THE DIGITAL TRANSFORMATION OF ROW CROP AGRICULTURE

A Report to the Iowa AgState Group

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DESCRIPTION OF IOWA AGSTATE

HISTORY

The seeds of the Iowa AgState Group were planted in the spring of 1997 as representatives of farm and commodity organizations, agribusinesses, state government and Iowa State University began to talk about the need for a long-range, strategic plan for Iowa agriculture. A name designed to help the public understand the purpose of the group was chosen. Iowa AgState is an acronym for "Agricultural Strategic Thinkers Acting Together Effectively."

The Vision and Mission Statements for Iowa AgState are:

VISION STATEMENT

- Empower Iowans to lead the world in responsibly-produced food and agricultural products to not only meet, but exceed, the demands of customers.

MISSION STATEMENT

- Dedicated to identifying challenges and opportunities in Iowa agriculture and recommending changes to help the entire state achieve the greatest possible benefit from Iowa's food, materials, and products industry.

MEMBER ORGANIZATIONS

- Agribusiness Association of Iowa
- Dairy Iowa
- Iowa Cattlemen's Association
- Iowa Corn Growers Association
- Iowa Corn Promotion Board
- Iowa Department of Agriculture and Land Stewardship
- Iowa Department of Economic Development
- Iowa Farm Bureau Federation
- Iowa Institute for Cooperatives
- Iowa Pork Producers Association
- Iowa Poultry Association
- Iowa Soybean Association
- Iowa State University College of Agriculture and Life Sciences
- Iowa Turkey Federation
- Midwest Dairy Association

MOTIVATION FOR THIS PROJECT

- Iowa farmers have always been innovators in adopting new technology.
- During the last two decades, precision agriculture tools have been adopted by Iowa farmers with somewhat mixed success: –
  - *Some tools being highly regarded as very useful;*
  - *Other tools providing minimal value to farmers.*
- During 2013-14, concern began to grow within farmer organizations about the use and potential misuse of farm data.
- The promise of Big Data in agriculture was alluring, but there was also concern about the potential adoption challenges of the technology.
- Several farmer organizations in Iowa decided to ask AgState, as an umbrella organization for state-wide agriculture, to investigate the implications of Big Data for farmers.

THE TASK FORCE

The consulting team was guided by a six member Task Force that devoted major amounts of time and invaluable insights to the project. Task Force members included:

- Dr. Ed Anderson, Chair, Iowa Soybean Association
- Dr. Matt Darr, Iowa State University
- Kim Heckert, Iowa Institute for Cooperatives
- Brian Jones, Iowa Corn
- Dean Lemke, Agribusiness Association of Iowa
- Dave Miller, Iowa Farm Bureau Federation

This report is much stronger because of the many conversations, discussions, and debates with the Task Force.

BACKGROUND

The following are key terms and definitions that are used throughout this report:

- **Big Data:** Data whose scale, diversity, and complexity require new architecture, techniques, algorithms, and analytics to manage it and extract value and hidden knowledge from it, e.g., weather data sets, satellite imagery of large farming areas, and aggregated farm level data from hundreds of thousands of acres.
- **Cloud Computing:** Computing in which large groups of remote servers are networked to allow centralized data storage and online access to computer services or resources.
- **Precision Agriculture:** The use of new tools that give farmers better operational control, e.g., auto-steer, yield monitors, variable rate applicators and planters. These are the hardware and software tools developed over the last two decades for key farming tasks.
- **Prescription Agriculture:** Detailed prescription of agronomic practices to maximize yield and profit per acre using computer algorithms, e.g., FieldScripts, Encirca, Answer Tech. These are sophisticated solutions which are largely based on computer models that are being introduced for row crop agriculture.
- **Enterprise Agriculture:** An integrated computer platform including planning, agronomy, human resource management, work orders, purchasing systems, risk management, inventory management, logistics control, machinery maintenance, marketing, and profit per acre. This is the development of an Enterprise Resource Planning system for the farm.
- **Digital Transformation:** This refers to the changes and challenges associated with digital technology application and integration into all aspects of agriculture. It is the shift from the physical to the digital.
- **Digital Agriculture:** A family of activities related to farming that includes Precision Agriculture, Prescription Agriculture, Enterprise Agriculture and depends on the collection, use, coordination, and analysis of data from a multiplicity of sources with the goal of optimizing productivity, profitability, and sustainability of farming operations, e.g., new decision making tools and new solutions. This is the comprehensive term used throughout this report that defines the complex process of digital transformation in farming and directly related sectors.
- **Advanced Farming:** The research activities that are designed to advance Digital Agriculture to achieve productivity and sustainability long-term, e.g., predictive phenomics. This concept is analogous to Advanced Manufacturing in the industrial sector.

The following abbreviations are used in this report:

- **APIs** – Application Programming Interface – In computer software an API allows software and hardware developed by different companies to “talk” to each other. This is a critical link to make the technology easier to use.
- **ATPs** – Agricultural Technology Providers – Companies that sell highly technical products and services to farmers.

- **CPC** – Crop Protection Chemicals.
- **Data Analytics** – The science of examining raw data with the purpose of drawing conclusions about that information.
- **Data Warehouse** – A central repository of integrated, current and historical, data from one or more disparate sources that is used for secure storage, reporting, and data analysis.
- **Embedded Knowledge** – Knowledge that is locked in products, processes, routines, structures, or systems that enables ease of use in practice. A good example is the iPhone.
- **FTE** – Full Time Equivalent employees – Two half-time employees equal 1 FTE.
- **IT** – Information Technology – The science of managing information with computers.
- **OADA** – Open Ag Data Alliance – An organization that seeks to encourage open sharing of data among ATPs.
- **PCAST** – President's Council of Advisors on Science and Technology.
- **Smart Data** – Data that is of high quality when generated or has been corrected post-collection.
- **Technology Pull** – The farmers specify their problems and challenges which can be addressed by technical innovations.
- **Technology Push** – The developers of new products and services attempt to interest the market in the technical innovations that have been made.
- **UAVs** – Unmanned Aerial Vehicles or drones.

The following caveats regarding this report should be noted:

- This report does not endorse any specific company, product, or service. The examples provided are considered appropriate based on the information collected and the analysis of the consulting team.
- All information in this report is considered to be public information.
- The information in this report is based on research conducted through November 15, 2014.

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A. SUMMARY

The purpose of this project was:

> To develop the most appropriate strategy and tactics for row crop farmers to utilize Agricultural Big Data to enhance the productivity, efficiency, and choices of American farmers while also protecting their farm data and intellectual property.

The approach used in this assignment was to:

- Conduct roughly 240 interviews with farmers, company executives, agronomists, industry association leaders, government officials, and academic experts.
- Analyze publicly available information on the internet and company websites.
- Lead four Focus Groups.
- Conduct an electronic survey of Iowa farmers.
- Conduct an electronic survey of Iowa agronomists.
- Synthesize all of the findings.
- Develop a farmer-centric strategy for the member organizations of Iowa AgState based on the findings and conclusions.

1. The New Digital Technology

The Digital Transformation of row crop agriculture is being driven by the rapid development of computer and communications technology in the U.S. economy, and the successful development of Precision Agriculture over the last 20 years. The wide adoption of yield monitors, GPS technologies and variable application equipment for seeds, fertilizer, and chemicals has enabled the development of computer generated prescriptions which have been introduced during the last few years. Farmers are experiencing a transition from simple mechanical based operations to complex computer based systems of systems.

A Technology Map in the form of a 6x3 matrix has been developed to: (1) categorize the very large array of products, services, and technologies that have been introduced and (2) identify how leading companies are positioned in the market. The major product and service categories are Precision Ag Equipment, Data Warehouse, Ag Retailer Software, Smart Data Deterministic Models, Probabilistic Models, and Farm Enterprise Systems. The major Technology Drivers are Data Generation and Capture, Cloud and Computer Processing Capacity, and Delivery Systems. The first two drivers move at the rapid pace of U.S. scientific and technology development and the third driver is based on the annual crop cycle.

The Gartner (a leading technology consulting firm) Quadrant methodology has been used to identify Leaders, Challengers, Visionaries, and Niche Players. The Leaders are John Deere & Co, DuPont Pioneer, Monsanto/The Climate Corp., SST Software, and WinField / Land O'Lakes.

Key conclusions are as follows:

- The Digital Transformation of row crop agriculture compares with past technological changes such as mechanization, hybrid seeds, and biotechnology.
- Data stewardship both in terms of privacy and security is a major challenge that will be prevalent for a long time.
- Digital Agriculture is still at an early stage of the adoption, and there is still time to shape both the technologies and the manner of adoption.
- Farmers are faced with a vast array of new products and services that do not have common standards so there is a major systems engineering problem to be solved.
- Decision-making in the future will be a complex mix of human and computer factors.

2. Company Positioning and Business Models

The business platforms that have been developed for each of the five leading companies identified above have been defined with an emphasis on the sources and structure used for technology development, the way the market is being accessed, and the major target customers. The level of investment is impressive with several companies reaching the $1 Billion plus level, and there is a significant level of partnering and collaboration. Digital Agriculture is still at an early stage of development and is thus far less consolidated than the more mature segments of the agricultural sector.

At this early stage there is still a lot of flux in the business models with a variety of approaches being tested. A key challenge is that, with the exception of Precision Agriculture tools such as auto-steer, telematics, and row shut-offs, the value for many of the products and services have not yet been clearly established.

It will be necessary to define clear value for both tools and solutions before sustainable business models can be developed.

3. The Education Challenge

The Focus Groups, the farmer survey, and many interviews with individual farmers confirmed that the current state of Digital Agriculture technology is complex and confusing to the average farmer. The technology providers should improve their products and services so that farmers are offered solutions rather than tools.

The farmer survey indicated a very wide range of farmer attitudes toward the introduction of Digital Agriculture ranging from skepticism and fear to enthusiastic adoption. The Iowa AgState member organizations should assist their stakeholders to become informed about the technology so that farmers, ag retailers, other businesses, and policy makers can make informed decisions regarding their responses to the technology.

4. Policy Issues

A national initiative led by the American Farm Bureau Federation has focused on the appropriate guidelines for the ownership and use of data between farmers and the major technology companies. AgGateway is developing standards and guidelines to enhance the ease of data exchange among different service providers that serve farmers. The Open Agricultural Data Alliance is developing APIs that will facilitate the transfer of data to and from companies under the control of farmers. All of these efforts are making a major contribution to the development of Digital Agriculture, and all of them serve the best interests of farmers.

To date the industry has not focused much attention on the legal uncertainty about data ownership and usage rights among farm operators, land owners, ag retailers, and other local service providers to farmers. These issues must also be resolved for Digital Agriculture to realize its full potential. One of the strategic initiatives cited below requires that the issue of ownership and use of data at the local level be resolved with clear, fair standards and guidelines.

5. Considerations for Strategy Development

The current status of Digital Agriculture can be summarized at a high level as follows:

- This technology will continue to improve rapidly.
- The farmers that adopt this technology will have an advantage in renting land and will expand.
- There is a significant gap between those farmers who are prepared to adopt this technology and those who are skeptical and/or fearful of it.

Therefore, the farmer organizations and the ag retailer organizations within Iowa AgState should assist their constituents in adopting the technology.

Four key issues surfaced repeatedly throughout the assignment as interviewees grappled with the implications of Digital Agriculture. These key issues were:

1. Will all of the components of Digital Agriculture combine to create a major "inflection point" in productivity similar to the introduction of hybrid corn many decades ago?
2. Will Digital Agriculture cause the row crop sector to become integrated, i.e., coordinated through contracts with farm operators by a few large ATPs or a handful of large corn and soybean customers?
3. How rapidly will consolidation occur within the row crop sector and among ag retailers?
4. Will the sophisticated agronomy models allow computers to provide agronomic advice with little local agronomic input?

While it is impossible to predict with precise accuracy how the technology will develop and how the industry will shift, the statements below represent credible scenarios for each of these questions.

1. During the next four years or so, Digital Agriculture will probably provide gradual improvements in productivity; however, beyond this time period Digital Agriculture has the potential to make significant step-function improvements in productivity and profitability.
2. It is unlikely that the major ATPs will attempt to integrate row crop production; however, it is conceivable that major corn and soybean customers might attempt to do so to manage their business more efficiently and control product quality more effectively.
3. Digital Agriculture is likely to accelerate consolidation of farm operators and ag retailers. In this respect it is no different than other new technologies introduced to agriculture.
4. Computers will assume a much greater role in the processing and interpretation of agronomic data in the future. Given the complexity of weather, crop diseases, and

agronomic variation, human judgment will always be required to some extent – but not in the same way as is presently the case.

6. A Farmer-Centric Strategy

The five major initiatives of the farmer-centric strategy adopted by Iowa AgState are:

- **Education:** Provide continuous, on-going education for farmers, ag retailers, other local businesses, and policy makers that will enable them to make informed decisions.
- **Data Warehouse:** Create an independent, farmer-controlled data warehouse for farm level data and aggregated agronomic data which can be used to better serve farmer participants.
- **Assessment:** Create mechanisms to provide an assessment of the many products, services, and business models in the market while promoting uniform, agreed-upon industry standards and guidelines.
- **Technology Pull:** Drive a "technology pull" strategy focused on products and services that provide solutions to farmer problems rather than just complicated tools.
- **Research:** Create a center for inter-disciplinary research that will position Iowa farmers to be at the cutting edge of digital technology for generations to come.

7. Next Steps

The strategy described above requires the collaboration and financial resources of many organizations beyond Iowa AgState and beyond the State of Iowa. This effort must now "pivot quickly" to engage the support and engagement of national agricultural organizations and state organizations in other states. The Iowa AgState project should be combined with other efforts that are seeking to shape the emergence of Digital Agriculture from a farmer-centric perspective.

The Board of Directors for Iowa AgState has approved the above strategy and is now pursuing efforts to expand the base of support for the strategy described in this report.

B. THE NEW DIGITAL TECHNOLOGY

During the course of the project the consulting team realized that a choice was required between a project with a tight focus on Big Data and a project with a broader focus on the Digital Transformation of row crop farming. The latter option was adopted since it would enable the development of a broader understanding of the key trends driving change and place the development of Big Data in the correct context.

1. Introduction to the Technology

The Digital Transformation of row crop agriculture is being driven by the rapid development of computer and communications technology in the U.S. economy, and the successful development of Precision Agriculture over the last 20 years. The wide adoption of yield monitors, GPS technologies and variable application equipment for seeds, fertilizer and chemicals has enabled the development of computer generated prescriptions which have been introduced during the last few years.

Currently, U.S. agriculture is at the leading edge of these broad trends, and a recent article by Professor Michael Porter of the Harvard Business School and James E. Heppelman used row crop farming as a case study to identify the major phases of digital transformation.

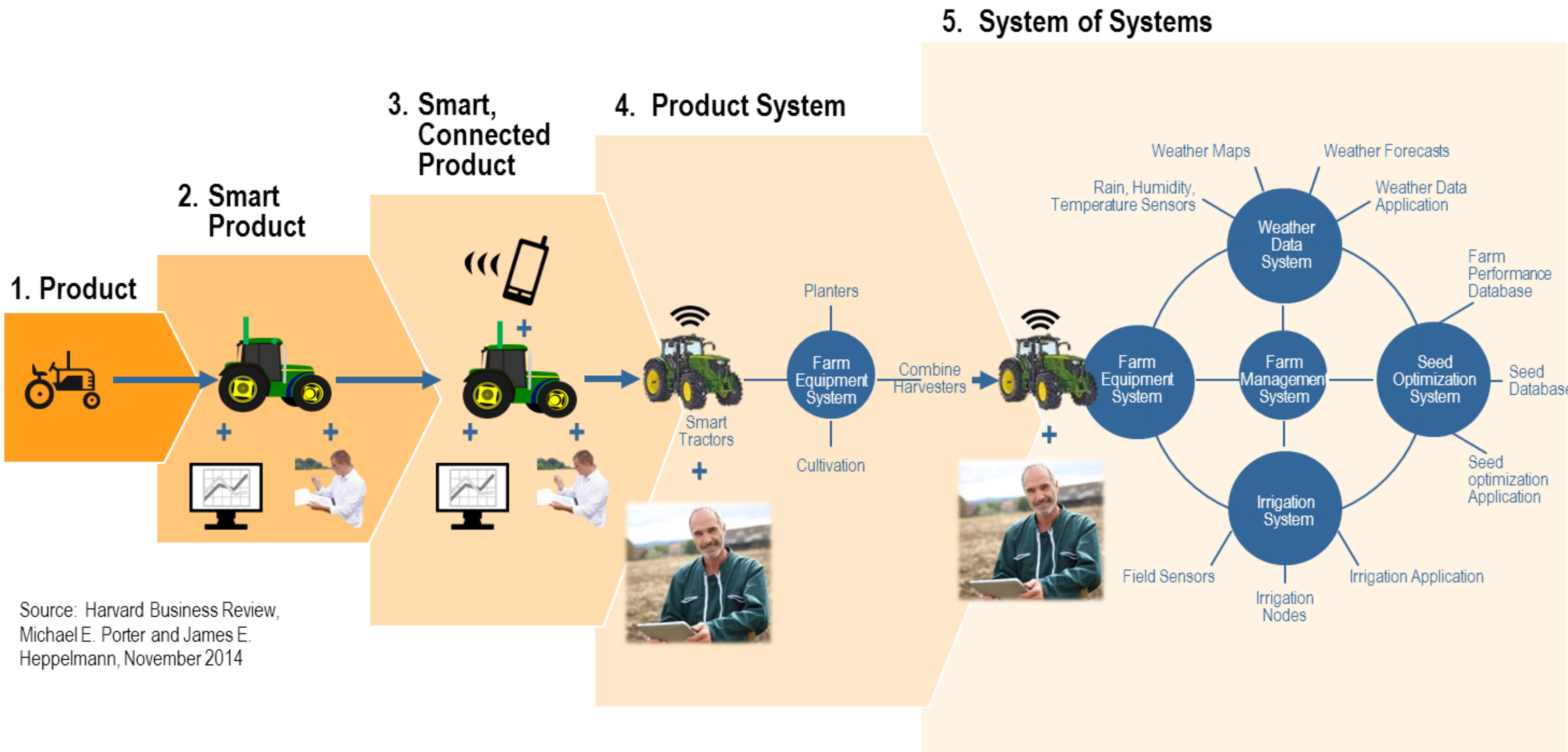
Figure 1. The Major Phases in the Digital Transformation of Row Crop Agriculture

Major Phase	Examples	Development Status
Product	• The traditional tractor which provided mechanized power on the farm	• Farm mechanization in the past. This is a mechanical-human system.
Smart Product	• A tractor or other equipment with the ability to capture performance and other data. Data transfer is via a card or stick.	• This development commenced in the early 1990s with the introduction of yield monitors, etc. It is still mainly a mechanical-human system.
Smart Connected Product	• A tractor or other equipment that can collect data and is connected via wireless to the cloud.	• This has become viable during the last 5 years and is now the state of the art. It has a computer-human-mechanical balance.
Product System	• A group of fully connected farm machines that perform functions such as planting, cultivation, fertilizer and chemical application, harvesting, and function as an integrated system.	• The most advanced farm operators can achieve this level today but there are major issues of incompatibility. It is more computer driven than mechanical-human driven.
System of Systems	• This is Enterprise Agriculture as, defined above, with all of the operational systems on the farm connected in an optimized manner.	• This is still in development but represents the future. • While largely computer driven, the human element is still important due to the biological nature of agriculture.

Source: Harvard Business Review, November 2014

A visual representation follows.

Figure 2. The Digital Transformation of Row Crop Agriculture



Source: Harvard Business Review, Michael E. Porter and James E. Heppelmann, November 2014

At the level of implementation on the farm, Digital Agriculture can be understood as a cloud based "system of systems" that includes the following:

- Remote sensors and smart farm machines that extract and store public and private agronomic data, machine data, and weather data in the cloud.
- Machine and human networks that collaborate in the generation and use of data.
- Farm-specific financial and accounting data systems.
- Big Data and Big Analytics that use computer-based algorithms and data analysis.
- Data visualization for human interpretation of insight and information.
- A communication system for the sharing of data, decisions and implementation plans with the right people, machines and vendors at the right time.

While the technology is available to generate and use a vast amount of data, several data collection and use challenges have been identified:

- Human Capital: Farmers need to be Tech-Savvy and to have access to IT skills for use of data in decision making.
- Quality Data: The majority of the data generated currently is not useable due to poor quality, e.g. lack of calibration.
- Data Access: Much of the data is on cards, sticks, hard drives or in binders of printed documents making access difficult.
- Better Analytics are required to automate the analysis of imagery and maps.
- Agronomic data held by ag retailers that is not easily available for farmer use and aggregation in a broad manner.

To meet these challenges the following key enablers have been identified:

- More Embedded Knowledge in the equipment, devices or systems that are developed so that they are easy to use by farmers.
- More standardization across the wide range of products, services, and systems that are being offered.
- Validation processes for services offered and business models.
- Effective security for data held both on-farm and off-farm.
- Technology Pull processes that empower farmers to define problems and influence innovation.
- User Training that can be accessed by the broad population of farmers.
- Attracting data scientists, software engineers, and computer scientists to the sector.

2. The Technology Map

The following approach was developed to categorize the vast number of products, services, and technologies being offered in the sector. Six major types of products and services and three key technology drivers have been identified. For this report, the map will be presented in the form of two 3x3 matrices. The illustrative examples provided are considered appropriate based on the information collected and the analysis of the consulting team.

Figure 3. Technology Map-Matrix 1

	Precision Ag Equipment	Data Warehouse	Ag Retailer Software
Data Generation & Capture	• John Deere • Trimble/CaseIH • Raven • 640 Labs • Ag Leader	• Geosys-LOL • GeoVantage • SST Software	• SST Software • Ag Junction • SMS • Premier Crop • Raven
Cloud & Computer Processing Capacity	• MyJohnDeere.com • Trimble • Ag Leader	• WinField Data Silo • Mapshots • GeoVantage • Amazon Web Services • SST Software	• SST Software • Ag Junction • Premier Crop • Raven
Delivery Systems	• Trimble • BASF	• Answer Tech • Mapshots • SST Software	• Agronomists -- ag retailers • Crop advisors

The definitions for each vertical column are as follows:

- Precision Ag Equipment includes precision ag tools, smart machines, yield monitors, and telematics – all of which generate on-farm data.
- Data Warehouse includes data generation and storage of farm data that is collected from many sources and used for data sharing.
- Ag Retailer Software includes the specialized software packages used by ag retailers and crop advisors to serve farmers and for internal logistics and operations by ag retailers.

Figure 4. Technology Map-Matrix 2

	Smart Data Deterministic Models	Probabilistic Models	Farm Enterprise System
Data Generation & Capture	• Farm Data to Vendor Cloud • Seed company data • Public data – weather & soil types • Market data	• Farm Link/True Harvest. • The Climate Corp. • AGSOLVER	• Current vendors and buyers: • Agronomic data • Farm Accounts • Machine data in future • Ag retailer data
Cloud & Computer Processing Capacity	• Encirca* • 360 Yield Center • My Farms	• The Climate Corp • True Harvest • IBM • Farmer's Business Network-FBN	• Conservis • Granular • Farmlogs • MyAgCentral
Delivery Systems	• Encirca* • My Farms – regional seed companies • Beck's Seed	• True Harvest • Climate Basic • AGSOLVER • FBN	• Advisors to farmers • Vendor IT customer support

*Elements of the Encirca model are probabilistic

The definitions used for each vertical column are as follows:

- Smart Data Deterministic Models include good quality, corrected farm data and utilize key variables with point estimates based on averages.
- Probabilistic Models provide outcomes in the form of a probability distribution rather than an average point estimate.
- Farm Enterprise Systems are integrated software applications with a common process that includes farm level planning, purchasing, field operations, inventory, marketing, accounting, and financial elements.

The Technology Map provides a mechanism to understand the vast array of products and services being offered to farmers and to categorize these offers for purposes of comparison.

We recommend the use of this structured approach for educational purposes and for the evaluation of the products and services that are offered to farmers taking into account the fact that each product/service category tends to be a silo with limited horizontal connections.

3. The Key Players

The following assessment of the key players has been developed based on a modified Gartner analysis using the "completeness of the company vision" and the "ability to execute" as the key dimensions. Gartner Inc. is a leading information technology research and advisory company. The definitions below have been modified to suit the needs of this project.

The definitions used are as follows:

- **Leaders** execute well against their current vision and are well positioned for tomorrow.
- **Visionaries** understand where the market is going or have a vision for changing market rules, but are still at an early/beta stage.
- **Niche Players** focus successfully on a defined segment.
- **Challengers** are executing on their vision but still need to establish a position in the market.

Figure 5. Assessment of Key Players

Completeness of Vision

Ability to Execute

Challengers	Leaders
• AGCO • CaseIH • Mapshots • Raven • Trimble	• John Deere & Co • Dupont Pioneer • Monsanto TCC • SST Development • WinField LOL
Niche Players	**Visionaries**
• Ag Junction • Ag Leader • Conservis • GeoVantage • MyFarms	• AGSOLVER • Beck's Hybrids • Farm Link/True Harvest • FBN

This assessment is a snapshot at a single point in time, and given the dynamic nature of the business the assessment can be expected to change as new products and services are introduced to the market.

All of the players identified are well regarded participants in the market with competitive products and services. Some companies are more focused on a specific segment of the market at this stage – such as the Niche Players. Other companies have very interesting offers but are at an early stage of development as with the Visionaries; the Challengers are executing well on a more limited vision.

The five key players that have been identified as Leaders based on the interviews and desk analysis during the course of this project all have a well-defined vision and are demonstrating the ability to execute on that vision. The next section of this report will focus on these five players and present their platforms in more detail.

C. Company Positioning and Business Models

1. Company Platforms

The following table sets out the structure of the platforms for John Deere & Co, DuPont Pioneer, and Monsanto/The Climate Corp. The backend indicates how the services are developed, and the frontend indicates how the services are delivered. The main user targets for each company are also identified.

Figure 6. Company Positioning: Backend and Frontend

	Deere & Co.	DuPont Pioneer	Monsanto/TCC
Backend Structure and Partners	• Software Cos: 100+ • Ag Gateway: 85+ companies • JD Link • IT Staff: 600-800 • API Developers	• John Deere & Co • DTN • USDA • Land Grant Universities • AGCO • Raven • Pioneer Agronomy • Encirca Tech Group	• Climate Corp: 200-300 IT staff • Precision Planting • Monsanto Seed Group • AgGateway • OADA • CaseIH
Frontend Structure and Partners	• John Deere Dealers • MyJohnDeere.com • DuPont Pioneer • Growmark • Dow Agro • BASF • Bayer Crop Science • Ag retailers	• Encirca sales agents • Encirca.Pioneer.com • Pioneer seed sales agents	• Climate agronomy reps • Climate. Com • Crop insurance agents • Helena • Growmark • CPS • WinField / LOL • Ag retailers
Target Users	• Farmers	• Farmers	• Farmers

A summary of the current positioning for each company is as follows:

John Deere & Co

- The data based service business is a major strategic focus for the company with about $1 Billion invested and a long term target of 20%+ of corporate revenues.
- The focus has been on data generation and capture from the JD machines using a closed proprietary software system.
- The company is open to partnering with whoever wants to partner; conditions for these agronomic partnerships are not public at this point.

DuPont Pioneer

- New data based services are a strategic priority for DuPont Pioneer with an established revenue target of $500 million in 10 years. The brand name is Encirca Services.
- The Encirca business is separate from the U.S. seed sales system and is considered to be brand neutral regarding seed and equipment.
- Encirca services focus on the technical and economic aspects of farming that drive productivity and profitability.

Monsanto / The Climate Corp.

- This is a major strategic priority for Monsanto with about $1.25 billion invested and having the goal of establishing a new business segment that contributes to earnings within five years.
- The services are being developed on the basis of an open source approach to software with the key elements being: (1) measurement of the farming world; (2) development of probabilistic models that are proprietary; (3) development of tools and apps that deliver insights and recommendations to farmers. The Climate Corp is willing to collaborate with a wide range of partners.
- Most of the data used, such as weather and soils information, is from the public domain but the models will perform more effectively if actual farm data is provided.

The following table sets out the structure and platforms for SST Software and WinField/Land O'Lakes. The backend indicates how services are developed and the frontend indicates how the services are delivered. The main user targets are also identified.

Figure 7. Company Positioning — Backend and Frontend

	SST Software	WinField / Land O'Lakes
Backend Structure and Partners	• SST Software: 75-100 staff • Data warehouse • AgX platform • Raven Slingshot • Ag Gateway: 85 + cos	• Geosys: Answer Plot: R7 tool • Climate Corp • Answer Tech: Winfield Data Silo • Ag Gateway: 85+ cos • OADA: 9 cos
Frontend Structure and Partners	• Helena • Ag Retailer A • Ag Retailer B • Co-op A • Co-op B • Crop consultants	• WinField.com • Co-op A • Co-op B • Ag retailer A • Ag retailer B
Target Users	• Retailers and crop consultants	• Retailers and large farm operators

A summary for the positioning of each company follows:

SST Software

- A technology company focused on providing IT technical infrastructure, data warehouse and data processing services to ag retailers and some farmers. Currently SST touches about 82 million acres in the U.S. and over 100 million acres globally.
- Fertility models for ag retailers and local co-ops are a key product; these models can be customized for each retailer and sold under a private label.
- AgX is a new addition to the SST platform that overcomes the current issues with the lack of standards in the industry, incompatibility, and fragmentation of the services provided to farmers.

WinField / Land O'Lakes

- WinField is the leading customer for all of the major U.S. seed companies with the exception of Pioneer. The key focus of the data services business is on supporting seed sales and proprietary product businesses.
- The main route to market is via the local cooperatives with a dedicated team using the "train the trainer approach." WinField / LOL is also supporting the retailers in introducing the technology to the largest growers.
- Significant internal capabilities have been acquired or built, and an important partnership has been established with The Climate Corp.

2. Business Models

The major findings relating to business models are that: (1) the industry has not yet settled on well-defined models, and (2) the industry has yet to establish clear value for the new services being offered.

The following table is focused on specific tools and solutions with an evaluation of whether or not clear value has been established. There are several well accepted tools where value has been established but there is also a large gap for solutions that have clear value.

Both industry participants and farmers have expressed the need for solutions. A number of potential value creating solutions have been identified; after greater experience has been gained, it will be possible to define value for these. Several of the tools and apps are at the launch stage and thus have not yet had sufficient experience to establish value.

On the positive side, it should be noted that many beta testers believe that the potential for value creation and capture is significant, and they continue to be very interested in the new products and service being offered. The major potential sources of value are agronomic value, operational management and logistics, crop budgeting at the sub-field level, and efficient information sharing.

It will be necessary to define value clearly before sustainable business models can be defined.

Figure 8. Establishing Value is a Challenge

	Tools	Solutions
Clear Value	• Auto steer • Variable rate seeding/fertilizer • Aerial imagery • Telematics	
Unclear Value	• Yield Maps • UAVs • Local weather • Scouting apps • Multi-hybrid planting	• Current prescription models • Nitrogen management systems. • Farm Enterprise systems • Benchmarking

As business models become more defined, the following criteria are proposed to evaluate the models. This evaluation can be carried out at the level of the individual farmer or by an organization that is independent of the ATPs.

Figure 9. Criteria to Evaluate Business Models

Criterion	Evaluation Methodology
• Economic value generated	• Yield increase • Reduction of input costs • Other cost savings
• Cost of the product or service	• Subscription and software fees • Cost per acre with a minimum • Sharing of value generated • Share of yield per acre • Investment amount
• ROI for products or services	• DCF or economic payback
• Transparence of pricing	• No hidden fees or costs
• Standalone or tied product/service offer	• Bundled/unbundled with other products or services
• Data ownership, use and control	• Farm Data: Permission sharing system • Aggregated Data: Ownership and farmer access
• Vendor Independence	• Product/service agnostic
• Software approach by ATP	• Closed proprietary or open source software

Additional findings regarding the potential economic benefits for farmer:

- A survey conducted by the American Farm Bureau Federation recently reported that farmers indicated that the use of precision technologies have reduced input cost by 15% on average and increased crop yield by an average of 13%. This is consistent with the survey and focus group findings.
- Based on the input received from "Innovators" in the focus groups, it is estimated that, using the best available Digital Technology and high quality data, it would be possible to achieve an incremental economic gain of $33-62 per acre of corn. The key assumptions are: (1) corn yield gain of 5-10 bushels/acre, (2) corn price of $3.50 per bushel, (3) nitrogen savings of $25-30/acre, and (4) an ATP fee of $3-10 per acre. The benefit is clearly significant in the current economic environment and will support continued testing of the new technologies by progressive farmers.

3. Key Conclusions Regarding Technology and Business Models

- The Digital Transformation of row crop agriculture compares with past technological changes such as mechanization, hybrid seeds, and biotechnology.
- Digital Agriculture builds on Precision Agriculture tools and systems that have been developed and adopted over the last two decades.
- Data stewardship both in terms of privacy and security is a major challenge that will be prevalent for a long time.
- Digital Agriculture is still at an early stage of the adoption, and there is still time to shape both the technologies and the manner of adoption.
- Farmers are faced with a vast array of new products and services that do not have common standards so there is a major systems engineering problem to be solved.
- Decision-making in the future will be a complex mix of human and computer factors.
- It will be necessary to define value clearly before sustainable business models can be defined.

D. THE EDUCATION CHALLENGE

1. Summary of the Farmer Survey

During the course of this project, an electronic farmer survey was conducted. Iowa Farm Bureau Federation, Iowa Soybean Association, and Iowa Corn Growers Association promoted the web-based survey to their constituents. A total of 384 farmers participated in the survey.

Major findings from the multiple choice questions of the survey included:

- The primary reasons for experimenting with new tools in agriculture are:
  - Increased profitability
  - Higher yields
  - Increased overall farm productivity

- Many of the Digital Agriculture products and services currently on the market are complex and difficult for farmers to use.
- Roughly 80% of farmers taking the survey are concerned or extremely concerned about unauthorized access to their farm data.
- The most trusted sources of information about new products and services, in descending order of trustworthiness, are:
  - The farmer's ag retailer agronomist
  - The farmer's seed salesman
  - An independent crop consultant
  - The Extension Service staff person
  - Neighbors
  - The farmer's equipment dealer

After numerous multiple choice questions, the survey concluded with the open-ended question,

> *"What other thoughts or comments would you like to share about precision agriculture or prescription agriculture?"*

The 95 responses to this final question can be grouped into three major categories:

1. **Skeptical and/or Fearful of the New Technology – 65%**
   - The biggest concern is misuse of farm data by ATPs, activists, government, hackers, and grain traders.
   - Some fear that it favors the large farmers.
   - Concerns that prescriptions will recommend only some products, i.e., are biased.
   - It doesn't work. Agriculture is a complex biological system.
2. **Neutral or Nuanced in Attitudes – 19%**
   - It has potential, but must be implemented carefully.
3. **Embracing the New Technology – 16%**
   - The technology is here to stay. Let's embrace it and make it work for us.
   - No one that is highly profitable today is doing it with only their own ideas and crop data.

The major educational needs of farmers – as derived from the farmer survey, the farmer interviews, and the farmer focus groups are:

- A clear explanation of how to understand the new Digital Agriculture technology.
- An assessment of whether the new tools actually perform as indicated by the manufacturers.
- An assessment of the legal documents that farmers are required to sign when purchasing the new products and services.
- An independent evaluation of the economic benefit of the new technology.

2. Summary of the Agronomist Survey

During the course of this project, an electronic survey was conducted with agronomists across Iowa. The Agribusiness Association of Iowa and the Iowa Institute for Cooperatives promoted the web-based survey to their constituents. A total of 215 agronomists and managers of ag retailers participated in the survey.

The agronomists expressed many of the same concerns and attitudes expressed by the farmers. For example, three of the major concerns among agronomists were:

- The potential use of the massive amounts of data for government regulation.
- The unauthorized access of data through computer hackers.
- The acceleration of consolidation of farm operators and ag retailers.

However, the above concerns were somewhat less strongly expressed by the agronomists than the farmers. That is, both groups expressed these as serious concerns, but the farmers were much more adamant about these issues.

The agronomists also believed that the new technology posed business threats and opportunities for the ag retailers.

The investment required at the ag retailers to serve the new technology may intensify competition among retailers and force some to exit. In addition, the ATPs may compete with ag retailers through the new services provided by the ATPs. In both cases, competition for ag retailers will likely intensify significantly.

On the other hand the new technology may provide new business opportunities for ag retailers, e.g., data management services for farmers and the use of UAVs for farming operations.

E. Policy Issues

One of the driving issues that stimulated the initiation of this project was farmer concern about the ownership and control of farm data. During the course of this assignment, these issues were raised with a very high level of frequency by farmers in the focus groups, in the electronic survey of Iowa farmers, and in the individual interviews with farmers.

The primary issues of concern are captured in concise form by the phrases displayed in the list below.

- Farmer ownership of data
- Farmer control of data
- Disclosure of data usage
- Farmer choice for use of data
- Portability of data
- Security from misuse
- Vulnerability to FOIA
- Compatibility of systems
- Protection of GPS
- Regulation of UAVs
- Use of aggregated data
- Consistency of agreements
- Simple language
- Transparency and consistency

It cannot be stated too strongly, that the vast majority of farmers have serious concerns about the ownership and control of data in relation to the major ATPs.

However, this project did not devote much effort to analyzing the underlying issues or possible solutions, by directive of the Iowa AgState Board of Directors, to avoid duplication of efforts with a national effort dealing with these issues led by the American Farm Bureau Federation along with the major agricultural commodity groups. These issues have been dealt with in a productive fashion and do not require further time or effort from this project.

In addition, AgGateway is developing standards and guidelines to enhance the ease of data exchange among different service providers that serve farmers, while the Open Agricultural Data Alliance is developing APIs that will facilitate the transfer of data to and from companies under the control of farmers. All of these efforts are invaluable and should be supported.

However, similar issues need to be resolved about the ownership and control of data at the "local level." That is, there is no widely accepted agreement about the ownership and control of farm data between:

- Land owners and renters (or farm management companies)
  - Cash rental agreements
  - Share crop agreements
- Farm operators and ag retailers
- Farm operators and other service providers
- Chemical and fertilizer applicators
- Drone services
- Current land renters *versus* potential land renters

We believe these issues must be addressed in order to avoid costly litigation in rural communities among local business entities.

In fact, implementation of one of the strategic initiatives described later depends upon resolution of these issues.

F. Considerations for Strategy Development

1. Overall Assessment

The business environment related to Digital Agriculture can be summarized at a high level as follows:

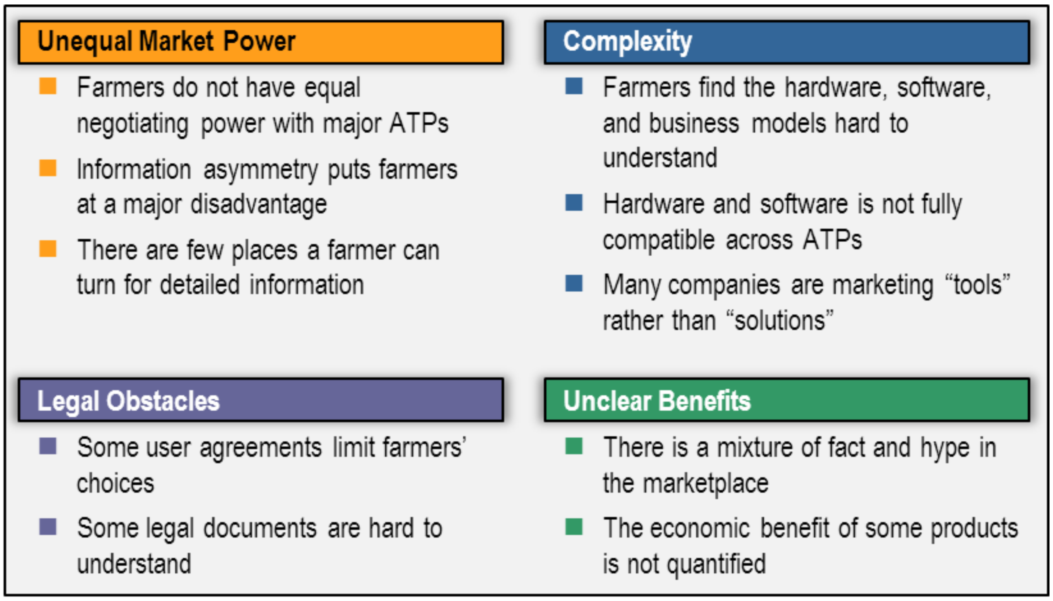
- This technology will continue to improve rapidly.
- Tech savvy farmers are already adopting it with enthusiasm.
- There is likely to be a major turnover in farm operators due to:
  - *The current age of farmers.*
  - *The prospect of low crop prices for the next several years.*
- The farmers that adopt this technology will have an advantage in renting land and will expand.
- There is a significant gap between those farmers who are prepared to adopt this technology and those who are skeptical and/or fearful of it.

Therefore, it is incumbent upon both the farmer organizations and the ag retailer organizations within Iowa AgState to assist their constituents in adopting the technology.

2. Problems to be Addressed by the Strategy

There are four major problem areas that the Iowa AgState strategy for Digital Agriculture should address. Each of these is described briefly in the chart below.

Figure 10. Problems to be Addressed by the Strategy



3. Four Strategic Issues

Four key issues surfaced repeatedly throughout the assignment as interviewees grappled with the implications of Digital Agriculture. These key issues are:

1. Will all of the components of Digital Agriculture combine to create a major "inflection point" in productivity similar to the introduction of hybrid corn many decades ago?
2. Will Digital Agriculture cause the row crop sector to become integrated, i.e., coordinated through contracts with farm operators by:
   - a few large ATPs, or
   - a handful of large corn and soybean customers?
3. How rapidly will consolidation occur within the row crop sector?
4. Will the sophisticated agronomy models allow computers to provide agronomic advice with little local agronomic input?

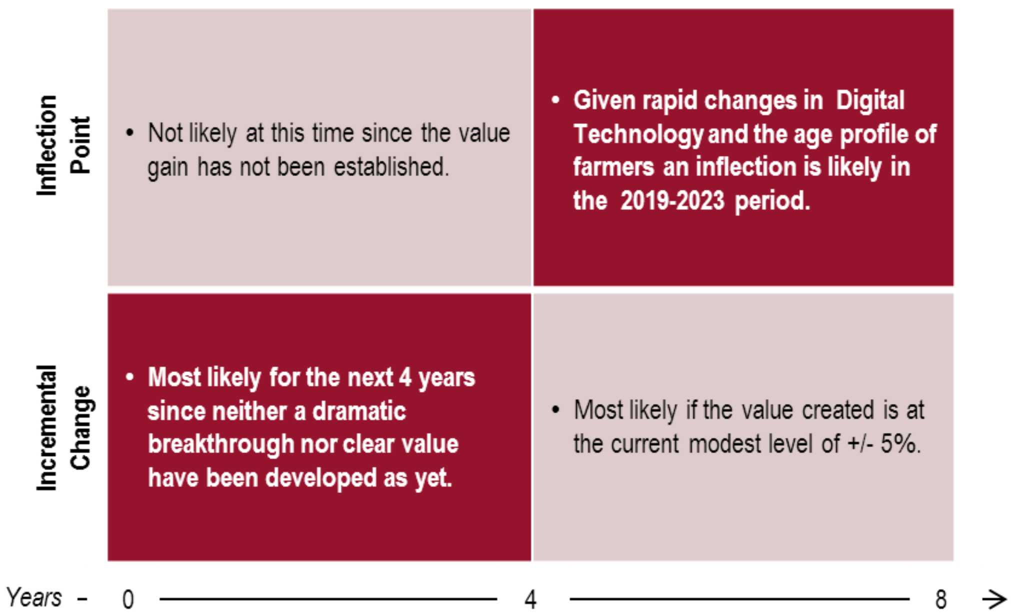
These are difficult questions, but the following presents a credible outlook regarding these complex issues.

i. Technology Inflection Point

Part of the hype surrounding Digital Agriculture is that it will cause the next great technological shift in agriculture that will cause productivity to improve in a dramatic way – similar to the introduction of hybrid corn.

Digital Agriculture is at an early stage in its development and has not yet reached its potential. The potential impact of this technology is captured in the graphic below.

Figure 11. Incremental Change or Inflection Point



It does not appear that Digital Agriculture is currently experiencing a major "step-function" upward in productivity, but the potential is there for the longer term horizon of roughly 5 to 8 years from now.

ii. Integration of Row Crop Sector

The situation is very different for ATPs and the major corn and soybean customers.

For the major ATPs, it is not likely that they will utilize the new technology to control row crop agriculture through astute use of the technology and contracts with farm operations. The major reasons for this conclusion are:

- The integrators of both the broiler and swine industry were marketing products to consumers and were trying to improve product quality to increase sales.
- The ATPs are not selling corn or soybeans to consumers.
- The asset base for row crop production is much greater than for broiler or hog production.

The major customers of corn and soybeans are not in exactly the same situation as the meat companies, but they are in a more similar situation than the ATPs. The possibility of backward integration by the major processors through contracts with farm operators cannot be ruled out because:

- Some farmers need help using the new technology.
- Large corn and soybean users might fill the gap.
- The exit of older farmers will create an opportunity for integration.
- Large feed, ethanol, soy processors, and other industrial users could use integration to control genetics and production conditions for greater product consistency and quality.

iii. Farm Consolidation

Virtually all new technology provides greater incentive for farm consolidation; this technology is no different. Accelerated consolidation of farming operations should be expected, primarily because:

- The prospect of low crop prices provides incentives to leave farming.
- Aging farmers will likely retire while high tech, low cost producers capture more land rentals.
- This technology is simplifying operations for large-scale farmers.
- Large farmers can hire people with specialty skills, e.g., IT and agronomy.

On the other hand, one can argue that the consolidation process may be somewhat slowed because:

- Caps on total farm payments under the Farm Bill may limit consolidation in a low price environment.

iv. Computerization of Agronomic Advice

With the major advance in computer capacity and the marketing of Digital Agriculture by various ATPs, considerable discussion has centered on the way in which agronomic advice will be provided to farmers in the future. The question in its starkest form is:

Will computers replace humans in providing agronomic advice?

While it is extremely difficult to predict precisely where the new computer technology will lead, it is most likely that that human judgment will always be required in making good decisions about a complex biological operation like farming.

However, the computer power now available at reasonable cost will provide farmers with a tool of vast power that they have never had available before. Farmers will be able to control some aspects of the farming process to a degree never dreamed imaginable previously – farming small plots within a field differently and then calculating the profit per acre or per plot individually.

The importance of computerization will certainly increase, and the role of human judgment in agronomic decisions may decline, but row crop production will always require human judgment to some extent from the farmer or his trusted agronomic advisor.

G. A Farmer-Centric Strategy

1. Vision

The vision that drives the Digital Agriculture strategy is:

> American row crop producers that are globally competitive, through continuously increasing yields, reducing costs, and protecting the earth, while maintaining their business independence, choosing among many input products and services, and controlling the use of their farm-specific data

2. Mission

The mission that farmer organizations in Iowa AgState should adopt in relation to Digital Agriculture is:

> To assist Iowa farmers during the Digital Transformation of Agriculture while fostering a business environment that is highly competitive and provides farmers with many business options.

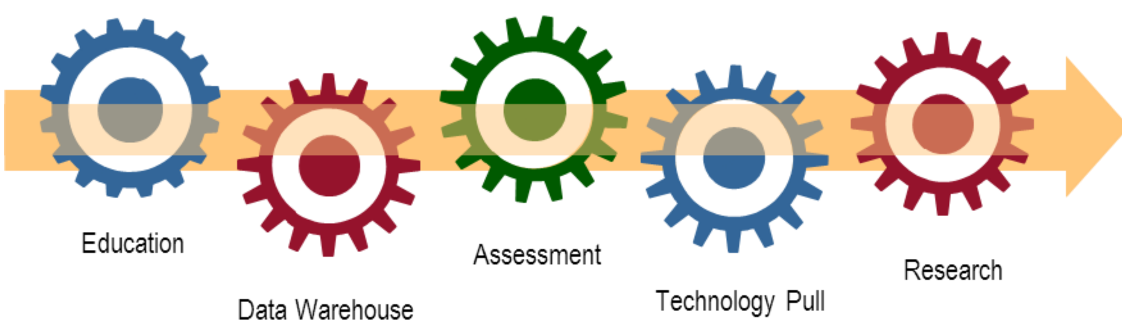
The mission that ag retailer organizations in Iowa AgState should adopt in relation to Digital Agriculture is:

> To assist Iowa ag retailers to: (1) capitalize on the new business opportunities; and (2) mitigate the threats to a strong rural business environment posed by Digital Transformation.

3. Components of a Farmer-Centric Strategy

There are five components of the Digital Agriculture Strategy for Iowa AgState members as depicted in the graphic below.

Figure 12. Farmer-Centric Strategy



4. The Five Strategic Initiatives

The goals for the five major initiatives are listed below:

- **Education:** Provide continuous, on-going education for farmers, ag retailers, other local businesses, and policy makers that will enable them to make informed decisions.
- **Data Warehouse:** Create an independent, farmer-controlled data warehouse for farm level data and aggregated agronomic data which can be used to better serve farmer participants.
- **Assessment:** Create mechanisms to provide an assessment of the many products, services, and business models in the market while promoting uniform, agreed-upon industry standards and guidelines.
- **Technology Pull:** Drive a "technology pull" strategy focused on products and services that provide solutions to farmer problems rather than just complicated tools.
- **Research:** Create a center for inter-disciplinary research that will position Iowa farmers to be at the cutting edge of digital technology for generations to come.

Each of these five goals has several objectives.

1. **Provide continuous, on-going education for farmers, ag retailers, other local businesses, and policy makers that will enable them to make informed decisions.**

   a. Distribute The Hale Group report:
      - Short and long PowerPoint presentations
      - Executive Summary Report
      - Short articles based on The Hale Group report

   b. Conduct state-wide and regional workshops and webinars for farmers, ag retailers, and other businesses on Digital Agriculture:
      - Intensively in 2015
      - Addressing new topics thereafter

   c. Provide the Iowa AgState Board with regular updates on the Digital Transformation of Agriculture developed for this project.

   d. Create short videos on specific topics:
      - Provide short videos on a specific topic so farmers and retailers can learn and apply the knowledge immediately.

   e. Educate State and Federal policy makers
      - Provide timely information about Digital Agriculture to policy makers on any issues which affect farmers and the rural economy

2. **Create an independent, farmer-controlled data warehouse for farm level data and aggregated agronomic data which can be used to better serve farmer participants.**

   a. Develop guidelines for the ownership and use of data among land owners, farm operators, ag retailers, and local businesses.

   b. Define the scope and scale of the agronomic data sets currently held by farmers, ag retailers, and their software providers.

   c. Define the costs and capital requirements for the establishment of a cloud based data warehouse for farmers that is coordinated with ag retailers. Potential options include SST and Amazon Web Services.

   d. Evaluate business structures that would enable both farmers and ag retailers to collaborate in an independent data warehouse entity.

   e. Develop a set of Privacy, Use and Control policies that fully protect the interests of the farmer while providing a high level of security.

   f. Establish the required API's to facilitate access on a permission basis for trusted advisors and ATPs.

   g. Prepare a pilot program that could be tested in 2016 with at least several hundred farmers.

   h. Develop a strategy to optimize the value of local data if the results of the pilot project are positive and establish feasibility.

3. **Create mechanisms to provide an assessment of the many products, services, and business models in the market while promoting uniform, agreed-upon industry standards and guidelines.**

   a. Create a website where farmers share their assessment of specific Digital Agriculture tools similar to Amazon's book evaluation.

   b. Create a mechanism for timely technical assessment for complex products and services similar to the Nebraska Tractor Test, Profi in Germany, or Underwriters Laboratory.

   c. Engage with companies at early development stages so that the products launched receive early, practical feedback and reflect farmer priorities.

   d. Create a mechanism for estimating the economic value of products and services to farmers.

   e. Evaluate alternative business models used by industry participants in terms of clarity, benefits provided, and fee structure.

   f. Simplify the technology through collaboration with standards organizations such as AgGateway and OADA.

   g. Provide an assessment of the farmer-friendliness of legal documents used by manufacturers and service providers, by collecting, analyzing, and scoring the documents.

4. **Drive a "technology pull" strategy focused on products and services that provide solutions to farmer problems rather than just complicated tools.**

   a. Conduct focus groups and surveys to identify the key "pain points" for farmers which are not being addressed by the ATPs.

      - Farmers decide by electronic ballot what is most needed.
      - Define categories of products and services of most interest for farmers.

   b. Conduct outreach to the tech community and ATPs so that the needs of farmers are understood and can be taken into account during the design and development phase for new products and services.

   c. Evaluate the potential for a "Challenge Award" process as a way to influence the direction of new technology development.

5. **Create a center for inter-disciplinary research that will position Iowa farmers to be at the cutting edge of digital technology for generations to come.**

   a. Commence the development of an Institute for Advanced Farming that would be based on the White House Policy to create six large Innovation Institutes in the Agriculture Sector using the public-private partnership model. Leadership by ISU.

   b. Define an inter-disciplinary research platform that includes Digital Agriculture, computer engineering, sensors, robotics, chemistry, genetics, genetic engineering, genomics, phenomics, and other non-traditional disciplines, supported by advanced simulation and predictive computer models.

   c. Conduct an Advanced Farming Workshop at ISU that would bring together all of the interested stakeholders from within the University and across the State of Iowa under the sponsorship of Dr. Steven Leath, President of ISU, Dean Wendy Wintersteen, and Secretary Bill Northey.

   d. Position the Advanced Farming Institute as the equivalent of the U.S. Advanced Manufacturing Institutes which focus on the development of new opportunities in that sector.

   e. Obtain the support of the USDA and the active support of Secretary Vilsack for this initiative. This will require an updating of the PCAST study which was completed in 2012 before the importance of the Digital Transformation of Agriculture became apparent.

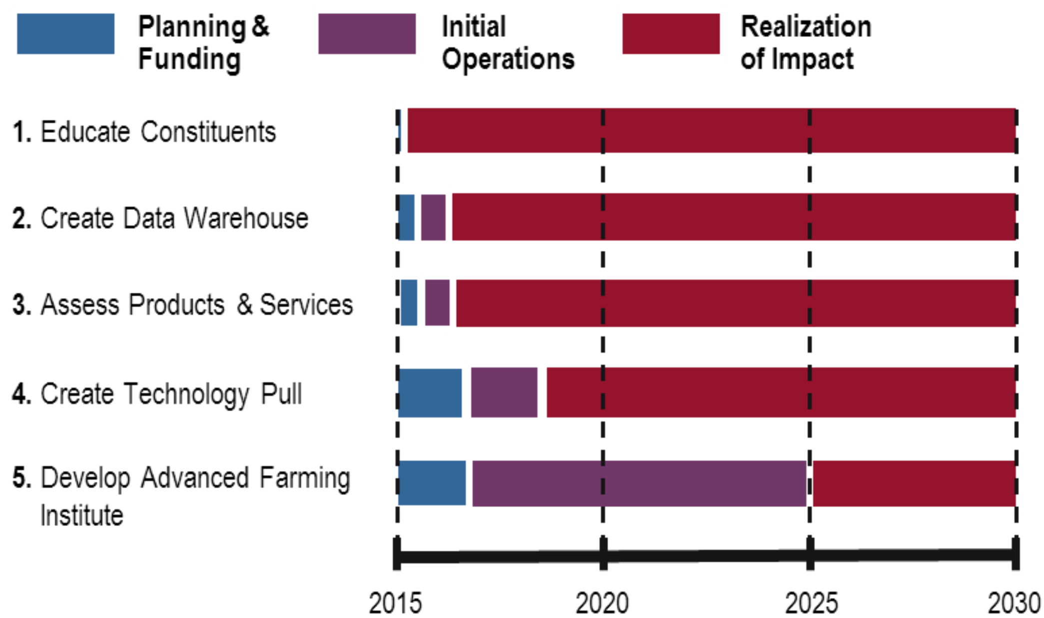
   f. Adopt a coordinated approach for this initiative among Iowa AgState members and raise specific funding to support the development of an Institute at ISU.

   g. Obtain the support of the national farm organizations since the research conducted at the Institute will be applicable across the Midwest Region.

6. High-Level Implementation Issues

The five initiatives will realize very short- to very long-term impacts. A best estimate for the timeframe for their impacts is shown below.

Figure 13. Expected Timeframe to Realize Impact of Initiatives



The five initiatives vary dramatically in investment requirements as shown below.

Figure 14. Annual Conceptual Budget Estimated Costs

Initiative	Launch Period	Establishment	Critical Mass Long-Term
#1: Education	• 2 FTE • $400K	• 2 FTE • $500K	• 2 FTE • $750K
#2: Data Warehouse	• 5 FTE • $1.25 MM	• 10 FTE • $2.5 MM	• 20 FTE • $5.0 MM
#3: Technical Evaluation	• 3 FTE • $750 K	• 5 FTE • $1.25 MM	• 5 FTE • $1.5 MM
#4: Technology Pull Program	• 1 FTE • $250 K	• 2 FTE • $500 K	• 2 FTE • $750 K
#5: Advanced Farming Institute	• 2 FTE-Core • $500K	• 10 FTE-Core • $2.5 MM • $7.5 MM-R&D-Contract	• 10 FTE-Core • $2.5 MM • $22.5 MM-R&D-Contract
TOTAL: $/year	$3.15 MM	$14.75 MM	$33 MM
TOTAL: FTE	13 FTE	29 FTE	41 FTE

Different organizations will be the initiative leaders for different initiatives. As the project attracts more supporters, the table below will be modified.

Figure 15. Responsibility for Implementation

No.	Initiative	Initiative Leader	Strong Support Role
1	Education	Farmer Organizations Ag Retailer Orgs	
2	Data Warehouse	Farmer Organizations	Ag Retailers
3	Evaluation of Products, Services, and Models	Farmer Organizations	
4	Technology Pull Incentives	Farmer Organizations	
5	Advanced Farming Institute	Iowa State University Iowa Dept. of Ag	Farmer Organizations Ag Retailer Orgs

H. Next Steps

Iowa AgState had the foresight to realize that Big Data in agriculture is becoming a force that will have major implications for the future of row crop production. It decided to provide "seed money" to assess this new technology from the perspective of row crop farmers. However, it is very apparent at the conclusion of this effort that the strategy described above requires the cooperation and financial resources of many more organizations.

This effort now needs to "pivot quickly" to engage the support and collaboration of national agricultural organizations and state organizations in other states. The Iowa AgState project should collaborate with other efforts that are seeking to shape the emergence of Digital Agriculture from a farmer-centric perspective.

The Board of Iowa AgState has approved the above strategy and is now pursuing efforts to expand the base of support for the five initiatives described above.

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Contents

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Farmers increasingly need to harvest and store not just food and fibre products but information and data. This information, generally held in unstructured digital datasets, is becoming so large and complex that traditional data processing applications are no longer sufficient. The collection and use of this information is principally known as big data.

Big data undoubtedly has the potential to have a revolutionary effect on agriculture. Similar to previous agricultural revolutions – such as the green revolution with innovative seed breeding, farm chemical application and irrigation developments in the 1960s – big data supported by capable data devices such as smartphones has the potential to dramatically increase agriculture productivity growth in all parts of the world.

Some of the benefits offered by big data in agriculture include real-time decision-making and efficiency enhancements in agricultural research, production and marketing. However, as the big data phenomenon in agriculture evolves, there are also negative risks for farmers that need to be worked through carefully. Some of the technologies used on-farm even collect data independently of the farmer's operations. These negative risks include privacy of data, lack of standardisation, limited access, loss of basic skills (due to an over-reliance on digital-aided farm production systems) and increased franchising of farming as many farmers' decision-making powers in agricultural production systems diminish.

The papers in this edition of the *Farm Policy Journal* provide some insights into the developments of big data in agriculture, with a focus on the opportunities for productivity growth and the risks that need further consideration before broad-scale adoption at the farm level can be achieved.

The first paper, written by Steve Sonka from the University of Illinois, explores the developments in big data, confers its relevance to agriculture and identifies some managerial lessons. Steve argues that while the term big data is new, application of information and communication technology (ICT) based innovations have driven economic transformation in many parts of the world over the last three decades. The paper mentions how the opportunities for big data in agricultural production have been made possible due to low-cost information systems, therefore changing the historical high-cost/low-benefit perception of data management in the agricultural sector. The paper also highlights that the impacts of the application of big data are as likely to be characterised as: from 'retail to farm'; as from 'farm to retail'.

The next paper, written by a team of university researchers, discusses the changing nature of the farm due to big data – based on European case studies. One of the key risks for big data, as discussed in the paper, relates to integrated supply chains and the potential for farmers to act simply as a franchisee with limited freedom. However, the paper discusses the potential advantages of big data whereby farmers are empowered by greater transparency and easier options for direct sales in consumer food webs. The paper then mentions the importance of data being exchanged with common standards through platforms coordinated by public and private partnerships with open systems. An example of these standards includes the Agri-Business Collaboration and Data Exchange Facility (ABCDEF) which is a common pool investment. The paper suggests that relatively open and accessible big data systems with low switch costs are better than proprietary systems, where the risk of the farmer becoming a franchise-taker of big firms in the chain, tied to their software system, is much higher.

The paper by James Rowe and Rob Banks discusses the role of genomics and digital data in the sheep industry. The paper highlights the advantages of data management through predicting breeding values, based on deoxyribonucleic acid (DNA) analysis, which relies on a calibration system that uses a large number of animals measured for all traits of interest. Rowe and Banks argue that efficient data capture and its effective use also underpins improved productivity through better management and value-based supply chain transactions. The true potential value of data is said to be achieved when it is combined with other information collected for flock selection decisions such as culling or feeding, enhancing carcase quality and improving labour productivity. The paper discusses how the benefits of faster genetic gain and better livestock management from more efficient data-use also have the potential to improve productivity through better informed and more timely management decisions. In conclusion, the paper presents some industry issues for big data in noting that genomics and data management are new skills to most sheep producers. Therefore, the paper stresses the importance of specialist training and the development of new infrastructure to ensure that the powerful enabling technologies of genomics and data-use are fully utilised by sheep breeders and producers.

The paper by Callum Eastwood and Ian Yule looks at the challenges and opportunities for precision dairy farming in New Zealand. Some major challenges for precision dairy systems for farmers in New Zealand were said to be the interpretation and use of collected data, and the process of building capability in farmers, staff, and their off-farm support networks. Another major issue involved the origin of data devices. Eastwood and Yule argue that international devices for precision dairy, and those designed within New Zealand, exhibited difficulties when trying to link and exchange data with other devices. Therefore, a lack of integration has led to some farmers running overlapping systems, with a degree of duplication. The paper mentions that precision dairy systems were also seen as a double-edged sword by some farmers as the technology might actually lead to a 'de-skilling' of farm staff. The paper does, however, offset these potential negative risks for big data, by identifying some benefits. One of the major benefits of big data systems in precision dairy included 'preventing surprises' by having regular and reliable data on parts of the farm production system. The paper concludes by saying there is a strong role for industry-good involvement in these challenges and opportunities, as individual farmers, or even individual technology firms have insufficient leverage to enact change in this area. It also says that new legislative and policy issues and additional market compliance demands surrounding data systems need to be considered – as the protection of the farmer's privacy and data ownership needs to be ensured.

The final paper by John McLean Bennett discusses how the unknowns in agriculture might be uncovered through the use of agricultural data and how this could be used advantageously to induce practice change. The paper argues that agriculture is on the cusp of rapid data collection and analysis through increased regional digital connectivity and technological advances. This means there are significant opportunities to realise the value of these data and to utilise them via intelligent means through a combination of analytics and human-based digital networks. McLean Bennett argues that a combination of networked learning discussion fuelled by relatively real-time data synthesis has the potential to be highly powerful and beneficial in the decision-making process, as well as adding value to the agricultural enterprise. The paper concludes by stating the need to focus on creating digital platforms that achieve both a social and big data analytics synthesis, and that the challenges in this process will be identifying trusted information sources and demonstrating the value of online interaction, particularly in comparison to the current data extension model of face-to-face interaction.

While providing a diverse overview of the risks and benefits associated with big data in agriculture, the papers provided in this edition of the *Farm Policy Journal* expose the complexity of the topic. It is clear from the discussion in these papers that there remains a need for both farming sector participants and the developers of big data systems to work through the risks so that all the potential benefits – of what some may call a digital revolution in agriculture – can be optimised.

Mick Keogh

Big Data: From Hype to Agricultural Tool

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Big data appears to be at the apex of its 'hype cycle', meaning that the media's breathless and uncritical enthusiasm for this term may be starting to diminish. When technology innovations reach this point, they enter a phase where investment is driven more by serious, critical analysis than by the desire to 'have the newest thing'. This paper explores the dynamics underlying big data's business potential as it relates to the food and agricultural sector.

First, let's recognise that adoption of information and communication technology (ICT) has been a nearly constant feature in agriculture, business and society for the last three decades. So what is different about big data?

- Big data is much more a **capability** than a single entity. It is the capability to extract information and generate insights where previously it was economically, if not technically, impossible to do so.
- Big data has three key dimensions – **volume, velocity,** and **variety**.
- The introduction of low-cost, novel **sensing technologies** (eg drones, satellites, cell phones) is a major means by which data (never before available because of the high cost of data capture) now can be gathered.
- Analytics, the ability to make sense of massive amounts of highly variable types of data, is a key source of the power of big data.

So, how might big data capabilities enter the food and agricultural sector?

- Tracking consumers, both in terms of shopping and purchasing behaviours as well as perceptions extracted from social media, has been an active area of big data application. These capabilities also will be employed to optimise supply chains, extending to agricultural production.
- Numerous research and development (R&D) initiatives are underway with a focus on greatly increasing the productivity of agricultural production. Today these R&D efforts tend to be concentrated on the underlying biology of crop and livestock production. What is different about these efforts is that they are occurring on the farm, not in the lab or the experimental plot.

As these linkages are formed, key strategic questions will need to be addressed, such as:

- What value, if any, is created by employing big data tools to optimise performance among and between these many firms?
- If value is created, what organisational structure in agriculture would facilitate effective initiation and operation of such systems?

Introduction

It seems difficult to get through a workday without seeing some mention of big data and its potential to have unprecedented impact. Providers of big data go to great lengths to stress the certainty of that potential. The rest of us say things such as, 'Big data, **whatever that is**, is going to be important.'

While a crystal ball's focus on big data may be cloudy, comfort can be taken from the reality that similar technology advances have been experienced and profited from in the past. Over the last three decades, the application of information and communication technologies (ICT) have had marked impact across society and the economy, and have been incorporated into daily life.

Many types of technologies have gone from novel to mundane over the last 30 years. As these tools were adopted, however, the eventual effects weren't nearly so clear. Over time, questions were asked such as:

- 1980s:
    - What is a microcomputer?
    - If an office has a Selectric typewriter, why buy a word processor?
- 1990s:
    - What is this internet thing?
    - Would farmers actually pay for global positioning system (GPS) enabled yield monitors?
- 2000s:
    - If you can receive phone calls on your cell phone; why buy something called a smartphone?
    - Have you Googled it?

Today big data is the latest advance offering opportunity and challenge, and big data is perceived to be as relevant for agriculture as it is for the rest of the economy. Padmasree Warrior, Chief Technology and Strategy Officer for Cisco Systems (Kirkland 2013), believes:

> In the next three to five years, as users we'll actually lean forward to use technology more versus what we had done in the past, where technology was coming to us. That will change everything, right? It will change health care; it could even change farming. There are new companies thinking about how you can farm differently using technology; sensors connected that use water more efficiently, use light, sunlight, more efficiently.

The purpose of this article is to examine the big data phenomenon and to explore its implications for agriculture.[1] From a managerial perspective, it is important to stress that the big data phenomenon really isn't just about lots of numbers. The important potential of big data is that it can enable managers to make decisions based on information never before available. For some of us, these innovations will offer opportunity, for others they will be threats.

1 In this paper, the term 'agriculture' includes the entire food/agriculture value chain from retail to production agriculture to input suppliers.

Exploring Big Data

Although of great potential importance, the big data phrase is also the latest buzzword to capture media attention. Interestingly, there seems to be a continual pattern in how managers respond to such phenomenon; overestimating the potential initial impact and underestimating the long-run effect. Both perceptions can lead managers astray. The big data concept has been travelling through its initial overemphasis stage, where media hype and advertising are capturing significant attention.

Big data generally is referred to as a singular entity. It is not! In reality, big data is much more a **capability** than it is a thing. It is the capability to extract information and insights where previously it was economically, if not technically, not possible to do so.

Box 1: Examples of big data usage.

- Amazon.com handles millions of back-end operations every day, as well as queries from more than half a million third-party sellers.
- Walmart handles more than one million customer transactions every hour, which is imported into databases estimated to contain more than 2.5 petabytes (2560 terabytes) of data – the equivalent of 167 times the information contained in all the books in the United States Library of Congress.
- Facebook handles 50 billion photographs from its user base.
- FICO Falcon Credit Card Fraud Detection System protects 2.1 billion active accounts worldwide.
- The volume of business data worldwide, across all companies, doubles every 1.2 years, according to estimates.
- Windermere Real Estate uses anonymous GPS signals from nearly 100 million drivers to help new home buyers determine their typical drive times to and from work at various times of the day.

Source: Wikipedia (2013).

Advances across several technologies are fuelling the growing big data capability. These include, but are not limited to computation, data storage, communications, and sensing. The growing ability of analysts and managers to exploit the information provided by the big data capability is equally important. To better understand, Box 1 illustrates the uses of 'big data'.

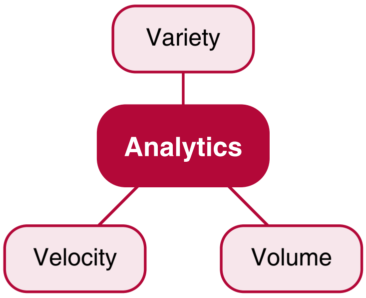


Figure 1: Dimensions of big data: 3 Vs and an A.

Three dimensions (Figure 1) describe the big data phenomenon: volume, velocity, and variety (Manyika et al. 2011). Each dimension presents both challenges for data management and opportunities to advance business decision-making. These three dimensions focus on the nature of data. However, just having data isn't sufficient. Analytics is the hidden 'secret sauce' of big data. Analytics refers to the increasingly sophisticated means by which analysts can create useful insights from the data available to them.

The volume dimension of big data is not defined in specific quantitative terms. Rather, big data refers to datasets whose size is beyond the ability of typical database software tools to capture, store, manage, and analyse. This definition is intentionally subjective; with no single standard of how big a dataset needs to be to be considered big, and that standard will vary between industries.

The velocity dimension refers to the capability to acquire, understand, and respond to events 'as they occur'. For analysts interested in retailing, anticipating the level of sales is important. McAfee and Brynjolfsson (2012) report on an effort to monitor mobile phone traffic to infer the number of people in the parking lots of a key retailer on Black Friday – the start of the holiday shopping season in the United States – as a means to estimate retail sales.

Variety, as a dimension of big data, may be the most novel and intriguing of these three characteristics. For many people, data refers to numbers meaningfully arranged in rows and columns. For big data, the reality of 'what are data' is wildly expanded. The following are just some of the types of activity that can generate computed data:

- financial transactions
- eye movement as you read this text
- 'turns of a screw' in a manufacturing process
- tracking of web pages examined by a customer
- photographs of plants
- GPS locations
- text
- conversations on cell phones
- fan speed, temperature, and humidity in a factory producing motorcycles
- images of plant growth taken from drones or from satellites.

Is Big Data Relevant for Agriculture?

Big data applications are being employed at the farm level. Below are four articles, from autumn 2013 in the northern hemisphere, which focus on applications of big data within production agriculture (Sonka 2013):

- Monsanto to buy Climate Corp for $930 million: loss widens (Kesmodel 2013)
- Crowdsourcing app fights food loss in Africa (Phys.org 2013)
- Dow Chemical wants its software to work in the field, literally (Bunge 2013)
- Traders seek an edge with high-tech snooping (Rothfield & Patterson 2013).

Table 1: Food retailing and big data.

i'm lovin' it	Any mention of food and large numbers brings McDonald's to mind. Not surprisingly, that firm is striving to be an innovative user of big data. For example: [A]lthough all McDonald's around the world look the same, each restaurant is slightly different as they are optimized using all that data for the local market. In addition, McDonald's uses operational data to automate and optimize the inspection of the burger buns to ensure a perfect seed distribution and colour. (BigData-Startups 2013)
WHOLE FOODS MARKET	Whole Foods Market occupies a space in the retail food market that is far from that of McDonald's. As stressed by Whole Foods CIO, Jason Buechel, 'Whole Foods Market Inc. is a grocer, but it's really in the information business.' For example: [C]ustomers want to know the next level of information. Along with pricing details, that includes details like animal welfare ratings on a prime cut of meat, whether a food contains GMOs, or what farm certain produce comes from. The key for Whole Foods will be getting that information from the company's systems into the customer's hands. (Norton 2014)
Walmart	Relative to food and retail, Walmart clearly is one of the 'elephants in the room'. Walmart anticipates that a better understanding of consumer concerns, desires and attention can be obtained through analysis of information from social media: Wal-Mart executives have turned to software called Hadoop that helps businesses quickly and cheaply sift through terabytes or even petabytes of Twitter posts, Facebook updates, and other so-called unstructured data. (King 2011)
Nestlé	The desire to better understand consumers is a critical concern of food manufacturers. Nestlé's Digital Acceleration Team strives: [T]o track online sentiments. Executives watch intently as California wakes up, smells the coffee and says whether it likes it. By monitoring conversation about its products on social media – right down to 'realtime recipe tweets' across the United States – they aim to win over a sometimes hostile world. (Thomasson 2012)
Coca-Cola	Food manufacturers also employ big data tools to design, produce, and consistently deliver the desired product (eg Coca-Cola's Simply Orange juice product): Satellite imagery, complicated data algorithms, even a juice pipeline are all part of the recipe. A computer model directs everything from picking schedules to the blend to maintain a consistent taste. (Stanford 2013)

Source: Logos courtesy of Walmart Stores Inc, Nestlé, The Coca-Cola Company, McDonald's, and Wool Foods Market IP.

Figure 2: 'Farm to retail' and 'retail to farm'?

Image source: www.cropnutrition.com

Here are four more from 2014:

- Monsanto pitches standards for farm data (Bunge 2014b)
- Cargill releases data-analysis service for farmers (Bunge 2014a)
- Can big ag put the cloud in the crops before someone else does? (Gara 2014)
- Conservis Corporation announces initial close on $10 million Series A financing (Jackson 2014).

A closely watched market offering came to market in the Midwest United States in 2014 (Monsanto 2015):

> FieldScripts[SM] integrates innovations in seed science, agronomy, data analysis, precision agriculture equipment and service to provide farmers with hybrid matches and a variable rate planting prescription to improve corn yield opportunity. FieldScripts will be the first offering from Monsanto's Integrated Farming Systems research platform.

Farmers will work with local company representatives to obtain farm specific data which then will be linked to big data-based knowledge of different yield environments. The output of these analyses will be hybrid recommendations and a variable rate prescription unique to each of the farmer's fields.

At the other end of agricultural supply chains, the actions and attitudes of consumers are an active source of big data. Table 1 highlights just a few initiatives in the food sector.

The discussion in this section has purposefully emphasised developments at the farm and at the consumer level. Historically, information connections were relatively weak between the various subsectors that comprise agricultural supply chains. Lack of technology made it expensive to maintain those information flows. As depicted in Figure 2, big data technologies offer the potential for novel information flows across food systems.

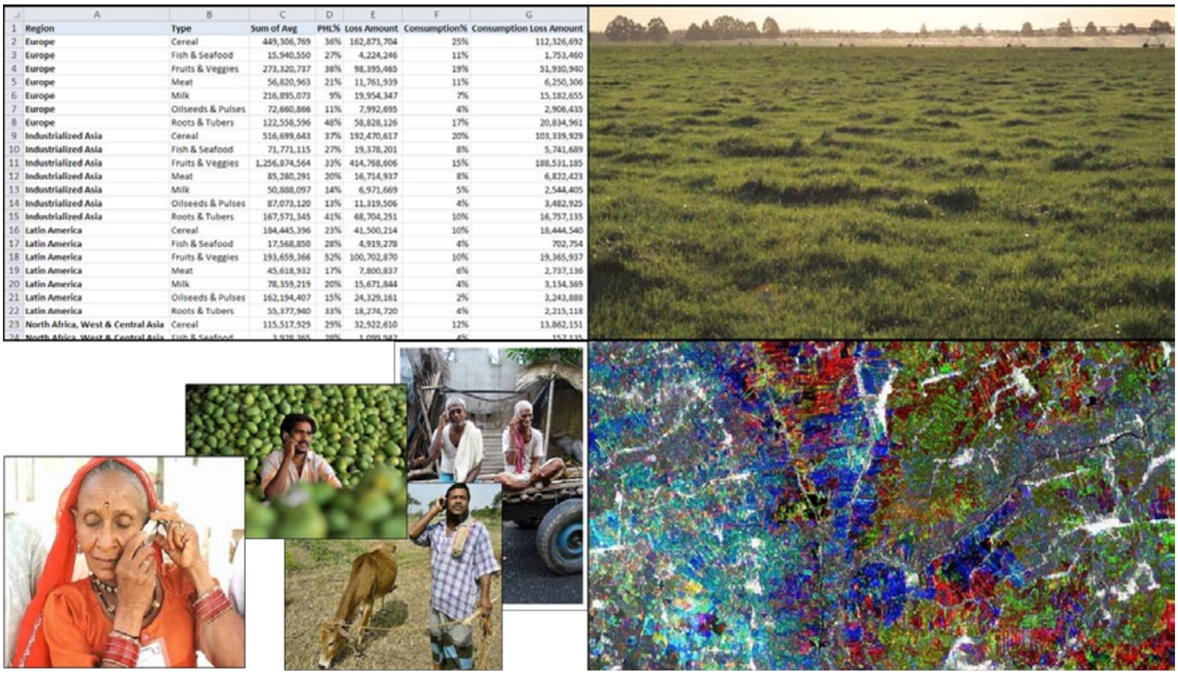
Managerial Lessons

The ability of ICT-based advances to enhance business operations and disrupt industries is **not** a recent phenomenon. Indeed, for managers in the 1990s, the challenge of dealing with the 'knowledge economy' was similar to the attention devoted to big data today.

At that time, there was considerable speculation regarding the potential effects of the knowledge economy. Two key concepts have emerged from that period which are applicable today. While the new technology is essential, the capability to exploit the learning that results from the use of the new technology is what really matters.

Low-cost data acquisition is critically important. The experience of the knowledge economy stressed that, per unit, the cost of acquiring each item of information needed to be close to zero for an effective ICT application to be established (Sampler 1998).

Historically acquiring data on the farm's own operations was expensive. Therefore, very



	A	B	C	D	E	F	G
1	Region	Type	Sum of Avg	PHL%	Loss Amount	Consumption%	Consumption Loss Amount
2	Europe	Cereal	449,306,769	36%	162,873,704	25%	112,326,692
3	Europe	Fish & Seafood	15,940,550	27%	4,224,246	11%	1,753,460
4	Europe	Fruits & Veggies	273,320,737	36%	98,395,465	19%	51,930,940
5	Europe	Meat	56,820,963	21%	11,761,939	11%	6,250,306
6	Europe	Milk	216,895,073	9%	19,954,347	7%	15,182,655
7	Europe	Oilseeds & Pulses	72,660,866	11%	7,992,695	4%	2,906,435
8	Europe	Roots & Tubers	122,558,596	48%	58,828,126	17%	20,834,961
9	Industrialized Asia	Cereal	516,699,643	37%	192,470,617	20%	103,339,929
10	Industrialized Asia	Fish & Seafood	71,771,115	27%	19,378,201	8%	5,741,689
11	Industrialized Asia	Fruits & Veggies	1,256,874,564	33%	414,768,606	15%	188,531,185
12	Industrialized Asia	Meat	85,280,291	20%	16,714,937	8%	6,822,423
13	Industrialized Asia	Milk	50,888,097	14%	6,971,669	5%	2,544,405
14	Industrialized Asia	Oilseeds & Pulses	87,073,120	13%	11,319,506	4%	3,482,925
15	Industrialized Asia	Roots & Tubers	167,571,345	41%	68,704,251	10%	16,757,135
16	Latin America	Cereal	184,445,396	23%	41,500,214	10%	18,444,540
17	Latin America	Fish & Seafood	17,568,850	28%	4,919,278	4%	702,754
18	Latin America	Fruits & Veggies	193,659,366	52%	100,702,870	10%	19,365,937
19	Latin America	Meat	45,618,932	17%	7,800,837	6%	2,737,136
20	Latin America	Milk	78,359,219	20%	15,671,844	4%	3,134,369
21	Latin America	Oilseeds & Pulses	162,194,407	15%	24,329,161	2%	3,243,888
22	Latin America	Roots & Tubers	55,377,940	33%	18,274,720	4%	2,215,118
23	North Africa, West & Central Asia	Cereal	115,517,929	29%	32,922,610	12%	13,862,151

Figure 3: A few sources of data.

Image sources: agrioptics.co.nz; T. Abdelzaher; Champaign, IL; Mock, Morrow & Papendieck (2013); and the International Rice Research Institute (2013).

sophisticated decision systems were developed at the farm level, which enabled managers to make good decisions with relatively sparse data. However, big data offers the potential to dramatically lower the cost of data acquisition.

Suddenly, the 'what is data' question – the variety dimension of big data – has new answers. Figure 3 provides a visual illustration of the change. The upper left hand corner shows data the way it was perceived in the past – rows and columns of nicely arranged numbers. The picture in the upper right hand corner is of a pasture in New Zealand. Pasture is the primary source of nutrition for dairy cows in that country and supplemental fertilisation is a necessary economic practice. The uneven pattern of the forage in that field is measured by a sensor on the fertiliser spreader to regulate how much fertiliser is applied – as the spreader goes across the field. In this situation, uneven forage growth is now data.

The lower left hand corner of Figure 3 shows the most versatile sensor in the world – individuals using their cell phones. Particularly for agriculture in developing nations, the cell phone is a phenomenal source of potential change – because of both information sent to individuals and information they can now provide. As illustrated in the lower right hand quadrant of Figure 3, satellite imagery can also be used to measure temporal changes in reflectivity of plants to provide estimates of growth (IRRI 2013).

While satellite imagery is one source of remotely sensed data, recent years have seen a pronounced increase in the capabilities and interest in Unmanned Aerial Systems (UAS) as a source of data for agriculture. There are numerous ongoing efforts to transform UAS technology originally focused on military purposes to applications supporting production agriculture. 'Universities already are working with agricultural groups to experiment with different types of unmanned aircraft outfitted with sensors and other technologies to measure and protect crop health' (King 2013). Example applications include:

- monitoring potato production (Oregon State University)
- targeting pesticide spraying on hillside vineyards (University of California, Davis)

- mapping areas of nitrogen deficiency (Kansas State University)
- detecting airborne microbes (Virginia Polytechnic Institute and State University).

Those specific examples are only a few of the numerous experiments and demonstrations being conducted to identify cost-effective means to employ UAS technology. UAS capabilities offer flexibility and potentially lower cost relative to the use of even small manned aircraft, especially for monitoring and measurement. Development efforts are being conducted globally; however, it is likely that initial commercial application will occur where higher value crops dominate.

As farmers and managers become increasingly familiar with the notion that data has value, many have questions regarding which entities benefit economically from use of data from farm operations. Over time, contract practices are likely to evolve to provide industry norms. As one step in that process, a recent article reported on an agreement among United States farmer organisations and agribusiness firms regarding protocols to address farm data practices (Stroisch 2014). The six principles in that agreement are:

- Farmers own the information generated on their farming operations.
- Explicit consent of farmers is required before data collection, access, and use of farm data occurs.
- Farmers must be notified that data is being collected and how data will be disclosed and used.
- Farmers must be notified of third-party use of their data.
- Entities that collect farm data must employ principles, policies, and practices that are transparent and consistent with legal contracts.
- Farmers have the choice to opt in, opt out or disable data collection and use options.

Wrapping It Up

Agriculture, globally and in the United States, is a promising target for big data application. Technology developers include both startup and multinational firms. Established technology firms include both those currently in and those outside of agriculture.

The experience of successful big data application in non-agricultural sectors uniformly stresses that the business issues and opportunities, not technological capabilities, determine success. That result is appropriate in agriculture as well.

Over the last 50 years, computation and analysis have enhanced performance in the economy and in agriculture. Today, farmers wouldn't think of heading to the field without their cell phone or checking the internet to make sure that they were getting a good price. In the not too distance future, we'll regard big data technology and information in the same fashion.

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A European Perspective on the Economics of Big Data

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Modern information-based technologies, such as self-driving tractors, GPS (global positioning systems), robot milking machines, automated egg production, drones, satellite data and social media, will change farm practices and agricultural structures and contribute to the prosperity and resilience of farming systems. Food chains will not only become much more data-driven but will also move away from a situation characterised by a low level of data integration. This will have a significant impact on such issues as sustainability, food safety, resource efficiency and waste reduction.

The economic and social effects of such developments are still to be explored. At first sight they could lead to more closely integrated supply chains that make the farmer act simply as a franchisee with limited freedom, but the opposite could be true. Farmers could be empowered due to greater transparency and easier options for direct sales in consumer food webs (using social media and smart solutions for the 'last mile' delivery). Therefore we can see conflicting pressures between the globalisation and localisation of supply chains.

As with previous technological developments, not all farmers will invest in new skills and where technologies are labour saving, farms will get bigger. Some farms or regions will become less competitive if the basic infrastructure (eg broadband internet or GPS systems) is lacking. Competition between advisors could increase, if they are able to serve farmers digitally. In addition, part of such value added activities may move from the most remote rural areas to regions with clusters of knowledge and could also become more international in nature.

A major issue is that information and communication technology (ICT), combined with higher food prices and demographic changes could fundamentally shift the competitive advantage from family farms to more industrial holdings, leading to radical structural change in agriculture.

Introduction

Over the last decade the use of information and communication technology (ICT) in the farm sector has increased significantly (Henten et al. 2009). Poppe et al. (2013) highlight a range of areas where ICT has been successfully applied. These include:

- Use of satellite data to precisely control field operations, making it possible to increase labour productivity by increasing the size of machines.
- Processes for combining remote sensing data on crop growth and farm data on crop interventions (and ex-post yields) leading to more informed decision-making.
- Wiring of glasshouses with sensors and computers to steer the production process in an optimal way.
- Introduction of robotic milking on family farms in North Western Europe where labour is expensive and farmers are highly educated.

- Increased use of sensor technology with cows increasingly measured as intensely with sensors as athletes. Sensor data are much better than the human eye at predicting diseases (such as lameness) or the optimal time for insemination.
- Tracing and tracking have become standard in agri-logistics.
- Retailers are increasingly using apps on smartphones to support consumers and to increase brand loyalty.
- Establishment of online shops by farmers due to sharp falls in prices of delivery services as a result of liberalisation of post and parcel markets.

This list of examples shows that several participants in the food chain are already making advanced use of ICT and are experimenting with new developments. However this is just the start of what could become a revolution in agriculture, not unlike the wider adoption of the tractor and the introduction of pesticides in the 1950s. It will change the way farms are operated and managed and it will change both farm structures and the wider food chain in unexplored ways – just as in the 1950s the extent of the changes in the next three decades could not be foreseen.

The key to this new revolution is unlocking the potential of the data generated through the application of ICT. At the present time, for example, farm data are still rarely shared with advisors or the processing industry, analysed by intelligent software or combined in regional analysis and advice. With the Internet of Things (IoT) (using data from sensors, machines and other devices) we have entered the era of big data. Especially in sectors with many small players, like agriculture, there is a need to invest in software that makes data seamlessly available to business partners and government agencies – like large firms already do internally in their enterprise resource planning (ERP) systems. These firms now have a need to connect to the digital data of farmers and logistic service providers. This brings us to the research question of this paper: how will big data, exchanged between farmers and their business partners change the nature of farming?

To address this question the paper is structured as follows. The next section considers ICT in the food chain and highlights how it has resulted in large amounts of data that are poorly integrated. It then introduces the project FIspace as an example of how the European Union (EU), in a public-private partnership construction – the future internet (FI-PPP) – is developing data exchange platforms to overcome the difficulties with integrating data across the supply chain. Following this, the paper discusses three areas where changes in farm systems may be induced by a seamless exchange of (big) data in food chains. These are: the market for apps and data; the evolution of food chains; and the organisation of the farm business itself. The final section pulls together the analysis to draw conclusions.

The Data Challenge

ICT in the food chain

Currently food chains are confronted with several business issues and societal challenges. In terms of new business models these include: advice being increasingly bundled with technology; precision farming; better service concepts in logistics; segmentation in the food industry to cope with heterogeneity in farming and among consumers; and consumer decision support (Poppe et al. 2013). Figure 1 summarises the extent that data and ICT contribute to the development of new business models and the relevant policy challenges that are addressed.

What is needed for many ICT-based solutions to address the challenges in the food chain, as highlighted in Figure 1, is a better exchange of data between business partners (and with the government). In the near future, Facebook-like data exchange platforms will make it possible to move data seamlessly from one partner in the food chain to another. A key issue is whether these systems will be proprietorial (developed, for example, by the global players in the food chain) or whether they will be more 'open' systems. An example of the latter is described in the next section which highlights how the EU's FI-PPP is developing the infrastructure for data exchange.

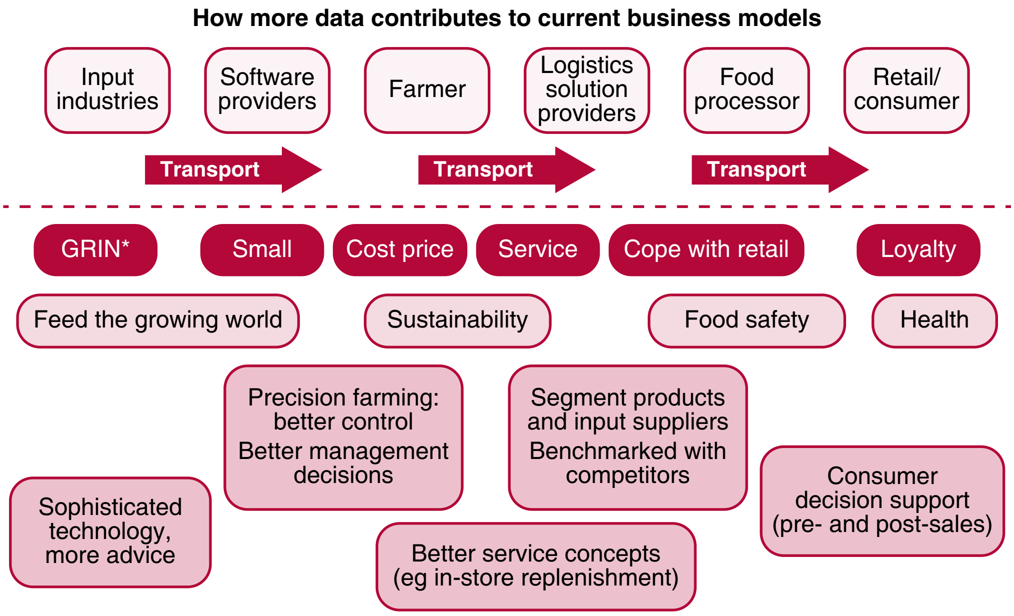


Figure 1: Business and societal challenges and their ICT solution in the food chain.

* GRIN: Genetic, Robotic, Information and Nano technologies

Source: Poppe et al. (2013).

Data Exchange with FIspace

Cloud technology (that gives people access to their data from different devices and places) also makes it easier to share. Open data (in which governments or others share their data free of charge) can be seen to be an example of such exchanges. Together with the Internet of Things this contributes to the era of big data.

Within an organisation these developments can be implemented relatively easy. Enterprise resource planning systems (ERPs) and customer relation management (CRM) software can be extended. However, between organisations it is more problematic, as the so called 'interoperability' of data and information systems is very low. This holds for SME[1]-to-SME or SME-to-government communication as well as SME-to-big company communication. Imagine for instance the challenge for a large dairy cooperative that wishes to exchange digital data with 10,000 farmers, or a manufacturer of milking robots that wants to monitor operational data from products that are sold to farmers.

The issue is even more complex, if one realises that the data exchange between, for example farmers and their cooperative or robot supplier, will lead to digital data that has to be used by third parties. This will mean accountants, for example, require access to the electronic invoices of the cooperative, whilst the farm management system, the vet and the herd book needs access to the data from the cows milked by the robot.

Data needs to be exchanged with common standards and an Agri-Business Collaboration and Data Exchange Facility (an ABCDEF) is required as an infrastructure for this data exchange. This is a common pool investment, and the EU has understood that it should help to build such infrastructure in the FIspace project of the FI-PPP.

FIspace (www.fispace.eu) can best be imagined as a business-to-business software tool comparable to LinkedIn or Facebook – a social media service that connects companies (instead of persons) and their operations. Businesses can contact each other (or a government agency) and start a collaboration. They could, for instance, detail a contract and specify which data they would like

1 Small and medium-sized enterprises

to exchange, the standards the data will conform to (eg EDIFACT[2] or XBRL[3]), and under which circumstances the exchange will occur. This could be data like invoices or delivery notes, but also Internet of Things data that allow for real time tracing and tracking.

Sharing such data should be as easy as uploading a photo on social media, but here the analogy with social media in private life ends. Companies may be more willing to maintain control of their data, specifying access and use rights, and whether their data can be centrally stored with a third party. Companies typically have their own databases (those CRM and ERP systems or simpler farm management systems) and use web services to connect them to each other.

SMEs can use specialised software applications to store their own data 'in the cloud'. As companies wish to maintain control of their data, FIspace does not store the data exchanged between companies. It only stores the links between companies and the rules that have been specified to share their data.

Another difference between companies and consumers is that companies need much higher standards of security for their data management. The future internet technology on which FIspace is built makes this possible (eg by encryption and selective access rights). Once the data is available in a digital form it becomes attractive to employ the data in business processes using special software, similar to how apps on mobile telephones or tablets enrich external data. For this reason, FIspace has an app store in which app developers can market and sell their software (see Poppe and De Smet, 2013, for more information on FI-PPP and FIspace).

Essentially, such ABCDEF software makes it possible to give business partners (and governments) access to farm data and farmers to combine data from different sources. This has important economic consequences and will improve the sustainability of the food chain. Whilst recognising that the impacts of this exchange of data are wide ranging, in the following sections three areas are chosen to illustrate some of the changes that will occur. These are i) the impact on the market for farm management software, ii) the changes in the food chain, and iii) the organisation of the farm itself.

The Market for Software, Apps and Data in Agriculture

There is significant diversity among European agricultural holdings in terms of farm type, size, geography, language etc. Network and communication infrastructures, software, service and media technologies systems throughout the agrifood chain are predominantly produced and distributed on a national or regional basis, or by manufacturers in relation to specific subsectors. The companies selling farm management software generally emerged in the 1980s with the introduction of the personal computer (PC) and are actively operating as SMEs in national markets. Their revenue stream is often relatively small, based on maintenance contracts from a declining number of farmers. However, due to software trends (like cloud technology) they are confronted with rising costs, especially if they have to build in new functionality to incorporate Internet of Things data as it becomes available.

This situation increases the costs of producing devices, software, service and media technology systems, it slows down the introduction of new products to the market, and it causes frustration among the stakeholders throughout the agrifood chain. Not only is data sharing between systems almost entirely absent, but there is also little tradition for incorporation of standardised components into the systems. However, ABCDEF's like FIspace and future internet technologies (as introduced in the FI-PPP) will change this.

FIspace establishes an infrastructure to exchange (or better, to give access to) central data for software-providers. In this cloud-based business-oriented social media the users (like SMEs and farms) can make the data they control available to apps. These apps can be bought (or downloaded free) in an app store, like those currently available on mobile phones.

2 Electronic Data Interchange For Administration, Commerce and Transport

3 eXtensible Business Reporting Language

Apps will replace some of the functionality of farm management information systems (as well as adding new functionality). Such apps can be built more cheaply with future internet standardised software-components (so called enablers, like a standard component for a web-shop or to run an auction). This implies that app builders do not have to worry about organising access to the data, as long as they use the data standards by which farmers access their data.

As FIspace is a European or global service, this also means that app builders have access to a large European or global market with many more potential clients than software makers have in their current national markets. Besides specialised apps for sale, governments, researchers, non-government organisations (NGOs) or businesses in the food chain might want to provide services and advice to farmers free of charge in an app. For example, it may be a way for governments to communicate public-good type advice (around animal health and welfare or the environment, etc) to farm businesses.

For current farm management information systems (FMIS), this means breaking up their software into one or more apps that help farmers in entering farm data manually, if needed in sync with data exchanged by the farmer (eg taking the data from delivery notes or invoices on pesticides bought and adding the information on the use on a particular crop in a particular field by entering additional data on a mobile telephone using its location service) and into apps that help farmers interpret the data.[4]

These technological developments replace a market for farm management software with a market for ABCDEFs (with FIspace as a first product in this category) that have an embedded market for apps. An intriguing question is whether or not this will also lead to an embedded market for data. Currently nearly all data are exchanged free of charge, exceptions being ticker data from stock markets and marketing data (eg shopping pattern data). In agriculture, data are used to prove that products are of a different quality (eg organic) and lead to a higher price for the product, but data itself is not priced.

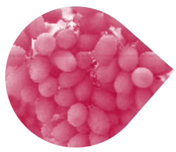
4 See Kaloxylos et al. (2014) for a first example of such a future internet based farm management system.

Changes in Current Food Chains

A seamless exchange of (big) data will have a significant impact on food chains. Important changes include: i) the end-to-end tracking and tracing and virtualisation of food chains, and ii) the emergence of direct farmer-consumer markets supported by ICT.

The most obvious change is that tracing and tracking, not only of products, but of the full history of their treatments will become a reality. This will lead to more influence from business partners on farm decision-making. This could be through the provision of advice or by tighter contract stipulations. In addition, service level agreements by advisors or, for example, companies that sell machines are possible.

With cloud-services like FIspace the tracing and tracking of products becomes much easier. Business partners can share the data on the history of the product with the buyers at the next stage of the chain. This implies that apps for consumers can provide information on the product, all the way back to the grower of the product and its seeds. This even holds for complex products like pizzas that are made of many ingredients.



Such data can also be used for real-time virtualisation. Through sensing of physical objects at different levels of aggregation (eg product, box, pallet, container, truck), rich and globally accessible virtual representations of these geographically dispersed physical objects can be created (Verdouw et al. 2013). Virtual objects must provide multiple views for different users who have distinct requirements. Visualisation plays an important role in creating views that are experienced by human users as reality.

As in a kind of second life environment one could ‘walk through’ the supply chain and see what is going on at any stage at any moment, and also place it in the context of its historical development (Poppe et al. 2013). Whilst this may be fun for children to see where their milk came from, or to see where the bottles of olive oil ordered online are en route to the consumer, real time virtualisation primarily has practical use in business processes. Examples include applications for advanced visioning (eg high-speed/low-cost solutions, three-dimensional, and of internal features such as ripeness of fruit) for quality inspection of food and flowers based on (mobile) augmented reality.

The exchange of data will also make it possible to add more (computer) intelligence to the chain, including monitoring, problem notification, deviation management, planning and optimisation. Examples of food-specific intelligence functionalities are apps for early warning in case of food incidents or unexpected quality deviations (eg temperature or humidity changes), advanced forecasting about consequences of detected changes by the time the product reaches destination (eg dynamic simulation of best-before dates). This could also lead to dynamic pricing and less waste.

These developments will contribute to greater levels of sustainability, where food processors, retailers and consumers can trace products to their source and investigate the different aspects of sustainability of individual products or batches of products. Ultimately, they can give feedback to farmers or penalise the least sustainable producers.

It is unclear to what extent the tracing and tracking as well as the real-time virtualisation services will be provided by current service providers, including ICT suppliers and auditing firms, or if new types of service companies will be established. As transaction costs change with such ICT solutions, it is likely that the way the food chain is organised will change too. In some cases, this will even lead to totally new chains that replace current ones. For instance, auctions could go online, making it possible to sell the fish when the fisherman's boat is still at sea.

Another example is direct marketing between farmers and consumers. There is an increased interest in 'local' as opposed to the dominance of 'global'. Food has always been a means for consumers to profile themselves in a social environment, but in the last decade food culture has clearly grown in importance. Sustainability aspects are much discussed, by chefs as well as large segments of consumers and NGOs. The consumer market has become more heterogeneous and so has the farm sector. Reducing market interventions in the Common Agricultural Policy (CAP) in Europe gives farmers more freedom to produce as well as exerting pressure to choose their own strategy. With heterogeneous consumers and farm systems, it becomes attractive to search for methods to match the demands of those segments (Poppe et al. 2013).

By reducing transaction costs, ICT enables collaboration in regional clusters such as local-for-local food webs that deliver local, often organic, food products to local consumers, restaurants or health care institutions. The internet plays an important role in these clusters by matching local demand with supply and subsequently managing the last-mile logistics. The liberalisation of postal markets and the restraining of labour costs, especially for low-paid jobs, have supported the trend towards an increasing market share for online shops.

Changes in the Scope of the Farm and Farm Organisation

As with previous technological developments, not all farmers will invest in new skills (Läpple et al. 2015; Islam et al. 2013). To what extent these developments in ICT will exaggerate differences between farms is an interesting question. For example, will they be scale-neutral or benefit larger farms more than smaller ones – which has been the case with innovations in the past, especially ones that improve labour productivity.

The devices (like smartphones and tablets) involved in data sharing with ABCDEFs like FIspace, as described above, are not very costly. The breaking up of complicated farm management systems into apps, based on standard components and marketed more broadly (eg Europe instead of one national market), makes software cheaper. This suggests that the trend to big data may not be detrimental to the position of small family farms. They might even benefit more than large farms from options for direct sales in consumer food webs, using smart solutions for the 'last mile' delivery, as described in the previous section.

However, this picture could be too optimistic for the small farm. In existing food chains farmers have to invest in data gathering and FMIS to satisfy demands from food businesses and retailers for tracing and tracking and quality assurance schemes like GlobalGap. As agricultural processes become more programmable (and are less dependent on unpredictable natural events), as investments are less general in nature but become more tied to specific products (such as know-how on how to grow organic broccoli) and marketing is a joint effort of a producer group and a retail chain (such as with some new apple cultivars), more complex organisational forms appear.

In part these complications arise because relying on the spot market is a major business risk for the parties in the food chain (Boehlje 1999). Such movements away from commodity markets towards more complex organisational forms favour larger farms – it is as easy to contract 1000 tonnes of potatoes as 10 tonnes. In the end this could lead to more closely integrated supply chains where the farmer acts as a franchise taker with limited freedom. There are likely to be ABCDEFs like FIspace that could counterbalance this situation to some extent, as they make a farmer less tied to the software of a supplier or food business, and reduce the switching costs between chains.

A second unfavourable aspect for small family farms is the fact that the monitoring of agricultural processes will greatly improve. To understand why this may work against family farms we have to address the question why we have family farms at all, and not large companies like in food business, retail or other sectors.

Markets generate income by making it possible to specialise, particularly in roles like farm manager, farm labourer, investor and land-owner. In family farms, farmers combine several of these roles (especially those of management, investor-owner and labourer) when the market provides insufficient incentives to specialise. There are two explanations why these incentives are too low.

The first is that the risks are too high and the profitability too low. This leads to low levels of interest (or too high profitability demands) from outside investors. Therefore large farms where farmers manage a number of specialised labourers (like in a plantation) cannot compete with family farms that accept a lower profitability (as long as it satisfies their income needs). The low profitability and structure of small farms is explained by the (inefficient) working of the labour market. For example, farmers do not leave the sector easily as this may lead to having to move to urban areas or giving up tax advantages, for example. This results in farmers having low opportunity costs.

The second explanation, put forward by Allen and Lueck (2002), deals with the fact that agricultural production processes are difficult to monitor. This leads to moral hazard and an agency problem. For example, the investor cannot monitor the farm manager and is faced with the question whether the disappointing results are due to weather or diseases as the manager claims or whether they are a result of poor performance by the manager. In the same way, a manager may wonder if the farm worker is working conscientiously in the field furthest away from the farm office. This Coasean way of thinking implies that the transaction costs of monitoring to address the agency problem determines the organisational form. It is therefore a trade-off between specialisation via the market or addressing moral hazard problems through doing it yourself.

Both theories that explain the strong position of the family farm also imply that some future trends may favour large non-family farms. In the first case, increasing prices and profitability make it more attractive for outside investors to invest in farming. This is a trend clearly seen in the Ukraine, for example. Western Europe's access to cheap labour from Eastern Europe also leads to more specialisation. In the second case, ICT is a clear threat for the family farm as with ICT monitoring options increase considerably and many agency problems can be solved.

Last, but not least, there is the threat of another change to the organisation of the farm (and rural areas). Some activities could disappear from the farm when they become automated. For example,

sensors that measure an animal's activity can determine when cows should be inseminated for reproduction purposes. If this sensor then sends an SMS, to the vet for example, the role of the farmer is bypassed. Taking this idea further could imply that some value added activities, like advice, move from the most remote rural areas to regions with clusters of knowledge where they are provided by ICT. For example, it is more likely that the apps for the farmers based in Europe are built in Berlin or Wageningen rather than in a remote area in Bulgaria.

These effects are probably stronger in propriety systems that are linked exclusively to the ERP system of a big food business, retailer or supply company than in a system where switch costs are low. This raises major questions as to whether the already significant imbalance of power in the food chain (see for example Renwick et al. 2012) will be further exacerbated. Such concerns may mean that an ABCDEF like FIspace should be favoured over a propriety system, especially if one wants to support family farms. However, the analysis does suggest that the era of big data is probably less innocent for the structure of farming than the low prices of smartphones and tablets suggest.

Conclusions

The use of ICT will increase strongly in agriculture in the next decade. This will mean that the agrifood chain will become much more data-driven and based on up-to-date ICT. A move away from a situation characterised by a low level of data integration will have major implications for the agricultural sector. In particular, it will help solve the mismatch between current applications of ICT and the increasing need for intelligent solutions. Such a development has the potential to have a significant positive impact on issues like sustainability, food safety, resource efficiency and waste reduction.

To increase the integration of data and interoperability, we argue that investments are needed in common pool infrastructure like Agri-Business Collaboration and Data Exchange Facilities (ABCDEFs) and highlights FIspace as an example. Our conceptual analysis suggests that these will lead to a market for such facilities as well as a market for apps and perhaps even for data. This could be preferable (especially for family farms) to situations where farmers are linked to a propriety ERP system of a big input supplier or food business. Overall, however, the trend to big data may have significant consequences for how farms and food chains are organised.

Until now the development of the future internet has been dominated by research activities to design software and re-engineer business processes based on business modelling and value chain analysis. However, the economic impacts and the longer-term effects on farm structures and rural areas of the future internet require more attention. Our preliminary analysis suggests that it is not necessarily positive for the family farm, but that open systems with low switch costs are better than propriety systems where the farmer becomes a franchise taker of big firms in the chain, tied to their software system.

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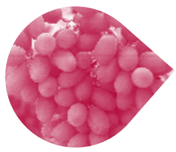

A main focus of his work has been the economics of agrifood supply chains from crop production through to retail pricing. Recently his research has focused on the innovation process in the agrifood sector. He has led over 30 research projects for such bodies as Scottish Government, Defra, the UK Environment Agency, the National Audit Office and the United Kingdom levy agencies.

Sheep Industry Productivity – the Role of Genomics and Digital Data

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As the sheep industry moves from focusing on wool production as its primary economic driver to the current situation where both sheep meat and wool are of similar importance, the challenge to maintain genetic improvement is significantly more complex. Selection for increased wool income only needs to focus on fleece weight and fibre diameter. Both parameters are easily measured and highly heritable. However, balanced 'sheep' production involves selection for increased reproductive efficiency and improved carcase characteristics as well as continued selection for wool traits. The sheep industry also has to breed for resistance to parasite due to the need to stop mulesing and the increasing problem of worm resistance to chemical drenches.

This paper focuses on three initiatives that are contributing to transformation of the sheep industry: genomic technologies; data management and skills development. Genomic technologies enable fast and well-balanced genetic gain, particularly when difficult to measure traits such as reproduction, parasite resistance and carcase characteristics are so important. Prediction of breeding values, based on DNA analysis, relies on calibration using large numbers of animals measured for all traits of interest. Cost-effective measurement of phenotypic parameters is therefore essential for genomic technologies. The development of automated and semi-automated measurement of production and carcase characteristics, combined with wireless data transfer and cloud-based computing, provide complimentary technologies to support the development and use of genomics.

Efficient data capture and its effective use also underpins improved productivity through better management and value-based supply chain transactions. Targeted training and skills development is the third component required to ensure that the sheep industry exploits the transformative and interlinked technologies of genetics and digital data.

Introduction

Changes in the sheep industry since 1990 have been very significant and were precipitated by two separate factors: a very successful strategic initiative to transform the lamb industry; and the end of the Wool Reserve Price Scheme. These two developments were principally responsible for the transition of the 'wool' industry into the 'sheep' industry.

Around 1990, The Meat Research Corporation's Prime Lamb Key Program was an integrated national program of research, development and extension focused on the production of Elite Lamb – larger, leaner lamb carcases, particularly suitable for the export market (marketed into the United States through the Fresh Australian Range Lamb program) and the domestic market (Trim Lamb). The Prime Lamb Key Program included the genetic improvement initiative 'LAMBPLAN'. This coordinated industry initiative set the lamb industry on a projectile of expansion and increasing profitability that continues today.

In January 1991, the suspension of the Wool Reserve Price Scheme had a dramatic effect on

This paper was presented to the Australian Farm Institute's Australian Roundtable Conference in Melbourne, 13 November 2014.

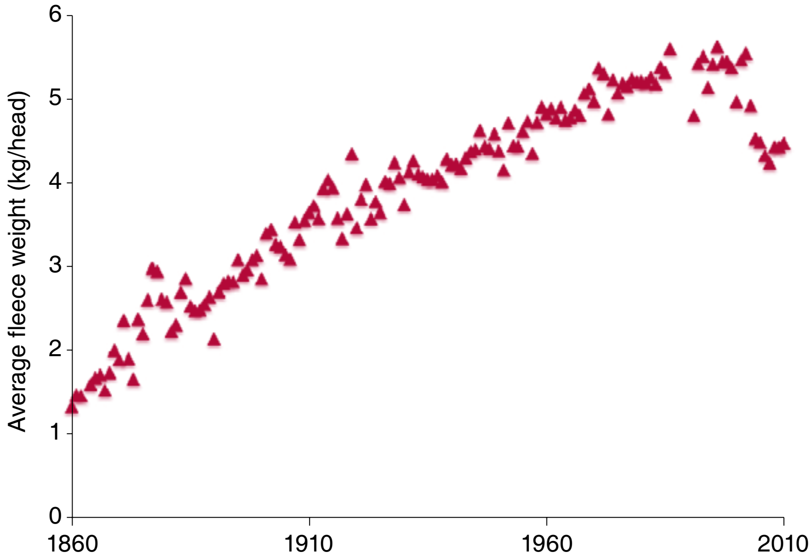


Figure 1: Improving productivity of the Australian wool industry between 1860 and 1990 through increasing average fleece weight.

Note: The decrease in fleece weights from around 1990 resulted from responses to the end of the Wool Reserve Price Scheme and greater focus on production of fine wool and decreasing numbers of wethers.

the price of wool and was largely responsible for the subsequent decrease in the size of the Australian sheep flock, from just over 170 million in 1990 to its current level of around 72 million. During this period, lamb production has increased from 0.28 Mt/year to 0.47 Mt/year and wool production has decreased from 0.85 Mt/year to 0.33 Mt/year (ABARES). These relative changes in meat and wool output reflect a combination of maintained or increased productivity in lamb (and sheep meat) production, and a decline in the number of animals retained purely for wool production.

The importance of genetic improvement in responding to these major changes in the sheep industry cannot be overstated. With wool as the main product from mid-1800s to 1990, Figure 1 shows the steady and impressive genetic improvement in average fleece weight. With the main selection criteria, focusing on fleece weight and wool quality, there was good progress because these traits are easy to measure and highly heritable.

However, in moving from a 'wool' industry pre-1990 to the current 'sheep' industry the challenge of genetic improvement has become very much more complex. Genetic selection for productive sheep, where lamb and wool income are of similar importance involves a lot more traits including a number of difficult to measure traits such as reproductive efficiency, carcase characteristics and resistance to parasites – as well as continuing to improve fleece weight and wool quality.

In order to efficiently improve a broad range of traits, it is essential to use estimated Australian sheep breeding values (ASBVs) and take account of the genetic correlations between traits using carefully constructed selection indices. Most breeders of specialist meat production sires have used LAMBPLAN estimates of breeding values and selection indices to simultaneously improve, growth rates and muscling while reducing fat. While many merino breeders have successfully adopted a similar approach using MERINOSELECT, this approach has not been widely adopted by the merino industry. This has resulted in a slower rate of genetic gain in the wool-focused sector of the Australian sheep industry and very little improvement in productivity to combat decreasing terms of trade for this component of the sheep industry.

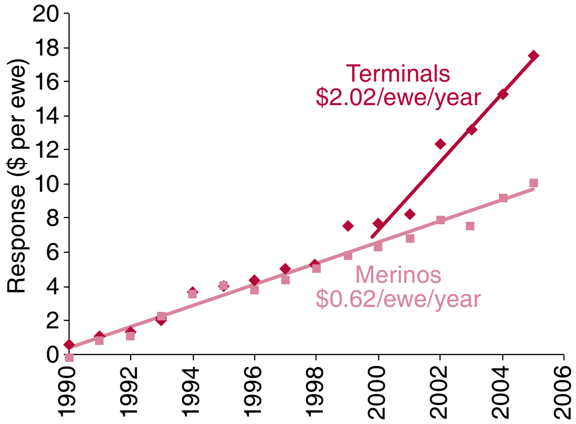


Figure 2: Estimated rates of genetic gain expressed as the $-value of the increased production per ewe joined.

Note: The trend line for average improvement of merinos registered in MERINOSELECT from 1990 to 2005 shows an increase of $0.62/ewe/year and is similar to the rate of gain in terminal breeds up to 2000. The gains in terminals since 2001 when across flock comparison was introduced is was $2.02/ewe joined per year.

Source: Adapted from Swan, Brown and Banks (2009) – AAABG.

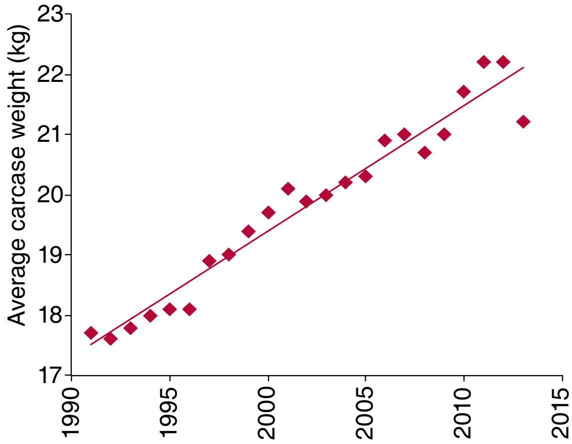


Figure 3: Increasing carcase weight of Australian lamb between 1990 and 2013.

Note: The trend line for carcase weight indicates an increase of 209 g/year on a cumulative basis.

Sources: ABS and MLA.

Swan, Brown and Banks, in a study published in 2009 (AAABG[1]), estimated that genetic gain, even in the merino breeders participating in the MERINOSELECT program, was around 33% of its potential. This sub-optimal performance was particularly noticeable from 1996 when across flock genetic comparisons started to be used. Since 2001, genetic gains valued at around $2.02/ewe joined per year (cumulative) have been achieved by terminal breeds and this compares with merinos still improving at around $0.62/ewe/year (Figure 2).

The impact of this impressive genetic gain in prime lamb production has seen an increase in average carcase weight rising from around 17 kg in 1990 to 22 kg in 2012 (sources ABS and MLA website). This rate of genetic improvement represents nearly 209 g/year additional saleable meat per lamb, on a cumulative basis. This steady increase has occurred without the concomitant increase in carcase fatness which would occur in the absence of having reliable genetic information on animals' genetic merit for growth rate, leanness and muscling – all available through LAMBPLAN.

1 AAABG – Association for Advancement in Animal Breeding and Genetics

A number of merino studs, recognising the future importance of a dual-purpose wool and meat production system, adopted the use of estimated breeding values and index selection. Since adoption, leading flocks using the dual purpose index have been improving at around 4.45 index points per year or around $2.20/ewe/year. This has been achieved through faster growth rates, increased reproductive efficiency and also higher fleece weights.

Genetic improvement is essentially a 'free kick' because most of the improvement is related to efficiency. Lambs that grow faster are slaughtered at an earlier age and have a significantly lower feed requirement for maintenance during their lifetime. The extra energy and protein required to achieve faster growth rates is far less than required to maintain animals during a longer period of growth. Similarly, improved reproductive efficiency requires additional nutrition for the ewe but when a full year's maintenance for the ewe is spread across the production of two lambs, the efficiency is far greater than if only one lamb is weaned.

Existing genetic improvement technologies have been adopted to great benefit in the lamb industry,

and to a more modest extent in the wool-focused sector. However, there is still considerable room for improvement in the utilisation of genetics and the challenge is to ensure that the new technologies are affordable and practical.

Genomics and Digital Data – Why it is Such a Good Fit

Genomic technologies are set to increase the rate of genetic gain by around 25% above the existing potential threshold based on conventional measurement of performance and pedigree information.

The well-worn phrase 'If you want to improve it… you need to measure it' is particularly true for the application for genomics to livestock breeding. In order to use deoxyribonucleic acid (DNA) analysis to predict breeding values, it is necessary to first calibrate the pattern of animals' DNA makeup against the full range of phenotypic parameters or traits that are to be predicted. The catch is that each trait needs to be measured in around 4000 animals that are representative of the breed for which the prediction is required. The Information Nucleus program, conducted by the Sheep CRC between 2007 and 2014, undertook this calibration task for the Australian sheep industry and the measurement program is summarised in Figure 4. A comprehensive set of measurements was made in around 20,000 animals and the process of data collection, storage and analysis would not have been possible without semi-automated data collection and the growing ability to transmit, store and utilise digital data. In order to maintain the accuracy of the predictive equations, it is also necessary

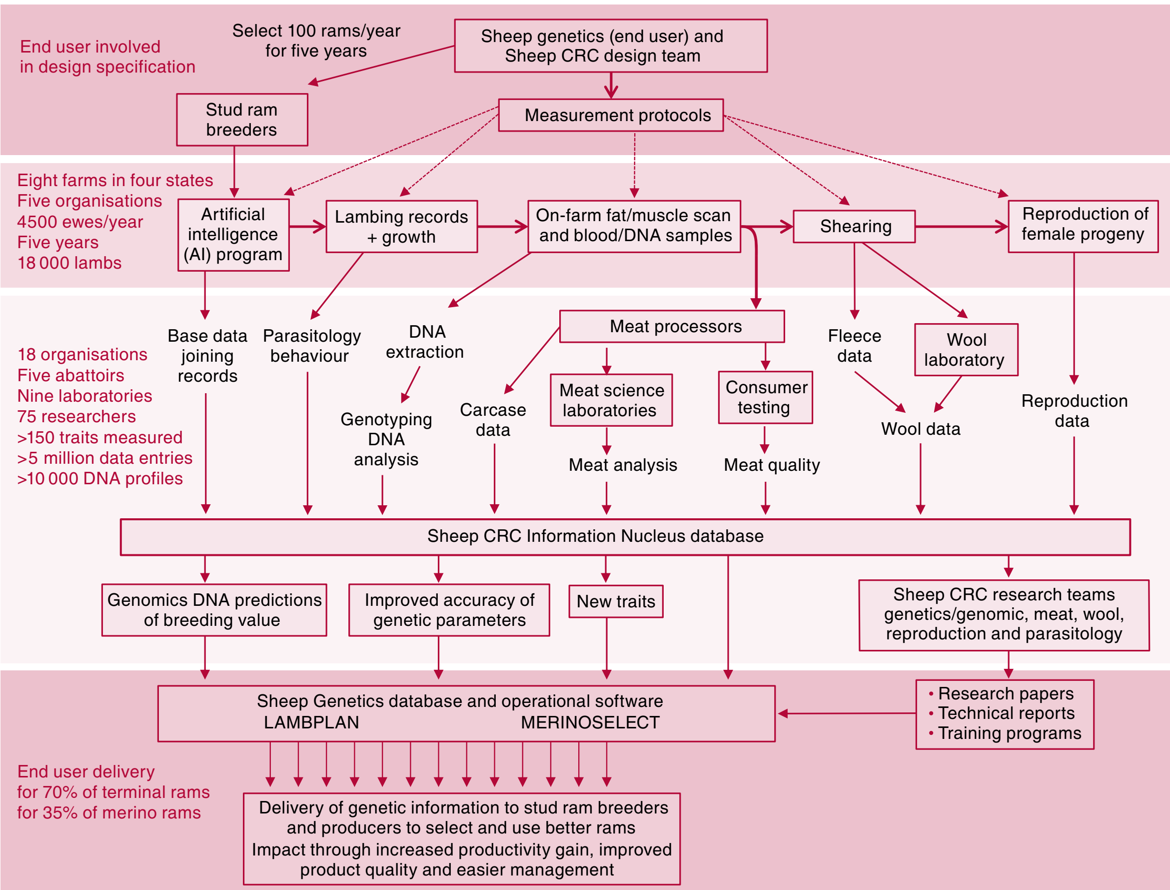


Figure 4: Schematic summary of the measurements made in the Information Nucleus program in order to calibrate genomic predictions of breeding values.

Note: The animals measured in this program were produced using artificial insemination with semen from rams representing a wide cross-section of each of the major breeds: Merino; Border Leicester, Poll Dorset and White Suffolk.

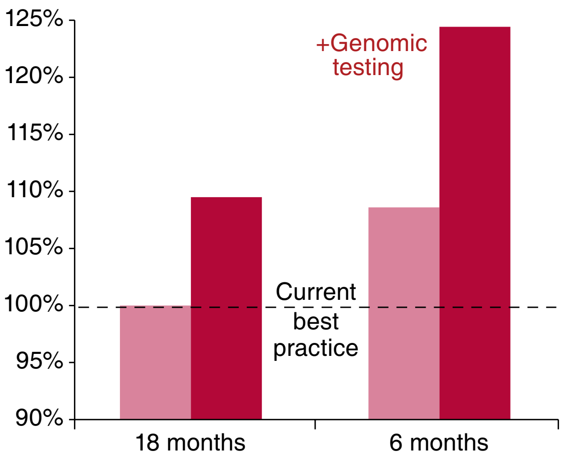


Figure 5: Potential benefits from genomic selection in merino sheep, with rams selected at either 18 months (current industry practice) or six months.

Note: The light red bars represent use of ASBVs as the basis of selection. The y-axis indicates the percentage improvement in genetic gain through using genomic information in a merino breeding program.

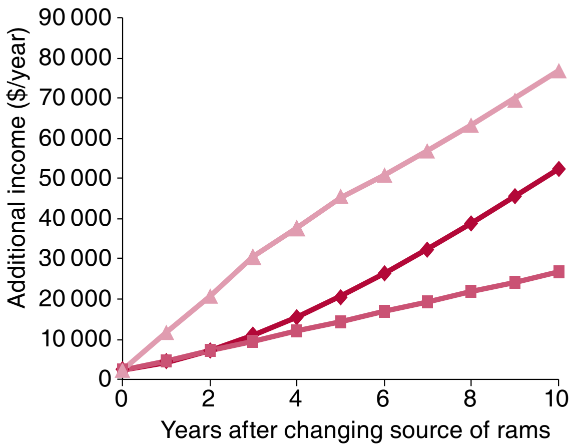


Figure 6: The effect of changing the source of rams in a 3500 ewe flock.

Note: The mid-tone (squares) line represents continuing with the same source of rams achieving gains of $0.70/ewe/year compared to changing to a source of rams with gains of $2.20/ewe/year (dark line, diamonds). The light line (triangles) shows the combined benefits of faster genetic gain plus the one-off benefit if the better rams delivered an increased performance valued at $7/ewe realised over the lifetime of their progeny.

to keep measuring subsequent generations of animals in order to ensure that changes in the patterns of DNA continue to accurately predict breeding values for traits of interest.

However once the predictive algorithms have been established, the use of DNA analysis to more accurately predict breeding values is powerful and very cost-effective.

Using Genomic Information in Breeding Programs

There are several well-defined benefits from using genomic information to assist in the selection of animals of superior genetic merit.

- Faster genetic gain for all traits is achieved due to increased accuracy in predicting breeding values.
- The ability to select breeding animals at a younger age through the fact that genomic predictions can be made as soon as a drop of blood can be collected. Genomic information therefore allows prediction of breeding values for traits that are normally only measureable later on in an animal's life or rely on measuring the performance of its progeny and siblings.
- Improvement of traits that are very difficult or too expensive to measure and are not normally included in performance recording programs.
- Genomics also provides a new starting point for studs and ram buyers that have relied on visual assessment and have only achieved limited genetic gain for those traits that are easily measured and highly heritable such as wool production and body size.

Figure 5 summarises the improvements possible in applying genomic technologies through more accurate ASBVs, when using rams at 18 months of age, and the additional benefits from using younger animals for breeding programs. This figure illustrates the potential improvement of over 20% in genetic gain through the application of genomics to select and use younger rams – a practice already being adopted by a number of merino breeders.

Figure 6 summarises the financial implications of changing to a ram source that has a faster rate of genetic gain ($2.20 compared to $0.70 per ewe/year) and significantly higher index than the source of rams previously being used. The cumulative benefit is shown by the centre line compared to the lower line. There is also a one-off benefit of selecting rams with a higher genetic

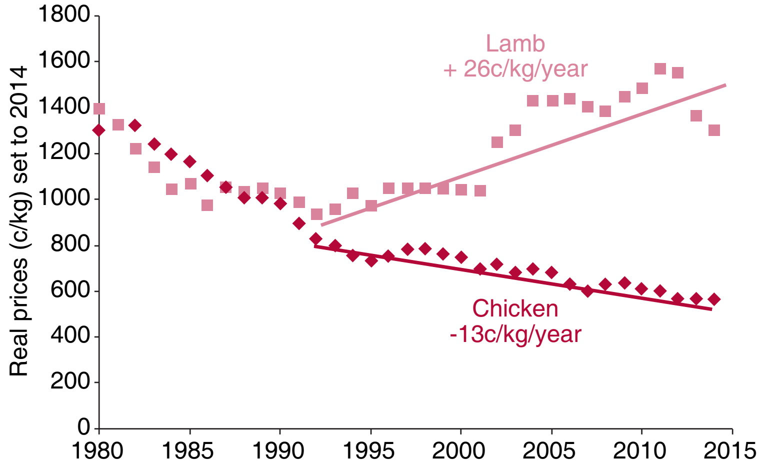


Figure 7: Retail price of lamb and chicken meat from 1980 to 2013 showing the increase in the price of lamb in response to the integrated program of marketing and product improvement program initiated in 1990.

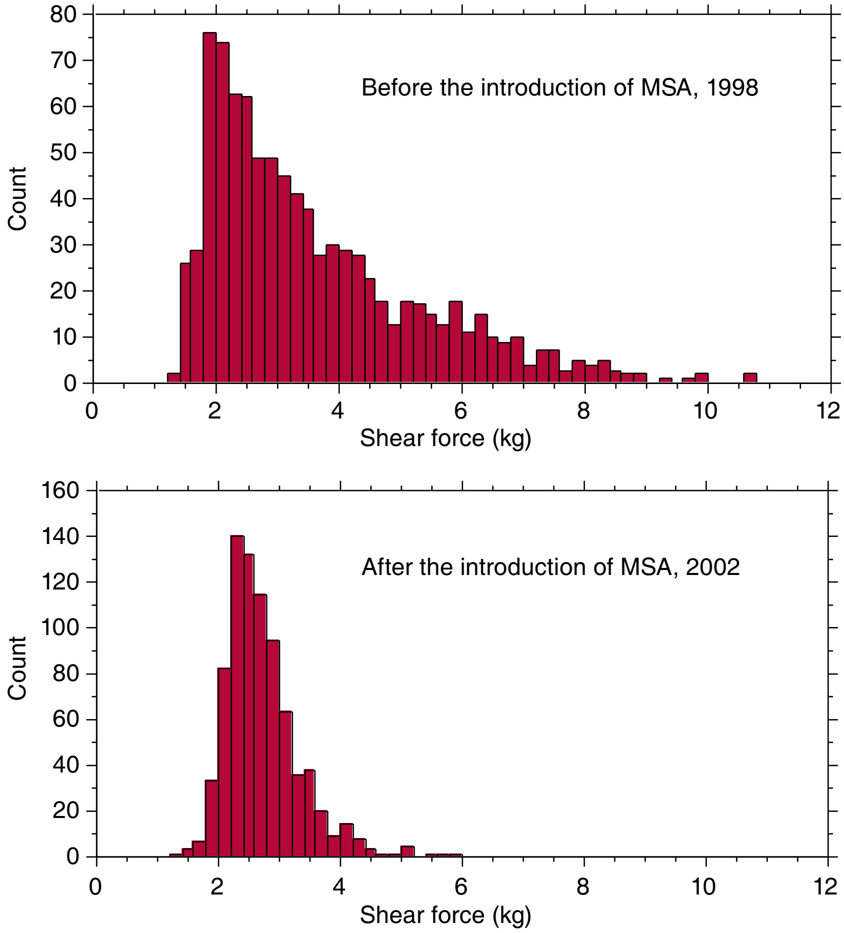


Figure 8: Decreased spread in the shear force (toughness) of lamb prior to and following the introduction of Meat Standards Australia (MSA) grading and processing standards.

Source: Pethick et al. (2008).

index. For a commercial flock of 3500 ewes, the combination of both faster genetic gain plus the one-off benefit of better rams from the new source is worth an additional $50 000/year by the tenth year following the change and will continue to grow year-by-year.

Quality Does Matter

In the sheep industry the quality of wool and meat have an important impact on price and therefore need to be part of the productivity improvement process. Figure 7 shows changes in the retail price of lamb and poultry paid by Australian consumers. From 1980 to 1990 the price of both meats fell at approximately the same rate of 35c/kg/year. Since then, the price of chicken has continued to fall at around 13c/kg/year. However, with the introduction of the Elite Lamb and Trim Lamb programs in 1990, the price of lamb has risen with a trend line of around +26c/kg/year. Over the period 1990 to 2014, the production of lamb has increased by over 50% and so the increase in price can be attributed to improving quality and not to decreased supply.

A major factor contributing to improving lamb quality during the 1990s was the increased consistency of eating quality achieved through the quality assurance system of Meat Standards Australia (MSA). Figure 8 shows the reduced spread in shear force (a measure of 'toughness') between the late 1990s and 2002.

The next impact on eating quality is expected to come from the results of the Information Nucleus program that delivered clear insights on the importance of genetic variation in eating quality and the importance of intramuscular fat in determining consumer perception of eating quality and willingness to pay. Fortunately, intramuscular fat is moderately heritable and quite variable amongst sheep industry rams so it is a trait that will respond to selection. It is also one of the hard-to-measure traits that can now be predicted from genomic testing. The next challenge for the industry is therefore to be able to select rams for improved intramuscular fat and lower shear force in order to maintain and increase quality and the flow-on benefits of consumer demand and price.

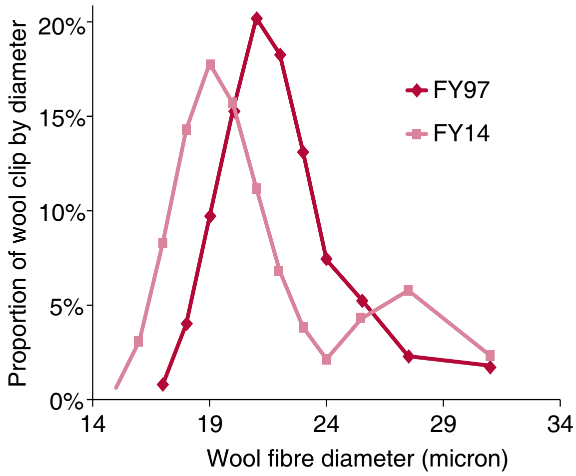


Figure 9: Change in the distribution of fibre diameter of the Australian wool clip between 1997 and 2014.

Source: Wool Forecasting Committee April (2014).

The selection pressure for improved eating quality will reduce the focus on increasing growth rates and improved lean meat yield. However, the impact on profitability through maintaining price premiums for lamb, far outweigh the slightly lower rates of gain in carcase lean meat production.

Importantly, new technologies being developed for carcase evaluation will soon allow accurate quantification of lean meat yield and intramuscular fat at line speed within abattoirs. The new measurement systems will allow abattoirs to set premiums/discounts for lean meat yield and for the supply chain to determine a value for eating quality and factors such as intramuscular fat and shear force.

Quality in the Wool Supply Chain

Over the years, merino producers have responded to the price premium paid for finer micron wools and between 1997 and 2014 the average fibre diameter of the Australian sheep flock decreased by a full 2 microns (see Figure 9). Despite the micron premium being variable and recently at its lowest level recorded during 2013–14, it remains a key determinant of next-to-skin comfort, luxurious handle and moister management properties. Fibre diameter is therefore likely to remain as a key determinant of quality in the long term and needs to be considered in genetic improvement programs.

In both meat and wool, selection for quality and productivity need to be carefully balanced. In both cases, selection solely for productivity (fleece weight in wool, growth rate and leanness in meat) is predicted to lead to unfavourable correlated responses in fibre diameter and meat eating quality. In both cases, balanced selection is possible, but depends on having genetic information for both the quality and productivity traits.

The Sheep Cooperative Research Centre (CRC) has recently developed measurement systems for objective analysis of next-to-skin comfort and the luxurious handle that distinguishes wool from other fibres. These new instruments are likely to play an important role in increasing consumer demand for finer micron wools and their functional value in the quality of next-to-skin knitwear.

Data Capture and Digital Data Management

The use of electronic identification of individual animals, in combination with automated data capture systems such as Walk Over Weighing, provides tools that are rapidly becoming mainstream options for improving sheep management. The semi-automated measurements of fleece weighing, collecting body weights, condition score and pregnancy provide more accurate data and reduce the cost of its collection.

There are substantial benefits resulting from data being retained so that it can be used for multiple purposes. Data is often used only at the time of collection for a management decision that is immediately implemented. The true potential value of data is achieved when it is combined with other information for within flock selection decisions such as culling or feeding and reducing the risk of compromised wellbeing. The same data can also be used for more accurate decisions on genetic selection and sharing information through the supply chain. New measurements being developed for carcase grading within abattoirs will primarily be used for carcase sorting and payment grids but will also have considerable value in contributing to information available for genetic selection and feedback to producers in order to improve management and production systems.

The development of cloud and internet computing systems facilitates the use of centralised databases that can be used to ensure that data is available for multiple purposes. Efficient data collection and its effective use have the potential to improve labour productivity considerably. When combined with the benefits of faster genetic gain and better livestock management, more efficient data use

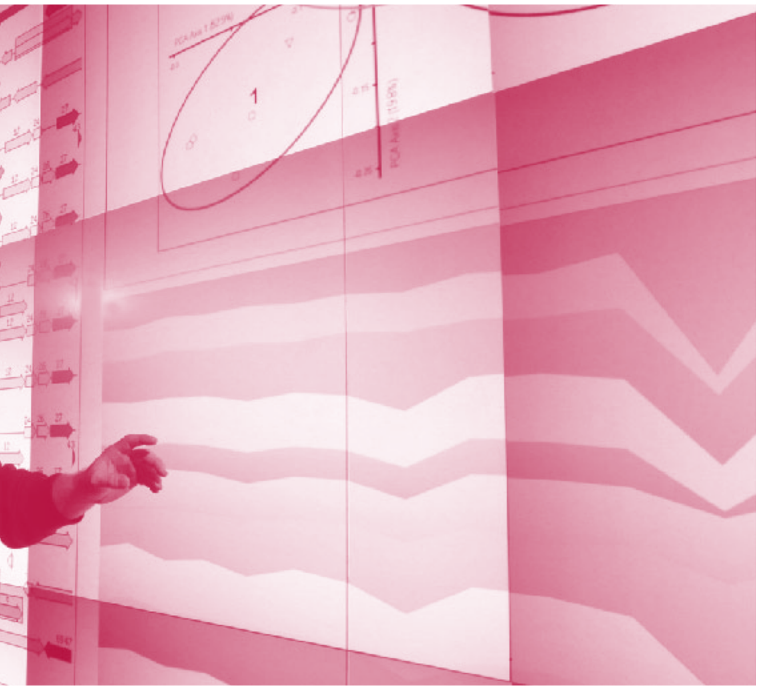
also has the potential to improve productivity through better informed and more timely management decisions.

Skills Development to Capitalise on New Technologies

Data capture and its management underpins genetic technologies, animal care and efficient supply chains. It is, however, a new skill to most sheep producers and, particularly given the age demographic of the sheep industry it is essential that specialist training and new infrastructure be developed to ensure that the powerful enabling technologies of genomics and data use are fully utilised by sheep breeders and producers.

It is also important that breeders and commercial producers are adequately skilled in using genetic information itself. The Prime Lamb Key Program, which contributed to significant change in lamb industry performance, included a strong focus on extension including the use of LAMBPLAN, and such extension has continued to some extent to this day.

Examples of successful training programs and possible infrastructure developments are listed below.



Specialist training:

- LAMBPLAN training including use of producer initiated demonstration sites
- producer demonstration sites
- electronic identification (eID) course
- RamSelect
- pregnancy scanners and wool classers.

Infrastructure:

- cloud computing with suitable apps
- automated data management
- careers for data specialists.

Conclusions

This paper has examined the role of genomics and digital data in improving sheep productivity. This prompts the question: What are the technologies or developments that will deliver sheep industry productivity gains in the next 10 years?

The answer can be thought of as developments in three waves:

- Firstly, there is considerable scope for improvement of commercial enterprise productivity and product quality simply by tapping into existing genetic improvement information available through LAMBPLAN and MERINOSELECT. Even at the current modest average rates of genetic improvement evident in merino flocks using this technology, commercial clients can improve gross margins by between $0.50 and $1.50 per ewe per year or more. Sourcing rams from the flocks making higher rates of gain is essentially a ticket to enterprise financial health.

- Secondly, the continuing development and increasing implementation of genomic methods into existing genetic improvement systems offers a revolution in our ability to make rapid genetic change in a broader range of traits than is currently possible. The exciting scope here is for improvement in quality, health and welfare traits that have to date been difficult to do anything about.

- Thirdly, the synergies between information technologies and genomic technologies hold scope for a step-change in profitability at both the enterprise and whole of industry levels. Genomics is completely information dependent, and can only assist with the hard-to-measure traits if data is being captured and used from the entire value chain. New information technology (IT) tools are making this possibility a reality. Better use of information technologies will make day-to-day decision-making simpler and faster is an added bonus.

The next 10 years will continue to see transformation of the sheep industry through technologies in various stages of maturity converging to accelerate our ability to develop new approaches and increase the rate of innovation. This is already apparent in the meat sector of the industry in the rapid implementation of genomic tests for eating quality, and the way this is stimulating new thinking in lamb and sheep meat value chains.

Finally, it cannot be stressed too strongly how this convergence of technologies, and the opportunity for faster gains in sheep industry productivity, builds on more than two decades of industry-engaged research and development (R&D) with sheep breeders, producers and processors working closely with Australian researchers on real problems. Maintaining this collaboration is vital to long-term industry success.

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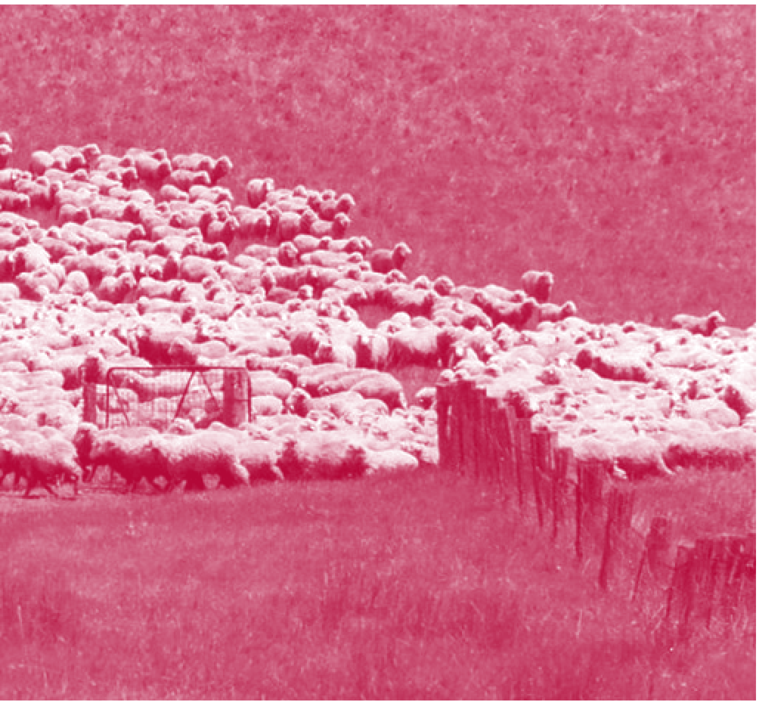
About the Authors

Professor James Rowe is CEO of the Sheep Cooperative Research Centre (CRC) based at the University of New England in Armidale, NSW. Prior to joining the Sheep CRC in 2002 he was Professor of Animal Science at UNE. He has over 30 year's experience in animal-based agricultural research and development working in the private sector and with a number of government and international organisations.

The Sheep CRC has made a significant contribution to development of the Australian sheep industry through a number of initiatives that have improved productivity and the quality of wool and meat products:

- introduction of precision sheep management and its benefits automated sheep management and for within flock selection to improve productivity
- development and delivery of new genomic technologies to enhance the rate of genetic improvement

- understanding of the biology of meat production and how to achieve balanced selection for improved lean meat yield and meat eating quality
- new measurement systems to underpin quality assurance, comfort and handle of next-to-skin lightweight wool knitwear
- improved reproductive efficiency through better ewe management and effective use of pregnancy scanning information



- the ParaBoss program for sheep parasite management
- training programs such as the RamsSelect and eID courses that position the sheep industry to use new technologies effectively.

Dr Robert Banks was born and educated in Tasmania, he graduated from the University of Tasmania with a First-Class Honours Degree in Agricultural Science in 1978. Following two years working in the poultry and brewing industries in Tasmania, he undertook a PhD in Genetics under Professor Stuart Barker at UNE in 1981. During the course of his studies he increased the size of fruit flies some 300%!

Following completion of his PhD, he spent two years back in Tasmania working in the state Department on applied genetics R&D and extension in a wide range of livestock industries. Then, in 1988, he took up the position as inaugural National Coordinator of LAMBPLAN, the new genetic evaluation and improvement system for the lamb industry.

LAMBPLAN has grown in adoption and impact, and is now the technical platform for a single national genetic evaluation and improvement system for the entire sheep industry, with backing from Meat & Livestock Australia (MLA) and Australian Wool Innovation. Its wide industry adoption has been a significant factor in the enormous growth in value of the lamb industry since the early 1990s. As LAMBPLAN grew, Rob's responsibilities grew to include management of MLA's Genetics R&D portfolio, covering sheep and beef cattle. In 2004, he took over the role of Manager for On-Farm Livestock R&D for Southern Australia within MLA.

After 25 years with Meat & Livestock Australia, he took on the role of Director of the Animal Genetics and Breeding Unit (AGBU), based in Armidale. AGBU is a joint venture of the University of New England (UNE) and NSW Department of Primary Industries (DPI), and conduct R&D underpinning the BREEDPLAN, Sheep Genetics, PIGBLUP and TREEPLAN genetic evaluation systems. Rob has combined a capacity for strategic thinking with great effectiveness as a change agent in the industries he has worked in.


Challenges and Opportunities for Precision Dairy Farming in New Zealand

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This study aimed to identify the key challenges and opportunities for New Zealand farmers using precision dairy technologies. A range of dairy farmers, researchers and service providers were interviewed using a semi-structured interview method. Interviews were recorded and subsequently transcribed for qualitative analysis. An open coding process was used to identify main themes across the case studies. The information gathered from the precision dairying community provided insights which were used to identify areas for future research and development. Findings from the study indicated that precision technologies had potential benefits for an industry with larger farms, scarce labour and increasing management complexity. A number of issues also existed around technology and management adaption, the level of information and communication technologies (ICT) skills, and engagement of farmers. There was also uncertainty around how to unlock potential benefits, some problems were identified around staff-technology interactions, and limited backup and after sales support from the service sector. The analysis identified eight key questions concerning farmer expectations and experiences with precision dairy technology, along with the role of service providers, and factors involved in successful and unsuccessful adoption. The questions were used to propose a research agenda based around five themes aimed at driving a coordinated precision dairy research program. These themes were:

- Where does precision dairy technology fit in New Zealand dairy systems?
- Are the New Zealand dairy farmers ready to adopt new technologies?
- How can trust and confidence in new technologies be built while managing expectations?
- What are the service sector roles around precision dairying?
- Where does industry engagement meet private delivery in precision dairy farming?

The paper describes the processes used in the case study work as well as farmer feedback on their experiences.

Introduction

Precision dairy technologies appear to offer benefits for New Zealand dairy farmers as they adapt to increasing farm and herd sizes, and as farming systems intensify. Technology use surveys in 2008 and 2013 found almost 20% of surveyed dairy farmers were using automation such as auto teat spraying and auto cup removal (Edwards et al. 2014). However, other forms of precision dairy (PD) technology was less prevalent with electronic identification used by 5% of survey participants, and 2% using electronic milk meters. PD technology use was shown to be higher in rotary dairy parlours, when compared to herringbone parlours (Edwards et al. 2014).

This is an updated version of a conference paper: Yule, IJ, Eastwood, CR (2012), Challenges and opportunities for precision dairy farming in New Zealand, Paper presented at the 11th International Conference on Precision Agriculture, Indianapolis, Indiana, US, 15–18 July 2012.

The definition of a PD farmer is open to debate, however one definition involves 'the use of information and communication technologies (ICT) for improved control of fine-scale animal and physical resource variability to optimise economic, social, and environmental dairy farm performance' (Eastwood et al. 2012). In practice PD relates to the use of tools to gather information for farm management decision-making, such as electronic animal identification, sensors for milk quality/quantity and animal performance, and smart pasture measurement devices. The challenge that PD poses for farmers is the interpretation and use of collected data, and the process of building capability in farmers, staff, and their off-farm support networks.

The dairy industry lacked in-depth information regarding the use of PD on farms, and the opportunities for increasing the usefulness of PD in the context of New Zealand dairy systems. This paper outlines a study that was conducted with the following objectives:

- Examine the impact of precision dairy farming on farm performance, farm management practice, and farming system profiles.
- Examine the adaptive management challenges precision dairy farmers have, and are, facing.
- Develop an understanding of the role of actors in the innovation network around precision dairy farmers.
- Propose a research agenda for the precision dairy farming space.

The study was specifically focused on the farm management opportunities for existing PD technologies, rather than on the development of new technologies. A qualitative research approach was used, as outlined below. This paper provides a summary of the research and interim findings.

Material and Methods

The study was conducted using farm and dairy industry case studies and a qualitative research methodology. The case studies examined the current practices of PD farmers, and issues faced by farmers and other sectors of the industry. Semi-structured interviews, lasting 60–90 minutes, were used to facilitate the exploration of relevant issues within each case study. Interviews were recorded and transcribed, with transcripts analysed using qualitative software (NVivo™) and open coding methodology to build emergent themes (Strauss & Corbin 1998). Data from each case study were combined to develop the main themes.

Participants were selected via networks of industry contacts, and through use of a snowball selection method (Bryman 2001). They were selected to cover a range of farming systems (farm size, farm system type, irrigated and non-irrigated), a range of technologies, and a range of experience with the technologies.

Fifteen interviews were undertaken in 2011 with commercial farmers (10), research farms (2), and precision dairy service providers (3) with more informal discussions also held with a range of technology providers at national agricultural field days. Brief details of the ownership, herd size as well as the technologies used on the individual farm businesses are identified in Table 1. The technologies were categorised as being related to measurement of the cow and her performance, or related to pasture management and soil moisture monitoring.

Results and Discussion

The interviews uncovered a range of challenges and opportunities for precision dairying in New Zealand. These are distilled as five main themes. Quotes from participants are used to highlight specific perspectives.

a) Integrating technologies into specific farming systems

Farmers faced challenges when integrating the PD technologies into their farm system. One issue was that many of the devices are of international origin and therefore designed for European or North American farming systems. Both the international products, and those designed within New Zealand, exhibited difficulties when trying to link with other devices, and in data exchange. The lack of integration led to some farmers running overlapping systems, with a degree of duplication. The ability for products to integrate proved to be a determining factor for some farmers in their investment decision-making, for example one case study farmer commented: ‘The thing I liked about [Technology system 1] was they had that whole package that you could bulk together, it was all integrated properly.’

Adaptation occurred on the case study farms in two ways, firstly farmers acted to adapt the technology to suit their needs, and they also adapted their management to incorporate the technology. Examples of the former were adjusting the placement of electronic identification (eID) readers to maximise accuracy, alteration of the auto-drafting set-up, and making changes to a pasture reader to make it more robust. In terms of management adaptation, a farmer said:

> People who haven’t been on an automated farm really struggle to get their heads around not just the fact that it’s the gadgets that’s automated… we’ve linked that with our management, trying to have efficient management, planning, organising... If that doesn’t go hand in hand with the machines you’ve got in the shed then… what you’re gaining on one hand you’re losing on another.

b) Emergent precision dairy learning networks

Learning to use the new technologies is a vital part of the implementation process and building learning networks is a potential method to promote learning. Technology suppliers provided most of the training available to case study farmers, using a variety of approaches including one-on-one support, occasional user groups, phone support, and remote computer access. The challenge for these training activities was in empowering farmers to proactively learn and think about how to use their new systems. User groups seemed the most popular method of learning, but according to the companies these groups had variable levels of attendance. Possible reasons for this may be related to lack of perception among farmers that the groups lead to positive outcomes, or that the level of learning was pitched at early users instead of more advanced users. One farmer commented:

Table 1: Characteristics of study participants and farms.

				Animal measurements							Pasture and natural resource measurement		
Farm	Farmer age	Ownership	Peak milk herd	EID	Milk meters	Conductivity	Auto-draft	Individual feeding	Activity	Weigh scales	Pasture meter	GPS map	Soil moisture monitoring
1	n/a	Corporate	600	Yes	Yes	Yes	Yes	-	-	Yes	Yes	Yes	-
2	n/a	Corporate	-	Yes	Yes	Yes	Yes	-	-	Yes	No	Yes	-
3	n/a	Research	600	Yes	Yes	-	Yes	-	Yes	Yes	-	-	Yes
4	40s	Family	1800	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
5	30s	P-Ship	1200	Yes	Yes	-	Yes	Yes	-	-	Yes	Yes	Yes
6	40s	Family	850	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	-	-
7	30s	Sharemilk	-	-	-	-	-	-	-	-	Yes	-	-
8	50s	Sharemilk	560	-	-	-	-	-	-	-	Yes	Yes	-
9	30s	P-Ship	225	Yes	Yes	-	Yes	Yes	-	Yes	Yes	Yes	-
10	30s	P-Ship	820	Yes	-	-	Yes	-	-	-	Yes	Yes	-
11	30s	Sharemilk	360	-	-	-	-	-	-	Yes	Yes	-	-
12	n/a	Research	650	Yes	Yes	Yes	Yes	Yes	-	Yes	Yes	-	-

> The best thing about those is just finding out what other people are doing. So we learn from each other. I think they're all in the same boat in terms of actually what information is in there, but some people are obviously more computer literate and dived into a bit further and found some bits and pieces that are useful.

There was little interaction between farm service providers, such as consultants and veterinarians, and PD systems. There is significant potential for service providers such as vets, nutritionists, and agronomists to enhance their service offering by not only using the data collected through PD but to also help their clients get more from the systems. These service providers can add knowledge and context to data being produced through milk meters, activity sensors, or pasture meters.

c) Primary benefits currently occur through labour saving and task automation

The benefits that farmers identified from PD were centred on labour and skills support, and management enhancement. Larger herds and increasingly complex farming systems demand more labour and skills in managing large enterprises. PD technologies such as ACRs, auto-drafting, and calf feeders had major time saving benefits. Also, heat detection in some cases saved having a dedicated labour unit looking for oestrus cows. EID and the associated databases also acted as an initial risk management, especially important where many different staff are used at milking time or where staff do not have the skills to recognise certain animal production and health issues. Added to this was an ability through the technology, to see mistakes more clearly, when in the past these mistakes may have gone unnoticed.

This is perhaps different to more academic or industry good approaches who see the major benefit in increased productivity, which in turn is often in response to farmers early questioning of economic viability. Although farmers had demands on equipment they often had only vague ideas of their current performance in terms of the successful completion of tasks such as oestrus detection or grazing management.

Management enhancement was derived through use of the data in decision-making. Identified benefits included 'preventing surprises' by having regular and reliable data on parts of the farm production system, for example weekly measurement of pasture data enabled farmers to know where they were in terms of pasture growth. Technology such as weighing was being used to achieve an earlier response to adverse events – such as the impact of cold weather on cow condition. Farmers also learnt via the data provided to reprogram their own mental models to respond faster to similar situations in the

future. The data showed them more about the actual impact of events or wrong decisions. One farmer said 'after the technology went in it was frightening to see the mistakes that were being made before.' A comment by a farmer was:

> I think that's the power of having data is that you know your system a lot better and then so you can say, okay well this is what we're currently doing and this is what we're planning for next year. How do you fit into that? Are you going to give me more production? Are you going to save me money?

d) Trust in technology

Trust and technology was a major issue amongst case study farmers as the level of trust farmers perceived had implications for their satisfaction with the technologies and extent of implementation on-farm. Trust involved two aspects: whether the technology would do the job it was supposed to when it was needed, performing reliably every day even in adverse conditions, and whether the data collected was trustworthy. The building of trust appeared to be subtle and complex, depending in part on user attitudes toward technology and awareness of the expected performance of the technology. Performance expectations were often built during the sales process. Experiencing errors soon after

installation without sufficient explanation also dented the confidence of some farmers in the study. A case study farmer said:

> [W]hilst we trust it [the technology] there's a couple of things that sometimes don't make bits of the technology work optimally. That's where I see a role for me or someone to come and help me. While we trust all this technology, for example the heat detection, I trust it but it's not always right and it's not always wrong either. Sometimes it's just feeding you information and some of it I'll discount based on other information it's fed me.

The implications of lack of trust meant that systems were underutilised or full efficiencies could not be achieved due to a perceived need for back-up systems. The higher the risk associated with a wrong decision, the more likely it was that back-up systems were used – for example using tail paint and noting cows on a whiteboard where cows were treated with penicillin.

e) Link between precision dairy technology and farm workforce issues

As mentioned many benefits from PD came from labour and skill related areas. There was a strong link between PD and issues related to the dairy farm workforce. While some farmers saw precision tools as a means of covering a lack of staff skills, other saw it as a double-edged sword as the technology might actually lead to a 'de-skilling' of farm staff. To them, basic dairy farming skills were still important to help them interpret the information being fed to them by the system, especially as some of these people will be the dairy managers or owners of the future.

New skills were also required around interaction with ICT, entering data and having some knowledge of how to operate the software systems. Not all staff had the skills or the motivation to develop the skills. Some of the farmers specifically tried to build skills around their ICT systems, for example getting all staff to use the pasture meter, making sure the herd manager was competent with in-shed technology, and actually providing some training to staff at the start of a new lactation.

Issues for Industry-Good Engagement with Precision Dairy Systems

From the themes above some broader discussion points emerged based around the challenge of aligning PD within the farm management context, and the potential entry points for industry-good engagement in the PD space. From the findings of this study, five main questions were posed to form the basis of a future research agenda:

- Where does precision dairy technology fit in New Zealand dairy systems?
- Are the New Zealand dairy farmers ready to adopt new technologies?

- How can trust and confidence in new technologies be built while also managing expectations?
- What are the service sector roles around precision dairying?
- Where does industry engagement meet private delivery in precision dairy farming?

Precision dairy represents an evolution, rather than revolution in managing dairy systems (Jago et al. 2013). The use of new technologies primarily provides greater information, and in more detail, for farmers making management decisions. The potential volume of new information heightens the need for farmers to have a solid farm planning process, for what is the point of collecting more data without a planning and decision-making structure to underpin its use? A review of farm management planning processes by Gray (2001) identified key components of planning, implementation, and control phases. These phases, and the sub-processes within each phase, are highlighted in Table 2. Also shown in the table are examples of how PD was used by the interview participants in relation to each farm management phase.

One of the case study farmers used a similar, but more defined approach based around steps of ‘plan, measure, manage, and review.’ He applied this approach to most aspects of the business and could do so with different timelines, weekly, monthly, the lactation, the lifetime of the cow. Where he saw most benefit from PD was in rapid feedback on his planning and implementation processes as well as his management strategies.

An important driver for making the most from PD appeared to be having a defined management plan as a basis for farm decision-making prior to making an investment decision. This plan is vital for making the appropriate investment decisions and provides farmers the ability to ask: how will this information allow me to make better decisions? Other research has noted that PD enables enhanced management practice, rather than providing a solution for poor management (Jago et al. 2013).

The importance of good farm management planning practice in the successful use of PD technologies highlights a challenge when considering industry-good research, development and extension (RD&E) investment. Determining the most appropriate allocation of funding in this area can be viewed in terms of the different scales at which issues occur. Examples of these scales are highlighted in Figure 1 and involve the farm level, supply chain and service provider farmer networks of practice (Eastwood et al. 2012), whole of industry, and cross-sector or international scale. Dairy industry-good organisations can have different potential impacts across these scales, as discussed below.

At the farm level, industry RD&E can potentially engage with private technology companies around technology design, installation, integration, and training. It is at this scale that private companies

Table 2: Precision dairy in the context of planning, implementation, and control processes.

Processes	Sub-processes	Role of precision dairy technologies and information from case study farmers
Planning	• Goals for the planning period • Predictive schedule of events • Targets • Contingency plans • Decision rules	• Historical information • Information on current status and trends • Potentially predictive information/ modelling on future trends
Implementation		• Use of automation and control devices to carry out plans
Control	• Monitoring performance indicators and external environment • Data storage and processing • Decision point recognition • Control response selection • Evaluation and learning	• Real-time monitoring of animal and plant resources • Automated setting of alerts for when decision points are reached • Automated decision rules to guide actions when decision points reached • Use of data to evaluate success/failure of processes

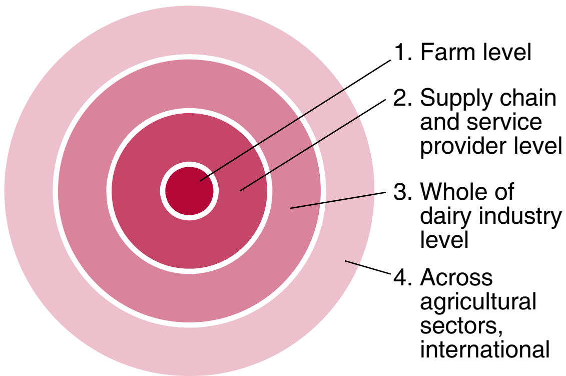

Figure 1: Differing scales of engagement for private and industry-good RD&E activities in the precision dairy space.

have the strongest potential role in technology design and on-farm support, with industry RD&E organisations providing independent research, leadership around best practice, and generalised extension. An example of facilitation of private and industry good engagement is through the Primary Growth Partnership fund (Ministry of Primary Industries 2013). Additionally some work has been undertaken to develop protocols for evaluating animal monitoring technologies (Dela Rue et al. 2014; Kamphuis et al. 2013) but these have only gone as far as recommendations rather than required standards.

At the supply chain and service provider level, in the networks that link with farmers, there is also significant opportunity for private organisations to build products and services focused on capturing the data from the farm level and value adding for the farmer and the industry. Industry organisations can play a role in facilitating standardisation of data transfer and ensuring the rights of stakeholders are protected around issues such as privacy.

Across the dairy industry there is an opportunity for organisations to guide development of training programs aimed at building capability in the use of advanced dairy technologies, in addition to skills in interpreting the information derived (Eastwood et al. 2013). In New Zealand this could include more focus on training at University as well farmer training organisations. Opportunities also exist for whole of industry databases which leverage off, and value add, to the data collected on farm. Recently the Dairy Industry Good Animal Database was formed (DairyNZ 2013). This represents a potential opportunity for further value adding by incorporating additional data already collected on farms. Industry level databases are well utilised in other countries, and in Ireland a database incorporating pasture growth data has been shown to have potential for benchmarking and industry use (French et al. 2014).

Precision technologies are increasingly being used across many agricultural sectors both in New Zealand and internationally. This provides the potential for learning across sectors, and collaboration around data analysis and integration. Cross-sector and international standardisation of data transfer is also a priority at this largest scale. There is a strong role for industry-good involvement in these issues, as individual farmers, or even individual technology firms have insufficient leverage to enact change in this area. In New Zealand efforts are being made to address the issue of data transferability and technology compatibility via the New Zealand Farm Data Code of Practice (Anon 2014). International RD&E collaboration between the New Zealand and Australian dairy industries has been initiated (Jago et al. 2013).

Conclusions

The qualitative method used in this study facilitated exploration of the challenges and opportunities faced by precision dairy farmers in New Zealand. Information gathered will be used to drive a future research agenda related to the linkage of new dairy technologies with best practice on farms. We observed that the technology has significant potential benefits for an industry with bigger farms, scarce labour, and increasing management complexity. Two key observations can be made: first farmers must have confidence in a technology to use it. The issue of confidence becomes more and more important as the dependency on technology increases. An increased level of automation also heightens dependency, if one component in the integrated system fails then the whole system may not work. This issue also has to be examined from the manufacturers' and service providers' perspectives, in a price competitive market it would be easy to underestimate the cost of supporting such products. Once a farmer has a bad experience then they are likely to be much more hesitant about further technology adoption.

Second, the level of planning, management and review exhibited by the farm management team is crucial. If there is no planning there is no purpose to employing these new technologies. In this emergent phase for precision dairy farmers the benefits are being hobbled by issues around technology and management adaptation, ICT skills and engagement, uncertainty of how to unlock benefits, staff-technology interactions, and a paucity of capability in the service sector. This makes the design of information systems extremely important and management systems must use the data to provide useful information to 'time poor' farmers or herd managers in a clear and efficient manner

Farmers and systems developers also face additional challenges into the future for development and use of new technologies which align with potentially diverse farmer needs in pasture and resource management. In addition likely new legislative and policy issues and additional market compliance demands need to be considered. Protection of the farmer's privacy and data ownership also need to be ensured.

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About the Authors

Dr Callum Eastwood has a strong background in agricultural systems research, and dairy farming systems in particular. His research interests include examining the learning challenges faced by farmers using new technologies, the features of successful innovation systems, and the human-technology interaction around precision farming systems. Through his research Callum seeks to understand the needs of ‘end-users’ (usually farmers) in his research. Callum has extensive experience with the application of precision technologies in dairy farming, including animal sensors and pasture measurement approaches. His social research tools include the application of concepts such as adult learning, networks of practice, and innovation systems.

Dr Ian Yule is Professor in Precision Agriculture at Massey University. He has been involved in a large number of research projects associated with cropping, viticulture and pasture production. He was one of the developers of the C-Dax Pasturemeter and has continued his interest in pasture measurement methods including remote sensing. He also brought electromagnetic soil mapping to New Zealand, a method which can rapidly assess soil type and soil moisture holding capacity. With others this work has been fundamental to the successful adoption of precision irrigation both in New Zealand and internationally. Professor Yule has a passionate interest in improving agricultural production and making farming systems more efficient.

Agricultural Big Data: Utilisation to Discover the Unknown and Instigate Practice Change

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This short discussion paper considers the current agricultural extension shortfalls and considers how agricultural big data might be used to change the way unknown on-farm issues are identified and managed. The premise being that if unknown issues are brought to light on an individual basis, and potential solutions discussed within trusted networks, that this will enhance the incidence of practice change. Knowledge is discussed in terms of that which is known and that which is not, with the discussion focused on the use of data to help realise unknown knowledge and thus determine on-farm issues, as well as predict cause and effect. The paper draws on the concepts of big data and networked learning to provide a base model on which digital platforms might operate to provide efficiencies in the on-farm decision-making process, as well as enhance the power of those decisions.

Background

Current extension models within the Australian context rely on a dwindling public extension physical resource to convey information to agricultural practitioners, with the further expectation that the public sector will convey the deficit of required information and advice through consultancy and agronomist services. Whilst the Australian Government have conceded that the basic premise of this model has failed (Commonwealth of Australia 2014), it was initially flawed from inception in that it relies on practitioners knowing they have an issue and therefore an information requirement.

That is to say, how do we ask for help if we do not know we have a problem? How do we realise the unknown issues if the question itself is unknown? Donald Rumsfeld referred to these as 'unknown unknowns – the ones we don't know we don't know', which was met with mixed response, but is actually quite apt in describing the current extension failing. In 2002, as United States Secretary of Defence, he gave the infamous address:

> Reports that say that something hasn't happened are always interesting to me, because as we know, there are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns – the ones we don't know we don't know. And if one looks throughout the history of our country and other free countries, it is the latter category that tend to be the difficult ones.

Here Rumsfeld essentially describes the relevance paradox, which explains how individuals will typically make decisions with information they feel is relevant to the issues at hand and will dismiss anything that *they* consider irrelevant information, or beyond that *they* perceive as necessary.

Irrelevant information perception is often based on current context and within the limitations of time, resourcing and other external demands, but given a positive change in the limitations could be perceived as relevant (eg more time to consider information from another context, further staff to research information, less pressure to conduct multiple tasks and thus ability to focus on the task at hand). Hence, it is accepted that we often exclude the unknown unknowns by not considering important information that might appear abstract to the current context and in doing so our decision-making power is diminished. Therefore, Rumsfeld's notion that facts we don't know we don't know are the most difficult, and by expansion usually quite important to a successful system, is also an important consideration for agriculture, as it was in terms of the military context he originally provided the speech for.

The solution to a successful agricultural system therefore lies in providing a means to ask the question about a problem we do not know we have. The agricultural extension industry is essentially intended to address this conundrum via conveying the important aspects of scientific and technological innovations in a relatable way to farmers and agricultural industry personnel.

However, the relevance paradox still holds in this traditional extension model, as the individual will not consider the innovation relevant if they do not: know they require it; see obvious relevance to their current farming system; or, understand the issues it is designed to address. This is where the power of big data, and more importantly the use of multiple data sources to model agricultural systems and expected changes/impacts in a non-reductionist manner, could be realised. Big data has traditionally been defined by increased data volume, velocity and variety in association with our ability to store and interrogate it (Laney 2001).

Whilst this is certainly still pertinent, it is pragmatic to consider agricultural big data by its source, as something dynamic and somewhat organic in terms of its evolution, and most importantly by how it is utilised. In this respect, Devlin (2012) proposes that data fits three main categories: *process-mediated* (PM), *machine-generated* (MG) and *human-sourced* (HS).

In an agricultural context: PM data can be thought of as data generated in the running of the business, on-farm data, including business transactions and farming inputs, as well as

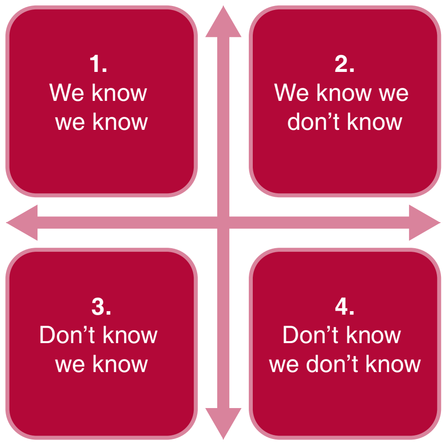

Figure 1: Rumsfeld's categorisation of knowledge states, with the inclusion of state 3 referring to tacit knowledge.

agronomic, soil and water analysis etc; MG data is data that is automated in its production and can include on-farm data (eg yield mapping, soil moisture sensors) and external databases such as climate information provided by the Bureau of Meteorology; while HS data is what we produce in the carrying out of our lives and can be as vast as discussions (now often digitally recorded through emails, blogs and social media) through to patterns in the information we view (exploited easily through internet usage). By harnessing these data sources and using them to provide diagnostic and forecast-based analysis of the farming system, in the broader context of regional, national and international performance, inefficiencies and potential pitfalls in the system could be flagged. In this way, information that might have previously been thought of as irrelevant becomes relevant through the highlighting of unknown unknowns.

When seeking to improve practice within our vocation, as individuals we most often start with known issues and address these. The information we seek becomes known, transitioning from knowledge state 2 to knowledge state 1 (Figure 1). During the process of seeking such information, we reinforce our tacit knowledge transferring it to the known state of knowledge; quite often we do not feel confident in that which we know and simply need an external source to provide validity to that information – this is tacit knowledge.

In researching information for a known unknown (knowledge state 2) we may happen upon information in knowledge state 4, transitioning it to state 1, but this is rarely the case given the relevance paradox. In agriculture, where individuals self report as time poor (Bennett & Cattle 2014; Kelly, Allan & Wilson 2009) the relevance paradox is highly prevalent, meaning practitioners are more likely to include only what they perceive as most relevant, subject to the limitation of time.

Conversely, scientific community function is based on knowledge gaps (state 2) leading to frequent uncovering of unknown unknowns, transitioning them back to state 2 for future attention. In fact, it is the aim of the scientific community to continue to push the bounds of knowledge in search of new questions and their subsequent solutions.

Agricultural extension is designed to connect the individual to scientific community outcomes, although not necessarily addressing knowledge state 4 in this process. On all levels, it is of further importance to note that information falling into knowledge state 4 need not be completely unknown to all; that is, one person's concept of common sense might be equivalent to another's 'unknown unknown'.

This short discussion paper presents a means of addressing current extension shortfalls and considers how agricultural big data might be used to change the way unknown on-farm issues are identified and managed. The premise being that if unknown issues are brought to light on an individual basis, and potential solutions discussed within trusted networks, that this will enhance the incidence of practice change.

Using Data to Identify Unknowns

Agricultural systems are complex, and running a highly successful agricultural enterprise requires an understanding of the system's complexities (interactions between characteristics, as well as cause and effect). Agricultural practitioners themselves have been shown to generally agree that farming is increasingly complex, especially as new technology/management options arise (Bennett & Cattle 2013), which enhance the quantity of PM and MG data able to be collected. Furthermore, technology and digital connectivity are rapidly advancing and becoming available to agricultural practitioners.

With this comes an associated increase in the potential to generate data pertaining to the enterprise through rapid, automated, and/or proximal means with real-time data collection a reasonable expectation into the future. This can be envisioned, for example, as a transition from the traditional keeping of hard records pertaining to monthly rainfall, paddock yield and market price received (PM data) through to the current ability to systematically digitally monitor numerous system characteristics such as soil moisture, irrigation water-use efficiency, yield maps at fine scale, detailed climatic data, nutrient budgets, crop model outputs, live animal tracking and weight gain, mechanistic performance, market options (MG data).

With access to all of this data the individual's ability to easily discern patterns and interactions is decreased resulting in many becoming overwhelmed and underutilising the data; it would be impossible to rely on human capacity alone to interrogate such data. Hence, the current situation is one where valuable data within agriculture is being underutilised or not utilised at all; information overload leading to decision-making paralysis, which sees business as usual the order of the day. There will be a major role for private consultants and publically available digital platforms to interpret and make this data useful.

Importantly, the current practice is to rely on individual knowledge, or externally consulted knowledge, to provide reasoning and solutions for issues as they arise. However, there is much to be learnt from interrogation of on-farm data, and then enhancing the value of this data by benchmarking it against regional data, or data from land resources with similar characteristics to one's own, although possibly not geographically proximal. That is to say, the farm and its performance, monitored across vegetation production, soil, water, nutrient, climatic and mechanistic systems, can be utilised to identify issues that were apparently unknown (knowledge state 4, Figure 1).

In Figure 2 the decision system is shown with support from on-farm and external data. External data could include open data sources, such as government databases for land resources and climate, market information, and regional data provided by other agricultural enterprises. In this figure, the width of the arrow indicates the power of individual components to enhance the decision-making process. Integral to maximising the use of data for on-farm decisions is the ability to interrogate and synthesise the output of this data through autonomous or semi-autonomous means.

Without such means, the ability to identify unknown issues is reduced. However, the current movement of big data analytics will provide solutions to this aspect of the model in Figure 2, whereby algorithms for known interactions can be incorporated into the analytics to raise a digital red flag for unknown issues occurring or potentially occurring. Hence, there needs to be a shift from low-level data collection towards high-level data collection on-farm and systems need to be put in place to interrogate and synthesise this.

Informed Decisions Through Community Interaction

The above section is focused on the use of on-farm PM and MG data, augmented by external MG data. However, while such data is useful for diagnostic analysis, interrogation of that data alone does not allow for efficient forecasting of cause and effect. To provide a predictive capability, it is useful to incorporate HS data into the analysis.

We as humans like to think we are individuals and that none of us are the same, but market research and targeted advertising on internet platforms (eg Facebook and Google) is based on the individual's patterns of internet usage compared to people with similar characteristics (ie we are not that individual and other's behaviours might be useful in predicting our own). Similarly, agricultural enterprises are viewed by their owners and managers as highly individual requiring enterprise specific detailed advice.

One example is a high demand for regionally specific demonstration sites of best management practices (Bennett & Cattle 2013), which is based on the commonly held belief that if data and practices haven't been produced locally then they aren't relevant. This might certainly be true in some instances, but geographically dislocated properties can have very similar ecological conditions and farming systems' characteristics. Furthermore, even where these differ dramatically, there is likely information that is valuable to the decision-making process, providing important lessons; the abstract information often discarded as per the relevance paradox.

What is currently missing from agriculture is the ability to connect individuals based on ecological conditions and farming systems' characteristics, as well as enterprise and personal interests. Regional farmer groups provide a way to address this locally and regionally, but rarely reach state and national level in terms of sharing information and discussion.

The power of this wider community interaction (HS data) is depicted in Figure 2 as community input and is shown to be more powerful than relying on individual perceived information of relevance only. This information is suggested in Figure 2 to be synthesised both through big data analytics, informing output predictions, as well as providing valuable increased power to the individual's internal decision-making process. This represents the individual's interaction within the community and with the information, as well as the use of deeper community usage and function analytics to inform predictions.

In other industries, digital platforms for the sharing of ideas have been developed and are highly successful in helping individuals make informed decisions through question and answer type forums (see: http://stackoverflow.com). These forums provide direct answers, but also provide a historical record of the discussion leading to the answer, which is invaluable for others seeking similar answers in future instances.

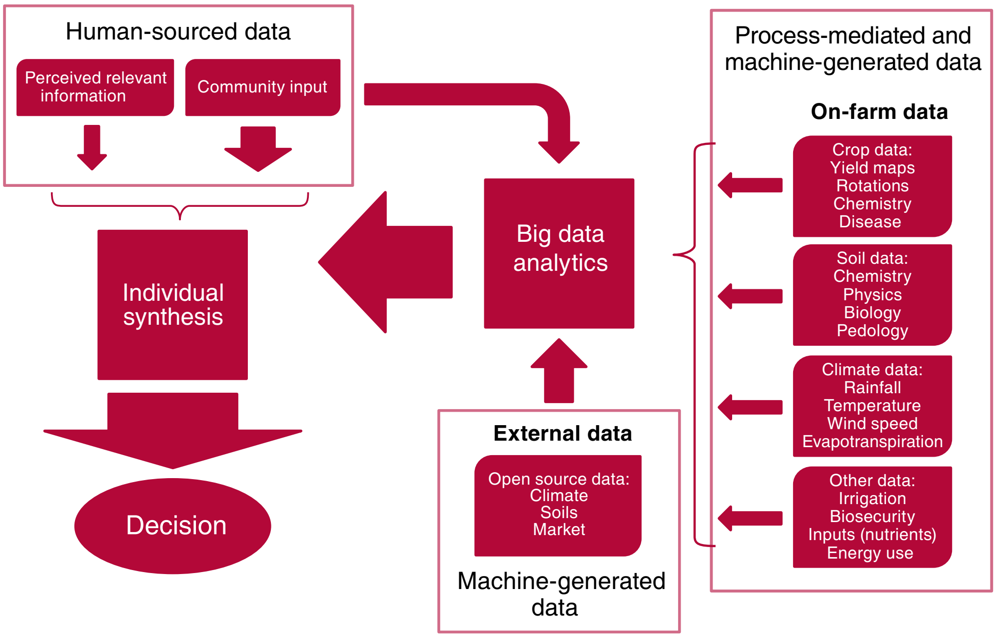

Figure 2: Depiction of decision process and outcome with support of data.

Note: The arrow width indicates the power of the information at that point in the decision process, and examples of data are not exclusive, but intended to demonstrate types of inputs.

This process is based on the social constructivist approach to learning and is termed networked learning (Goodyear 2001; Veldhuis-Diermanse et al. 2006). Individuals utilise their own personal context and motivations to co-construct, deconstruct and reconstruct ideas through a digital dialogue based on a common information requirement. Deeper learning is achieved as more aspects of the information requirement are explored and upon individual reflection. The process of reflection considers personal information requirements, shortfalls within current knowledge, and how other individual's approaches and contributions to the potential solution might affect the initial individual information requirement.

Quite often, ideas for dealing with a problem conflict between contributing individuals and instigate this reflection process. In this sense, a community approach to solving a problem allows the seemingly irrelevant information to be considered, and does so in a way that the weight of this consideration is not solely with any one individual.

Agricultural practitioners currently have a reliance on consultants and extension officers to fulfil information requirements as identified by Kelly et al. (2009), and Bennett and Cattle (2014), which is due to dealing with the inherent complexities of the farming system, but also diminishes the connection practitioners have with the farm. A shift of paradigm to a socially constructivist learning approach via networked learning should see a greater internal reliance of the agricultural community to understand and fulfil its own information requirement. This will enable a more involved approach to understanding and dealing with farming system complexities for the practitioner; a deeper more meaningful understanding with which to make informed decisions.

However, agronomists, other private consultants, extension officers and scientists will be integral to successful agricultural enterprises and on-farm decisions, but should not be seen as the sole-holders of information. Indeed, the current agricultural extension models do not support this reliance in terms of the required human resources (Bennett & Cattle 2013; Hunt et al. 2012; Marsh & Pannell 2000).

In the same way that PM and MG data alone do not provide the full analytical power, nor does usage of community based HS data; a question must be evident to ask and the on-farm data is useful in identifying this to address knowledge state 4 (Figure 1). A major benefit of community interaction has already been alluded to and is in the form of confirmed tacit knowledge (knowledge state 3 transfer to knowledge state 1). In a functioning community agricultural practitioners will become empowered as legitimate information sources as their tacit knowledge is confirmed.

In Figure 2 the suggestion is that on-farm and external data sources be used to realise the unknown-unknowns on-farm and thus identify the questions that a community could contribute towards constructing a reasonable solution to. Finally, it must be stressed that the final decision still rests with the individual (Figure 2), although the power of that decision is enhanced where big data analytics and community interaction are incorporated, as compared to a decision based on information the individual simply perceived as relevant.

Hypothetical Case Study

In order to understand how this integrated data model of extension might work, it is useful to consider a hypothetical case study. Consider an irrigated cotton cropping enterprise based in a temperate climate with limited access to freshwater irrigation resources and increasingly uncertain rainfall trends. A likely focus of such an enterprise would be to utilise water resources efficiently in order to maximise crop production in an uncertain climate.

Now, let's consider an issue that may arise in water use efficiency decreasing, but crop production remaining stable. In this case, PM data (irrigation water use) has alerted the farmer to the issue, which is a likely scenario irrespective of a big data approach. A farmer's intuition might suggest that crop productivity is stable as more water is being used to compensate the unchanging crop water demand and increased run-off, likely due to decreased soil infiltration, which would be a fair assertion.

What is not immediately apparent, however, is the cause of the decrease in soil infiltration and thus water use efficiency. In the traditional extension model the farmer might contact their local extension agent or agronomist and ask for their advice, but the advice given would not necessarily identify the correct cause of soil infiltration decrease without further investigation on-farm. In fact, the issue could quite likely be treated as an irrigation management issue whereby the irrigation regime is altered to account for soil infiltration, rather than identifying what the soil infiltration issue is.

Let's now assume the farmer has been diligently collecting on-farm PM data, and more recently been using soil moisture sensors and irrigation run-off sensors (MG data), which they upload to a cloud based platform capable of utilising big data (HS, PM and MG data) on an individual basis and then analysing it against the broader dataset (regional, national, and/or international) as per Figure 2.

Water use efficiency has once again been identified as decreased, with crop production remaining stable, prompting the system to flag water use efficiency issues prior to the farmer even noticing the issue. The platform also analyses information sought by previous farmers who have undergone similar issues and ascertains that such farmers looked at information concerning soil compaction and/or soil sodicity, both of which are usual causes of reduced soil infiltration. However, the farmer has also been uploading their soil tests (PM data) and the system can see that the soil has no issue with sodicity. Additionally, using a combination of the on-farm PM and MG data the platforms identifies that nitrogen use has increased significantly since water use efficiency has decreased.

The farmer is now presented with the full multitude of issues, more quickly than they might have been, and the system has used community HS data to identify possible causes of soil infiltration decline. This now realises the unknown unknown and provides the farmer the right information to ask the right question: have I made a change to my farming system that is likely to have increased soil compaction? Having realised this question, the farmer is able to identify that the recent introduction of a new heavier harvesting system is likely to be causing soil compaction issues and is now able to set about researching how to alleviate soil compaction impact in their system.

Whilst this is an elementary hypothetical case study, it serves to demonstrate that the use of HS, PM and MG data in combination with individual experience can enable the identification of system inefficiencies and provide sufficient information to identify the correct impacting factors.

In the example of the big data supported platform a further input inefficiency of decreased nitrogen efficiency was also identified, which may not have been otherwise. In this example, the HS data was crucial to augmenting the power of the PM and MG data analytics in providing the potential cause of infiltration decrease. If a strongly networked community of practitioners exists in a digital space, then the user traffic and patterns of use become extremely valuable in being able to provide context and sense to patterns observed in on-farm data.

Conclusion

Agriculture is presented with a significant potential to enhance system management capability via rapid data collection and analysis as technology advances and increased regional digital connectivity are achieved. The current use of data for most agricultural enterprises is low and interrogation of on-farm and external data is stymied by lack of an intelligent platform capable of this. Using a combination of analytics and human based digital networks, the agricultural industry will be able to diagnose on-farm issues and predict potential cause and effect of these. There is great importance though in ensuring that PM and MG data are reinforced and further interrogated with HS data; networked learning applied to a digital agricultural community is one potential approach to provide the required HS data. Hence, a focus on creation of digital platforms that achieve both a social and big data analytic synthesis is warranted.

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About the Author

Dr John McLean Bennett is a Senior Research Fellow (Soil Science) at the National Centre for Engineering in Agriculture, where he is the Sustainable Soils Research Theme Leader. He is also a senior lecturer in soil science within the Faculty of Health, Engineering and Sciences at the University of Southern Queensland (USQ), and is a level two Certified Professional Soil Scientist. John has a PhD from the University of Sydney, a Bachelor of Science (Resource and Environmental Management) with honours from the Australian National University, and a Postgraduate Certificate in Tertiary Teaching and Learning from USQ.

John's primary expertise are in soil structural integrity as influenced by salinity and sodicity, both in rain-fed and irrigated systems, which has seen him working extensively on solute movement and subsequent impacts on soil and water in wheat, cotton, meat and livestock, and coal seam gas mining industries. The focus of this work has been on the development of strategies for irrigation and soil management that facilitate productive crop water use and ensure longevity of landscape function. A primary objective of this work is effective communication of outcomes to industry, which has led to detailed work into understanding how industry research and innovation is adopted, with a specific focus on a digital rural future.

John is an integral researcher within the Collaborative Research Network Project 5 – Connected Learning at USQ and through this was successful in being awarded the Queensland Department of Fisheries and Forestry Innovation Hub opportunity along with an industrial partner, which has focused on the development of a business case for the use of networked learning and data analytics within a digital platform to enhance agricultural extension and practice change.

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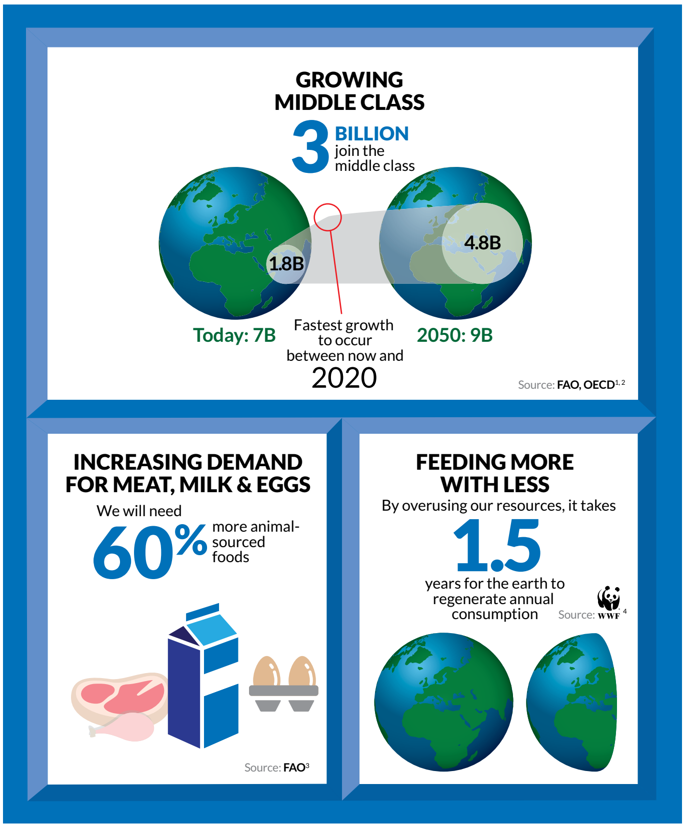
As the world population grows, the global middle class will more than double in size to nearly five billion by 2050.[1,2] This means billions of people – mostly in Asia – living better lives and demanding access to better diets, including meat, milk and eggs.[3] But we are already overusing the world's resources – by 2030 we'll require double the planet's resources to meet our needs.[4]



Improving Australian agriculture's international competitiveness can help to ensure a food-secure world and more sustainable farming communities at home. There are three top solutions:

1. By using innovation instead of adding animals, Australian farmers could save significant amounts of feed, farmland and water.
2. By ensuring consumers have a variety of choices to meet their cultural, health and lifestyle needs, Australian farmers can choose production systems that make sense for their operations.
3. By supporting consistent, science-based global food standards, Australian farmers can increase productivity and reduce supply chain complexity to ensure more Australian food is available for more export markets.

Australia's response to global food security can help ensure the future prosperity of Australian rural communities.

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By enabling innovation, supporting science-based standards in international food trade and ensuring choice for consumers and producers, Australia can help to rewrite the story of global food security while becoming more internationally competitive – and ensuring sustainable farming communities and rural environments for future generations.

For more information about the global fight for a food-secure tomorrow visit **www.sensibletable.com**, follow us **@jeffsimmons2050** or ask your local Elanco representative.

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Australian
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will consumers stop agricultural technology?

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Mick Keogh
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One of the most perplexing paradoxes of modern life is that consumers will willingly ingest potent mixes of chemicals or submit to analysis by some of the most advanced technological instruments in order to sustain their health, yet baulk at the use of the same technology in the production of the food they consume. The most obvious example is the use of insulin for the treatment of diabetes. The insulin used by diabetes patients around the world is produced via the use of recombinant DNA gene technology, and its use is absolutely uncontroversial. Yet the use of that same technology to produce GM crops triggers virulent opposition and government regulation, despite the fact that such crops have been grown for 40 years without a single adverse impact on consumers.

Why technology that is absolutely uncontroversial in some uses suddenly becomes the subject of consumer protests and government bans when used in food production is the topic that is addressed by the papers included in this edition of the *Farm Policy Journal.* Perhaps equally important is the need for the agriculture sector to find ways to ensure that farmers' access to technology is not unnecessarily restricted, especially in the event that robust science supports the safety of the technology for use in the production of food for human consumption.

The first paper is written by Charlie Arnot, the CEO of the Centre for Food Integrity (CFI), a United States-based organisation that aims to better understand the reaction of consumers to the use of new agricultural technologies, and to find better ways to communicate with those consumers about the use of those technologies. One of the more interesting conclusions of the CFI's research is that consumers are much more likely to be reassured about the use of a new technology when the information about it is provided by a peer or someone who has shared values with the audience, rather than by someone with a high level of technical qualifications and competency. As the author notes:

> The goal should not be to win a scientific or social argument, but to find more meaningful and relevant methods to introduce science in a way that encourages thoughtful consideration and informed decision-making.

The second paper is by Mark Swift, an Australian farmer and recent Nuffield scholar, who has focused on these issues as part of his recent studies. The paper examines issues of consumer acceptance associated with a wide range of different agricultural technologies, noting the scepticism held by many towards technology, despite the advances that it brings. The author makes a very pertinent observation about the fact that the more successful science and technology is in securing food supplies, the more sceptical consumers can afford to be about the provenance of that food, and the technologies used to produce it.

The third paper by Diederik van der Hoeven, a science journalist, asks whether scientists should take note of the concerns that the public often appear to hold about genetic engineering in particular. The paper argues that there are three 'dimensions' to the judgements that are made by consumers about the products of different technologies and production systems, and these are health, fashion and ethics. The use of technologies for products that improve human health is generally uncontroversial, hence the paper notes that health-related products are generally quickly accepted. The fashion and ethics dimensions are less predictable and more variable, and the paper provides a range of different examples that on occasion seem contradictory. A conclusion is that health is the overriding dimension; that fashion is fickle; and that ethical transparency is also a critical factor in gaining consumer acceptance.

The fourth paper by Emmanuel Domonko and co-authors examines the issue from the perspective of consumers in developing nations, who often have the threat of malnutrition as a major driver of their decision-making, and who are also frequently both producers and consumers of food. The paper examines a range of different case study examples of specific issues associated with either malnutrition or nutrient deficiencies, and the solutions for these that are available through the use of genetically modified (GM) crops. The paper concludes that even in situations where malnutrition and nutrient deficiencies are key challenges, there is still a need for careful communications with, and education of both producers and consumers in order to gain broad acceptance of the use of new technologies in agriculture.

The fifth paper, by Alice Woodhead and co-authors, looks specifically at the challenges that are faced by Australian farmers in producing and marketing products for wealthy Asian consumers. The paper points out that the reason that Australian products are preferred by Asian consumers is that they are perceived to be safer and more natural than products from other nations. This presents a challenge in that the widespread adoption of GM crops in Australia could potentially place Australia's reputation for natural production in jeopardy. The paper reports on consumer survey data from major Asian markets that presents a confusing picture about consumer acceptance of GM foods. It generally appears that Asian consumers have a relatively high level of acceptance of GM foods compared to consumers in places like Europe, but that the level of acceptance amongst Asian consumers appears to decrease as the level of education and wealth of consumers increases. This suggests that even if Asian consumers currently appear to readily accept GM foods (predominantly because they are less expensive) this may change in the future as consumer education levels and wealth increases.

The sixth and final paper by Grahame Coleman and co-authors examines issues of consumer concerns about animal welfare. Many of these arise in response to new technologies or more intensive production systems that have been adopted, especially in the pork and poultry industries. The paper has some interesting parallels to some of the earlier papers, in particular the observation that the opinions of consumers about animal welfare standards in different sectors seem to be related to the attitudes of animal welfare groups, rather than to individuals' personal knowledge about animal production systems.

The papers in combination highlight that, irrespective of the science, it is consumer attitudes and public opinion that ultimately determine the scope of agriculture's 'social licence to operate.' Reliance on science alone as a basis for the justification of a practice or a technology is unlikely to be successful, and much more comprehensive and encompassing communication strategies are required between the agriculture sector and the community.

Mick Keogh

Building Trust When Science and Consumers Collide

Charlie Arnot

The Center for Food Integrity 2014 Consumer Trust Research

Fortified by their own sources of information and their own interpretations of research, doubters have declared war on scientific consensus in food production. How can the food system connect with consumers who reject science? The Center for Food Integrity (CFI) 2014 consumer trust research provides a model for making complex and controversial technical information relevant and meaningful – particularly to mums, millennials and foodies – bringing balance to the conversation, while helping consumers make informed decisions about food and building trust in today's food system.

Technological advances in food and agriculture have provided countless benefits to society, but more must be done. Increased technology and innovation are needed in food production if there is to be enough food for a planet of 9 billion people by mid-century. Finding better ways to support the informed public evaluation of technologies and the food production system is a challenge. The goal should not be to win a scientific or social argument, but to find more meaningful and relevant methods to introduce science in a way that encourages thoughtful consideration and informed decision-making. How technical and scientific information is introduced is key to supporting informed decision-making.

CFI's peer-reviewed and published model for building trust in today's food system shows 'confidence' (shared values) is three-to-five times more important than 'competence' (skills and technical expertise or science) in building consumer trust. In other words, an increasingly sceptical public doesn't care how much experts know until they know how much they care. A clear theme in CFI's latest survey results is that food system experts can make a difference when they choose to engage by first establishing shared values and then providing factual, technical information that is relevant and meaningful. After confidence has been established, people are more willing to consider technical information, or competence, in their decision-making process.

In society today, scientific knowledge faces strong, organised opposition. Fortified by their own sources of information and their own interpretations of research, doubters have declared war on scientific consensus.

How does the food system connect with consumers who reject science? The Center for Food Integrity (CFI) 2014 consumer trust research provides a roadmap for making complex and controversial technical information relevant and meaningful – particularly to mums, millennials and foodies – bringing balance to the conversation, while helping consumers make informed decisions about food and building trust in today's food system.

Partnering with Iowa State University, CFI was the first to build a research-based consumer trust model. CFI's peer-reviewed and published model for building trust in today's food system shows 'confidence' (shared values) is three-to-five times more important than 'competence' (skills and technical expertise or science) in building consumer trust (Figure 1, over page). In other words, an increasingly sceptical public doesn't care how much experts know until they know how much they care.

Communicating about food and agriculture can no longer be focused only on giving consumers more science, research and information. To build trust, those in the food system must demonstrate

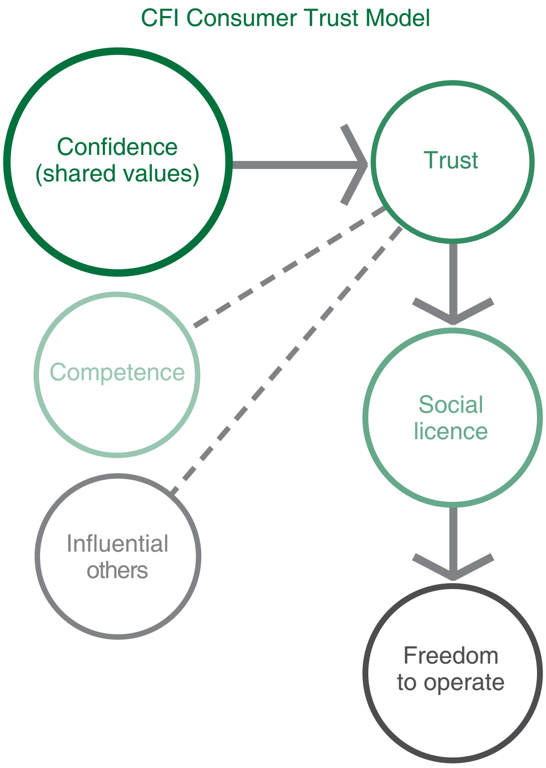

Figure 1: CFI Consumer Trust Model.

Note: Earning and maintaining social licence, the privilege of operating with minimal formalised restrictions, depends largely on building trust based on shared values. Of the three primary elements that drive trust – confidence (shared values and ethics), competence (skills and ability) and influential others (family, friends and credentialled individuals), CFI's peer-reviewed research shows that confidence, or shared values, is three-to-five times more important than competence in building trust.

shared values when it comes to topics they care most about, such as safe food, quality, nutrition, appropriate animal care and environmental stewardship, among others.

The Challenge of Introducing Complex, Controversial Issues into the Conversation

Overwhelming scientific consensus tells us that childhood vaccines and foods with genetically modified ingredients are safe (Maglione et al. 2014; USDA 2015) and that climate change is real. Yet, doubt persists. The public is divided on issues that scientists feel have been adequately addressed.

Those dedicated to improving society through science-based technologies and innovation ask: Science says it's so, so why is there still debate? Many issues remain contentious, regardless of the facts, because the social decision-making process is complex.

How can the food system communicate controversial scientific and technical information so consumers and stakeholders take science into consideration when making decisions? CFI's latest research, *Cracking the code on food issues: insights from moms, millennials and foodies* (2014), set out to find the answer.

Tribal Communications

Today's environment is one in which many factors drive consumer opinions, feelings and beliefs, particularly when it comes to controversial, emotion-laden issues. Facts are only one element in the complex, multi-dimensional decision-making equation.

In his book *Tribes: we need you to lead us,* entrepreneur, marketer and digital expert Seth Godin (2008) explains that while the internet was supposed to homogenise society by connecting everyone, it has instead created silos of interest. People can easily find online communities where their values and interests align. Ordinary people who are passionate about a hobby, issue or cause have the power and platform to lead and impact change.

American TV host and actress Jenny McCarthy lent her high-profile voice to a movement against childhood vaccinations, claiming vaccines caused her son's autism despite overwhelming scientific consensus that vaccines are safe. Food activist Vani Hari, a former banking consultant in the United States (US), has built a considerable following and garnered a great deal of media attention as the Food Babe, rallying her online tribe to successfully pressure food companies to ban ingredients despite scientific evidence that they are harmless.

The power of tribes when it comes to food issues was underscored by consumer focus groups organised by CFI in 2013. When asked what sources of information led to the conclusion that genetically modified food is dangerous, one mum replied:

> I'm part of a moms group. When there is a big consensus, I think 'there's something here.' You don't need doctors or scientists confirming it when you have hundreds of moms.

Along with tribal consensus comes tribal shunning and the related personal guilt as illustrated by another panelist's confession:

> I think mom guilt is a huge factor. If someone is telling you something is dangerous, for example fructose, and you hear the message more than once, you owe it to yourself to research it or quit consuming it. I can't keep giving my kids fructose if there's a potential problem. We have to do our best job.

The challenge of communicating to those in tribes is that they limit perspective and insight to only those in the tribe, which may lead to assigning credibility to those who share tribal values but lack technical expertise to support decision-making that incorporates factual information.

Confirmation Bias and Cultural Cognition

Two more factors complicating communications are confirmation bias and cultural cognition – distinct decision-making processes that help explain how people digest evidence and make decisions about controversial issues.

Confirmation bias is the tendency for people to favour information that confirms their existing beliefs and opinions regardless of whether the information is true. Its effect is stronger for highly personal issues such as food.

For example, an anti-GMO (genetically modified organism) advocate isn't likely to put much stock in information from the Genetic Literacy Project. A vegetarian will probably not follow the National Pork Board's @PorkandHealth account on Twitter. People tend to look for information that confirms their current belief structure and reject information that is inconsistent with their values or current worldview.

Cultural cognition refers to the tendency of people to conform their beliefs about controversial matters to *group values* that define their cultural identities.

According to Dan Kahan, professor of law and psychology at Yale University and a member of the Yale Law School Cultural Cognition Project, people endorse whichever position reinforces their connection to others whose values they share. As a result, Kahan says public debate about science is polarising.

Additionally, when new evidence is introduced, cultural cognition causes people to interpret it through the lens of pre-existing bias. According to Kahan, this explains why groups with opposing views become even more polarised when exposed to scientifically-sound information.

Kahan (2010) equates cultural cognition to fans at a sporting event. No matter what the issue, they take their cues about what they should feel and believe from the cheers and boos of their team's crowd.

Science is Difficult

Everyone is exposed to complex issues they are not qualified to evaluate. Decisions are made and information is processed based on 'bounded rationality' – access to information, cognitive ability to understand the information and the amount of time a person can allocate to the decision-making process.

Decision-makers often lack the ability and resources to arrive at the best solution, so they simply settle for a satisfactory one. For example, how many people take the time to read the policy positions of candidates before voting, or read safety and performance research before purchasing a car?

However, not being able to fully grasp a complex issue does not preclude people from making decisions or having strong opinions. People often have strong opinions on issues they know very little about. The complexity of science and science illiteracy can impact informed decision-making.

Other factors, like bad news bias, tend to complicate the environment. It's why negative political advertising campaigns are effective and why people are quick to believe the worst in the latest celebrity scandal. It also accounts for why

negative claims about agriculture and food eclipse the science that says otherwise.

Negative information weighs more heavily on our decisions than positive information, and the impact is significant. In fact, it has been shown that a single item of negative information is capable of neutralising five similar pieces of positive information and that negative information more strongly influences attitudes and purchasing intentions (Richey et al. 1975; Weinberger & Dillon 1980).

All it takes is for one person – a friend, a colleague, a reporter, a blogger – in an individual's sphere of influence to make a single 'bad news' claim and trust begins to erode.

A history of contradictions muddies the water, too. Remember when butter, eggs and coffee were considered unhealthy? Now the research says otherwise. It's difficult to trust science when it seems to change like the weather.

Add to that the erosion of trust in all things 'big' – big food, big government, big oil, big corporations. There have been plenty of incidents (oil spills, automobile recalls) that have resulted in a loss of trust in science-based technology. CFI research shows an inverse relationship between trust and the size of a company or organisation. Many consumers believe that 'big' companies will put profit ahead of public interest. So 'big' technology from 'big' companies is plagued by significant public scepticism.

Communicating in this complex environment warrants a new approach. Encouraging informed social decision-making that fairly evaluates food and agriculture and results in greater trust in systems that make food accessible and sustainable.

How to Introduce Science so it Makes Sense

Technological advances in food and agriculture have provided countless benefits to society – from refrigeration to precision planting, from pasteurisation to drought-tolerant crops. Innovation and technology aid in the production of safe, nutritious food – one of humanity's most basic needs.

However, more must be done. Producing food has more impact on the planet than any other human activity and more food must be produced using fewer resources every year. The responsible use of technology is key to addressing this moral imperative.

The challenge is not only better technology, but finding better ways to support the informed public evaluation of those technologies and the food production system. While science alone will not build public support for complex, controversial technology, there's a need to encourage earnest consideration of scientific consensus in the social decision-making process when it comes to innovation and technology that drive agriculture and food.

Scepticism about food production is understandable. The consolidation, integration and application of technology that makes food safer, more available and more affordable than ever also prompts concerns about whether science and technology benefit society or only those who control it, as well as scepticism about the motivation of those in food and agriculture.

The goal should not be to win a scientific or social argument, but to find more meaningful and relevant methods to introduce science in a way that encourages thoughtful consideration and informed decision-making.

CFI's 2014 Consumer Trust Research explores consumers' complex decision-making processes in order to better understand how to introduce technical information into the public discussion on issues in agriculture and food so that it is embraced and incorporated into attitudes, opinions and the social decision-making process. The research also helps us better understand the communication channels and processes used by mums, millennials, foodies and early adopters in today's environment when forming attitudes and opinions about issues in agriculture and food.

Research Approach

The issues selected as stimulus for the research were genetically modified (GM) ingredients in food and antibiotic use in food animals. The intent was not to define messages and strategies specific to these issues but to use them to develop models that can be applied across food and agriculture.

Previous work from three areas of social science was integrated into the research approach – anthropology, psychology and sociology – to gain greater strategic insight.

Anthropology: The previously discussed work of Dan Kahan and others (2006) at the Cultural Cognition Project at Yale University speaks to societal values that are firmly embedded and drive the decision-making process.

Psychology: The research measurement approach was built around 'outrage factors' as detailed in the research of Peter Sandman and others on risk communication and previous work by CFI. Sandman and colleagues studied what causes the public to become outraged about a situation they deem hazardous, when in fact there is little evidence of risk.

Sociology: CFI's research explores 'diffusion of innovation', a theory by communication scholar and sociologist Everett Rogers that seeks to explain how, why and at what rate new ideas and technology spread through cultures. Rogers' model divides social groups into five adopter categories: innovators, early adopters, early majority, late majority and laggards. CFI focuses on early adopters as they are the opinion leaders in their social circles.

Individuals don't ignore science. They simply interpret it through their own cultural, psychological and social lenses, synthesising the information into their decision-making process. Better understanding how to align information with the lens of those interested in agriculture and food can help focus efforts to increase understanding and informed decision-making.

Methodology and Measurement

A multi-step process was used to develop the information stimulus tested in CFI's research.

First, overarching key messages were developed for the topics of GM ingredients in food and antibiotic resistance. Based on a comprehensive review of each topic, four fundamental message elements were identified:

- Unifying message – a singular compelling message that touches the deeper drivers of human behaviour (connecting on shared values).
- Openness/transparency – acknowledging both sides of the story, providing a level of depth to avoid the appearance of withholding information and avoiding oversimplification.
- Accurate presentation of risks – present known risks since they trump unknown risks by accurately communicating safety facts.
- Trust sources – leveraging trusted sources.

Next, outrage factors were combined into three groups to create three different scenarios for each topic.

- Scenario 1 – Voluntariness, familiarity and control
- Scenario 2 – Fairness, morality and process
- Scenario 3 – Memorability and dread.

Voluntary vs. imposed: People tolerate more risk if it has been voluntarily entered into rather than forced upon them (the difference between being pushed out of an airplane with a parachute against your will as opposed to choosing to skydive).

Control vs. no control: The extent to which government agencies address the risk in a competent manner. People feel alienated and frightened when they believe that government agencies are not doing a good job of regulating potential hazards (if I choose to go skydiving, then I hope the skydiving company is being well-regulated).

Familiar vs. exotic: It is difficult to feel threatened by something familiar – your basement recreation room (in the case of radon) or the car (in the case of seatbelts). However, anything perceived as strange and unfamiliar can raise the concern just on that fact alone (skydiving for the first time).

Finally, each of the three scenarios were written in different 'voices' to determine how consumers viewed information coming from various messengers to evaluate the impact of messengers who demonstrated shared values against those viewed as technically competent:

- Mum scientist (a mother with scientific education and/or work experience)
- Government scientist (self-explanatory)
- Peer (a person who shares your interest about food).

Main Findings

In an effort to measure the impact of information on the perception of the messenger, survey participants were asked to rate the messenger on several attributes both before and after reading informational stimulus.

After rating the believability of the message and rating the degree to which the message promotes comfort with the topic, the messenger was rated on a 0 to 10 agree/disagree scale as a source of information about antibiotic resistance and GM ingredients in food. These statements were used:

- This person is competent as a source of information.
- I have confidence in this person as a source of information.
- I would trust this person as a source of information.
- This person is a credible source of information.

An overall messenger composite value score was created by combining the scores on all statements. On the issue of antibiotic resistance (Figure 2), mum scientist and government scientist were viewed as the best sources of information. On the issue of GM food ingredients (Figure 3), mum scientist and government scientist were viewed as the best sources of information.

The composite value score reflects the relative importance of confidence and competence. The mum scientist consistently had the highest score, indicating that messengers that combine a perception of shared values (confidence) and technical expertise (competence) are likely to be viewed as more credible and trustworthy than messengers that are viewed as only technically competent (government scientist) or only demonstrate shared values (peer).

CFI's research also looked into where mums, millennials and foodies go for food system information (Figure 4). Websites were the top-ranked source of information for all three segments.

Like mums, millennials and foodies, the top food system source for the general population is websites, followed by local TV stations, friends (not online), family (not online) and Google.

Applying the Learnings

The 2014 CFI research provides a five-part model that can help in creating and sharing information that fosters informed decision-making.

1. Believability is a key driver in creating information that is trusted. Evaluate the information you want to share against the fundamental message elements and outrage factors in the research models and modify where necessary to align your information with them.
2. Identify the groups to be engaged. Who are the early adopters – or opinion leaders – within those groups? What are their values and concerns? Who are the likely sources they view as credible? Listen to the concerns and understand their values before developing a strategy.
3. Meet them where they are. Today's monitoring technology allows you to identify the digital and physical communities where conversations about food and agriculture are taking place.

Composite MESSENGER Scores* – After Scenarios

	SEGMENT			
	Total (A)	Moms (B)	Millennials (C)	Foodies (D)
Antibiotic Resistance – Scenario #1				
Mom Scientist	6.34	6.54	6.46	7.27
Federal Government Scientist	6.52	6.38	6.76	7.60
Peer	5.64	5.75	5.59	6.57
Antibiotic Resistance – Scenario #2				
Mom Scientist	6.94	6.98	7.04	8.18
Federal Government Scientist	6.75	6.60	6.75	7.61
Peer	6.18	6.98	6.19	7.42
Antibiotic Resistance – Scenario #3				
Mom Scientist	6.82	6.78	6.93	8.06
Federal Government Scientist	6.70	6.89	6.66	7.76
Peer	6.00	5.76	6.21	7.25

Scenario #1=Voluntariness, Familiarity, Control
Scenario #2 Fairness, Morality, Process
Scenario #3=Memorability, Dread

*Combines competence, confidence, trust, credibility

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Figure 2: Overall messenger composite value score for antibiotic resistance.

Composite MESSENGER Scores* – After Scenarios

	SEGMENT			
	Total (A)	Moms (B)	Millennials (C)	Foodies (D)
GM Food – Scenario #1				
Mom Scientist	6.19	6.59	5.83	6.73
Federal Government Scientist	6.10	6.10	6.41	7.35
Peer	5.60	5.79	5.97	6.90
GM Food – Scenario #2				
Mom Scientist	6.36	6.44	6.52	7.34
Federal Government Scientist	6.15	6.24	6.36	7.44
Peer	5.60	5.73	5.50	7.06

Scenario #1=Voluntariness, Familiarity, Control
Scenario #2 Fairness, Morality, Process

*Combines competence, confidence, trust, credibility

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Figure 3: Overall messenger composite value score for GM food ingredients.

Trusted Information Sources

Here's where mums, millennials and foodies go for food system information.

TOP SOURCES RANKED #1

MUMS

Websites (21%)
Family – not online (12%)
Google (12%)
Local TV station (12%)
Friends – not online (11%)

MILLENIALS

Websites (22%)
Friends – not online (16%)
Google (15%)
Family – not online (13%)
Friends – online (8%)

FOODIES

Websites (25%)
Friends – not online (15%)
Google (12%)
Family – not online (10%)
Food-specific TV program/ networks (9%)

Figure 4: Trusted information sources for mums, millenials and foodies.

Source: CFI (2014).

Select those communities that are important to you and develop engagement strategies. Be a good neighbour when you 'move in' to the community and remember that how you choose to engage will determine how your new neighbours respond.

4. Develop a values-based engagement strategy that starts with listening and embracing scepticism. Engage with the groups you've identified and focus on building relationships before sharing information. Understand and appreciate the group expectations and cultural norms as they will influence how to best share information.
5. Commit to engaging over time. Building trust is a process, not an event. Authentic transparency and continued engagement using the models developed through this research will encourage objective evaluation of information that supports informed decision-making.

In Conclusion

Food issues are important to mums, millennials and foodies. They help define who they are as people and shape their cultural identifies. Foodies, in particular, express a higher level of concern about all topics than the other segments. These issues are meaningful and relevant to each of these groups, so ways to connect can be found if the approach outlined in CFI's 2014 research is followed.

The change in messenger trust before and after survey participants were provided the informational stimulus provides specific insight into shaping an effective strategy. Prior to reading the information, respondents generally rated mum scientist most trusted followed by peer, with government scientist being the least trusted.

After reading the information, mum scientist was still the most trusted, but her scores often decreased as her halo was tarnished by sharing information that may have conflicted with existing beliefs.

The trust scores for government scientist increased as the unifying message helped communicate a commitment to shared values, which was then supported by technical expertise and a credential.

Scores for peer generally decreased because respondents were looking for more than shared interests on technically complex issues. They were looking for expertise.

How technical and scientific information is introduced is key to supporting informed decision-making. The shift in trust scores clearly indicates that starting with shared values is an important first step.

Once the values-based connection has been made, permission is granted to introduce technical information. The shift in trust scores for the peer voice clearly indicate that technical information from a credible source is still an important element in building trust and introducing complex, controversial topics.

In the 17th century, Galileo used science and his powers of observation to declare that the sun, not the earth, was the centre of the universe. For his contribution to science and society, he was declared a heretic and spent the rest of his life under house arrest.

While nobody is likely to be arrested for sharing scientific facts today, simply having science on your side is clearly not enough to encourage and support informed decision-making. Being right is not enough to assure information is considered in the social decision-making process.

A clear theme in CFI's survey results is that we can make a difference when we choose to engage by first establishing shared values and then providing factual, technical information that is relevant and meaningful from a credible source. After confidence (shared values) has been

established, people are more willing to consider technical information, or competence, in their decision-making process.

To download the 2014 CFI Consumer Trust Research report or learn more log-on to www.foodintegrity.org or email CFI at learnmore@foodintegrity.org

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The Implications of Societal Risk Management on Agricultural Productivity

Mark Swift

2012 Nuffield Scholar and farmer

The scope for agricultural productivity gains is immense with technologies such as autonomous systems and biotechnology. However, there is a growing concern in modern society about the safety of the systems which underpin a modern lifestyle. The full potential of productivity enhancing tools is likely to be impeded by society, using risk management instruments such as the precautionary principle.

Not all productivity gains are planned, there needs to be room for trial and error, and serendipity. Innate problems in the food sector will not all be overcome through higher regulation. Regulators and activists need to fully understand the unintended consequences of their actions. The food supply chain needs to improve communication with its customers to highlight why innovations matter, how they help and how they work.

Over the past 10,000 years the man-hours required to produce enough wheat for the annual calorific requirements of a single person has dropped from 600 hours to roughly 10 minutes. Progress in making food more affordable through productivity gains has resulted in half of the global population occupying the relatively affluent middle class and has enabled a diaspora from the fields. For this process to continue agriculture's relationship with the broader community will be of crucial importance if it is to maintain a degree of liberty in furthering productivity. Presently many of the opportunities to achieve productivity gains are being met with blunt regulatory risk management tools such as the precautionary principle. The gains that have been made are not readily recognised as necessary for modern society to maintain present living standards. Overcoming this oversight and ensuring access to future productivity gains will be important for agriculture to sustain its contribution to modern living standards.

Three technologies, that have had a significant impact on increasing agricultural productivity or have potential to be, were chosen as case studies. These included agricultural chemicals, biotechnology, and mechanical agriculture. These technologies will be vital to enabling future productivity gains in agriculture and were chosen because of this. It is anticipated that new technologies will face greater regulatory oversight as they come to market, based on the trend of increased regulation.

This report is the result of a study into the frustration that faces a typical Australian producer when attempting to improve their productivity. There appears to be a glass ceiling for productivity improvement, where tools that would provide valuable gains are in view but there are impediments to access. These impediments are a culmination of regulatory burdens on innovators, and self-imposed restrictions from innovators where there is legal uncertainty and societal pressures of various persuasions. In reality all these impediments are reducing the power of compounding on productivity gains, meaning that present restrictions will have an effect on future productive capacity.

The Precautionary Principle

The precautionary principle was the impetus for this study. The scope of the study had to shift as the evidence was indicating that it was a symptom of a larger problem, but it is pertinent that the term be placed in context and defined to assist the reader in understanding the journey.

> The precautionary principle or precautionary approach states that, if an action or policy has a suspected risk of causing harm to the public or to the environment, in the absence of scientific consensus that the action or policy is harmful, the burden of proof that it is not harmful falls on those taking the act. (Wikipedia 2013)

The precautionary principle poses a major problem for innovators. It is usually viewed from the perspective that a new technology will provide more risk than the status quo. The result if implemented in its strongest sense, would be continuation of the status quo indefinitely. This is due to the impractical demands that can be argued for by the proponents of the precautionary principle, which has left it open to criticism.

This criticism has altered the use of the precautionary principle. Discussions with companies and lobbyists traditionally affected suggest that overt implementation is becoming increasingly rare. In Europe where it originated and is most widely used, the trend is waning (Council for Agricultural Sciences and Technology 2013) but the legacy of its intent remains a powerful influence. Further criticism of the precautionary principle is its role in inhibiting experience. Experience is how things are learnt; not all failures can be anticipated.

Agriculture and Society

Agriculture may view itself as unique in the modern context given its history and operating environments, but broader society is demanding that industry meet contemporary standards. Elements of society are not content with a laissez faire approach and with increasing frequency are demanding regulatory intervention. Many of the restrictions are not directly imposed on the agricultural producer but this does not mean they are not acutely affected. A recent example of these expectations the author experienced first-hand is bans on livestock exports.

Whilst travelling in the Middle East in September 2012 there were multiple incidents with a shipment of sheep, firstly in Bahrain and then in Pakistan which had repercussions for the trade across the Middle East. The decision was made by the Australian Minister for Agriculture to ban all live sheep trade to the region due to political pressure in Australia.[1] This limited the number of sheep available in Qatar from several thousand a day, to several hundred, and created a genuine potential for a food shortage. As a visitor on the ground in Qatar it was evident that the welfare of the livestock met or exceeded the standard normally experienced in Australia, unfortunately this was overlooked in the blanket decision to ban all trade.

This incident was not the focus of the study but highlights the symptomatic pressure that agriculture and its supply chain receives from external parties. Furthermore it stressed the real impact that political forces can have on an industry and its supply chain. The research undertaken was more concerned with the impact of society and its regulatory structures on agricultural productivity.

Agricultural Chemicals; Slower to Market, More Expensive but Safer

Agricultural chemicals are a lynch pin of conventional agricultural systems but are under continuing pressure from increased use, slower discovery and regulation. These products are presently being discovered at a rate of 1:140 000 molecules tested in contrast to the 1980s rate of 1:20 000 (Wehr 2014). This is despite rapid advancement in the capacity of chemical companies to test a molecule's efficacy on various agricultural pests. The slowdown is being met with a lengthening timeline to move from discovery to market for effective molecules, with increased demands from regulatory processes, particularly in the field of toxicology. In relation to toxicology many common household items are equally toxic, if not more so on certain scales, than many agricultural chemicals, as can be observed from Table 1.

Agriculture is now at the point where it is encountering new problems faster than the chemical companies can find solutions. This is evident with the lack of new fungicides for broadacre cropping and the dearth of novel weed

1 Australian consumers/voters have high standards regarding how livestock exports should to be treated in destination markets. However, Australian consumers don't seem to demand the same stringent oversights on the production systems of imported goods, this is a truly vexing situation.

Table 1: Comparison of LD50 values for common herbicides and household items.

Herbicide	LD_{50}	Common consumer chemicals	LD_{50}
Paraquat (Gramoxone)	~100	Nicotine	9
Triclopyr	630	Caffeine	192
2,4-D	666	Bleach	192
Pendimethalin (Prowl)	1050	Tylenol	338
Atrazine	3090	Household ammonia (10%)	350
Glyphosate (Roundup)	4900	Codeine	427
Imazaquin	>5000	Table salt	3000

Note: The LD50 is the dose, in milligrams per kilogram, required to kill half the population exposed. The lower the dose the more toxic is the chemical.

Source: Fishel et al. (2014).

control chemicals. The issue will not spell the end of mainstream agriculture but it will require a culture and/or paradigm shift for the industry to find novel ways to minimise the impacts of pests.

Biotechnology: Not Illegal but Unusable

Biotechnology shares similarities with agricultural chemicals in its regulatory regime in that it is very expensive and time-consuming to bring novel genes to market. The process consumes hundreds of millions of dollars and takes many years just to meet the regulatory requirements. The European Union (EU) has the tightest rules and the most open hostility to biotechnology. The EU regulatory system was described by an expatriate Belgian working in the United Sates (US) as being 'designed for mediocrity'. However there are signs that the US is moving in the same direction. A biotechnology company has had a trait (Dicamba tolerance) left in limbo due to concerns from the United States Department of Agriculture (USDA) over future litigation (Vroom 2013).

This trait has cleared all the regulatory requirements, but fear of potential litigation from opponents of this technology has resulted in the product not being given market access. This is a novel addition to the precautionary principle, which is usually concerned with the harm a technology may pose to human health or the environment, not to the reputation and budget of a government entity (Vroom 2013). It was further highlighted that the anti-biotechnology lobby had viewed this as a victory as if it was a 'no decision'; which essentially means that the product cannot be used (Dobert 2013). This particular incident is very concerning for the future potential of biotechnology in agriculture, as who would be willing to invest their capital in a venture with such a regulatory system.

Biotechnology and agricultural chemicals are an obvious space where governments are regulating agriculture with good intentions and unintended consequences. Governments and regulators the world over need to realise that a little bit of regulation may be good but like chemicals there is a point at which the deleterious effects take over. It does not matter if that chemical is H_2O or 2,4-D.

Farmers should heed this in their future management. Research and development (R&D) companies have been very effective at delivering genetics and products that have overcome many problems. The future will require farmers to be more proactive in their business management and industry policy setting if they wish to maintain their present productive capacity.

Agricultural Machinery

Agricultural machinery manufacturers are facing different challenges. Firstly they are facing demands to add emissions technology to their products. This technology is demanding on their R&D budgets, provides limited performance benefit to the machine, and can reduce utility and reliability. Concurrently in areas where there are limited or no regulations companies are struggling to bring products to market that offer novel risks such as autonomous control systems. This self-imposed limitation is understandable but is also delaying the future productivity gains of agriculture.

Good Intentions versus Thermodynamics

Tier Four emissions standards for diesel engines in Europe and the US are to be phased in over the period from 2008–15. These are two of the largest markets for agricultural machinery and are home to the largest manufacturers of modern equipment. This new standard is absorbing up to one-third of machinery companies R&D budgets (Nacke 2013). A product strategist for a large manufacturer highlighted that the evolving emission standards were having profound effects on their business and reducing the longevity and quality of their product (Nacke 2013). The reasons include:

1. Engineers want to build exciting new things, not redesign old pieces of equipment to fit around particulate filters and 'add blue' systems.
2. Engines now have to run substantially hotter, increasing the risk of burning the machine especially in hot, dusty conditions that are typical in agriculture.
3. R&D that could be put into making machines better, is being spent on making machines work nearly as well as they could previously.
4. Business competitors are emerging, selling parts salvaged from the increasing number of burnt machines.

This raises serious concerns about the future regulatory burden for the industry, as the standards will become more burdensome. The original regulations had the unintended consequences of increasing the number of particles under two microns, which are deemed dangerous to human health (American Lung Association 2013). They were anticipating that new standards would rectify this and probably add CO_2 emissions. The impost has become so great that a new industry body is being developed to counter this growing threat.

Furthermore, it was forecast that a transfer of standards being worked on for road usage would essentially be cut-and-paste to off-road machines (Nacke 2013). This particular law is intended to reduce the fuel usage per 100 km by 20% across road auto makers' fleets. If this standard was applied to agriculture the representative admitted there was some redundancy in the system (Nacke 2013). They could remove the straw chopping and spreading systems from the harvesters they built. It was admitted this was not a practical solution, but it would enable them to reach the regulatory target despite the obvious downstream consequences.

Autonomous Tractors

The development of autonomous machinery is very interesting, as the technological capabilities are already present and not necessarily overly expensive with the rapid development of unmanned aerial vehicle control systems. However, the move to larger-scale terrestrial vehicles is slower and not necessarily due to any technological difficulties or concern over consumer backlash.

Several years ago there were rumours in Australia that John Deere had autonomous tractors working and that these have not been released for commercial usage due to legal reasons. These rumours have been confirmed by a John Deere representative (Popescu-Gatlan 2013). The company is still unclear on where the issue of responsibility lies in the event of an accident. Is it with the farmer who has bought and is using the equipment or is it with the software provider? Until someone has an accident there is no way of testing this in law. This standoff is a very real reason why agriculture is not getting better faster. We live in a litigious world and large companies that have the capital to invest in this R&D are limited by their risk profile.

Agriculture is in a unique space; working near public environments. This means it can pose a threat to the public. At some point society will have to deal with the issue of the risk posed by this technology, weighing up the potential benefits versus the threats. Discussions on this topic are highly influenced by the environment which people are familiar with. The more closely settled the area, the more concern there is about the public interaction. Nowhere is this more evident than in Britain; with walk and bridle ways in England.

Farming is constantly in the news as a result of its poor safety record. Would not removing the operator from the point source of potential injury be a major benefit for the safety of farm workers? The issue seems to be in the rationalising of known, real threats with unknown, potential threats. With precautionary approaches there seems to be a greater sympathy with the 'devil you know.' It is to be hoped that a prolonged hiatus for the discussion of this technology does not prevent real progress from being made in both improving worker safety and enhancing productivity.

Risk and Innovation

Future advancements in agricultural productivity will require new technology and better management, or a combination of the two. This is going to require a degree of novelty to achieve improvements but this novelty will come with a degree of risk. Daniel Kahneman (2011), a renowned Israeli-American psychologist, states in his book *Thinking, fast and slow:* 'survival prospects are poor for an animal that is not suspicious of novelty.' However he continues that, 'it is also adaptive for the initial caution to fade if the stimulus is actually safe.' These two points capture the psychology of the suspicious consumer, but also leave open the opportunity for success from a novel product.

It is rational that people are cautious of that which they do not understand. At some point society (or at least the ruling authorities) have deemed it appropriate that society be protected from some of the things not fully understood. Societies, particularly wealthy westernised versions, are now being 'protected' from people learning about things not fully understood. The risk from this approach is evident in what may not exist if the present mind-set/regulatory regime had been in place in the past. Would the motor car or jet engine be commercially released in the current environment?

It could be argued that only certain areas are facing this treatment. The impacts of the mobile phone on brain function and longevity are probably not fully understood and there are individuals such as respected brain surgeon Charlie Teo who claims there is evidence of potential links between mobile phone use and brain tumours (Morton 2014) but governments are not about to ban or even restrict them. What then drives this inconsistency in regulation and why does it appear certain areas come under more scrutiny? This inconsistency is probably due to the nature of products in question. The mobile phone is a step change in communication to the end user and imparts a high degree of additional utility.

Biotechnology in its current form has been a step change for the upstream users such as the farmer and breeder. However, for the consumer there has been little discernible difference; in many regards biotechnology has been introduced as something for the consumer to be scared of not embraced. It may have made food cheaper but this has not been significant in the scheme of things for the developed world. The result has been a consumer left feeling they are bearing the risk with intangible benefits. The consumer is overlooking an important contextual detail of how modern living standards have been achieved. Many if not all the modern conveniences we take for granted required people to take risks in researching, marketing and consumption.

Personal Responsibility

The current risk aversion is manifesting as a fear of the some of the systems which sustain the modern standard of living. This psychological response to novelty will need to be considered in the innovation process. Mechanisms are required to meet the responses to this fear, because if left unchecked the risk management apparatus being implemented to quell it could result in blockages in the systems which provide agricultural innovations. Engaging politicians and bureaucracies in a broader discussion of why innovation is necessary and where the opportunities are, will be an important component in enabling continued agricultural productivity. This itself will require somewhat of a paradigm shift in agricultural policy and will require the supply chain to be more engaged and aligned in working to ensure practical policy is achieved regarding innovations in the food supply chain.

Concurrently entrepreneurs need to show a high degree of responsibility in their actions when researching innovations. They have a responsibility to their customers to ensure that they are not placing them at undue risk. This will require a more open process of involvement with the supply chain to ensure that significant changes are supported by the supply chain and evidence of benefits to the customer is provided. Furthermore there will need to be a workable environment for innovators to show due diligence where accidents occur and show how they are working to overcome any safety issues that arise.

Consumers are becoming more aware of their own influence and the impacts of agricultural production on the environment. This paradigm shift is still in its initial stages but is becoming more mainstream. If modern agriculture maintains its present silence in the face of the legion of critics it will continue to face tighter restrictions. This silence will be met with more regulations restricting what tools are available, and further limiting the capacity of farmers to innovate. If farmers wish to gain influence to the point where the authorities will leave them alone, they need to change their approach to product marketing. Industry should not believe that the present approach is working to improve its standing in the eyes of the public. If it were working, the share of organics, 'natural' and free-range would not be increasing and new regulations on modern techniques would be slowing.

Agriculture now has an opportunity to put its case and highlight the achievements that have been made with the rapid technological improvements over the past century. This will require a change in the zeitgeist from agriculture being portrayed as either a quaint 1950s stereotype or an all-consuming environmental vandal that is the anathema of modern society; to that of an adaptive and aware industry. How agriculture and its supply chain manages this awareness will determine the liberty it has in providing cheap, safe and nutritious food for its customers.

Conclusion

Agriculture's role in increasing the standard of living over the past 12 millennia cannot be overstated. The time, which has been liberated through improvements in agricultural productivity, has enriched so many lives. It has enabled an ever-increasing number of people the freedom to do what they want and not what they have to. In developed countries this is because the population has to spend so little effort attaining the food they require that they have time to spend making things better. There is an emerging trend to limit agriculture's access to tools that will facilitate the continued liberation of time. This trend is far more evident in societies that are more developed, and have sufficient wealth and time to allow for questioning the system that sustains their standard of living.

Scepticism is pertinent for the agricultural system that has resulted in many past failures, some of which occurred on monumental scales, damaging both the environment and human health. This was evident in the mid-20th century with the frequency of dust storms during droughts. Despite some very long and wide-spread droughts during the early 21st century these events have become quite rare. This is largely due to the development of new management systems and exploitation of new technology.

Prior damage is being managed and the world is a better place to be now than at any point in time. The restrictions being placed on agriculture now, will have effects into the future and risk consigning people to poverty for longer than would otherwise be the case. Counter points to this argument are that the system is keeping the populace safer and healthier. This is not without merit, but it raises a debate on which group most needs assistance. Is it wealthy educated people with the capacity to inform themselves and buy what they wish in developed societies, or poor people in food scarce environments with limited choice who must buy what they can afford. Questioning the agricultural system for its failings is astute. Intervening in the system without consideration for how progress has been achieved and who bears the burden, is not.

An abundance of food beyond what can be consumed leads to discerning customers. These discerning customers have choices to ensure that the food they consume is as safe as they can afford. Pricing poor customers out of the food market for safety's sake is not acting in their best interests. This is particularly important for poor people in food scarce regions. The food will probably be imported and any costs that are placed on the exporting producer will inadvertently be passed on. If they cannot afford these additional costs it may result in an alternate use being found for the food, which may be as livestock food in the exporting nation. Equally, the producer may decide not to produce and substitute the production for an alternate higher value proposition.

Mainstream society and agriculture need a better understanding of each other. Without this, society will probably continue taking agriculture's bounty for granted. To enable the remaining half of the global population to access the middle class, more tools should be made available. Where there are opportunities to reduce the cost burden of food they should be explored. There will be consequences and lessons will be learned as has been done with countless other technologies from the steam engine to the jet plane. Not all the impacts will be positive but history suggests the overwhelming outcome will be.

Regulatory authorities and politicians need to develop a better awareness of the implications of their involvement on complex systems; agriculture is only one such area. Despite its complexity, agriculture has a history of innovation and this has assisted in remarkable increases in the standard of living over the past 12 millennia. Joseph Schumpeter's creative destruction is as potent now as it was when he first coined the idea (Wikipedia 2014). As a result many of the issues now faced will be overcome and forgotten as new techniques and technologies supplant the current ones. If this process is stifled, then agriculture cannot play its full role in improving living standards and providing all people with the opportunity and time to choose.

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Food, Genetic Engineering and Public Opinion: Do Popular Concerns Matter?

Diederik van der Hoeven

Genetic Literacy Project

Can scientists learn from listening to public reaction to the products they develop? and should they?

As a philosopher by training (and as a science journalist by profession) I am delving into ethical questions surrounding genetic modification. My reflections were triggered by an article by my friend Alle Bruggink (2015), a professor in industrial chemistry at the University of Nijmegen in the Netherlands. He explored why the public remains suspicious about biotechnology – a surprise to many biotechnological researchers.

‘Bringing new products or concepts to the market resembles running the gauntlet in many ways,’ he wrote. ‘Invariably, there are many more obstacles than foreseen and they arise from unforeseen angles.’ He made a case for considering the public reception of biotechnological innovations before bringing products to the market, or even before starting the research at all.

> The psychology of innovation is unrelenting: researchers develop their product for the good of the public; it is their judgement that counts. Researchers will have to learn to listen: with their hearts, with their moral senses.

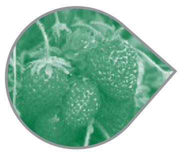
They should look to social researchers, if possible, for guidance.

Alle Bruggink has quite a track record in genetic modification. Backed by a team of 80 researchers, both academic and corporate, he developed the first fully fermentative synthesis of an industrial product (cephalosporin, a semi-synthetic penicillin). The project established the corporation DSM as a player in the green chemical industry, and it still contributes to DSM’s balance sheet.

An Innate Wisdom in the Public Mind

Biotechnological researchers need to learn from the public’s views; it seems to me that there is a kind of innate wisdom in the public mind. Public judgments can steer us away from unfortunate genetic developments like Herman the bull (Wikipedia 2015), the first genetically modified cow (1990–2004) and embrace production of medicines by genetic engineering. That is to say: an unfavourable public reaction is not just a nuisance, but may well represent a genuine moral judgment. Bruggink wrote:

> Without pressure from the public and NGOs, we might have seen meadows full of GMO bulls and sheep. Or we might have produced embryos on a large scale, in order to mine stem cells.



So this commentary will look into how the public forms its views in order to unravel the logic of the public mind. Public judgment is largely determined by three dimensions: health, fashion and ethics. Researchers can better anticipate how the public receives their products if they take these three dimensions into account. This does not mean to say that the public is always ‘right’. On the contrary, the public’s judgment is often inconsistent. Nevertheless, my quest may provide researchers with some guidelines when developing new production pathways for food ingredients, nutraceuticals and other materials. This article is restricted to genetic modification of microorganisms.

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The Difference Between Medicines and Food

I was struck by the major difference in how the public has received genetically engineered (GE) drugs versus GE foods. In the medicine, almost anything goes. In general, science journalists write favourably about the role of synthetic biology in the development of new drugs, and nobody minds. In the race for a vaccine against Ebola, there has generally been just one criterion: the drug should work. (Although more recently, the Organic Consumers Association has begun criticising the use of GE tobacco in developing GE drugs to fight Ebola.) However, when it comes to food, public criticism of pathways involving GE organisms may be severe.

The production of nutraceuticals and food ingredients by fermentation, using genetically engineered organisms, is growing fast. Public reception varies greatly. Isobionics, a daughter company of DSM, produces valencene, the orange flavouring, nootkatone, the grapefruit flavouring and similar products using fermentation technology. Would orange juice, produced with this valencene, be equivalent to traditional orange juice? Is it somehow artificial or unnatural? These are questions to which we can directly apply the wisdom in the public mind by consulting our own emotions. Most of us will view the original as superior, even if industry could approach the natural composition of orange juice by adding vitamin C, fibres (eg from wood) and micronutrients. 'Natural' would imply 'better'.

However, this does not hold true in the case of genetically engineered drugs. Nobody would suggest that the natural artemisinin (the most powerful antimalarial drug now) made from *Artemisia Annua* is superior to industrially produced artemisinin, administered through a pill. The public long ago embraced the view that a cure could come from a pill, rather than from a vegetable extract. In fact, the proposed 'natural' cure might even be perceived as quackery. Many people view the industrial production of artemisinin as a major scientific breakthrough.

Why is there such a difference? There may be perceived health issues (natural orange juice might be thought of as healthier than the manufactured counterpart); natural products may be thought of as more fashionable; or ethics might be in play. In general, I submit, public opinion will flow along these three dimensions. In this case of orange juice versus medicines, we might learn that according to public opinion healing is more important than consuming (the ethical and health angles), leaving more room for genetic engineering in the field of medicines; and that as far as food is concerned, 'natural' has an extra (the fashionable angle, with a so far unproven bit of perceived health effects).

Fashion May Change

Some of these conclusions, however, are immediately challenged by our next example, the development of artificial, cow-free milk by Muufri, a start-up founded by vegans (Randall 2015). 'Our solution is to make real milk from the bottom up,' wrote Muufri (undated) on its website.

> It's a fairly simple mixture: six key proteins for structure and function, eight key fatty acids for flavor and richness. In different ratios, these components give us cow's milk, goat's milk, or even buffalo milk – all suitable to become countless products, from toppings to cheeses to desserts. (Muufri undated)

Muufri then elaborates the advantages of artificial milk, an argument that can be extended easily beyond milk. Synthetic milk conceivably could circumvent the environmental problems associated with milk production. Dairy cows produce so much methane gas in their stomachs that they are major contributors to the greenhouse effect. Synthetic milk tackles that very serious problem. Questions of animal welfare also do not arise with synthetic milk, and less agricultural land may be needed. Muufri even suggests that its synthetic food might be better than the natural stuff.

> We don't just solve problems, we add new value to dairy, too. Because we choose what goes into our product, we can choose to leave out lactose, which is at least partially indigestible by 75 percent of adults; and we can choose to leave out bad cholesterol for a much healthier product… because our products are made with the same precision as medicines, they'll be free of all bacteria – meaning

a great-tasting milk with unprecedentedly long shelf life, no pasteurization needed. (Muufri undated)

The takeaway: It's healthy because it's artificial!

Fashion may (and will) change. 'Natural' – quite a multi-faceted and scientifically imprecise term – is a fashionable marketing tool at the moment; the booming 'natural' cosmetics market and celebrity chefs' cooking testify to that, but the next fashionable fling might well be 'scientifically cutting-edge products'. These might even carry health claims, as the Muufri example illustrates. So, if the ethical dimension is absent (like in this case), public opinion may surprise us in the future. Or alternatively, Muufri's milk might remain a fringe product.

Genetic Modification in Cheese

In other issues, matters may get complicated very much by a combination of marketing tools and public ignorance. Let us apply the three dimensions to deconstruct the public reaction to cheese and beer production. From time immemorial, cheese was produced using rennet extracted from the maw or fourth stomach of ruminant calves. However since the 1990s, cheese has been increasingly produced from rennet obtained from genetically engineered microorganisms (except in France, where food laws prohibit their use). Researchers extract rennet-producing genes from animal stomachs and insert them into bacteria, fungi or yeasts to make them produce rennet by fermentation. The genetically modified microorganism is killed after fermentation, and rennet is isolated from the fermentation broth. The final product does not contain any GE component or ingredient. Lo and behold, public opinion does not seem to mind. The legislature of state of Vermont in the United States, which is very strict on labelling GE foods, has exempted cheese from this obligation – although almost all cheese sold in Vermont is produced in this way.

The difference may be that cheese has always been looked upon as processed food anyway, whereas orange juice was not. Isn't the difference that most of us never *saw* beer or cheese being produced from scratch, unlike orange juice? In other words: most consumers are just ignorant about how beer and cheese are produced. They value the proliferation of unique varieties made possible by special kinds of rennet. They have no idea that those unique qualities are linked, in part to genetic engineering. The next premium cheese might proudly advertise and brand itself as being produced from cutting edge, science developed, sustainable rennet.

The Courage to Face Opposition

Still, I see no reason to diverge from my earlier conclusion that the public mind, medicines are more important than food and that therefore, companies developing food ingredients with the intermediate use of GE organisms will have to think twice – but public ignorance is a major factor producing uncertainty. Will people react favourably to biodegradable and biobased carpets, or will they be dismayed when they discover that they let their babies crawl on a substance produced by GE organisms? People might even refuse to know the truth because this could complicate life – this might be the case with beers and cheese. Companies make themselves vulnerable to unfavourable reactions in the future, not just by deceiving their customers, but also by hushing up uncomfortable truths. They might be better off proudly advertising their products as the result of cutting-edge technology, than sitting still waiting for the storm that might descend on them. For all it is worth, the acceptance of GE production methods in cheese and beer production shows that there is a certain basis for accepting this technology in the food industry.

A company that has understood this message is Ecover, a Belgian company that produces household and personal care products. Ecover is sold in the United States under the name Method. Ecover is quite a remarkable company; it has conquered the niche of environmentally benign products and has the environmental community as the backbone of its customers. The company recently decided to substitute a vegetable oil produced by Solazyme from modified algae for palm kernel oil as the feedstock for its detergents (palm kernel oil being regarded by many environmentalists to have a poor sustainability record), and – this being the point here – it decided to announce this project before embarking upon it. This project too became the object of criticism of Friends of the Earth. As a result of that opposition, Ecover shelved its plans for the time being. Both parties agreed to engage in a mediation process, that still goes on at the time of writing.

What should Ecover do on the basis of the arguments developed in this article? Well, just carry through their project, as far as that is commercially advisable in view of the specific makeup of their customers. There are no ethics nor health issues here; and as people already accept *food* produced by the intermediate use of genetic modification, why should they object to a similar product they apply to their floors?

Baby Milk

So far, the 'innate wisdom in the public mind' appears to boil down to two ground rules: technology is questioned more in food production than in medicines, and: be careful about potentially misleading your customers. Reflections on the case of baby milk, however, challenge that conceptual framework.

Scientists generally agree that breastfeeding, when possible, is best for the baby (with a few exceptions). Yet, we also have been feeding processed animal and soy milk to our babies for many decades. Fashion? To some degree yes. Prolonged breastfeeding is increasingly at odds with women's role in society. Apparently, those economic and social demands are so powerful that many women push aside the maternal instinct.

Science might help alleviate the guilt of parents who are concerned that they might be hurting their child in some way by not raising him or her on breast milk. Researchers are narrowing the differences between breast milk and their processed cow milk. The Flemish company Inbiose (2014) recently developed special carbohydrates on demand as additives to (for instance) baby milk powder. Using GE organisms, to be sure. In production method, there is virtually no difference with Evolva's vanillin or Isobionics' valencene.

One would tend to expect resistance to mount, because it is not our own health but our baby's that is at stake – and yet, no social upheaval here. Maybe even to the contrary: we will go the extra mile for the health of our baby!

So health and fashion lead the way to our emotions in the case of artificial baby milk, although the outcome is unexpected. Ethics: not an issue, otherwise than a general preference for sustainability, but here, if I am not mistaken, a fourth dimension comes into play: reputation. One of the strongest trademarks in this area is

Nutricia, a subsidiary to Danone. Its baby milk powder is not an exceptional product, according to food experts; but once one has the reputation that one's trade mark has an extra for the baby, and one succeeds in keeping that up throughout the years – then that appears to constitute a premium product to the consumer. Reputation, consumer confidence, premium product. Something that is worth the premium price, no questions asked.

Conclusion

When it comes to medical biotechnology we accept each production method, provided the pill actually cures, but that does not hold true in the case of food. Producers of food ingredients will have to be very careful to account for their actions to themselves and to their customers. Today's fashion appreciates the 'natural' – but then, in the confusing example of baby milk that does not hold true. As long as there is no adverse health effect, fashion is the strongest factor – but do not neglect ethics. Ethical deceit can backfire on the entire industry.

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Diederik van der Hoeven is a Dutch science journalist. After working as a policy consultant in the fields of energy, the environment and sustainable transport systems, he wrote several books on these subjects. For the past 15 years he has worked as a science journalist concentrating on the biobased economy. His last book (in Dutch) is titled *Green growth, towards the society of 2040* and is the editor of www.biobasedpress.eu (bilingual, Dutch/English).

The Genetic Literacy Project

Agricultural and human biotechnology are reshaping farming, food and medicine. The Genetic Literacy Project (GLP) explores the intersection of DNA research and real world applications of genetics with media and policy to disentangle science from ideology.

Genetic research and biotechnology can improve food security, the environment and public health. Yet dramatic innovation can lead to unintended consequences and present ethical challenges. In theory, the study of genetics and related cutting edge sciences are widely celebrated, but in practice, the words 'gene' and 'genetic engineering' and 'biotechnology' and 'synthetic biology' often stir fear and misunderstanding when applied to biomedicine and farming. Intricate science scares people who don't understand risk and complexity. What is the potential of agricultural and human genetics? The commitment of the GLP is to promote public awareness of genetics, biotechnology and science literacy.

Biotechnology Applications for Consumers in Developing Areas and Consumer Acceptance

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Malnutrition is the most common cause of death for young children and pregnant women in developing countries. Regions like sub-Saharan Africa and South Asia contain 98% of the world's malnourished population. About 67% and 63% of the total population in South Asia and sub-Saharan Africa, respectively, reside in rural areas where agriculture is their main source of food and income. Adoption of biotechnology such as genetically engineered crops and transgenic livestock provides an alternative solution against malnutrition in these regions since most consumers are also producers of agricultural products. However, the potential positive impacts of biotechnology can be limited by public acceptance. Education coupled with a more relaxed regulation, in both developing areas and by trade partners, will help these technologies reach full potential.

Introduction

Food insecurity and malnutrition are rampant in developing nations, predominantly in sub-Saharan Africa and South Asia. Approximately 98% of the world's population with malnutrition is found in sub-Saharan Africa and South Asia (Berman et al. 2013). The use of biotechnology can be an effective way to decrease food insecurity in developing countries (Farre et al. 2011), and also provides micronutrients for human health (Beyer 2010).

Approximately 6.3 million children younger than the age of five lost their lives in 2013 (Liu et al. 2012). Fortunately, this is down from almost 9 million deaths in 2008 (Black et al. 2010). The most devastated areas are in sub-Saharan Africa and South Asia, where four out of every five deaths of children occur. However, there is hope as more than half of these children die from preventable or treatable diseases.

Of the 6.3 million deaths in 2013, 51.8% were caused by infectious diseases (Liu et al. 2012). Diarrhoea is considered to be one of the primary infectious diseases leading to childhood morbidity and mortality. Approximately 2.5 billion cases of diarrhoea are reported each year (UNICEF & WHO 2009) and diarrhoea is estimated to kill at least 800,000 young children worldwide annually (Kotloff et al. 2013; Patel et al. 2011). Table 1 (over page) shows the burden associated with diarrhoea for World Health Organization (WHO) regions. As shown, more than 80% of the deaths due to diarrhoea in WHO regions occurred in Africa and South-East Asia. Thus, there are opportunities to make substantial difference in these developing areas.

While diarrhoea is a primary infectious disease causing death for children under the age of five, second only to pneumonia, malnutrition is the underlying cause of more than 50% of deaths (Chen 2012). Vitamin A deficiency is prevalent in developing areas and has significant consequences (Luo et al. 2010; WHO 2009; Sherwin et al. 2012). The consequences of vitamin A deficiency includes anaemia, immune dysfunction and increased vulnerability to respiratory infections, poor growth, mortality, visual problems, diarrhoea and measles (Jr and Darnton-Hill 2008; Tang et al. 2009; Farham 2011).

Table 1: Burden of diarrhoea by WHO regions in 2010.

WHO Regions	Population (0–4 years)	Incidence (%)	Total deaths
Africa	133,340,762	3.3	353,300
South-East Asia	179,956,087	2.4	277,700
America	76,995,700	3.2	11,000
Eastern Mediterranean	72,151,965	2.9	96,600
Western Pacific	116,411,580	2.2	16,900
Europe	54,605,243	2.8	6,300
Global	633,461,337	2.7	761,800

Source: Walker et al. (2013).

Table 2: Burden of vitamin A deficiency by WHO regions from 1995–2005.

WHO Regions	Preschool age children		Pregnant women	
	Prevalence (%)	# of people affected (millions)	Prevalence (%)	# of people affected (millions)
Africa	44.4	56.4	13.5	4.18
South-East Asia	49.9	91.5	17.3	6.69
America	15.6	8.68	2	0.23
Eastern Mediterranean	20.4	13.2	16.1	2.42
Western Pacific	12.9	14.3	21.5	4.9
Europe	19.7	5.81	11.6	0.72
Global	33.3	189.89	15.3	19.14

Source: WHO (2009).

Table 2 shows the prevalence of vitamin A deficiency in WHO regions. The WHO (2009) estimated that approximately 33% of the world's preschool age children are vitamin A deficient. The situation is worse in Africa and South-East Asia where 44–50% of preschool children are vitamin A deficient. Additionally, the incidence of night blindness in pregnant women, a consequence of vitamin A deficiency, is also higher in African and Asian regions than the rest of the world (WHO 2009; Imdad et al. 2010).

In 2000, the Millennium Declaration established targets for reducing disease and child mortality. The efforts to reduce the child mortality rate has had some success as the number of deaths for children under the age of five years has declined by 49% between 1990 and 2013 (WHO 2015), and there has been a 4% global annual decrease in diarrhoea mortality (Kotloff et al. 2013). However, further steps are needed to in order to further reduce vitamin A deficiency and diarrhoeal diseases in Africa and Asia. Vitamin A deficiency can be reduced by consuming a diverse diet, fortification of staple foods, and high-potency supplements. Diarrhoea can exacerbate vitamin A deficiency due to dehydration. Thus, it is important to promote hydration therapy and breastfeeding to minimise the effects of diarrhoea.

Fortification of staple foods and high-potency supplements are being adopted in many developing areas to reduce vitamin A deficiency. Unfortunately, these interventions have not eradicated vitamin A deficiency and both interventions have limitations. Industrial fortification does not effectively reach poor people in rural areas, while supplements are costly and likely not sustainable; Edejer et al. (2005) estimate that vitamin A supplementation costs $10.84 per child per year, implying a cost of at least $2.8 billion per year to alleviate vitamin A deficiency through supplementation (Jones & De Brauw 2015).

Practically all current applications of biotechnology on the market were developed to assist commercial farmers. However, an increasing number of biotechnology applications are being developed for the direct benefit of consumers, including commodity producers in developing countries who are net consumers of agricultural products. Some applications have been developed to minimise the effects of malnutrition and disease in developing areas. Improved nutrition profiles of staple foods is an example of consumer based benefits possible from biotechnology innovation in agriculture. Currently, there are biotechnological solutions developed with hopes to reduce the number of deaths associated with vitamin A deficiency and diarrhoea that have yet to reach the market.

Biotechnology Solutions

Adoption of genetically engineered (GE) crops in developing countries has resulted in higher yields, increased farm income, and health benefits (James 2010; Adenle 2011). In addition to decreasing food insecurity, poor farmers in South Africa, Burkina Faso, and Egypt have benefited from increased farm income from GE crops. Economically, South Africa gained a total of US$809 million between 1998 and 2010, and US$133 million in 2010 alone due to GE crops (James 2010). Likewise, expansion of GE cotton production in Burkina Faso has resulted in an annually economic gain of more than US$100 million due to 30% increase in yield in 2010 (Adenle 2011). Biotechnology has the power to limit damage from pests and insects. GE crops can reduce by up to 50% the volume of insecticides that is applied on farms (Adenle 2011). Due to the benefits of GE crops, there has been an annual double digit adoption growth rate of GE technology by farmers in both developed and developing countries since 1996 (James 2010). However, the ability of biotechnology to decrease food insecurity and malnutrition is dependent on acceptance by governments and consumers in developing nations.

While industrial fortification may not be viable in rural areas, biofortification may be a feasible option. Vitamin A biofortified seeds for maize and planting material for cassava and sweet potato have been developed through conventional breeding practices and the sweet potato varieties have the ability to significantly reduce the burden of vitamin A deficiency (Meenakshi et al. 2010). Additionally, unlike industrially fortified rice, golden rice has the potential to sustainably reach the poor population in urban and rural areas (Albabili & Beyer 2005; Dawe & Unnevehr 2008; Tang et al. 2009). Golden rice is a genetically engineered variety of rice which contains up to approximately 30 micrograms of beta-carotene per gram of dry rice that can be converted to vitamin A (Dawe et al. 2002; Albabili & Beyer 2005; Tang et al. 2009, 2012). The added beta-carotene causes the rice grain to have a yellow colour when milled, hence the name golden rice (Schaub 2005; Albabili & Beyer 2005).

In areas where vitamin A deficiency is rampant, like South-East Asia, consumption of golden rice could have great impact (Dawe & Unnevehr 2008). Tang et al. (2012) found that consuming 50 grams of dry golden rice can provide approximately 60% of the vitamin A intake for a seven year old child. To put that amount of rice in perspective, the per capita calorie intake of rice is 1245 Kcal/day in South-East Asia and 234 Kcal/day in Africa (IRRI 2015). There is approximately 4 Kcal in a gram of dry rice, thus, the average person in South-East Asia and Africa is consuming more than 50 grams of dry rice per day.

The Artemis line of transgenic goats was established in 1999 to produce milk containing human lysozyme (for more details read Maga et al. 2003). The goal of this application of biotechnology is to provide agriculturally relevant animals to developing areas that include targeted novel traits to minimise the growth of pathogens within the gut and subsequent diarrhoeal diseases. Goats were chosen over cows because of a shorter generation interval and the ability to thrive in adverse conditions common in developing areas.

Lysozyme is an enzyme and an important antimicrobial factor that can directly attack a variety of bacteria and thus control their growth, and modulate the gastrointestinal bacterial composition. High quantities of lysozyme are found in human breast milk, and the incidence, prevalence, and duration of diarrhoea episodes have been found to be lower for breastfed infants (López-Alarcón, Villalpando & Fajardo 1997). Unfortunately, there is little lysozyme in the milk of ruminants like cows and goats.

Lysozyme concentration in transgenic goat milk is 68% of that found in human milk (Maga et al. 2006). A recent study by Cooper et al. (2013) used two groups of pigs, a treatment group and a control group, to determine the effectiveness transgenic goat milk containing lysozyme compared to non-transgenic goat milk. The study concluded that transgenic goat milk was an effective treatment for diarrhoea caused by enterotoxigenic E. coli, a common cause for bacterial diarrhoea. Pigs consuming transgenic goat milk had significantly increased recovery time from clinical signs of infection, improved faecal consistency, and activity levels compared to pigs that consumed non-transgenic goat milk.

Acceptance of Biotechnology in Developed Areas

Adoption of herbicide-tolerant and insect-resistant crops by growers have been widespread in the United States (US). In 2014, 93% of corn planted, 96% of cotton planted, and 94% of soybeans planted in the US were genetically engineered (GE) varieties (USDA 2014). Despite the widespread adoption by growers, consumer perceptions about GE food has not been as positive. In fact, less than 40% of US consumers believe GE food is safe to eat (McFadden & Lusk 2015; Pew Research Center 2015).

While the majority of US consumers do not believe GE food is safe to eat, 88% of scientists connected to the American Association for the Advancement of Science (AAAS) believe it is safe to eat GE foods. Thus, there is a large gap in opinions between the public and scientists. It appears that better science communication about GE foods is necessary. However, it is not obvious that scientific communication alone will be fruitful.

Figure 1, borrowed from McFadden and Lusk (2015), shows the effect of scientific information on beliefs about the safety of GE foods. Each line represents a belief category prior to receiving scientific information. Believers were people who thought GE foods were safe to eat, deniers were people who thought GE foods were unsafe, and neutrals were people who were unsure about the safety. The horizontal axis in Figure 1 measures how people assimilated scientific information. The conservative group were people whose beliefs were unchanged after receiving scientific information, convergent were people whose beliefs converged to scientific information and now believe that GE foods are safer to eat, and divergent were people whose beliefs diverged from scientific information and now believe that GE foods are less safe to eat. Interestingly, people in the denier category were more likely to diverge from information rather than converge, although the difference was not significant.

However, public acceptance may be more favourable for some applications, and indeed previous research has indicated that consumers in developed countries do not view all applications of biotechnology uniformly (eg He & Bernard 2011; Lusk et al. 2004; Gaskell, Allum & Stares 2003; Hossain et al. 2003). Moreover, a recent study determined that public acceptance of bioengineered food increases when the technology brings tangible benefits to consumers compared to benefits for growers (Lusk, McFadden & Rickard 2015). Figure 2 shows the relative desirability ratings for various biotechnology applications to food. Consumers in the US are concerned about where food is produced, the price of food, and the nutritional value of food. Insect-resistant crops are beneficial to growers as they decrease input costs and boost yields, but consumers also see the reduction in pesticide residues as a direct benefit. Interestingly, consumers desire herbicide-tolerant biotechnology the least, which is the application currently most used.

Acceptance of Biotechnology in Developing Areas

While it is known that consumers in developing countries are generally concerned about GE foods, it is not known from where the concern originates. Furthermore, it is likely that the concern about

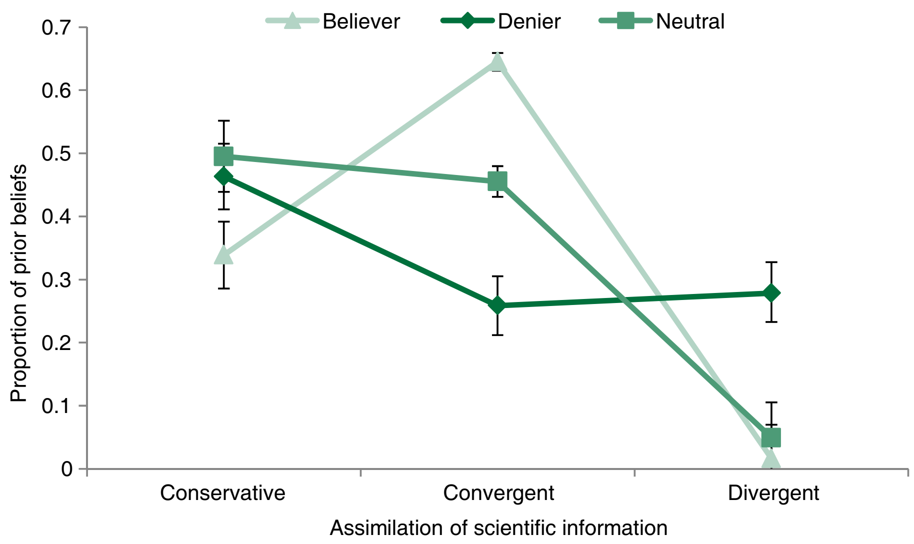

Figure 1: Assimilation of scientific information about GE foods by proportion of prior beliefs.

Source: McFadden and Lusk (2015).

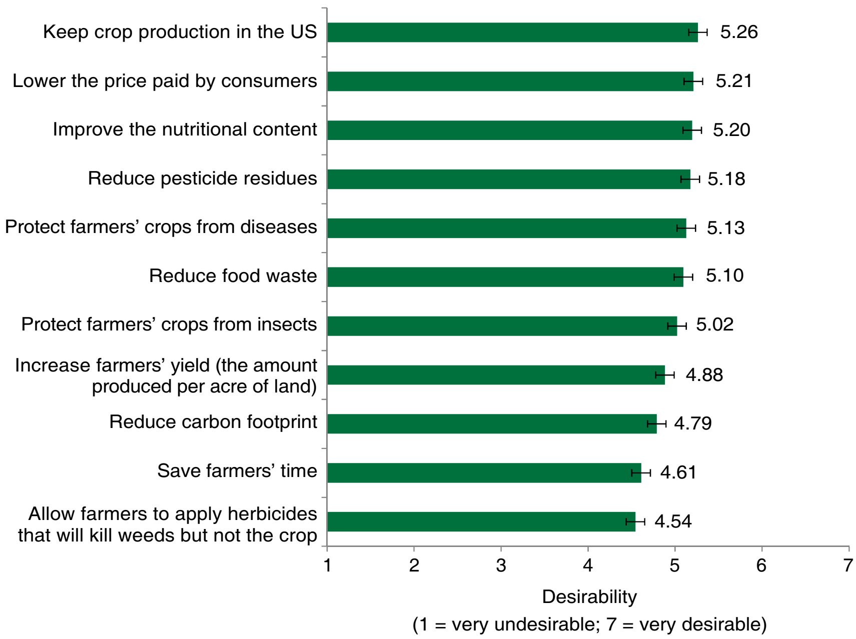

Figure 2: Relative desirability ratings for motivations to adopt food and agricultural biotechnologies.

Source: Lusk, McFadden and Rickard (2015).

GE foods have various origins for individual consumers.

Understanding concerns about biotechnology in developing areas is even more convoluted. Attitudes towards biotechnology differ across developing countries. It is difficult to understand concerns in developing areas because many people lack awareness, education, and knowledge on biotechnology applications (Adenle 2011). In addition, limited studies have been conducted to assess awareness and attitudes of African consumers and stakeholders towards GE food (Kimenju et al. 2013). Recent surveys found that 75%, 19%, and 5% of consumers in Ghana, Tanzania, and Bangladesh, respectively, had knowledge about GE rice prior to the survey (Mwaijande et al. 2014; Durand-Morat et al. 2015). Consumers in Ghana were relatively more informed, and more prior knowledge was associated with lower willingness to accept GE rice (Mwaijande et al. 2014). Thus, consumers who were knowledgeable about GE rice did not have favourable beliefs. Furthermore, similar to developing areas, information had little effect on willingness to accept GE rice.

An aspect of the developing countries context that differs from that of wealthier countries is that many potential consumers of GE products are also agricultural producers. In South Asia and sub-Saharan Africa, for example, 67% and 63% of the total population can be found in rural areas where the dominant economic activity is agriculture.[1] This shapes the situation with respect to biotechnology in two ways. Firstly, poverty and malnutrition are disproportionately present in rural areas of developing countries (FAO 2012); to the extent that biotechnology can positively impact nutrition and agricultural output, it would seem that the potential gains from biotechnology are particularly large in rural areas of developing countries. Secondly, the interlinkage of production and consumption within agricultural households in developing countries means that the benefits of biotechnology will only be realised if both consumer awareness and the factors that affect technology adoption on the part of producers are addressed.

1 See http://data.worldbank.org/topic/agriculture-and-rural-development

On the producer side, farmers in poor countries typically operate in an environment characterised by weak institutions and poorly functioning markets. For example, agricultural producers cannot or will not in general make use of financial instruments like insurance or formal savings accounts that might allow them to maintain a steady level of consumption in the face of income shocks. Farmers may have uncertain property rights, which will weaken incentives to invest in new technologies because of uncertainty over the ability to capture the benefits in the future. The market for knowledge transfer (eg agricultural extension) can fail due to the high costs associated with serving small, remotely located producers. These are but a few of many constraints on decision-making that can make agricultural producers in developing countries more hesitant to adopt new technologies than their counterparts in the developed world.[2] In addition, for agricultural households that are net producers with respect to food production, new crops will only be adopted by producers if they find them agreeable as consumers.

At the micro level, successful policy interventions designed to promote the adoption of biotechnology must therefore simultaneously address market and institutional failures as well as consumer preferences. One example of a program taking this approach is HarvestPlus, an initiative seeking to improve nutrition in developing countries through the introduction of biofortified crops. The HarvestPlus program addresses failures in the market for knowledge by training farmers to produce bio-fortified crops, addresses input market failures by distributing planting material, and targets consumer preferences by training household members (almost exclusively women) to incorporate biofortified crops into their diet. In a recent study of the impact of the introduction of biofortified orange-flesh sweet potato (OSP) in Mozambique, Jones and De Brauw (2015) estimate that access to OSP vines as well as training on production and consumption of OSP caused a 11.4 % reduction in the prevalence of diarrhoea among children under five years of age, and a reduction of 18.9 % among children under three years of age.

2 See Jack (2011) for a survey of the evidence on how constraints can affect technology adoption by farmers in poor countries.

Biotechnology also has the potential to affect commercial agricultural production in developing countries. However, the potential positive impacts of biotechnology can be limited by the unwillingness of trading partners to accept GE crops. For example, due to political relationships, many African countries are bound by a European regulatory framework that is hostile to GE crops (Kimenju et al. 2013; Adenle 2011). Although not explicitly related to biotechnology, an anecdotal example of the unfortunate consequences of the interconnectedness of African agriculture and the European regulatory framework is found in a paper by Ashraf, Giné and Karlan (2009). The authors of the study measure the impact of an agricultural development program called 'DrumNet' offering credit, agricultural extension, and marketing services to Kenyan horticultural producers in order to promote export to Europe. The authors estimate that the program increased income by 39% for producers with no prior experience in export markets. Unfortunately, the program collapsed a year later when participants could not meet new requirements for certification needed to export to Europe; the authors estimate that the cost of compliance with certification requirements were equal to twice annual net gain from program participation. These high participation costs are likely too much to bear for producers in poor countries, where access to finance is low. The story of DrumNet is a cautionary one for agricultural producers seeking to benefit from biotechnology, as the benefits of adoption must be weighed against the potential cost of exclusion from some markets.

Conclusion

Agriculture is an important sector in developing areas, particularly in sub-Saharan Africa and South Asia. A large proportion of the population is found in rural areas and the labour force is mainly committed to agriculture. The amount and type of food available often does not contain the needed micronutrients. Treatable or preventable diseases, such as diarrhoea and vitamin A deficiency, are the leading cause of death for children and pregnant women in developing areas. Supplementation and food fortification programs may be less likely to reach rural areas and are expensive.

Applications of biotechnology and biofortification have the potential to go beyond what supplementation and industrial fortification can provide by further reducing malnutrition. Reductions in malnutrition will result in improved household food security and household welfare. These methods, however, should not be viewed as the only methods to decrease malnutrition, but rather complements to industrial food fortification and supplementation programs.

Nevertheless, the potential of biotechnology and biofortification may be limited by public acceptance. There is a need for better education for producers and consumers in developing areas to inform the public both to the source of malnutrition and how it can be minimised. Education coupled with a more relaxed regulation, in both developing areas and by trade partners, will help these technologies reach full potential.

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Sushi Set

Review of Asian Consumer Attitudes Towards GM Food and Implications for Agricultural Technology Development in Australia

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This paper highlights the dilemma challenging the future development of genetically modified (GM) crops in Australia: How do we define and manage the development of new agricultural technologies on the farm while taking into account Asian consumer purchasing preferences? Do we focus on brand Australia – clean, green and safe for wealthier Asian's who will pay higher prices for Australian non-GM produce or do we develop GM crops and food products for poorer consumers?

Our review of the literature shows that while the less wealthy in Asian countries will purchase food based on best price, the rapidly increasing percentage of wealthier Asian consumers tend to be concerned about food safety and the healthy aspects of food. Chinese consumers in particular, are becoming increasingly discerning. Australia has been recognised by many around the world (including consumers in Asia) for its integrity and ability to produce high quality food products that are safe, clean and green. We conclude that Australia's clean, green and safe brand has a market value, and needs to be included along with consumer purchasing behaviour when valuing technological advancements and GM food crops on Australian farms.

Introduction

The issue of food security has historically been important for Asian countries, which had a combined population of 4.427 billion in 2014. China with a current population (2015) of 1.4 billion and India with 1.2 billion people are respectively ranked the first and second most populated countries in the world. They represent over half the population of Asia. Rapid economic development over the last two decades in most Asian countries has resulted in raising disposable incomes and changing diets. According to the National Bureau of Statistics of China (2014), the per-capital disposable income of urban households was about ¥$26,955 in 2013, which was an increase of 9.7% from the previous year.

Genetically modified (GM) crops have enormous potential to increase food security in Asia. GM crops were first commercially grown in 1996, and since then the area sown annually to GM crops has expanded, from 1.7 million hectares in 1996 to 170 million hectares in 2012 (James 2013; Chen & Lin 2013). The top four GM crops growing countries in terms of their area are United States (US), Brazil, Argentina and India (Kamle & Ali 2013).

The four major GM crops grown in the world are soybean, cotton, maize and canola (Kamle & Ali 2013). GM crops have enormous environmental and economic benefits. For example, in 2010, as a result of GM crops the global farm income benefits increased by US$14 billion (Chen & Lin 2013). Similarly, since 1996, the use of pesticides on GM crops decreased by 448 million kg (9% reduction) (Chen & Lin 2013). Greenhouse gas saving from GM crops due to reduction of pesticide use and fuel use, and additional soil carbon sequestration were equivalent to the removal of tens of millions of cars from the road (Brookes & Barfoot 2012).

This paper reviews literature on GM crops in Asia with an emphasis on Chinese consumer awareness and attitudes to GM crops. It takes a systematic approach to discussing the dilemma challenging Australia's future development of GM crops: How do we define and manage the development of new agricultural technologies within the Asian context? Do we focus on brand Australia – clean, green and safe or do we develop GM food products for poorer consumers?

Changing Asian Food Preferences and Consumption

Changing Asian consumer food preferences are resulting in a change in the way food is being marketed. Modern and efficient food marketing chains with established quality and safety regimes have become increasingly prevalent (OECD–FAO 2013). China's consumers, in particular, are becoming increasingly discerning and many are seeking food products with the following attributes:

- safety and ingredients' integrity
- higher quality
- better nutritional value
- more varieties
- modern packaging
- freshness
- convenience (Austrade 2014).

Increasing international cultural exchanges as well as the presence of different types of international restaurants, steakhouses, and hotels in urban cities in China has exposed consumers to a greater diversity of food choices, which have facilitated changes in Chinese consumers' tastes and preferences (Zhou et al. 2012). This has led to changes in Chinese diets, in terms of the quantity, quality and composition with an increasing preference for higher quality food. The reasons for these changing food consumption patterns in China can be summarised into five key drivers: namely (1) rising income, (2) rapid urbanisation, (3) changing lifestyle, (4) changes in tastes and preferences, and (5) better organisation of food production and marketing (Zhou et al. 2012).

The changes to Asian food consumption patterns have presented Australian food industries with a challenge – how to increase productivity while maintaining Australia's 'natural' reputation. Australia has been recognised by many around the world (including consumers in Asia) for its integrity and high quality food products that are safe, clean and green. To develop Australia's exports, the food export sector needs to take advantage of this reputation in order to serve a growing consumer base that is prepared to pay a premium price for product assurance, reliability and safety guarantees.

GM Crops in China and India

In India, more than 215 million people are food insecure (FAO, WFP & IFAD 2012). GM crops can play a significant role in food security in India. For this to happen, two factors are critical in India: (1) a change in the regulatory system for GM crops; and (2) consumer acceptance of GM crops, as most of the crops produced are consumed domestically (Shew et al. 2015). In India, public acceptance on GM crops is poor, and therefore, the regulatory system is very critical. As a result, so far only one GM crop (cotton) is grown commercially, which accounts for >90% of domestic cotton production (Shew et al. 2015). In fact, the Indian Supreme Court had placed a moratorium on commercialisation of all GM food crops from 2005 until 2014.

The current Indian Prime Minister is considered to be a supporter of GM crops. When he was Chief Minister of Gujarat, he enacted legislation to allow the production of GM cotton in 2002 and it subsequently became a huge success. Prime Minister Modi has already conducted several meetings in favour GM crops in India.

With one-fifth of the world's population and only 8% of its arable land, China has always faced food security challenges. It has emerged as one of the world's largest agrifood markets (World Bank 2015). To ensure people have enough food on the table, the Chinese Government has proposed the development and adoption of agricultural biotechnology as a priority for increasing food production and reducing environmental costs.

China has issued GMO Safety Certificates to seven domestically developed, genetically modified (GM) crops, including varieties of tomato (1997), cotton (1997), petunia (1999), sweet and chilli peppers (1999), papaya (2006), rice (2009), and corn (2009). GM cotton has been broadly cultivated in China. As of 2010, China grew 3.3 million hectares of the GM cotton and a few hectares of papaya, while the other GM crops had not been cultivated broadly (Library of Congress 2013).

Licences have been granted for the importation into China of four foreign GM crops: cotton, soybean, corn, and rape. In 2011, imported GM soybeans constituted two-thirds of the soybeans consumed domestically (Library of Congress 2013).

Traditionally, China had a positive attitude towards GM crops. The Chinese Government regarded GM technology as one of the most important tools for increasing food production. This resulted in China being one of the earliest countries to develop and implement genetically modified organism (GMO) regulations in the world, and many management measures and regulations were gradually introduced and implemented from 1993 onwards. Before 2001, China spent approximately $120 million per year on the research and development (R&D) of biotechnology for the GM food production (FAS 2002).

Consumer Awareness and Attitudes to GM Crops in China: A Literature Review

In the early stages of introduction of GM technology, the Chinese public showed a positive attitude towards GM food (Asian Food Information Centre 2002, 2003). Results indicated that about two-thirds of consumers not only accepted GM foods but also believed that they would personally benefit from consuming GM foods. Similar results were also reported by Li et al. (2002) in their Beijing survey which revealed that 73% to 80% of respondents intented to buy GM foods. Some research even indicated Chinese consumers are willing to pay a premium for GM foods (Wang 2003; Zhang 2002).

Chinese consumers had limited knowledge of GM technology. The survey conducted by Li et al. (2002) in Beijing indicated only 1% have knowledge of GM. The very low rate in Beijing, one of the most highly educated cities in China, indicates that most Chinese have no knowledge of GM. An additional survey conducted by Xuan and Zhou (2002) in China sought to identify consumers' awareness of GM foods. Results from questionnaires showed that only about 5% of Chinese consumers think that they understand the issues concerning GM foods well. Among those 5% of people, most of them have incorrect knowledge of GM. According to Ming's Report (2002) only 28.6% people in the Chinese urban area are aware of GM food.

In the past 13 years, people's awareness of GM food in China has increased from 35.1% in 2004 (Wang 2005), to 42.2% in 2008 (Wang 2008), 75.4% in 2010 (Wu 2011), to 85.3% in 2014 (Xia 2014), mainly due to the debate about the GM food issue in public media. However inconsistent results have been reported of people's willingness to buy GM food.

A survey conducted by Ho et al. (2006) suggested that the majority of the respondents (60%) were either unwilling to consume GM food or were neutral about the idea, but when given neutrally-worded information about potential GM food the unwillingness to buy GM foods dropped sharply.

This may indicate possible future scenarios of consumer resistance against GM food as has happened in European Union member states. Another survey conducted in 2005 by Hu and Chen showed that more than 67% of the respondents were concerned with GM foods, and about 20% of them believed that GM food was harmful for their health. This is further confirmed by Zhang's (2005) study which reported that only 23.3% people interviewed were willing to buy GM food while the awareness level of GM food was 35% of his sampled population. Consumers' concern about the lack of available information on GM food was found to be the most important factor affecting their GM food purchasing decisions (Kim 2009).

The price and quality of GM food is the main factor affecting purchase decisions. The percentage of consumers who were willing to buy GM foods increased from 65 to 74%, if the prices of GM foods were 10% lower than those of non-GM foods (Huang et al. 2006). This conclusion was similar to experimental result from six European countries where customers were willing to choose GM foods provided there was a price advantage (Shao, Cai & Chen 2014) (see Table 1).

Table 1: Retail price difference between organic, non-GM and GM cooking oil (2015).

Organic	Non-GM	GM
A$6/L to A$8.8/L	A$3.2/L to A$4.6/L	A$1.6/L to A$2.6/L

Sources: http://news.sciencenet.cn/htmlnews/2013/9/282725.shtm and http://www.agrogene.cn/info-597.shtml

The research conducted by Xia (2014) suggests that education level and income have a negative correlation on attitudes to GM food. The higher the education level and income, the more negative the attitude to GM food. Although this research has not explored Chinese perceptions about food produced using other agriculture technologies in detail, indications are that any technologies that are perceived as having a risk to human health will be negatively received by consumers. This can be demonstrated by the development of the poultry industry in China.

Intensive poultry production was introduced into China in 1980s. As a result broiler meat production has increased dramatically from a total of 1.49 million metric tonnes (MMT) in 1986 to 13 MMT in 2014. A shift to larger operations has supported increases in Chinese food animal production. In 1998, only 30% of broilers in China were produced on farms that produced greater than 2000 broilers annually. In 2009, this number was 70% (Pi, Rou & Horowitz 2014; Woolsey, Beckman & Zhang 2011). Between 2007 and 2009, the number of poultry operations in China with more than 100,000 broilers increased by 34% (Woolsey, Beckman & Zhang 2011). In 2015, this number is likely to be higher although there is no data to confirm this.

The use of antimicrobials in food animal production is now common in China. Antimicrobial use in feeds for food animal production first started in the 1940s when they were added to feeds used in broiler poultry production. It was claimed that chickens gained more weight in a shorter amount of time resulting in greater feed efficiency. As of 2010, a chicken weighing greater than 2.27 kg [5 lbs] can be produced in less than 50 days (The Pew Charitable Trusts 2013). The use of antimicrobials has caused concern to Chinese consumers. Free-range and organic products are taking market share even though they are sold for a premium price (see Table 2).

Table 2: Retail prices of whole chicken produced from different production systems (2015).

Shed	Free-range	Old hen
A$2/kg to A$2.8/kg	A$5/kg to $12/kg	A$5/kg to $12/kg

Systematic Analysis and Discussion

This paper has highlighted the dilemma challenging Australia's future development of GM crops: How do we define and manage the development of new agricultural technologies on the farm while taking into account Asian consumer purchasing preferences? Do we focus on brand Australia – clean, green and safe for wealthier Asian's who will pay higher prices for Australian non-GM produce or do we develop GM crops and food products for poorer consumers? At this point it is worth noting that Australia currently produces 5% of the world's food. By 2030 Asia is forecast to represent approximately half of the world's population. Therefore, Australia cannot become the food bowl for Asia, rather many contest that Australia should concentrate on becoming the premium provider – the delicatessen.

People's perspectives on food risks and uncertainty, their motivations, what they can and can't control, and what they choose to purchase are important. Without an understanding of the relationships among factors that create food products, from politics to market forces to technology, change towards sustainable food production systems cannot be effectively achieved nor sustained by individuals or corporations. Consumer purchasing choices ultimately define the success or failure of production systems, take for example the powdered milk scandal in China that destroyed the reputation of the Chinese dairy industry. A systemic, holistic approach, that includes an understanding of culture and purchasing choice, provides policy-makers with the capacity to understand the impacts of GM production systems and food products. It also helps to understand what the impact of GM products could be on other products, the food system, and the likely acceptance of these products across countries and socioeconomics.

India and China have very different cultural traditions, food tastes and policies towards GM. The literature review on Chinese consumers has highlighted the demand by the increasingly affluent middle class for clean, green and safe produce. Literature has shown that the typical GM customer is in a lower socioeconomic bracket with non-GM consumer higher up the socioeconomic scale.

Chinese consumers are risk averse; if they can afford it, they prefer to buy non-GM. They trust Australian products, they preferentially purchase food from Australia because they consider Australian food to be safe and premium quality. These consumers do not consider GM produce to be clean, green or safe.

The review of literature on India has shown that the new government is supportive of GM technology and consumers there are less concerned about GM than Chinese consumers. However, the literature also shows that increasing media attention on the health impacts of GM food has influenced consumers' purchasing choices; therefore India's rapidly growing middle class are likely to follow China and become averse to GM produce. In summary, while the less wealthy in Asian countries will purchase food based on best price, the rapidly increasing percentage of wealthier Asian consumer tend to be concerned about food safety and the health aspects of food.

Governments have tended to concentrate on goals of increased agricultural production and economically efficient use of resources. Critics contend that governments need to include the environmentally efficient and socially acceptable use of agricultural and rural resources, and that consumer preferences for clean and green produce needs to be acknowledged when developing new production technologies. Asian consumers frequently did not identify with agencies' vision of intensification of agriculture and technologies because they have concerns about the health impacts of these food products. They are also concerned about low compliance to regulations and the efficacy of best management practices in Asian countries, and purchase Australian produce for its clean, green and healthy criteria. These consumers will purchase based on production methods. One of the reasons why GM crops are not popular in India and elsewhere could be due to the perceived lack of health benefits. People believe that the GM crops primarily benefit growers not consumers (Rommens 2010).

Conclusions

This analysis has shown that the production benefits on-farm in Australia cannot be considered in isolation of consumer perceptions in Asia. GM and technological advancements that are perceived to create uncertainty about the safety of food need to be carefully considered in terms of the markets that Australia is developing. GM products can adversely impact on brand Australia. Further, the lower value of GM produce in China may offset the productivity gains in Australia. That is, higher costs of production in Australia are likely to be offset by the premium that can be attained from the retail price of 'non-GM' food.

Australia is confronting a difficult reality. While GM crops can provide farm productivity gains, GM produce has a lower retail value. Further GM crops and food could seriously 'taint' the brand position of non-GM Australian produce in Asian markets. We conclude that Australia's clean, green and safe brand has a market value, and needs to be included along with consumer purchasing behaviour when valuing technological advancements and GM food crops on Australian farms.

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Public Attitudes Relevant to Livestock Animal Welfare Policy

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Rising concerns for animal welfare standards from consumers have started to change the way we produce and purchase meat products. Engaging in public forums has become a popular way to express individual and community views on animal welfare, regardless of whether it is in support of, or in opposition to various aspects of livestock farming. These behaviours and the public opinions driving them can have a considerable influence on how governments either react to publicised 'animal welfare events' or regulate contentious management practices. Furthermore, community concerns and behaviours also impact on how governments react to animal welfare events and more broadly on the livestock industry's social licence to practice. Animal welfare issues together with issues relating to climate change, water scarcity, and declining biodiversity all threaten farmers' social licence to farm. This paper highlights the distrust in the community about management of farm animals, and suggests the need for appropriate interventions and monitoring processes to be developed. On the other hand, the paper illustrates the mismatch between the community's perceived and actual knowledge of livestock practices.

There is growing public concern for animal welfare. This concern is documented in reports from many industrialised nations including Sweden, Spain, Finland and Australia (European Commission 2007; Gracia 2013; Parbery & Wilkinson 2012; Phillips et al. 2012; Prickett, Norwood & Lusk 2010; Southwell, Bessey & Barker 2006; Vanhonacker et al. 2008). Much of the concern about animal welfare is centred on livestock animals and this is reflected in changing consumer behaviours. Many consumers report thinking about animal welfare when they purchase meat and meat products (Department for Environment Food and Rural Affairs 2011; European Commission 2005, 2007).

Coleman et al. (2005) found a high correlation between the number of behaviours that people performed in support of the livestock industries and behaviours in opposition to the livestock industries. In other words, people who reported engaging in any kind of community behaviour tended to do so regardless of whether the behaviour was in support of, or in opposition to various aspects of livestock farming. This suggests that there are some members of the community who actively engage in expressing their views in the various forums that are available to them and are possibly opinion leaders in this field. The possible existence of opinion leaders, their characteristics, extent of knowledge and

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influence should be explored further. The opinions of these leaders have the power to influence the thoughts and actions of those they communicate with. As such they are an asset to the promotion of ideas but can also be responsible for leading active opposition (Chan & Misra 1990).

Increasing concern for the welfare of livestock animals is also reflected in community behaviours in opposition to the livestock industry. These behaviours are distinct from lobbying behaviour that involves deliberate and repetitive campaigning of politicians and regulatory bodies for change (Coleman & Toukhsati 2006). According to Coleman and Toukhsati (2006, p. 21), ‘community behaviour is less deliberate and involves taking advantage of situational opportunities to express an attitude through action.’ These behaviours include actions such as signing a petition, donating money to an animal welfare organisation, participating in rallies and speaking with acquaintances/friends/family about an issue. With the increasing popularity of social media, community behaviours in opposition to the livestock animal welfare industry may also take the form of posting videos or writing blogs. Coleman and Toukhsati (2006) found the prevalence of community behaviours to be quite high. They surveyed 1061 Australians at supermarkets and by telephone and found that 56% of respondents reported that they had engaged in at least one activity in opposition to livestock farming. The frequency with which community members engaged in online activities in opposition to livestock farming was not however investigated.

These behaviours and the public opinions driving them can have a considerable influence on how governments either react to publicised ‘animal welfare events’ or regulate contentious management practices in industry. This is especially the case when concerns are expressed by non-governmental animal welfare or rights organisations. For example, in 2006, Animals Australia, a federation of animal welfare groups, launched the ‘Save Babe’ campaign to agitate against and raise public awareness about the containment of sows in farrowing crates (Animals Australia, undated). This campaign and the community pressure that followed, was one factor that led to industry changes whereby the revised Australian Code of Practice has included changes to the duration that gestating sows can be housed in stalls.

These public attitudes often target changes in livestock production practices, including the technologies used. For example, The ‘Save Babe’ campaign was all about the use of farrowing crates. Slaughter practices often are the subject of adverse publicity. In a recent survey on feedlotting of sheep, there was substantial opposition to intensification and confinement of sheep in feedlots (Coleman et al. 2015). All of these attitudes are antecedents of community behaviour.

Not only do community concerns and behaviours impact on how governments react to animal welfare events but they also impact more broadly on the livestock industry’s social licence to practice. Animal welfare issues together with issues relating to climate change, water scarcity, and declining biodiversity all threaten farmers’ social licence to farm. Social licence to farm is defined by Martin and Shepheard as, ‘the latitude that society allows to its citizens to exploit resources for their private purposes’ (2011, p. 4). Social licence is granted when industries behave in a manner that is consistent, not just with their legal obligations but also with community expectations (Arnot 2009; Gunningham, Kagan & Thornton 2004; Williams, Gill & Ponsford 2007). Failure to maintain social licence can lead to increased litigation, increased regulations, and increasing consumer demands all of which hamper the success of industries (Arnot 2009). According to Martin and Shepheard (2011), working with the community, understanding their opinions towards important issues like animal welfare and the environment and in a manner indicative of cooperation rather than working against them in a defensive manner, is the most successful means to addressing threats to social licence. In this light, exploring public opinions towards the livestock industry is an important first step to engaging with the community.

The extent to which an organisation or industry is given a social licence to operate largely depends on whether or not the community have trust in the organisation or industry (Arnot 2009). Food scandals (Premanandh 2013), disease outbreaks affecting livestock (Jacob & Hellstrom 2000), genetically modified (GM) foods (Ding, Veeman & Adamowicz 2012) and media coverage of poor animal handling practices (Bettles 2013) erode trust in the livestock industries.

To the knowledge of the authors, little is known about current levels of trust in the Australian livestock industries. It may therefore be instructive to gauge and monitor levels of trust in Australia.

Public opinions change over time. Livestock animal welfare issues thought to be particularly salient at one point in time can be superseded by another animal welfare issue at another point in time. For example, according to a Roy Morgan survey, only 3% of Australians disapproved of mulesing in 2000 (Roy Morgan Research 2000). By 2006 this percentage grew to 39% (Coleman & Toukhsati 2006). Responses by government in the form of changes to regulations, industry responses and media exposure are likely factors underlying these changes in opinion. It is therefore important to not only measure current concerns of the community but to monitor changes in opinion over time. Knowledge of public perceptions towards the livestock industry and livestock animal welfare can be used to inform the industry of possible changes in practice throughout the supply chain and provide a basis for educating the public where this is desirable. This knowledge will also allow industry and government to align their policies with consumer and community perceptions.

In sum, attitudes to animal welfare and livestock practices have the capacity to influence the way in which the community responds to current and new techniques. These responses, in turn, affect the livestock industries directly by precipitating change (eg banning of sow stalls) and indirectly by influencing stakeholders such as retailers, regulators and legislators. This paper reports on the attitudes in the community that are relevant to livestock practices and the ways in which they impact on the livestock industries.

Aims:

1. Determine current attitudes towards livestock animal welfare
2. Explore levels of trust in the livestock industries
3. Determine levels of knowledge of livestock practices in the community
4. Investigate the extent to which demographics, attitudes, trust and knowledge are related to community behaviours
5. Identify opinion leaders and their characteristics in terms of demographics, attitudes, levels of trust and behaviours.

Method

A total of 479 participants (228 males, 251 females) were selected from all states within Australia. Participants ranged in age from 19 to 90 ($M = 48.55$, $SD = 17.35$). In order to obtain a representative sample, 449 were recruited randomly via the telephone by I-View, a market research company in Victoria, Australia. As the younger age groups were under-represented by the telephone survey, an additional 30 interviewees aged between 18 to 34 years were recruited via email sent to registered I-View panel members. All participants were interviewed by telephone.

A questionnaire was developed using an iterative process beginning with a literature review and discussions with key industry, government and research representatives. The questionnaire was divided into five sections: demographics, attitudes to animal welfare, perceived and actual knowledge of various livestock industries and practices, attitudes towards livestock practices and whether or not the respondent had engaged in behaviours to express their dissatisfaction with the Australian livestock industries, the frequency with which they access or distribute livestock animal welfare information and the extent to which they trust various sources of livestock animal welfare information.

Results

The results reported here describe some of the outcomes of this research.

Animal welfare attitudes and trust

Figure 1 shows respondents' perceptions of the standard of animal welfare experienced by different types of farm animals. Welfare ratings were measured on a 5-point scale (-2 = very poor, +2 = very good). As can be seen in Figure 1, laying hens were believed to experience the poorest standard of welfare. On the other hand, dairy cows and sheep produced for wool, were perceived as to experiencing the best standards of welfare.

Attitudes towards livestock animal welfare

The measure of attitudes towards livestock welfare included items such as 'livestock have the same rights as domestic pets' and 'people should do whatever is necessary (legal or illegal) to stop animals being used in livestock production systems' and these were scored on a 5-point scale (1 = strongly disagree, 5 = strongly agree). As can be seen in Figure 2, 60% of respondents scored above the neutral point of 3 on the subscale. This indicates that while more than half of the respondents hold positive attitudes towards livestock animal welfare, there is a substantial minority who do not.

Responses to the single item 'people should do whatever is necessary (legal or illegal) to stop animals being used in livestock production systems' showed that 22% of respondents agreed or strongly agreed.

Beliefs about Australian anima welfare standards

Beliefs about Australian animal welfare standards included such items as 'livestock animal welfare standards in Australian abattoirs are very high' and 'live animal exports should continue'. All items were scored on a 5-point scale (1 = strongly disagree, 5 = strongly agree). High scores on this scale reflected positive beliefs about welfare standards in the Australian livestock industries. As can be seen in Figure 3, people are equally divided in their attitudes towards the Australian livestock industries. Fifty-two percent of respondents held negative attitudes while 48% held positive attitudes.

Trust in the Australian livestock industries

Levels of trust of different people working in the livestock industry are presented in Table 1 (over page). Respondents had the greatest level of trust in farmers to properly care for their animals with 72.1% of respondents reporting high levels of trust in farmers and only 8.4% of respondents reporting low levels of trust in farmers. In contrast, respondents reported the least amount of trust in people responsible for transporting livestock animals by sea. While 36.4% of respondents reported high levels of trust in these people, a further 40.9% reported low levels of trust. Approximately 45% reported high levels of trust in land transporters but just under a quarter of respondents (23.7%) reported low trust. Just under half of all respondents (49.5%) reported high levels of trust in abattoir workers with 23% of respondents reporting low trust in abattoir workers.

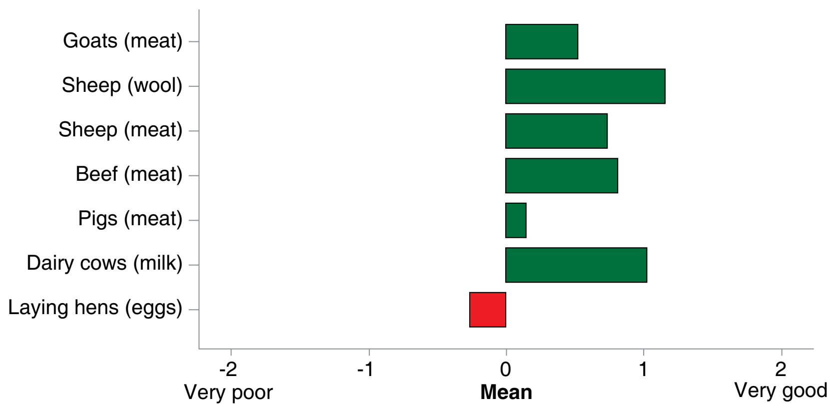

Figure 1: Perceived welfare of livestock.

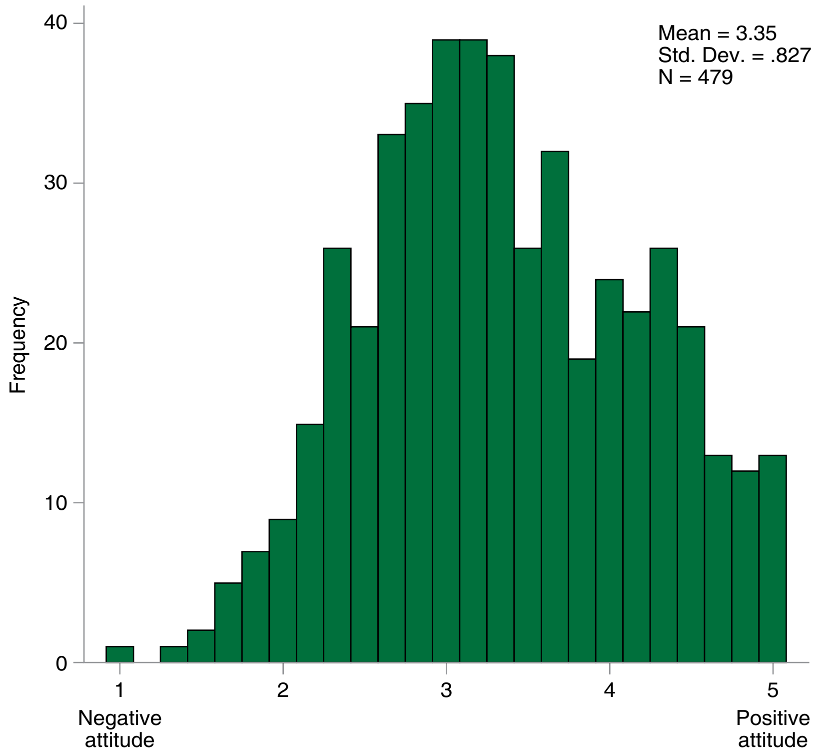

Figure 2: Attitude towards livestock welfare.

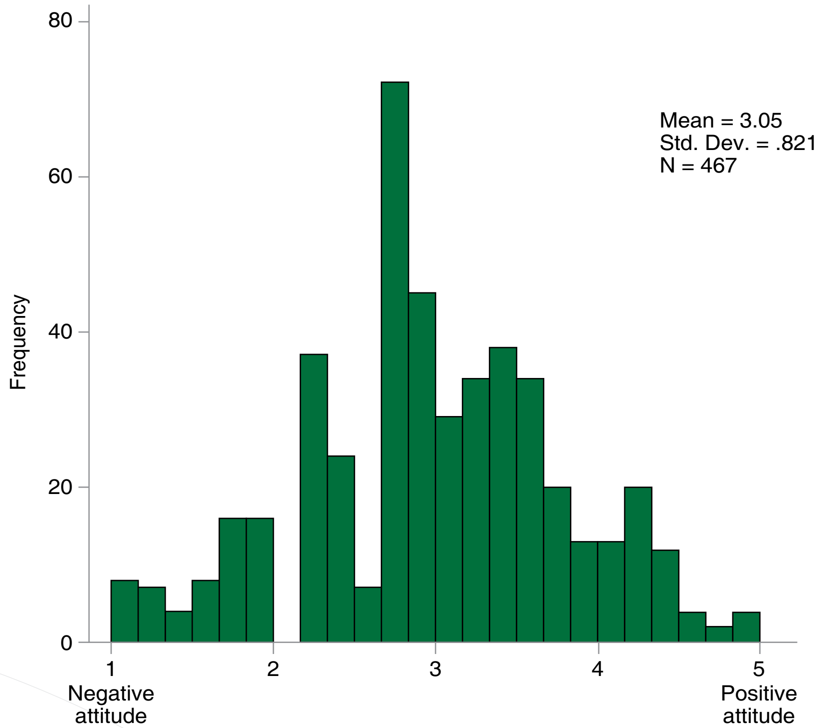

Figure 3: Beliefs about welfare standards in the Australian livestock industries.

Table 1: Distributions of levels of trust (%) in people involved in the Australian livestock industries.

	Low trust				High trust
Farmers	3.8	4.6	19.5	37.4	34.7
Abattoir workers	8.1	14.9	27.6	28.9	20.6
Animal handlers	5.5	8.3	25.1	38.6	22.5
People transporting livestock animals by sea	18.8	22.1	22.7	20.1	16.3
People transporting livestock animals by land	9.3	14.4	30.7	26.6	19.0

Trust in livestock animal welfare information

Distributions of levels of trust across the various sources of information are displayed in Table 2. The most trusted source of livestock welfare information is information gained from reading product labels. The least trusted source of livestock welfare information was information received from social media network sites and related social media (eg Facebook, YouTube, Twitter).

Table 2: Distributions of level of trust in sources of livestock animal welfare information.

	No trust 1	2	3	4	Complete trust 5
Social media	24.3	28.1	33.0	13.0	1.6
Print media	7.8	13.0	50.9	23.9	4.4
Radio	6.2	16.6	48.3	23.4	5.5
Television	7.3	13.8	47.3	25.5	6.1
Animal welfare related websites	14.1	10.5	26.2	29.6	19.5
Friends, relatives or colleagues	4.6	12.4	38.1	32.4	12.4
Product labels	6.6	8.9	34.9	37.4	12.3

Knowledge

Perceived knowledge consisted of five items measured on a 5-point scale (1 = nothing at all, 5 = a lot). High scores on this scale indicate high levels of perceived knowledge with respect to various livestock animal industries. As can be seen in Table 3, on average, perceived knowledge is generally quite low ($M = 2.76$, $SD = 0.92$). In particular, respondents felt that they knew the least about the pork industry with 23.8% of respondents reporting that they know nothing at all about the pork industry. In comparison, respondents felt that they knew the most about the egg industry. For example, only 12.3% of respondents reported that they knew nothing at all about the egg industry. Further to this, 22.3% and 9.4% reported that they knew at least a moderate amount or a lot about the egg industry.

Table 4 contains the questions used to assess *actual* knowledge of livestock practices. Actual knowledge was assessed by asking respondents to correctly identify (from two possible alternatives) 11 livestock procedures. Of all the 11 knowledge questions, most participants (73.5%) answered between six and nine questions correctly.

The most well-known practices were hot iron branding (85.8%), free-range chickens (77.7%), tail docking (77.7%), feedlotting (72.0%) and dehorning (71.0%). The least well-known procedures were those relating to slaughter. These were Halal meat (26.6%), pre-slaughter stunning (51.1%), and Kosher meat (53.0%). Interestingly, mulesing and crutching were answered correctly at levels not much greater than chance (chance = 50%).

Table 3: Distributions of perceived knowledge of livestock industries (n = 479, Cronbach's alpha = 0.86).

	Nothing at all (%)	Very little	A little bit	A moderate amount	A lot (%)
Pork	23.8	35.7	22.5	12.5	5.4
Sheep (meat)	15.4	31.3	30.7	15.7	6.9
Sheep (wool)	14.0	26.7	26.9	24.0	8.4
Beef	11.3	25.1	32.4	22.8	8.6
Egg	12.3	23.8	32.2	22.3	9.4

Although significant, the correlation between perceived knowledge and actual knowledge was quite low ($r = .15$, $p < .01$).

Community behaviours

Table 5 shows that the most common community behaviours that were engaged in by respondents were talking to colleagues, family members or friends (55.3%), donating money to an animal welfare organisation (46.6%), or signing a petition (36.3%).

Table 4: Actual knowledge of livestock practices.

	Percentage correct	Don't know[a] (%)
Halal meat – in Australia, production of Halal approved meat typically involves pre-slaughter stunning	26.7	13.57
Pre-slaughter stunning – renders an animal unconscious immediately prior to stunning	51.1	6.68
Kosher meat – in Australia, Kosher approved meat typically comes from animals that have not undergone any stunning	53.0	17.33
Crutching – shearing of wool around the rear end of the sheep	58.7	6.26
Mulesing – cutting and removal of skin around the rear end of a sheep	61.8	9.18
Clipping teeth – clipping teeth on intensively farmed pigs to prevent injury	67.8	10.44
Dehorning – removal of the horns to prevent injury	71.0	2.71
Feedlotting – fattening animals in a relatively small enclosure	72.0	4.38
Tail docking – removal of a tail	77.7	4.17
Free-range chickens – chickens that have access to an outdoor area as they please	77.7	0.83
Hot iron branding – use of a hot iron to brand livestock for identification purposes	85.8	1.25

Note: [a] Don't know options were classified as incorrect.

Table 5: Types of activities engaged in by respondents in order to express dissatisfaction.

	Frequency	Percentage
Spoken to colleagues, family members, or friends	265	55.3
Donated money to animal welfare organisations[a]	223	46.6
Signed a petition	174	36.3
Shared or liked a page on a networking site (eg Facebook)	123	25.7
Volunteered your services to animal welfare organisations[a]	56	11.7
Written a letter to a politician	45	9.4
Written a letter to a newspaper	19	4.0
Contributed to an online collaborative project (eg Wikipedia)	18	3.8
Posted a video or other media to a content community (eg YouTube)	18	3.8
Called a radio talkback segment	11	7.5
Written a blog (eg Twitter)	7	1.5
Created a group on a networking site (eg Facebook)	6	1.3

Note: [a] Animal welfare/rights groups most commonly noted by respondents discussed in text.

Donating money to animal welfare and animal rights groups

Respondents reporting that they donated to animal welfare or animal rights groups were asked to list up to three groups that they donated to. When asked which groups, 38.84% named more than two groups or organisations. By far the most common group donated to was the RSPCA which was named by 122 respondents. The next most common groups were the Animal Welfare League ($N = 21$), World Wildlife Fund ($N = 18$) and Animals Australia ($N = 10$).

Few respondents have volunteered at an animal welfare or animal rights group or organisation (11.7%). When asked which groups, 38.18% mentioned more than one organisation. Again the most common group or organisation was the RSPCA ($N = 28$).

Only 45 respondents reported that they are currently members of an animal welfare or animal rights group or organisation. Of those respondents that were current members, the most common membership was to the RSPCA with 16 of the 45 respondents claiming membership.

Indicators used for assessment

Opinion leadership consisted of three items adapted from Childers (1986) and assessed the extent to which respondents were used by

Table 6: Comparisons of opinion leaders and non-leaders on demographics, attitudes, knowledge and behaviour.

	t	df	Sig. (2-tailed)	Mean difference
Remoteness	-.15	473.00	.88	-.01
Household weekly income	-1.75	354.00	.08	-.85
Attitudes towards livestock animal welfare	3.75	477.00	.00	.39
Attitude towards eating meat	-3.37	477.00	.00	-.32
Beliefs about welfare standards in the Australian livestock industries	-2.61	477.00	.01	-.27
Trust in the people involved in Australian livestock industries	-1.77	475.00	.08	-.22
Welfare ratings	-3.07	475.00	.00	-.32
Perceived knowledge	6.26	477.00	.00	.70
Knowledge of livestock practices	.37	477.00	.71	.09
Perceived negative impact of the Australian livestock industries on the environment	-.36	477.00	.72	-.21
Approval of livestock practices	-1.49	477.00	.14	-.14
Husbandry attributes	3.10	477.00	.00	.16
Natural living attributes	3.14	477.00	.00	.25
Animal welfare/rights group membership	6.59	477.00	.00	.34
Community behaviour	7.24	477.00	.00	1.72
Donations	3.71	477.00	.00	.39
Count volunteer	6.29	477.00	.00	.40
Accessing information	10.34	477.00	.00	.95
Trust in information	3.67	477.00	.00	.30
Age	-2.11	477.00	.04	-4.62

friends and family as sources of animal welfare information. Few respondents (15.4%) were identified as opinion leaders in the area of livestock welfare. A two-step cluster analysis was used to identify those respondents who could be classified as opinion leaders.

A comparison between opinion leaders and non-leaders showed that leaders generally expressed more concern about and more positive attitudes towards animal welfare (Table 6). Opinion leaders also reported higher perceived knowledge, but not actual knowledge. They also reported engaging in more community behaviours and in accessing more information about animal welfare.

Variables that correlate with community and consumer behaviours

Correlational analyses were undertaken to determine those variables that best correlate with community and consumption behaviours. A number of demographic variables correlated with community behaviours but these correlations were only weak to moderate in strength. Females were more likely to engage in a higher number of community behaviours to display dissatisfaction with the way livestock animals are treated than males ($r_{pb} = .24$, $p < .01$). Younger respondents ($r = -.10$, $p < .05$), respondents with higher levels of education ($r = .16$, $p < .01$), and respondents living in more highly accessible areas like major cities ($r = .12$, $p < .01$) engaged in a higher number of community behaviours than older respondents, respondents with lower levels of education and respondents living in more remote areas.

Attitude and trust variables were more strongly correlated with community behaviours than demographics. Among these, attitudes towards livestock welfare ($r = .40$, $p < .01$), trust in sources of animal welfare information ($r = .32$, $p < .01$), perceived importance of husbandry ($r = .10$, $p < .05$), and natural living attributes ($r = .28$, $p < .05$) positively correlated with community behaviours. Attitudes towards eating meat ($r = -.36$, $p < .01$), beliefs about welfare standards in the Australian livestock industries

($r = -.43$, $p < .01$), trust in the people involved in Australian livestock industries ($r = -.37$, $p < .01$), perceived welfare ($r = -.36$, $p < .01$), perceived negative impact of the Australian livestock industries on the environment ($r = -.36$, $p < .01$), and approval of livestock practices ($r = -.38$, $p < .01$) were negatively correlated with community behaviours.

Perceived knowledge but not knowledge of livestock practices was found to be positively correlated with community behaviours ($r = .12$, $p < .01$).

Discussion

Attitudes towards livestock welfare

Most people expressed positive attitudes about livestock welfare with 60% scoring above the neutral point of 3 on the subscale. This finding is in line with previous studies which suggest Australians rate animal welfare as an important issue. A report conducted by Roy Morgan (2000) for example, found that 54% of Australians consider animal welfare and animal cruelty to be an important issue. Although Australians believe animal welfare to be an important concern, the majority of respondents hold positive attitudes towards eating meat believing that meat, for example, is part of a balanced diet. These attitudes are reflected in the high meat consumption of this sample. Over 90% of the respondents eat a diet of meat and vegetables with most respondents eating meat and other animal products at least once a week.

Respondent were equally divided on their beliefs about the current state of Australian livestock welfare standards. It may be useful to explore the reasons for this. If half the population have some concerns about current standards, it may help in forming policy to determine the specific nature of these concerns. They may relate to a specific industry or practice or simply may be a general impression that is not based on any detailed knowledge or experience.

Attitudes towards eating meat consistently positively correlated with reported frequency of eating meat. While this is not too surprising, the results in this survey showed much higher correlations between attitudes to animal welfare and consumption than had been previously reported by Coleman and Toukhsati (2006). In this survey, significant negative correlations were found between 'attitudes towards livestock animal welfare' and frequency of eating lamb, pork and beef. In comparison, 'humane treatment of animals' showed low correlations with beef and lamb consumption in the survey conducted by Coleman and Toukhsati (2006). It may be that community attitudes are beginning to become more salient to meat consumption or it may be that differences in the specific attitudes measured in the current survey compared to the Coleman and Toukhsati's survey may account for these differences. Only by tracking public attitudes over time using the same attitude measures will it be possible to determine this.

Trust in the people involved in the livestock industries consistently correlated with all forms of meat consumption except for seafood, as did beliefs about welfare standards in the Australian livestock industries and approval of livestock practices. It may be useful to follow up these results with some point-of-sale research or the use of food diary research to determine whether these self-reported consumption patterns are reflected in actual consumption behaviour.

Interestingly, on almost all measures there was little concern about the seafood industry.

Knowledge of livestock practices in the community

The degree of knowledge of livestock practices varied depending on the procedure. Livestock procedures such as hot iron branding, free-range chickens, tail docking, feedlotting and dehorning were correctly identified by most respondents. Procedures relating to slaughter including Halal meat, pre-slaughter stunning and Kosher were commonly mis-identified. This lack of knowledge about slaughter practices may be indicative of a lack of information available on the procedures or, because in the case of Halal slaughter the percentage correct was only 26.7%, some kind of misinformation in the community. It may also be indicative of respondents' desire to be deliberately ignorant of this aspect of the livestock industry (IGD 2007). Of interest, crutching and mulesing were also commonly confused. When asked what crutching was, approximately 41% respondents thought that crutching was cutting and removal of skin around the rear end of a sheep. The results in this survey are generally similar to those found by Coleman and Toukhsati (2006) survey.

Generally speaking, a substantial proportion of respondents felt that they knew little about the livestock industries. For the sheep (wool), beef and egg industries, about 32% felt that they knew a moderate amount or a lot, while for pork and sheep (meat) this figure was much lower at 22.6% and 17.9% respectively. The correlation between perceived and actual knowledge was significant but numerically low ($r = .15$). Together these results do suggest that the community is not well informed about livestock farming. It would be useful to undertake a public education program in a specific community (for example a country town) to determine the effects on community attitudes and behaviour. If effective, such a program could be used in the wider community.

Trust in the livestock industries

Two aspects of trust were investigated in this survey; first trust in the available information and second, trust in the people working with livestock.

The greatest trust in information sources was in product labels and in friends and relatives, presumably because labels are regulated sources of information and friends are well-known and have a history of trust. Animal welfare websites were also well trusted. However, this is difficult to interpret because of the huge diversity of sites nominated. Respondents were given the option of nominating up to three sites. The most common site nominated first was the RSPCA at 22.5% with no other site being endorsed by more than 10% of respondents. There was a large miscellaneous other group of sites that were cited first but no individual site being nominated with a high frequency. Animal rights groups including PETA, Voiceless, Animal Liberation Front, Animal Welfare League and WSPA combined were nominated first by 3.8% of respondents. Government and industry sites were nominated first by 12.1%. Social media and the mass media received lower trust ratings with social media clearly the least trusted. These results suggest that there is an important role for the RSPCA to disseminate accurate information and there is an implication that government and industry sites may have some penetration into the community.

In general, the majority of respondents (about 60%) indicated some level of trust that livestock workers properly care for their animals. However, while only 8.4% indicated a low level of trust in farmers properly caring for their animals, 41% expressed low trust in sea transport workers, 24% indicated low trust in land transport workers, and 23% indicated low trust in abattoir workers. These results probably indicate that the adverse publicity that sea transport has received has led to a popular view that sea transport workers are responsible for the welfare issues that have been reported. This is an empirical question and little research of the kind that Hemsworth and Coleman (2011) have done on-farm has been done on stockperson attitudes and behaviour in land or sea transport. This needs to be done and appropriate interventions and monitoring processes developed.

Community behaviours

Despite high levels of meat consumption, three-quarters of the sample engaged in at least one of the 13 community behaviours to express their dissatisfaction with the way livestock animals are treated. Speaking to colleagues, family members, or friends and donating money to an animal welfare or animal rights group were the most frequent behaviours. The prevalence of speaking to friends and colleagues (55.3%) is higher than that found by Coleman and Toukhsati (2006) survey (44.6%), petition signing was also higher (36.3%) compared to 23.1% in the survey conducted by Coleman and Toukhsati. The proportion of respondents donating money was similar in both surveys. Volunteering services to a welfare organisation was higher in this survey (11.7%) compared to the Coleman and Toukhsati survey (6.0%), liking a page on a networking site such as Facebook was a common behaviour found in this survey (25.7%) and this has not been assessed before. These data indicate that community behaviour patterns are changing, in part due the social networking, but also due to increases in proactive behaviours such as volunteering and petition signing. These may reflect an escalation in community activities that may impact on the livestock industries.

When asked which organisation people engaged with, the RSPCA was the most common response. This may reflect an awareness of the role that the RSPCA has in monitoring animal welfare. It also indicates that people are more engaged with an animal welfare organisation rather than the organisations that focus on animal rights.

The demographic variables that correlate with community activity were gender with females engaging in these behaviours more than males; education, with the better educated engaging in more behaviours; and animal welfare group membership with members engaging in more behaviours. However, most attitude variables also correlated with community behaviour. Altogether, 46% of the variation in community behaviour could be accounted for by a combination of demographics, attitude and trust variables. Actual knowledge was not correlated at all with community behaviours.

These results give a clear indication that community attitudes are associated with a range of activities that have the potential to impact on both livestock practices as well as social licence. The fact that trust in livestock workers and approval of practices had amongst the highest correlations with behaviour provides some evidence for this. This suggests that not only should attempts be made to address the negative attitudes that exist in the community, but also that trust and acceptability of practices need to be addressed.

Opinion leaders

While it was possible to identify a group of people who reported being used as a source of animal welfare information by those around them, there was little demographic information that could be used to identify them. Age was the one demographic variable with younger people more likely to be opinion leaders. Animal welfare group membership was also an identifying characteristic. The remaining variables that discriminated opinion leaders from non-leaders were attitudes and perceived knowledge.

Interestingly, opinion leaders, similar to the full sample, nominated the RSPCA first as a trusted source of information (25.7%), and nominated government and industry sources 12.2% of the time. Animal rights groups received no first nominations by opinion leaders.

Given that attitudes have been shown in this survey to be correlated with meat consumption and community behaviours, opinion leader attitudes clearly are important. However, opinion leader attitudes reflected a less positive view of the livestock industries and lower trust. Interestingly, although actual knowledge of livestock practices did not differ between opinion leaders and non-leaders, nor did their experience in living on farms, opinion leaders perceived their knowledge to be greater than non-leaders.

It seems likely, therefore, that opinion leaders may be motivated by an ideological perspective that is not necessarily informed by knowledge or experience. This is reflected in the fact that opinion leaders tended to attribute the same rights to livestock as to humans to a greater extent than non-leaders.

Given the fact that welfare organisation membership was an identifying characteristic of opinion leaders and given the observed differences in attitude and perceived knowledge between leaders and non-leaders, engaging animal welfare organisations in processes that facilitate good communication amongst stakeholders is a good approach to educate all stakeholders. The Australian Animal Welfare Strategy (AAWS) is an example of this that is no longer available, so alternative approaches need to be found.

Implications

This survey has provided some important data on community attitudes and knowledge as well as the relationships between these variables and consumption and community behaviours. In some cases there needs to be more research to clarify the reasons for some of the findings, in other cases appropriate responses to deal with the issues need to be developed and implemented. Some of the key possible actions are:

- There is a distrust about how well some off-farm animal workers care for their animals. There may be a need for training programs of the kind that Hemsworth and Coleman (2011) have conducted on-farm, but focusing on stockpeople working in land or sea transport. Appropriate interventions and monitoring processes need to be developed.

- Given the important role that the RSPCA appears to have as a source of information, a means of engaging the organisation as well as other animal welfare organisations in ongoing discussions of welfare issues needs to be established, particularly given the demise of the AAWS.

- The characteristics and role of opinion leaders need to be investigated further. If forums such as AAWS are not available to communicate directly with at least some opinion leaders, an alternative strategy needs to be developed.

- To address public concerns about the livestock industries and their actions that may impair farmers' social licence to practice, there needs to be accurate and reciprocal communication between the livestock industries and the community. This is essential if the community is to be well-informed and able to make rational choices and if the industry is to respond appropriately to community expectations.

- There is a mismatch between the community's perceived and actual knowledge of livestock practices and this needs to be improved. A public education program in a specific community (for example a country town) could be developed to determine the effects on community attitudes and behaviour. If effective, such a program could be used in the wider community.

- This survey can be used as an ongoing monitoring tool and should be repeated at regular intervals to identify trends in public attitudes and behaviour. Further, the database is extensive and can be used to answer a wide range of industry specific and general questions.

These actions have the potential to facilitate changes in practices and technology in the livestock industries and to ensure that the case for change has been effectively communicated to the community and that the livestock industries are well informed about the acceptability of change to the community.

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