www.csiro.au

CSIRO Submission 15/543

Agricultural Innovation

House of Representatives Standing Committee on Agriculture and Industry

September 2015

Enquiries should be addressed to:

John Quantrill
CSIRO Ministerial and Parliamentary Liaison
PO Box 225, Dickson ACT 2602
T 02 6276 6026

Main Submission Authors:

Brian Keating, Executive Director
CSIRO Agriculture Food & Health

and
Michael Robertson, Deputy Director
CSIRO Agriculture

Table of Contents

Table of Contents 3

Executive Summary 5

Introduction 7

CSIRO response to the Terms of Reference (ToR) 7

Improvements in the efficiency of agricultural practices due to new technology, and the scope for further improvements 7

Emerging technology relevant to the agricultural sector, in areas including but not limited to telecommunications, remote monitoring and drones, plant genomics, and agricultural chemicals 9

Barriers to the adoption of emerging technology 12

A case study in successful agricultural innovation: the Australian cotton industry 14

References 17

Executive Summary

This submission focuses on both the opportunities and challenges that confront Australia's agri-food industries. The opportunities are driven by growing markets and the challenges relate to continued international competitiveness. This will require strong innovation that lifts productivity, reduces costs and transforms products for higher value market segments.

SITUATION ANALYSIS

1. Australia's agri-food/fibre sector is poised for significant growth with a doubling in demand in key export markets and significant domestic market growth over the next 30 years; however we face significant competition in capturing these opportunities.
2. Rates of agricultural productivity increase have slowed over the last 20 years and Australia's net agri-food exports have change little over that period, despite significant market growth. Food imports have more than doubled over the last 20 years.
3. Generalising across all economic sectors, Australia ranks poorly on an international scale for the rate of translation from research outputs to outcomes for end users.

TECHNOLOGICAL LANDSCAPE

4. There are sizable gaps between what farmers can potentially produce with current technology and average farm production, and hence scope for improvements in farm production through better application of existing technology.
5. No one technology, or technologies, will be transformational for agricultural productivity. History tells us that progress will be incremental because of the nature of innovation and adoption. Contributing technologies cover the gamut of plant, soil, chemical and engineering technologies, and will be aided by two key enabling information technologies: seasonal climate forecasting and digital technologies.
6. There is a lack of comprehensive and frequent information on farm and farmer performance across Australia, to guide R&D investments and innovation policy.
7. **Digital Science** – We are just seeing the start of digital disruption in agri-food and fibre production systems and value chains – all indications are that digital approaches will play a significant role in closing the yield gaps (point 4 above) and potentially reducing costs and adding new value to supply chains. CSIRO sees a role for government in partnership with industry and knowledge institutes to provide trusted and commercially sustainable enabling services for farmers to fully exploit the potential for digital products and services.
8. **Biological Science** – The biological revolution has been 30-40 years in the making and many outputs are already delivering value in production systems (e.g. pest resistant cotton, herbicide tolerant crops etc). We see a new surge in crops, pastures and potentially animals becoming available delivering higher value products (such as cereals with enhanced health attributes, novel aquaculture breeds and feeds, designed plants with bio-industrial applications etc). Regardless of whether the route to market happens via a GM or non-GM pathway, there is no doubt Australia's agri-food/fibre industries will not remain competitive without leading edge biological technologies.
9. **Materials Science** – Recent advances in our abilities to custom design new materials with unique properties hold promise for agricultural applications (eg., biodegradable polymers for water control based on CSIRO's RAFT technology (Reversible Addition Fragmentation chain Transfer) and CSIRO's

MOF technology (Metal-Organic Frameworks) structures for the storage, separation and release of chemically or biologically active molecules.

10. **Seasonal forecasting** - An important development in the last 20 years has been the advent of seasonal climate forecasting (SCF) to aid risk management by farmers. Increases in physical understanding of climate together with improvements in observations, modelling techniques and computer speed will all lead to an increase in seasonal forecast skill. SCF will 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.
11. CSIRO would encourage a broad view of "innovation", not restricted to the invention and adoption of single component technologies by farmers for on-farm issues, but to include business model and value-chain innovation.

AGRI-FOOD INNOVATION SYSTEM

12. The agri-food/fibre innovation system, comprising of government, industry and knowledge institutes, is showing signs of stress, imbalance and lack of clarity around roles and national goals, and is at odds with contemporary models in high performing countries.
13. There is a lack of evidence-based information on the form and function of Australia's current agri-food/fibre R&D system, in particular with regard to the leverage of public and private funds and the portfolio mix across commodities.
14. The Research & Development Corporations (RDCs) provide valuable industry input to priorities and adoption pathways. However, their relatively narrow commodity focus limits wider system improvement. Many Australian farms produce more than one commodity and manage natural resources, labour and capital across the whole-farm business.
15. The need to generate solutions that cater for the vast majority of stakeholders (i.e. levy payers) means that outputs are often of a general nature, potentially missing out on opportunities to meet needs of sub-groups of stakeholders and who may in fact be willing to pay a premium for a customised solution.
16. Agricultural research and development in Australia is dominated by pre-farm gate concerns. This leads to disconnects between "on-farm" productivity research, whole-of-chain costs and value and market drivers.
17. The Australian cotton industry provides a salutary example of consistent productivity improvements being generated due to a range of success factors. These may offer lessons and insights for other industries.

SOME KEY OPPORTUNITIES LOOKING FORWARD

1. Development of **national leadership forum** focused on improved functionality of the agri-food/fibre innovation system with evidence-based leadership inputs from Govt, Industry and Knowledge Institutes. (i.e., Australia's Agri-Food & Fibre "Golden Triangle").
2. Development of **emerging market road maps** for higher value capture from Australia's major commodity sectors (coordinated by the Food and Agri-business Industry Growth Centre with input from RDC, State and federal Governments and Knowledge Institutes).
3. Development of a set of **"national targets" for agri-food sector growth and innovation** – to inform the national policy and practice across industries, governments and knowledge institutes.
4. Development of a **national digital agriculture strategy**, including a plan for a structured data platform to address longer term private and public interests.

Introduction

CSIRO welcomes the opportunity to provide input to the House of Representatives Standing Committee on Agriculture and Industry Inquiry into Agricultural Innovation.

CSIRO's perspective is that Australian agriculture is at a crossroads for the following reasons:

1. Australia's agri-food sector is confronted by a very significant growth opportunity. There are two billion middle class consumers emerging to our north in the next few decades. Asian food markets are projected to increase 2.5 fold by 2050. However, we have competitors for this opportunity. For example, there has been a 3-fold growth in Brazilian agricultural exports since 2000.
2. For broadacre agriculture as a whole, rates of productivity increase have stalled in the last 20 years, although there are notable industries that are exceptions: cotton, dairy, and large grain farms for example. The slowing of productivity has been linked by some researchers to a declining R&D spend (in absolute and research intensity terms). Others have argued that it is due to a small percentage contribution by the private sector, at least compared to other OECD countries. There is certainly a notable lack of public-private partnerships in Australia compared to Israel, the Netherlands and Denmark. Yet others claim it is due to the inability of various industries to adapt to a drying and warming climate, reduced irrigation supplies, and rundown in productive capacity of soils.
3. While Australia ranks favourably on the international scale for expenditure on R&D, and on the volume of research outputs, it ranks poorly for the rate of translation from research to outcomes for end users. This suggests there is something critically failing in the system.
4. There is a lack of congruity in the roles and relationships between various institutions in the innovation ecosystem and we suspect this leads to under-performance, although evidence-based analyses are limited.
5. The advent of new technology, including digital and biotechnology, provide much promise in delivering to the needs of the agriculture sector. However, despite the hype about the transformational possibilities, there still remains sizable gaps between what farmers can potentially produce with current technology (and what elite farmers do produce) and average farm production.

Our submission is based around the three terms of reference.

CSIRO response to the Terms of Reference (ToR)

The Committee will inquire into and report on the role of technology in increasing agricultural productivity in Australia. The inquiry will have particular regard to:

Improvements in the efficiency of agricultural practices due to new technology, and the scope for further improvements

While we acknowledge the interest in the potential for new technology to improve the efficiency of agricultural practices, we wish to remind the inquiry that there are sizable opportunities for productivity gains through better adoption of current technology. Recent work by CSIRO and GRDC has shown that current national average yields for grain crops are at about 50% of what is potentially possible with current technology. We know that potential yields are possible because studies with elite farmers show that they are at this frontier now. There is a notable dearth of such "yield gap" studies for many industries and a greater focus on this would highlight the scope for improvement. Even though the private sector is largely responsible for technology transfer now in Australian agriculture, it does not have the analytical tools to know what scope there is to increase production with current technology for any given farmer. This is a notable barrier to productivity gain through more effective extension.

New technology and "bundles" of technologies have contributed to on-going progress in agricultural efficiency in Australian agriculture. The wheat industry is a notable case in point. Historical progress in the yield of wheat in Australia has been well documented together with attribution of the role of various innovations in determining such progress (Figure 1). Apart from an initial phase of system rundown before 1900, yield progress has been characterised by phases of gain interspersed with 'plateau periods' where progress slows. The intermittent periods of rapid yield improvement occurred where packages of improved management combined to allow the underlying improvements in genetic yield potential to be realized. Since 2000 there has been a noticeable flattening of this upward progress in average yield and more year-to-year variation; in the last 4 years Australia wheat yield has averaged 1.9 t/ha. What is important to realise from the history of progress in wheat yields is that no one technology contributed to jumps in yield. So we believe it to be with new emerging technology.

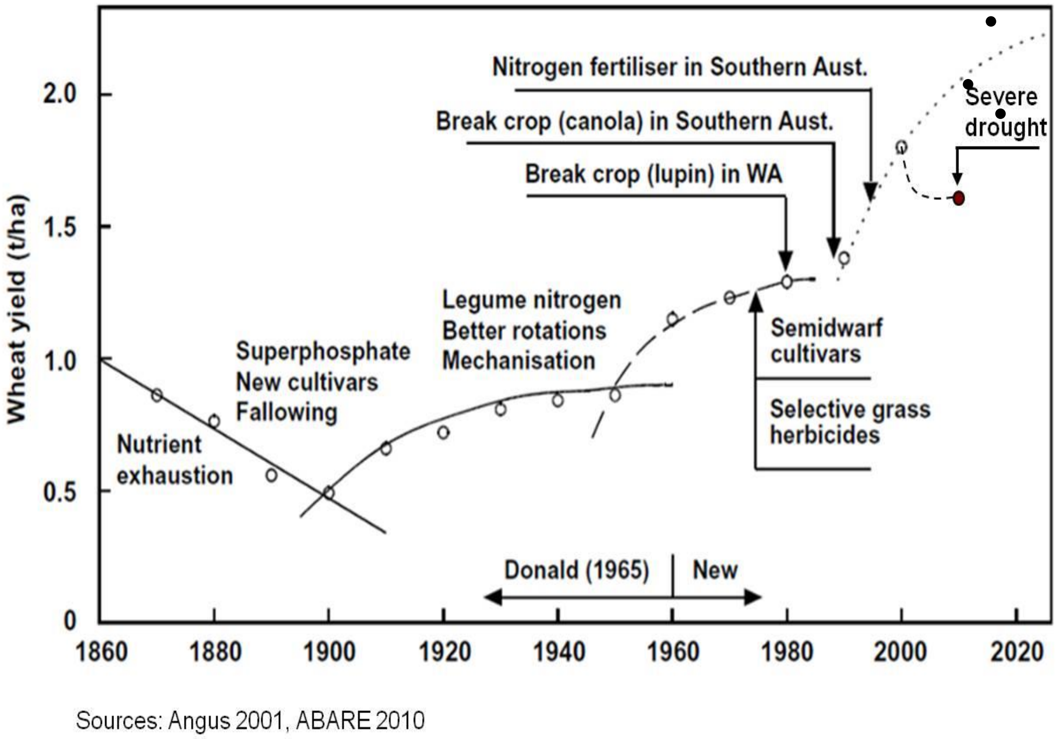

Figure 1: Historical progress of yield in the Australian wheat industry, together with key casual factors.

We have recently analysed the current and future potential levels of adoption of current management technologies by Australian grain growers, together with average benefits in yield and/or cost savings. We found that levels of adoption by grain growers of current technologies span the full spectrum from around 10% (e.g. use of decision support systems for risk management) to 90% (autosteer and guidance on farm vehicles). There are a significant cluster of technologies that are currently adopted by 30% or less of grain growers and which we estimate could potentially be adopted by 70% or more. Rapid and high levels of adoption are achieved with technologies that have clear benefits to adopters, are easy to learn, adopt and dis-adopt, and are applicable to a broad range of farmers. The adoption of a new technology is influenced by its complexity, the difficulty of use and capacity to determine what the benefit is.
While we are able to provide some examples from the grains industry of technology adoption and scope for future gains, the database upon which these analyses are based are patchy and limited. This is also the case for other industries. There is a real lack of comprehensive and frequent information on farm and farmer performance across Australia. We acknowledge the expense and effort required to collect such

information. A "big data" approach could be designed to provide a monitoring program that would service multiple clients, and could be designed to overcome concerns about privacy and security of information. What is clear from the above summaries is that there is a need to have a balanced portfolio of research, development and extension (RD&E) to address adoption of current technology and new technology. Progress in production and efficiency will be a mix of better application of existing technology and adoption of new technology and this will require RD &E.

Emerging technology relevant to the agricultural sector, in areas including but not limited to telecommunications, remote monitoring and drones, plant genomics, and agricultural chemicals

No one technology or technologies will be transformational. History tells us that progress will be incremental because of the nature of innovation and adoption. All of the above technologies listed will have a role to play when linked to traditional disciplines of agronomy, animal husbandry, soil science, and economics. We believe the list is much broader than listed in the ToR. For instance, Table 1 lists what we consider to be the key future agronomic technologies that will underpin productivity gains in the Australian grains industry. They cover the gamut of plant, soil, chemical, digital, and engineering technologies.

Table 1: Focus areas for productivity improvements in the Australian grains industry and associated key future technologies

Focus area	Percent benefit in yield or cost saving	Future technology
Timely sowing	20-30%	Seed coatings to delay seed imbibition Varieties with adapted phenology for new early-sown systems Varieties with alternative dwarfing genes with long coleoptiles Varieties with vigour for establishment and weed competitiveness
Soil surface management	10-30%	Sprayable biodegradable plastic mulches Further advances in precision seeding systems
Fertiliser efficiency	10-20%	Improved fertiliser formulations On-the-go proximal methods for easier, cheaper soil testing Technologies for managing seasonal risk Varieties with enhanced nutrient use efficiency
Greater rotation diversity	10-20%	Low-input break options Novel intercropping facilitated by precision technology High value grain legume
Sub-soil constraints	20-80%	Means to map and diagnose constrained soils Means to increase penetration of ameliorants Novel ameliorants and carriers Varieties with tolerance to sub-soil constraints

Biological science: The biological revolution has been 30-40 years in the making and many outputs are already delivering value in production systems (e.g. pest resistant cotton, herbicide tolerant crops etc). We see a new surge in crops, pastures and potentially animals becoming available delivering higher value products (such as cereals with enhanced health attributes, novel aquaculture breeds and feeds, designed plants with bio-industrial applications etc). Regardless of whether the route to market happens via a GM or non-GM pathway, there is no doubt Australia's agri-food/fibre industries will not remain competitive without leading edge biological technologies.

Materials science: Demand for resource efficiency, including new materials that control and target the release of agricultural chemicals, provides many opportunities for the Australian agricultural services sector. Areas of market demand include the temperature controlled release formulations for pesticides; seed treatments/coatings such as film formers and adhesion promoters; Ribonucleic acid interference (RNAi) delivery; biosolutions for fertiliser market; anti-soil leaching active formulations and improved solubilisation of actives in waterborne formulations. CSIRO has a range of technology platforms which provide the ability to precisely tune the performance of materials for a broad range of applications. In response to the above mentioned demand CSIRO has developed and is now testing: sprayable biodegradable membranes to increase water savings in crop production; synchronised nutrient delivery to match nutrient release to crop demand for healthy crop growth; micro-encapsulation of plant-beneficial microbes for more effective and sustainable crop protection and nutrition; materials that can be used to trigger the release of fertiliser formulations; seed coatings to germination control; RNAi delivery systems for agricultural application; insect hormone receptor research to discover safer chemistries for the control of insect pests. This research occurs through deep engagement across the Agricultural and Manufacturing business units and in close collaborations with Australian industry.

Enabling the full expression of the benefits of technologies listed in Table 1 will require two key enabling information technologies: seasonal climate forecasting (SCF) and digital (information and communication technologies - ICT).

Seasonal forecasting: An important development in the last 20 years has been the advent of seasonal climate forecasting (SCF) to aid risk management by farmers. SCF will 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. Adoption of seasonal climate forecasting by Australian farmers is 30-50% with the benefits, based on a perfect forecast, estimated in a number of studies to be AUS$12-60/ha. The benefits likely to accrue to farmers through the use of SCF will remain limited while forecasting skill is modest. Progress in seasonal forecast skill is likely to parallel the improvement of short-term weather forecast skill over the last few decades. Since 1980, weather forecasts have increased their lead time at a defined level of skill by about 1 day per decade for the northern hemisphere, and 1 day per 3 years for the southern hemisphere. This progress has been underpinned in Australia by the partnership between the BOM and CSIRO that has led to the development of the ACCESS climate/earth system simulator. Increases in physical understanding of climate together with improvements in observations, modelling techniques and computer speed will all lead to an increase in seasonal forecast skill.

Digital science: Just as the agricultural revolution of the 19th century built on the industrial and scientific revolutions which were taking place around the same time, the rapid growth of ICT over the past decades is expected to also have a similar effect in driving new directions for agriculture. Automation is already relatively commonplace amongst agricultural systems, such as in automated guidance systems and automated weed-spraying. While full automation of large vehicles is occurring in mining, this is unlikely to happen in agriculture for cost and safety reasons. However, relatively cheap, lightweight robotic platforms for both ground and air are becoming commercially available - with functions such as navigation, path-planning and obstacle avoidance and potential for undertaking tasks such as planting, weed control and pest management.

The rapid growth in use of 2D mapping services such as Google Maps and widespread availability of satellite data such as SPOT or Landsat means there is an increasing availability of spatial data to improve estimates of plant quality and biomass over large areas, as well as navigation or tracking location of assets. Emerging technologies such as low-cost and portable laser-ranging units and cheap stereo cameras now mean that there is the possibility to rapidly form 3D maps of the quality and quantity of grains from devices mounted on vehicles or hand-held units.

From the late 1990's, as Moore's Law saw the exponentially decreasing size and cost of computer chips, many started to predict a future of "Smart Dust" - networks of tiny devices which could sense, store and communicate information about the environment into which they were distributed. While limitations around energy storage and communications hardware has prevented the smart-dust vision becoming reality to date, there has been significant progress in cheap, low-power, wireless data loggers. Within the next decade it is possible that tiny, disposable devices which could be buried in soil to monitor moisture levels or scattered among crops to monitor for pests and diseases will become available. One recent example which signals what might be possible in future is CSIRO's tracking of individual bee movements with micro-sensors in studies of honey bee health. CSIRO has also developed and is testing sensors that monitor water quality and "livestock" health in the oyster industry.

The rise of the Internet over the past three decades was largely driven by the desire to reduce transaction costs in communication, storage and analysis of information. Developments in mobile devices, data stored on remote cloud servers, and high-speed, broadband networks will allow emerging infrastructure to develop new services which can integrate both local data from the farm and integrate with external information such as weather or price forecasts.

Lack of broadband access will limit the uptake of digital technologies by many Australian farmers, at least in the short-term as networks evolve. However, there are technological solutions available now, such as CSIRO's Ngara technology, which can provide local wireless systems on farms where there is no 3G or 4G coverage. This has the potential to allow farmers to use computer decision aids in the paddocks, control autonomous machinery, and monitor crops and livestock from the homestead.

The key social challenge in the digital revolution will be to provide platforms for farmers to store, access, re-use and even market their own data with appropriate protections of ownership and privacy. These farm-scale data will need to be "fused" with broader scale national and regional datastreams covering issues such as climate, soils, water and biodiversity. Activity is already starting in regard to data services for agriculture, either from "big business" aspirations for vertically integrated datastreams or via local "data service" providers emerging organically. However, there is a risk of fragmentation and dysfunction – with proprietary or local data models generating a modern day "Tower of Babel". There is growing evidence of market failure in Australia in the provision of "fit for purpose" data services to rural industries. There may be a role for government in partnership with industry and knowledge institutes to design and initiate a network service, potentially via a co-operative or not-for-profit business model. CSIRO in association with the newly formed Data61 capability (via the merger with NICTA) is currently scoping the feasibility of such an initiative. Furthermore, to exploit the potential of this technology will require capacity building in the advisory sector, as in general it has low capacity to inform and support the use of information intensive technologies.

<u>Broader view of innovation</u>: It is easy to be seduced by the novelty of the technologies listed above. However, we would encourage a broad view of "innovation", not restricted to the invention and adoption of single component technologies by farmers. It is well understood that much of the gain in productivity in Australian agriculture over the last 30 years has come about through increasing scale and mechanisation and evolving business models. Many believe that there are still significant unrealised gains in new business models that will make more efficient use of resources. For example, the sheep and beef sector in New Zealand is moving to stratification whereby "unfinished" stock from hill country farms are supplied on contract to lowland farms for finishing to slaughter. This creates more secure returns for both types of farms and is being accelerated by large companies that own a range of properties in wet and dry districts that effectively utilise pasture grown at their various properties. In Australia, the idea of separating ownership from management for land, livestock and machinery is gaining traction. For example, in the grains industry share-farming is being seen as a viable alternative, particularly now that there are dedicated companies, providing professionally managed share-farming opportunities. The on-going stratification of the beef industry into specialist production, backgrounding and finishing enterprises provides opportunities for faster rates of technology adoption, which also has the potential for greater adoption by the sheep industry. This allows the scale of farmed area to be adequate so that fixed costs are reduced on a per hectare basis and plant investment per hectare is reduced. Public-private research partnerships could contribute to more active business model innovation.

Barriers to the adoption of emerging technology

Any new technology faces adoption challenges but in this section we focus on the effectiveness of our R&D system in the generation of relevant technologies and practices that are able to stimulate industry and policy innovation. As a long-term participant and observer of rural R&D in Australia, CSIRO can see many disconnects and incongruous drivers that hamper its innovation effectiveness. These are discussed below.

Key relationships: As Prof Mark Dodgson has explained, *"Innovation happens when the ideas and resources of different organisations connect effectively. Systems are defined by their connections, and innovation systems link businesses with one another and with research organisations and government. Australia's innovation system is disconnected." (Mark Dodgson, Professor of Innovation Studies, University of Queensland Business School https://vimeo.com/44224654).*

In Australia's rural R&D system, we don't seem to have developed clear shared national goals and clear leadership roles for Govt, Industry and Knowledge Institutes. The traditional linear model of Govt => RDC => Uni/CSIRO as shown in Figure 2a is at odds with a more dynamic innovation ecosystem (Figure 2b) that is evident in high performing agriculture sectors in countries like Israel, Netherlands, and perhaps increasingly New Zealand. The launch of the Industry Innovation Precincts and Industry Growth Centres hold promise as a step in the right direction, but much more needs to be done to re-balance, streamline, and improve the connectiveness of Australia's agri-food innovation ecosystem.

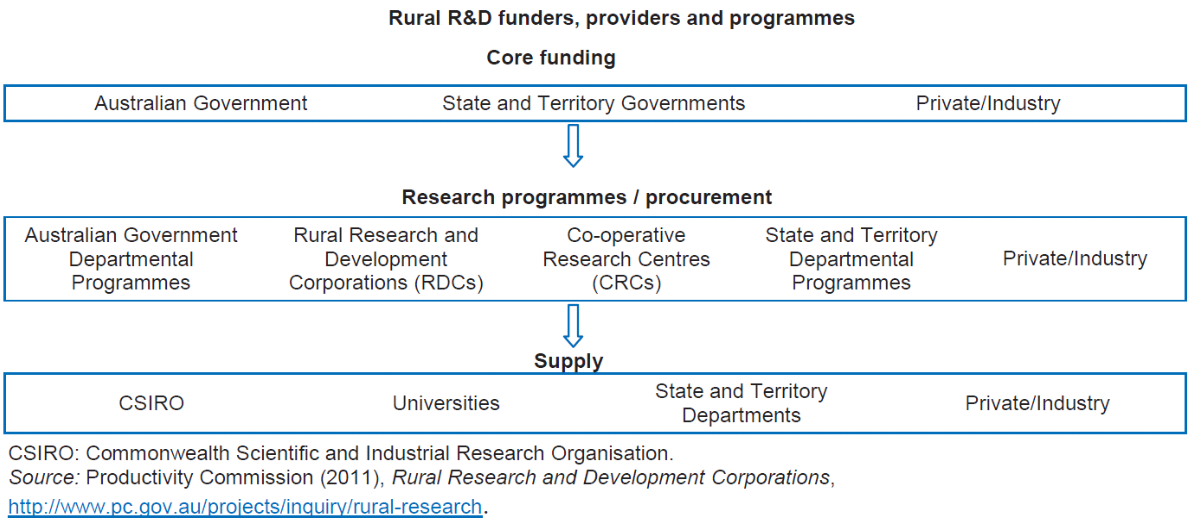

Figure 2: (a) A "traditional" view of the relationship between rural R&D funder, providers and programmers in the Australian agricultural innovation system

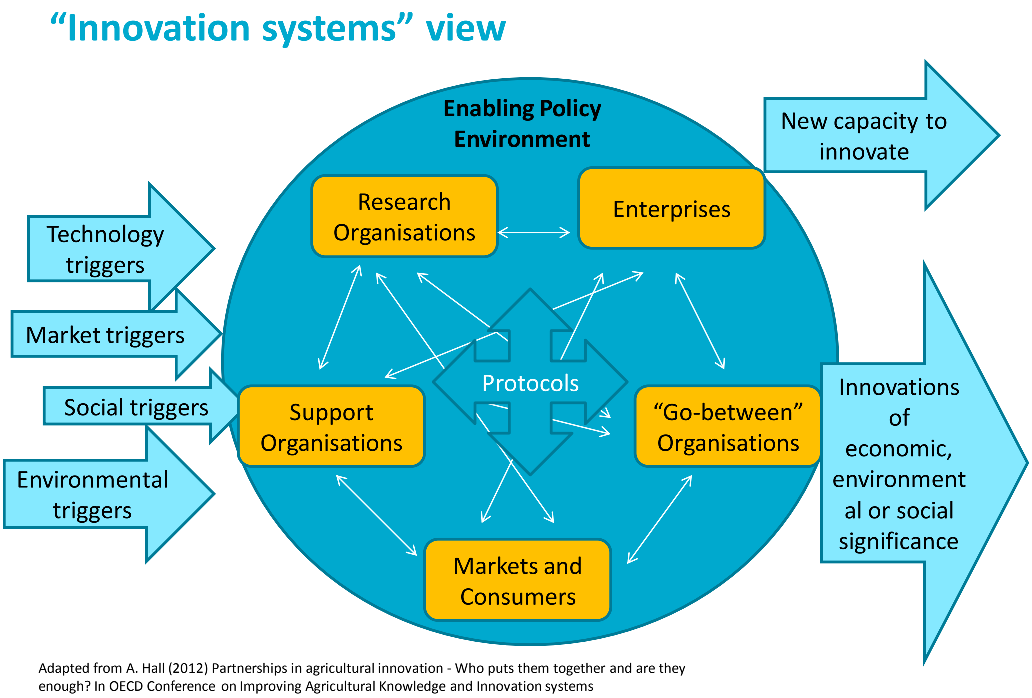

Figure 2: (b) An "innovation ecosystem" view of an agri-food innovation system

The RDC system: The links to industry needs enabled by the RDC system are very valuable but the need to produce general outputs for all levy payers means that tailored solutions for farming are limited. This runs the risk of missing out on opportunities to meet needs of sub-groups of stakeholders and who may in fact be willing to pay a premium for a customised solution.

The narrow commodity focus of many RDCs can also limits wider system improvement. Many Australian farms produce more than one commodity (e.g. grain & livestock; cotton, grain & beef) and manage the interactions between enterprises at the business level. A broader system focus to R&D would allow farmers to maximise the synergies between enterprises and manage sustainably the soil and water resource base that underpins all production activities on the farm.

Agricultural research and development in Australia via the RDC system is invariably dominated by pre-farm gate concern as this reflects the major sources of levy. This can sometimes lead to disconnects between "on-farm" productivity research, whole of chain costs and value and market drivers. More linking of pre- and post-farm gate issues will lift the performance of the whole value chain. In the Australian cotton industry textile engineers and chemists work closely with plant breeders and agronomists to ensure that the total value of the product (yield and quality) for any given market is maximised.

There are barriers to the fuller participating of agri-business in R&D. One factor that impedes greater investment is that RDCs are intent on capture of Intellectual Property (IP) from their R&D investments. While wise management of IP is important in modern R&D, this goes beyond simple notions of IP capture and control. CSIRO (under its Act) is required to work towards industry benefits that are in the national interests. This includes spreading innovations from one industry to another when that is in the national interest. IP protection and competition amongst different RDCs has created difficulties for CSIRO in working across industry sectors. The lack of a consistent contracting and IP management framework across the RDC's and government departments adds to these difficulties and inefficiencies.

Funding flows and leverage: There is no definitive analysis of how funds are leveraged through the national rural innovation system. There is a lack of transparency where funds flow, and there is excessive leveraging of funding. Typically, $1 of industry levy funding leverages $3 of government funding ($1 from the levy matching funding and $2 from the knowledge institute co-investment). Sometimes these leverage rates go much higher, when for instance a CRC is drawn into the funding model. While the industry input to priorities and adoption pathways that characterises the RDC system is very valuable, excessive leverage and hence control through the RDC system runs the risk of eliminating longer-term science investments and distorting the full public interest, whether that be in terms of cross-commodity “systems” work, whole of value chain work, or environmental sustainability work.

Universities often cross-subsidise this leveraged research system via funds associated with their education functions (Green, 2015, page 5). Universities form the largest element of the rural innovation system (perhaps 50 to 60% compared to CSIRO’s 20%) but reward signals continue to be dominated by scientific publication with less focus on innovation impact in industries. CSIRO can co-invest up to a point (typically 30 to 50% of total costs depending on strategic priority) but such co-investment quickly removes any internal flexibility for deeper, longer term science that is not the top priority for RDC investment. The private sector involvement in agricultural R&D in Australia is limited and with some notable exceptions, is probably putting a brake on agricultural innovation.

Partnerships not transactions: CSIRO sees a stronger “partnership” approach as fundamental to improving innovation system performance. RDCs or other government programs which help set objectives and provide co-funding to the research programs (and leverage significant resources) provide very valuable inputs, but they not the source of all wisdom on science, technology or innovation. Likewise, institutions like CSIRO would be less effective without the inputs coming from funding and priority setting partners. Universities have critical skills and roles to play in both education and research but need to connect more with the wider innovation ecosystem. Over recent years CSIRO has observed (with notable exceptions) a general degradation of such partnerships – increasingly activities are short-term project based and transactional. This has produced a shift to more of the purchaser-provider relationship implicit in Figure 2a rather than a dynamic partnering culture as envisaged in Figure 2b. This transactional culture is not one in which it is possible to build and maintain world class scientific capability as the time frames are mismatched – typically 3 year project cycles compared to scientific capability that is built up in individuals and teams over multiple decades.

Looking forward, re-framing of partnerships with research providers ought to be possible, where participation is priced on value and outputs (and not on inputs), with shared income streams from the value that is created. The cotton example below illustrates that value generation for a R&D provider inevitably benefits industry because value-based returns (at home and abroad) can be re-invested in further R&D, creating a virtuous circle.

A case study in successful agricultural innovation: the Australian cotton industry

To highlight the point that many of our recommendations are achievable we would like to hold up the Australian cotton industry as an example:

- $2.5 B p.a. export industry that would not exist without science-based innovation
- CSIRO varieties & Australia leads the world in cotton yields. These varieties now occupy a significant market share in the USA cotton industry.
- Productivity has not stalled! Yields have improved at 2% year-on-year, greater than in any other agricultural industry in Australia, 45% of the improvement due to better varieties, 55% due to better management.
- Cotton growing has become more efficient. Irrigation water use has dropped by 30% in the last 15 years, and pesticide use has reduced by 80-90% with the use of GM varieties.
- There is a virtuous circle between public and private interests. Cotton variety breeding is a private –public partnership (Cotton Breeding Australia - CBA) between Cotton Seed Distributors and CSIRO,

with value-based pricing of technology innovations reinvested by CSIRO and CBA in long-term R&D. Constant improvement of new genetics lifts yields and reduces costs.

- The Cotton Research & Development Corporation (CRDC) adds significant value and partners well – but does not seek to dominate and control the innovation ecosystem.
- The industry has a strong leadership for a young industry with coherent common interests
- There is a deep long term R&D commitment with staff (including CRDC) embedded in cotton regions.
- A value chain approach that retains a focus on a differentiated high value quality end product, achieved via multi-disciplinary science teams extending from plant breeding to farm management to textile science.

CSIRO and Agriculture

From a complete focus on the challenges of agri-food and fibre industries at its outset in the early 20th Century, CSIRO has retained a strong agricultural and food science capability. In 2014/15, this represented a total investment of $355M, of which $198M came from government appropriations to CSIRO and $157M from competitive external co-investment (from RDCs, industries, State and Federal Government programs etc). This represented around 30% of the total CSIRO activity in 2014/15. While we don't have great confidence in the data, we estimate that CSIRO is directly engaged in around 20% of the national agri-food R&D activity in 2015 – although this will vary across different industry sectors.

CSIRO's agricultural science is still strong, being in the global top 10 for many of the agricultural science disciplines. CSIRO continues to be a major national/global force in agri-food R&D and our Strategy 2020 seeks to move us more to the role of "Innovation Catalyst" for the national system. Our effectiveness as a catalyst for industry innovation is mixed, some areas are "best practice" and in some areas we could do better.

CSIRO is committed to agri-food innovation and wants to partner more effectively with Industry and Government in the "Golden Triangle" (Figure 3).

SOME KEY OPPORTUNITIES LOOKING FORWARD

We wish to offer the following four suggestions as a way of addressing some of the issues raised in our submission.

1. Development of **national leadership forum** focused on improved functionality of the agri-food/fibre innovation system with evidence-based leadership inputs from Govt, Industry and Knowledge Institutes (i.e., Australia's Agri-Food & Fibre Golden Triangle).
2. Development of **emerging market road maps** for higher value capture from Australia's major commodity sectors (coordinated by the Food and Agri-business Industry Growth Centre with input from RDC, State and Federal Governments and Knowledge Institutes).
3. Development of a set of **"national targets" for agri-food sector growth and innovation** – to inform the national policy and practice across industries, governments and knowledge institutes.
4. Development of a **national digital agriculture strategy**, including a plan for a structured data platform to address longer term private and public interests.

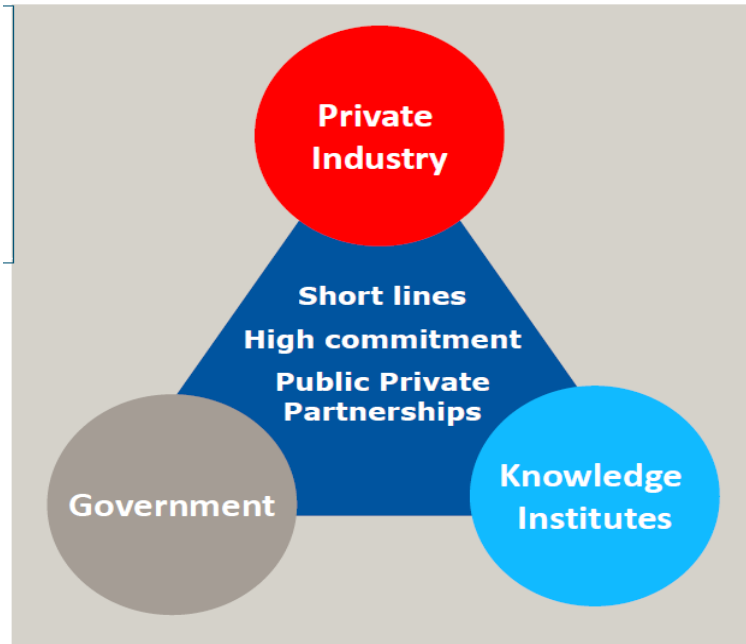

Figure 3. The "Golden Triangle" – effective leadership across Government, Industry and Knowledge Institutes is put forward as the foundation for the Netherlands agri-food innovation success (Netherlands is the second ranked exporter of agri-food products by value in the world)

References

Constable G 2004. Research's contribution to the evolution of the Australian cotton industry. "New directions for a diverse planet". Proceedings of the 4th International Crop Science Congress, 26 Sep – 1 Oct 2004, Brisbane, Australia. Published on CDROM. Web site www.cropscience.org.au

Green R 2015. Senate Inquiry into Australia's Innovation System - Issues Paper. Attachment to the Interim Report Senate Economics References Committee Inquiry into Australia's Innovation System. http://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Economics/Innovation_System/Interim_Report

Keating BA, Carberry PS 2010. Emerging opportunities and challenges for Australian broadacre agriculture. Crop & Pasture Science, 61: 269–278.

Robertson MJ 2010. Agricultural productivity in Australia and New Zealand: trends, constraints and opportunities in "Food Security from Sustainable Agriculture". Edited by H. Dove and R. A. Culvenor Proceedings of 15th Agronomy Conference 2010, 15-18 November 2010, Lincoln, New Zealand.

Robertson MJ and Kirkegaard JA 2011. R&D Priorities for Productivity Growth in Agriculture – report of workshop. CSIRO Sustainable Agriculture Flagship