Emerging technologies in agriculture:

Consumer perceptions around emerging Agtech

by GHD and AgThentic

August 2018

AgriFutures™
National Rural Issues

Emerging agricultural technologies:

Consumer perceptions around emerging Agtech

Agtech

ISBN 978-1-76053-013-6
ISSN 11440-6845

Emerging agricultural technologies:
Consumer perceptions around emerging agtech

Publication No. 18/048
Project No. PRJ-011141

Researcher Contact Details
Michael White
GHD Level 15,
133 Castlereagh St
Sydney NSW 2000:

+61 2 9239 7184
michael.white@ghd.com

In submitting this report, the researcher has agreed to AgriFutures Australia publishing this material in its edited form.

AgriFutures Australia Contact Details
Building 007, Tooma Way
Charles Sturt University
Locked Bag 588
Wagga Wagga NSW 2650

02 6923 6900
info@agrifutures.com.au
www.agrifutures.com.au

Electronically published by AgriFutures Australia
AT www.agrifutures.com.au in January 2019

AgriFutures Australia is the trading name for Rural Industries Research & Development Corporation (RIRDC), a statutory authority of the Federal Government established by the Primary Industries Research and Development Act 1989.

Foreword

The adoption of emerging technologies in Australian agriculture is expanding at a rate greater than the consumer's capacity to understand the opportunities.

Emerging technologies have already proven be a key driver in the future sustainability and profitability of Australian agriculture. With the sector likely to continue to increase its reliance on new technologies over the short to medium term, it is important to understand what the likely implications from consumers will be, and whether there is a role for industry and others to proactively engage with consumers in this space.

Specifically, the report contributes to better understanding the substantial impact that consumer perceptions can have on the adoption of agricultural technology throughout the value and supply chain, especially as it relates to the top ten transformative technologies in agriculture. Driving this information need is recognition that:

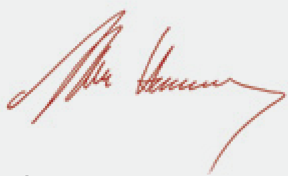
1. Public perception of technological innovations in agriculture is increasingly having an impact on adoption; and
2. Agricultural producers who adopt highly innovative technologies will be required to maintain a 'social license' from consumers to remain competitive in the global marketplace.

This project provides an updated and expanded assessment of the top ten emerging technologies across the agricultural sector to examine the real and perceived barriers to technology adoption, and to ensure the agriculture industry is well-equipped to maintain social licence.

Analysis was completed on different transformative technologies to identify any existing knowledge gaps, and develop strategies to discuss and address these issues. The extent to which Australia's profitability and production efficiency can improve in the next decade depends largely on the success of national efforts to reduce the ambiguity surrounding emerging agricultural technologies, and to constructively engage with consumers to identify possible concerns and overcome bottlenecks to adoption.

This report has been produced under AgriFutures Australia's National Rural Issues Program. It is an addition to AgriFutures' diverse range of over 2000 research publications and it forms part of our National Challenges and Opportunities arena, which aims to identify and nurture research and innovation opportunities that are synergistic across rural sectors.

Most of AgriFutures Australia's publications are available for viewing, free downloading or purchasing online at: www.agrifutures.com.au.



John Harvey
Managing Director
AgriFutures Australia

About the Authors

GHD is one of the world's leading professional services companies operating in the global markets of water, energy and resources, environment, property and buildings, and transportation across 75 service lines.

In agricultural and farming systems, GHD offers a unique blend of knowledge and practical experience across commodities and markets, natural resource management, economics and policy, water and biodiversity with our integrated approach to agribusiness solutions encompassing the entire supply chain. Privately owned by our people, we deliver engineering, architecture, environmental, advisory, digital and construction services to public and private sector clients across five continents and the Pacific region. Committed to creating lasting community benefit, we connect the knowledge, skill and experience of our 10,000 diverse people with innovative practices, technical capabilities and robust systems.

www.ghd.com

AgThentic is a strategy consultancy with expertise in food systems, agriculture, venture capital, technology and entrepreneurship. AgThentic has been instrumental in building the early stage agtech ecosystem in Australia, supporting industry, universities and government to develop and implement forward-looking initiatives in food system innovation. We have designed and delivered national producer-led accelerator programs, advised dozens of startups on fundraising, product and go-to-market strategy, and are driven by a belief that companies innovating must meaningfully connect with the existing agriculture industry. We work with entrepreneurs, farmers, established agribusinesses, government, and service providers across the industry, both in Australia and the US.

www.agthentic.com

Contents

Section

7

Introduction

Section 1

Introduction

Technology has transformed many of the industries around us, and agriculture, as the least digitised globally, has seen momentum for the development and commercialisation of agricultural technologies ("AgTech") growing. The sector is attracting new perspectives and capital, as well as emerging technologies. Though not the only innovators, start-up companies, often backed by venture capital investors, are leading the charge and attracting the attention of the agriculture industry, consumers, and investors. According to AgFunder, USD $10.1B was invested into agrifood tech globally in 2017[2].

In Australia specifically, support for digital technologies in agriculture is growing, with support from both private and public sector stakeholders increasing. There are currently eleven accelerators, pre-accelerators and incubators supporting agrifood tech start-ups in Australia, as well as a growing number of conferences featuring AgTech content and even startup pitch competitions. Combined, these programs and events are growing awareness for the industry and it's potential. Simultaneously, Rural Research and Development Corporations (RDCs) and government are contributing, for example by providing funding and programs that support innovation.

Public and private sector support for agrifood tech innovation in Australia is being driven, at least in part, because of recent research into the significant potential benefits that technology can unlock for the sector. According to the report 'Accelerating Precision Agriculture to Decision Agriculture', the implementation of digital agriculture alone could lift the gross value of the Australian agricultural industry by $20.3 billion, a 25% increase on 2014/15 levels[3].

The 2016 Report "Powering Growth: Realising the Potential of AgTech for Australia" outlined the role that AgTech can play in the vision to turn Australian Agriculture into a $100 billion industry[4], with specific reference to:

- attracting investment into technological innovation
- cementing Australian AgTech within the context of Global Market Opportunities
- creating an attractive environment for Agriculture as an opportunity for Startups
- supporting Australian Agricultural ambition to boost productivity and yield noting the critical role that AgTech plays to achieve this
- ability to export Australian AgTech to global agricultural markets
- elimination of waste both in terms of on farm production (e.g. weed control) and post farm gate.

In addition to these commercial opportunities, there are several macro factors behind the growing momentum for agrifood tech innovation. At the highest level, there is a need to ensure a sufficient and secure food supply for the growing global population. According to the Food and Agriculture Organization of the UN, global crop production will need to double to feed an expected population of 9.8 billion in 2050[5]. The agriculture industry must meet this growing food demand while overcoming risks posed by other megatrends, such as globalisation, climate change, and natural resource availability[6].

Simultaneously, today's consumers are placing increasing demands on the global food and fibre system. Consumers want to know where and how their food is grown, processed, packaged, and transported. There is unprecedented concern for animal welfare, stewardship of natural resources, and working conditions for labourers along the supply chain. This is evidenced by, for example, the growth of the global organic industry[7], as consumers often trust the organic certification as a proxy for the characteristics described above[8]. In today's social media-fuelled world, consumer preferences have an even greater impact on food and fibre supply chains: as the saying goes, the consumer is king.

Though not the only solution, emerging technologies hold promise to help the food and fibre industries adapt to, engage with, and even thrive despite these challenging macro trends. For example, technologies hold potential to unlock productivity improvements, improve animal welfare, unlock new value chains, create new communications pathways between farmers and consumers, and, ultimately, have a positive impact on the lives and businesses participating along the supply chain.

As emerging technologies are brought to market, understanding the impacts of consumer perceptions on emerging technologies in agriculture will be critical for two reasons:

- to both align with consumer demands, as well as mitigate against negative public perceptions of technology innovation in agriculture, especially those that may prevent otherwise beneficial adoption by primary producers; and
- to ensure primary producers have access to technologies that will help them maintain their "social licence" to farm, remain competitive in the global marketplace, and thrive in a world of rapidly changing consumer preferences.

As an example, the agriculture industry has already seen the impact of negative consumer perceptions in the case of Genetic Modification (i.e., GMOs), where global adoption of the technology has been stymied by activist campaigns[9]. Understanding and, where possible, proactively identifying and mitigating perception issues is critical in ensuring farmers have access to beneficial technologies, as well as in maintaining the 'social license to farm'.

While the expanding impact of consumer perceptions can be seen as a negative influence on agricultural production systems, it equally holds potential to create opportunities for the Australian agriculture industry. Emerging technologies can help primary producers to meet, or even benefit from, the rapidly changing desires and needs of our growing population, as well as cope with the macro trends impacting natural resources and supply chains.

With increasing consumer attention on agrifood and fibre supply chains, the exponential rate of technology development, and increasing investment into, and focus on, emerging agricultural technologies, it has never been more critical to understand the impact of consumer preferences on barriers to, and opportunities for, technology adoption in agriculture.

In this report, we examine ten technologies, as shown below, that hold potential for benefits in agriculture within Australia. First, the report examines consumer perceptions: which product attributes are appealing to today's consumers, and which will cause concern or even rejection. We then present insights, derived from consultations with industry experts and developers of emerging technologies, about the impact of consumer perceptions on adoption of emerging technologies. Finally, for each technology, we present a case study in Section 8, Case Studies, summarising potential issues and opportunities in relation to consumer perceptions. The ten technologies examined were:

Blockchain

Internet of Things (IoT) / Sensors

Big Data / Artificial Intelligence (AI)

Gene Editing

Nanomaterials

Automation / Robotics

Synthetic Biology

3D Printing

Satellites

Drones

---

[1] McKinsey Global Institute, 2015. Digital America: A tale of the haves and the have-mores. [2] AgFunder 2017 Annual Report, available at www.agfunder.com [3] Cotton Research and Development Corporation, 2017, Accelerating precision agriculture to decision agriculture: Enabling digital agriculture in Australia. [4] Startup AUS and KPMG, 7 September 2016), p. 10. https://home.kpmg. com/content/dam/kpmg/au/pdf/2016/powering- growthealising-potential-agtech-australia.pdf [5] http://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf [6] Hajkowicz, S. & Eady, S, 2015. Rural Industry Futures: Megatrends impacting Australian agriculture over the coming twenty years. [7] Aginnovators http://www.aginnovators.org.au/news/global-organic-food-sector-now-worth-100-billion-following-double-digit-growthcheck [8] Gemma C. Harper, Aikaterini Makatouni, 2002. "Consumer perception of organic food production and farm animal welfare", British Food Journal [9] For example, see: M Lynas. Seeds of Science: Why We Got It So Wrong On GMOs. Bloomsbury Publishing. 2018

Methodology

Section 2

Methodology

Introduction

In this section we outline the methodology used for this project.

2.1 Overview

The methodology for this report comprised two phases:

1. Review of existing literature via traditional top-down market research; and
2. Consultations with industry experts and emerging technology developers.

The purpose of the first phase was to develop a baseline understanding of both consumer perceptions, as well as emerging technologies. Focus was placed on industry trends, historical perception issues, and understanding the current state of research, development, commercialisation, and adoption of the ten emerging technologies.

The purpose of the second phase was to understand the current state of technological maturity, understand barriers to adoption, and identify relevant- or potential- positive and negative consumer perception attributes. For each technology, a minimum of three consultations was conducted, the only exception was Nanomaterials, where two consultations occurred. Interviewees included a mix of Australian and International contacts, from both large and small (i.e. startup) companies. As agreed with AgriFutures and our contacts, all consultations were undertaken on the basis of anonymity in this final report.

Following the data collection phase, case studies were developed for each of the ten technologies (see section 8 Case Studies). Each case study includes the following themes:

- Summary of the technology
- Acceptance by consumers
- Acceptance by farmers
- Applications and benefits to agriculture
- Key facts
- Selected quotes from the consultation phase
- Related technologies
- Key perceptions and impacts
- Key insights

2.2 Limitations

Three key limitations apply to the data and insights summarised in this report:

First, it is important to note that a sample size of three consultations per technology, while appropriate to gain insights and an understanding of the current state, is still relatively small and not statistically significant.

Second, the pace of change for both technology development and consumer preferences is rapid, and insights gained from this report may evolve as the AgTech sector matures and emerging technologies are brought to market.

Finally, though the current project has examined each technology somewhat in isolation, they will not be developed independently. There are huge benefits to unlock, as well as consumer perception issues to identify and understand, from the combination of technologies. For example, there is potential to 'build' a biosensor into a plant that a multi-spectral or hyper-spectral camera on a drone would be able to detect and 'read'. This drone could be made into a robot, such that it could then take action in the paddock (e.g., shot of fertiliser, antifungal treatment, etc.). In this use case, we've moved beyond precision agriculture to something more like preventive medicine for plants. Many other examples exist. Further analysis of the interdependencies between emerging technologies was out of scope for this project.

Understanding Consumer Perceptions

Section 3

Understanding Consumer Perceptions

The increased consumer awareness of our global food system can have both positive and negative impacts. Aligning with consumer demands creates opportunities, as evidenced by the growing market for products that offer consumers environmental and ethical benefits. However, negative consumer perceptions can also prevent adoption of technologies that hold benefits for participants along the supply chain. It is therefore important to understand the drivers and dynamics of consumer perceptions.

In this section, we summarise key themes in regards to consumer perceptions of the agrifood and fibre supply chain, and the impacts on purchasing behaviour. Ultimately, we provide an overview of the attributes, both positive and negative, impacting purchasing decisions and perceptions.

Consumers don't always do what they say they will do

A recent report by the Food Marketing Institute indicates there is a growing desire from consumers for transparency around issues such as food safety, health and wellness, and product discovery[10], both in terms of quality and ingredients. But, largely, purchasing behaviour indicates that consumers are primarily concerned with the cost, safety, and quality of products. This may change in the future as millennials and gen Z gain purchasing power and "can put their money where their mouths are."

Despite good intentions, consumers don't always know what they are buying

Food labelling may not provide the benefits that consumers think it does when they buy it. For example there is a common perception that organic foods are better than non-organic ones, when studies show there is little significant difference in the health benefits[11].

Consumers also often do not understand the costs and implications for the upstream supply chain of producing products that align with characteristics they are seeking, especially given the complexities of modern agriculture. For example, though consumer demand for cage-free eggs is skyrocketing and companies are responding to meet this demand, the implications in terms of cost, animal welfare, and other issues of relevance to consumers are still unclear[12].

Activists are increasingly active and influential

Activists, through both physical and digital channels, are continually influencing consumer perceptions and purchasing decisions. In some cases, the influence has extended to the regulatory sphere. Social media is now more than ever being utilised by activists to capture the public's attention, often to spread their own interpretations about food system conditions (e.g., ingredients, working conditions, animal welfare). Their influence can be significant. For example, Patagonia has reconfigured supply chains on multiple occasions as a result of activist group PETA posting videos of wool production conditions[13].

The increased accessibility of information means trends can manifest faster

The ubiquity of social media is influencing consumers more than ever. Food trends such as flexitarians, 'meatless Mondays' and 'clean eating' are able to gain traction quickly, and drive behaviour changes in ways unprecedented before the internet. Underpinning many of these movements is continued demand for more environmentally and socially responsible practices and products.

Food producers, companies, and brands are also increasingly accepting social media influencers as a method of conveying information to consumers, and are looking to develop long-term relationships to tell stories and share values. The increasing power of social media cannot be underestimated in relation to consumer perceptions, both positive and negative.

Developing and developed world issues are very different

Though developing and developed world issues vary, both have implications for Australia given domestic and export markets, and globalisation generally. Due to Australia's global reputation as a supplier of high quality and safe food and wine in the international marketplace, the counterfeiting of Australian products in key export markets is potentially costing the industry nearly $2 billion each year in lost profits[14]. Consumers are increasingly wanting proof that what they are buying is the genuine good, and Australian brands need protection should a food safety incident occur.

Summary: positive and negative consumer perception attributes

Understanding the subtleties and complexities of purchasing decisions, especially regarding highly emotive issues like food, is a challenge. Further, given the rate at which consumers change their minds, staying up to date on consumer demands is a constant challenge for food producers and companies alike. However, given the potential impacts- both positive and negative- of consumer perceptions on adoption of emerging technologies by primary producers, even a high-level understanding of perception drivers can help participants along the supply chain to stay ahead of the risk curve. In particular, it is useful to identify the key purchasing drivers and areas of concern; in other words, what consumers perceive to be positive and negative attributes related to food and fibre. The table below summarizes these attributes.

It is worth noting that while we have classified these attributes as either positive or negative, many can be both positive and negative. For example, there is evidence that consumers will make purchasing decisions based on both good and bad indications of Corporate Social Responsibility performance.[15] The same applies to attributes such as social and environmental sustainability: consumers are increasingly supporting products and brands that express such attributes, and rejecting or pushing back against those that do not.

Table 1 Consumer Perception Attributes

Consumer purchasing drivers (positive attributes)	**Areas of increasing consumer concern** (negative attributes)
• Product quality (e.g., taste) • Health benefits • Convenience (e.g., packaging, value add processing) • Price • Transparency/ provenance • Authenticity of marketing, especially storytelling • Local, including specific origins (e.g., "Aussie made") • Corporate Social Responsibility of the brand	• Production externalities and "sustainability" - Environmental impacts, especially with respect to climate change - Social impacts • Animal welfare • Corporate Social Responsibility (CSR) performance of the brand • Consolidation of corporate power • "Industrial" agriculture or "factory" farming (vs. smaller scale farming that is perceived to be more "natural")

[10] FMI, 2017 [11] Stanford Medicine, 2012 [12] Wired, 2016 available at https://www.wired.com/2016/01/the-insanely-complicated-logistics-of-cage-free-eggs-for-all/ [13] Reuters, 2015 [14] Food Innovation Australia, 2017 [15] http://www.nielsen.com/ie/en/press-room/2014/global-consumers-are-willing-to-put-their-money-where-their-heart-is1.html

Insights and Implications

Section 4

Insights and Implications

In this section, we present a summary of consumer perceptions issues in regards to the development and commercialisation of emerging technologies along agrifood and fibre supply chains. We then outline insights on both consumer and farmer perceptions, as well as identify associated implications for industry stakeholders, including RDCs, researchers and technology developers, producers, and policymakers.

4.1 Summary of Consumer Perceptions Issues for Emerging Technologies

The ten technologies explored in this report hold potential to help farmers both improve their bottom line, as well as more rapidly, simply, and profitably meet the needs of today's (and tomorrow's) consumers. However, the technologies vary in terms of how they relate, both positively and negatively, to consumer perceptions.

Table 2 summarises the potential risk, related positive and negative consumer perception attributes, and the commercialisation timeframes of the ten technologies, as synthesized from the desktop research and consultations for this project.

All of the technologies explored in this report hold potential benefits to consumers and align with positive consumer perception attributes, with the exception of 3D printing which, though it has potential benefits for producers, does not yet have strong, direct alignment with positive consumer perception attributes. Some technologies pose a medium or even potentially high risk of aligning with negative consumer perception attributes, though it is important to note that the research for this project did not uncover any current instances of consumer perceptions having a negative impact on technology adoption in agriculture (see below for more on the high risk technologies).

Overall, our findings are consistent with overseas treatments of these emerging technologies, though it is important to note that efforts to mitigate negative consumer perceptions risks and explore necessary government control measures seem to be more advanced in countries where technology development is more well-funded and therefore prominent (e.g., USA), or where regulation has already been put in place (e.g., Europe[17]).

It is also important to note that the pace of development and commercialisation of these technologies is incredibly rapid, and often underestimated. Consumer perceptions may- and likely will- change rapidly as commercial applications are brought to market.

Table 2: Summary of Potential Impact of 10 Emerging Technologies

Threat level: Low Risk · Medium Risk · Potentially High Risk

Timeline: N Near (0-3 years) · M Medium (3-7 years) · F Medium (7+ years)

Technology	Threat level with respect to the impact of negative consumer perceptions	What is the likely timeline for commercialisation in Australian agriculture?	Most relevant consumer perception attributes (positive and negative)
Blockchain	Low Risk	N	Transparency/provenance; food fraud/safety; Environmental impacts/climate change; local/specific origins
IoT	Low Risk	N	Transparency/provenance; food fraud/safety, environmental impacts and animal welfare
AI / Big Data	Medium Risk	N	Industrialisation of agriculture, data security, potential price benefits
Genetic Editing	Potentially High Risk	M	Environmental impacts/climate change; animal welfare; product quality; health benefits
Nanomaterials	Potentially High Risk	F	Environmental impacts; health impacts
Robotics	Medium Risk	M	Price impacts, quality of production, industrialisation and corporate consolidation
Synthetic Biology	Potentially High Risk	M/F	Environmental impacts/climate change; product quality; health benefits
3D Printing	Low Risk	F	Too early to predict but possible concern around regional job security
Satellites	Low Risk	N	Privacy concerns; environmental benefits
Drones	Low Risk	N	Privacy concerns; environmental benefits

4.2 Consumer Perceptions Insights and Implications

High Risk Emerging Technologies

- Three of the technologies explored in this project- synthetic biology, gene editing and nanomaterials- are noted as "potentially high risk" (see Table 2) in terms of negative consumer perceptions. This classification can largely be attributed to two factors. First, these technologies still require further research, development, and regulation before commercialisation and adoption in agriculture will be possible. They are therefore characterised by significant uncertainty, and have not yet had a chance to demonstrate benefits that align with consumer desires. Second, consumers may be likely to associate these technologies with GMOs, and therefore develop a negative perception. Overall, given the state and complexity of development, consumer perception issues are less certain for these technologies at this time.

Implication: consumer perceptions of these higher risk technologies should be carefully monitored as research and development progress. Specifically, Government control measures may be appropriate, given the unique social and ethical issues related to their development and commercialisation.

Implication: the relative immaturity of these specific emerging technologies for agricultural uses creates an opportunity for multi-stakeholder dialogue where the agriculture community, consumers, and activist groups can discuss the potential commercialisation of these technologies. In such forums, it may be possible to proactively identify and even overcome potential issues related to consumer perceptions (see Section 6, Considerations, for more on this).

Transparency and Effective Marketing

- In the cases where emerging technologies hold potential to help farmers make accurate claims that align with the 'positive attributes' that consumers want to see (see table 2?, above), consumers are especially likely to be in favour of adoption by primary producers, and may even be more likely to purchase the resulting end products, perhaps for a premium price. In particular, emphasising the environmental benefits, often referred to as 'sustainable' characteristics, may help to win consumers over.
- Shifting consumer demands have put pressure on supply chains, especially brands and retailers who are increasingly looking to their marketing teams to communicate benefits to consumers. However, consumers are increasingly sensitive to inauthentic marketing. Instead, they are seeking transparency and effective and emotive storytelling. They want to understand what happens within farming systems, and get to know the people who are producing their food.
- Rigorous and unbiased scientific research, especially regarding evidence of safety in food products, is important to consumers. However, purchasing decisions, especially in relation to food, are often emotional, snap decisions that are not based on logic. Too much talk of technology, therefore, may be negative for some consumers, especially as there is growing momentum for a return to what consumers perceive as more "natural" production systems (e.g., smaller scale, without use of large equipment or synthetic inputs).

Implication: additional capabilities may need to be developed in the area of communications, especially for new mediums such as social media. Storytelling capabilities are of particular importance, as is an emphasis on transparency and authenticity. Technological attributes and scientific evidence, while important, are much less likely to drive consumer perceptions than stories that evoke emotion. These stories can be harnessed to align with the positive consumer perception attributes described above.

Tomorrow's Consumers

- Millennial and Gen Z consumers are more likely than previous generations to accept new technologies, especially when they have demonstrable benefits[18]. These consumers especially value technologies that will help avoid the negative attributes described above. Gen Z will comprise 32% of the global population of 7.7 billion in 2019, nudging ahead of millennials, who will account for a 31.5% share[19] based on a Bloomberg analysis of UN Data and using 2000/2001 as the generational split. It is important to note that Gen Z only know a digital world, and their impact will now be felt as they start to vote and make financial decisions.[20]

Implication: as emerging technologies are developed and commercialised, it is critical that entrepreneurs, investors, and policymakers consider the initial use case (i.e., the problem being solved, and benefits being achieved). More specifically, it is more likely that negative consumer reactions can be avoided if the initial use of the product both avoids the negative attributes that consumers are concerned about, as well as aligns with the positive attributes that consumers are seeking. The consumer and regulatory backlash against GMOs provides a useful example of this. In hindsight, it is clear that the coupling of the introduction of GMOs with chemical company business models focused on selling branded input products, negatively contributed to activist (and ultimately consumer) reactions. This use case triggered negative consumer reactions to several attributes described above, including environmental impacts (i.e., from chemical usage) and corporate power/consolidation. It is important to note that even when these attributes are not actually true, the perception that they may be true is what drives the backlash. Where possible, it is recommended that the initial application of an emerging technology have a clear benefit that aligns with the desired attributes of consumers.

A Broader Perception Issue

- There is some concern amongst consumers around potential loss of jobs, especially in regional areas, as a result of the adoption of emerging technologies. This concern, however, is largely disconnected from food and fibre purchasing decisions. In other words, though this concern exists, there is not currently evidence that it will prevent purchasing of certain products, or incite negative reactions (e.g., from activists, media). It is also important to note that research on future joblessness is inconclusive, and some believe that emerging technologies will help create new business models and new industries in regional communities.

Implication: as farmers also share this concern, this issue may present an opportunity for discussion around common ground between farmers and consumers.

The Role of Startups

- The entrance of startup companies as a pathway for technology development and commercialisation may fundamentally change the character of consumer perceptions in agriculture. Historically, agriculture technologies have been brought to market by large, well-established firms. The introduction of these technologies therefore often aligns with negative consumer perception attributes such as "corporate power and consolidation" and "industrial" agriculture. Further, the brand reputation of these companies, especially around their Corporate Social Responsibility (CSR), can influence consumer perceptions[21]. Startup companies in agriculture, in contrast, are generally well received by consumers[22] as they avoid the negative associations with the above attributes. As startup companies bring technologies to agriculture, consumers may be more accepting of their value to farmers and the food system more broadly.

Implication: companies of all sizes developing technologies for agriculture need to pay attention to their corporate reputation and positioning in relation to the positive and negative consumer perception attributes. Large companies are advised to be cautious of the advantage that startups may have here; in some cases, partnering with startup companies may be a strategic option.

4.3 Farmer Perception Insights

Value Propositions

- In terms of on farm perceptions of emerging technologies, farmers are primarily concerned with the value proposition, or benefit to their business, of emerging technologies. Whilst there is an understanding that some AgTech products and services will provide additional benefits, and in many cases an appreciation of these benefits (e.g., animal welfare), the immediate focus on farm remains on sustainable profitability. As such, the economic benefits and return on investment (ROI) are of primary importance to primary producers.
- While many of the emerging technologies explored in this report hold promise to deliver value to consumers, it is not yet clear whether consumers will pay a premium for these products. Farmers are not likely to adopt technologies solely because of the potential value to consumers. Rather, adoption by farmers will be driven by factors of importance to the farmers.

Implication: for developers of emerging technologies, farmer-facing marketing efforts may need to focus on different product attributes than consumer-facing marketing and communications efforts. Further, AgTech companies need to be aware of farmer requirements and context to ensure their offering delivers a strong value proposition and ROI. Promises of eventual premiums from downstream consumers are not likely to be sufficient as incentives for adoption.

Other Barriers to Adoption

- Adoption of emerging technologies by farmers is constrained by their ability to readily use the technology, or easily adapt their systems to accommodate the technology. When the adoption process is complex, lengthy, or expensive, farmers are not likely to participate.

Implication: in addition to broader (and well documented[23]) barriers, such as connectivity, usability and customer service are key issues that may impede adoption. AgTech companies, including startup companies and established firms, need to focus on user experience, and ensure they can provide commercially viable and high quality service to their customers.

Implication: a related and relevant barrier to adoption for farmers is education, especially digital literacy skills. Training and educational programs around technology usage, both for simple as well as complex, emerging technologies, may therefore help producers to realise the potential benefits of these technologies.

- Many of the emerging technologies covered in this report hold the potential to help farmers diversify their production base from within their existing farming systems (e.g., weeding robots that may improve the economics of organic farming; new seed technologies that unlock different crops, alternative use of existing infrastructure such as indoor farming in sheds when not in use). Implementing these technologies will require more than adoption; practice changes may be necessary. Producers will need accurate and practical resources about how to unlock the value of these new technologies and the practices they enable. Some of these production systems may not be economically viable now, but may become viable with emerging technologies in the future.

Implication: as farmers look to diversify production and explore new farming practices and systems, they will need additional support, such as extension of research findings and training on new practices. Further, given the increasing role of digital technologies for dissemination of information, including in agriculture[24], it is important to consider alternate, digital means of extending information to growers.

[16] There are many applications of synthetic biology, including "clean" meat as well as upstream agricultural applications. The former, which is distinct from plant-based meat as it is grown using stem cells in laboratory environments, is gaining traction globally, including in Australia and New Zealand. The commercialization timeframe for this technology therefore varies significantly across applications. [17] For example, recent gene editing decisions https://www.nature.com/articles/d41586-018-05814-6 [18] Though these insights are derived from our consultations, there is evidence of supporting data, for example: Epsilon 2018 Trend Report and https://www.marketingcharts.com/brand-related-60166 [19] Bloomberg Report August 2018 [20] Bloomberg Report August 2018 [21] Agriculture chemical companies, for example, and their relationship to previously introduced non-agricultural products that consumers have rejected (e.g., Agent Orange). [22] For example, AgTech startup Impossible Foods uses a GMO in their products, but has avoided consumer backlash. While this is likely due to a combination of factors, including their use of the best practices described above (e.g., transparent marketing; environmental impact), their positioning as an innovative, disruptive startup company is surely helping them gain traction with consumers. https://medium.com/impossible-foods/how-gmos-can-save-civilization-and-probably-already-have-6e6366cb893 [23] See Precision to Decision, for example. [24] Many of the AgTech companies consulted in this project mentioned using digital channels to engage with, and acquire, customers.

Considerations

Section 5

Considerations

5.1 Agricultural and AgTech Career Pathways

Relevant to: Next Generation of Producers and Consumers

As noted above, Gen Z producers and consumers will continue to have increasing influence on the agrifood and fibre industry. Though the next generation of farmers, service providers, and innovators may not be currently thinking about careers in Agriculture, highlighting the opportunities enabled by emerging technologies may increase the attractiveness of careers in this industry. With the current level of activity in the AgTech sphere in Australia rapidly increasing, there is potential to promote emerging career pathways that have not existed in the past.

For consideration, and in conjunction with Tertiary Research Institutions, an avenue to consider for AgriFutures and RDCs is to promote technology-related careers in agriculture within High School curriculums. To build momentum, this may include AgTech idea competitions and possibly even scholarships or sponsorship opportunities (e.g. to conferences). Such an effort could help to ignite broader discussions around agricultural career pathways, as well as continue to build the pipeline of talent from regional areas into universities, and ultimately back to regional areas again.

5.2 Technology Adoption and AgTech Readiness

Relevant to: Current Primary Producers

There are various extension programs around Australia, and there is an opportunity to incorporate “AgTech adoption readiness” discussions into existing infrastructure and investments. Such discussions, or trainings, would need to focus specifically on helping producers to understand positive and negative drivers of consumer perceptions, as well as the role that emerging technologies can play in aligning with positive attributes.

For example, existing industry events (e.g., conferences) or gatherings of producer-groups could feature workshops that help producers to understand the role of AgTech startups in technology commercialisation, the changing landscape of consumer perceptions, and the potential ways that emerging technologies may benefit their industry. Such workshops would need to be tailored to relevant use cases and practical issues, to ensure they are valuable to producer participants.

Another example, also implementable at existing industry events, is forums where farmers and consumers can discuss their perceptions of emerging technologies, and the role they will play in the future.

5.3 Watch Brief

Relevant to: Government, Research Institutions and Industry

As discussed in this report, consumer perceptions are changing rapidly and the pace of technology development is accelerating. It is therefore likely that both positive and negative consumer perception attributes will change as more commercial use cases are developed.

For the medium and potentially high risk technologies identified above, it is recommended that an active watch brief be developed. Specifically, consumer and activist sentiments overseas should be proactively monitored, as well as the strategies of research and technology developers in engaging with these groups. As research evolves, regulatory considerations should also be actively explored. Importantly, consumer backlash is likely to be an international phenomenon, especially across developed countries and in today's social media-enabled world. Therefore, proactively engaging with international organizations to mitigate the risk of negative consumer perceptions may be an opportunity that will help Australian agriculture to remain on the cutting edge of these issues.

5.4 Broad Dialogue

Relevant to: Global Community

There is potential to increase engagement with activist groups and other stakeholders who may play a role in influencing consumer perceptions (e.g. media). The purpose of such engagements can be to identify where negative perception attributes may arise, as well as effectively communicate the positive attributes of these technologies and the envisioned commercial use cases. Discussions will include scientific, ethical, economic, and social/environmental considerations, and therefore need to include a broad range of stakeholders.

With Australia's burgeoning AgTech landscape there is potential to take a lead locally with this engagement and dialogue to maintain presence at the forefront of conversation and debate.

One example of this type of engagement from the U.S. is efforts by agriculture chemical company DuPont Pioneer around CRISPR-Cas, the genome editing technique. In an attempt to engage with stakeholders and communicate the potential benefits, DuPont Pioneer has held several forums[25] and developed a website to explain how the technology works, and the benefits it will bring[26]. Though it is too early to tell whether this strategy will help gene editing to avoid the negative consumer perception issues associated with GMOs, this effort holds promise to avoid polarisation and help Australian Agriculture to champion the adoption of safe, productive, and beneficial emerging technologies.

---

[25] https://www.washingtonpost.com/news/wonk/wp/2017/06/13/how-one-company-plans-to-change-your-mind-about-genetically-edited-food/ [26] http://crisprcas.pioneer.com/

Conclusions

Section 6

Conclusions

Agricultural enterprises will need to adopt emerging technologies to remain competitive within both local and global markets. Australia's high labour costs and challenging climatic conditions, combined with macro factors such as the growing and changing global demands for food and fibre, are increasingly putting pressure on primary producers. More than ever before, there is a need to reduce production costs, increase production yields, and reduce environmental impacts, all while maintaining competitive advantage, instilling product differentiation, and improving product safety and quality.

Agricultural technologies hold potential to enable primary producers to meet these needs and remain competitive. Therefore, it is critical to cement the relationship between technology development and commercialization, and consumer confidence, so that agricultural producers can continue to adopt technological innovations that have demonstrable benefits for their operations, the industry, and consumers.

However, the widespread implementation of innovative technologies across the agricultural industry increasingly depends on consumer perceptions. As evidenced by the GMO labelling debate in the United States, and global consumer scepticism of this technology, disruptive technologies cannot achieve integrated success when consumers deem them unacceptable. As the voice of the consumer increases in volume, for example through social media, proactive engagement around emerging technologies is increasingly critical and new mechanisms and forums are needed to support these engagements.

Societal beliefs, value systems, norms, and behaviours influence the extent of consumer acceptance in technology. This is amplified in the agricultural industry as development and implementation of innovative technologies is increasing. The support and adoption of emerging agriculture technologies by producers, as well as from consumers, is essential in remaining competitive in the global marketplace. This ultimately will facilitate the future sustainability and profitability of Australian agriculture.

The work and effort of Government into AgTech across Australia, along with high level interest in this sector from research institutions and the private sector, is an impressive testament to the importance of AgTech. This also cascades to the important role that this sector is playing in keeping Australian Agriculture at the forefront of innovation.

The consumer perceptions relating to the role of emerging AgTech in providing economic, social, and environmental benefits is an important opportunity to promote. Increasingly AgTech will be assisting managing scarce resources (water), minimising inputs (fertiliser and chemicals), increasing production diversity, and reducing the environmental impacts of agricultural production and consumer perceptions will play a big role in adoption of the various technologies. The considerations in this report around promoting Ag Tech career pathways, enhancing AgTech adoption readiness, identifying risks and maintaining broad dialogue are designed to build momentum that propels Australian Agriculture towards a $100 billion industry.

---

[86] Keogh, M and Henry, M 2016, The Implications of Digital Agriculture and Big Data for Australian Agriculture, Research Report, Australian Farm Institute. [87] RIRDC 2016, Transformative technologies – Sensors, publication No 16/032 [88] Perrett E, Heath R, Laurie A and Darragh L 2017, Accelerating precision agriculture to decision agriculture: Enabling digital agriculture in Australia, November 2017 [89] Rabobank 2017, Does sensor adoption make cents? accessible on 31 July 2018 via https://www.rabobank.com.au/media-releases/2017/170801-agtech-does-sensor-adoption-make-cents/ [90] Ruiz-Garcia L and Lunadei L 2011, The role of RFID in agriculture: Applications, limitations and challenges, Computers and Electronics in Agriculture 79:42–50, accessed on 18 May 2018 via https://www.sciencedirect.com/science/article/pii/S0168169911001876 [91] Rabobank 2017, Op cit.

Case Studies

Section 7

7.1 Blockchain

Summary

Blockchain is a type of distributed ledger (which is essentially a database) that was invented by the creators of Bitcoin, a cryptocurrency. Since Bitcoin was introduced, it was discovered that the logic behind the cryptocurrency, the distributed ledger, has important applications for managing data in all sectors of the economy, especially agriculture. The distributed ledger allows a shift away from costly, inefficient, and centralised record keeping.

In agriculture, the application of distributed ledgers is ideally implemented in conjunction with Internet of Things (IoT) devices, such as sensors and scanners, which remove the human error component to data entry into the ledger. Key applications for distributed ledgers in agriculture include removing costs (e.g., middle actors capturing margin) and improving traceability (e.g., food safety control). Blockchain also holds potential to create financial incentives for ecologically and economically beneficial production practices. All of these applications align very strongly with what consumers are seeking.

Case Study 7.1

Blockchain

Acceptance

Consumers: Globally, consumers are seeking clarity and information on food production to address food fraud and food safety concerns, and to understand the health and environmental impacts of consumption. Consumers also want verified information about production practices, so they can choose products that were produced in alignment with their values. Therefore, blockchain holds huge potential to positively align with consumer perceptions.
In some cases, as evidenced by price premiums for organic and the growth of the sector, consumers may be willing to pay a premium for production characteristics when they have confidence in their veracity. However, it is important to note that while there is broad awareness of blockchain in association with cryptocurrencies, there is little popular understanding of differentiated ledgers or their use in agriculture. In other words, consumers are not (yet) actively looking for blockchain applications in agriculture.

Farmers: There is confusion and scepticism around blockchain amongst primary producers, as it is often associated with cryptocurrencies. As this confusion dissipates, scepticism may persist around the adoption of distributed ledgers unless clear benefits to producers are incorporated and communicated from the beginning (e.g., efficiency gains, financial premiums). If the initial attempts to implement distributed ledger technology are solely focused on ensuring government compliance and regulatory requirements are met, or are based on unverified promises of eventual premiums, there may be push back from producers. In addition, it will be critical that the cost to implement these new systems is distributed amongst the shareholders, and not placed entirely on producers, especially if they are not gaining value immediately.

Application and Benefit to Agriculture

- **Efficient inventory and transaction management systems:** Distributed ledgers offer agriculture an opportunity to leapfrog other sectors with established digital transaction and compliance systems in place. As much of the agriculture industry still uses manual data entry, and as the systems that are in place are largely fragmented (i.e. do not interoperate with each other), agriculture is in a unique position to more rapidly adopt decentralized systems. Doing so would minimise the error-prone human element of data entry, as well as enable the sharing and safeguarding of transactions amongst the many actors and geographies that are currently part of agriculture production systems. In addition, smart contracts could be used to shrink the time between order fulfilment and payment, thereby reducing risk and error and increasing efficiency.
- **Supply chain provenance:** End consumers increasingly want to understand where their food comes from and how it was produced and transported. Distributed ledgers can provide participants all along the supply chain with data on provenance, production practices, transaction details, and product quality and safety, and verified regulatory and financial compliance. Supply chain provenance, in addition to transparency, provides two key benefits: reducing food fraud and enabling food safety.
    - **Food fraud** is largely an issue in emerging markets, where food companies are investing significant capital to increase their market share. If that market share is eroded due to sub-quality food products entering the market under their brand names, it is costly. The ability to trace their supply chain enables food companies to demonstrate and verify the quality and safety of their products, for example by proving when a product is not theirs, or by identifying and eliminating a faulty actor in the supply chain.
    - **Food safety** is an expensive and global issue for food companies. If a food safety concern arises, a distributed ledger that allows a food company to quickly trace back and do a targeted recall of only those food packages that come from areas of concern, ensures fewer customers get sick, saves perfectly safe food that would have otherwise been recalled, and saves significant expense for the food companies.

Differentiated and premium production: The combination of the IoT and distributed ledgers holds potential to allow consumers to assign value to differentiated production practices (e.g. certifications; resource efficiencies; welfare standards). Price premiums may incentivise the development of supply chain infrastructure that supports differentiated production (i.e., as opposed to conventional commodity-based supply chains), for example different crops or production systems. Primary producers would then have more options, as well as an enhanced ability to communicate their production choices to end consumers and receive a premium back.

Key Facts

- The global blockchain market reached over $700M USD in 2017, and is anticipated to reach $60.7B USD by 2024.[27]
- Tracking commodities, including but not limited to agricultural commodities, is a key use case being explored globally, with participation from large agribusiness and technology companies (e.g., IBM, Intel, WalMart, Cargill).
- Distributed ledgers (e.g., blockchain) use independent computers - referred to as nodes - to record, share, and synchronize transactions in their respective electronic ledgers, instead of keeping data centralized as in a traditional ledger [e.g. with a bank].[28]
- There is a broad spectrum of distributed ledger models, with different degrees of centralisation and different types of access control, to suit different business needs.[29] Applications within agriculture most often use 'permissioned' ledgers. Here, only relevant stakeholders (e.g., farmer, processor, consumer, developer) are owners and only they can add records and verify the contents of the ledger. This distributed system makes it impossible for one stakeholder to alter the books, as each receives a copy of the ledger and all copies are updated at the same time. These constraints are what hold potential to enable new models of trust, transparency, and traceability.
- Key limitations to the widespread diffusion of commercial blockchain applications in agriculture include: extremely high energy requirements to fuel processing power; mechanisms, such as sensors and automated data capture, to capture error-free data; and the complexity of incentivizing players all along the supply chain to use a blockchain-enabled system.

"Establishing a premium is critical for Australian agriculture, and that's not just through quality. Consumers are demanding transparency and a story. It's not just about establishing a brand, but maintaining the brand, and this is getting harder to prove as everyone is "clean and green now". You don't get a premium for clean and green anymore, but you get a penalty if you're not."

Head of R&D, large Agribusiness

"There are great use cases in agriculture- a number of different parties that don't trust each other and need shared information. Food supply chains are one of the first practical applications of blockchain driven by need of a defensive brand strategy, worries of counterfeit can be prevented through letting customers know that they can trace the real product."

Blockchain and Digital Currency Expert

"I think we'll start to see farmers being able to prove that they're accredited in some kind of way for sustainability and welfare practices. Blockchain will help them prove, in a global market, that they have produced in a way that's truly compliant with a set of standards. This may be a differentiator for Australia, as well as for individual farmers."

Agribusiness analyst

Related Technologies

- IoT
- Satellites
- Drones
- Big Data
- Synthetic Biology (biosensors)

Case Study 7.1

Blockchain

Key Perceptions and Impacts

The two most common use cases for developing and deploying distributed ledger technology in agriculture are: (1) preventing food fraud; and (2) minimizing the impact of food safety issues. Consumers, especially in developed countries, are extremely concerned about these issues, and therefore blockchain aligns positively with consumer perceptions.

Barriers to Adoption

- **Commercially viable use cases:** while distributed ledger technology holds promise to enable transparency along the supply chain, and ultimately for consumers, doing so will require an investment in additional, accurate data collection. If producers do not see direct benefits for their efforts (e.g., premium prices, cost savings, labour savings), adoption may be limited. Further, if significant practice change is required, producers may not feel the benefits outweigh the costs.
- **Connectivity** remains an issue in most rural communities. Connectivity is required to support the IoT devices that will automatically capture and enter data into the distributed ledgers.
- **Presentation of information and price premiums:** Consumers want a digestible summary of the information about production that is 'carried' within a distributed ledger. If there is no mechanism through which valuable information can be provided to consumers in easy and engaging formats, it will be difficult to command a premium for the products. Without a premium, it will be difficult to justify additional expense (assuming the additional expense is not saved by efficiency gains within the supply chain).
- **Blockchain fatigue:** The proliferation of companies attempting to serve the agriculture industry with blockchain-inspired solutions suggests excitement for this transformative technology. However, the use of blockchain is often not necessary, and therefore is being used more for investors than in direct support of developing solutions for the needs of the agriculture industry. This may increase producer scepticism of, and fatigue with, blockchain solutions and ultimately hinder adoption.

Key Insights

The adoption of distributed ledger systems in agriculture has begun, including in Australia . The potential benefits of blockchain are extremely well-aligned with positive consumer perceptions: blockchain promises to bring transparency and provenance to consumers, as well as prevent food fraud and food safety issues. Also, blockchain holds the potential to bring farmers back in contact with their end consumers and, in doing so, bring additional margin back to the farm.

However, most agricultural instances of blockchain- globally and within Australia- are still in the pilot stage (i.e., not commercial), and there are a number of barriers that must be overcome for the promised benefits to be realised. Barriers include: technological challenges, such as connectivity, processing power requirements, and scalability and interoperability; privacy concerns; and lack of required skills and capabilities, such as digital literacy.

To realise the potential benefits, and to ensure the agriculture industry benefits from a technology that has such a strong alignment with positive consumer perceptions, support for commercialisation efforts is needed. For example, through support for both blockchain and IoT pilots, education and digital capability building, and establishment of common protocols.

Ultimately, blockchain first needs to be adopted by the supply chain before it can deliver the benefits that consumers are demanding (e.g., transparency). Given that it is unclear whether consumers will pay premiums for blockchain-enabled attributes, it is critical that blockchain developers go to market with applications that provide immediate benefits (e.g., efficiency gains, reduced risk) to their customers.

[27] Market Reports Center [28] World Bank [29] UK Government [30] For example, AgriDigital has completed multiple blockchain pilots in the grains industry.

7.2

Internet of Things / Sensors

Summary

The Internet of Things (IoT) is a network of objects that are connected wirelessly using sensors, and can transmit information to each other, or a wider network, without human intervention. Connected objects can include humans, animals, plants, and infrastructure (e.g., equipment, buildings, etc.). Though sensing data is not new, technology advancements in cost, quality, and robustness of sensors and enabling data analysis and connectivity technologies, have accelerated the potential of the IoT for agriculture.

It is predicted that IoT device installations in agriculture will increase from 30 million in 2015 to 75 million in 2022, for a compound annual growth rate of 20%[31].

Case Study 7.2

Internet of Things / Sensors

Key Perceptions and Impacts

The common consumer-facing use case for the IoT is paddock-to-plate transparency: consumers want more data about, and confidence in, where their food and fibre comes from and how it was produced and transported. This includes food safety, animal and worker well-being, and production practices (e.g., organic; water usage). However, the IoT may not be able to realize this benefit due to the mismatches in how data are collected (continuously), how brand value is developed (over time), and how consumers make buying decisions (instantaneously). To realize this use case, the IoT needs to be extremely inexpensive for farmers, or provenance has to be a secondary benefit to the farmers (e.g., after yield improvements, cost savings, etc.). Further, it is still challenging to communicate production and supply chain data effectively to consumers in ways that are not confusing, and help them gain confidence. Thus far, brands have not been great at this, to the detriment of the agriculture industry.

Acceptance

Consumers who have had personal experiences with IoT devices have a generally positive view of the technology with no major negative perception. A recent survey conducted by Cisco concluded that 53% of respondents believed personal connected devices made their life's easier, while 34% believed the technology would 'help protect them and their family'. However, a level of suspicion still surrounds IoT particularly around data security as only 9% of survey respondents felt highly assured their data is secure[32].

In terms of agriculture and food, implementation of the IoT along supply chains has the potential to bring transparency and provenance to consumers, as well as improve food quality and reduce food safety issues and food fraud. The IoT will also help give consumers confidence in the veracity of claims they may see on marketing materials, for example around animal welfare or environmental stewardship.

Farmers are beginning to see the potential of the IoT, but barriers to widespread adoption remain. Farmers will only adopt the technology if it is cost effective and produces real value such as efficiency, yield improvements or other operational savings. The cost of implementation and ongoing service is a major limitation for farmers, particularly when there is no immediate value received, which for IoT, can take several years of accumulating data.

Further, some farmers may hold the belief that installing IoT devices may result in major operational changes, away from traditional practices. This belief may result from a lack of education around digital farming practices and the associated benefits.

Application and Benefit to Agriculture

- **Precision agriculture:** IoT devices collect data that can help improve grower decision making, including the ability to cut costs, improve yields, monitor crops, and generally increase situational awareness across the farming operation. Field sensors connected to the IoT can record information regarding soil moisture and nutrient levels, control water usage for efficient irrigation systems, determine custom fertiliser blends based on soil profiles, and determine the optimal time to plant and harvest. In greenhouses, IoT sensors can eliminate the need for manual monitoring as the completely controlled environment can be tweaked to change temperature, humidity, light levels and carry out automatic irrigation.
- **Livestock monitoring:** Wireless IoT applications can be used to monitor health, well-being, reproductive cycle and location of livestock. In the dairying industry, wearable sensors can be used to detect disease signals that are otherwise hard for farmers to notice, while sensors can also measure milk fat, protein, somatic cell counts, progesterone, and antibiotics at every milking[33]. By continuously collecting data on the animal, farmers can determine which cows are able to produce more milk, and consequently make steps to improve diets that improve productivity.
- **Improve supply chains:** the IoT is being utilised to monitor commodities along the supply chain to ensure quality, safety, and efficiency, as well as enable traceability for consumers and regulators. By providing visibility, IoT sensors can help to avoid spoilage of perishable items by monitoring and sending safety alerts when the condition of goods deviate from safe levels. By monitoring the goods during transportation, food manufacturers can identify possible contaminated items which, during times of food recalls, can accelerate the investigation process and give quality assurance to consumers.

Key Facts

- The IoT is often thought of as sensors, but is actually a convergence of technologies (e.g. Big Data, wireless communication, machine learning, etc.) that has seen extensive adoption in industries as broad as manufacturing and retail.
- Agricultural applications include both on farm, and cross-supply chain, use cases, and apply to all types of commodities and production systems. Horticulture, especially closed environment systems, have seen the most adoption of IoT technologies to control and monitor the production system.
- The main consumer-facing use case for IoT is around paddock-to-plate transparency; however, it is not clear whether this use case will be sufficient in itself to justify farm-level adoption given barriers such as cost, connectivity, capability, and value proposition. However given the forecasted technology improvements and volume increases, sensor prices are predicted to decrease from around $50 per device for today's technology, to $0.05 in 2024 using printed electronics[34]. This will significantly increase value for farmers and perhaps prompt further adoption.
- Efficiencies gained from the IoT increases over time as farms become more connected and sensors can be applied to monitor more variables. With more IoT devices, the average farm is expected to generate an average 4.1 million data points per day in 2050, up from 190,000 in 2014. Furthermore, studies have found that the usage of IoT on the average farm resulted in yield increases by 1.75%, energy costs dropped $7 to $13 per acre, and water use for irrigation fell by 8%[35].

"To realise the benefits of the IoT for Australian producers, use cases need to involve not just data, but also management decisions that have a commercial benefit, and business models that account for the use of sensitive electronics in harsh production environments"

- AgTech Entrepreneur

"Paddock to plate data may be of interest to today's consumers, but until the farmer gets a guaranteed premium, they're not going to invest in the IoT just for that"

- AgTech Entrepreneur

"I can't imagine a future without sensors on animals... these [and other technologies] can enable artisan production and premiums through really high tech systems that enable safety, transparency, and well-being"

-Livestock Consultant

Related Technologies

- Remote sensing, including drones and satellites
- Big Data
- Artificial Intelligence
- Automation/robotics

Case Study 7.2

Internet of Things / Sensors

Barriers to Adoption

- **Capabilities:** many farmers lack the skills to operate and troubleshoot electronics and digital systems. In rural areas, there is a general lack of awareness regarding digital technologies and further knowledge is required to understand how to implement, effectively use and maintain the technologies. Rural centres may lack technological expertise needed to service IoT and regional development is needed to promote greater uptake. Further, moving to proactive (vs. reactive) management may be a challenge for some farmers without practical training and support.
- **Security and data management:** according to studies, 52% of consumers and 85% of developers say they don't believe IoT devices are secure enough[36]. Farmers are concerned about data privacy and security but also want to create value with their own data. The restriction of sharing data is there a limitation on development as farmers may sometimes be afraid if their information falls into the wrong hands[37]. This is supported by the findings of the Precision to Decision project as well.
- **Connectivity:** rural connectivity in Australia is a major limitation on the deployment of IoT devices and major improvements in wired and wireless solutions are needed for the technology to be beneficial. For IoT sensors, the issue of connectivity is more nuanced as networks are needed to work over long ranges while also consuming low power. Sensors that send small bits of data need to be sustained over long periods of time and networks such as LoRaWan (Low Powered Wide Area Networks) that are specifically designed for IoT connectivity are already being deployed in cities across Australia[38].
- **Interoperability:** many current use cases are point solutions, rather than platforms. Farmers are frustrated, and value is limited, when systems do not share data. Furthermore, data itself is not of sufficient value to producers; rather, data needs to be embedded into actionable decisions. Where possible, these decisions should be automated and can be easily implemented with the assistance of technologies such as AI and robotics/automation.
- **Trust:** farmers are used to physically and visually inspecting assets, and may not have confidence to offload critical tasks to technology. The benefits of IoT are also accelerated when data is exchanged between different providers along the value chain, and there is a general lack of confidence in data privacy and security amongst farmers. The IoT industry therefore needs consideration into industry-wide data standards, protocols and overarching regulation to remain competitive[39].

Key Insights

The IoT has huge potential benefits for agriculture, especially as it enables data-driven decision making to optimize costs at the farm level and throughout the supply chain. Benefits will apply to all industries, including both premium and commodity products.

Although there is great hype surrounding IoT and sensors in the agricultural space, actual value needs to be accompanied by converting farming systems to be IoT ready. Technology companies need to provide products that are valuable and well-designed that can handle the rugged Australian conditions. Sensors recording moisture and nutrient levels are useful however the farmer needs actionable insight that can assist in decision making and solve on-farm problems.

Consumers have no negative perceptions toward IoT technologies for agriculture, and actually see benefit in availability of data along the supply chain. However, it is not clear that consumers will be able to interpret such data, or be willing to pay premiums for products from farms on the IoT. Further, key barriers remain for widespread adoption. Barriers are related to cost and value proposition, necessary infrastructure and security, and capabilities.

[31] Business Insider, 2016 [32] Cisco, IoT Value / Trust Paradox report, 2017 [33] Dairy Reporter, 2017, SomaDetect technology brings transparency to dairy farms [34] Communications Alliance, 2015 [35] Business Insider, 2016 [36] Auth0, 2015 [37] Wolfert, Ce, Verdouw, Bogaardt, (2017), Big Data in Smart Farming – A review [38] Farm Institute Insights, 2017, AFI [39] KPMG, 2018

7.3

Artificial Intelligence / Big Data

Summary

Big Data and Artificial Intelligence (AI) technologies are playing an increasingly essential role in agriculture as the amount of data collected on and about farms increases (e.g., machines equipped with sensors), and as the capabilities of these technologies rapidly mature.

Big Data refers to data sets that are so large and complex that traditional data-processing applications are inadequate. AI refers to intelligence demonstrated by machines that are able to 'learn' from experience, and can be trained to accomplish specific tasks by processing large amounts of data. The types of applications vary from relatively simple feedback mechanisms (e.g. a thermostat regulating greenhouse air temperature) to complex algorithms that provide growers with timely decision support (e.g. recommendations on crop protection strategy), or prescriptively and proactively implement automated management interventions (e.g., robotic weed control).

The integration of multiple sources of data such as weather, market data, agronomic data or benchmarks with other farms further enhances its effectiveness. With a multitude of sources, AI increases the value of data being collected by analysing and converting it into information to support farm management decision-making. It can be applied at a range of scales from converting data collected on individual animals and plants, to a whole farm level by presenting information for crop planning and monitoring.

A recent study titled "Is big data for big farming or for everyone?" highlighted that there are key questions and issues that need to be addressed in further development of digital technology and Big Data in agriculture, specifically around trust, equity, distribution of benefits and access[40].

Case Study 7.3

Artificial Intelligence / Big Data

Acceptance

Consumers: The general acceptance of Big Data and AI by consumers is evolving. Consumers are concerned about moving away from natural farming practices to solutions developed by AI and further research is required in this area. This concern around a move away from "natural" production towards more "industrial" systems does pose a risk of consumer backlash and is flagged as a potential concern. This concern will potentially evolve as a "medium" term risk to be monitored.

Farmers: The availability, quality and dissemination of data at an individual farm level that is robust and simple is still evolving. A critical issue for farmers is around ownership and security of data – farmers generally don't want to see third parties gain profits from their data. Understanding the value of data will be a critical area moving forward for all parties.

The opportunities for AI in farming will continue to evolve in areas of decision making, variable needs of plants and animals, that lead to maximise productivity and yields. The big link here to acceptance by farmers is cost of production. AI and Big Data can help farmers be more efficient, and in turn if production costs decrease, profitability will improve. There may also be benefits around improved environmental outcomes from efficiencies in production and where less productive land is identified and rehabilitated.

The evolution of AI is creating concerns around job loss in regional areas and safety aspects will play a part in farmers accepting the technology.

Application and Benefit to Agriculture

The synthesis of Big Data and use of AI can help farmers gain access to complex information that can inform critical on-farm decisions. Big Data is required to enable AI and both technologies are integral to each other's success. The applications in agriculture offer huge potential for the industry. Although the technology can be applied in a wide range of settings, here are examples of just a few[41]:

- **Development of new plant seeds:** Huge developments in biological information collection and analysis have accelerated plant genomics. Research in laboratory settings is producing data that can be analysed to develop new hybrid seeds that perform across different ranges of environments.
- **Precision Farming:** New technologies and software that track yields, control equipment, monitor field conditions and manage inputs at precise levels across fields are substantially increasing productivity and profitability. Software with machine learning allow for smarter and more customized interactions which are creating opportunities for better decision-making on the farm.
- **Animal welfare:** Big Data and AI has the potential to help farmers manage their livestock efficiently with minimum supervision. New trials are being conducted where the technology is able to examine individual animals to determine their condition and suitability for market, while in dairying, AI already has use in automated milking units that can analyse the milk quality and flag for abnormalities.
- **Reduced operating costs:** The opportunity that Big Data and AI offer to agriculture is the potential for better cost allocation and reduction in operating costs via targeted allocation of inputs such as fertiliser and chemical application. The consumer benefit of this is the opportunity for potential benefits around quality and volume of production that could see price benefits longer term as these costs savings are realised.


HORTAU
ST2
-0.9
GPS POSITION

Case Study 7.3

Artificial Intelligence / Big Data

Key Facts

- In many cases, the technology for Big Data and AI applications on farms already exists. For example, it is now possible to combine large data sets and analyses including:
  - Long-range climate forecasts and local weather station data
  - Crop production models and sensors on farms
  - Pest management data
  - GIS mapping technology
  - Industry historical data (past yields, market data)
  - Current consumption data (supply chain logistics, prices, distributions, volumes)
  - Social media data (trends, events, political and social movements)
- An example of the emerging importance of Big Data in the agricultural supply chain is the Amazon acquisition of Whole Foods Market for USD$13.7 billion in the US. Whole Foods Market aspires to several standards for many of their products; sustainability in seafood, antibiotics in meat, and pesticides in vegetables among others. To validate these claims, data on specific items need to be kept right through the production chain[43].
- The use of Big Data in variable rate application (VRA) has become widely accessible however adoption from farmers is still slow. In the US, a recent survey of corn growers in Illinois found that 75% utilised VRA for fertiliser and 40% utilised VRA for planting. However in Australia, another survey of grain growers found that only 17% of respondents claimed to use VRA technology[44].
- The global AI in agriculture market is forecast to be worth USD$2.6 billion by 2025, up from USD$518 million in 2017. The key factors driving the rise of AI in agriculture include the growing adoption of information management systems, advanced technologies for improving crop productivity, rising crop productivity as a result of deep learning techniques, and increasing initiatives by governments supporting the adoption of modern agricultural techniques[45].

"RDCs and other organisations have collected and created data over many years that's not fully being used. With modern technology, we can utilise this information and make large data sets available for both internal analytics, and for external or 3rd party usage"

- Big Data Subject Matter Expert

"Very few organisations have good, structured data that can be useful to train AI algorithms to unlock value. This is especially true in agriculture, and will pose a challenge to the advancement of technology in the sector"

- Emerging Technologies Expert

"Current AI technology is highly dependent on large data sets, and most of the useful AI right now needs to be assessed by humans and then used to train machines (e.g. neural networks). Cloud-based services right now are capable of this however other AI applications are earlier in their development."

- AI Subject Matter Expert

"Decision based agriculture simply follows a series of rules that are pre-set. Optimised decision making – based on a set of variables is when AI come to fore to help manage the variables, and present a scenario that allows optimal decisions"

- AI Subject Matter Expert

Case Study 7.3

Artificial Intelligence / Big Data

Related Technologies

- Satellites
- IoT
- Sensors
- Robotics
- Gene Editing
- Synthetic Biology.

Key Perceptions and Impacts

The Precision to Decision report notes that learning from successes overseas is just one part of a broader project to give farmers the confidence, legal guidance and tools they need to access datasets, analytical platforms and data systems. The issues of safety and protection of people, livestock and property is an area that is going to require careful scrutiny to ensure this is appropriately balanced to deliver industry benefits[46].

Barriers to Adoption

- **Connectivity:** Connectivity will pose as a barrier particularly in Australia where poor mobile communication networks and data transfer ability are making digital agriculture technologies expensive. To fully utilise Big Data technology, regional Australia's mobile connection needs improvement as there is no doubt that the relatively low quality broadband coverage in rural areas has been a major reason for the slow adoption of internet functions.
- **Security:** Loss of data to could undermine a grower's competitive advantage and may force producers opting to store their data locally rather than through a third party or in a cloud computing environment. The potential dispute between farmers and service providers may arise regarding data ownership as ownership rights vary depending on how data is being collected and who is performing collection.
- **Trust:** As in many key business relationships "trust" is a key underlying factory in building and maintaining relationships. Whilst this potential barrier is linked to security concerns, the trust that farmers have in the systems and operators that are evolving will be a critical factor.
- **Quality of Data:** The quality and veracity of data is a central theme to adoption – as an example, the loss of ear tags in animals has big impacts on data quality relating to livestock systems and processes. For agriculture, it is difficult to find structured, high quality data as records are being kept in different formats and are unable to unlock any value.
- **Regulation:** Governance and systems will be needed around the use of AI and Big Data, for example regarding liability for accidents with autonomous equipment[47]. Farm insurance policies will eventually need to evolve to cover this aspect of new farming practices.
- **Safety:** Especially, with respect to integration with autonomous equipment. Farmers and their advisory / representative bodies have procedures and protocols build around Safe Work Australia standards. This will need to evolve with AI-enabled equipment.
- **Usability:** Need products and services that sufficiently abstract the complex technology to enable practical decisions. But, farmers also want to understand and be able to tweak, as needed, what's happening "under the hood". If they don't know what it's doing and trust it, they won't use the technology.
- **Cost, Value and Return on Investment:** Business models are still evolving and require work to commercialise. The question of data ownership / sharing and sale is a critical component – i.e. what is the value of a piece of data in the open market or what buying power can emerge from Big Data that delivers positive outcomes for farmers.
- **Data ownership:** Regulations surrounding intellectual property rights is an issue as potential disputes between farmers and service providers may arise regarding the ownership of information. Ownership rights vary depending on how data are being collected and who is performing collection. For example, ownership and use of data generated using ground-based equipment owned by the farmer will be controlled by the farmer, except in the case of machinery operating data, which the equipment manufactures may reserve ownership rights over.
- **Data Collection:** Collection of data is still a key problem. The question on how to do it accurately and at scale along with who pays for and owns this service is a key issue.

Key Insights

Big Data and AI involve the whole supply chain. The opportunities to harness Big Data and AI in agriculture to assist in decision making that improve yields and reduce input costs are real. This is also developing rapidly with the evolution of other technologies like the IoT.

There is an emerging question of trust associated with use of Big Data and AI, and who is going to be able to benefit from the use of the data. The size of a farming operation may impact ability to harness and use Big Data whilst new entrants at various stages of the supply chain will potentially have the ability to leverage influence, or derive value, from data sets.

Like many technologies, connectivity in regional areas is going to be a major influence on the ability to adequately secure quality data, then analyse and use it. As this evolves it may also see gradual changes in skill sets and demographics in certain areas in regional Australia. This could lead to dislocation of employment but then increased reliance and requirement for alternative skill sets in data analytics that creates new opportunities.

The regulatory framework around data ownership and security along with privacy considerations will need to evolve with Big Data and AI. This may also potentially consider areas such as safe work practices and insurance considerations that may emerge in the future.

Consumer perceptions around Big Data and AI are evolving and expected to see long term positive impacts around prices, animal welfare and environmental benefits. Medium term risks though are expected with consumer perceptions around industrialisation of agriculture and automation of production that Big Data and AI may bring. Of equal concern will be the question of data ownership and control through the supply chain.

[41] AgFunder News: How Big Data is Disrupting Agriculture from Biological Discovery to Farming Practices, Vonnie Estes. June 2016 [42] Fleming, A., Jakku, E., Lim-Camacho, L. et al. Agron. Sustain. Dev. (2018) 38: 24. https://doi.org/10.1007/s13593-018-0501-y [43] Barry, S, Darnell R, Grundy M, Moore A, Robertson M, Brown J, Gaire R, George A (2017) Precision to Decision – Current and Future State of Agricultural Data for Digital Agriculture in Australia, CSIRO, Australia. [44] AFI, 2016, The Implications of Digital Agriculture and Big Data for Australian Agriculture [45] MarketsandMarkets, 2017, AI: Agriculture Market Forecast until 2025 [46] AgriFutures National Rural Issues Transformative Technologies. Case Study - Artificial Intelligence (2016) [47] AgriFutures National Rural Issues Transformative Technologies. Case Study - Artificial Intelligence (2016)

7.4

Gene Editing

Summary

Gene Editing is one of a suite of modern biotechnologies designed to change the genomes of living organisms for health and/or economic benefits. It allows scientists to make small and precise changes to the genome of plants, animals, and humans. To date, its primary use has been in human health; however, there are many emerging applications for food and agriculture.

In plants, gene editing is performed on cultured plant cells, which are then regenerated into whole plants, resulting in improvements such as disease resistance, drought tolerance, or the absence of allergens. In animals, gene editing is performed on the single cell that develops into an embryo, which grows into an animal. Gene editing has created improvements to date such as polled cattle, in-egg sex identification for poultry, and virus-resistant pigs.

CRISPR/Cas9 is often mentioned in conversations about gene editing. This is one of many tools that have been developed to enable gene editing. CRISPR/Cas9, and other similar tools (e.g., ZFNs, TALENs, rAAV, Transposons), makes the process simpler and therefore, more accessible for scientists and biotechnology companies.

Gene editing runs a high risk of being negatively perceived by consumers, largely because it is similar to, and therefore often associated with, GMOs. As development and commercialisation of gene editing progresses, it is critical that the lessons from the GMO use case be leveraged to ensure adoption, where appropriate, of this technology for the benefit of Australian agriculture.

Case Study 7.4

Gene Editing

Acceptance

Consumers- proximity to GMOs: at this point consumers seem willing to accept gene editing in a way that they have not been willing to accept GMOs, perhaps driven by the fact that gene editing is being used successfully in life-saving healthcare applications. However, the risk of negative consumer perceptions is high due to their perceived proximity to GMOs. Gene editing does hold significant potential to help agriculture meet the demands that consumers are placing on the agrifood and fibre supply chain, such as reducing environmental impacts, delivering high quality products, and improving animal welfare, and these benefits especially must be clearly communicated to consumers.

Consumers- advanced applications: the fact that the potential impact of genetic engineering is extremely high may be cause for concern, including for consumers. Gene Drives, an advanced application of gene editing, for example, may be an area where specific attention needs to be paid as the science advances. This technology rapidly forces genetic traits into future generations through sexual reproduction, ensuring edited traits are passed on to all future generations. Concerns may arise around the wider impact of this process on ecosystems- a key issue of concern for consumers. In addition to proactive dialog around the ethics of such an application, more science is needed so we can understand how gene drives could remove or substantially alter species and environments.

Farmers are willing to adopt solutions that improve the profitability of their operations. For gene editing in particular, this willingness extends to organic producers and even activist organizations who have been resistant to GMOs in the past.

Application and Benefit to Agriculture

Improved profitability: It is estimated that if 60-100 million farms adopt gene-edited seeds by 2030, global production will increase by 100-400 million tonnes, and 5-20 million tonnes of lost production will be eliminated. As a result, farmer incomes would increase by $40-100 billion48.

Diversified production: the lower cost (vs. genetic modification) and accelerated timeline (vs. conventional breeding) offered by gene editing will allow investment of research and development dollars into a diversified set of commodities. This will increase the number of crops that farmers can profitably adopt into their rotations, as well as increase farmer's ability to profitably produce products that meet consumer demands (e.g., higher protein content).

Decreased input costs: gene editing may enable the creation of plants and animals that are tailored to work with other advanced technologies, such as robots. Robotic technology reduces labour requirements and allows for more efficient input usage in both plant and livestock agricultural systems. Even without robots, gene editing holds potential to create varieties that require fewer inputs, or eliminate they completely.

Climate change adaptation: climate change is shifting growing conditions, and is of concern to today's consumers. The ability to rapidly alter plants to suit changing growing conditions will enable farmers to continue growing traditional crops, and/or successfully adopt new crops that are fit for their environments and consumers.

Improved Animal Welfare: gene editing may enable the breeding of animals that do not require human interventions that are currently being challenged by consumers (e.g., mulesing; antibiotic use).

Key Facts

Gene editing creates small, subtle, and precise changes to the DNA of plants and animals, bringing about changes to a gene or a gene group. Gene editing can mimic changes that occur in the natural processes of genetic variation. Therefore, it is impossible to detect whether a plant or animal has been breed traditionally, of through gene editing.

While similar at a high level, the critical differentiator between gene editing and genetic engineering (i.e., GMOs) is that gene editing does not incorporate foreign DNA into the genome.

Gene editing holds huge potential for agriculture, and could be a truly transformative technology. However, it is at high risk for backlash from consumers. In addition to general association with GMOs, and therefore a potential for negative perceptions, there are two critical concerns around gene editing. The first is around the ethics of creating animals or plants with novel features. The second is around 'gene drives,' and the potential impact on natural ecosystems (see perceptions section for more).

"Gene editing enables many different use cases that are aligned with consumer demands, as well as creates opportunities for new entrants [not just big companies] because of the faster speed and lower cost to enter."

- Agriculture Consultant and Sustainability Expert

"In the future we may be able to use gene editing to ensure our animals are fit for different current and future production systems. For example, we may be able to engineer sheep for use in robotic shearing."

- Livestock Geneticist

"There is a strong trend towards de-commoditized agriculture and more connection between farmers and consumers. Gene editing would drive and enable this for example, speciality wheat with higher protein. Farmers can be profitable and have identity preservation so they can get premiums, longer contracts, and profitably meet consumer demands."

- Agriculture Consultant and Sustainability Expert

Related Technologies

- Robotics and automation
- Synthetic biology[49]

Key Perceptions and Impacts

The science of genetic engineering is complicated, and can be conflated with genetic modification (GMOs) - a technology that is widely criticised- in the minds of consumers. Because of this, genetic engineering is at high risk of not being accepted by consumers. The agriculture community will need to gain consumers trust, both by advancing their understanding of this complicated science, and by proactively discussing the associated benefits.

In addition to education and communication, it is critical that local and/or international agreements (or regulations) be put in place to prevent the potential misuse of the technology. This is critically important with respect to consumer acceptance, as any such example would severely and negatively impact perceptions and stymie further development and commercialisation.

Barriers to Adoption

- **Consumer and activist backlash:** Consumers and activists who have rejected GMOs may similarly reject genetic engineering. If consumers and activists do resist genetic engineering as they did GMOs, widespread adoption will prove extremely challenging. Even without the association to GMOs, gene editing will be at high risk of rejection if consumers perceive it to increase the concentration of power within agri businesses. Given that genetic engineering can be lower cost and faster than existing techniques, it holds the potential to do the opposite (i.e.. allow new entrants, and distribute power). Consumers may be more likely to be receptive to the benefits of genetic engineering if they are delivered through companies without any previous negative reputation or association.
- **Regulatory constraints or limitations:** While Australia, China, and the United States have granted access to gene editing technologies, The European Union- which has banned GMOs and contributed to the global GMO backlash- has not granted access. If regulation creates significant financial barriers to entry, agricultural companies (compared to healthcare) will struggle to invest in the necessary research and development required to realise the potential benefits. Further, it is possible that new governance models will need to be developed to ensure control over, and access to, this technology[50].
- **Additional research:** For gene editing become widely adopted, more research and technology development must be done. One area of particular importance to agriculture is identifying genes that have a major effect on a trait of economic importance. In some cases we currently understand the relationship between genes and traits (e.g., eye colour in sheep), so gene editing can be applied; however, for many other traits, the true impacts of editing genes is unknown and must be researched before gene editing can be used to its full potential.

[48] World Economic Forum [49]Given the similar applications and technological complexity, there may be lessons learned or tools that can be leveraged between the two technologies. [50] This is of particular importance, according to the World Economic Forum, for smallholder farmers in developing countries.

Case Study 7.4

Gene Editing

Key Insights

There are still scientific hurdles to overcome before we can achieve the anticipated benefits of gene editing, and do so affordably and with significantly reduced development times. Further, effective regulatory/governance and registration processes are needed to ensure gene editing will have the intended broad impact.

Gene editing has huge potential benefits for the agriculture industry, and especially primary producers. However, given the perceived proximity to GMOs, there is a significant risk of consumer and activist backlash. Where gene editing use cases align with consumer desires (e.g., improved quality, taste) and/or help to alleviate areas of consumer concern (e.g., by reducing environmental impacts; improving animal welfare; distributing corporate power), these benefits should be communicated early and often to consumers. To avoid backlash, engaging in dialogue, including with activist groups, is critical. Another important tactic will be to monitor the reception of genetic engineering within the healthcare industry, and look to harness positive consumer perceptions where possible.

Gene editing can be truly transformative for agriculture globally, as well as in Australia. To achieve this, a proactive- rather than reactive- approach must be taken in terms of addressing potential concerns and cultivating conversations with diverse perspectives, both around science as well as ethics. Rather than wait to see if negative perception issues arise, we can instead proactively engage in dialogue and begin to identify and address potential concerns. There are many lessons to be learned- and mistakes to be avoided- from the example of GMOs, and gene editing especially can benefit from a careful study of this use case.

---

[48] World Economic Forum [49]Given the similar applications and technological complexity, there may be lessons learned or tools that can be leveraged between the two technologies. [50] This is of particular importance, according to the World Economic Forum, for smallholder farmers in developing countries.

7.5

Nano Materials Data

Summary

Nanomaterials are tiny - a nanometre (nm) is one billionth of a metre and nanoparticles have one or more dimensions in the order of 100 nm or less. So far, the main uses for nanomaterials are in medicine, environmental science, and food processing (e.g. additives and food contact materials). The potential of nanomaterials in agriculture lies in in improving seed germinations and growth, plant protections, pathogen detection and pesticide / herbicide residue detection are being explored. The targeted end result is ultimately increasing yields while minimising input costs, and providing environmental benefits.

Consumer perceptions around this technology are considered high risk, mostly around the unknown factors relating to environmental considerations and potential impact on humans.

Case Study 7.5

Nano Materials Data

Acceptance

Consumers: There is a lack of general knowledge about nanomaterials amongst consumers; however, the applications of nanomaterials mean that this technology is potentially going to be coupled with GMOs in the minds of consumers. Nanomaterials are therefore at high risk of backlash from consumers.

Nanomaterials though do hold potential to help align with positive consumer perceptions and provide significant potential to help reduce the amount of chemicals used in agriculture, particularly in cropping. The potential for recued input costs and improved environmental benefits are expected to help consumer acceptance perceptions in the longer term as this technology continues to evolve.

Farmers: The availability, quality and dissemination of data at an individual farm level that is robust and simple is still evolving. A critical issue for farmers is around ownership and security of data – farmers generally don't want to see third parties gain profits from their data. Understanding the value of data will be a critical area moving forward for all parties.

Key Perceptions and Impacts

Nanomaterials hold potential benefits around improved environmental outcomes with potential reduction in chemical use and animal welfare aspects relating to potential targeted releases of medication. However, these are complex issues with significant scientific research underway, and given consumer desires for "natural" products, coupled with concern around too much technical intervention, there is a need to clearly communicate benefits and proactively manage concerns.

A key theme with on farm adoption of Nanomaterials, like other technologies, is that it needs to be easily understood and also easy to use- otherwise adoption may be slow or even not taken up. Early engagement with farmers is a critical step in the pathway towards commercialisation.

Application and Benefit to Agriculture

Nanomaterials have great potential for agricultural applications due to their small size, high surface to volume ratio, and unique optical properties particularly in the areas of:

- **Sensors:** Nanomaterials with unique chemical, physical and mechanical properties have been developed and trialed highly sensitive bio-chemical sensors. These are of particular relevance for agriculture such as soil analysis and bio-chemical sensing and control (e.g. electrochemically active carbon nanotubes, nanofibers and fullerenes).
- **Fertilisers:** The development of nanofertilisers is being explored as research into fertilisers coated in nanoscale polymers are being shown to increase product stability and can control nutrient release from the granules. The potentially positive environmental impacts of this is significant and will assist in driving positive consumer sentiment.
- **Pesticides:** Nanomaterials are being developed as a tool for the sensing and remediation of pesticides with nanoparticles, nanotubes and nanocomposites being used for the detection, degradations and removal of pesticides. Again this is a key focus of nanomaterial development that will see the potential reduction of pesticide use and provide consumer benefits.
- **Animal Husbandry:** Nanomaterials have shown potential for use in targeted animal health products and as additives to stock feeds. Nanomaterial studies are also being utilised to provide opportunities to better regulate livestock growth and improve fertility while in other studies, antibiotic use is being reduced in food-producing animals as medicine can be administered at a target site and at a sustained rate.
- **Food Safety:** Nanomaterials are being utilised in food packaging with benefits to detect microbial contamination and potentially enhanced bioavailability of nutrients. Nanomaterials can also be used to develop nanoscale ingredients for improved nutrient and dietary supplements with additives such as vitamins, antimicrobials and antioxidants added for enhanced absorption and bioavailability. All of this is of significant consumer benefit.
- **Water Treatment:** Numerous studies have shown that nanomaterials can effectively remove various pollutants in water which has great potential for use in agriculture particularly with effluent reuse for irrigation or animal supply.

Key Facts

- Nanotechnology is global and widely accepted in other applications such as biotech, medicine and manufacturing, but still requires more research and funding for agriculture. There is an emerging body of research underway, as evidenced by both the rapid growth of the nanotech food market, as well as growing numbers of patents (there were 128 patents in 2016 alone in Australia)[51].
- It is predicted that the nanotechnology market focused on food industry will increase from 7 billion US dollars in 2015 to 20.4 billion US dollar in 2020 [52].
- A recent study found over 150 nanotechnology applications in the food industry at present, with some of the world's biggest companies (like Nestle, Kraft, Heinz and Unilever) involved in nanotechnology research and development [53]. [Nanotechnology in Agriculture and Food Production].
- There is significant research and development underway that is focused on using nanomaterials in farm production systems. A recent Australian example of this is the commercialisation of research that Associate Professor Neena Mitter is leading at the University of Queensland into the production of BioClay, a non-toxic, non GM, and biodegradable crop platform.

"The opportunity that Nanomaterials potentially provide in efficiency of production and added value with societal value via controlled chemical use is very exciting."

-Researcher

"Consumers are very conscious of environmental impacts relating to food production and this trend is increasingly important for all of agriculture to embrace. If Nanomaterials can help reduce reliance on chemicals then this will be beneficial to farmers, consumers and the environment."

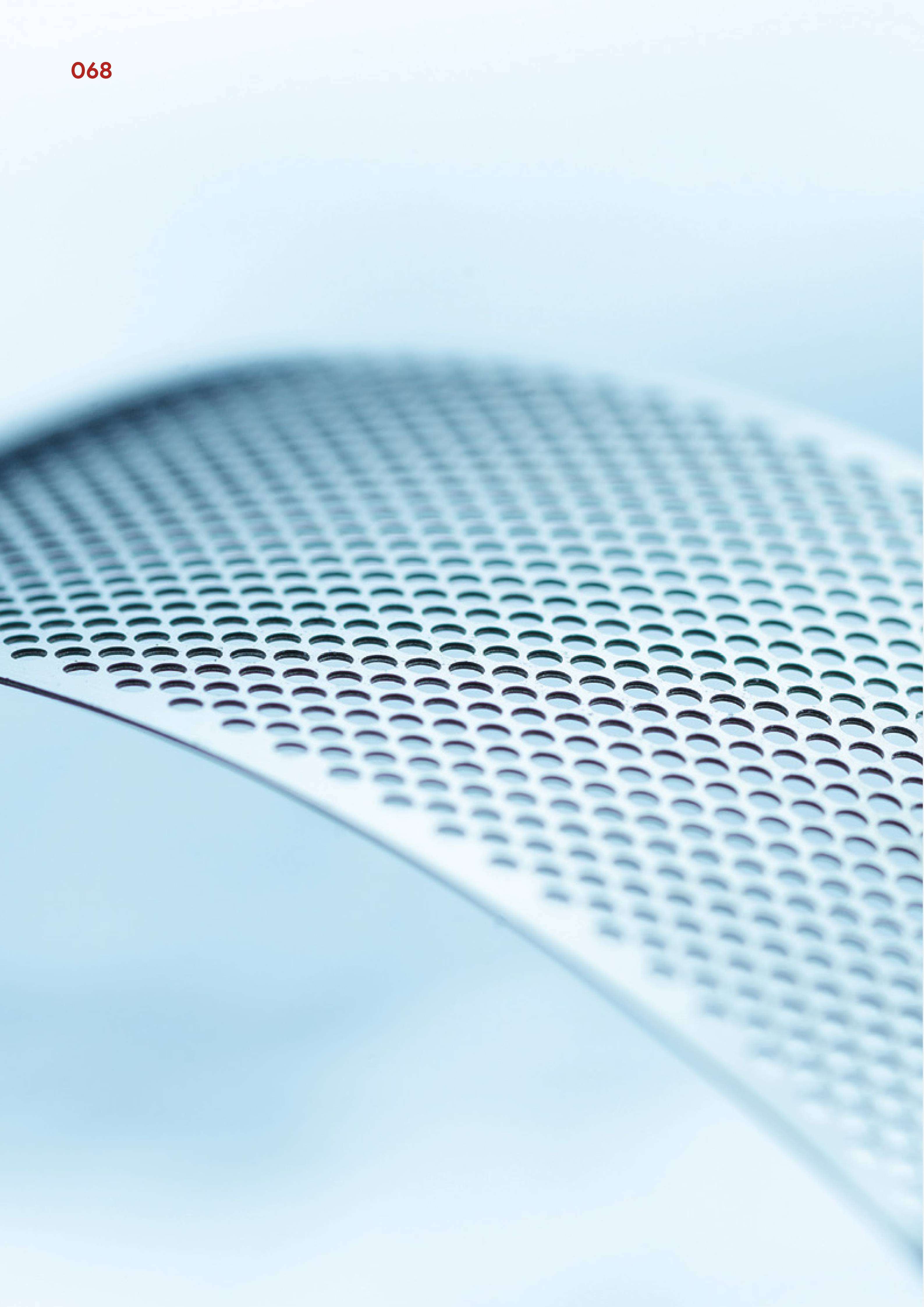
- Researcher

"The nanoscale dimension is similar to that of naturally occurring bio-molecules, which are effective in getting into the cells where they will work—but which also increases the risk for both the target animals and the environment. While the technology holds promise across a range of domains and applications, there are considerable technological and regulatory hurdles before we will see widespread implementation."

- CSIRO

Related Technologies

- AI and Smart Agricultural Practices
- IoT
- Sensors



Case Study 7.5

Nano Materials Data

Barriers to Adoption

- **Consumer backlash:** There have been public concerns about nanomaterials relating to food quality, and subsequent effects on human health and the environment. Nanomaterials, whilst widely used in other areas, are evolving in agriculture and significant levels of research and development are still proceeding.

- **Regulatory oversight and governance:** This point is reinforced by the Federal Department of Health which states on their website: "While many of the novel properties of nanomaterials may be beneficial, concerns have also been raised about the risks that these novel properties may present to human health, workplace safety and the environment. Assessment of the risks of any chemical (include its nano-forms) involves consideration not only of its hazards, but also its uses and consequently the exposure of people and the environment to the chemical. Research into the potential hazards of these materials is increasing, but is not yet comprehensive" 54

- **Additional research and development:** The level of research required for nanomaterials generally is quite extensive and the costs of development need to be borne with long lead times to develop more viable use cases. These lead times see the ability to use nanotechnology now in Agriculture as a little limited as the technology is still evolving

- **Education and capabilities:** Another barrier is the general level of farmer education and awareness around nanomaterials. Developing educational programs and support for necessary practices changes, where applicable, will take some time to develop. Bringing farmers along for the journey is very important to (a) explain the technology; (b) discuss the commercial benefits and (c) take the time to assist with testing and adoption.

Key Insights

The opportunities for use of nanomaterials is broad and has significant potential benefits to Agriculture. Taking the time, and providing the resources including capital, to undertake quality research is critical for the advancement of nanomaterials. Clear focus on education and awareness to explain the benefits to farmers of nanomaterial technology will also be a key area for commercial adoption.

Another opportunity for focus of nanomaterial research and development in Australia will be the potential export of approved technologies associated with nanomaterials – a potential benefit of this will be what can be used in Australia may be easily adopted internationally.

Regulatory considerations though relating to nanomaterials in Agriculture is an emerging area that will require a co-ordinated response. The key focus here is to ensure that stated benefits and nil impact with human consumption are clearly identified.

Considerations around labelling for products produced using nanomaterials is one example of the emerging landscape in this area. There is more testing that needs to be done but it is envisaged that consumers will be seeking clarity around food produced with nanomaterials.

Despite the volume of information about individual nanomaterials available, the toxicity level of many nanoparticles is still indefinable, thus the application of these materials is limited due to the lack of knowledge of risk assessments and understanding of the effects on human health. Development of comprehensive database and alarm system, as well as international cooperation for regulation and legislation are necessary for exploitation of this technology. [55] The early success of BioClay however provides an example of what is possible in this area of research and subsequent commercialisation.

Whilst there are huge potential benefits from nanomaterial use in agriculture there are still significant areas of research that are underway and should continue. The potential for negative consumer sentiment around nanomaterials is high and continued efforts in proactive dialogue between researchers, farmers and the broader community is encouraged. Conferences in nanomaterials internationally are emerging and Australian scientists have been sought after in these forums – efforts to promote their work in broader media channels may assist in these broader communications.

---

[51] AgriFutures [52] Nanotechnology in the food industy:'plenty of room' to innovate by Lorenzo Pastrana (INL) and Miguel Cerqueira 21 June 2017 [53] Nanotechnology in Agriculture and Food Production [54] https://www.nicnas.gov.au/chemical-information/Topics-of-interest2/subjects/nanomaterials-nanotechnology [55] Prasad, R., Bhattacharyya, A., & Nguyen, Q. D. (2017). Nanotechnology in Sustainable Agriculture: Recent Developments, Challenges, and Perspectives. Frontiers in Microbiology, 8, 1014. http://doi.org/10.3389/fmicb.2017.01014

7.6

Automation / Robotics

Summary

Robotics is the science and technology of mechanical, movable structures functional under some form of autonomous control. Robotic technology is being utilised with machines that can substitute for humans to increase efficiency or complete tasks deemed too dangerous, dull or impossible for humans, in industries such as logistics, mining, healthcare, military, manufacturing and agriculture.

In agriculture, the use of robots to complete tasks such as dairy milking, harvesting, spraying and surveying has replaced the need for human labour, and delivered benefits including higher quality of fresh produce and lower production costs. Robotics and automation technology also holds promise to provide growers with greater knowledge of the state of their operation, and the capability for acting in real-time to increase efficiency, reliability, and productivity whilst minimising environmental impact.

- The opportunity that robots afford to potentially make food cheaper with precision farming whilst simultaneously protecting the environment are positive outcomes from a consumer perspective. Equally though, the fear of industrialised agriculture and a move away from what is perceived as natural farming practices, may cause concern for consumers along with risk of job losses in regional areas. These concerns may evolve over the medium term.

Case Study 7.6

Automation / Robotics

Key Perceptions and Impacts

The rise of robotics and AI has received mixed public perception, as the development of the technology has historically been seen as a threat to jobs: 60% of people believe robotics will lead to fewer jobs within 10 years[56]. Although 53% do not trust robots to perform surgery, 49% do not trust robots to drive buses and 62% do not trust robots to fly commercial aircraft, 70% of people are in favour of robots to monitor crops in agriculture.[57]

Robotics will not only change the face of the agricultural workforce, but also the way farmers undertake operations. Farmers will need to be skilled in IT Systems and robotics maintenance and suppliers will need to be able to provide support services on a continuous basis. Farmers will also need to be skilled and up-skilled in computer operations and data analytics to support their physical management capabilities. These impacts have the potential to diversify farming skillsets to accommodate the technology, and potentially accommodate regional subject matter experts. Quality of life for farmers may improve as automation will save time for farmers, reducing pressure during peak periods and improving farm income by input savings.

Acceptance

Consumers potentially see three key aspects in accepting robotic technology in agriculture:

First, robotics can help make food cheaper and help improve environmental outcomes via the huge potential for mistake free production. The combination of robotics with other technologies that may reduce inputs like fertilisers and chemicals is also favourably viewed in terms of environmental management.

Second, tempered against this enthusiasm is the general fear of more agricultural industrialisation and robotics may bring this. Also it is perceived as less 'natural' and as such is an identified risk.

Third, the threat of job displacement, especially in regional areas, is real but may be balanced with more highly skilled jobs in select regional areas.

Farmers are in favour of balancing productivity gains with capital input costs, that potentially reduces the need for low-skilled workers. In general, the farming community can see the benefit of the technology to balance expensive labour that is often in in short supply, especially in remote locations. The opportunity for potential use of robots on farm, particularly in horticulture, is borne out in the 2018 Farm Workforce Survey that was carried out by the National Farmers' Federation (NFF). A key finding was the sector's workforce shortage; this was noted as industry wide. Equally two thirds of respondents rated labour concerns amongst the top three challenges expected to be faced in coming years. "Most farmers surveyed reported
a significant shortfall of skilled, semi-skilled, and unskilled workers during both peak and non-peak seasons, and substantial financial and productivity losses as a result of these shortfalls. The results also showed that the workforce needs of farmers can surge by as much as 500% during peak periods."[58]

Farmers are aware that robotics can be potentially working for longer, more precisely, and delivering environmental benefits via reduced inputs. There is concern, though, around ensuring that issues around safety and compliance are adhered to with robotics. This will be an evolving area.

Application and Benefit to Agriculture

- **Crop Management:** The use of robotics for tasks such as mowing, pruning, seeding and thinning crops will be of particular benefit to horticulture. For specialty crops in horticulture such as lettuce, broccoli, tomatoes and onion, robotic weeding is beginning to replace the need for hand-weeding which is slow and becoming increasingly more expensive. Developments in robotic weeding have the potential to cut the cost of weed control significantly.
- **Labour reduction and production improvements**
  - **Dairies:** Robotics used in dairies provide fully automated milking systems and reduce the need for labour in the dairy, such that it can be deployed elsewhere on farm. Installation of robotic dairies can contribute to an increase in milk production while the price of automated systems is moving towards being comparable to traditional rotary-style dairies.
  - **Cropping:** High speed planting technology that is evolving rapidly has the opportunity to combine with autonomous tractors and sensors along with management software to help lift crop yields by 70% by 2050[59]. As noted above, the developments in robotic weeding holds significant opportunity to reduce labour costs.

Case Study 7.6

Automation / Robotics

- **Autonomous** tractors: hold huge potential for diversification of production. For example, farmers that cannot expand into other crops or different production systems (e.g., organic) because of a lack of equipment currently, may be able to do so if/when current equipment business models are disrupted by smaller, autonomous (swarm, electric, etc.) equipment solutions.

- **Harvesting:** Currently being developed at an experimental level, the use of robots could be applied during the harvesting phase for crops, reducing labour costs for farmers and increasing efficiency while saving time. Although robotics for harvesting is still in a development stage, there is evidence that the technology is being utilised by greenhouse and vegetable growers[60] .

- **Manufacturing:** Utilising robotics during the food processing and packaging phases already improves the production line to create safer and more efficient conditions. Automation has traditionally benefited larger companies with products of high volume, long life or a single product. However with advancements in robotic technology, faster and more agile machines are completing more complicated tasks for a larger variety of products and at a reduced price which for smaller manufacturers, could come as a huge benefit.

Key Facts

- The market for agricultural robotics is rapidly growing, driven by global population growth, an increasing strain on food supply, the challenges, complexities and cost of farm labour, climate change, and the growth of indoor farming. Shipments of agricultural robots are predicted to significantly increase rising from 32,000 units in 2016 to 594,000 units in 2024, with the market reaching $74.1 billion in annual revenue[61].

- The development of artificial intelligence (AI) has accelerated robotic development as smart robots can now learn, process and adapt to the changing environment around them. AI- enabled robots that have the ability to share information and knowledge are assisting farmers in making better decisions. By combining historical data from farmers, and the data processed by farm machinery, machine learning is continuously improving decision-making, as machines learn the characteristics of each paddock over time and progressively refine information for automated and semi-automated farm management.

- One of the key features of robots is the ability to collect data, include information on yield, chemical use, soil data, livestock stress, and crop condition. Robotic technology has the potential to utilise many other technologies such as satellites and IoT to link live information in the field to data such as commodity prices, market demand and supply, and predicted weather patterns. By collecting and processing this field data, robots have the capability to help reduce operating costs associated with insecticides, herbicides and fertilisers by 40%.[62]

"If agriculture is to remain competitive into the future then labour requirements and precision agriculture are going to become more important. Robotics and automation are part of the answer."

Robotics Researcher

"Producers who are already using imagery see huge value in the autonomous robotic solution, because they've felt the pain of having to fly the drone, including costs, labour, and time."

Robotics Company

"Robots will change the business of farming as farmers may spend more time operating computers and analysing data rather than physically managing livestock or crop. Farmers will be required to gain additional expertise in maintaining robots and a high level of IT skills."

British Science Association

Related Technologies

- Drones
- AI
- Satellites
- IoT
- Sensors

Barriers to Adoption

- **Cost** - High cost of hardware and robotic smart technology pose as a restriction to agricultural uptake as limited access to capital for smaller farming enterprises has delayed adoption (as evidenced by the uptake of robotic dairies). The return on investment for farmers may also be lagged as machine learning robotics will need several years for data to create accurate decision making. The cost of failure is a perceived risk for farmers that may impact on enterprises yield, profit and potentially also reputation.
- **Education and capabilities** – There is a lack of technical expertise in the agricultural industry around this technology, particularly to assist in software and hardware development and maintenance. Skilled workers will be needed both to develop the technology and to manage it in the field. However, the requirement for this skill set may help attract a younger, more tech-savvy demographic into agriculture.
- **Complexity of technology** – There is resistance from farmers who may not be ready or want to install the technology. An ageing population in farming who is not easily adaptable to the scale of modern technology has the potential to slow adoption. Despite large investment and activity in the field, robotics development still has quite a long way to go to become of beneficial commercial use. The technology also needs to be supported by manufacturers and support service i.e. customer support, after sales service and help lines to ensure the adapted technology is being utilised to its full extent.
- **Worker displacement** – The negative perception that robots will replace humans in the workplace is restricting development as companies resist the need to lay off workers in favour of robots[63]. However, it is farmers who will ultimately choose how much of their farm will be robotised. Self-guiding agricultural machinery is already available however some machinery companies do not intend to give complete control of their equipment to autonomous vehicles, as they do not believe it is what the farmer wants.[64]
- **Ease of Adoption** – like other technology adoption on farm, there needs to be a simplicity to integrate into existing farming practices. Excessively hilly or rocky terrain may not be ideally suited to current robotic technologies and connectivity on farm for remote work is also a key issue.

Key Insights

Currently there are significant investments into research, development and commercialisation of robotic technology for agriculture that will have continued beneficial impacts in the areas of precision agriculture, and this is expected to evolve further in the short term.

Robotic adoption in agriculture will require farmers to rethink the way their farm operates, as autonomous systems will require more structured environments in order to facilitate efficient workflow. This issue of (a) capital investment into the technology and (b) set up of on farm systems to operate the technology are barriers to on farm adoption. However the need for time critical labour requirements, which remains a critical issue for farmers, and demonstrated control of inputs moving forward, will necessitate farmers to increasingly explore options with robotics.

The opportunity that robots offer for efficient farming practices may lead to improved production and potentially cheaper food for consumers. This may be tempered though by perceptions that perhaps only bigger companies benefit and consumers may push back because they fear more consolidated power and industrialisation of agricultural practices.

Equally, skill sets on the farm in the future will be required to operate and maintain the technology, or have ready access to support services / hubs that are able to provide an on-demand response to issues or problems as they arise. It would be expected that these support services and hubs will be located in regional centres as robotic operations turn agricultural enterprises into around the clock operations.

Robotics provide high potential to align with consumers' needs relating to quality production of produce that has positive environmental impacts. The highest potential benefit though, is for farmers themselves, with improved productivity that robotics provide,potential resolution of labour availability in remote areas, or for time critical intensive operations. From a perception viewpoint, robotics still pose a medium term risk owing to uptake barriers on farm and a perception at a consumer level that this represents an industrialisation of farming practices.

[56] British Science Association –[57] British Science Association –[58] 2018 Farm Workforce Survey carried out by the National Farmers' Federation (NFF) Workplace Relations & Legal Affairs Manager Ben Rogers –[59] Goldman Sachs 2014 –[60] https://asia.nikkei.com/Business/Trends/Robots-helping-to-keep-Japanese-farms-alive-and-thriving –[61] Tractica –[62] QUT, 2015 –[63] PWC –[64] https://www.weeklytimesnow.com.au/machine/crop-gear/driverless-tractors-future-of-robotic-farming-takes-shape/news-story/1c3593805e94346c353c7c929a94a6cc –

7.7

Synthetic Biology

Summary

Synthetic biology, a collaborative discipline that combines biology, genetics, chemistry, engineering and computer science, is the design or (re) construction of biological systems and machines. The potential applications for food and agriculture are tremendous, complicated, and not without controversy. Though applications of synthetic biology have the potential to enable producers to better meet the needs of consumers (e.g., reduced environmental impacts; improved food safety and reduced food fraud), given its technological complexity and perceived proximity to genetic modification (GMOs), it is at high risk of consumer and activist backlash.

There are both current and future potential commercial applications in food and agriculture. Current applications include: increased knowledge of how biological systems work (e.g., to support gene editing technology); and the development of lab-grown food (e.g., synthetic meat and milk) and fibre (e.g., synthetic clothing and footwear). The latter two applications have received very little push back from consumers[65]. Future applications include: crops with biosensors that alert producers and consumers to unwanted bacteria, or alert growers via drone imaging systems to crop stress well before any visible weed or pest pressure; and crops with re-engineered systems for nutrient uptake that will optimize nutrition and production outputs (e.g., amount, size, quality).

Before this future is realized, however, significant additional research must be done to determine if lab experiments can reach commercial scale, and to better understand the subsequent biological consequences. Consumer perceptions must be carefully monitored, as there is a high risk of backlash. In addition, an international system of policies, regulations, and intellectual property protection will need to be put in place to safeguard consumers, the environment, and investors. Finally, though many applications of synthetic biology will improve existing agricultural systems, other applications pose a clear threat to the current agriculture industry and should be closely monitored.

Case Study 7.7

Synthetic Biology

Acceptance

Consumers- synthetic food and fibre: though few synthetic-biology-created products in the plant-based and lab grown meat sectors are currently available, consumer demand is outpacing current supply and overall these products have had an extremely positive reception in the market. There are indications of geographical differences, however. According to survey data, US consumers are more likely to eat lab grown meat (40%) than UK consumers (18%)[66]. This is perhaps because the majority of product development in this space has happened in the US, so consumers may be more familiar with these products. One key driver of this acceptance is that the companies promoting these products are effectively and frequently emphasizing the environmental and climate change benefits over meat products. Currently, growth in demand for these products is limited primarily by cost; however, costs are dropping rapidly as the technology advances and companies achieve more scale. In fact, the cost to create a lab-grown burger has fallen from USD $325,000 in 2013 to $11.36 in 2017[67]. With costs continuing to drop, we can expect to see rapid uptake by consumers. Synthetic fibre is following a similar trajectory.

Consumers- other applications: synthetic biology has the potential to help the agriculture industry to meet consumer demands for high quality products, improved food safety, reduced environmental impacts, and improved animal welfare. However, given the proximity to GMOs, even these applications of synthetic biology face a high risk of consumer backlash. One area of promise is that Gen Z and millennial consumers are more likely than previous generations to adopt technologies where they provide positive social and/or environmental benefits.

Farmers- synthetic food and fibre: these products pose a significant risk to much of the conventional agriculture industry, including in Australia. Farmers are therefore resistant to the growth of these new industries.

Farmers- other applications: farmers are generally willing to adopt technology if it provides a commercial benefit. Applications such as bio pesticides, alternative inputs, solutions to antibiotic resistance, and new crop types will both provide commercial benefits to farmers, as well as align with consumer demands. However, awareness of this technology and its potential benefits for agriculture is low, given the relative immaturity of commercial applications.

Application and Benefit to Agriculture

- **The field of synthetic biology is rapidly evolving, with a broad range of potential use cases being explored. The applications for agriculture are vast, a sample of which are described below.**
- **New industries:** synthetic biology allows food and fibre products to be grown in lab environments. As the economics of these production systems improve, they will continue to gain market share. While this new food system will be disruptive to some conventional production systems, it may also open the ability for the existing soil-based agriculture food system to reimagine their operations to be more in line with consumer demands and, in some cases, premium prices. Producers may, for example, develop completely new ecologically and economically viable crop (food, fibre, and fuel) and livestock rotations, products, or value chains.
- **Decreasing or eliminating input costs:** with synthetic biology, we can develop crops that more efficiently utilize nutrients, both in soil and applied, as well as inherently resist pests and diseases via their genetics. This will reduce, or in some cases eliminate, input requirements for farmers. Also, advanced antimicrobials (e.g., that eradicate harmful bacteria, and spare beneficial bacteria) are being engineered, which may improve soil microbiome health, ultimately improving plant health and reducing the need for inputs.
- **Climate change resilience:** climate change is shifting growing conditions. Synthetic biology has the potential to allow us to design crops that rapidly adapt to changing growing conditions, even within a single season. This would dramatically increase farmer's resilience and continued ability to produce (e.g., by growing crops in semi-arid areas that previously have not been able to support this). Synthetic biology, through production of specialty crops and protein alternatives, also holds the potential to significantly reduce the greenhouse gas impact of agriculture. These applications are in alignment with consumer demands.
- **Improved supply chains:** through the development of biosensors that alert producers and processors to potential contaminants and quality issues, synthetic biology may significantly improve food quality and safety for end consumers, as well as enable farmers to verify when their products were (or were not) the culprit of an issue.

Key Facts

- According to BCC research, "the global market for synthetic biology will grow from nearly $4.4 billion in 2017 to $13.9 billion by 2022, with a compound annual growth rate (CAGR) of 26.0% for the period of 2017-2022."[68]
- Funding for synthetic biology companies has been increasing. In 2017 fifty-two companies raised over USD $1.8 billion (a 50% increase from 2016), and the industry continues to grow; as 27 companies raised $650 million in just Q1 2018[69].
- At its core, synthetic biology involves understanding living organisms at a molecular level, and using this knowledge to (re)design existing biological systems. The products that can be developed range from food and fibre (e.g., synthetic meat and clothing) to biochemicals and biofuels, to high value pharmaceuticals.
- Lab grown and plant-based meat are the most well-known commercial use cases amongst the consumer population, with popularity and acceptance increasingly rapidly. In fact, in July 2018 Air New Zealand began serving plant-based burgers from Impossible Foods, a company that uses synthetic biology to create a meat-like eating experience with plant ingredients[70]. Synthetic food and fibre applications pose a direct threat to conventional agriculture, and need to be carefully monitored.
- Synthetic biology as a science, and as applied to production agriculture, is rapidly evolving but still relatively commercially immature. Noteworthy potential applications include new bio-based pest and disease control measures, new crop types, and bio-based sensors for environmental and food monitoring.
- While the majority of potential applications align strongly with attributes consumers are seeking, given existing concerns with biological engineering and manipulation (e.g., GMOs), synthetic biology is at high risk of consumer and activist backlash. In particular, biosecurity, biosafety, and ethical concerns must be proactively discussed with a diverse group of stakeholders.

"Being able to more precisely control plant growth, for example, fruit production, [through use of synthetic biology techniques] makes for a more uniform product, improved efficiencies and much less wastage."

Dr. Claudia Vickers, University of Queensland's Australian Institute for Bioengineering and Nanotechnology[71]

"[Cellular meat] will be a part of the future- that is clear. The question is only around how much of the industry it will represent. Depending on who you ask, that ranges from 100% down to .05%."

Cellular agriculture expert

"The future is where conventional agriculture and new farming systems [such as cellular agriculture products] exist together to enable proliferation and consumer choices."

AgTech Investor

Related Technologies

- **Gene editing**- synthetic biology leverages principles gained from gene editing, and knowledge from synthetic biology can be applied back to gene editing and other biotechnology fields
- **Nanomaterials**- synthetic biology happens at the nanoscale
- **AI/Big Data**- advanced algorithms are needed to model and design biological systems
- **IoT**- Biosensors, created through synthetic biology, can become part of the IoT
- **Drones** - Biosensors, created through synthetic biology, can be deployed via drones

[65] In fact, most pushback has come from the agriculture industry, especially around product labelling. –[66] Surveygoo via Food Ingredients First –[67] Big Think –[68] BCC Research; Note that Markets and Markets predicts a value of USD $8.84b by 2022 –[69] SynBioBeta –[70] Press release here –[71] Synthetic Biology, Transformative Technologies. National Rural Issues. Australian Government. Rural Industries Research and Development Corporation. 2016. –

Case Study 8.7

Synthetic Biology

Key Perceptions and Impacts

There are potential applications for all industries, including fuel, food, fibre, manufacturing, cosmetics, and medicine. For the food and agriculture industry, lab grown food is the most visible and commercially funded application to date. The impacts of lab grown food on the current soil-based food system, should it become commercially viable at scale, will be far-reaching: it will introduce an entirely new food system that optimizes production to maximize economic benefits and minimize ecological impacts. The same is true for synthetic fibre products, which will compete with cotton, wool, leather and other natural fibres.

In addition to lab grown food and fibre, synthetic biology holds the potential to help agriculture meet consumer demands. For example, new or significantly altered biological systems, when possible at commercial scale, will further allow farmers to reduce or eliminate input usage, thereby aligning with consumers demands for more environmentally sustainable production systems.

Barriers to Adoption

- Consumer acceptance: though a growing subset of consumers are willing to accept synthetic food and fibre products (see key facts section), consumer acceptance of the broader applications of synthetic biology (i.e., changing a plant and animal biological systems) is much less certain. Fears around biosecurity applications, such as uncontrolled genetic changes, and biosafety use cases, such as uncontrolled release of products, are legitimate and more work is needed on all aspects of development, commercialisation, and governance. In addition, synthetic biology is likely to be grouped with genetic engineering and GMOs, and is at high risk of similar consumer and activist backlash.
- Farmer resistance: as described above, synthetic food and fibre applications will be in direct competition with existing production systems. Farmers are therefore likely to resist the commercialisation of these products.
- Scientific complexity: additional research into, and testing of, applications of this complex technology is required. In addition, tools, like CRISPR for gene editing, need to be developed to facilitate research and commercial application.
- Policy and Regulation: international policies and regulations need to be established to protect against biosecurity and biosafety breaches. In addition, the interdisciplinary nature of synthetic biology make intellectual property protection necessary, yet complicated.

Key Insights

Synthetic biology is a complex technology with a broad range of applications that are just starting to be understood and commercialised. While applications of synthetic biology largely align with consumer demands, especially around reducing the environmental impact of agriculture, it is at high risk for pushback from consumers. In addition to the proximating to GMOs, the complexity of synthetic biology, and the magnitude of its potential impacts, raises unique social and ethical issues about human interventions in natural systems that will need to be discussed globally.

If we are to continue seeing the commercialisation of technologies developed through synthetic biology, it will require significant investment in research, as naturally-occurring biological systems are extremely complex. Also, there will need to be international policy and regulations developed to prevent biosecurity, and biosafety breaches. In addition, to foster an investable environment for continued research, cross-disciplinary intellectual property controls must be put in place.

It is also important to note that while synthetic food and fibre products are likely to be accepted by consumers, they pose a threat to conventional agricultural systems. Opportunities will exist, and must be identified and explored proactively.

---

[65] In fact, most pushback has come from the agriculture industry, especially around product labelling. –[66] Surveygoo via Food Ingredients First –[67] Big Think –[68] BCC Research; Note that Markets and Markets predicts a value of USD $8.84b by 2022 –[69] SynBioBeta –[70] Press release here –[71] Synthetic Biology, Transformative Technologies. National Rural Issues. Australian Government. Rural Industries Research and Development Corporation. 2016. –

7.8

3D Printing

Summary

3D printing, also called additive manufacturing, is the processes of constructing a three dimensional object of almost any shape or geometry, using almost any material. In 3D printing, successive layers of material are built up in an additive way, using a computer aided design (CAD) file that specifies the desired object. Because 3D printing works directly from a computer model, shapes and designs can be produced with significantly more flexibility in regards to materials, volumes, and required manufacturing infrastructure (e.g., casting; machining).

3D printing has three main uses cases: rapid prototyping; faster, cheaper manufacturing of small runs of parts to eliminate the need for expensive tooling; and manufacturing of end-use parts at reduced costs. 3D printing has also enabled the establishment of innovative, small manufacturing companies, educational programs to expose students to manufacturing at low cost, and new business models such as manufacturing and prototyping as a service.

In terms of agriculture, 3D printing holds promise to change equipment supply chains by enabling on-site printing of parts; however, commercial applications in agriculture do not yet exist. Barriers to adoption in agriculture include lack of skills, and the overall nascence of the technology.

Case Study 8.8

3D Printing

Acceptance

Consumers - there is no indication that 3D printing is aligned with negative consumer perception attributes. However, it is important to note that 3D printing, especially when combined with robotics/automation and artificial intelligence (AI), may contribute to a reduced workforce. Where 3D printing enables new jobs to be created (e.g., in regional logistics or materials warehouses), this benefit should be highlighted to consumers. Additionally, as noted above, some emerging 3D printing applications hold potential to align with positive consumer perception attributes, especially around environmental benefits (e.g., reduced carbon footprint of supply chains) and health/convenience (e.g., 3D printed personalized nutrition products). As the technology develops, highlighting these potential benefits for consumers is critical.

Farmers - though on-farm uses cases are not yet commercially available, farmers are likely to be willing to adopt this technology if it reduces their costs and/or allows business diversification. Currently, however, awareness of this technology and its potential for agriculture is likely to be low amongst the farming population, given the lack of practical use cases at this time. One application that is likely to be positively perceived by farmers is the entrance of new equipment suppliers that may support a diversification of crop types or operational models, or just reduce costs due to increased competition.

Application and Benefit to Agriculture

- **Diversified production:** 3D printing reduces the cost and time required to design and manufacture equipment, which, if adopted widely in agriculture, could increase the number of small to medium size equipment manufacturers. More diversity in the equipment supply chain will increase the development and commercialisation, at scale, of equipment to support a wider variety of crop types and farming operations. This has the potential to support economically-viable diversification in cropping operations, as well specialized production and new markets for livestock.
- **Decreased costs:** the ability to locally print and distribute parts, on demand, will alleviate downtime, as well as reduce overhead costs. Further, this creates an opportunity to recycle parts, or even waste products, by printing them into other parts or products. If a link to improved environmental outcomes can be drawn, this should be highlighted, as it aligns with what consumers are looking for.
- **Improved supply chains:** on-site 3D printing will shorten equipment and parts supply chains from global to local production, thereby reducing the carbon footprint and ensuring parts are available on-demand. For example, farmers may be able to 3D print parts for their tractor, or even 3D print an entire machine (e.g., drone) without leaving their farm. This is likely to be perceived positively by consumers.
- **Research and Education:** the prototyping capabilities enabled by 3D printing create opportunities for advancements in agricultural research (e.g., 3D soil modelling) and education (e.g., STEM opportunities for children, at low cost). 3D printing could potentially be used to create models that allow farmers to show consumers their operations, thereby providing transparency; however, this application does not yet exist.
- **New Industries:** 3D printing may be especially applicable for protected cropping, vertical farming, and other forms of indoor farming as it may enable the cost-effective printing of small, precise parts. 3D printing can also be used to print food products, and holds potential to change how and what consumers eat. For example, 3D printing may advance the personalised nutrition industry (i.e., creating products tailored to the dietary needs of individual consumers).

Case Study 8.8
3D Printing

Key Facts

- The global 3D printing industry grew 21% from 2016 to 2017, and is estimated at USD $7.336 billion in 2018.[72]
- The main industries currently applying 3D printing are medical products and aerospace, followed by automotive equipment and consumer products. In aerospace, Boeing is a pioneer in 3D printing, trialling hundreds of 3D printed parts in their Dreamliner aircraft.
- While agricultural engineers currently use 3D printing to rapidly develop low cost prototypes of new parts, the agriculture industry is not currently one of the main sectors using, or driving the development of, 3D printing.
- 3D printing is currently limited to specific materials, but there is active work to broaden the range of materials that can be used, therefore expanding the number of potential use cases across industries.
- Regulations and standards will need to be developed for 3D printing. Global leaders in the development of product standards, ASTM International and ISO, have formed the Committee F42 to address this situation. The committee is chartered with creating and publishing the test methods needed to validate 3D printed components and parts.

"3D printing is advancing quickly, but appears to be more sophisticated in other industries like the airline industries where big players are engaged."

Technical Expert

"3D printing is all materials based, that's where the real science is. Everyone is looking for more options for materials, and options that can be used on cheaper printers. The challenge is getting the materials to act a certain way in and after the printer."

Mechanical Design Engineering Expert from major 3D printer manufacturer

Related Technologies

- IoT
- Artificial Intelligence

Key Perceptions and Impacts

3D printing is not strongly related to either positive or negative consumer perception attributes, largely because it is not commercially available in agriculture, meaning specific applications are not yet clear. The most commonly discussed use cases do, however, align with positive consumer perception attributes, including: (1) shortening supply chains or otherwise reducing the carbon footprint of food production; (2) diverting waste by printing waste into valuable products; or (3) enabling the creation and/or delivery of healthy, convenient, sustainable, or engaging 3D-printed food products.

Barriers to Adoption

- **Trust and Safety** - users of 3D printing parts must develop confidence in the mechanical strength of the part, and in the software and hardware technologies governing the specifications of the design.
- **Learning curve** - widespread adoption of 3D printing will require new mental models for how products are developed, manufactured, and brought to market. Older generations who are accustomed to traditional manufacturing techniques and processes may be resistant to 3D printing and rapid prototyping methodologies, and/or may lack training in the required skills.
- **Skills** - use cases for 3D printing in agriculture are still embryonic, and largely have not been tested commercially. Achieving widespread adoption in agriculture will require a workforce with skills in software, design, manufacturing, and prototyping.
- **Cost** - the cost of 3D printers and relevant materials is expected to decline following, like many other technological innovations, Moore's law. The pace at which this happens will determine significance of this barrier to adoption in agriculture.
- **Materials** - as additional materials are able to be used affordably and effectively in 3D printers, more applications and end products will be available across industries, including agriculture.
- **Regulations** - to support the widespread adoption of 3D printing, there will need to be regulations to address intellectual property, as well as consumer and public safety. For example, regulations to ensure there are safety standards in place for when parts are printed and used in industrial equipment capacities will be critical.

Key Insights

3D printing is an emerging technology, and while there are commercial applications in some industries, its place in agriculture is yet to be established. The technology holds promise to improve the process of design and prototyping, especially for equipment, and can enable the cost-effective creation of new industries (e.g., indoor farming, personalised nutrition) and products (e.g., drones that can be printed and assembled on farm).

Where applications of 3D printing align with positive consumer attributes- especially reduced environmental impacts, transparency, and healthy and convenient products- these benefits should be proactively communicated to consumers.

Risks of consumer pushback are low for 3D printing; however, both farmers and consumers are likely to be concerned about unemployment, especially in regional areas, due to technologies replacing humans. Of course, 3D printing may equally create jobs, for example by introducing competition in the equipment space.

To encourage the adoption of 3D printing in agriculture, it will be important to balance commercial incentives with worker capabilities and skills. In addition, intellectual property laws and regulations, including design rights, trademarks, copyright and patents, need to be addressed copying or counterfeiting of objects using 3D printing may occur.

[72] Wohlers 2018 3D printing report, available here: http://wohlersassociates.com/2018report.htm

7.9

Satellites

Summary

Satellite technology assists farming management via observing, measuring and responding to inter and intra-field variability. Global Navigation Satellite Systems (GNSS) technology has provided huge benefits to agriculture with Australia leading the world in high precision Global Positioning Systems (GPS). This has also evolved into the development of auto-steer guidance technology for tractors. Since then, precision agriculture and satellite technology has matured to include practices such as variable rate technology (VRT), yield mapping, topographic mapping and soil data analytics. Farmers can now access real-time data about how their farm is operating, enabling more informed and precise decisions.

There is potential for satellite technology to enable new solutions such as estimating crop yield from satellite data through measuring vegetation growth and health at different stages of the crops life and with increased spatial resolution. Estimating yield has the potential to help growers make better informed and earlier crop decisions, and to increase the lead time of crop yield forecast and knowledge of changing supply and price trends.

Case Study 7.9

Satellites

Acceptance

Consumers are demanding more information about the produce they consume, and satellites will assist in securing information and demonstrating that the natural environment is being cared for. Consumers are becoming more mindful of the environmental footprint of their food and satellite technology can be used for compliance, marketing and assurance.

Farmer's acceptance of satellite and precision agriculture technologies is growing, particularly in Australia, where there is an increasing focus towards achieving higher efficiency. However, compared to the traditional farm consultant, farmers are wary of new digital service providers using their information for their own benefit and with value not returning to the farm. Secondly, with the continued advancements in satellite technology, adoption by farmers will only occur if the technology is of value
and is easy to implement and use.

Application and Benefit to Agriculture

- **Data Collection:** satellite technology enables farmers to gather soil and crop condition information about specific fields, including nutrient levels and information about previous crops. Such information, when processed and presented, can assist farmers in making decisions about variations in fertiliser, chemical, and water applications. Satellites can also assist in providing information on potential yields, soil types, crop or soil colour index maps, soil types and electromagnetic soil mapping.
- **Environmental Protection:** precision agriculture and satellites hold potential to reduce the environmental risks and footprint of farming by limiting fertiliser and chemical runoff through enabling decisions about more efficient applications. For example, VRT for nutrient application directly contributes to lowered emissions, with studies showing the technology can reduce fertiliser use 10-30%, while maintaining the same productivity[73].
- **Connectivity:** increasingly, satellites will enable connectivity within remote and regional areas.
- **Service Providers:** financiers and insurance agencies may increasingly rely on satellite imagery for provision of services to agriculture. With climate change looking like it will increasingly affect agricultural operations, insurance companies are utilising the technology to enable farmers a fair and immediate compensation for crop loss due to weather events.[74]

Key Facts

- Adoption rates of satellite technology in cropping operations in Australia are amongst the highest in the world, with 80% of crop farmers in a recent study claiming they use auto steer and another 30% create yield maps using GNSS.
- Global precision agriculture market reached a value of US$ 4.8 billion in 2017 with suggestions it will reach US$ 10.0 billion by 2023. This is being driving by advancements in cloud-based technology, rising use of smart phones, environmental conservation and the expanding application of navigation systems[75].
- The importance of satellite technology is clearly evident with the current Federal Government push for the development of an Australian Space Agency, and allocation of $260 million in the 2018 Federal Budget to develop satellite technology that will assist agriculture. This is approximately broken down via (a) $160.9 million to deliver a Satellite-Based Augmentation System (SBAS) (the technology underpinning GPS), (b) $64 million investment in the National Positioning Infrastructure Capability (NPIC) complementing SBAS to improve GPS to an accuracy as precise as 3 cm; and (c) $36.9 million for Digital Earth Australia.
- Currently there are circa 80 earth observations / spatial data start-ups in Australia[76] and the recent establishment of the Australian Space Agency should help the industry develop globally competitive capabilities. However, there is concern that this number of organisations could use better coordination moving forward to avoid duplication of work and resources.

Key Perceptions and Impacts

Satellite imagery is rapidly becoming better, more accessible, and cost effective to the point where it may replace other remote monitoring systems that are in place. Importantly it may also completely change the data privacy conversation moving forward, if it is possible for anyone to get an image to the precision of a couple square centimetres. On a farmer's paddock, issues around privacy, security and data ownership will come to the fore.

Australia has enjoyed a distinct advantage in the area of satellites with no sovereign capability in space. A key to this success has been Australia's ability to manage multiple collaborations with other countries (e.g. NASA in the US, Europe, Japan). The opportunity for Australia now to develop its own capability is timely and should allow Australia to maintain market leadership, especially in Agriculture. With the formation of the Australian Space Agency, formed in July 2018 with a goal of tripling Australia's space economy by 2030, Australia is now better positioned to be a part of an industry worth over $400 billion, with enormous economic and community multipliers[77].

The current and potential impact of satellites on Agriculture are wide ranging, especially in the areas of:

- increased communication efficiency
- producing high resolution / high frequency imagery
- collecting data that can be used in estimating production values
- collecting data to assist with maintaining optimal stocking rates in livestock operations
- optimisation of fertiliser and water applications or identifying areas of poor drainage

"Increasingly there will be a need to derive more value from the land and that means choices are required and satellites can assist in decision making processes."

Satellites Expert

"The role of Government in facilitating satellite technology needs to be better understood at a consumer level. Satellites are expensive and the return on investment and cost recovery is a long lead time."

Satellites Expert

"Satellite technology's importance to precision agriculture is to produce more efficient outcomes for farmers."

Technology Developer

"The ability for farmers to keep reducing costs in an increasing era of compliance and regulatory requirements will become limited. As a result tech development needs to focus on how to assist farmers make more money via improved yields and prices."

Satellites Expert

Related Technologies

- IoT
- Big Data
- Artificial Intelligence
- Robotics
- Drones

Barriers to Adoption

- **Costs:** costs associated with the construction of devices and the cost of launching devices have historically restricted development and uptake of satellite technology. This has, however, changed in recent years with the reduction of construction costs and the introduction of nano-satellites. In fact, some companies are even making it possible to send satellites into orbit for as little as $295,000, compared to a few years ago when it would cost in excess of $2 million.[78]
- **Signal Reliability:** unreliable signals pose a barrier, as signal strength and reception may cause outages and impair operations. Threats such as bad weather and sunspots, which are unavoidable, also pose a risk to the technology along with general connectivity in regional and remote areas. Many Australian farm businesses are restricted to operating with broadband connections that are slower, more costly and less reliable than those available in other nations that compete for similar agricultural export market opportunities. As a result, many farmers may resist adopting precision agriculture technologies, including satellite imagery.

Case Study 7.9

Satellites

- **Resolution:** satellite imagery for agriculture has a limited spectral resolution. Therefore, it lacks the resolution required for many quantitative remote sensing applications. Minimum-area requirements make satellites more suited to large-scale operations as orders for imagery are often at least 100 to 1000 sq. km per order. Satellites are also limited in providing on demand imagery, particularly of high resolution, and are vulnerable to limitations on visibility (e.g., clouds). Compared to drone imagery that can provide a far higher resolution on demand, satellite technology requires additional development to stay competitive.
- **Data Quality:** existing farm-level data may have insufficient spatial resolution, or be of too low frequency, for viable farm use. Farmers also face problems in utilising historic data with current imagery, as many systems (over time) are upgraded or changed, thereby undermining quality. Value from the technology is gained over time by combining various sources of data and this is problematic for farmers if data are kept in different formats and metrics or if there are slight changes in geographic coordinates.
- **Personnel:** traditionally, the operation, maintenance and analysis of information attached to satellite technology has rested with Government / Government Agencies who have held the resources and talent. Evidence of emerging talent in the Private Sector to complement this and allocation of funds within the Australian Space Agency is also designed to stimulate private investment, but this will take some time to evolve.

Key Insights

Consumers will continue to demand more information about the produce they consume. Satellites can help collect the data needed to demonstrate specific information relating to consumer demands, including providing paddock-by-paddock evidence that the natural environment is being cared for.

There may be an opportunity via local government (i.e., Councils and LGA's) to play a role in encouraging and/or facilitating satellite usage via expansion of the current Smart Cities Program into a Smart Regions program[79] This trend appears to be emerging in the US and Europe, and might benefit both the cities and towns in the region whilst at the same time provide tangible benefit to the regional areas that support production based agriculture via improved connectivity.

Satellites can collect data, as well as enable the collection and transmission of data from other sensors, to enable farmers to make data-driven management decisions. These data may also be used for compliance and marketing, helping farmers demonstrate their practices to consumers. More efficient farming practices will enable farmers to boost productivity and enhance cost savings via maximising their ability to cover wide areas in a timely manner[80].

Australia has an enviable position as a global leader in satellite use in Agriculture and this can continue with current Government support targeted at this technology and supported by sovereign capability.This is expected to also continue to stimulate appetite and demand for private entities to be involved in this technology and further general uptake in agriculture.

[73] Future Farming, 2018 –[74] FAO, 2017 –[75] IMARC Group, 2018, Precision Agriculture Market: Global Industry Trends, Share, Size, Growth, Opportunity and Forecast 2018-2023 –[76] Sourced from consultation with Satellite industry subject expert –[77] Spatial Source, 2018 –[78] CB Insights, 2017 –[79] https://cities.infrastructure.gov.au/smart-cities-program –[80] USDA Economic Research Service, 2017

7.10

Drones

Summary

A drone is defined as an unmanned, radio-controlled aircraft that can be operated remotely, or autonomously, through software-managed flight plans in their embedded systems of onboard sensors and GPS. There are different types of drones, though the most common in agriculture is aerial drones, including fixed wing, rotor and hybrid systems. For aerial drones, the following terms are used interchangeably: drone, UAV (Unmanned Aerial Vehicle), UAS (Unmanned Aerial Systems), and RPA/S (Remotely Piloted Aircraft / Systems)[81].

Case Study 7.10

Drones

Key Perceptions and Impacts

As the use of drones has historically been imbedded in a military sense, drones were seen in quite a negative light. Since their emergence for use in the consumer market, drone-related coverage in the media has been wide ranging; from reported in-flight near misses, to more positive profiles of how drones have helped preparation and recovery from natural disasters[82]. In a study by the Civil Aviation Authority for the UK on public perception of drones, it was found that 24% of respondents had a positive perception of the technology while 27% cited they had a more negative perception. Results from the study also showed that 48% of respondents found the technology 'unregulated' while another 45% see it as 'dangerous'. However for agriculture, 58% of respondents had positive outlook for drone use in the industry, compared to 40% who responded in the negativ[83] .

There is a real opportunity for continued collaboration between tech companies and the agricultural industry to encourage positive relationships. Farmers that are adopting drone technology are harnessing the ability to capture high value/resolution images and, with the assistance of support services, utilise this to translate into meaningful information that supports decision making. There is also an opportunity for drones to assist in livestock and crop management, including monitoring and mustering, as it can provide timely services around crop inspection, watering points and fence inspections, as well as ancillary services such as property valuation inspections and insurance assessments.

Acceptance

Consumers: a common consumer perception is that drones are only used for (a) military purposes or (b) toys for enjoyment (e.g., capturing images for fun). However, there is growing awareness of potential alternative uses, such as delivery vehicles in metropolitan areas. Public trust in the technology does pose an issue, including fear of malfunctions. Concerns around intentional misuse have also shaped the new social perception of drones and this is reflected in Civil Aviation Safety Authority (CASA) guidelines for use[84]. In agriculture, consumers are demanding transparency in the food system and that the food they are consuming is produced with minimal environmental footprint, both of which drones can assist in.

Farmers: initial applications for drones within agriculture produced a lot of hype, particularly from off-shore retailers where there were big promises around potential benefits to farmers, but with limited actual returns. The rise of these perception issues has required drone companies to re-evaluate their value propositions and marketing strategies in hopes of rebuilding confidence in drones. Increasingly, farmers are seeing the benefit of drones from proven service providers (who are licensed and certified by CASA). Producers are needing to continually demonstrate environmental stewardship through decreased fertiliser, chemical and water use, and drones are able to assist in variable rate applications to increase efficiency, especially when linked to other technologies.

Application and Benefit to Agriculture

Through instant data gathering and processing, drones have the potential to help agriculture in the following ways:

- **Soil and Field Analyses:** Drones have the capability to produce precise maps for soil analysis in pre-planting, and further analysis for irrigation application, fertiliser and chemical requirements. Using normalized difference vegetation index (NDVI), a mapping method that identifies whether an area contains live green vegetation, data from drones can be applied to gridded management maps, where information can be used within variable rate systems for sowing, spraying and other management operations.
- **Crop Spraying:** With automated distance-measuring equipment, drones can scan the ground and spray the correct amount of chemicals with increased efficiency and decreased environmental impacts. This targeted spraying of chemicals is a key beneficial feature of drones, as it reduces input costs and provides positive environmental outcomes such as a decrease in chemical and artificial fertiliser use.
- **Health Assessment:** Drones can be used to provide high resolution imagery to show detailed crop development and reveal crop health and spot bacterial or fungal infection on trees. By scanning a crop using both visible and near-infrared light, drone-carried devices can identify which plants reflect different amounts of green light and NIR light. This information can produce multispectral images that track changes in plants and indicate their health. Farmers can therefore monitor crops for disease and in the case of damaging weather events, document losses more efficiently for insurance claims.85

- **Livestock Monitoring:** Drones can be used to monitor livestock remotely and potentially improve profits via timely monitoring, negating the need for physical inspections. Drone operators can check in on livestock to monitor injuries, birthing, or to ensure none are missing.
- **Irrigation:** Drones with hyperspectral, multispectral and thermal sensors can be used to inspect fields for moisture deficiencies and to calculate vegetation index / heat signatures. This information can then be used by farmers to make more efficient adjustments to irrigation operations that focus on specific areas that are moisture deficient.

As the technology around drones evolves, farmers will increasingly use their own drones and collect their own data, thereby enabling beneficial outcomes around timeliness of decision making as it is possible to launch a drone quickly, compared with satellite technology that may take a day to process imagery. This will also assist farmers in managing their properties in a sustainable fashion with a focus on conservation practices around soil and water resources which consumers are increasingly demanding.

Key Facts

- With changes in regulation to allow for drone industry growth, total drone unit sales was expected to climb to 3 million worldwide in 2017, up by 39% from 2016. Total revenue in 2017 reached over $6 billion and this figure is expected to increase to more than $11.2 billion by 2020. Although the drone market is still heavily dominated by the military, the commercial and personal side is growing at a compound annual growth rate of 19% by 2020, as opposed to 5% in military[86].
- A recent report and survey by Frontiers SI[87] found that the most significant feature of interest in agriculture relating to drones are crops, with 83% of users declaring an interest in using the technology for crop related operations. Farmers and farm managers are also interested in vegetation mapping (47%), pipelines (17%), dam monitoring (17%), water (13%) and tree monitoring (10%). Furthermore, it was mentioned that data about pests and weeds help with effective control strategies[88].
- Of interest was that the Frontiers SI project also found that currently, the average project size in most agriculture applications is 2 km sq. or smaller. While 89% of responses indicated this, a few participants (11%) highlighted area sizes of between 5 and 10 km sq. while another 11% highlighted area sizes of between 2 and 5 km sq. As expected, this correlates with farm size.
- Stakeholders both inside and outside of the top Drone companies globally have been able to demonstrate the real and future value of this technology, and a focal point now appears to be evolving partnerships between drone companies and software providers[89].

“Technology’s importance to precision agriculture to will be to produce more efficient outcomes for farmers.”

Drone Operator

“Environmental benefits are just as important as economic benefits. By providing the farmer information to make more efficient decisions (less water and chemical use), drones deliver economic and environmental benefit”

Drone Operator

“Drones are not just for on farm production activities but increasingly will be used for ancillary services attached to the farming activity required by third parties such as financiers, valuers and insurance requirements”

Drone Expert

Related Technologies

- Remote sensing, including satellites
- Big Data, especially around multi – spectral imagery
- AI / Automation for long range flights

Case Study 7.10

Drones

Barriers to Adoption

- **Connectivity** – drone technology is not effective if unable to transfer information quickly and in remote or regional areas, this can be a problem due to limited connectivity infrastructure.
- **Ease of use** – Licensing and operating challenges laid down by CASA requirements can make operating drones on a larger scale or in remote locations difficult. Whilst this may be potentially solved via remote command centres to allow drone operations to move beyond line of sight, at present this is not allowed. The required labour to operate drones may also present a barrier, as the technology is currently too complex for most farm operators to fully utilise. Instead, there will be demand in regional centres for more drone operators and service companies.
- **Security** – there are questions around whether the farmer or service provider own the information. This also relates to Big Data and some of the algorithms that will evolve with the evolution of data that is collected and utilised.
- **Data vs. decision making**- bulk data do not really have value for farmers, and some farmers / agronomists/ advisors may not have capabilities needed to analyse the data themselves. If farmers are utilising their own data, they may potentially need assistance with analytics and whilst service providers will be able to assist and assess in a meaningful way, this will be balanced around the cost of the service.
- **Technological development:** drone technology is still limited to smaller scaled operations and further development is needed to accommodate large area coverage of Australian farms. However, this will evolve with improved battery life of the drones and interplay with satellite technology.
- **Cost:** the cost of operating drones to operate and cover over large areas. Farmers will need to see a return on the investment of the new technology and balance the costs of managing, storing and processing large datasets in a user friendly and meaningful way.

Key Insights

While some farmers are seeing value from drones, key barriers remain (e.g., labour required, costs, utility of imagery, data analysis, connectivity and scale of use), but these are starting to melt away as drone use increasingly interplays with other technologies such as satellites,
AI and robotics.

One use case that is commonly seen is using drones for fun and to capture imagery for use in marketing or social media. Whilst this has benefit in marketing activities there could be an explosion of brands and farmers will need to exercise caution relating to the cost and development of individual brands that may be using drone footage to promote their brand and be diluted in a broader market.

The scale of area that drones can currently cover is limited by battery life of the drone and regulatory requirements around how far they can fly. Whilst there is evidence of service providers being able to cover areas up to 600 ha this appears to be the limit of current capability and broader coverage in remote locations will eventually be required.

Environmental benefits are just as important as economic benefits. By providing farmers with information to make more informed, precise decisions (e.g., chemical usage), drones can help deliver economic and environmental benefits. Increasingly this may be demanded by financiers and consumers who require evidence of natural resource management.

Transparency / trust is vital to overcome barriers (data ownership, negative perceptions, the use of technology to solve a problem and add direct value to farmer) and enhanced value propositions are needed to maintain trust between tech companies and farmers. Advisors have a key role to play here in encouraging ongoing engagement.

Development of other technologies (e.g., enhanced sensors, autonomous drones, algorithms to analyse multiple sources) will evolve and farmers will increasingly need to be aware that service providers will be using drones to monitor activity such as financiers, insurance and valuations. The question as to whether these entities require permission to undertake a drone pass over a selected property at any time, with associated liability provisions in the event that there is a malfunction or collision with another drone,
is an area for further consideration.

---

[81] http://www.crcsi.com.au/ –[82] Apvrille, Ludovic & Tanzi, (2014), Autonomous Drones for Assisting Rescue Services within the context of Natural Disasters –[83] Civil Aviation Authority UK, 2016, Consumer Drone Users: An audience insight report –[84] https://www.legislation.gov.au/Details/F2017C00742 –[85] PWC, 2016, PWC global report on the commercial application of drone technology –[86] Business Insider, 2017 –[87] Frontiers SI UAV Data Acquisition in Australia and New Zealand User Needs Report. Dr Sam Amirebrahimi, Dr Nathan Quadros, Dr Isabel Coppa, Jessica Keysers August 2018 –[88] Frontiers SI UAV Data Acquisition in Australia and New Zealand User Needs Report. Dr Sam Amirebrahimi, Dr Nathan Quadros, Dr Isabel Coppa, Jessica Keysers August 2018 –[89] https://www.droneii.com/ –

Disclaimer

This report: has been prepared by GHD for AgriFutures and may only be used and relied on by AgriFutures for the purpose agreed between GHD and the AgriFutures as set out in the Introduction of this report.

GHD otherwise disclaims responsibility to any person other than AgriFutures arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by AgriFutures and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

Appendix

Companies that are active in this space.

This list is not an exhaustive list of entities engaged in these technologies, but represents a sense of the current depth and breadth of activity in these areas:

Blockchain

Australia	International
AgriDigital	ING – Easy Trading Connect
AgUnity	UPS - Blockchain in Transport Alliance (USA)
FlashFX	Agriledger (UK)
Beef Ledger	Everledger (UK)
Othera	Ripe.io (USA)
Everledger	Filament (USA)
Provenance	IBM (USA)
	SkuChain (USA)
	Walmart (USA)
	FarmShare (USA)
	Origin Trail (Slovenia)

Big Data

Australia	International
KG2	Monsandto (USA)
AgDNA	FarmLogs (USA)
Hewlett Packard Enterprise	Benson Hill Biosystems
	AWhere (USA)
	DuPont Pioneer (USA)
	Iteris (USA)
	Granular (USA)
	Farmers Edge
	Farmers Business Network (USA)
	Climate Corp

Nanomaterials

Australia	International
BioClay	Gingko Bioworks (USA)
	Covestro (Germany)
	Zymergen (USA)

Drones

Australia	International
Australian UAV	DJI Innovations
Measure Australia	AeroVironment
Agronomeye	Parrot
	SenseFly
	Zipline
	Yuneec

Satellites

Australia	International
CRCSI / Frontiers SI	NASA
Geoimage	Satellite Imaging Corporation
Bureau of Meteorology	John Deere
Satamap	European Space Agency
Precision Agriculture	CaseIH
Myriota	
DataFarming	

Robotics

Australia	International
Fastbrick Robotics	Irobot
Australian Centre for Field Robotics	Yaskawa
Robotic Automation	KUKA
Swarmfarm	FANUC
	Harvest Automation
	ABB
	Oceaneering International
	Naio Technologies
	Intuitive Surgical
	Clearpath Robotics

Internet of Things

Australia	International
FarmMap4D Spatial Hub	Conservis (USA)
Telstra	Hortau (USA)
CropLogic	FarmLogs (USA)
The Digital Homestead	John Deere Field Connect (USA)
The Yield	Pynco (UK)
	Cisco (USA)
	Amazon Web Services (USA)
	Hitachi (Japan)
	IBM (USA)
	Kontakt.io (Poland)
	Cowlar (USA)
	AT&T (USA)

Gene Editing

Australia	International
CRISPR	CRISPR
	Caribou Biosciences
	Calyxt
	Precision Biosciences
	Transposagen
	Sangamo Therapeutics
	Twist Bioscience
	Monsanto & TargetGene
	Intellia
	Benson Hill Biosystems
	Editas

Synthetic Biology

Australia	International
Food Frontier	Hampton Creek
Symbio Laboratories	BioCurious
Vickers Lab & CSIRO	Monsanto
Australian Wine Research Institute	Protix
	Evolva
	Genspace
	Bayer Crop Science
	Bento Labs
	Intrexon
	SynBioBeta
	Perfect Day Foods
	Solazyme
	Clara Foods
	RebelBio
	New Harvest
	NuLeaf Tech
	Chinova Bioworks
	Memphis Meats

3D Printing

Australia	International
RIPPA	Biozoon
CSIRO Lab 22	GVL Poly
Aurara Labs	NASA
	Natural Machines
	MakerBot
	Modern Meadow
	Microsoft
	3Dponics
	3D System
	Voodoo manufacturing

Emerging agricultural technologies:
consumer perceptions around emerging agtech

AgriFutures Australia Publication No. 18/048
AgriFutures Australia Project No. PRJ-011141
ISBN 978-1-76053-013-6

Electronically published by AgriFutures Australia at www.agrifutures.com.au in January 2019

AgriFutures Australia is the trading name for Rural Industries Research & Development Corporation (RIRDC), a statutory authority of the Federal Government established by the Primary Industries Research and Development Act 1989.

AgriFutures Australia

Building 007
Tooma Way
Charles Sturt University
Locked Bag 588
Wagga Wagga NSW 2650

02 6923 6900
info@agrifutures.com.au

agrifutures.com.au

Researcher

Michael White
GHD Level 15
133 Castlereagh St
Sydney NSW 2000:
02 9239 7184
michael.white@ghd.com

In submitting this report, the researcher has agreed to AgriFutures Australia publishing this material in its edited form