosting	services	services
Private sector	51.5	18.3	31.4	7.5	17.8
Ag Production Network					
Scientific R&D services [5417]	66.4	25.9	38.8	8.2	21.6
Chemical manufacturing [325]	79.1	17.5	61.1	Х	х
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



GRADUATE SCHOOL OF

AG Digital technology and Internet use

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

· · · ·	/ 1		
	Firm size	Private sector	Agriculture & FFH
Any capital expenditures on	Total	51.3	36.7
ICT in the past three years	Large	85.5	83.1
	Medium	76.5	73.0
	Small	48.2	34.0
Computer hardware	Total	47.4	34.3
	Large	84.7	59.1
	Medium	73.8	69.6
	Small	44.2	31.8
Customized computer	Total	15.6	4.3
software	Large	52.5	33.8
	Small	12.5	2.1
Network Operating Systems	Total	18.3	13.9
or Equipment	Large	65.7	66.3
	Small	14.6	11.6
Off-the-shelf software	Total	32	27.1
	Large	62.6	50.6
	Medium	50.3	61.4
	Small	29.6	24.6
	Small	29.6	24.6

Barriers to use of ICT, 2012

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



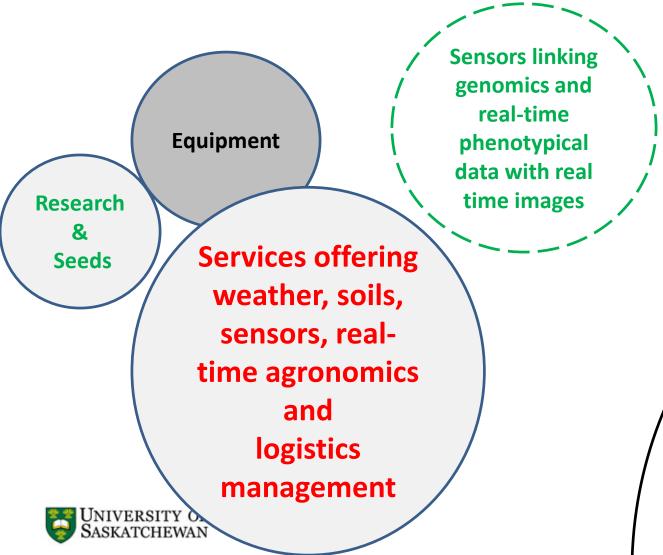
GRADUATE SCHOOL OF

Hypothesized impacts

	Designed crops	Precision ag
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 pred But also differentiated b	•
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

UNKNOWNS

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



(Matt McGee)

MINING

(NOT OIL & GAS)





12 disruptive technologies with \$125T gross value and mining relevance (McKinsey Global Institute)

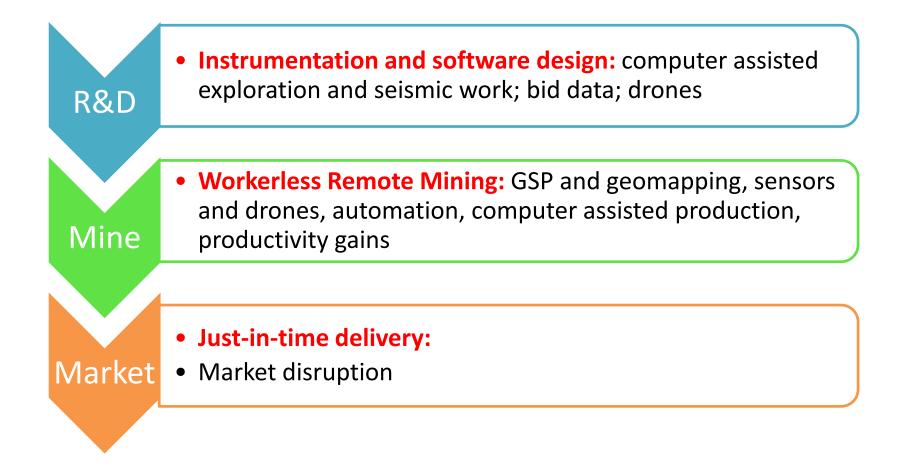
- Internet of Things (\$40T)
- Mobile internet (\$26T)
- 3D printing (\$11T)
- Automation of knowledge work (\$9T)
- Advanced Robotics (\$8T)
- Net-generation genomics (\$8T)

- 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)

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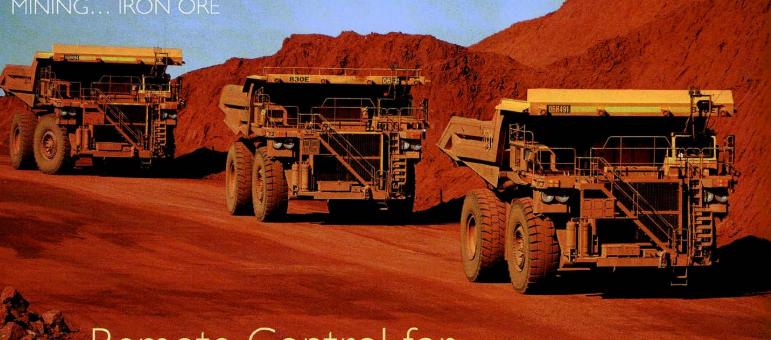
The Digital Revolution in Mining







The Future Happened Yesterday —in Australia



Remote Control for Remote Locations

By Tony Grant-Taylor

Rio Tinto's autonomous trucks have now moved over 200 million tonnes of earth. IMAGE COURTESY RIO TINTO



GRADUATE SCHOOL OF

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'
- BHPBiliton 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	Total	51.5	51.6
services in the past 3 years	Large	88.7	99.2
	Medium	80.1	83.6
	Small	48.1	46.5
Data processing services	Total	7.5	1.6
Database services	Total	17.8	13.1
	Large	54.7	91.1
No ICT service expends	Small	32.2	34.4
Other ICT services	Total	12.2	24.7
	Large	32.4	6.3
Software as a service	Total	18.3	25.7
	Large	44.3	79.4
	Medium	29.9	50.9
	Small	16.7	20.3
Web site design or hosting	Large	69.3	93.4

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





Capital outlays on ICT

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

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Source: Stats Can 358-0201



Investments in training

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

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	8.6
Employee resistance to introduction of new technology	Total	9.6	17.6
Lack of technical expertise and skilled personnel in-house	Total	29.5	12.6
Lack of technical expertise and skilled personnel in-house	Large	18.4	6.8
New systems not compatible with existing systems	Large	18	5.5
Security and/or privacy concerns	Total	18.7	6.9
Unaware of what technologies exist in the marketplace	Total	16.4	5.8





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



G STADUATE SCHOOL OF SEPUBLIC POLICY

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





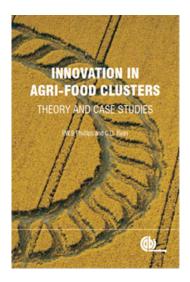
Theme 3 Methods (so far)

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 ≣≣ graduate school of
SASKATCHEWAN		EPUBLIC POLICY



GenomePrairie





The Global Digital Revolution and Canadian Agriculture and Mining

Peter W.B. Phillips, Ph.D. Distinguished Professor of Public Policy

Brian Wixted, Ph.D. Adjunct Professor

Johnson-Shoyama Graduate School of Public Policy Saskatoon, Canada



