

Editorial

Resilience of Agri-Food Systems

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Agriculture was launched in June 2011 as a scholarly, open access journal for publishing research covering the breadth of the agriculture value chain from an international perspective. In the decade since, *Agriculture* has evolved into an influential journal with an impact factor of close to 3 and a ranking in the top quartile of “Agronomy” journals. This excellent achievement is a credit to many contributors: the authors who submitted papers, the editorial team, peer reviewers, those who work behind the scenes in the publishing chain, and the MDPI publishing house. I congratulate them all on a wonderful accomplishment and wish *Agriculture* great success in continuing on this exciting journey. I look forward to reading the cutting-edge science that will be published in *Agriculture* along the way.

In my initial editorial as Founding Editor-in-Chief [1], I discussed the global challenges in the agriculture industry of increasing food production and ensuring food security. Now, in writing an editorial for this commemorative Special Issue, I see the emphasis of agri-food systems shifting gradually from a need to continually increase food productivity to producing food in a better way that builds sustainability and resilience. This was the theme of an address I gave to the Australasian Grain Science Association’s 73rd Annual Conference in August 2021 on being awarded Association’s Guthrie Medal (The Guthrie Medal recognises the contribution of pioneer cereal chemist F B Guthrie to grain science research in Australia and for his work with William Farrer in establishing the modern Australian wheat industry). The following personal reflections on resilience of agri-food systems are based on my address.

The efficient operation of food supply chains is often taken for granted, but the COVID-19 pandemic has raised questions about agri-food systems and their resilience. Agri-food systems encompass the complex chain from production to consumption, according to the definition of the International Food Policy Research Institute (IFPRI): “the sum of actors and interactions along the food value chain from input supply and production of crops, livestock, fish, and other agricultural commodities to transportation, processing, retailing, wholesaling, and preparation of foods to consumption and disposal” [2]. The enabling policy environment and impacts on nutrition, health, environment and sustainability are considered relevant to this definition [3]. The resilience of food systems is determined by their capacity to eliminate weaknesses and deal with future uncertainty and disruptive shocks [4]. In considering resilience of agri-food systems, we need to take a holistic perspective of many factors that can influence supply chains and their logistics: declining availability of arable land, water and healthy soils; pests and diseases of crop plants and livestock; unpredictability of weather and changing climate; growth in emerging economies; aging and increasingly urbanized populations; greater demand for convenience foods; consumer interest in provenance and ethical values in food production.

Agri-food systems are subject to uncertainty, which can make decision-making difficult. Uncertainty brings risks, which need to be managed by assessing appetite and tolerance for risk and the relationship between risk and reward. Risks may be short term, affecting day-to-day operations, or they may have a longer-term horizon, requiring strategic decision-making. There are risks in production (e.g., weather and climate, selecting appropriate



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genotypes and practices, biosecurity); markets and trade (supply vs. demand, prices, exchange rates); externalities (government policies). There is also risk from inaction. We take risks every day in normal life, often subconsciously, and accept that nothing we do is completely safe.

Most predictions indicate the world's population will continue to increase, albeit more slowly, before stabilising at about 10 billion by 2050. The United Nation Food and Agriculture Organization (FAO) predicts that about 70% more food will be needed to feed the world's population in 2050. However, some modelling indicates the challenge may well shift from continuing to increase food productivity to producing it in better, more sustainable ways [5,6]. Healthwise, there is an ongoing need to alleviate hunger and micronutrient deficiencies in the human diet, most notably for iron and vitamin A. In 2020, close to 12 percent of the global population was severely food insecure, while one in three people did not have access to adequate food [7]. At the other end of the scale, the rise in adult obesity and its greater risk of diet-related ill-health is now a global problem, not just one for the developed world.

To look to the future, we should consider how far agri-food systems have progressed in recent times. Since 1971 (a year chosen because of its personal significance of submitting my PhD thesis and celebrating my wedding) the world's population has doubled from four to nearly eight billion, yet the global average daily energy and protein consumption per person have increased by about 20–25% [8], indicating a significant boost to food production. Taking Australia as an example of a developed economy, life expectancy at birth has increased from 67.8 to almost 80 years for males and from 74.5 to 85 years for females. Coinciding with these advances is a significant shift in the approach to biological research, from being mostly empirical hypothesis testing 50 years ago, to a new paradigm using tools brought by spectacular advances in biotechnology, sensors and big data.

Similarly, advances in technology can be seen to have driven growth in food supply since the time of early humans. Transformational change has occurred mostly through an accumulation of incremental steps rather than through step change breakthroughs. The Green Revolution of the 1960s, the adoption of conservation farming in the 1970s, precision agriculture in the 1980s, the biotech revolution in the 1990s, and the digital revolution of the 2000s are all examples of incremental evolution by integrating knowledge across multiple disciplines. Nevertheless, the current rate of technological change seems unprecedented.

What are the transformative forces acting on the agri-food supply chain? Selective breeding remains the cornerstone of agriculture, but it has been greatly boosted by the genomics revolution. Increased speed and reduced cost of gene sequencing and the capacity for data analysis have extended the frontiers of biology, greatly enhancing genotyping and marker assisted selection, and enabling new sources of genetic variation to be explored and the analysis of quantitative traits such as yield, quality and genome by environment interactions. These advances are augmented with tools for specific gene editing (e.g., CRISPR), linking genetic variation with phenotype using genome wide association studies (GWAS), rapid detection of DNA or RNA for pathogen tracing in the field, and understanding epigenetic adaptations to environment and the critical importance of microbiomes in human health and agro-ecosystems.

On farms, real-time sensing technologies are used for: monitoring weather, soil conditions and water availability; the growth and health of crops and livestock; outbreaks of pests, diseases and weeds; spoilage in grain storage; and to provide decision support and land-use mapping tools. Connectivity of sensors, controllers and machinery (the Internet of Things) allows for operations such as sowing, irrigation, fertilisation, crop protection and harvesting to be controlled remotely and performed as needed. In supply chains, real-time evaluation of raw materials, ingredients, products, processes and assets can be achieved from microanalytical devices that measure temperature, moisture, CO₂, constituents (e.g., protein, fat, carbohydrates) and contaminants. The information gleaned can

support transactions amongst a decentralised network of growers, processors, suppliers, retailers, regulators, traders and consumers.

Identifying areas for research is essential to building resilience and helping to eradicate weaknesses and deal with uncertainty. There will always be a need for genotypes with improved tolerance to abiotic (heat, drought) and biotic (pests, diseases) stress, and with improved quality of products for processing and nutrition, especially in a changing climate. Essential research will be needed on appropriate practices for use with new genotypes, to improve efficiency of input use (water, fertiliser, energy), on agricultural systems for mixed cropping and livestock, reducing waste and valorising co-products. Interest in alternative food sources and obtaining more dietary protein from alternative sources such as plants or insects is generating important research questions on “green” methods for processing of raw materials and developing flavoursome and nutritious products attractive to consumers, and how such systems can add value to the agri-food chain, given that a significant amount of food production currently comes from livestock grazing on marginal lands unsuited to cropping. In terms of nutrition, there is a need to improve communications around health claims and dietary messages, including greater promotion of healthy diets rather than simply healthy foods. Probably the greatest uncertainty facing the agri-food system is climate change, which will not only affect food production, but also influence policies of governments and international trade. Permanent changes have already occurred in weather patterns affecting rainfall and temperature in various agro-ecological zones, for example as seen from the expansion of the semi-arid tropics [9].

The COVID-19 pandemic has been a major shock that has tested the resilience of agri-food systems. Disruptions to supply chains have occurred where there is a dependence on itinerant labour and long-distance transport. However, at least initially, supply chains seemed to continue to function reasonably well in places with good logistics and communications infrastructure [10], although the increase in the FAO World Food Price Index throughout 2021 is an indicator of ongoing disruptions [11]. There are signs the pandemic will be a catalyst for longer term changes, some of which were already starting to occur before COVID-19. For example, trends to increasing automation and digitisation, on-line purchases and eCommerce are likely to continue apace. There may also be longer term changes in work places and practices, lifestyle choices and travel. Effects on agri-food systems and supply chains may bring changes in how ingredients and foods are packaged and sold, and increase demand for local warehousing and storage capacity. The science of tracking and tracing pathogens has advanced greatly during COVID, which will benefit applications in agriculture and food processing. Most importantly, lessons need to be learned from the current pandemic to help prepare for the next, inevitable disruptive shock.

The agri-food system has made great advances in the last 50 years. Adoption of research discoveries has been the major stimulus for these advances. Although many challenges lie ahead for the agri-food system, the promises brought by digital, data and biological technologies give cause to be optimistic about the resilience and adaptability of the agri-food system in the next 50 years. Most people accept the need for innovation but are less enthusiastic about the disruptive changes it often brings. However, as noted by the evolutionary biologist Charles Darwin: “It’s not the strongest of the species that survives, nor the most intelligent, but the one most adaptable to change”.

Conflicts of Interest: The author declares no conflict of interest.

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