Australian National University

Centre for Entrepreneurial Agri-Technology

Parliamentary Inquiry into Food Security

Centre for Entrepreneurial Agri-Technology Submission

Contents

Introduction

The Centre for Entrepreneurial Agri-Technology (CEAT) at the Australian National University (ANU) is pleased to make a submission to the Federal Parliament Inquiry into *Food Security in Australia*.

ANU has a well-deserved reputation for conducting world-class research and for providing excellence in research-led education to undergraduate and graduate students. While it does not host a faculty of agriculture, it is investing in initiatives that are helping Australia address some of the most complex challenges facing the agri-food sector. Through its world-class research schools and colleges, and through interdisciplinary, cross-college initiatives such as CEAT, ANU is increasingly contributing to industry-relevant projects of high significance to the agri-food sector. Many of those projects deal with issues related to national and global food security.

CEAT was established in 2018 through a collaboration between the ANU and CSIRO, combined with investment from the ACT Government. It was subsequently elevated to the status of an ANU Innovation Institute (along with the ANU Institute of Space) in 2020. A key role of CEAT is act as a frictionless connector between the ANU and external agencies in industry, government and society. Our goal is to use harness the interdisciplinary capabilities of the ANU to address complex challenges facing the agri-food sector. Key to this is understanding the nature of national and global agri-food challenges; here, our network of CEAT Industry Fellow provides us with intelligence on the most pressing issues that limit our ability to grow and distribute food and fibre. CEAT has used this network of Fellows to inform the content of this submission.

In this submission, we highlight the need to consider the term food security in the context of factors influencing operation of the wider agri-food system. The role of climate change and strategies to improve the resilience of the agri-food system in the face of rising temperatures and extreme weather events is considered. The importance of linking Australia's ability to produce and export food with global drivers in climate, geopolitics, market demands, technology and demographics are considered. Factors influencing Australia's ability to produce food are considered, including links to our reliance on supply lines of resources needed to produce livestock and crops. We highlight threats and opportunities to food production created by climate change. The importance of developing a national agri-food resilience strategy is highlighted, as is the need for Australia to reimagine how innovation is funded and conducted in Australia. A recommendation is made for Australia to invest in transformational mission-style projects that address complex, long-term challenges facing Australia's agri-food sector and to initiate policies and programs that defray risk from changing the current focus of farm and farming systems.

National food security context

Australia is one of the most food secure nations in the world as it produces much more food (particularly major food groups) than it can consume, and exports over 70% of its produce. The term food security encompasses 'availability, access, utilisation and stability' dimensions. However, food security is more than the amount of food and nutritional quality of what we produce, critically, it requires that the *agri-food system*[1] has a supply chain that is resilient in the face of diverse and complex shocks and stresses, and our submission focusses on these issues.

Australia's climate outlook going forward, based on the IPCC *Climate Change 2022: Impacts, Adaptation and Vulnerability* Group II Assessment, offers a framework for understanding the escalating, severe, interconnected and often irreversible impacts of climate change on food systems, ecosystems including biodiversity, and human systems. It highlights the reciprocal interplay between climate change and the future of our agrifood system. The Working Group advises that temperatures and extreme weather events will directly affect Australia's agricultural output, with predicted yield decreases for grain crops (wheat and rice) and reduced meat and dairy production, as well as global supply chain shocks. ABARES *Insights Report* also indicates that changes in Australia's climate over past 20 years has resulted in average broadacre profits being 23% lower in Australian agriculture[2].

As a nation with food security sovereignty, we need to acknowledge our responsibility to ensure and support food security for the Asia-Pacific region. More broadly, we also need to address food security issues of vulnerable populations internationally – populations who are bearing the legacy of historical disparities in energy consumption between first and third world economies and which will be most affected by adverse effects of climate change and geopolitical shifts. The effects of these factors on the international grain market have played out in real time through 2022. This will further deteriorate as climate change amplifies these inequalities given that in the global south, climate change effects will seriously reduce yields.

The Standing Committee on Agriculture will need to consider and resolve what is meant by food security and for whom. Food and nutrition security is not the same as security of agricultural production. A whole of system approach to food security issues will enable deeper insights into the factors influencing food security, both nationally and internationally. An agri-system approach should consider elements including food distribution, transportation logistics, affordability, retail, processing standards and accountability and the need for social income and wage reform. This further includes the various sectors and stakeholders who contribute to the food system (and food security), including households, communities, small businesses, and farmers producing crops and managing livestock on a large scale. A related dimension of domestic food security is why, in Australia, are we so reluctant to regulate food and nutritional standards, labelling and marketing to support informed decisions about food product choices for our population.

Climate change and impacts on the Agri-food system

Climate is a fundamental driver of agriculture and food security with specific influences through both climate averages and climate extremes. Consequently, if climate changes then agriculture and food

[1] The FAO outlines Agrifood systems as referring to "the totality of actors involved in the production, distribution, and consumption of food, the relations between them, and the regulatory apparatus governing these arrangement". https://sdgs.un.org/un-system-sdg-implementation/food-and-agriculture-organization-fao-44217

[2] ABARES, *Insights*, Issue 8, 2022

security will change too. Importantly agriculture and food systems are also key drivers of climate change with the IPCC estimating that 29% of global GHG emissions arise from food systems.

There is accumulating evidence that climate changes to date are already impacting on both averages and variability of agricultural productivity. Globally, agricultural production has been reduced by climate change by about 20% compared with what it would otherwise have been. In some countries (particularly developing nations in the equatorial and subtropics) it is 30 to 40%. This is not the same as saying that agricultural production has gone backwards, because it depends on the balancing factors of improved agricultural management and technologies. Importantly, disruptions to both cropping and livestock systems have increased in both magnitude and frequency over time, leading to major food shortages in different regions and global food price spikes, both of which tend to hit poorest people hardest. At the same time, amongst other impacts, climate change has reduced protein and key nutrient concentrations in key crops and higher temperatures have increased the occurrence of food-borne diseases.

These existing overall negative impacts of climate change on food systems are likely to accelerate over the next decades given current GHG emission trajectories, increasing concerns about food insecurity both globally and intermittently here in Australia.

One World

Australia's domestic agri-food system is enmeshed in an international system. As such it is not insulated from flow-on effects across the world. We have direct experience of the rising prices and lack of availability of critical agricultural inputs, volatility in markets, and food price spikes.

Various global factors that are driving change in our domestic agri-food system that require us to rethink our current system. These factors include:

- *Geo-political changes* and the associated policy, social and demographic changes which arise from these shifts
- *Market demand changes* and expectations of consumers and investors with a particular emphasis on sustainability imperatives, traceability, provenance including accounting for carbon emissions and sequestration
- *Climate induced changes* including changes in disaster risk, increasing uncertainty and aridity, greater water variability and increased competition for natural resources
- *Technological changes* based on advances and the potential for disruptive innovations arising from research and development
- *Demographic changes* and intergenerational impacts arising from cumulative and compounding natural disasters which will impact on regional growth and investment decisions on infrastructure renewal.

These drivers mirror the complex and intersecting risks that the agri-food system is exposed to, risks that cluster into five primary domains:

- *Reputational risks* arising from inadequate actions to mitigate environmental harm, including reducing emission from land use and land use change that could influence market access and capital investment
- *Climate change risks* that will mean dealing with and adapting to the changing climate, including increasing aridity and weather extremes in many of the main agricultural regions
- *Changing market demands*, including the need for confidence in low-carbon and sustainability claims.
- *Financial risks* that include changing lending criteria towards more sustainable practices, including for example, banks requiring environmental sustainability plans, including carbon

- *Innovation system risks* stemming from a lack of research intensity, prioritisation and investment in transformational research and mitigation strategies.

As a global player, Australia needs to fulfill and uphold its international responsibilities and obligations and recognise and capitalise on future opportunities.

Current state of the Australian agri-food system

The Australian agri-food sector has increased in gross value over the last two years through benefiting from high global commodity prices. In 2021-22, gross value of agricultural production was $85B, with a projection for 2022-23, $82B[3]. As highlighted by ABARES[4] on farm performance is increasingly driven by the largest and most productive farms. Farms with receipts above $1 million per year in real terms – have increased their share of total farm numbers from around 3% to 15% over the past four decades. Individual famer equity has increased substantially through the amalgamation of land assets. This has created a substantial barrier to market entry for new players.

However, this is paralleled in 2022 by large areas of South-Eastern Australia experienced severe flooding arising from consecutive La Niña weather systems. These events caused significant damage to farms, private property, public assets, and regional infrastructure, as well as severe crop and livestock losses. They also placed significant demands on emergency and defence services personnel. Recovery from these events will be protracted and the cost to individuals, businesses, local, state and federal government and the Australian population will be substantial. Insurance council figures indicate that to June 2022 the cost payouts for insured losses was $5.45 billion. Further, Deloitte[55] estimates indicate that cost of natural disasters in Australia currently is at $38 billion per annum, with a projection that this will rise to at least $73 billion per annum by 2060. These issues highlight the repercussions of climate change on the Australia population and economy.

Inquiry Terms of Reference

National production, consumption, and export of food

In the face of adverse changes in climate, food producers in Australia need to develop adaptation strategies that improve farm system resilience. Many farming groups and states and territories have undertaken regional assessments of their farming systems, but have not advanced these to a whole of system level. With this in mind, the ANU has consulted with industry experts who are Industry Fellows with the ANU Centre for Entrepreneurial Agri-Technology (CEAT). They nominated the following priority areas for action:

- Strengthen production capability and capacity through strategic alignment of environmental and economic factors
- Improve technical capability in protected cropping – through drawing on international expertise.
- Design and invest in mega food hubs situated where production is likely to be more favourable.
- Review production processes, through auditing of in process research to better understand the balance between, incremental, transitional and transformational innovation
- Establish sovereign capabilities to manage risks in input resourcing and secondary processing to increase value, storage life and transportability of food products
- Direct scientific and technical capability to focus on:
    - modifying food and fibre production in light of abiotic and biotic stresses

[3] ABARES, *Insights*, Issue 8, 2022

[4] ABARES, *Insights*, Issue 8, 2022

[5] Special report: *Update to the economic costs of natural disasters in Australia*, Australian Business Roundtable for Disaster Resilience & Safer Communities, 2021, Deloitte Access Economics

  - intensifying the pursuit of nitrogen use efficiency trait development
  - providing greater investment in regulatory innovation and gene editing capability
  - investing in water use efficiency (drought and heat tolerance research)
- Encourage and incentivise the corporate sector as well to invest in and ramp up innovation in water use efficiency
- Investigate circular economy opportunities at different points of the food system (e.g. minimise food loss/waste at each point of the supply chain)
- Support opportunities for farmers to contribute to the circular economies in agri-food and in the uptake solar energy and/or solar thermal energy (renewable energy)
- Establish a Renewable Energy Transition Strategy for Agri-food sector.

Access to key inputs such as fuel, fertiliser and labour, and their impact on production costs

Farming production systems in Australia have been adversely affected by difficulties in sourcing farm labour and price hikes and often lack of availability of crucial inputs that their businesses rely on. Among the significant issues are:

- Water availability will continue to reduce in key agricultural areas, despite increasing demands from production and non-production water needs
  - Price spikes in water markets may encourage water speculation and holding rather than efficient use in dry periods
  - Non-production values of water for ecosystem health, First Nations' needs, and urban water supply will feature in allocation decisions
  - Structural shifts towards perennial crops increase risk during drought
- The crisis in availability of on farm labour need to consider longer term policy and regulatory settings to address this need such as:
  - Deeper exploration of diverse options for greater access to overseas labour through government schemes.
  - Additionally structural reform is needed here to reduce "red tape".
- The need to establish domestic sovereign manufacturing and infrastructure capabilities in order to manage input resourcing risks. This includes areas such as:
  - agricultural machinery, such as tractors, harvesters, motors, drive-train and hydraulic equipment, as external factors are limiting access to required machinery from overseas
  - pesticide and fertiliser manufacturing of active ingredients, (as almost no sovereign fertiliser manufacturing capability rather complete reliance on imported fertiliser product)
  - secondary processing to increase value, storage life and transportability of food products
  - local fuel supply and sovereign fuel stocks, including increased renewable fuels including biodiesel for agriculture and critical heavy industry and transport
  - secondary processing to increase value, storage life and transportability of food products
- The need to rethink inter-dependencies of movement between Distribution Centres (DCs) given disruption in the context of recent floods which was further compounded by a shortage of skilled drivers. Given the likelihood of ongoing disruption, timely to review the Distribution Centre model and just in time logistics.

The impact of supply chain distribution on the cost and availability of food

Australia's Agri-food supply chain is vulnerable to shocks and stressors domestically and internationally. Currently we are experiencing climatic interventions in our domestic context as floods are disrupting our supply chains. There are a range of measures here that need to be actioned to improve the resilience of these supply chain. This includes:

- Embracing digital, whole-of-value-chain management systems targeting improved productivity (exceeding $20B annually[6]), as well as increased transparency and integrity of food produced for local and export markets
    - Australia needs a national cross-industry approach to this digital transformation as detailed in the Precision to Decision Report [7] to achieve this outcome
- Government and industry together reviewing supply chain needs. The following factors need to be considered:
    - the sector generally has not undertaken systemic analysis across the full supply chain along with investment in new products, consideration needs to be given to processing, access to markets and access to logistics
    - further effort is needed to build on and leverage the excellent track record of our producers and supply chain participants being adopters of technology and innovation
- There is an imperative to better insulate Australian growers, supply chain and consumers from greater variability as this will being ongoing.

The potential opportunities and threats of climate change on food production in Australia

Australian agriculture's productivity, viability and longer-term sustainability is challenged by climate change. The sector faces a range of enmeshed threats (biosecurity, natural disasters, climate and weather volatility, international geo-political and market volatility), however there are also opportunities (new products, markets, practices.) Risks need to be identified, prioritised and mitigated which can be advanced through a national review of the impact of climate change on the agri-food system.

Threats

- There is a need to recognise and acknowledge that business as usual approaches in the food security domain in Australia are not sustainable
- The lack of a food system policy at national and state/territory levels is a major threat to transformation and mitigation
- Climate variability is opening up (and closing down)¬† areas of production capability
- Changing land use driven by hotter and more volatile climates
- Climate variability and volatility is not going away and will continue to challenge production and potential to fill export orders.
- The continuing decline of Australia's agri-food research capabilities and level of investment
- A lack of international collaboration and partnership with 'best in class' food researchers in their respective fields. Need to scout for and establish who is the best and collaborate with them. An example would be that when the Hort Innovation funded glasshouse was commissioned at Western Sydney University, the lack of suitable design experts in Australia meant that advice from Wageningen in the Netherlands had to be sourced to assist with the build.
- Over reliance of bulk commodity exports to major trading partners, who over the next 10-20 years will increase their own food production (i.e. reduce their dependency on food imports) using a range of new technologies (e.g. vertical farming, cell-based foods), combined with higher levels of education
- Imposition of further non-tariff trade barriers to Australian food production
- Industry has moved away from a foundational approach of market development, market access and market improvement which needs to be prioritised and reinstated

[6] Accelerating Precision Agriculture to Decision Agriculture, Cotton Research and Development Corporation, Australia, 2017 p.?

[7] Leonard, E. (Ed), Rainbow, R. (Ed), Trindall, j. (Ed) et al, *Accelerating Precision Agriculture to Decision* Agriculture, Cotton Research and Development Corporation, Australia, 2017

- Lack of extensive consumer insights research (noting that there has been some good individual work done) into potential new markets and food types and the potential impact of new technologies (such as lab-grown meat) in re-shaping markets.
- The length of time that successful market access negotiation takes for Australian product relative to other countries who we compete with
- The ongoing short-medium term research focus of projects (many of which are incremental in nature) funded by Research and Development Corporations in Australia. This pre-occupation continues to ignore new research opportunities.
- The increasing stress and fragmentation of the agri-food research system, including the on-going decline in the number of researchers and investment in Australia
- Although we have good diversity of horticultural crops in Australia, broadacre crops are still dominated by a very small set of staples, there is a need to explore diversification options.
- Climate change while impacting on drought and flood risks for production, will also have a significant impact on disease, pest and weed pressures, with potential for catastrophic losses, particularly with plant pathogens and invertebrate pests. National monitoring of pest pressures, pesticide resistance and monitoring of global biosecurity incursion risks needs to be amplified.
- The length of time and processes to register new crop chemical use patterns with the Australian Pesticides and Veterinary Medicines Authority (APVMA). There needs to be regulatory and policy innovation to ensure these occur simultaneously rather than retrospectively

Opportunities

- Climate variability opening up (and closing down)¬† areas of production capability
- Greater policy analysis of the agri-food value chain, which would highlight Australia's strengths (e.g. global producer of bulk commodity products) and weaknesses (e.g. lack of value-add capabilities, including food processing)
- Embracing new "green" policies and technologies to reinforce Australian agriculture as "clean, environmentally sustainable and high quality"
- Further regional growth opportunities that will develop alongside the growth of more distributed growing areas.
- Australia has diverse landscapes and climates so it can produce diverse foods to meet new and emerging markets as well as produce commodities that are not conventionally grown. For example, we grow only a limited variety of pulse crops although the Asian market for example consumes a large variety of pulses.
- Grow the protected and vertical farming sector through investment in knowledge and incentives to produce food this way, production per sq meter needs to be the KPI
- Build on the ethnic diversity of Australia's population to help drive production trends (Asian veg, Asian tropical fruits)
- The CRC for Northern Australia is undertaking an evidence-based approach to drive support the long-term, sustainable economic development of Northern Australia. Its remit in a**g**riculture and food includes aquaculture, horticulture and forestry. To date it has scoped what type and scale of produce might be applicable, however there is significantly more to be done.
- Australian bushfoods are still seen as niche commodities. There is increasing interest in exploring native species and their potential applications and use to produce new commodities and foods. This will require marketing effort and further investment in R&D
- Food systems development across scale –local, city, regional and national to improve system resilience, innovation, and transformation
- Policies that encourage large multi-national agri-food companies to establish research and product development capabilities in Australia
- Involve multiple sectors, disciplines, and fields of expertise to address food system issues (use systems thinking and avoid silo effects)
- Australia as an export focused nation needs to be fully engaged in:

- international trade agreements around sustainable production practices, i.e. regenerative farming in EU is essentially how the majority of Australian grain farmers current produce crops with no-tillage and stubble retention.
- international FAO/WHO agreements on global acceptable pesticide residue standards including CODEX, CCPR, JMPR etc.

Driving a National Agri-food Resilience Strategy

Stakeholder engagement and input from multi-disciplinary expertise at the ANU over the last year have reinforced the urgent need to transform beyond business-as-usual practices. Our discussions continue to identify the need for national leadership and agenda setting to adapt to, and mitigate the impacts of, these global challenges. The Australian government has a clear role to provide leadership in implementing national reforms which can span areas of food distribution, equity of access and in coordinating environmental management outcomes in the national interest. In addition, it is a significant investor in managing critical national infrastructure which is needed to support our supply chains. The federal government also has regulatory responsibilities in trade, setting food standards, and in marketing to name a few areas of core responsibility, which can drive change to meet global challenges.

A key recommendation of the Food and Agricultural Organisation of the United Nations (FAO) is the need for the national governments to initiate and coordinate the development of sustainable, holistic agri-food systems[8]. We see this being progressed through the development of a National Agri-food Resilience Strategy to ensure necessary measures are aligned to enshrine food security at a sovereign level.

Our investigation into food systems transformation highlights the need to focus on structural reforms that can provide the enabling environment and policy mechanisms for transformation in the sector. Current policy settings across regional development, sustainable natural resource use and agriculture, lack coherence and integration, resulting in many piece-meal, fragmented projects. A national strategy would articulate a long-term agricultural reform framework to adapt to and mitigate against the impacts of rapidly emerging drivers of change and perverse outcomes built-in to the current system. A well-constructed strategy, working with industry and state governments, would adopt and give effect to principles for structural reforms with measurable long-term objectives. Further, a national strategy would provide confidence for industry to invest over a 30-year planning horizon.

Reimagining the Innovation Sector

A key role in a national strategy would be to incentivise the national innovation sector to transform through agreed and well-resourced national missions and to also embrace spill over innovation possibilities from other sectors. We know from numerous papers that there are opportunities within the agri-food innovation system to address identified impediments to transformation. This includes setting R&D priorities and investments that go beyond business as usual practices, a greater focus on system level analysis and decision-making, ensuring clear and strong directionality, moving to longer term funding cycles, addressing innovation system fragmentation, providing strong evidence bases

[8] Building a common vision for sustainable food and agriculture, FAO, 2019, p.19

to support transformation and a greater focus on novel approaches and mission orientation (Hall and Dijkman, 2019[9]; Klerkx and Begemann, 2020[10]).

Contemporary innovation systems need to 'start with the end in mind' with the 'end' embracing the whole system rather than individual producers or farming groups. A priority is to identify where substantive change can occur to keep our supply chain in equilibrium. Transformational concepts and technologies are required to underpin research programs, based on a collaborative co-creation process that clearly define and articulate pathways to impact.

Much of our agricultural innovation effort to date has focussed on increasing production. A transformative future will require moving agriculture innovation beyond a 'production only' focus to managing coupled and integrated natural and social assets able to cope with climate and other external shocks. A systems-view of food security can be characterised by an agri-food system which is:

- Capable of meeting changing market demands and responding to cultural diversity with a focus on sustainability and circular economies
- Accepting of production technologies and novel food processing and consumption processes such as protected cropping, use of alternative proteins and nutritional security
- Increasingly confident in assessing and managing business risk.
- Considering innovations across the entire value chain
- Balancing technologies of production with the necessary social innovation to support uptake and adoption of new economies.

Measures of a transformative strategy

CEAT Fellows and stakeholders are working towards realising an agri-food innovation system that has transformative capability and agreed system wide priorities. A transformative national agri-food resilience strategy would:

- establish a strategic national government approach guided by coherent, long-term objectives and clear indicators of desired outcomes
- communicate a shared vision of desired futures informed by divergent scenarios
- integrate measures of resilience and flexibility
- identify leverage points and transition pathways that characterise the reform agenda
- support local and regional scale devolved governance cognisant of our heterogenous landscapes
- broker partnership between, government, industry and civil society
- ensure the necessary agility to respond and act definitely
- initiate policies to strengthen the health, longer-term sustainability and impact of the Australian research "engine"
- reshape institutional arrangements to clearly place agriculture within regional economic development.

This strategic framing would also be of benefit in guiding business as usual approaches as well.

[9] Hall, A. and Dijkman, J. 2019. Public Agricultural Research in an Era of Transformation: The Challenge of Agri-Food System Innovation. Rome and Canberra: CGIAR Independent Science and Partnership Council (ISPC) Secretariat and Commonwealth Scientific and Industrial Research Organisation (CSIRO), IX + 67 pp.

[10] Klerkx L, Begemann S. Supporting food system transformation: The what, why, who, where and how of mission-oriented agricultural innovation systems. Agric. Syst. 2020 Sept:184: 102901

Mission-oriented innovation systems

Australia lacks a deliberate mission-oriented approach to addressing national issues. Missions are measurable, ambitious, and time-bound targets that have the potential to become a significant vehicle for change. They work to tackle complex societal challenges such as climate change and global health by taking a purpose-oriented, market-shaping approach. They set the direction for a solution**, but do not specify how to achieve success**. Mission-oriented innovation systems operate as a "network of agents and set of institutions that contribute to the development and diffusion of innovative solutions with the aim to define, pursue and complete a societal mission"[7]. They need to be consciously steered *by intended directionality*[8]. Directionality can be seen as "a temporary innovation system in which policy makers and other actors aim to coordinate innovation activities, with the objective of developing a coherent set of technological, institutional and behavioural solutions" (Hekkert et al., 2020: p.78)[11].

Transformation of these knowledge and innovation systems is particularly relevant in food systems, as Fuglie[12] estimates that around USD $56 billion is spent every year on agricultural research and development (R&D) (Fuglie et al., 2020), but they are often focused on incremental as opposed to transformative change (Hall and Dijkman, 2019)[13], which is very much the case in Australia. Reorienting these investments to accelerate the transformation in food systems under climate change presents a major opportunity to incorporate missions as a way to drive and enact national strategy.

Indicative missions

Here we present examples of indicative missions to help conceptualise how missions-based approaches can drive transformation, guided by a national resilience strategy.

Mission: Achieving a low emissions agri-system. Goal: To create economies of scale and net environmental good, centred on reducing GHG emissions and climate change adaptation across the agrisystem based on public and private investments.	*Mission: Rural adjustment* Goal: to reinvigorate rural and regional communities by providing clear pathways for community adjustment
Possible R&D themes • Reducing net GHG emissions from across the value chain • Enhance carbon sequestration in the landscape	*Innovation themes* • Revitalising regions through new 'future-ready' industries and employment opportunities • Changing capital markets

[11] Hekkert, M.P. , Janssen, M.J., Wesseling, J.H, Negro, S.O. "Mission-oriented innovation systems", *Environ. Innov. and Societal Transitions*, 34 (2020), pp. 76-79

[12] Fugiie, K. et al, 2020, *Harvesting Prosperity: Technology and Productivity growth in Agriculture*, Washington DC, World Bank

[13] Hall, A. and Dijkman, J. 2019. *Public Agricultural Research in an Era of Transformation: The Challenge of Agri-Food System Innovatio*n. Rome and Canberra: CGIAR Independent Science and Partnership Council (ISPC) Secretariat and Commonwealth Scientific and Industrial Research Organisation (CSIRO), IX + 67 pp.

• Bio economy and circular economy agri-manufacturing (e.g. bio refineries) • Planning for landscape scale agroecology models • Widespread integration of agri-forestry into conventional farming systems • Increasing enterprise diversity beyond conventional annual and perennial crops	• Changing product markets and consumer requirements • Informed transitions governed by forces driving change

Spill over Innovation Opportunities

CEAT has also actively been scanning associated innovation domains (e.g. defence, pharmaceutical, space) for possible spill overs that apply in agri-food contexts. Recently we ran a workshop on *What crop breeding can learn from the experience and road map for transformative development and delivery from COVID 19 vaccine innovations*. CEAT Fellow Alison Bentley, Director of the Global Wheat Program for CIMMYT was the initiative instigator to improve crop varieties that contribute internationally and nationally to food security through resilient staple cereals. Like vaccines, crops can generally take more than 10 years to reach end-users.

We have identified key innovations that transformed vaccine discovery, development, regulation, manufacture, supply and adoption and are analysing how they can be applied to a new context. Collaboration between researchers and biotech leaders is contributing to mapping and analysing parallelism in breeding trials, regulatory reforms, open forms of collaboration and research sharing (including prepress), changing of IP arrangements, application possibilities of new platforms for Messenger RNAs, modelling applications and better ways to manage the huge data and analysis challenges and bridge the genotype – phenotype gap.