Chapter 13

Improving agri-food supply chains in Asia

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1 Introduction: nutrition security and sustainability in Asia

Food and nutrition security faces unprecedented risks and challenges in Asia, and globally, including climate change, COVID-19, environmental degradation, trade friction and regional conflicts; consequently, food security is becoming increasingly important.

Food insecurity exists in many developing countries, with Asia being home to almost 65% of the world's undernourished population (Zhou and Wan,

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2017). Moreover, the COVID-19 pandemic has exacerbated food insecurity and malnutrition. Data and reports from the United Nations Food and Agriculture Organization show that 720–811 million people worldwide faced hunger in 2020, while more than half of those were in Asia (FAO et al., 2021). Furthermore, the growth of income, urbanization and population has led to a substantial rise in food demand. Income growth and urbanization are continuing in China, India and Southeast Asia, while population growth is expected to continue, especially in South Asia (FAO, 2018). Therefore, reviewing the challenges and threats to the agri-food supply chain in Asia and pathways to solutions is more relevant than ever.

1.1 Human health and nutrition

The food supply system in Asia is under unprecedented strain as a result of the global pandemic and regional conflicts. Although economic and food system revolutions and changes in dietary patterns have been substantial, undernutrition, overweight/obesity, hidden hunger and malnutrition rates have remained high in all regions, making it difficult to achieve the sustainable development goal (SDG) 2 aiming at eliminating hunger and all forms of malnutrition. Asia has recorded the highest rate of increase in moderate or severe food insecurity, from 21.3% in 2019 to 24.6% in 2021, with the highest rate in the southern subregion (UNICEF, 2021).

In 2021, Asia experienced the second largest occurrence of undernourishment, after Africa, with more than half (425 million) of the world’s hungry residing in Asia (UNICEF, 2021). Child malnutrition continues to be a problem, with more than half of the world's stunted children (81.7 million or 54.8%) living in Asia (Micha et al., 2020), and the increase in childhood obesity between 2000 and 2020 was considerable, particularly in Eastern and South-eastern Asia, causing developmental problems and lasting ill health (FAO et al., 2021; Micha et al., 2020). In addition, over 30% of Asian women suffer from anaemia (Micha et al., 2020). The double burden of malnutrition is particularly concentrated in South Asia and East Asia, with the prevalence of overweight and obesity among the poor in the majority of East Asian nations (headed by China and Indonesia) rising substantially (Popkin et al., 2020; Damsgaard et al., 2016). Between 2012 and 2016, adult obesity increased in every subregion, with none on track to meet the 2025 world health assembly (WHA) objective (Micha et al., 2020). These many types of malnutrition result in new challenges in various locations and have led to an increase in diet-related non-communicable diseases (NCDs) such as diabetes, heart disease and stroke. Furthermore, South Asia’s low-income nations are disproportionately afflicted by hypertension.

1.2 Resources and environment

Asian agriculture is responsible for approximately two-thirds of the global agricultural gross domestic product (GDP) and also plays an important role worldwide (Mendelsohn, 2014). Eleven countries in Asia contribute approximately 87% to the total global rice production, with the export of eight of these countries comprising around 35% of the global rice export. Global food security is highly impacted by rice production in Asia, in general, and particularly in India and China (Bandumula, 2017). Compared with other emerging regions of the world, in recent years Asia has experienced a slower decline in agricultural employment compared with its output, rapid growth in labour and land productivity, and a shift of the agricultural output from traditional to high-value products (Briones and Felipe, 2016).

Although global crop productivity has more than doubled over the past few decades, negative impacts on the environment, biodiversity, soil quality and air quality are common (Tilman et al., 2011; Godfray and Garnett, 2014). The food production system is the largest cause of global environmental change, with agriculture occupying approximately 40% of global land (Foley et al., 2005) and food production being responsible for up to 30% of global greenhouse gas (GHG) emissions (Vermeulen et al., 2012) and 70% of freshwater use (Molden, 2013). The Green Revolution resulted in Asian farmers accounting for two-thirds of global agricultural productivity (Mendelsohn, 2014). However, the overuse and misuse of nitrogen and phosphorus fertilizers can cause eutrophication and dead zones in lakes and coastal zones (Diaz and Rosenberg, 2008; Jat et al., 2020). The present situation is anticipated to worsen with climate change, with rising temperatures and changing monsoon rainfall patterns projected to cost India 2.8% of its gross domestic product (Mani et al., 2018). Asian agriculture has become a global ‘hotspot’ for contemporary and future climate vulnerability (Jat et al., 2020). We are facing the challenge of feeding 10 billion people a healthy and sustainable diet by 2050, while a rising number of environmental systems and processes are being pushed beyond safe boundaries by food production requirements (Willett et al., 2019).

2 Challenges and solutions across the supply chain: crop production

Improving agri-food supply chains is crucial for food and nutrition security, resource conservation and environmental sustainability. Figure 1 illustrates the pathways and corresponding solutions to improve agri-food supply chains in Asia via food production, food storage, distribution, processing and consumption stages. In each supply-chain stage, we explore the challenges and threats driving the transformation of the agri-food supply chain. We also reveal the key points for each stage in the process of transition to a more nutritious,

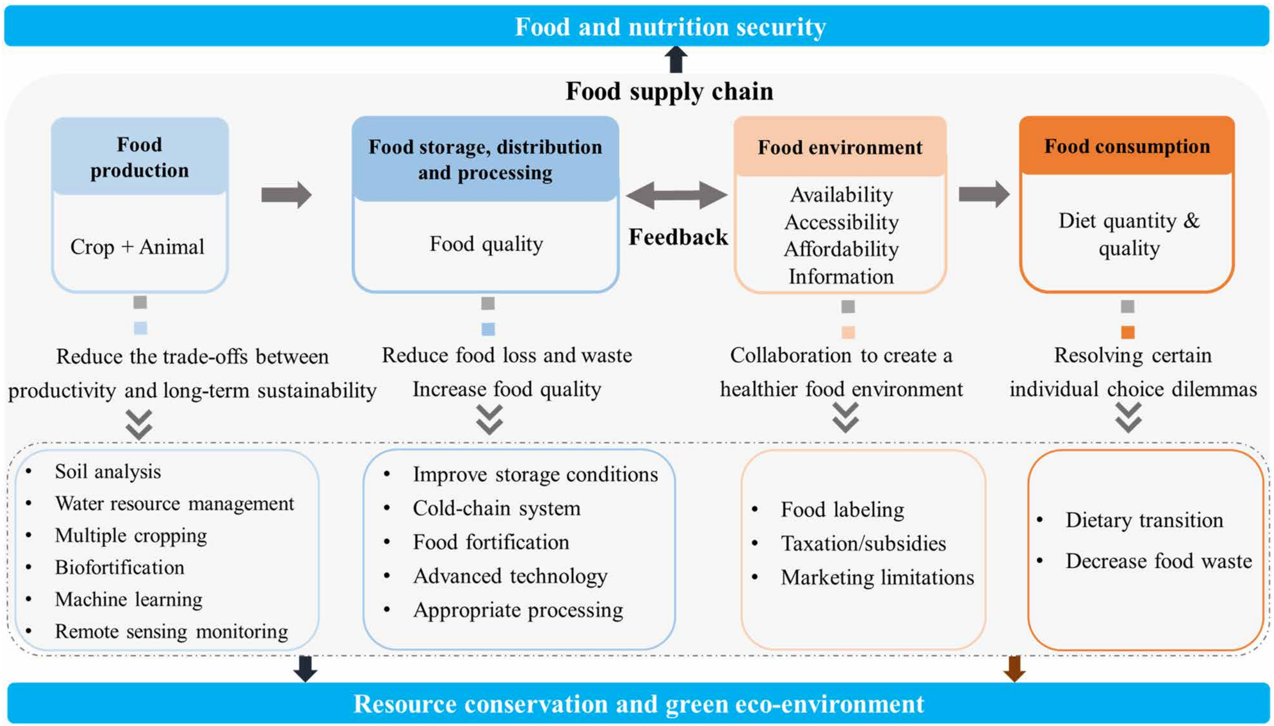

Figure 1 Pathways to solutions for improving agri-food supply chains in Asia.

environmentally friendly and economically sustainable path, with specific interventions discussed around every key point. Subsequently, the case studies later in the chapter will further demonstrate the potential of the interventions and their effects on successfully improving the sustainability of the agri-food supply chain and supporting its transformation. This section starts by looking at crop production.

The Green Revolution began in Asia in the 1960s, with the primary aim of introducing high-yielding varieties of cereals, e.g. rice, wheat and maize, to alleviate poverty and malnutrition with a high investment in infrastructure, crop research, market development and appropriate policy support (John and Babu, 2021; Pingali, 2012). Between 1970 and 1995, although the population increased by 60%, food production rose faster. Consequently, cereal and calorie availability per person increased by nearly 30%, and at the same time wheat and rice became cheaper (Hazell, 2009). By increasing the supply of food and reducing the prices of staple foods in Asia, the Green Revolution improved the nutrition of poor people and the absolute number of poor people declined by 28% from 1975 to 1995 (Brainerd and Menon, 2014). In conclusion, the Green Revolution lifted many populations out of poverty, jump-started economic growth and saved large areas of other fragile lands and forest wetlands from conversion to cropland (Hazell, 2009).

Despite great success in increasing food production, Asia still faces enormous food security challenges (John and Babu, 2021). At present, agriculture faces the unprecedented challenge of securing food supplies for a rapidly growing human population while seeking to minimize the adverse impacts of agriculture production on the environment and reduce the use of non-renewable energy and resources (Garnett and Godfray, 2012). A shift towards more sustainable agricultural production entails the adoption of system-oriented strategies, which include farm-derived inputs and productivity based on ecological processes and functions (Garnett and Godfray, 2012). Sustainable agricultural systems also involve traditional knowledge and entrepreneurial skills of farmers (Beintema et al., 2009). The greatest challenge for agriculture is to reduce the trade-offs between productivity and long-term sustainability (Niggli, 2015). Improving the sustainability of food systems means not only continuing to increase food production but also enhancing food nutrition, adapting to global climate change and minimizing GHG emissions and environmental impact (Davis et al., 2019; Godfray et al., 2010). However, sustainable agriculture offers entirely new opportunities by emphasizing the productive values of natural, social and human capital, all assets that Asian countries either have in abundance or that can be regenerated at a relatively low financial cost (Pretty and Hine, 2000).

Soil plays a critical role in securing food production and consequently, it is necessary to monitor the soil at the field scale to obtain information regarding soil health to make precise decisions at different crop developmental stages. The main objective of soil analysis is to measure the content of nutrients present in the soil to increase fertilizer use efficiency and decrease pollution to air and water (Martínez-Fernández et al., 2016). Due to the increase in irrigation requirements, freshwater will only be available to those countries that have adopted the best water resource management practice. To overcome the water shortage problem, new irrigation techniques, including sprinkler and drip irrigation methods, are used to reduce losses and water shortage (Motoshita et al., 2018).

Plant growth, development and reproduction mainly depend on receiving the necessary nutrients from fertilizers or organic amendments. New technology is used to estimate the spatial-temporal application of nutrients for the fulfilment of fertilization, which is relatively less laborious and achieves maximum efficiency (Ihtisham et al., 2020). In addition, the need for increased crop yields has led to growing interest and research focused on agricultural intensification, which has a myriad of environmental impacts (Tilman, 2020). Intercropping can bring the benefits of intensification within a reasonable footprint (Li et al., 2020). It is expected that the future of agriculture will develop into a progressive sector when integrated systems appreciate artificial intelligence and big data capabilities. Advanced technologies, such as robots in agricultural production processes, cloud computing, artificial intelligence and big data calculation, can usher in a different era of super-convergence in different farming sectors (Khan et al., 2021a).

3 Challenges and solutions across the supply chain: storage, distribution and processing

The impact from each process in the food supply chain are added together to give their cumulative environmental impact and nutritional output. Over 40% of food loss occurs at the post-harvest handling and processing stages in developing countries, which is particularly true for China (Lu et al., 2022).

During the process of food storage and transportation, reducing food loss is an effective way to simultaneously achieve food and nutrition security as well as reduce the environmental externalities of the food supply chain (HLPE, 2014; Luo et al., 2020; Gibson et al., 2020). Many researchers have endeavoured to identify the possible factors that influence food loss and waste (FLW) and suggest possible interventions. In the following section, we first focus on revealing the development of interventions aimed at food loss reduction during storage and transportation phases for non-perishable and perishable foods. Then, from the operations management perspective, we describe the current topics, themes and methods applied to the FLW of the supply chain.

The major contributor to food loss occurring at the storage stage for non-perishable food, e.g. cereals and dry beans, is inadequate storage conditions (Luo et al., 2020; Kumar and Kalita, 2017). In China, warehouses and bags are widely used storage facilities for rice and wheat. Nevertheless, local storage facilities like storage baskets, tanks, and jars are generally used for corn storage (Luo et al., 2020). The lack of appropriate storage conditions leads to the greatest food loss for corn in China, compared with rice and wheat.

Temperature, humidity and the biophysical properties of grains determine how much energy will be applied to grain storage. Energy input is regarded as a solution that can prevent grain from being affected by pests, mould and respiration (Puri, 2016). In the context of the crop production stage in India, energy allocated to provide suitable storage conditions for grain only accounts for 8–16% of the entire energy input (Gibson et al., 2020); however, the potential for loss reduction is huge. According to the estimation, if grain losses can be saved and targeted to the nutrition deficiency population in India, protein, calorie, zinc and iron deficiency can be reduced on average by 46%, 27%, 26% and 11%, respectively (Gibson et al., 2020). Similarly in China, if the loss rate of household storage falls to the advanced rate (1.00%), 379 000 hectares of land, 2.66 billion m^3 of water resource, 510 600 tons of GHG emissions could be reduced and 5.87 million people could be fed in 1 year (Luo et al., 2020).

Perishable foods, e.g. fruits, vegetables and animal-sourced foods, comprise the largest portion of total food loss (Xue et al., 2021; Parfitt et al., 2010). The application of cold-chain logistics is identified as an efficient investment in preventing perishable food losses (Han et al., 2021). An efficient and complete cold-chain system is necessary to maintain perishable foods at an appropriate temperature and humidity range. Any interruption during the cold-chain stages will greatly reduce the effectiveness of the whole system.

Han et al. (2021) explored current research topics related to cold-chain logistics for perishable foods. Efficiency optimization, integrity and accurate control as well as green and sustainable cold chains are major topics. During the storage stage, the refrigerated warehouse (RW) plays a critical role in reducing food loss and balancing supply and demand. Three research streams were recently investigated: one stream focused on balancing the electric power demand of cold storage with the conservation of product quality; the second stream investigated the influence of storage atmospheres on food quality; the third stream explored the optimization of refrigerating systems. For the transport stage, refrigerated transport (RT) is used to maintain stable temperature and humidity conditions during the delivery period. Advanced innovations such as cloud computing (for data processing and mining) and artificial intelligence (data interpretation) will be helpful in the upgrade of RT.

From the operations management perspective, Luo et al. (2022) analysed the topics, research themes and methods of FLW along the food supply chain by reviewing 346 articles (see Fig. 2). For research topics, the causes, measures, barriers and drivers of FLW have been widely investigated, especially by studies focused on one or several supply-chain stages. Regarding research themes, sustainability and environmental impact, food supply chain management and activity analysis are the main explored themes. Concerning methodology applied to FLW, around 30% of studies quantitatively analysed the FLW problems; among these, statistical analysis and life-cycle assessment (LCA) are mainly used for empirical research.

Food processing refers to activities that transform a raw product into edible food, including milling, heating, canning, drying or mixing (Nordhagen, 2020). Insufficient investment in infrastructure and auxiliary equipment was one of the reasons behind the loss of processing in China. Over the past few decades, the use of advanced technology and equipment has greatly reduced loss and waste during the processing of staple foods, but the problems still exist in most small-scale staple food processing industries.

There is another primary reason that the lack of relevant technology leads to a low utilization rate of food processing by-products. During the process of harvesting, selling on the market and then serving to consumers, the inedible parts of fruits and vegetables are thrown away, which leads to kitchen waste that is difficult to deal with, and the whole process also leads to a waste of resources. The large-scale processing and non-damaging treatment technology of fruits and vegetables should be improved and applied to increase the edible rate and resource utilization rate, which is conducive to the centralized treatment of fruit and vegetable wastes, such as technology involved in precooling, peeling, preservation and drying.

In addition, food processing activities such as excessive peeling and cutting are known to not only lead to a quantitative loss but also compromise the micronutrient quality. For example, minerals and vitamin B are easily lost

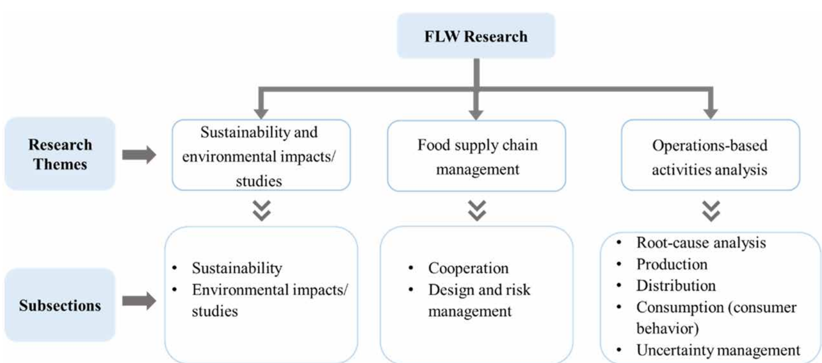

Figure 2 The structure of the research stream related to FLW (food loss and waste). Source: Adapted from: Luo et al. (2022).

in refined grain flour after milling compared with whole-grain flour. However, in China, the definition of whole-grain food is unclear, and relevant standards and labelling are insufficient. There is no effective supervision, resulting in the uneven quality of whole-grain products in the market. New processing technology with high efficiency and low cost should be developed to enhance the quality of whole-grain products and improve nutrient retention.

4 Challenges and solutions across the supply chain: consumption

Food environments, dietary patterns and food choices are influenced by globalization, urbanization and wealth growth. Along with economic and social expansion, advancements in technology and the food supply chain have made agricultural goods in the agri-food system more affordable and diverse for consumers. Throughout the consumption stage, consumers make decisions regarding purchasing, preparing and consuming food based on their local food environment. The retail and food environments, notably the rapid expansion of supermarkets and fast-food chains, altered consumer food preferences and eating patterns. Household consumption of most food is heavily commercialized in metropolitan areas, and the retail and food environments, particularly the rapid proliferation of supermarkets and fast-food chains, have influenced consumer food choices and dietary patterns (WHO, 2013; Baker and Friel, 2016).

However, there are still several challenges throughout the stages of food consumption. First, the ongoing shift in diet exerts pressure on agricultural production, individual nutrition, the environment and climate. In recent years, the Asian diet has become more calorically dense, with the increased consumption of salt, fats and oils, and sugar (Fan et al., 2017). In the majority of middle-income nations, packaged and ultra-processed foods, which do not conform to the World Health Organization's (WHO) definition of a healthy diet, comprise an increasing proportion of diets (Micha et al., 2020; Baker and Friel, 2016). The nutrition transition that goes along with it exacerbates the double burden of malnutrition and NCDs. It also affects natural resources, climate change and other costs that are hard to measure (Reardon and Zilberman, 2018). Urbanization, population and wealth growth will continue to raise consumer demand for food that is more nutrient-dense and safer; yet, how to feed Asia's numerous and enormous cities remains an open subject (Fan et al., 2021b). Second, the food environment does not encourage healthy eating choices among customers. Consumers' food choices are often influenced by food availability, accessibility, cost and desirability. Along the food supply chain, the food processing, retailing and food service sectors are key drivers of the nutrition shift in Asia (Baker and Friel, 2016), but the effort they put into providing nutritious and sustainable food remains limited. Third, the cost-effectiveness of healthy diets remains a concern. Asia is home to more than half of the world's population unable to afford a nutritious meal in 2020 due to the high cost of nutritious diets and substantial income disparities (1.89 billion out of 3.07 billion) (UNICEF, 2021).

To deal with the many problems in terms of people and planetary health, different parts of the food supply chain should work together to create a healthier food environment and encourage consumers to change their habits. Information campaigns on modifying habits, such as dietary transition and decreasing food waste, have been shown to be effective in increasing consumer knowledge and demand for nutritious and healthful food, as well as in resolving certain individual choice dilemmas (Fan et al., 2021a). To achieve this, consumer-oriented approaches like food labelling, taxation/subsidies and marketing limitations could be implemented. By investing in technical breakthroughs, food fortification and nutrition-sensitive interventions, the food industry and the corporate sector may contribute to improved nutrition. The labelling and marketing of foods should be monitored to ensure that consumers are able to make informed decisions without being misled. With simple nutrition information, such as front-of-package labelling, consumers can make better-informed food choices (Hawkes et al., 2015; Julia et al., 2015). In order to safeguard children and all other age groups from the negative effects of food marketing, these practices should be re-evaluated and revised. A number of Asian nations have enacted food marketing restrictions based on best practices. For instance, the Philippines has regulated marketing and legal protection for newborns and young children (Reeve et al., 2018), while Turkey has broadcast laws to protect children under 18 years old (Bosi et al., 2018). In addition, greater emphasis should be placed on raising the equity among consumers by reducing the price of food. As long as the price of nutritious and healthy food remains high, low-income and disadvantaged groups may be unable to afford it. In these circumstances, initiatives to promote consumer demand, such as unemployment insurance and other social safety nets, can be crucial for protecting the most vulnerable populations and can also lead to increases in welfare and food and nutrition security (Nordhagen et al., 2021).

5 Challenges and solutions across the supply chain: a system perspective

Several leading institutions have explored solutions to improve the agri-food supply in China. CCICED (2022) (China Council for International Cooperation on Environment and Development) proposes four categories of solutions to transform the agri-food system in China, i.e. producing more (and more nutritious) food, protecting nature, reducing agri-food system inefficiencies and pollution, and restoring degraded lands. AGFEP (2021) (Academy of Global Food Economics and Policy) found that agricultural GHG emissions in China can be mitigated to a large degree through technological innovations, reduction of FLW, and transformation of dietary patterns, even while ensuring long-term food security. Transforming the agri-food supply, China demands a shift towards more sustainable and healthy diets, long-term prevention and treatment of agricultural non-point-source pollution, and proactive participation in the governance of global food and agriculture. PwC (2019) (Pricewaterhouse Coopers) emphasizes the importance of technology innovation during the process. Asia will not solve its food challenges through a continuation of traditional farming practices or via linear modernization. New technologies will need to be deployed to increase yields, reduce the environmental impact of farming, improve food safety, traceability and nutritional value, reduce waste, shorten the supply chain and bring food to consumers in their increasingly urban settings.

Technology will be essential in helping to solve this food challenge; however, this requires investment and collaboration across the food and agricultural industry, including corporates, start-ups, investors, academia and government (PwC, 2019). Therefore, policies, governance and institutional innovations are recommended to facilitate such concerted transformation and improvement of the agri-food supply chain. Over the next 10 years, an estimated cumulative investment requirement of US$800 billion is above existing levels. The majority (around US$550 billion) will help to satisfy the demand for better quality food (including safer, healthier and more sustainable food). The remainder (around US$250 billion) will drive increased quantities of food to feed Asia's growing population. PwC (2019) pointed out that government co-ordinated ecosystems and the development of regional agri-food tech hubs are critical catalysts for investment and innovation. Khan et al. (2021b) suggest that government food authorities, global agencies, non-government organizations and food businesses collaborate to make the food supply chain resilient in low-income countries of Asia.

Policy recommendations proposed by CCICED (2022) are to develop a national agri-food system transformation strategy, repurpose agricultural fiscal incentives and finance, promote healthy diets and consumption, accelerate the agri-food system transformation through private sector leadership and incentivize alternative sources of protein and food technology and green international foodvalue chains. Regarding reforming the agricultural support policies, AGFEP (2022) explores how to reposition China's agricultural support policies in the new development era, and their recommendations include:

- review agricultural support policies to promote a win-win situation of nutrition and health security and green and low-carbon development;

- support policies should be optimized according to the concept of 'Big Food';
- adjust agricultural support policies to promote the development of green and low-carbon technologies in agriculture;
- enhance investment in high-standard farmland construction and green agricultural R&D (research and development) and extension;
- better use of China's fiscal expenditure on agriculture to narrow the income gap between urban and rural populations; and
- reducing the minimum purchase price to the amount that can cover the total cost of agricultural production and combining the minimum price with full-cost insurance.

6 Case studies: production structure optimization in India

Several Asian countries have taken steps at regional and national levels to improve the sustainability and food nutrition of their local food systems. This section provides an overview of case studies from India, China, and Singapore on their efforts to improve production structure, joint distribution, e-commerce and supply-chain innovation, as well as their food policies to enhance the food environment. The discussion starts by looking at India.

From 1947 to 1960, food production in India was insufficient as there was a growing population and food availability was 417 g per day per person (Nelson et al., 2019; Ghosh, 2004). The Green Revolution began in the 1960s aiming to introduce high-yielding varieties of cereals to alleviate poverty and malnutrition with a high investment in research, infrastructure, market development and appropriate policy support (Pingali, 2012; John and Babu, 2021). The total production of cereal crops tripled with only a 30% increase in the cultivated land area, helping India move from a state of importing grains to a state of self-sufficiency (Brainerd and Menon, 2014).

However, India had faced substantial negative consequences involving the environment, resources and the health of its growing population (Davis et al., 2018; Bhattacharya et al., 2015; Anupam and Khajuria, 2016) as a result of unsustainable production measures including the increased usage of pesticides (Neethu et al., 2016). In addition, the majority of Indian crops are cereal, which accounts for almost 50% of the dietary water footprint, causing severe stress on water resources (Kayatz et al., 2019; Bkab et al., 2019). Moreover, there was reduced cultivation of indigenous varieties of rice, millets, lentils, etc., but an increased harvest of hybrid crops (Taylor, 2020). As a result, the modern food production system failed to provide a diverse diet but increased calorie consumption with fewer micronutrients (Kumssa et al., 2015).

Sustainable food systems aim to provide sufficient and nutritious food while maximizing climate resilience and minimizing resource demands as well as negative environmental impacts. However, the Green Revolution prioritized the single objective of maximizing production over other nutritional and environmental dimensions. In India, diversifying crop production to include more coarse cereals, such as millets and sorghum, can make the food supply more nutritious, reduce resource demand and GHG emissions, and enhance climate resilience without reducing calorie production or requiring more land (Davis et al., 2019). The extent of these benefits partly depends on the feasibility of switching harvested areas from rice to coarse cereals. National- and state-level strategies considering multiple objectives in decisions regarding cereal production can move beyond many shortcomings of the Green Revolution while reinforcing the benefits. This ability to realistically incorporate multiple dimensions into intervention planning and implementation is the crux of sustainable food production systems worldwide. Similar multidimensional approaches to food production challenges in other parts of the world can identify win-win scenarios where food systems meet multiple nutritional, environmental and climate resilience goals (Davis et al., 2019).

7 Case studies: joint distribution of perishable food in China

Joint distribution, also known as co-operative distribution, was first proposed by the Japanese government in 1977 to improve resource utilization (Liu et al., 2020). This is a distribution mode jointly organized by several different enterprises, e.g. manufacturers, wholesalers and retailers, and is widely conducted in many developed regions such as Europe and Japan. With increasing high-frequency and low-quantity orders, joint distribution implementation can help meet the growing requirements of customized orders, improve the utilization efficiency of distribution facilities and equipment and make the whole process more efficient and intensive. It can also effectively reduce the total delivery distances, contributing to reducing carbon emissions (Maruyama, 2004; Chen and Hsu, 2015).

The typical modes of joint distribution can be categorized by horizontal and vertical integration. Horizontal integration is conducted by several companies at the same stage of the supply chain, for instance, several manufacturers. In terms of vertical integration, different companies along the whole supply chain will typically create an alliance, deliver the products to a joint distribution centre and then deliver the products to final stores.

Joint distribution can effectively satisfy small shipments and timely delivery requirements. With the growing demand for fresh food, the application of joint distribution under the context of the cold chain has been widely considered.

Kuo and Chen (2010) proposed a multi-temperature joint distribution (MTJD) system to minimize the total cost and investment of storage and transportation stages, improve truck usage flexibility and logistics performance and achieve food quality and safety goals under the cold-chain context. Figure 3 demonstrates the MTJD example for perishable food. Multi-temperature food can be stored together in a shared refrigerated distribution centre and then delivered to various stores and markets using multi-temperature trucks. Note that the reason why joint distribution can increase resource utilization efficiency and improve logistics performance is that it changed the previous situation of independent distribution by multiple enterprises. By maximizing truck utilization and promptly gathering the latest demand information, MTJD makes it possible to quickly meet customers' needs at a lower cost.

In the MTJD system, two modules were put forward to tackle the challenges and fulfil requirements. The service-integrated module was designed to standardize the logistics service process and to balance delivery time and diverse demands with high efficiency and low cost. The other is the resource-integrated module, in which the transportation resource planning system was the core engine. This module aimed to integrate resources to minimize total cost and improve operations efficiency. With the application of the MTJD system, cost reduction, improved satisfaction, food safety and quality can be achieved simultaneously.

Not only lower costs and higher efficiency can be realized in the MTJD system, but carbon emission reduction can also be achieved. Chen and Hsu (2015) compared the traditional multi-vehicle distribution system (TMVD) with the joint distribution system in terms of GHG emissions and total cost in the context of fresh foods. They considered 20 fresh food items with multiple temperature-controlled requirements, e.g. fish, duck, pork, beef, vegetables, milk. Figure 4 demonstrates the difference in unit carbon footprint with shipping volume between the traditional distribution system and the joint distribution system. It is noticeable that for range 3 food (livestock, poultry meat and fish

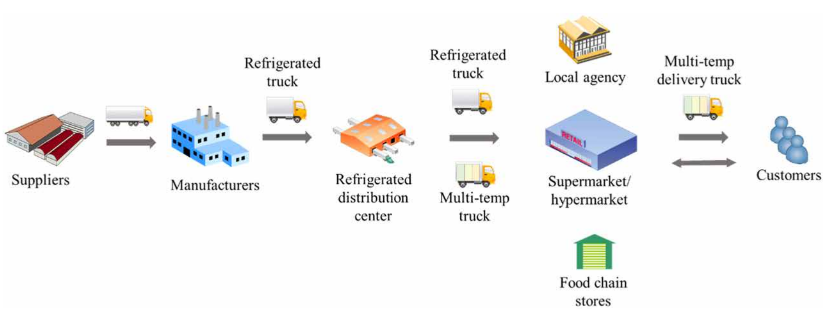

Figure 3 An example of multi-temperature joint distribution for perishable food. Source: Kuo and Chen (2010).

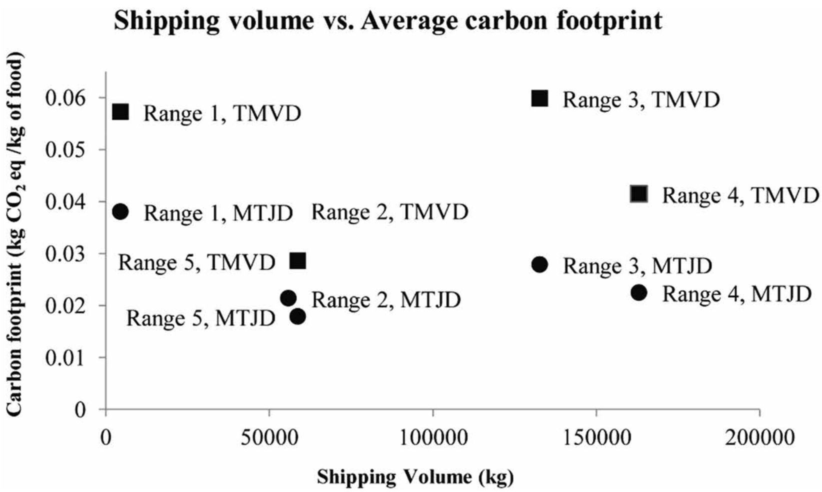

Figure 4 Distributed volume vs. average carbon footprints (source: Adapted from: Chen and Hsu, 2015). TMVD, the traditional multi-vehicle distribution system; MTJD, multi-temperature joint distribution. Ranges 1, 2, 3, 4, 5 represent the temperature ranges <−30°C, −30°C ~ −18°C, −2°C ~ +2°C, 0°C ~ +7°C, > +18°C, respectively.

meat with a temperature-controlled range between –2°C and +2°C), the joint distribution showed great potential to decrease carbon emissions. The higher the distribution volume, the greater the potential reduction of GHG emissions can be achieved by implementing joint distribution.

In conclusion, joint distribution is an effective system to lower total cost, reduce GHG emissions and satisfy dynamic demands.

8 Case studies: e-commerce and supply-chain technology innovation in China

China is a global leader in e-commerce, food delivery and other consumer-facing platforms (AGFEP, 2021). The development of e-commerce has changed the traditional circulation system of food and other agricultural products. Internet technology provides a virtual platform to conduct a direct transaction between individual farmers and final consumers nationwide, leaving mediators and intermediate steps less critical in the food supply chain.

With the support of the internet platform and modern logistics industry, smallholder farmers can access consumers through e-commerce via three modes (Fig. 5), in which e-commerce can boost smallholder farmers' connections with larger markets. First, farmers rely on the e-commerce platform to help them operate independently. In recent years, with the help of the internet, some farmers have set up online stores on third-party e-commerce platforms to have direct contact with consumers so that they can successfully

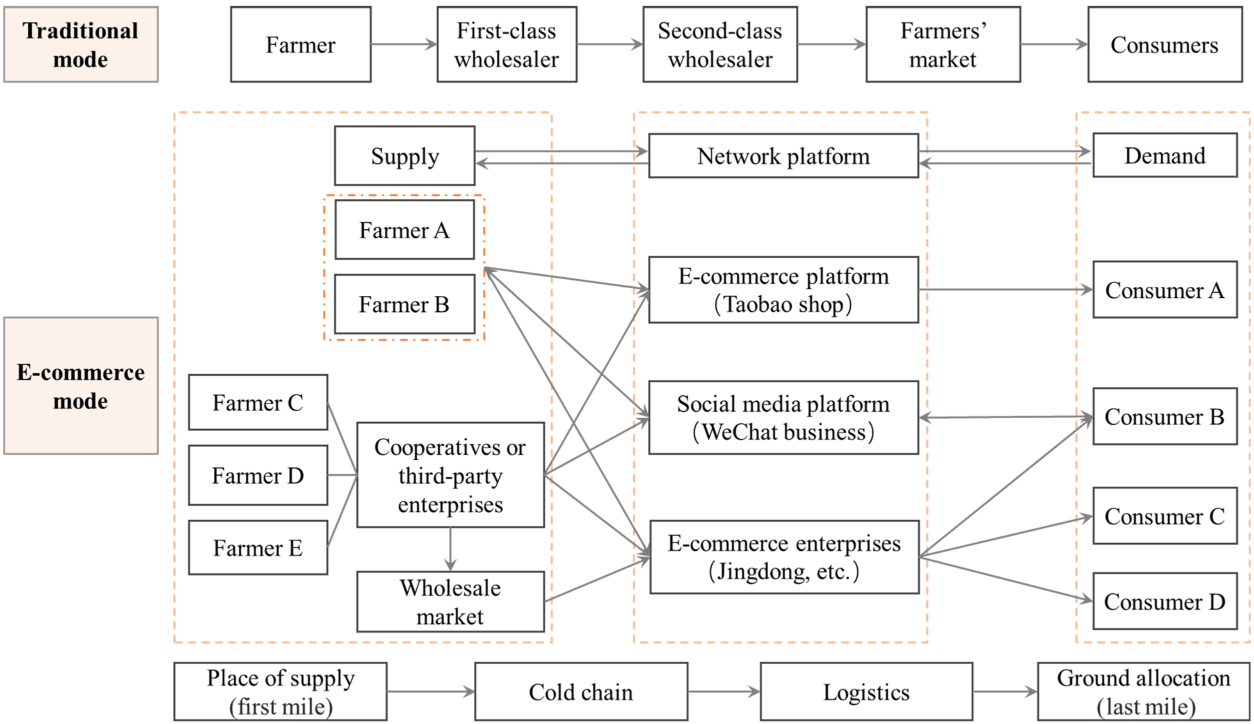

Figure 5 Circulation systems of agricultural products, traditional versus e-commerce modes. Source: Adapted from: AGFEP (2021).

bypass mediators and sell directly to foreign consumers. Second, farmers rely on social media platforms to help them operate independently. Apart from the independent business model of the e-commerce platform, in rural areas of China, some farmers also display their production processes and product information on social media such as WeChat, Weibo and TikTok, thus enhancing their direct connection with consumers. With the help of social media, people as critical actors and social relations as a link, this new business model based on mobile internet is called 'We Business'. Third, farmers work in co-operation with e-commerce enterprises. In rural areas, some farmers work in groups, families or professional co-ops, using the internet to connect with the market indirectly by establishing a co-operative relationship with an e-commerce platform enterprise or an operational service provider and sharing certain digital dividends. Here, we elaborate on how e-commerce enterprises strengthen the connections between smallholder farmers in rural areas and large markets and how management strategies and innovative technologies play an inseparable role in building this connection.

As a leading Chinese e-commerce enterprise, JD (JD Com, Inc.) is also known as a logistics-integrated solutions provider with an extended warehouse network to nearly all counties and districts nationwide until 2022 (JD, 2023). In 2015, JD began investigating the potential of leveraging its e-commerce platform to directly connect farmers' products with consumer markets, aiming to boost farmers' income (Fang and Huang, 2020). JD utilizes its advanced e-commerce platform and logistics network in multiple stages, from agricultural input procurement to the retail and distribution of final products, to explore this potential (Kong and Loubere, 2021). Agricultural product suppliers can directly publish product information on JD's platform, eliminating the need for intermediate stages in the traditional agricultural product supply chain and ensuring that agricultural products can enter the market more quickly and efficiently. As estimated, there was a remarkable 6.4-fold increase in online sales of agricultural and food products from poverty-stricken rural areas, observed from the first quarter of 2016 to the second quarter of 2018 (Fang and Huang, 2020).

The agricultural industry in rural or poverty-stricken areas faces problems mainly due to insufficient processing, decoupling of production and distribution, lagging market sales information, and logistics and transportation barriers, which significantly hinder the linkage between agricultural products and larger consumer markets. To overcome these problems and boost more direct connections between farmers' products and consumer markets, JD contributes to building a whole-process supply-chain system by applying advanced management strategies and innovative technologies. First, brand images of agricultural products are established to differentiate from other similar products and to better integrate into retail markets. JD worked with local enterprises (or groups, families or professional co-ops) that source agricultural products from individual farmers and then assisted these enterprises in branding regional agricultural products (Fang and Huang, 2020; Wu et al., 2023). This is beneficial in shaping the regional brand image of agricultural products and enhancing consumer awareness. Second, tailored marketing strategies are devised for potential consumers through big data platforms and algorithms to increase the possibility of purchase and increase sales. Applying big data platforms and algorithms such as personalized recommendation algorithms, JD conducts precise marketing of agricultural products and identifies potential consumers. To provide farmers with timely information on market demand, JD analyses real-time retail data and shares this information with farmers to help them adjust production and sales strategies. Based on the advanced cold-chain system of JD, the transportation conditions of fresh foods can be improved, breaking through regional restrictions and entering a broader consumer market (Li et al., 2023).

The development of e-commerce has dramatically boosted the connection between smallholder farmers in China and the larger market. It has become an essential way for smallholder farmers to connect to the fast-growing demand of the Chinese urban population, which will help promote the transformation of China's agri-food systems into one characterized by safety, nutrition, sustainability and resilience. In addition, e-commerce enables smallholder farmers to enter the global value chain by reducing their transaction costs for information, thus facilitating their entry into the market.

Some experiences of e-commerce development in China can be shared with other countries in Asia and worldwide. Rural e-commerce needs an ecosystem suitable for the participation of smallholder farmers, composed of network operators, government and service providers. Creating an e-commerce ecosystem suitable for the development of smallholder farmers requires: (1) an expanded and improved infrastructure, including information and communication infrastructure and other facilities; (2) improved ability of smallholder farmers to use the internet effectively; (3) supporting the development of inclusive digital business platforms; and (4) giving full play to e-commerce public service providers. In the process, a benefit distribution mechanism needs to be developed to ensure and enhance the profitability of smallholder farmers participating in e-commerce. Logistics and communication infrastructure, inclusive digital business platforms for smallholder farmers and a new generation of farmers are prerequisites for developing rural e-commerce. Thus, farmers need to be trained with e-commerce insights, knowledge and skills to help them lead other smallholder farmers to join e-commerce. As e-commerce may exclude smallholder farmers who cannot participate in the digital economy or lack the required skills, attention must be paid to the regional disparities and inequalities among farmers caused by the digital divide.

9 Case studies: Singapore's policy innovations for improving whole-grain consumption

Government policies can be critical in shaping the food environment towards health and sustainability. In Singapore, the consumption of whole grain used to be extremely low, with an average of just 0.2 servings per day, and only one in ten Singaporean adults consumed a serving or more of whole-grain foods (Health Promotion Board (HPB), 2004). To increase whole-grain consumption and protect Singaporeans' health, the national HPB has adopted rules to encourage the use of whole grains since 2009. The following strategies were implemented in order to raise the level of whole-grain knowledge among consumers, enhance their ability to recognize whole grains and expand the availability and accessibility of whole grains in the marketplace. The percentage of adults consuming more than one serving of whole grains a day has risen from 8.4% in 2004 to 27.0% in 2010 in Singapore (HPB, 2010).

9.1 Communicating with consumers

After communicating with consumers, HPB revised the dietary guideline and the healthy diet pyramid (increasing the daily whole-grain consumption recommended from 1 serving to 2–3 servings or 50 g) and recognized whole grains to be an essential part of daily meals. HPB also launched an educational campaign titled 'Eat More Whole Grains' to inform the public regarding the health benefits, suggested amounts, where whole-grain items can be found, and how they can be prepared and creatively included in the daily diet. The HPB mandates the serving of whole grains in schools and preschools through the Healthy Meals in School Programme, aiming to help students cultivate habits of eating whole grains and other healthy foods from their youth.

9.2 Regulating food labels and health claims

HPB regulated labels and health claims of whole-grain foods to eliminate identification barriers for consumers. Whole-grain foods which meet the HPB requirements can carry the Healthier Choice Symbol (HCS) with 'higher in whole grains'. In order to use this health claim or label a product as 'higher in whole grains', manufacturers must also declare the whole-grain content in the product's ingredients list. For example, a compliant ingredients list might say, 'Rice (20% brown rice), fish, cheese, salt, flavouring'. The package must also include a statement expressing the amount of whole grain per serving as a percentage of the 50 g/day whole-grain requirement established by the HPB (e.g. '1 serving of [name of product] provides [x]g of whole grain, which meets [x%] of your daily whole-grain requirement').

9.3 Providing market incentives for private sectors to increase the availability and accessibility of whole grains

HPB collaborated with food stores and food outlets to increase the availability of whole grains. Approximately 80% of Singaporeans eat at a hawker centre at least once a week, so the potential nutritional impact of incorporating more whole grains into these food courts is huge. HBP incentivized hawker stalls to adopt the whole-grain options by covering up to 80% of the investment cost (including product and packaging development, marketing, publicity and trade promotion) through the Healthier Ingredient Development Scheme. In addition, restaurants, cafes and quick-service restaurants were also incentivized to offer whole-grain dishes/items to diners. The number of healthy meals sold under the programme climbed from 7.5 million in fiscal year (FY) 2014 to 50 million in FY 2017 (HPB, 2018).

Accessibility to whole-grain foods is also crucial. HPB partners with suppliers to offer discounts on brown rice and drive competition in the market. The collaboration with major supermarket chains such as FairPrice, Cold Storage and Shop N Save outlets features targeted in-store promotions of whole-grain products. In addition, HPB teams up with noodle suppliers and food vendors to develop and market partially whole-grain noodles that would be sold at the same price as their refined grain counterparts (Toups, 2020). By experimenting with different product formulations, a balance was struck among health considerations, taste and manufacturing costs.

All of these strategies to increase whole-grain consumption in Singapore involve government policies and private–public partnerships along the food supply chain, and it creates a win-win business case that benefits all parties involved.

10 Conclusion and future trends in research

We summarized and highlighted effective measures and methods aimed at achieving sustainability, efficiency, resilience and nutritional health across various stages of the supply chain (Table 1). Engaging stakeholders is also essential during an agri-food system transformation.

10.1 Crop production stage

A sustainable food supply chain requires innovating agricultural production technologies as well as promoting the application of these innovative technologies. For example, a new generation of fertilizer, the so-called ‘green intelligent fertilizer’, is designed to meet the nutrient requirement of crop growth by considering the characteristics of plant growth and the fertilizer, as well as their interactions with climatic and soil conditions. The green

Table 1 Summary of agri-food supply chains in Asia

Supply-chain stages	Successful interventions	Key words	Primary stakeholders	Secondary stakeholders
Production	Multi-objective optimization of crop production structure in India	Sustainable	Farmers	Policymakers
	The Science and Technology Backyard platform in China	Green		Governments
Storage, distribution, processing	Multi-temperature joint distribution	Efficiency	Manufacturers, wholesalers and retailers	Inspection services
	E-commerce and supply-chain technology innovation	Resilience	Food traders	Certification bodies
Consumption	The Health Promotion Board in Singapore	Healthy	Consumers	Scientific community,
		Nutritious		non-governmental organizations and media

intelligent fertilizer can thus enhance crop production, crop quality and reduce environmental pollution (Bruulsema et al., 2020). One example regarding technology adoption is that agricultural scientists living in villages among farmers advance participatory innovation and technology transfer via the Science and Technology Backyard platform or via collaboration with extension agents and agri-business personnel, garnering public and private support (Cui et al., 2018; Zhang et al., 2016).

10.2 Storage, distribution and processing stages

Crucial issues of the storage, distribution and processing stages of the agri-food supply chain are to minimize food loss in post-harvest stages through applying standard facilities and equipment, adopting advanced technology and management measures, to improve the absorption efficiency of nutrients in food as much as possible, and to reduce environmental externalities.

In future, it is important to consider strengthening the resilience of the agri-food supply chain via storage and transportation planning. This will substantially improve our capacity to deal with various challenges such as extreme climate events, warfare, market risks and other unforeseen circumstances.

10.3 Consumption stage

Considerable advances have been made in improving the food environment and ensuring food availability in many Asian countries; however, consumers continue to face challenges in obtaining nutritious food at reasonable prices, and with different food cultures and dietary habits, better food utilization remains a problem. With the changing climate and limited natural resources, it is unclear how our food systems will deliver sufficient and nutritious food to future generations. Food systems must be transformed to improve efficiency, nutrition and sustainability. Given that SDG-12 stresses responsible consumption and production, important participants in the consumption stage, such as consumers, processing, retailing and marketing firms, should be motivated to adopt actions that contribute to healthy and sustainable local and national food systems. To this end, consumers, as influential actors in food systems, can not only improve their own behaviour by adopting sustainable and nutritious diets and reducing food waste, but they can also reward fair and ethical food production by making these changes.

10.4 System perspective

Changes in technologies, policies, institutions and behaviour are vital to transform the agri-food supply chain to achieve the multiple objectives of nutrition, health, sustainability, efficiency, resilience and inclusiveness. Aside from the pathways mentioned previously, the following aspects need to be further addressed when we aim to improve food security and nutrition in Asia through the lens of systems thinking. It includes emphasizing food production and consumption, encouraging public and private sector synergies and promoting policy innovations and public investment.

11 Where to look for further information

Key research in nutrition and food system can be found at the following organizations:

- Food and Agriculture Organization of the United Nations (https://www.fao.org/home/).
- International Food Policy Research Institute (IFPRI) (https://www.ifpri.org/).
- Harvestplus (https://www.harvestplus.org/).
- Geonutrition(http://www.geonutrition.com/).
- Academy of Global Food Economics and Policy (http://agfep.cau.edu.cn/col/col39575/index.html).
- Academy of Global Food Economics and Policy (AGFEP) (http://agfep.cau.edu.cn/).

Good introductions to the food system, food supply chain and nutrition subject:

- Searchinger, T., Hanson, C., Dumas, P., Waite, R., Ranganathan, J. and Matthews, E. (2018). Creating a sustainable food future, WRI: World Resources Institute. United States of America. https://policycommons.net/artifacts/1360128/creating-a-sustainable-food-future/1973409/ on 29 Sep 2022. CID: 20.500.12592/0397jv.
- Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S. and Murray, C. J. (2019). Food in the anthropocene: The EAT–Lancet Commission on healthy diets from sustainable food systems. *The Lancet* 393(10170), 447–492.
- HLPE. (2017). *Nutrition and Food Systems*. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome.
- Uccello, E., Kauffmann, D., Calo, M. and Streissel, M. (2017). *Nutrition-Sensitive Agriculture and Food Systems in Practice: Options for Intervention*. FAO.
- Food Systems Summit Brief.

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