



FOOD 4.0: THE FUTURE OF FOOD INNOVATION IN ASIA

Written by



Foreword

Harnessing innovation to strengthen our food system

Innovation in our food system comes in various forms.

On one end of the scale we have disruptive technologies and there are some fascinating innovations we are seeing across the supply chain. For example, one technology that always intrigues people is facial recognition for cows. Through careful analysis of individual cows coupled with AI, a dairy farmer is able to anticipate issues and adjust his operations to enhance animal health, improve efficiency, and increase his profitability. We are applying or exploring other incredible technologies for application to areas like cultured meat, insect proteins and more. One example is acoustic technology that tells aquaculture farmers when to feed their shrimps.

On the other end of the innovation spectrum, we find more basic technologies like irrigation systems, inter-cropping, mobile financing and such. In Asia, where a majority of farmers are smallholders, even these basic technologies applied en masse could tip the scale into making farming more attractive and subsequently strengthen our food system.

Technology, whether basic or cutting-edge, will be key to improving efficiency, which in turn will impact all the processes along the supply chain and beyond. Ultimately though, our ambitions are simple. Give the farmer and his family a decent living; give people affordable, safe and nutritious food; and make agriculture and food supply chains sustainable. We sincerely hope this research series with The EIU will help drive more conversations and collaboration in the industry to make these goals a reality.



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1. About the report

This report is part of the Asia Food Systems 2030 series, developed by The Economist Intelligence Unit and sponsored by Cargill. The analysis is based on wide-ranging desk research and in-depth interviews with agriculture and food experts. The report focuses on the role of technology and innovation in the past, present and future of Asian agriculture, examining the extent to which it can tackle current challenges. Recognising the diversity of the region's needs, the report looks at a range of innovations, from crop science, laboratory-grown meat and precision agriculture through to low-cost, simple, smallholder-focused farm productivity aids (such as weather apps and mobile-enabled "fin-tech").

Our thanks are due to the following people (listed alphabetically by surname) for their time and insights:

- Ishteyaque Amjad, Coca-Cola India and South West Asia
- Dr Sumiter Broca, Food and Agriculture Organisation of the United Nations
- Ron Christianson, McDonald's
- Gwyneth Fries, Agility Logistics
- Dr Paul Teng, S. Rajaratnam School of International Studies
- Delfin Ganapin, World Wide Fund for Nature
- Matt Kovac, Food Industry Asia
- Pushpanathan Sundram, former Deputy Secretary General of ASEAN for ASEAN Economic Community
- Dr Achmad Suryana, Indonesian Centre for Agricultural Socio-Economic Policy Studies
- Dr Tan Siang Hee, CropLife Asia
- Dr Tan Sze, Nestlé
- Zee Yoong Kang, Asia Roundtable on Food Innovation for Improved Nutrition

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2. Executive summary

Asia is a fulcrum of the global food system, both as a producer and a consumer of critical commodities including rice, wheat, oil crops, cereals, livestock, root vegetables and aquaculture. The region's agricultural productivity in these and other foods has increased markedly over the last 50 years, thanks to crop science, government policy and the delivery of extension services to smallholders, often with donor assistance.

There is reason to believe that Asia will make a substantial contribution to both domestic food security and, thanks to its large population, global efforts to achieve the Sustainable Development Goals (SDGs). It has rich natural assets, including major rivers such as the Yangtze, Mekong, Ganges, Brahmaputra and Indus, as well as large lowland areas, which together create fertile alluvial plains and deltas. Its wealthier countries also have significant scientific capacity, including the latest innovations in genome editing. However, there is no guarantee that Asia's food system will prosper. Behind the headline statistics, productivity growth is stalling in a number of countries, due to environmental degradation, the limited availability of new arable land and the pressures of climate change.

In order to understand the systemic concerns regarding Asian food systems, this report focuses on two questions:

- Which trends are driving innovations in Asia's food system?
- What are the challenges and opportunities for policymakers and the private sector in managing these trends?

The answers to these questions are summarised below and discussed in more detail in the remainder of the report.

1. Which trends are driving food system innovations in Asia?

● **There is a shift from input-based technology to information and knowledge-sharing tools**

While the development of genetically optimised crops is crucial for Asia, innovations in mobile telephony, apps, sensors, data analytics and the Internet of Things (IoT)—part of the emerging field of “precision agriculture”—are playing an important role in increasing productivity and reducing food loss. These innovations range from simple tools that inform farmers' decisions (for example, by supplying weather and climate information) to more complex technologies such as precision agriculture, which varies the rate of agricultural inputs and allows field monitoring over large areas. There are also efficacious knowledge-sharing platforms that expose smallholders to the latest science and knowledge about suitable crops to cultivate and improved growing methods.

● **Emerging technology can help to address citizen concerns about biotechnology, while also supporting Asia's resource-heavy nutrition transition**

As protein consumption increases, there is a growing interest in emerging technologies among donors, philanthropists and the private sector, such as “clean meat”, which is developed in laboratories. Asia now has clean meat and cellular agriculture research in Japan, and a recent trade deal in China will enable clean meat imports, all of which can help to reduce the environmentally damaging impacts of the livestock industry. Genomic editing is another advanced science trend with broader applicability. Unlike genetic modification, gene-editing technologies introduce genetic mutations that are indistinguishable from the processes of natural breeding. These have already been applied to agriculture in China and South Korea and can help the region develop more resilient crops without the controversies of genetic modification.

● **Innovation in biotechnology and climate-smart agriculture will become more urgent as concerns grow about environmental degradation and climate change**

Climate change and resource degradation have created a need to develop new ways of growing food, and to reduce the environmental harm of agriculture. Asia has already benefitted from biotechnology—including seeds that are resistant to flooding, drought or temperature changes, as well as innovations that help to protect crops from pests and diseases—and biotechnology will continue to play an important role in agriculture in the region. Climate-smart agriculture can also support a more resilient food system. Tools such as solar-powered irrigation, drip irrigation and smarter crop-planting strategies help farmers to work within climate and environmental constraints, and to adapt to climate and environmental changes.

● **Delivery (not just discovery) of technology will be increasingly important in order to overcome technology literacy and infrastructure constraints**

Technological innovation is of little use if it does not percolate throughout the supply chain. Limited technology literacy means that agricultural extension services are crucial to help bring new knowledge and tools to all who could benefit from them, ensuring broad-based productivity growth. Government agencies have a dual role to play here: distributing better inputs, and supporting the education of farmers. Information and communication technology (ICT) tools are already playing a powerful role in delivering better information and analytics, and collaborations between governments and large companies are helping to improve smallholders' exposure to new knowledge and technologies.

● **Technology is helping to change supply chains in food systems, both for producers and consumers**

Technologies can optimise supply and demand matching, and companies are already exploring Internet-based food and grocery delivery, helping to create more densely networked and nimble food delivery systems. Parts of the continent are well-suited to food delivery services due to high population densities in urban areas. There is also evidence that e-commerce platforms are already

being used to connect producers to consumers directly, although the economic viability of such efforts is likely to depend on large retailers working with delivery and logistics entities, rather than small farmers selling produce directly to consumers.

● **Reformulation and fortification are likely to be the key focus of food technology, particularly given the region's concerns about nutrition**

Food fortification addresses micronutrient deficiencies, and Asian regulators are already promoting the fortification of crops and final food products, including wheat flour, rice and yoghurt, ensuring the addition of iodine, vitamin A, iron, folic acid and vitamin B12. Attention is now beginning to focus on the quality of fortification, rather than just the amount, and consumer food companies are actively engaged in these efforts, in some cases exceeding regulatory requirements. In the realm of final consumer products, reformulation is another area of product innovation—a process that allows companies to remove substances such as sugar, salt and harmful fats and replace them with healthier alternatives.

2. What are the challenges and opportunities for policymakers and the private sector in managing these trends?

● **Invest in extension services and capacity-building to support agricultural stakeholders**

While agricultural extension services are in place across the region, there is room for improvement in both design and delivery. For instance, some extension services have a gender bias—emphasising cash crops that tend to be managed by men, or failing to invite women to seminars on agrochemical use. Research has also highlighted farmers' limited access to, and adoption of, technology and extension services due to obstacles such as risk aversion. Agribusinesses can play a greater role in strengthening supply chains through commercial collaborations with smallholders, leading to the development and dissemination of new crop varieties, machinery and technology. Improving access to finance is another important capacity-building intervention. Smallholder farmers lack the capital to invest in labour-saving technology, partly because banks tend not to lend to smallholders (who lack conventional forms of collateral and formal book-keeping). Innovations will not deliver their full benefits if farmers are reluctant to borrow, or if banks refuse to lend.

● **Balance commercial needs against consumer concerns in science-based policymaking**

It is crucial that companies producing genetically modified (GM) foods, as well as policymakers in favour of genetic modification, embrace transparency and engagement in response to concerns about GM foods in Asia. Strict and transparent regulations could help to build trust by increasing consumer visibility for their products. Countries also need to invest in capacity-building and strengthen regulatory frameworks so that they can make evidence-based policy choices in complex areas such as genetic modification, as well as areas of newer scientific innovation such as gene editing. There are no simple answers to the health and environmental questions raised by innovations such as genetic

modification, which suggests that decisions will need to be made on a case-by-case basis. Making those evaluations in an informed way can only be done if governments have the capacity to measure and quantify the risks, and to effectively communicate the rationale for their decisions to the public.

● **Encourage co-operation in technology transfer and openness to trade in technology**

Technology transfer, cross-border trade and intellectual property (IP) all shape the development and diffusion of agricultural innovation. While strong IP protection can encourage innovation, it is important to recognise that Asia has a large number of smallholder farmers, and that the high prices enabled by IP can exclude large segments of the agricultural community, who cannot afford to buy or licence patent-protected innovations. There are added complexities wherever commercial research builds on (or is indirectly funded by) donor or government grants, including understandable resistance to patent protection for innovations that may have required public funding in earlier phases of development. However, there is evidence that industry, government and civil society groups can work together to balance commercial needs against the rights of the economically disadvantaged by embracing patent flexibility. Trade policy can also play a role, as reducing tariff and non-tariff barriers to agricultural technologies from abroad can positively affect farm-level productivity.

3. Background

Food production in Asia has increased significantly over the last 50 years thanks to government policy, public investment and innovation, from the Green Revolution of the 1960s through to the latest advances in precision agriculture and genome editing. However, the region does not yet have a well-functioning and inclusive food system, characterised by sustainable production methods, efficient supply chains, smallholder integration, minimal use of harmful substances and reduced food loss, all of which can support the well-being of the general population. As a result, Asia remains home to 60% of the global hungry, with particularly high malnutrition rates in South Asia.¹ Productivity growth in rice has (with the exception of South-east Asia) generally kept pace with population growth, rather than exceeding it,² and there has been a plateau or decline in productivity as years of environmentally damaging practices take their toll on soil and water resources. In China, Indonesia and the Indo-Gangetic plain, for example, rice yield increases began to tail off in the 1990s.^{3,4,5,6}

Climate change has added new pressures. Reduced rainfall has depleted water resources, and increasing temperatures have disturbed crop development cycles and rendered some unviable.⁷ Rising sea levels and flooding also threaten fertile geographies, including China's wheat and maize-growing regions, such as the Pearl River Delta, Yangtze River Delta and coastal Jiangsu Province; Vietnam's rice fields in the Mekong Delta and Red River Delta; and large swathes of low-lying countries, such as Bangladesh, India and Indonesia.⁸ Infrastructure development projects, such as dams in the Mekong River, could worsen water supply dynamics, according to Dr Siang Hee Tan, executive director of CropLife Asia, as could the continuing lack of regulations regarding water withdrawal.

Together, these trends pose a serious threat to the region's economies, and to global food supply. Asia is the dominant producer of rice and fish, and a major producer of cereals and palm oil.^{9,10,11,12} Agriculture is also a significant source of GDP for many Asian economies, contributing around 20% of GDP in Bangladesh, Bhutan, India and Pakistan, and 33% in Nepal. It also accounts for around half of the total employment in Bangladesh, India and Pakistan; 31% in Sri Lanka; and 65% in Nepal. Recognising its systemic importance to economic development, multiple governments have included agricultural productivity goals in their periodic national development plans.¹³

Thankfully, innovation and technology are now helping to tackle these problems. Agricultural producers are already adopting a wide array of innovations and technologies, from vertical farming in urban Asia to solar-powered irrigation in rural Bangladesh; and from genomic editing, synthetic meat production and precision agriculture in Singapore, Japan and China to low-cost apps and mobile services that help smallholder farmers access information, financial services and training in Nepal, India and Bangladesh. These innovations are already reducing environmental damage, improving yields, cutting food waste and helping the region adapt to the era of climate change. However, the

scale of the challenges means that wider adoption of these innovations, and continued improvements to them, will be necessary to offset growing environmental and climate challenges.

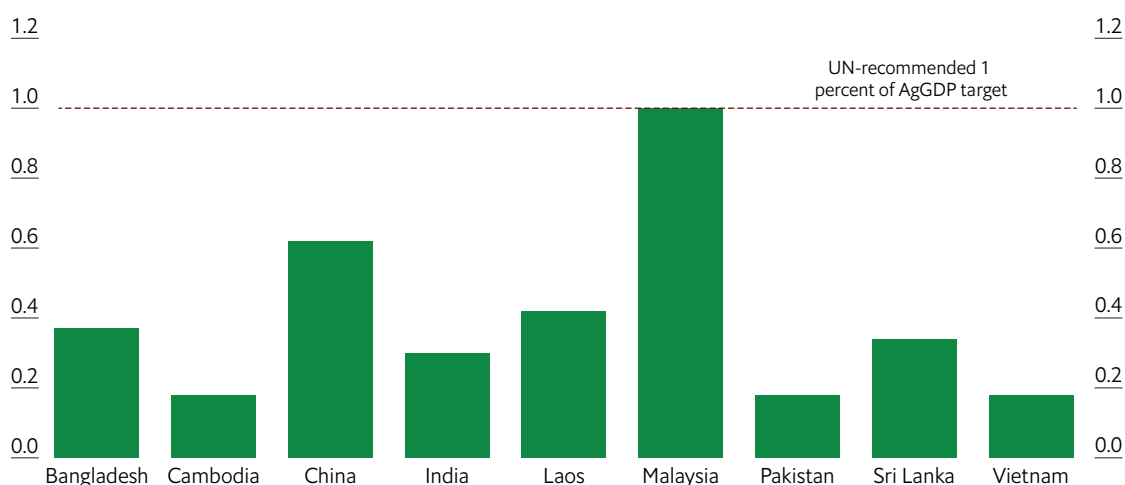
There is broad acknowledgement that food innovation research should be undertaken in low- and middle-income countries, not just developed ones. A study produced by the Consultative Group on International Agricultural Research (CGIAR) estimated that for every US\$1 invested in its research, at least US\$9 worth of additional food is produced in developing countries.^{14,15} Technology adoption doubled Vietnam's rice production, and the Philippines leveraged hybrid and genetically modified corn to dramatically increase productivity and turn the nation towards self-sufficiency. Another study has argued that a portfolio of innovations—including integrated soil fertility management, precision agriculture and water harvesting, applied to wheat, rice and maize—could reduce the number of people at risk of hunger by 35%. It also argued that all climate change-related increases in child malnutrition in the Pacific Islands could be eliminated by introducing a package of policies that includes increasing research and development (R&D) to 2% of agricultural GDP.^{16,17}

While the case for food innovation is strong, countries differ markedly in their research capacities and therefore their R&D agenda. The more developed economies of Japan, South Korea, Singapore and China are advancing high-level agricultural research in robotics and automation, as well as biological innovation in genomics, cellular agriculture and synthetic foods. In contrast, lower income nations with more limited research capacities have focused on collaborative crop science research and low-tech apps and products for farmers. Some efforts involve genetic adaptation of crops so that they can withstand climate change, pests and disease. Other efforts, particularly in countries with high malnutrition rates, fortify crops or final consumer products (such as yoghurt) with additional nutrients such as iron, zinc, and vitamin A.¹⁸ Out in the field, a growing number of start-ups and small and medium-sized enterprises (SMEs) are developing apps and mobile-based tools to help farmers.

This food innovation research is being carried out by a wide range of entities, from the public sector to NGOs and private firms. At present, most agricultural researchers in Asia are employed by the government, the university sector or non-governmental organisations.¹⁹ In China, state-owned entities carry out significant agricultural research, including the China National Agricultural Development Corporation, which is exploring biotechnology, materials technology, advanced equipment manufacturing, precision farming, intelligent control technology and genetic research.²⁰ Many other Chinese agencies are involved in genetics, developmental biology and fisheries research.^{21,22} India's R&D is partly carried out through its State Agricultural Universities, with the Indian Council for Agricultural Research (ICAR) functioning as the country's overall research and education co-ordinating body. Bangladesh, Nepal, Pakistan and Sri Lanka also have national agricultural research councils. In addition, the region is home to influential non-government research organisations, notably the International Rice Research Institute (IRRI, based in the Philippines) and the International Crops Research Institute for the Semi-arid Tropics (ICRISAT). These are often assisted by global institutions such as the CGIAR.

Inevitably, public-sector agricultural research spending varies, reflecting countries' economic circumstances. China spent the largest amount on research in 2013 (\$9.4bn), followed by India and Indonesia (which spent \$3.4bn and \$1.4bn, respectively, in 2014). Spending in all three countries mushroomed in the early 2000s, quadrupling in China, increasing by 75% in India, and doubling in Indonesia. In Bangladesh, Cambodia and Vietnam, spending has increased modestly in recent years. In Malaysia, Laos and Sri Lanka, however, research spending has fallen. (In Laos, spending fell particularly dramatically, from \$32.7m in 2000 to \$8.8m in 2014.) Of course, these figures only reflect public spending and may be offset by private spending in some cases. However, even in countries that increased spending, it continued to lag behind the growth of agricultural output. Indeed, one analysis found that none of the 12 Asian countries sampled had reached the United Nations' (UN) recommended "investment intensity" ratio for agricultural research spending (1% of agricultural output).²³

Figure 1: Agricultural research spending (excluding the private, for-profit sector) as a proportion of agricultural output, latest year
(as a share of AgGDP, %)



Source: International Food Policy Research Institute.²⁴

In Western economies, commercial firms have accounted for an increasing share of agricultural research and development, helped by tightening patent protection frameworks in the life sciences. By 2011, 52% of research into crop breeding, informatics, fertiliser, pesticides and food technology was conducted by private enterprises, up from 42% in 1980.²⁵ In Asia, a considerable amount of food-related R&D by private firms is done in the local offices of global food multinationals. In China, for example, Nestlé, Syngenta, PepsiCo and General Mills all have a research presence. National subsidiaries of global firms, such as Hyderabad-based Pioneer, owned by DuPont, also play a role—in Pioneer's case, in plant genetics.²⁶ In the broader economy, the private sector's role in innovation appears to be increasing in relevance (when start-ups and SMEs are included, along with the various ICT-based tools they are developing).

4. Trends and implications

4.1 Technology is expanding from research into advanced inputs to greater use of information and technology knowledge-sharing tools

Knowledge intensive	Emerging technology	Climate change	Discovery to delivery	Changing supply chains	Reformulation and fortification
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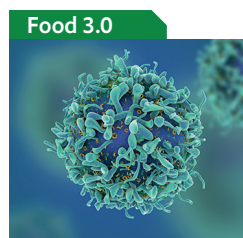
For many decades, agricultural R&D in Asia focused on crop science and the development and dissemination of new and improved inputs, such as fertilisers and pesticides. That is now beginning to change, partly because of the environmental damage caused by some of these innovations. This change is also driven, in part, by the rapid development of the “digital economy” over the last five years, bringing a new generation of tools that improve productivity and can be used by smallholder farmers, most of whom have historically lacked access to agricultural technologies.



Simple cultivation



Mechanisation and manufacturing



Advanced technology, processing and genetics



Harnessing knowledge-intensive, collaborative and integrative approaches

Source: National Centres for Universities and Businesses.²⁷

The rise of ICT has been accompanied by an expansion of ICT-based innovation in agriculture.

In previous years, agriculture R&D focused significantly on genetics and crop science, with the aim of improving seeds and developing more resilient crops. While this research is valuable, ICT has the potential to accelerate productivity growth.²⁸ In particular, mobile telephony, applications, Geographical Information Systems (GIS), remote sensors, data analytics and the IoT are driving the development of precision agriculture. By improving crop visibility, precision agriculture helps farmers anticipate problems, respond to threats and reduce waste.²⁹ Investors and innovators in precision agriculture include crop and seed companies, equipment manufacturers and digital start-ups, and the agricultural community is positive about the benefits of their efforts. Indeed, 60% of respondents to one global survey believe that precision agriculture will be widely adopted by 2030.³⁰

Precision agriculture can be divided into two categories: “soft” and “hard”.³¹ Soft precision agriculture facilitates the observation of crops and soil to inform farmers’ decisions. Hard precision agriculture involves more statistical and scientific analysis, higher costs and more complex technology, including

remote sensing and variable-rate technology (VRT), which allow farmers to alternate the rate of inputs, such as irrigation and fertiliser. For smaller farmers, the most appropriate knowledge tools are often singular, low-cost tools, such as chlorophyll meters, although smallholders involved in co-operatives can make use of larger precision agriculture packages.^{32,33,34} Other notable low-tech innovations in the region include kits for digital soil testing, smallholder algae production³⁵ and solar-powered irrigation.³⁶

4.1.1 Field monitoring and precision agriculture in Asia

Unlike crop science, which is technical and capital-intensive, many knowledge-driven agricultural innovations can be developed by start-ups and entrepreneurs.

Precision agriculture and field monitoring—including satellites, drones, weather-tracking tools and remote sensors—are being developed by a diverse group of companies, from large agricultural and technology powerhouses to SMEs. There are also thriving “ag-tech” communities in countries such as Argentina, Chile and Brazil, allowing smaller, nimbler players to contribute their valuable knowledge of local industrial networks, agronomical conditions and regulations. The same is true in Asia. According to Professor Paul Teng at the National Institute of Education, Nanyang Technological University, knowledge-intensive agriculture (which combines digitalisation and ICT) will allow farmers to close yield gaps. The beauty of such technologies is that a wide range of companies can develop them. Vietnam-based MimosaTek has developed a cloud-based system that allows farmers to control and manage their farms using sensors, produces alerts in response to challenges, and can execute remote irrigation by mobile phone. HelloTractor, dubbed the “Uber” for tractors, has developed a two-wheel smart tractor with a GPS antenna, and it allows small-scale farmers to request and pay for tractor services through

SMS on a just-in-time basis. Farmers have seen yield increases of as much as 200% since Hello Tractor’s launch in 2014. Another start-up, Indonesia-based eFishery, developed a smart fish feeder that automatically dispenses feed when fish are hungry. In a region with high fish consumption, and with feed representing 80% of production costs, innovations like this (which could reduce feed costs by 20%) could have profound benefits.³⁷

Precision agriculture and field monitoring can be used in both high-income and lower-income countries by focusing on tools suited for various needs and capabilities.

Asia’s wealthier nations are advancing IoT and automation in field monitoring and precision agriculture: in 2016, Japan opened the world’s first robot farm; Singaporean firm Garuda Robotics is providing drones to South-east Asian farmers; and Malaysia’s government included agriculture as part of the national 2015 IoT plan, incorporating a pilot project that applied the IoT to aquaculture traceability. MIMOS, Malaysia’s ICT R&D centre, is also trialling sensor technology to inform the timing of oil palm pollination. In South Korea, the government began testing a “smart farm village” in Sejong City in 2015, providing farmers with a suite of smart agriculture tools including remote sensing and automated controls, all connected to smartphones. This project, which reportedly

improved productive efficiency by 23%, inspired a government fact-finding delegation from Vietnam.

Lower-income countries are also adopting precision agriculture and field-monitoring tools suited to their needs. Japanese-style automation is less appealing (because agriculture is a critical provider of employment), but tools like drones are popular. For instance, the Philippines has been using unmanned aerial vehicles equipped with navigation and photographic technology to identify land vulnerable to natural disasters, and the country's space satellite programme included the launch of Diwata-1, designed to provide forecasts and weather monitoring and to survey farmland. Researchers at Thailand's Mahidol University have also explored the use of drones for monitoring crops using multispectral, hyperspectral, thermal and LIDAR imaging, and in India, digital mapping tools have been applied to crops including tea. Drone technology can help to improve the sustainability of crop production. With better information, farmers can utilise water and fertiliser efficiently to maximise yields, while preventing over-spraying or water wastage.

There is still room for improvement, with some evidence suggesting that there are still too few precision agriculture and field-monitoring tools for smallholders.

There are also structural issues limiting the overall precision agriculture market. In India, for example, land plots are often small, which means that some of the key benefits of precision agriculture—notably its ability to give farmers insight into crop variability over large acreage—are irrelevant. Even in China, a more advanced agricultural economy, precision agriculture technologies were considered “inaccessible, unsuitable and unnecessary” for smaller farms.³⁸ Land rights are another structural challenge, as no farmer will invest significantly in long-term productivity aids if they do not own their land or have secure tenure, according to Delfin Ganapin at the World Wide Fund for Nature. Current concerns over affordability (such as the costs of smartphones) and infrastructure issues such as network coverage in rural areas may also limit the uptake of ICT in agriculture, particularly in developing countries, driving the need for targeted interventions to expand rural access to ICT.³⁹

Information-sharing platforms are playing a growing role in farmer outreach, facilitating productivity growth and providing market intelligence. Knowledge-driven innovations extend beyond precision agriculture (which is primarily focused on field monitoring); they can also facilitate the sharing of information to encourage new entrants into farming, or to shift existing farmers towards growing other, more advantageous produce. Information sharing can also help farmers improve their practices. For instance, the CGIAR Research Programme on Dryland Systems, adopting what it terms an “innovation platform” approach, showed that knowledge-sharing networks could stimulate innovative practices in environmentally harsh environments.⁴⁰ South Asia's drylands—mostly located in India, Pakistan and Afghanistan, and populated by over 1bn people—experience low rainfall, frequent drought and excessive groundwater exploitation. CGAIR's programme undertook “innovation brokering” between governments, NGOs, farmers and industry. In Rajasthan, Karnataka and Andhra Pradesh, such brokering led to the promotion of resilient intercrops, such as medicinal herbs, that

require little maintenance and can be sold into the Ayurveda health system. Adoption increased from around 20 Rajasthan-based farmers in 2014 to over 1,000 a year later, with annual financial benefits reaching 45,000 rupees (US\$702).

Greater Internet connectivity in rural areas has also enabled the dissemination of information, from real-time crop prices through the AgriMarket Mobile App in India⁴¹ to agronomic information in regional languages (or even in audio-visual format, to get around literacy issues) through Jayalakshmi Agro Tech.⁴² Knowledge-exchange approaches also help disparate smallholders work together for mutual gain. Community co-management of fisheries and the establishment of community rights have been shown to reduce over-fishing, while in India and Nepal, joint forest management programmes that allocate rights to local groups have successfully increased biodiversity.⁴³

4.2 Emerging technology can support the region's nutritional transition and better address citizen concerns about biotechnology

Knowledge intensive	Emerging technology	Climate change	Discovery to delivery	Changing supply chains	Reformulation and fortification
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While simpler technologies and information sharing can lead to fruitful outcomes, high-tech scientific research still has a role to play. Some of the challenges facing agriculture, such as a changing climate, diseases and pests, cannot be solved through field-monitoring tools alone. These tools have a valuable role to play in optimising the management of viable crops, but they do not address concerns about crop yields or the constraints imposed by more resource-intensive diets.

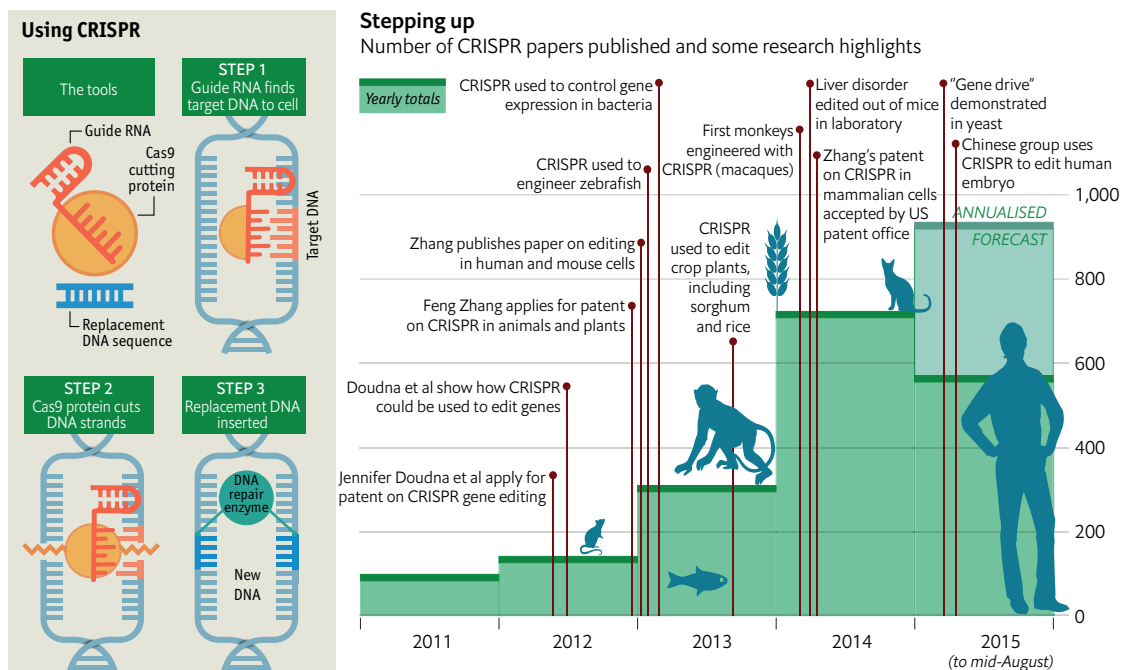
Increased concerns about genetic modification and “natural” foods are likely to increase alongside rising incomes and the growing prevalence of social media. Some Asian consumers share European and US citizens' concerns about food safety, although the mood varies by country. In Japan, shoppers oppose GM food more strongly than those in the UK or the US.⁴⁴ In China, where food security is a major concern, GM products were once regarded positively, but this has changed as awareness about GM foods has grown, leading to significant public opposition to GM crops.⁴⁵ The Indian market, which is more price-sensitive, may be more accepting of GM foods.⁴⁶ In one survey, 75% of global respondents strongly or somewhat agreed that they were “concerned” about the long-term health of artificial ingredients, with the highest level of agreement recorded in Asia Pacific.⁴⁷ Consumers in Asia are also increasingly demanding sustainable-certified food, according to Professor Paul Teng at the National Institute of Education, Nanyang Technological University. This may negatively affect companies whose food production methods rely heavily on chemical or biological manipulation.

Attitudes among farmers are generally more positive because GM crops can increase yields and profitability. In China, for example, over 90% of cotton growers have adopted GM varieties (although cotton is not a food product, which means that health concerns are less of a problem). However,

public sentiment may curb the commercialisation of new GM crops. Although China imports several transgenic crops and has invested heavily in the development of its own varieties, it has approved the commercial planting of very few GM crops.⁴⁸ China's 13th Five-Year Plan for National Science and Technology Innovation highlighted that China will push forward with the commercialisation of genetically engineered crops, but that it is taking a cautious approach and will focus on cash crops first. Officials have cited low public acceptance as an important factor behind the slow pace of biotechnology commercialisation in China, where public opinion plays an important role in approval reviews.⁴⁹

Advances in biotechnology have the potential to address concerns about genetically engineered food. GM crops are available and sold in Asia, but there has been resistance from some civil society groups and scientists, both in the region and globally. Genes are complex, and critics argue that the modification of food genes could lead to health problems for humans. In particular, fears relate to long-term genetic changes, with some studies arguing that GM foods have toxic effects in animals.⁵⁰ However, a comprehensive evidence review conducted by an expert committee, partly funded by the US Department of Agriculture, argued that there was no substantiated epidemiological evidence that food from GM crops was less safe than food from non-GM crops.⁵¹ Other studies have identified research design flaws in some anti-GM toxicity literature.⁵² A review by the World Health Organisation also found that GM foods are unlikely to pose risks to human health,⁵³ while the Royal Society noted that there has been no evidence of ill effects linked to the consumption of approved GM crops.⁵⁴

Figure 2: CRISPR technology



Source: The Economist.⁶⁰

A more exciting innovation (and one that is less likely to face resistance) is a new generation of techniques known as New Breeding Techniques (NBT) which includes techniques such as genome editing, reverse breeding and agro-infiltration. Among these techniques, genome editing has attracted the most attention.⁵⁵ Unlike genetic modification, gene editing involves the insertion, deletion or replacement of genetic traits found within an organism's genome.⁵⁶ While genetic modification involves the artificial transfer of genes between organisms that are not bred, or the introduction of genes from outside an organism's genome, genome editing methodologies—specifically, Clustered Regulatory Interspaced Short Palindromic Repeats (CRISPR) and Transcription Activator-Like Effector Nucleases (TALEN)—introduce genetic mutations that can be indistinguishable from those found in natural breeding.⁵⁷ This means that they are able to introduce certain traits in crops, such as increased resilience, without the artificial transfer of genes.⁵⁸ In particular, CRISPR has become the preferred technique for genome editing due to its simplicity and efficiency.⁵⁹

Genome editing is not entirely without controversy, but this is largely limited to research on human embryos. In agriculture, the trend seems positive because it can help to strengthen resistance to pathogens in crops such as rice and tomatoes, and prolong shelf life.⁶¹ In the US, gene-edited crops are already on the market, including a browning-resistant mushroom, a waxy maize that produces higher starch and an improved storage potato.⁶² Berkeley-based Caribou Biosciences is also using gene editing to create drought-resistant corn and wheat.

Asian researchers could move to the forefront of genome editing. Since around 2014, Chinese researchers at institutions such as Sichuan University and the Chinese Academy of Sciences⁶³ have used gene editing to create wheat that is resistant to powdery mildew (a destructive fungal pathogen).⁶⁴ Others have applied CRISPR to rice^{65,66} and have used the technique to create cold-resistant, lean-body-mass pigs.⁶⁷ Japanese scientists have shown how CRISPR affects DNA using real-time footage, and South Korean researchers have published peer-reviewed work on genome editing of plants.^{68,69} Scientists in China are also active in human research, conducting the majority of CRISPR trials in humans,⁷⁰ and researchers from South Korea and China have already used CRISPR to correct disease-causing mutations in human embryos.⁷¹ China's regulatory stance is accommodative, leading researchers in South Korea to lobby their government for a more facilitative framework to avoid falling behind. The government's hesitance is informed, in part, by its sub-par research scandals of the past, notably the stem cell fraud saga in 2006.^{72,73}

The European Commission's definition of a genetically modified organism (GMO) as a genetic material that "has been altered in a way that does not occur naturally by mating and/or natural recombination" technically excludes gene editing, which means that it is not subject to current GMO regulations.⁷⁴ Elsewhere, decrees and enforcement ordinances are generally encouraging of gene editing. In 2015, for example, New Zealand determined that a final product with no transgene did not fit the definition of genetic modification, and regulatory filings from the US Department of Agriculture confirmed that a number of gene-editing products did not fall under genetic modification regulations.⁷⁵

While clean meat is yet to reach mainstream consumers, progress in making it affordable and accessible shows its potential to complement existing food production methods. Efforts to create artificial meat and protein have attracted investment from future-looking billionaires such as Richard Branson and Bill Gates, as well as large food firms. So-called “clean meat” can meet consumer needs without the heavy resource costs of rearing livestock, including the deforestation required to create grazing land and the atmospheric damage from livestock emissions. Innovation has already cut costs significantly since the infamous \$330,000 in-vitro burger that debuted in London in 2013. Lab-grown meats are forecast to be accessible for mainstream consumers by 2020, according to some experts.⁷⁶

Asia is an active player in this area. Tokyo-based Integriculture is developing cellular agriculture and clean meat, winning the Singularity University’s Global Impact Challenge in 2017. Its founder, Yuki Hanyu, also runs Shojinmeat, a non-profit that provides microwave-sized heated boxes that enable school children to culture cells at home.⁷⁷ Acknowledging technological progress in other regions, and the benefits this could have for domestic meat consumption, China’s government recently signed a \$300m trade deal with Israel, a clean meat innovator, enabling the purchase of laboratory-grown meat from the country’s suppliers.⁷⁸ Media reports indicate that Silicon Valley-based Hampton Creek has also been “in talks” to licence lab-grown meat technology to South Asia.⁷⁹

Laboratory-grown protein will face less consumer resistance than GM foods because there are powerful environmental and ethical benefits. That said, scrutiny will be needed to ensure that clean meat has no unforeseen health impacts. Interviewees pointed out that consumers will also take time to adjust to alternative foods such as lab meat, as well as other innovations like insect protein products. While insects are already part of the national cuisine in some countries, such as Cambodia, it may take time for them to be accepted in countries where insects are not typically part of people’s diets. The second challenge is scaling lab-meat production, as laboratory facilities cannot easily move from prototypes to mass-market output.

Another high-tech innovation is 3D printing, which can manufacture farming equipment and even food. Additive manufacturing layers ingredients to create bespoke products on-demand, and is attracting investment from global players including Mondelez and Hershey’s. 3-D food printers could even become home appliances, allowing the production of everything from pizza to chocolates, and reduce food waste in restaurants by allowing tailored portion sizes and easier adaptation of products to exclude allergens. However, 3-D printing is not, currently, a significant disruptive force for the Asian food system. It is most likely to be a product for higher income consumers, and those visiting high-end restaurants. The wealthy hubs of Asia, such as Hong Kong, Seoul, Taipei and Singapore, have been exposed to visiting roadshows and exhibitions showing off the wonders of 3-D food, but for the mass population of Asia this is not likely to be of significant importance.⁸⁰

A more impactful trend is the application of 3D printing to the creation of bespoke agricultural tools and machinery. This is already a growing industry in the US, and there is evidence of 3D printed farm technology in low-income contexts such as Myanmar. This could prove useful for farmers seeking specific tools and technologies.⁸¹

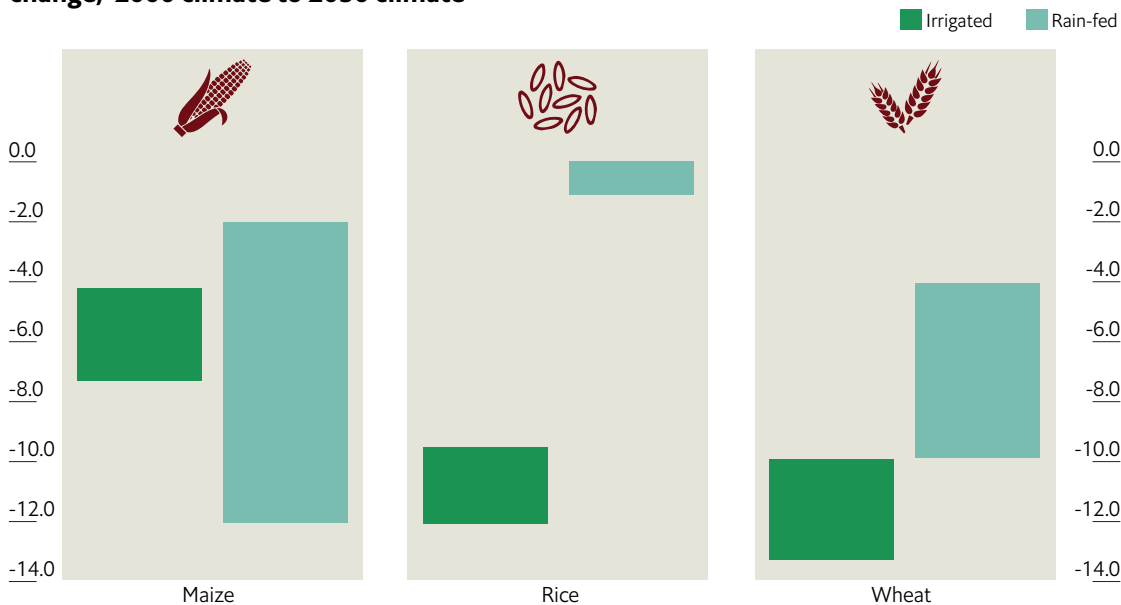
4.3 Environmental degradation and climate change are driving agricultural innovation in genetic modification and biotechnology



Climate change and resource degradation have created a need for more advanced agricultural innovation in inputs, especially the genomic basis of crops. To deal with these more radical challenges, biotechnology remains a critical scientific endeavour. In Asia, developing seeds that are resistant to flooding, drought or temperature changes is crucial, as is continued research into protecting crops from pests and diseases. As Figure 3 shows, climate change is projected to have a generally negative effect on the yields of key crops.

Biotechnology techniques can help crops and farmers adapt to environmental and climatic change. Despite public opposition, GM crops are the fastest-adopted crop technology in the history of modern agriculture,⁸³ and biotechnology-related R&D to develop more resilient agriculture has garnered the attention of Asian scientists. For instance, the IRRI and its partners have developed new generations of rice that can tolerate submergence, drought, heat and salinity. This includes over 100,000 rice varieties that are resilient to drought, submergence, flooding and heat, delivering benefits valued at US\$1.46bn per year and boosting rice yields by an average of 11.2% annually in

Figure 3: Projected range of biophysical effects of climate change on world yields, percent change, 2000 climate to 2050 climate



Note: Range of projections covers both the CSIRO and MIROC modes in the study
Source: International Food Policy Research Institute (IFPRI)

South-east Asia.^{84,85} India has also developed rice that can tolerate 15 days of flooding, helping the country to become an exporter, according to Professor Paul Teng at Nanyang Technological University. Singapore's Temasek Holdings, meanwhile, has developed Temasek rice, which can withstand extreme weather.⁸⁶ Other recent projects include work by researchers at the Hyderabad-based International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and BGI-Shenzhen, which explored the genetic re-sequencing of pearl millet—a valuable staple for over 90m farmers in Africa and Asia. The goal was to provide greater resilience to climate change by increasing heat and drought tolerance.⁸⁷

Biotechnology is not the only mechanism for preparing agriculture for a changing climate. The “climate-smart agriculture” sector covers a broad range of technologies, services and methodologies that help to improve the resilience of both crops and farmers. In the context of Asia, this now includes state-of-the-art simulation modelling technologies that show the impact of storm surges and sea-level rises, as well as field focus technologies such as laser land levelling and solar-powered irrigation, which have been deployed in countries such as Pakistan. Countries have also adopted climate-smart patterns of crop growth, optimising planting dates based on improved intelligence regarding weather conditions. Climate-smart agricultural strategies in Nepal include drip irrigation and the increased use of intercropping, and in Bhutan, strategies like the alternate wetting and drying of paddy rice have been shown to help farmers remain productive in the face of climate hazards.⁸⁸ Sri Lanka's climate-smart agriculture approaches include improved rainwater harvesting, the use of cover crops and shade management to overcome heat stress, as well as the reduction of synthetic fertilisers and pesticides used for mulching and thatching.⁸⁹ In the Philippines, practices include adaptive crop calendars, which adjust growing schedules based on weather forecasts.⁹⁰

4.4 The shift from technology discovery to delivery will become even more important in light of technology literacy constraints and a lack of supporting infrastructure

Knowledge intensive	Emerging technology	Climate change	Discovery to delivery	Changing supply chains	Reformulation and fortification
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Agricultural extension work—defined as efforts to spread knowledge and technology throughout the supply chain, including to the smallest farmers—is crucial for ensuring broad-based agricultural productivity growth. This is particularly important in Asia, where small farms operate a significant share of farmland; there are estimates that in developing countries such as the countries of East Asia (excluding China), and South Asia, about 70–80% of farms are smaller than 2 ha and operate about 30–40% of land in those countries.⁹¹

According to Pushpanathan Sundram, former Deputy Secretary General of ASEAN for ASEAN Economic Community, government extension agencies have a dual role: distributing better inputs, such as quality seeds and fertiliser; and educating farmers. In Asia, governments have developed a range of extension programmes (sometimes with support from donors), from top-down distributions of inputs and subsidies through to more participatory models that encourage engagement among farmers. Countries differ in the design and execution of their extension services, with public sector-led approaches common in countries such as Nepal and Pakistan, while more pluralistic and collaborative extension systems are used in Bangladesh and India.⁹² Examples of specific extension supports include providing tele-help to farmers in India⁹³ and distributing fertiliser subsidies in Nepal.⁹⁴ Vietnam’s efforts include applying ICT to support information sharing between farmers, researchers, rural dwellers and science research institutions.⁹⁵

As well as sharing technology and knowledge, extension services play a crucial role in connecting research institutes with farmers, according to Professor Achmad Suryana. At present, studies confirm that extension services are insufficiently linked to research institutions, which means that extension workers may be under-informed about the latest tools and trends.⁹⁶ Without well-designed extension services, innovations and new knowledge will tend to accrue to large agribusinesses, and not to smaller value chain participants. Farmers need to be aware of ICT innovations and able to afford them, which will require governments or NGOs to help translate such technology, according to Delfin Ganapin of the World Wide Fund for Nature. Such extension work can also help to improve hygiene and food contamination protections among smallholders, helping them to participate in international value chains.

Expert interviewees expressed concern about smallholder farmers’ access to, and ability to use, current technology. For instance, there is evidence of gender bias, with some ICTs excluding female farmers, and some extension services designed in ways that exclude women (such as failing to engage them in seminars and workshops).⁹⁷ Research has also pointed to farmers’ limited access to, and adoption of, technology and extension services, due to a range of obstacles such as poor service

delivery mechanisms, risk aversion and a shortage of required equipment. A recurring critique in the region is that extension services are too top-down in their design. For instance, a study of Pakistan identified a number of weaknesses, including requiring farmers to visit extension agents to gain access to services, despite a weak rural transportation infrastructure.⁹⁸ Research in Nepal, meanwhile, showed that while the fertiliser subsidy programme was increasing fertiliser usage, this mostly occurred among larger farmers, delivering unwanted impacts in terms of inequality.⁹⁹

There is some Asia-based evidence of low-cost tools and collaborations with business and government diffusing knowledge and technology through the supply chain. ICT tools are delivering information and analytics to farmers. VinaPhone, a Vietnamese state telecom company, launched a service that turns mobile phones into “farm assistants”, providing agricultural information services (such as weather forecasts, plant disease alerts, guidelines on government policies and advice on plant diseases) through a low-cost monthly package, delivered through social media. Similar services exist in Indonesia, through 8Villages.¹⁰⁰ Collaborations with governments and larger companies can improve exposure to technology and knowledge among smallholders. Formal collaborations can also help to make product supply chains more visible to end-consumers. Indonesia’s Partnership for Indonesia Sustainable Agriculture, established in 2012, tightens collaboration between the state, companies and smallholders to improve the production of commodities including cocoa, dairy, maize, palm oil, potatoes, rice and soybean.¹⁰¹ Another Indonesia-based initiative, the Oil Palm Development Plasma Programme, works to improve farmers’ knowledge of oil palm cultivation and management best practices.

4.5 Food supply chains are being disrupted by the advent of technology



While research agencies and companies have focused on innovation to boost farm-level productivity, technology is also affecting food supply chains. Greater efficiency throughout the agriculture value chain can promote the broader goal of sustainable food production by reducing food loss—a substantial problem in both developed and emerging markets. It can also improve traceability along the supply chain.

Technology is changing not only the way food is grown, but also how food is distributed and consumed. Technologies can optimise supply and demand matching, and companies are already exploring Internet-based food and grocery delivery, helping to create more densely networked and nimble food delivery systems. Interviewees note that the region is well-suited to food delivery services, thanks to high population densities in urban areas. Amazon has already demonstrated its interest in fresh food e-commerce with its \$13.7bn acquisition of Whole Foods in the US, and while its direct Asia footprint remains light, roots were laid in Singapore in early 2017. It also invested in

Shanghai-based food delivery e-commerce site Yummy77, as well as tabling a bid for Redmart, the Singapore-based grocery delivery start-up from Facebook co-founder Eduardo Saverin.

Asian e-commerce players could dominate the food delivery business. Nasdaq-listed JD.com is reportedly building an Amazon-like delivery model (including its own warehouses), and it led an investment round into FruitDay, which sells fresh produce across China. Yihaodian, another Chinese online grocery business, has attracted investment from Walmart. Other Asian economies are also making moves. India's online food delivery market boomed in 2015–16,¹⁰² and Japanese messaging service Line has taken steps into perishable and non-perishable sales and delivery in South-east Asia. Companies have launched similar businesses in Indonesia, Malaysia and Thailand. There is also evidence that e-commerce platforms are being used to connect producers to consumers directly. In some cases, such exchanges are taking place on e-commerce platforms such as Taobao.com.¹⁰³ DHL is also currently working with Thailand's Ministry of Commerce to deploy e-commerce and logistics expertise to connect Thai farmers to e-commerce platforms.

However, the food e-commerce sector will take time to develop. Not all food e-commerce initiatives have been successful in Asia: Asian food-tech company HappyFresh closed businesses in Taiwan and the Philippines to focus on Indonesia and Malaysia; Thailand-based HonestBee scaled back an ambitious six-country plan to focus on a handful of cities instead;¹⁰⁴ and Redmart eventually sold its business to Lazada after encountering financial issues.¹⁰⁵ One of the challenges is that e-commerce-based food delivery is more viable in urban areas, and many of Asia's residents still live in rural areas. A further consideration is that e-commerce may not necessarily benefit smallholders. Economic viability depends on large retailers working with delivery and logistics entities, rather than small farmers selling produce directly to consumers on the Internet. Indeed, e-commerce is particularly weak when it comes to connecting smallholders who produce perishable foods, because the transport and logistics costs of getting those foods to consumers are not economical on a just-in-time basis.

Food safety considerations will also be a key factor in the uptake of technology in food supply chains. Food quality scandals in the region have raised questions about the viability of direct-to-consumer food commerce without appropriate intermediaries. Sanitary and phytosanitary measures (SPS) are tightening in Asia, according to interviewees. Without support and upskilling, smallholders may struggle to produce food that consistently meets specific (and rising) standards, and may rely on inputs that are harmful to human health. One study in Cambodia, Laos and Vietnam, for instance, found that farmers depended heavily on synthetic pesticides, which can have adverse health effects.¹⁰⁶

On the other hand, new technology such as blockchain technology, which can monitor and track food in the supply chain, can help in driving food supply transparency as well as increasing responsiveness to food safety issues. It would allow specific products to be traced at any time, allowing contaminated products to be traced easily and quickly. This would ease product recall while reducing food waste, as safe foods can remain on the shelf. Interest in such technology has led to projects such as the Blockchain Food Safety Alliance, a collaboration between Walmart, JD.com, IBM and Tsinghua University. The four organisations are working to improve food safety and traceability in China by using blockchain technology to provide real-time traceability throughout the supply chain.¹⁰⁷

Innovation can bring benefits at both ends of the supply chain by reducing food loss and food waste. Connectivity initiatives, driven by wider usage of electronic processes and information-sharing platforms, can smooth logistics and reduce food loss. Crop research can help to reduce food losses at the farm level caused by adverse weather, but much is lost from the “farm to the fork”. In South and South-east Asia, for example, about one-third of the food produced is lost as it travels through the supply chain.¹⁰⁸ In India, goods pass through an average of six or seven middlemen before reaching the consumer, resulting in large mark-ups and poor quality.¹⁰⁹ The costs of moving food depend more on supply chain efficiency than distance; for instance, it is cheaper to ship rice from Ho Chi Minh to Manila than from Manila to Mindanao.¹¹⁰ Slow and costly supply chains are a particular concern because foods like fruit and vegetables are more likely to perish than grains, and these are precisely the foods that need to account for a larger portion of citizens’ diets. For crops that cross borders, electronic customs processes, efficient trade corridor systems and transport connectivity initiatives—such as the Greater Mekong Sub Region project and the East ASEAN Growth Area (BIMP-EAGA), which includes food as one of its six strategic pillars—can smooth logistics.

Innovations are emerging to tackle these challenges. For example, Nestlé is looking into “sidestream valorisation”—using spent coffee grounds as fuel in its factories. Apps are also helping to reduce food waste in urban clusters: Singapore’s 11th Hour shows users discounted menu items offered by restaurants and food stalls before close of trading, while No Food Waste India allows entities with large quantities of waste, such as hotels and restaurants, to notify users when it is available for collection, whereupon groups collect it and distribute it to slums, orphanages and the elderly.¹¹¹ JD.com, a Chinese e-commerce company, is developing heavy-duty drones capable of carrying payloads of over a ton. This potentially allows farmers in rural areas to quickly ship perishables such as fruits and vegetables to urban centres.¹¹²

New innovations that enable urban farming may help to create more balanced urban food systems. Urban farming is a growing trend in Asia, and start-ups are selling growing kits and information packs to encourage citizens to grow food for themselves, or to sell. Malaysia’s Cityfarm uses hydroponic technology to enable soil-less farming, helping urban dwellers to grow salad crops. With nearly 90% of forecasted urbanisation through to 2050 anticipated in Asia and Africa, urban farming could make a sizeable contribution to nutrition.¹¹³ A number of cities, including Tokyo, Shanghai and Beijing, are all seeing an uptick in urban farming, according to Professor Paul Teng at the National Institute of Education, Nanyang Technological University. A related trend is vertical farming, where food is grown in vertically stacked layers, allowing greater output without using more arable land. This is particularly suited to more densely populated areas. Japan is an Asian frontrunner in this field, with Spread, Fujitsu and Aerofarms all pursuing hydroponic (soil-less) and vertical agriculture. Spread, which has been active in vertical agriculture since 2006, now produces over 20,000 heads of lettuce a day, shipped to over 2,000 supermarkets.¹¹⁴ Fujitsu’s entry into hi-tech agriculture is especially noteworthy and is seen as an effort to deploy greater technology R&D in the food sector. The same is true of Toshiba, which has converted one facility (where it once made floppy discs) into a lettuce and salad factory.

4.6 Food technology in Asia is focusing on reformulation and fortification

Knowledge intensive	Emerging technology	Climate change	Discovery to delivery	Changing supply chains	Reformulation and fortification
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The agricultural system does not exist in a vacuum; it is closely tied to changing consumer tastes and preferences, as well as government initiatives. For this reason, innovation and technology in food also involves efforts to enhance and develop products in alignment with what consumers seek. One area of engagement in Asia is the fortification of food products with vital nutrients and the reformulation of consumer food products to remove or reduce unhealthy ingredients.

Food fortification will play an increasingly important role in addressing population health concerns, from micronutrient deficiency to the challenges of an ageing population.

In Asia, where high poverty levels mean that many people cannot afford to eat nutrient-rich foods, 16% of the population is malnourished. Under-nutrition causes illnesses ranging from anaemia to cognitive impairment and stunting, which hurt both individuals and national economies (in terms of productivity and economic growth). In Vietnam, for example, vitamin and mineral deficiencies reduce GDP by over \$544m annually.¹¹⁵ By adding essential micronutrients to staple foods and condiments, governments can tackle micronutrient deficiency. Governments have responded positively to the task, with food fortification efforts advancing in Asia since the 1990s.¹¹⁶

Today, Indonesia, Vietnam, Nepal and the Philippines all require wheat flour to be fortified with micronutrients including iron, folic acid and vitamin B12.¹¹⁷ Legislation in Afghanistan and China promotes voluntary fortification, and India introduced draft standards for food fortification in 2016.¹¹⁸ India also targets the poor by distributing the majority of its fortified flour through welfare schemes.¹¹⁹ Some Asian countries also require salt to be fortified with iodine, or vitamin A to be added to cooking oil. Rice, the region's staple, is trickier to enrich in nations that operate small, decentralised mills, but both the Philippines and Papua New Guinea have made rice fortification mandatory.¹²⁰ Food companies in Asia are also focusing on fortification to address concerns about health and nutrition, and to respond to local tastes, product competition and government regulation.¹²¹

In the long term, food manufacturers are likely to focus on reformulation to meet demand for healthier alternatives. Food reformulation involves the adaptation of consumer products to remove harmful substances, or to find natural replacements for ingredients like sugar and fat. Nutrient profiling (NP) covers a range of related interventions, including promoting healthier consumption through marketing and labelling, and reformulating products to remove harmful ingredients or optimise nutritional balance. Research has shown reductions in trans-fats (TFA) in the US thanks to reformulation over the last two decades, and in the UK, a public-private collaboration reduced the salt content of supermarket products by around 20–30%, resulting in an estimated 10% reduction in salt intake at the population level. The same article identified nutrient profiling activities in Singapore, Indonesia, South Korea and Thailand, although it noted that specific targets for nutrient levels were not yet present.¹²²

Asian countries and companies are moving towards best practices, however: the Food Industry Asia (FIA) Co-ordinating Council includes firms such as Crisp Sensation, which developed patented technologies enabling snack manufacturers to reduce fat,¹²³ and the Asia Roundtable on Food Innovation for Improved Nutrition (ARoFIIN) is a public-private partnership (PPP) formed to explore food product innovations to tackle obesity and chronic disease. Product reformulation collaboration between health bodies and food manufacturers is particularly strong in Singapore, driven by the country's Health Promotion Board (HPB). It has a particular focus on reducing high salt levels in processed food such as noodles and bread, as well as more natural foods such as fish cakes.¹²⁴

Beyond legislation, international targets have inspired action among fast-moving consumer goods (FMCG) companies. For instance, Nestlé has been consistently reducing sugar and sodium in its products and recently renewed this commitment under the UN Sustainable Development Goals. In Singapore, Nestlé launched a new iteration of MILO (a popular chocolate malt drink), with 50% less sugar and 30% more protein, reinforcing the local government's efforts in the "war on diabetes".

Nestlé's position is that fortification efforts should be relevant, population-specific, affordable and supported by research. It is also necessary to take into account the demographics of target consumers to avoid over-fortification. The quality of fortification is also becoming more important. For example, in infant milk, work is being done on the types of protein that should be included, not just the level of protein. In some cases, food producers have even started to move beyond legislative requirements. For instance, Grameen Danone is a joint venture between Danone and Grameen Bank that focuses on tackling malnutrition—which afflicts over half of Bangladeshi children under the age of five—by selling yoghurt enriched with iron, zinc and vitamins to poor families at low prices. Door-to-door vendors sell 100,000 pots daily. Each pot meets 30% of a child's daily nutritional needs.¹²⁵

5. Opportunities and challenges

To ensure that agriculture, farming and food product innovations are maximally beneficial, and to take advantage of the commercial opportunities they bring, it is necessary for all stakeholders to work collaboratively, especially governments and large agricultural companies. The final section of this report explores the key practices and principles that help to promote broad-based agricultural innovation.

5.1 Invest in extension services and capacity-building to prepare farmers, and support the transmission of technology and tools

Targeted extension services are needed to bring new research and high quality data to farmers, particularly smallholders. Supply chain efficiency depends on the transmission of new technologies, tools and knowledge to all participants in the value chain, especially smallholders, who are major participants in production but are often slower or less able to adopt new knowledge and institutional innovations.¹²⁶ Extension services are an important way of ensuring that new research and innovation reaches smallholders, who are generally less inclined to make “risky” investments in new technologies, which they may not understand how to use. For this reason, it is important to strengthen extension services to ensure that smallholders have access to the latest tools and insights, with a focus on reaching the excluded or most marginalised. In the era of climate change, targeted services that give farmers access to high-quality data on temperature, rainfall, wind and soil moisture (as well as vulnerability analyses and projections) will be particularly important. Research shows that pest and disease forecasting services and weather-based crop insurance programmes are among the fastest-growing agricultural “climate services” in the Asia region.¹²⁷ Services that help farmers to connect to markets and consumers more efficiently, or provide real-time pricing information on commodities, also help to improve outcomes for farmers. For example, Indonesia has supported the launch of five apps that are meant to support farmers; one of the apps, Pantau Harga, allows users to track food prices across the country.

Extension services also need to tackle gender bias. The Food and Agriculture Organisation (FAO) has already highlighted the feminisation of agriculture in developing countries, particularly in South Asia.¹²⁸ The importance of taking gender into account when designing agricultural extension services has also been documented since the 1970s, but gender bias remains a problem. The IRRI reports that female farmers have been excluded from technology, design, testing and dissemination,¹²⁹ in part because extension workers tend to target men in their outreach efforts, limiting women’s access to new knowledge. An FAO report highlighted that female farmers are as efficient as male farmers but produce less because they control less land and have less access to resources and extension services.

The report estimated that giving women equal access to resources could raise production on women's farms in developing countries by 20–30%.¹³⁰ A second problem is that many extension services relate to market integration and cash-generation activities. In many contexts, women primarily produce food for home consumption, partly as a result of cultural biases against them.¹³¹

Examples of gender-targeted extension services include innovations like the motorised micro rice mill, which was reportedly the first technology intentionally designed for women when it was rolled out in the Philippines in the 1980s. More recent efforts include ensuring that women are actively invited to attend training programmes in pest management. In the past, women's knowledge about agro-chemicals was limited because they were not invited to attend such seminars.

Focusing on innovations that ease financial access for farmers, leveraging ICT and fin-tech can overcome infrastructure constraints. Access to finance is one of the fundamental components of agricultural extension efforts. Smallholder farmers lack the capital to invest in labour-saving technology, partly because banks do not tend to lend to smallholders (who lack conventional forms of collateral and formal book-keeping). Even the best innovations may not percolate through the supply chain if farmers are reluctant to borrow, or if banks refuse to lend. Access should cover four operational areas—payment, credit, savings and insurance—and ideally, these should be accessible via mobile phones, recognising the limited physical bank branch penetration that exists in rural Asia. Relevant innovations include digital government-to-farmer payments (for sending farmer subsidies, as occurs in India), mobile-enabled transactions, and institutional changes, such as tools that help lenders establish credit scores.

Asia has a number of promising initiatives in play, mostly in mobile money. USAID's mStar project, operational in Bangladesh, sought to reduce reliance on physical cash transactions among smallholders by rolling out mobile services across the rice value chain. This enabled farmers to receive loans and payments from partners via mobile phones, with USAID using its convening power to work with mobile operators on reducing disbursement fees.¹³² There have also been experiments with micro-financing with partners down the supply chain, such as the Integrated Supply Chain Corn Partnerships, co-developed with Syngenta, which brings together banks, retailers and grain traders and provides micro-financing to farmers, helping them access markets in the Indonesian province of West Nusa Tenggara. The scheme increased farmers' productivity by 10%, earning them IDR1.8m more per hectare (approximately US\$144), in turn giving businesses a steady supply of commodities. Another collaboration, called Farmer Nature Net, established savings and credit associations and co-operatives, which improved farmers' liquidity.¹³³ These innovations need to be complemented by policies removing structural barriers that impede access to finance, such as lack of land rights. Secure land tenure can encourage farmers to invest in improving farm productivity, and also provide collateral for obtaining finance.

Agribusinesses have a critical role to play in closing the gap between technology knowledge discovery and delivery. There are positive examples of PPPs in the Asian context making a substantial contribution in this area. One FAO review described five agribusiness PPPs in Thailand as

“excellent”. These involved collaboration on developing and distributing disease-resistant okra, the design of fans to increase health in poultry feeding houses, test kits to identify disease in sugar cane, biogas systems, and the implementation of hybrid corn yield trials. A related FAO review of Indonesian agribusiness PPPs also found shared benefits, including farmers’ increased access to technical education from commercial partners and, for the plantation companies, greater security of supply.¹³⁴ Of course, PPPs are not without challenges; for instance, the FAO study identified problems including side selling, where farmers sell to market actors outside the contract, and inadequate risk-sharing mechanisms. However, it concluded that when incentives are aligned, public and private partners can fruitfully collaborate to support the diffusion of knowledge, technology and best practices.

5.2 Science-based policymaking will need to balance commercial needs against consumer concerns

Governments will have to balance the need to protect consumers against the need for yield and productivity improvements. Food is a sensitive subject, and agricultural policies are often subject to political and social considerations. One particularly controversial issue is the use of biotechnology in agriculture, especially genetic modification. Worldwide, GM food first reached supermarket shelves in 1994,¹³⁵ and it is widely cultivated for both human and animal consumption. GM crops are available and sold in the Asia region, both in domestic products and in imported food and feed crops, such as rice, soybean and maize. By 2011, five countries in “Monsoon Asia” (China, the Philippines, India, Pakistan and Myanmar) reportedly grew GM crops domestically.¹³⁶ GM crops have been shown to improve yields and can be better equipped to face climate change. There is, however, a chasm between farmers’ acceptance of GM crops and citizens’ resistance to such products, on the basis of potential health risks.¹³⁷ Governments need to ensure that they draw from the best scientific research when making decisions about GM crops.¹³⁸

Developing countries need to invest in capacity-building and strengthening regulatory frameworks to deliver evidence-based policymaking. Governments need to develop their own capacities and regulatory frameworks to ensure that evidence-based policymaking occurs in all areas of scientific research.¹³⁹ New technologies such as CRISPR, and even policies regarding import regulations and standards, require significant investment by governments to develop both understanding and regulation. As the National Academies of Sciences, Engineering and Medicine pointed out in its review of scientific papers covering genetically engineered food and crops, the effects of GM crops depend on the fit of the genetically engineered trait and the plant variety to the farm environment, as well as the quality and cost of the seeds.¹⁴⁰ As such, a case-by-case approach would best balance the competing needs of productivity and consumer safety, although this will place higher demands on regulators in terms of both expertise and the resources required.

Concerns about genetic modification and sustainability are likely to increase, making transparency and engagement more crucial. Consumers around the world are increasingly wary of artificial ingredients, hormones, antibiotics and genetic modification. Resistance to genetic modification has been strong in the US and Europe due to fears about safety, and some Asian

consumers share these concerns. Efforts to support consumer adoption were also hindered by the lack of transparency and engagement on the part of agricultural scientists involved in its development.

Stricter regulations could help to build trust by increasing consumer visibility. Japan mandates the labelling of a handful of GM products and is considering an extension to that list.¹⁴¹ In 2015, China also passed a food safety law mandating the labelling of all GM foods.¹⁴² Companies that pre-empt this trend and embrace proactive, voluntary labelling will be able to get ahead of regulations and help to drive more positive consumer expectations. Calls for voluntary labelling have highlighted not only the benefits of greater transparency, but also the benefits of managing risk perception.^{143,142} Scientists and companies also need to engage with the public to ensure that the subject is debated rationally, and in a manner that takes differing values into account. As noted in a recent paper examining perceptions of genetically modified food,¹⁴⁵ a purely factual approach is insufficient; providing more information cannot, on its own, combat fears about critical economic or social aspects of food.

5.3 Encourage regional and global co-operation in technology transfer and openness to trade in technology

Governments and supranational bodies have to balance the need for IP protection (which is necessary to encourage R&D) against ensuring sufficient access to those technologies beyond large agribusinesses. At the international level, technology transfer, cross-border trade and IP all shape the development and diffusion of agricultural innovation. While strong IP protection can encourage innovation, it is important to remember that Asia is a region with a large number of smallholder farmers, and that the high prices enabled by IP can exclude large segments of the agricultural community, who cannot afford to buy or licence patent-protected innovations. There are added complexities wherever commercial research builds on, or is indirectly funded by, donor or government grants. In particular, there is understandable resistance to patent protection for innovations that may have required public funding in earlier phases of their development.

During the Green Revolution, when South-east Asia achieved an 80% increase in rice yields, IP law was weak relative to modern standards. Over the last three decades, however, patent protection in agriculture has strengthened, including through tools such as the US-based Bayh-Dole Act (1980), which enabled universities, non-profit research institutions and small businesses to patent inventions that had been developed under federally funded programmes. As companies and institutions acquired greater patenting abilities in agriculture and biology, there was a marked increase in filing activities. For example, US patents on rice-related innovation grew from below 100 per year in the early 1990s to 600 by 1999–2000. Patenting is also applicable to technical procedures, such as the “gene guns” that insert genes into plants, and critics worry that researchers in developing countries might never explore innovations in areas like genetically modified maize for fear of legal retribution.

Productive collaborations involving patent flexibility could balance industry needs against the rights of the economically disadvantaged. The University of California’s patent on the Xa21

Kinase gene, which strengthens grains' resistance to disease, built on work done by the IRRI, and that organisation's access to the gene was protected. Collaborative global ventures such as the International Rice Genome Sequences Working Group, involving Japan, Korea, China, the US, the European Union (EU) and the Rockefeller Foundation, facilitate gene research, while at the same time binding participants to publicly publish findings, and not to file patent applications from discoveries emergent from the programme.¹⁴⁶ Another positive example is Golden Rice, a biotechnology innovation that adds beta-carotene to rice. Scientists made an agreement with Zeneca, a Swiss company, that provided for commercial use but included preferential pricing for low-income farmers.¹⁴⁷

Other collaborative approaches include the Affordable, Accessible, Asian Drought Tolerant Maize Project (AAA), which focuses on developing drought-tolerant maize for Asian smallholders. The project includes the International Maize and Wheat Improvement Centre (CIMMYT), the Syngenta Foundation for Sustainable Agriculture, and national agricultural research institutions across Indonesia, Philippines and Vietnam, and each participant brings value, from Syngenta's Asia germplasm to national institutions' knowledge of local farmers, networks and infrastructure.¹⁴⁸

Innovation needs should be factored in when setting trade and investment policy. Innovation is also affected by trade policy. For example, trade rules can encourage innovation and raise standards by requiring farmers to meet a higher bar in order to sell to international markets, argues Pushpanathan Sundram, former Deputy Secretary General of ASEAN for ASEAN Economic Community. Countries that are more integrated into global food value chains increase their quality standards, which in turn stokes demand for innovations related to food quality and hygiene. Increases in exports to markets such as Europe tend to increase food safety as exporters align with higher standards, according to Dr Sumiter Broca at the FAO.

Donors can also play an important role in providing the funding and convening power to facilitate technology transfer, especially to smallholders who may not be able to afford technologies, even if import duties are light. The EU, for example, invested in an Asia-wide technology transfer programme to help smallholder farmers. Specific projects included the transfer of low-cost environmentally friendly technologies to boost the production of rice, vegetables, fruit, livestock and fisheries in Jamalpur and Assam. Another initiative, this time in Nepal and Bangladesh, transferred water management technology, including micro-irrigation, treadle pumps, drip irrigation and water storage technologies. A third project involved an inter-regional partnership, bringing Chinese plant protection technology to help smallholders in Yunnan, Myanmar and Laos.¹⁴⁹

When it comes to agricultural innovation, trade and foreign investment instruments have a somewhat different impact. Measures that encourage foreign investment in, or ease imports of, vital innovations such as cold-chain technology, agricultural machinery, food processing, and drone and satellite technology can all help Asia's farmers. Even India, which has a strongly protectionist agricultural policy, has put incentives in place to attract foreign investment in these areas.¹⁵⁰ Unless the country is seeking to build an agricultural technology industry, tariff and non-tariff barriers will negatively affect farmers' productivity by restricting their access to best-in-class technology. Expert interviewees highlighted barriers to importing higher-yield seed varieties—for example, in Indonesia.

6. Appendix: Research approach

The term “food system” can be defined in different ways. At its simplest, a food system covers “end-to-end” activities, from production to consumption, and even disposal. More broadly, it covers “the governance and economics of food production, its sustainability, the degree to which we waste food, and how food production affects the natural environment. The FAO defines a food system as encompassing all the stages of keeping us fed: growing, harvesting, packing, processing, transforming, marketing, consuming and disposing of food.

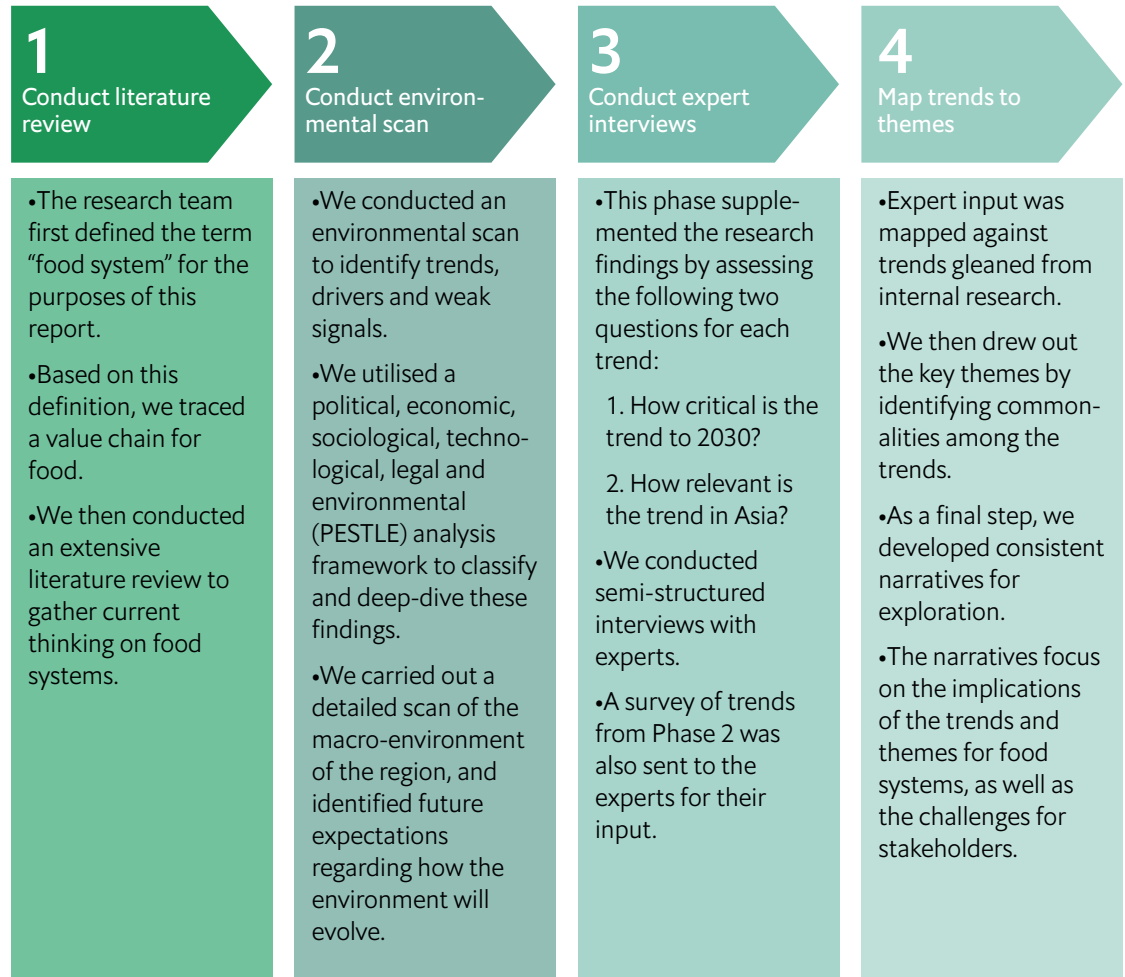
For the purposes of this report, we have defined a food system as including “all activities in the food supply chain, from production, processing and packaging to logistics, distribution, consumption and disposal, as well as policy considerations such as the environment, health, governance, sustainability and supporting infrastructure and institutions.”

Asia is also defined differently in various publications and databases. In this report, Asia refers to South Asia, East Asia and South-east Asia, unless otherwise stated. Middle East countries (which are sometimes known as West Asia countries) are not included.

6.1 Overview

The objective of this research was to analyse food-related trends along the value chain (from production to waste) and to draw out underlying themes that will be critical in 2030 and themes that are particularly relevant to Asia. For this reason, our methodology focused on identifying a list of key trends through a literature review, and then narrowing the list of over 90 trends down to key thematic issues for Asia, based on our internal analysis and expert input (gathered via interview). Each thematic issue was then explored to develop a consistent narrative for Asian countries.

Figure 4: Research programme phases

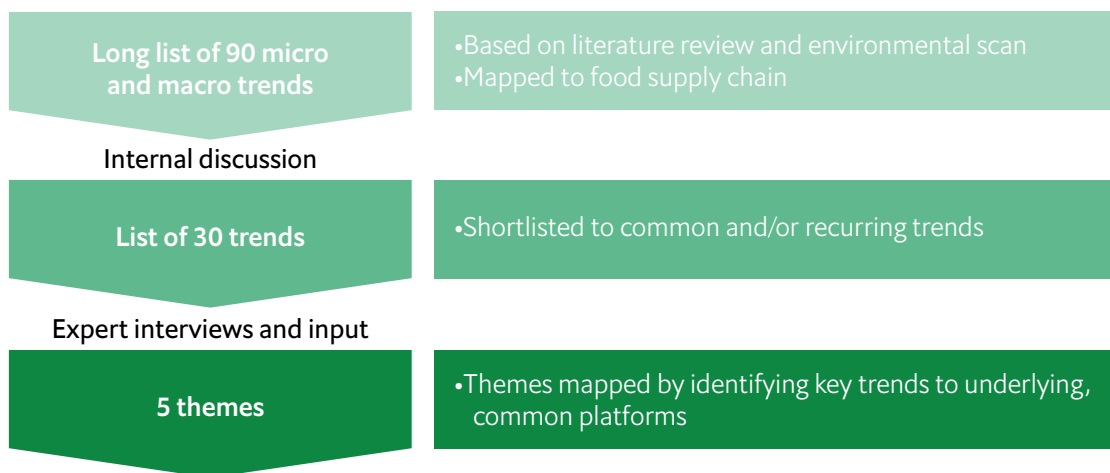


6.2 Triangulating themes

We identified more than 90 trends along the various parts of the food value chain, based on the literature review and the environmental scan.⁹ A PESTLE analysis was then carried out to categorise these trends, and to ensure that the list of trends was comprehensive. An internal discussion was held to validate and review the PESTLE analysis, and to identify the 30 major and consistent trends (based on the literature review).

An online questionnaire focused on the shortlisted trends was then developed and shared with the experts who were being interviewed for the study. We ran concurrent interviews with these experts to obtain their views on the overall food system(s) in Asia, as well as underlying trends. The interviews provided deeper insight into critical research issues and topics, ensuring that the study incorporated the latest thinking and expertise of those working directly in this field. The insights from the interviews and the results from the questionnaires were then analysed to draw out the themes.

Figure 5: Steps in triangulation of themes



Source: The Economist Intelligence Unit.

⁹ The list of publications reviewed during this phase is listed in the section titled "Literature review: references."

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