3

Emerging technologies in agriculture

3.1   As discussed in the previous chapter, the need for technology to drive advances in agricultural productivity is well understood by governments, researchers, industry, and farmers.[1]

3.2   The Committee heard that emerging technologies, such as those driven by the biological revolution, the digital revolution, materials science and seasonal climate forecasting, would all have a role to play in promoting ongoing productivity in agriculture.[2]

3.3   The Commonwealth Scientific and Industrial Research Organisation (CSIRO) noted, however, that no one technology would be a 'silver bullet'. Rather, each technology would need to be progressed as part of a broader effort to innovate across value chains and commodities, and in concert with other enabling technologies.[3]

3.4   For farmers to capitalise on potential productivity gains arising from these technologies, an enabling environment, including suitable infrastructure, systems, regulatory structure and market operating environment, must be in place.[4]

3.5   This chapter discusses some of the technologies emerging in the above areas, relevant to the agricultural sector. Barriers to the further development and adoption of these technologies will be discussed in later chapters.

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1   Rural Industries Research and Development Corporation, *Submission 74*, p. 2.

2   Dr Michael Robertson, Science Director, Agriculture, CSIRO, *Committee Hansard*, Canberra, 26 November 2015, p. 1.

3   Dr Michael Robertson, Science Director, Agriculture, CSIRO, *Committee Hansard*, Canberra, 26 November 2015, p. 1.

4   RIRDC, *Submission 74*, p. 6.

Trends

3.6   The Rural Industries Research and Development Corporation (RIRDC), in partnership with CSIRO, reported into the five megatrends that are envisaged to impact Australian agriculture over the next 15 to 20 years, one of which is transformative technologies.[5]

3.7   Transformative technologies — defined as advances in digital technology, genetic science and synthetics — have the potential to change the way food and fibre products are made and transported, such as in the following ways:

   ■ farming and fishing enterprises would increasingly have sophisticated tools to assist with decision-making;

   ■ farming would be a more transparent activity;

   ■ many new business models would develop; and

   ■ the concept of farming would be expanded to non-food land use as new markets and opportunities for land-based products emerge.[6]

3.8   The Committee was told that technologies relevant to the sector were emerging in areas beyond those captured in the terms of reference — that is, beyond the areas of telecommunications, remote monitoring and drones, plant genomics, and agricultural chemicals.[7]

3.9   Adjunct Professor Tony Sorensen, of the University of New England, submitted:

> … we are on the verge of a huge and accelerating surge in technological capacity that will rewrite dramatically nearly every aspect of economy and society within as little as ten or twenty years: products and services; their production methods; machinery and equipment; range of inputs and their sources, including especially energy; downstream processing; market destinations; and logistics.[8]

3.10   Professor Sorensen considered that under these conditions, just about every aspect of farm production could experience radical transformation

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5   See RIRDC, *Rural Industries Futures*, July 2015, p. 6.

6   RIRDC, *Submission 74*, p. 3.

7   See CSIRO, *Submission 55*, p. 9. See also, Adjunct Professor Tony Sorensen, School of Behavioural and Cognitive and Social Sciences (BCSS), University of New England, *Submission 114*, p. 1; Entrevators Pty Ltd, *Submission 62*, pp. 2-4.

8   Professor Tony Sorensen, School of Behavioural and Cognitive and Social Sciences (BCSS), University of New England, *Submission 114*, p. 1.

over the medium to longer term—from inputs to production management, harvesting and delivery to end use.[9]

3.11 While recognising the need to identify and support the development and adoption of emerging technologies, CSIRO cautioned against restricting the view of 'innovation' to the invention of single component technologies by farmers. Rather, CSIRO advocated for the adoption of a broader view of innovation, noting that much of the productivity gains in Australian agriculture over the past 30 years had come about through increasing scale and mechanisation and evolving business models.[10]

3.12 The University of Melbourne similarly submitted that agricultural innovation needed to be understood as a combination of systems:

> Put simply, innovation requires a focus not just on the "hardware" (that is, the new idea or technology), but also on the "software" (the skills and knowledge required to use and derive benefits from the technology) and the "orgware" (the formal and informal relationships and arrangements between stakeholders that are required to support the successful and sustained deployment of the technology).[11]

3.13 Areas where technologies are emerging with implications for the agricultural sector include (but are not limited to):

- biological science;
- materials science;
- seasonal forecasting; and
- digital science.[12]

Biological science

3.14 CSIRO noted that the biological revolution in the past 30 to 40 years had already delivered value in production systems, evidenced in developments such as pest resistant cotton and herbicide tolerant crops.[13]

3.15 However, a new surge was emerging in crops, pastures and potentially animals, which would deliver higher value products—for example, cereals

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9   Professor Tony Sorensen, School of Behavioural and Cognitive and Social Sciences (BCSS), University of New England, *Submission 114*, p. 4.

10   CSIRO, *Submission 55*, p. 11.

11   University of Melbourne, Faculty of Veterinary and Agricultural Sciences, *Submission 4*, p. 1.

12   See CSIRO, *Submission 55*, pp. 5-6.

13   See CSIRO, *Submission 55*, pp. 5, 9.

with enhanced health attributes, novel aquaculture breeds and feeds, and designed plants with bio-industrial applications.[14]

3.16   Australia's Biotechnology Organisation (AusBiotech) submitted that biotechnology offered a set of innovative tools that would create new and improved food and fibre products, and more efficient and resilient farming systems with far-reaching agronomic, environmental, nutritional, human health and economic benefits.[15]

3.17   The Australian Academy of Technological Sciences and Engineering (ATSE) considered that the suite of technologies and techniques available through modern biotechnology offered enormous potential for improving the efficiency and productivity of Australian agriculture. As referenced in a recent ATSE position statement on enabling growth in agriculture:

> Biotechnology, integrated with modern genetics, breeding, and other techniques, offers opportunities to improve agricultural productivity, natural resource management, and consumer demand, while offering new opportunities for bio-industries across the agricultural value chain.[16]

3.18   The Australian Genome Research Facility and the University of Adelaide jointly submitted that the next revolution in genomic technology could see potential benefits including the development of sustainable and productive farming methods for the dry tropics in northern Australia; shifting crop and animal production systems into new climatic zones; and improved resource-use efficiency across all agricultural systems.[17]

3.19   However, the Committee heard evidence that the widespread adoption of genetic technologies in Australian agriculture had been slow and patchy.[18] It was noted that new techniques for gene transfer or expression that were coming on-stream were beyond current regulations.[19] To access the potential benefits of such technologies, the ATSE submitted that adoption of new technologies had to be simpler and faster, while also maintaining appropriate regulatory oversight and addressing public concerns.[20]

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14   See CSIRO, *Submission 55*, p. 5.

15   AusBiotech, *Submission 33*, p. 4. See also, for example, Australian Plant Phenomics Facility, *Submission 42*; Tasmanian Institute of Agriculture, *Submission 44*; NSW Farmers' Association, *Submission 45*; CSIRO, *Submission 55*; ATSE, *Submission 56*; RIRDC, *Submission 74*.

16   ATSE, *Submission 56*, p. 8. See also, ATSE, *Enabling growth in agriculture: Position statement*, Melbourne, 2014.

17   Australian Genome Research Facility and University of Adelaide, *Submission 18*, p. 1.

18   ATSE, *Submission 56*, p. 8.

19   Dr Lindsay Campbell, *Submission 31*, p. 4.

20   ATSE, *Submission 56*, p. 8.

3.20   The regulation of genetic technology and other barriers to the adoption of emerging biotechnologies are discussed in later chapters.

Materials science

3.21   Demand for resource efficiency, including new materials that control and target the release of agricultural chemicals, provides many opportunities for the agricultural services sector.[21]

3.22   Recent advances in custom designing new materials with unique properties held promise for agricultural applications. Examples of such advances provided to the Committee include the development of biodegradable polymers for water control, based on CSIRO's Reversible Addition Fragmentation chain Transfer (RAFT) technology; materials that could be used to trigger the release of fertiliser formulations; and seed coatings for germination control.[22]

3.23   Dr Lindsay Campbell submitted that a major innovation for the Australian and agricultural economy was 3-D printing, a technology still in its infancy yet already achieving amazing things. To make full use of this technology, Dr Campbell argued that Australia would require experts in material science, design and computer-aided design, computer programming, and engineering, among others.[23]

Seasonal forecasting

3.24   CSIRO submitted that increases in the physical understanding of climate, together with improvements in observations, modelling techniques and computer speed, would lead to an increase in seasonal forecast skill. It was noted that the advent of seasonal climate forecasting in the last 20 years had been an important development to aid risk management by farmers, and would have an important role to play in the future in maximising the benefits of improved fertiliser management practices, weed management practices, decisions about timely sowing, and feed forecasts.[24]

3.25   The Council of Rural Research and Development Corporations (Council of Rural RDCs) highlighted a project led by the RIRDC, which aimed to improve on the productivity and profitability of Australian farmers by bridging the gap between seasonal climate forecasts and on-farm business

21   CSIRO, *Submission 55*, p. 5.
22   CSIRO, *Submission 55*, pp. 5, 9, 10.
23   Dr Lindsay Campbell, *Submission 31*, p. 4.
24   CSIRO, *Submission 55*, p. 10.

decisions, with new tools to be developed, and training and information to be provided to farmers.[25]

3.26   The South Australian Government advised that it was investigating the use of automatic weather station networks and submitted that the Australian Government should give consideration to supporting CSIRO and the Bureau of Meteorology to research and deliver information on seasonal climate variability and climate change across Australia.[26]

Digital science

3.27   The rapid growth of information and communications technology in recent decades is expected to drive new directions for agriculture, in areas such as automation, and developments in infrastructure and platforms that will allow farmers to store, access, re-use and market their own data.[27]

3.28   The University of Sydney told the Committee that emerging technologies in this area included all aspects of automation and robotics ranging from automated aerial and ground vehicles, drones, and associated intelligent software and data analytics for crops; automated milking, herding and sampling and animal production systems such as dairying; to cultivating sampling, applying treatments, and harvesting in agriculture and horticulture.[28]

3.29   Entrevators Pty Ltd explained the practical applications and potential impact of digital science on Australian farms:

> We do not need people to sit in tractors or any other farming vehicle. Autonomous driven vehicles are here to stay and the labour and labour cost saving will have ramifications for farmers and their traditional workforce …
>
> … Drones will check the water troughs, feeders and tanks and the conditions of livestock with direct feed back to the home computer …[29]

3.30   The Department of Agriculture and Water Resources (DAWR) submitted that the future of precision agriculture—where integrated data from various sources could be used to achieve desired outputs and minimise the incidence of pests and diseases—could lie in decision agriculture,

25   Council of Rural Research and Development Corporations, *Submission 90*, p. 14.

26   Department of Primary Industries and Regions South Australia, *Submission 19*, p. 8.

27   CSIRO, *Submission 55*, pp. 10-11. See also, Australian Centre for Field Robotics, *Submission 94.*

28   University of Sydney, *Submission 40*, p. 5. See also, CSIRO, *Submission 55*, p. 10.

29   Entrevators Pty Ltd, *Submission 62*, p. 3.

which integrates spatial and seasonal data at a site-specific level for producer decision-making.[30]

3.31   Dr Campbell noted that 'big data'—that is, 'lots of small data that has been aggregated together in a compatible format'[31]—was generated in most emerging digital technologies, from global positioning system (GPS) data collected in the field, to remote sensing from satellites.[32]

3.32   Emerging technologies with the potential to improve agricultural productivity include technologies within the Internet of Things ecosystem, such as connectivity to ensure efficient collection of data from sensors; and data storage and management techniques that could be used to transform data from many sources into information, projections and suggested actions for individuals and the sector.[33]

3.33   Entrevators Pty Ltd submitted:

> Agriculture can and will collect huge amounts of data in the future. The volume of data will exponentially grow and the analytics tools will be developed to provide useable information. It is happening now and the demand is huge.[34]

3.34   The Committee was told that remote sensing drones had the potential to ascertain a wide range of helpful data, including movement of stock, state of fencing, remote control of gates or electric fences, dam levels, water flows, crop monitoring for weeds, pests and diseases, pasture assessment to optimise livestock numbers, and early detection of stress or drought.[35]

3.35   SST Software Australia submitted that to evolve the ability to apply findings in a decision support context:

> … we need to have the ability to reference that data to a farmer's management regime and practices, so as to connect it to documented decision making. This requires compatibility with on farm data applications and systems.[36]

3.36   CSIRO submitted that farm-scale data would need to be 'fused' with broader scale national and regional data streams covering issues such as climate, soils, water and biodiversity.[37]

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30   Department of Agriculture and Water Resources, *Submission 88* , pp. 7-8.
31   Mr Mark Pawsey, General Manager, SST Software Australia Pty Ltd, *Submission 13*, p. 9.
32   Dr Lindsay Campbell, *Submission 31*, p. 5.
33   National Narrowband Network Co., *Submission 34*, pp. 4-5.
34   Entrevators Pty Ltd, *Submission 62*, p. 2.
35   Dr Lindsay Campbell, *Submission 31*, p. 3.
36   SST Software Australia Pty Ltd, *Submission 13*, p. 9.
37   CSIRO, *Submission 55*, p. 11.

3.37   The University of Sydney submitted that the key to achieving gains in the development and application of digital technologies lay in the integration of multidisciplinary science and collaboration among national and international organisations.[38]

3.38   CSIRO noted that the key social challenge in the digital revolution was to provide platforms for farmers to store, access, re-use and market their own data, while maintaining protections of ownership and privacy.[39]

3.39   Dr Campbell asked the Committee to consider the important questions of who owned this data; to whom the information should be made available; what protections could be placed on the data; and for what purpose the data could and should be utilised.[40]

3.40   Issues of collaboration and the adoption of research and development are discussed in Chapter 6.

Adoption of emerging technologies

3.41   The University of Melbourne considered that there were many factors that influenced individual farmers' decisions to adopt emerging technologies. The university identified four key factors that have affected the level of adoption of a technology or practice by farmers, and the time taken for adoption:

- characteristics of the technology or practice (for example, cost, difficulty of implementation);

- characteristics of the target population (for example, social norms, financial capacity, education levels);

- relative advantages of using the technology or practice (for example, profitability); and

- capacity to learn or adapt to generate a relative advantage (for example, support networks to aid decision-making and learning).[41]

3.42   As noted earlier, CSIRO considered that no one technology or technologies would be transformational, and progress on technologies would be incremental, because of the nature of innovation and adoption.[42]

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38   University of Sydney, *Submission 40*, p. 5.
39   CSIRO, *Submission 55*, p. 11.
40   Dr Lindsay Campbell, *Submission 31*, p. 5.
41   University of Melbourne, Faculty of Veterinary and Agricultural Sciences, *Submission 4*, p. 1.
42   CSIRO, *Submission 55*, p. 9.

3.43   The RIRDC submitted that for emerging technologies to deliver 'game changers' for agricultural industries, those technologies must be adopted by the agricultural industry. In this way, it was hoped that the Rice Industry Extension Coordination Project, aimed at improving the uptake of rice industry best management practices and adoption of new technologies, would become a sustainable model for other industry extension and innovation dissemination.[43]

The enabling environment

3.44   The Committee was told that an enabling environment must be in place to capitalise on potential productivity gains of new technologies at the farm gate. That is, the right infrastructure, systems, and regulatory and market operating environment must be in place. The RIRDC considered that some of these enablers were within the domain of governments, while other enablers were outside government remit.[44]

3.45   Accordingly, the challenge for governments was to create an attractive policy environment for private sector investment in agriculture, while also maintaining public sector investment.

3.46   A 2014 RIRDC report considered that better recognising and exploiting the spill-over benefits of R&D outcomes through a more organised approach to the sharing of R&D outcomes may help deliver greater efficiencies, less duplication and wider uptake of innovation.[45]

3.47   The current R&D environment and barriers to R&D are discussed in detail in Chapter 6.

Infrastructure

3.48   Reliable access to telephone and internet coverage has been identified as a key enabler for adapting and adopting technological advances in agricultural industries.[46] Access to such communications infrastructure allows farmers to optimise their production systems in terms of inputs and outputs, and allows them to remain competitive in global markets.[47]

3.49   Professor David Lamb, of the University of New England, submitted that achieving nationwide, reliable on-ground telecommunications, including

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43   RIRDC, *Submission 74*, p. 5.

44   RIRDC, *Submission 74*, p. 5.

45   RIRDC, *Submission 74*, p. 5.

46   RIRDC, *Submission 74*, p. 6. See also, for example, CSIRO, *Submission 55*, p. 11; Telstra, *Submission 81*, p. 1.

47   Adjunct Professor John Hamblin, *Submission 3*, p. 6.

access to high speed internet, is crucial to realising e-business and technology opportunities on Australian farms.[48]

3.50   The United States Studies Centre at the University of Sydney submitted that providing sufficient broadband and telecommunications would allow the market to innovate around emerging the Internet of Things and big data technology.[49]

3.51   Professor Lamb contended that a critical impediment to Australian farmers adopting technology and innovation on farms, and realising the benefits of emerging technology, was a lack of nationwide 'whole of farm' communications infrastructure and multipoint access models that allowed farmers to connect to high speed internet from anywhere on their farms.[50]

3.52   Telecommunications infrastructure and digital connectivity, as barriers to innovation, are discussed further in Chapter 4.

Investment in people and capacity building

3.53   As part of an enabling environment, investment in people and capacity building may also be seen as a key driver of agricultural innovation.

3.54   The RIRDC considered that young people were important to include in conversations around the opportunities for agricultural innovation, given that they are not only the current adopters of new technology and innovations, but also the future adopters.[51]

3.55   For this reason, the RIRDC initiated the Horizon Scholarship Program, in partnership with industry sponsors, which supports undergraduates studying agriculture at university. The program aims to support the next generation of agricultural leaders.[52]

3.56   Programs such as the Horizon Scholarship Program have also highlighted how multi-disciplinary agriculture has become, and how occupations outside of the traditional agricultural sector, including engineers,

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48   Professor David Lamb, *Submission 11*, p. 1. See also, for example, Alun Davies, *Submission 1*; National Rural Women's Coalition, *Submission 5*; Pastoralists and Graziers Association of Western Australia, *Submission 16*; Precision Cropping Technologies, *Submission 24*; National Narrowband Network Co., *Submission 34*; United States Studies Centre, *Submission 39*; NSW Farmers' Association, *Submission 45*; Southern Farming Systems and the Australian Controlled Traffic Farming Association, *Submission 61*; Entrevators Pty Ltd, *Submission 62*; Australian Women in Agriculture, *Submission 63*; ADF-DA, *Submission 65*; Australian Sugar Milling Council, *Submission 68*; RIRDC, *Submission 74*; Telstra, *Submission 81*; South East Premium Wheat Growers' Association, *Submission 83*; CCA-SCA-ALFA, *Submission 84*.

49   United States Studies Centre, *Submission 39*, p. 2. See also, Entrevators Pty Ltd, *Submission 62*; RIRDC, *Submission 74*; Grain Growers Limited, *Submission 82*.

50   Professor David Lamb, *Submission 11*, p. 1.

51   RIRDC, *Submission 74*, p. 7.

52   RIRDC, *Submission 74*, p. 6.

biochemists and physicists, are now playing a critical role in driving agricultural technological innovations.[53]

3.57   Dr Campbell submitted that agriculture no longer operated as a silo, but was highly dependent on a very wide range of expertise outside its traditional boundaries:

> Agricultural technologies must be underpinned by a strong, vibrant research and development (R&D) sector to maintain competitiveness. New technologies arise from many different disciplines, frequently from basic research, and these technologies are applied into agricultural situations.[54]

3.58   The investment in people and capacity building is discussed in more detail in Chapter 5.

Committee comment

3.59   In this chapter, the Committee has identified some of the key areas where technologies are emerging, with implications for the agricultural sector.

3.60   It should be noted, however, that the technologies discussed in this chapter do not represent an attempt to cover the vast field of separate technologies that are emerging in Australia, with potential application in agriculture over the coming years.

3.61   Instead, in this chapter the Committee has sought to illustrate how dynamic the area of agricultural innovation has become, to identify factors that contribute to the development and adoption of these technologies, and to identify barriers that prohibit the adoption of these technologies onto Australian farms.

3.62   These barriers to innovation are considered throughout the remaining chapters of this report.

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53   RIRDC, *Submission 74*, p. 7.
54   Dr Lindsay Campbell, *Submission 31*, p. 1.