2021 CHINA AND GLOBAL FOOD POLICY REPORT

AGFEP

Rethinking Agrifood Systems for the Post-COVID World

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Foreword I

I would like to offer congratulations on the publication of the 2021 China and Global Food Policy Report, led by the Academy of Global Food Economics and Policy (AGFEP) at China Agricultural University. The release of this report is a milestone in the agriculture and food sector: it focuses on the transformation of China's agrifood systems for the post-pandemic era, and conducts an in-depth analysis of major domestic and global issues from a multidisciplinary perspective, including food security, nutrition and diet, carbon neutrality, green agricultural development, e-commerce, and agricultural trade. The report is both timely and visionary.

Since the outbreak of the COVID-19 pandemic in 2020, the supply chain of the global agricultural and food system has suffered unusual fluctuations, and food concerns and hunger have been escalating in some areas. Despite being hit hard by the pandemic, China's grain output in 2020 reached a record high of 670 million metric tons. Moreover, as of the end of 2020, absolute poverty had been eliminated. China has achieved impressive gains in improving food supply and ending hunger. Nonetheless, China's food security still faces challenges. First, an imbalance is apparent between supplies of major staple foods and major non-staple foods, with a constantly growing shortage of meat, milk, sugar, oil products, and feed grains. Oversupply and supply shortages of agricultural products coexist. Second, China's current agricultural resources and production and processing technologies are failing to meet public demand for personalized, differentiated, and high-quality foods. The production structure is partially decoupled from the demand for agricultural products. Third, in view of China's large population, the country's arable land and freshwater resources are insufficient. Its agricultural capacity has not been fully tapped into, and current productivity and resources cannot meet China's own consumption needs.

As a major economy with a population of 1.4 billion, China needs to ensure food security and fill people's plates primarily with domestic foods. The fundamental principle of China's food security policy is to ensure basic self-sufficiency in grains and absolute security of staple foods. In addition, China must ensure the supply of other critical food products including meat, milk, sugar, and oil. To better ensure the supply of grains and other agricultural products and to better meet the public need for more nutritious, healthier, and safer foods at the new stage of the implementation of the 14th Five-Year Plan, China should start with two approaches. First, on the premise of strictly limiting the reduction of cultivated land, the country must improve agricultural technologies; facilitate the structural adjustment of agriculture; optimize the allocation of domestic agricultural resources; promote the cultivation of high-quality varieties, quality improvement, and branding; and thus increase the effective supply of domestic agricultural products. Second, it must make full use of the two markets (domestic and international) and of resources both at home and abroad through imports and exports, thus increasing the effective global food supply by internationalizing Chinese agriculture. To this end, China should optimize agricultural trade patterns, implement a strategy of diversified agricultural imports, and assist enterprises in participating in the global supply chain of agricultural products.

In sum, China needs to use the "new concepts" of innovation, coordination, green development, openness, and sharing to promote its strategy of food supply security, and develop a "new pattern" for a dual circulation between domestic and international markets. The publication of the 2021 China and Global Food Policy Report is of great theoretical and practical significance. The report will deepen public understanding of the transformation of China's agrifood systems and offer lessons for the transformation of the global agrifood system in the post-pandemic era.

Xiwen Chen
Chairman of Agriculture and Rural Affairs Committee of National People's Congress
Chairman of Academic Committee of Academy of Global Food Economics and Policy

Foreword II

During the past few decades, China has made remarkable strides forward in agricultural development. The poverty alleviation program has achieved its ambitious goals of eliminating absolute poverty by 2020 and living standards of citizens have improved significantly. Nonetheless, China's development has been hindered by malnutrition, chronic diseases, and increasingly evident environmental problems. In response, the country has formulated multiple policies: According to the 14th Five-Year Plan (2021–2025) for National Economic and Social Development and the Long-term 2035 Vision, national priority will be given to developing agriculture and rural areas, promoting rural revitalization on all fronts, and ensuring national food security. The Chinese government has committed to achieve carbon neutrality by 2060, take an active part in global climate governance, and promote green and low-carbon transformation and development. And in 2016, China's State Council issued the Outline of Healthy China 2030 Plan, incorporating "building a healthy China" into the national development strategy. All these initiatives show that China has begun to incorporate the win-win of improving human health and planet health into its development agenda. As a key national university, the China Agricultural University (CAU) works toward the ambitious mission of offering scientific solutions to help meet the major requirements of national development.

The CAU aims to become a world-class agricultural university with Chinese characteristics. According to the CAU's 14th Five-Year Plan and Vision 2035, the university will expand its mission from grains to food systems; the research scope will be expanded from agricultural technologies and grain security to agrifood technologies, food security, and food economics and policies; and from a domestic mandate to both domestic and global agendas. Thus, the CAU will contribute Chinese knowledge to the development of China and the world through broad international vision and advanced international concepts. To better support the national development strategy and achieve the university's development objectives, the CAU has established the Academy of Global Food Economics and Policy (AGFEP), supported by the College of Economics and Management in collaboration with experts of multiple disciplines from both within and outside the university. Professor Shenggen Fan, former director general of the International Food Policy Research Institute (IFPRI) and world-renowned agricultural economist, serves as the academy's dean. The AGFEP aims to conduct studies on key issues related to global and national development, including food and nutrition security, environmental sustainability, and climate change, as well as agricultural and rural modernization.

The outbreak of the COVID-19 pandemic in 2020 hit the global supply chain of agricultural products hard, and food and nutrition security face new challenges. In this situation, it is imperative to consider how best to facilitate the transformation of existing agrifood systems. Against this backdrop, the AGFEP is co-publishing the 2021 China and Global Food Policy Report with experts and scholars at home and abroad. The report focuses on major issues such as the role of agrifood systems in achieving carbon neutrality; dietary transition and nutrition; environmental sustainability; nonpoint-source pollution and green agricultural transformation; e-commerce and small-farmer development; and evolution and challenges in agricultural trade, in order to examine the future transformation paths of the agrifood systems of China and as well as the world in the post-pandemic era. As the first policy research report released by the AGFEP, the visionary and detailed publication is of great importance. I believe this report can provide policymakers and researchers with a valuable reference and I hope that it will spark extensive discussions across our whole society on the transformation of agrifood systems.

Qixin Sun
President of China Agricultural University

Preface

During the past several decades, significant progress has been made in reducing global hunger and malnutrition. The number of people suffering malnutrition, however, is rising again. The hidden costs and externalities in the agrifood systems are among the major contributors to various economic, social, and public health crises including food insecurity, zoonotic diseases, climate change, and malnutrition. Compounding the ongoing challenges facing the global agrifood systems, the COVID-19 pandemic, beginning in 2020, has intensified food insecurity and malnutrition in many parts of the world. Global food price indexes increased by more than 27.3 percent from the second half of 2020 to March 2021. Moreover, with many people losing their jobs during the COVID-19 outbreak and therefore facing a dramatic income decrease, the number of people confronted with food crises and extreme poverty increased significantly. Furthermore, the outbreak and prevalence of COVID-19 also increased regional inequalities in global food security, especially in Africa and the Middle East.

With its policy of "reform and opening up" over the past 40 years, China has become increasingly connected to the rest of the world and actively participates in global governance on issues related to agriculture and food security. For example, the country's Belt and Road Initiative has the potential to strengthen cooperation with Asia, Africa, and Latin America in agricultural investment, benefiting these regions in terms of economic growth, social development, food security, and improved nutrition. At the UN General Assembly in 2015, President of China Xi Jinping called for all countries to build a sound global eco-environment and pursue green, low-carbon, sustainable development. China committed to mitigating climate change and supporting other developing countries to do the same. At the Paris Conference on Climate Change in the same year, China called for the establishment of an equitable and effective global mechanism on climate change. Furthermore, the Chinese leader stated at the 75th UN General Assembly in September 2020 that the Paris Agreement on climate change charts the course for the world to transition to green, low-carbon development. China plans to increase its intended nationally determined contributions by adopting new policies and measures to achieve carbon neutrality before 2060. In November 2020, China announced its intention to host an international conference in 2021 on reducing food loss and waste. Such reductions can decrease the impacts of climate change by lowering greenhouse gas (GHG) emissions and can also alleviate pressure on land and water resources. Equally important, China has committed to hosting the 15th Conference of the Parties to the Convention on Biological Diversity (COP15), a meeting of environment ministers to deliberate how to protect biodiversity and develop a shared vision of living in harmony with nature, set to take place later in 2021. With China's increasing political will on these global development agendas, it is equally important for China to conduct research of global relevance and contribute to a common understanding of challenges and opportunities for agrifood systems transformation worldwide.

In this context, the China and Global Food Policy Report (CGFPR) is published to review Chinese policy developments and lessons related to its agricultural and food system, and to promote mutual understanding between China and the world. The report is jointly prepared by the Academy of Global Food Economics and Policy (AGFEP) at China Agricultural University, China Academy for Rural Development (CARD) at Zhejiang University, the Center for International Food and Agricultural Economics (CIFAE) at Nanjing Agricultural University, the Institute of Agricultural Economics and Development (IAED) of the Chinese Academy of Agricultural Science, and the East and Central Asia Office of the International Food Policy Research Institute (IFPRI).

The 2021 CGFPR focuses on the transformation of China's agrifood systems for the post-pandemic era, covering major topics including carbon neutrality, dietary transitions, green transformation of agriculture, e-commerce and the small-scale farmer economy, and challenges to agricultural trade. The report has been developed through a close collaboration of a number of research organizations applying multidisciplinary approaches to focus on China's practices but with a global lens. This report is designed to provide a scientific, rigorous, and cutting-edge decision-making and research reference for policymakers, researchers, and practitioners who are concerned with both the Chinese and global agrifood systems.

Changes in technologies, policies, institutions, and behaviors are key for transforming agrifood systems in order to achieve the multiple objectives of nutrition, health, sustainability, efficiency, resilience, and inclusiveness. As evidenced by the research findings reported in this CGFPR, agricultural GHG emissions in China can be mitigated to a large degree through technological innovations, reduction of food loss and waste, and transformation of dietary patterns, even while ensuring long-term food security. Among these measures, agricultural technology is the most effective mitigation measure, with agricultural GHG emissions in 2060 predicted to fall from current levels by 7–16 percentage points and 9–23 percentage points, respectively, through the use of improved crops and livestock.

In addition, transforming the dietary pattern of Chinese residents by following the recommendations of the Chinese Dietary Guidelines, EAT-Lancet, the Mediterranean diet, and the flexitarian diet could also contribute to a reduction in GHG emissions while ensuring residents' nutritional requirements. A shift toward more sustainable and healthy diets could reduce GHG emissions by 150 million to 200 million metric tons by 2030, a reduction of 18–25 percent. However, unsustainable agricultural production practices dependent on high input usage in China put a huge stress on ecosystems, creating a challenge to sustainable development and threatening nutrition and food security in the long run. As a result, long-term prevention and treatment of agricultural nonpoint-source pollution is essential to transforming the agrifood systems and should be prioritized to upgrade the country's agricultural production methods to circular, regenerative agriculture.

The development of e-commerce in China has helped small farm households connect with the larger market and enjoy growth dividends. Investment in infrastructure such as information and logistics facilities in rural areas is crucial for the development of rural e-commerce and is the foundation for developing an efficient and inclusive agrifood systems.

The COVID-19 pandemic poses great challenges to the global agrifood trade system. Specifically, growing trade protectionism sparked by the pandemic, increased trade restrictions, rising prices, and increased price volatility have added uncertainties to the global agricultural market and trade. Thus, China should not only focus on its domestic market but also proactively participate in the governance of global food and agriculture by boosting the coordination mechanism for global agricultural trade policies, supporting open trade and building mutual trust, stabilizing global agricultural markets, and strengthening the resilience of the agrifood systems. Through all these measures, food and nutrition security can be better guaranteed in China as well as around the world, especially in developing countries.

We expect that this first report will stimulate discussion and dialogue among Chinese and international scholars and policymakers. Going forward, we hope to produce a series of additional reports related to food systems transformation. We welcome your feedback, comments, and suggestions.

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Finally, we would like to thank Pamela Stedman-Edwards for her editorial assistance.

The novel coronavirus pneumonia sounds an alarm for future agrifood systems transformation.

Chapter 1

Rethinking Agrifood Systems for the Post-COVID World

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1.1 Introduction

The outbreak of the COVID-19 pandemic in early 2020 has caused a global public health crisis. It has also severely damaged the world's agrifood systems. Before the pandemic, agrifood systems were already vulnerable to many threats, including climate change, frequent extreme weather events, degradation of natural resources, economic slowdown, and regional conflicts (Fan, Wei, and Zhang 2020; Chen et al. 2020). The number of undernourished people worldwide had been increasing for five consecutive years to 690 million in 2019. More than 135 million people in 55 countries and territories were facing acute hunger, 144 million children younger than five were stunted, and 47 million children were wasted (FSIN 2020; FAO et al. 2020).

The pandemic has increased poverty for the first time in 22 years—about 100 million more people have fallen into extreme poverty (FAO 2021b). Moreover, an additional 130 million people are threatened by acute severe food insecurity during the pandemic (WFP 2020a).

A recent study has shown that the total number of children affected by stunting could increase by 2.8 million because of the pandemic (World Bank 2021). At the same time, the number of children experiencing wasting could increase by 6.7 million (UNICEF 2020; WFP 2020b). The livelihoods of vulnerable groups such as smallholder farmers, women, and migrant workers are threatened as they face losing jobs and incomes (FAO 2021b). Without effective measures, 840 million people in the world could face undernourishment and suffer from hunger by 2030, far from the "zero hunger" of the UN Sustainable Development Goals (IFPRI 2021b).

As vaccines are gradually deployed globally, the pandemic is expected to be under control to some extent by the end of 2021. But we should not simply recover from the crisis; it is time to rethink how to build back better to achieve green, low-carbon, healthier, inclusive, and more resilient food systems.

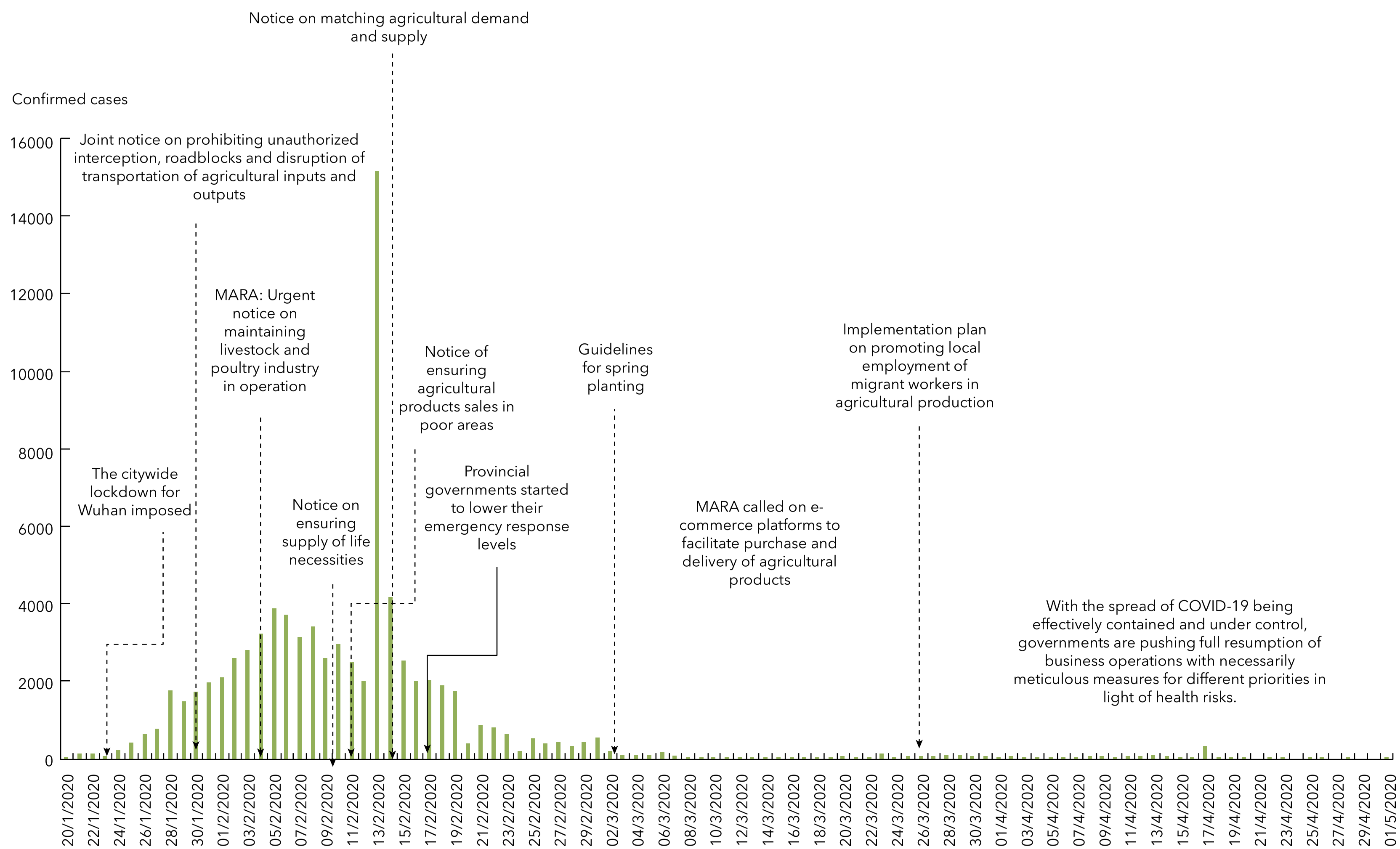
1.2 China's Measures for Ensuring Food Security during the COVID-19 Pandemic

China was the first country hit by COVID-19. Initially, the epidemic had a significant impact on the production of poultry products and vegetables, and on the employment of migrant workers (Fan, Wei, and Zhang 2020; Zhan and Chen 2021). Due to the restrictions affecting live poultry trading, enterprises could not sell chickens and ducks. Poultry had to be destroyed, and breeding enterprises and farmers were on the verge of bankruptcy. Furthermore, farmers had no incentive to restock. The number of chicks and ducklings fell by about 50 percent (Si, Zhang, and Fan 2020). Total poultry meat production declined by 19.5 percent, year over year, in the first quarter of 2020 (China, NBS 2020). Vegetable production was also affected. A survey by the China Center of Agricultural Policy at Peking University found that the production of 24 percent of vegetable farmers was affected during the outbreak, with an average reduction of one-third (Huang et al. 2020).

Rural migrant workers are a vast, unique, and vulnerable group, facing severe challenges and suffering the hardest hit as a result of the restrictive prevention and control policy measures during China's early lockdown phase. The number of migrant rural laborers in the country decreased by 30.6 percent, and their average monthly income dropped by 7.9 percent at the end of February 2020 (Zhang et al. 2020). In addition, catering, tourism, and other industries that employ large numbers of rural migrants were greatly affected, and some small and medium enterprises (SMEs) were facing bankruptcy.

Both the central and local governments in China have taken unprecedented steps to contain the pandemic. A Central Leadership Group for Epidemic Response and the Joint Prevention and Control Mechanism of the State Council were established immediately (Zhan and Chen 2021). China has been successful in containing the spread of the virus by imposing lockdowns early and then transitioning to a RT-PCR testing and green code strategy, accompanied by public information campaigns to encourage precautionary behavior (World Bank 2020). Food security has been a top priority in the Chinese government's response. There has been strong cooperation between government and various stakeholders from the private and public sectors to combat the pandemic and safeguard food security for the population (Fan et al. 2021). The government has also released a number of policy documents to ensure continued food production and supply (Figure 1.1).

Figure 1.1 Confirmed cases of COVID-19 and China's policies to ensure food security



Source: *Policy documents from various government websites.*

Note: MARA = Ministry of Agriculture and Rural Affairs.

1.2.1 Implementing the "Green Channel" Policy

In the first days of the pandemic, prevention and control measures effectively blocked the transport of agricultural products and agricultural inputs. To resolve this issue, China opened a "green channel" for fresh agricultural products. On January 30, 2020, one week after the lockdown in Wuhan, the Ministry of Agriculture and Rural Affairs (MARA), the Ministry of Transport, and the Ministry of Public Security jointly issued an emergency notice strictly prohibiting unauthorized interceptions, roadblocks, and other disruptions of the transport of agricultural inputs and outputs. To accelerate restoration of production and marketing in the livestock sector, on February 4, 2020, MARA issued another emergency notice addressing practical difficulties and targeting shortages of animal feed and products. It called for ensuring smooth delivery of animal feed, breeding animals, meat, dairy products, and seafood, and for providing incentive measures to support livestock farming (Zhan and Chen 2021). At the same time, the State Council called on government ministries for better coordination and emphasized the responsibility of local governors. The "green channel" has played an important role in ensuring the smooth transportation of important agricultural products and inputs.

1.2.2 Promoting Information and Communication Technology

In early February 2020, when lockdown measures had increased the demand for home delivery of groceries, e-commerce companies came up with an in-app feature for contactless delivery, allowing a courier to leave a parcel at a convenient spot for a customer to pick up, thus eliminating person-to-person contact. E-commerce and delivery companies played a key logistical role especially in food delivery. Methods such as contactless delivery and community group purchasing effectively solved the issue of the surge in demand for fresh food delivery due to the lockdown measures and reduced the potential risk of infection from crowded markets (Fan et al. 2021; Fei, Ni, and Santini 2020; Zhan and Chen 2021).

On February 11, 2020, the Ministry of Commerce issued a notice urging all regions to take comprehensive measures, especially to make full use of information technology to coordinate and organize chain supermarkets, large wholesale markets, and others to fulfill accurate online procurement and sales with agricultural production and operation entities, thus solving the problem of "difficult selling" of agricultural products. Other measures included the establishment of a national agricultural and rural data service platform to support responses to the COVID-19 pandemic, strengthening the monitoring of agricultural product prices and market supply and demand, and continuing to support the interconnection of farmers and businesses to improve agricultural product supply chains (China, Ministry of Commerce 2020).

1.2.3 Providing Financial Support to Agricultural Enterprises

On February 14, 2020, to stabilize agricultural production and ensure the supply of agricultural products, the Ministry of Finance and MARA jointly issued a notice to reduce and in some cases eliminate expenses related to agricultural credit guarantees; allocate agricultural production disaster relief funds; extend tax and fee reduction policies to increase funding for support to family farms and farmer cooperatives for refrigeration and storage of agricultural products; and to implement financial measures such as supporting large-scale vegetable production and processing entities to increase their production and supply capacity (China, Ministry of Finance 2020).

Entering March 2020, as the spring planting season was approaching, MARA issued several notices to support spring planting preparations, requiring farmers to work in the fields in different time slots for their personal protection, as well as encouraging returning migrant workers to participate in agricultural production on site and participate in online agricultural production technical training and service guidance. The notices emphasized that even as people adopted district-level and differentiated measures for epidemic prevention and control, it was important to optimize approval services, innovate approval methods, and help agricultural enterprises resume work and production as soon as possible (China, MARA 2020).

By the beginning of April 2020, China had gradually opened up, and economic and social life had returned to normal. Although the epidemic showed a resurgence in some provinces in June and December 2020, effective control of the epidemic nationwide was not affected. Therefore, China became the only major economy in the world to achieve positive economic growth in 2020. GDP in 2020 was 101.6 trillion renminbi (RMB), an increase of 2.3 percent over the previous year, of which the added value of the primary industry was RMB 7.8 trillion, an increase of 3.0 percent, and the annual grain output was 670 million metric tons, an increase of 0.9 percent (China, NBS 2021). The grain market and comprehensive production capacity have redeveloped steadily. In short, China's agrifood systems has proved quite resilient.

1.2.4 Measures to End Poverty and Protect Disadvantaged Groups

In 2020, the COVID-19 pandemic led to a sharp decline in economic growth. Nevertheless, China achieved its goal of eradicating absolute poverty, making a major contribution to global poverty reduction, and reaching the zero poverty goal of the UN 2030 Agenda for Sustainable Development 10 years ahead of schedule (Xi 2021). In addition, China has established a set of effective policies, measures, working mechanisms, and institutional systems for poverty reduction and governance, including guaranteeing financial investment in special poverty alleviation funds, encouraging economically developed and underdeveloped areas to carry out cooperation and paired assistance for poverty alleviation, adhering to a policy of well-targeted poverty alleviation, stimulating the self-motivation of the poor to change their living conditions, and implementing strict assessment and evaluation mechanisms.

1.3 COVID-19's Impacts on Global Agrifood Systems and International Policy Responses

Even before COVID-19, there was an urgent call for an inclusive food system to address food security and nutrition. A report by the Food and Agriculture Organization of the United Nations (FAO) and other international organizations (FAO et al. 2020) estimated that almost 690 million people, or 8.9 percent of the world population, went hungry in 2019—up by nearly 60 million in five years. The number of people affected by severe food insecurity, another measure that approximates hunger, showed a similar upward trend. In terms of regional distribution, Asia was home to more than half of the undernourished people in the world—an estimated 381 million people in 2019. More than 250 million undernourished people lived in Africa, which is 19.1 percent of the continent's population, and that number is growing faster than in any other region of the world. In Latin America and the Caribbean, the prevalence of undernourishment was 7.4 percent in 2019, which translates to almost 48 million people. COVID-19 is expected to worsen the prospects for food security and nutrition. A preliminary assessment suggested that the pandemic may add between 83 and 132 million people to the total number of undernourished in the world in 2020 (FAO et al. 2020). These estimates demonstrate the serious challenges global policymakers face in transforming agrifood systems to put us on track. For countries still struggling to curb the spread of the virus, COVID-19 will exacerbate the challenges of hunger and poverty, and continuing or reintroduced movement restrictions will create additional uncertainty.

According to the 2021 Global Food Policy Report of the International Food Policy Research Institute (IFPRI), the pandemic and measures adopted to curb it have impacted agrifood systems from the global to the local level (IFPRI 2021b). Movement restrictions and partial border and market closures implemented around the world affected food supply chain logistics, disrupting the flow of agricultural inputs and outputs as well as agriculture-related services. The pandemic also caused widespread loss of livelihoods and incomes, threatening the food security, health, and nutrition of poor and vulnerable people around the world.

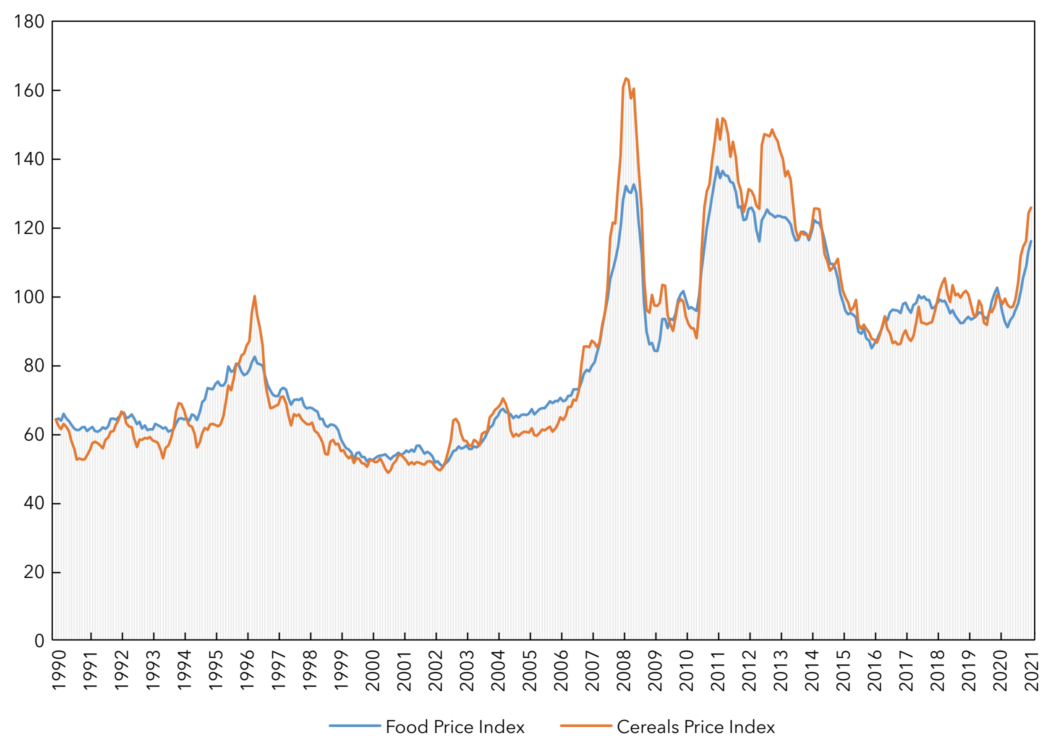
The pandemic's impacts on food security have been induced primarily by falling incomes and reduced working hours. IFPRI research estimated that the number of poor people globally was likely to increase by about 150 million in 2020, 20 percent above pre-pandemic poverty levels (Laborde, Martin, and Vos 2020). Poor households facing income losses will be forced to reduce their food expenditures, which in turn will worsen food insecurity. Such impacts can be immediate for smallholder farmers and migrant workers, who are particularly vulnerable to pandemic-related income losses (Chen et al. 2020; Si, Zhang, and Fan 2020). Remittance income was also particularly affected by international travel restrictions and the full or partial closure of businesses and industries. Migrants and their families have lost purchasing power due to the reduced flow of remittances, which are their primary income sources and mostly used to purchase food.

At present, global agricultural production has been less affected by the global downturn (AMIS 2020), but food supply chains have been disrupted by labor restrictions and falling demand, although impacts have varied along supply chains and between countries and commodities. Logistics disruptions have reduced the availability of workers and the flow of seeds, animal feeds, and fertilizers for farm production, with the most severe impacts on labor-intensive products such as fruits and vegetables. Market and border closures implemented around the world to contain the pandemic have restricted consumers' physical access to sources of nutritious food, as well as affecting food supply chain logistics and disrupting the flow of agricultural products and agriculture-related services across countries. These disruptions have large impacts for import- and export-dependent countries and may drive up food prices.

According to the FAO, global food commodity prices rose for the ninth consecutive month in February 2021. The FAO Food Price Index, which tracks monthly changes in the international prices of commonly traded food commodities, averaged 116 points that month, reaching its highest level since June 2014 (FAO 2021b). This increase is partly driven by production shortfalls; for example, abnormal dryness continues to undermine the production outlook for vegetable oils in several major production areas. Another contributing factor is reduced export supplies, largely because some countries initially implemented trade restrictions to increase their food reserves due to the increasing uncertainties. Increased trade costs and government restrictions on cross-border movement of food have significant potential to increase price volatility through slower and more complex logistics that increase costs. In addition, because some developed countries have increased their money supply to support economic growth in response to the pandemic slow-down, a mix of currency depreciation and rising prices of commodities such as petroleum and chemical products has caused food prices to rise further (Hai, Liang, and Sheng 2021).

Increasing food prices and declining incomes may

Figure 1.2 Monthly changes in the FAO food and cereals price indexes worldwide, March 1990 to March 2021



Source: *Authors' construction using data from FAO (2021a, 2021b).*

have negative impacts on diet quality and diversity, thereby increasing the risk of malnutrition. Poor households facing income losses will be forced to reduce their food expenditures by replacing expensive foods like animal sourced foods and vegetables with less nutritious options. The dangerous decline in dietary quality could increase the risk of both undernutrition and overweight and obesity.

The pandemic magnifies differences and inequalities between regions and countries in terms of food security. For some countries, economic recovery, better nutrition, large social protection networks, and effective governance eased the pressure on their food systems in the short term. For example, in countries such as China, sufficient food stocks, enough to support domestic consumption for about one year, helped to stabilize food availability and market prices. However, for many developing countries, including some in Africa and the Middle East, food security status is likely to deteriorate further due to disruptions to food supply and price volatilities. A report jointly issued by the World Food Programme (WFP) and the FAO warned that more than 34 million people worldwide are already grappling with emergency levels of acute hunger—hunger classified as Integrated Food Security Phase Classification (IPC) level 4—meaning they are one step away from starvation. More than 20 countries will experience soaring rates of acute hunger in the coming months in the absence of immediate and scaled-up assistance. Of these countries, northern Nigeria, South Sudan, and Yemen are facing the highest catastrophic levels of acute hunger (WFP and FAO 2021). Conflict or other violence is a factor that contributes to vicious cycles of increasing inequality and food insecurity. This calls for strengthening international cooperation toward achieving global food security and sustainable development in the future.

Since the pandemic's onset, governments have adopted thousands of response policies, from increasing spending on health systems and vastly expanding social protection to supporting private businesses (IFPRI 2021a). Social safety nets such as Ethiopia's flagship Productive Safety Net Program and Bangladesh's Vulnerable Group Feeding offer a vital cushion for families hit by the health and economic crises. In Ethiopia, for example, households that experienced problems in satisfying their food needs initially increased by 11.7 percentage points during the pandemic, but participants in the long-running Productive Safety Net Program were shielded from most of the negative effects (Abay et al. 2020). These experiences have highlighted the imperative of increasing the world's investments in social protection systems.

To mitigate the negative impacts on farmer incomes, a variety of financial and fiscal tools have been employed. These include allowing farmers to defer loan repayments for a specific period of time (Ethiopia, India, Nigeria, Pakistan), issuing new loans to farmers (China, Kyrgyzstan, Myanmar, Nigeria, Sri Lanka), and allowing a temporary moratorium or exemption for agricultural land taxes (Egypt, Kazakhstan, Uzbekistan) (Kennedy and Resnick 2020). Other efforts have focused on the informal sector; for example, Burkina Faso announced a US$9 million fund for informal-sector workers, especially women, to relaunch their sales of fruits and vegetables. Such actions showcase ways to support small actors who are critical to urban food systems. Data from IFPRI's COVID-19 Policy Response Portal also show that many countries, such as Egypt, Mali, and Rwanda, have adopted market regulation and price-fixing policies, especially for cereals (IFPRI 2021a). Because they focus on staples, these price controls have little impact in terms of supporting quality of diets, including healthier and more diverse food options.

As these responses continue to evolve, actions targeting the same problem vary widely in approach and impact. For instance, to maintain domestic food supply, some countries have provided direct support to farmers, some have imposed food export bans, and some have adopted both. Early in the pandemic, at least 27 countries introduced some form of trade restrictions (ITC 2021). Although many of these restrictions were removed or loosened in the second half of 2020, some remained in place as we prepared this report. For example, Russia's agriculture ministry is limiting the amount of grain that can be exported from February 15 until June 30, 2021. India also continues to implement export controls in 2021. These restrictions, even if temporary, seem entirely unnecessary and may threaten access to food, especially for low-income and import-dependent countries. The FAO, together with other international organizations such as the WFP, the International Fund for Agricultural Development, the World Health Organization, the World

Trade Organization (WTO), and the World Bank, have underlined both the need to keep value chains in food and agriculture functioning and the detrimental effect export restrictions could have on the global market (FAO et al., 2020). During the 2007–2008 food price crisis, panic-driven export bans and rapid escalation in food stock procurement through imports exacerbated price volatility. The results of these measures proved extremely damaging for low income, food import–dependent countries, as well as for the efforts of humanitarian organizations to procure supplies.

Global policymakers have responded to the call. During the G20 Agriculture Ministers' Meeting on April 21, 2020, the ministers committed to "guard against any unjustified restrictive measures that could lead to excessive food price volatility in international markets and threaten the food security and nutrition of large proportions of the world population, especially the most vulnerable living in environments of low food security" (G20 Information Centre 2021). They also agreed to implement measures that are transparent and temporary and that do not result in disruptions to global food supply chains, in line with WTO rules. Furthermore, the European Union and 21 other WTO members pledged to ensure well functioning global food supply chains and committed to open and predictable trade in agricultural and food products during the pandemic (G20 Information Centre 2021).

1.4 Rethinking Agrifood Systems for the Post-COVID Era

Current global agrifood systems are unsustainable and unhealthy. More than 3 billion people cannot afford a healthy diet (FAO et al. 2020). The COVID-19 pandemic has severely disrupted agrifood systems, highlighting their fragility. As vaccines are gradually deployed globally, the COVID-19 pandemic is expected to be controlled to a certain extent in 2021. But we should not simply recover from the crisis; it is time to rethink how to build back with better agrifood systems to achieve a green and low-carbon transformation, how to adapt to rapid digitalization while addressing the interests of vulnerable groups, and how to unblock international trade in the face of counter-globalization during the post-COVID era.

Meanwhile, governance issues related to food security and nutrition have become increasingly complex. This calls for strengthening the governance of the global agrifood systems. The United Nations will convene a Food Systems Summit in 2021, calling on governments, businesses, and citizens to take actions together to promote the transformation of agrifood systems, responding to the UN Secretary-General's call to "rebuild better" after the coronavirus pandemic and advance the 2030 Agenda for Sustainable Development.

Based on the research findings in Chapters 2 to 6, this report proposes the following seven major measures to reshape agrifood systems for the post COVID-19 era. Although these measures are largely drawn from Chinese experience, they have international and global relevance.

(1) Reprioritize agricultural research and development for multiple-win technological innovations. To cope with future multiple-risk challenges such as climate change, extreme weather, and natural resource degradation, agrifood systems must shift from focusing only on increasing production, as in the past, to on multiple-win technological innovations. First is to develop green and low-carbon technologies that reduce the carbon footprint of agrifood systems while also improving production efficiency and yield. The research in Chapter 2 shows that improvement of agricultural technology is the most effective climate-change mitigation measure in the agrifood sector; technological improvements in crops and livestock can reduce agricultural greenhouse gas (GHG) emissions in 2060 by 7–16 percentage points and 9–23 percentage points, respectively. Therefore, it is critical to change the priorities of agricultural science and technology innovations; create a conducive environment for disruptive, integrated, and comprehensive technological innovation; and strengthen the promotion and application of low-carbon, green agricultural technologies to reduce emissions from agrifood systems and respond to climate change. The second is to give priority to the development of sustainable, intensive, and nutrition-focused technologies, such as breeding high-yield, high-nutrient crop varieties with biofortification technology, and to adopt clean agricultural production technologies, thus improving the nutrition and health of residents while also taking into account environmental sustainability.

(2) Reform agricultural subsidies and innovate fiscal policy support. Inappropriate agricultural subsidy policies aggravate the pressure of agrifood systems on resources and the environment and affect human nutrition and health negatively. Therefore, to transform agrifood systems to shift toward supporting nutrition, health, and environmental protection, policy approaches must be reformed. First, measures should include increasing financial support for nutritious, healthy, and sustainable food supply; imposing taxes on unhealthy and unsustainable foods; and using part of the funds from fiscal stimulus policies to support the transformation of agrifood systems. Second, an improved ecological compensation mechanism should be established. Chapter 4 of this report points out that upstream and downstream financial transfer payment arrangements that are built into interprovincial ecological compensation pilot projects in Zhejiang and Anhui have a significant effect on maintaining the water quality of the Xin'an River and tackling the eutrophication challenge of Qiandao Lake in Zhejiang.

(3) Facilitate institutional innovations to build efficient and inclusive food value chains. Institutional innovation helps create an enabling environment for building efficient, safe, nutritious, inclusive, and sustainable food value chains, thus accelerating the transformation of agrifood systems. For this to happen, first, it is critical to establish a cross-departmental (or ministerial) coordination mechanism for agricultural production, the ecological environment, food safety and nutrition, and financial support to work together; and incorporate indicators of greenness, health, and nutrition into the performance appraisal system of government institutions at all levels. Second, it is important to expand social security; explore the establishment of a social security system that integrates urban and rural areas; improve health, nutrition, and education of vulnerable groups, especially smallholder farmers; and help smallholder farmers improve their production efficiency or increase their opportunities for nonagricultural employment and income. Third, it is crucial to empower women in agriculture. Women play an intermediary role in the pathway from agriculture to nutrition. Improving the nutrition conditions and health status of mothers, increasing credit support for women, offering women cash transfers, and training them through nutrition education programs can effectively improve family dietary diversity and reduce children's malnutrition.

(4) Increase investment in rural information and communication technology. China's e-commerce platforms have played an important role during the COVID-19 pandemic in ensuring the normal supply of food and reducing the risk of potential infection caused by crowds. As a breakthrough technology, e-commerce is an important means to achieving the digitalization of agrifood systems. It can also create new job opportunities and help smallholder farmers connect with large markets. The research presented in Chapter 5 of this report shows that e-commerce can help smallholder farmers enter the global value chain by reducing the information and transaction costs of entering the market. Measures such as strengthening the construction of rural information and communication infrastructure and establishing a rural e-commerce knowledge and skills training mechanism for farmers will help to give full play to the role of e-commerce in the transformation of smallholder agriculture as well as agrifood systems.

(5) Maintain free trade and enhance agrifood systems resilience. As the world is undergoing rapid changes on a scale unseen in a century, the concept of a community with a shared future is widely supported. However, the international environment is becoming complex, with instability and uncertainty increasing significantly. The world has entered a period of turbulence and adjustment, and economic globalization has encountered a countercurrent. As pointed out in Chapter 6 of this report, "The COVID-19 pandemic has brought great challenges to the global agrifood systems and agricultural trade, especially the rise of trade protectionism, the increase of trade restrictions, and the rise and fluctuation of agricultural product prices, all of which have greatly increased the uncertainty of the global agricultural products market and trade prospects." Faced with an uncertain external environment, trade restrictions will lead to tighter markets and aggravate the crisis. It is important than ever to eliminate distortionary and harmful trade policies, maintain unimpeded trade between countries, strengthen global agricultural trade policy coordination mechanisms, improve mutual trust in agricultural trade openness and food safety, and maintain the stability of the global agricultural products market, thus ensuring the food and nutrition security of all countries in the world, and especially developing countries.

(6) Respect nature and protect wildlife habitats. Respecting nature and natural environmental processes is an important foundation for promoting the transformation of agrifood systems to achieve sustainable development. The research in Chapter 4 of this report shows that the "high input and high output" agricultural production method is not sustainable because it places a heavy burden on the ecological environment and severely impedes the sustainable development. Going forward, long-term prevention and treatment of agricultural nonpoint-source pollution must be taken as the starting point to promote the upgrading of agricultural production methods to "circular agriculture" and "regenerative agriculture." In addition, in the past few decades, the interaction between humans and wild animals has increased dramatically, greatly increasing health risks. Therefore, the expansion of agriculture and other activities into natural forest habitats should be stopped; laws, regulations, and policies for the protection of wild animals and plants should be formulated; and the implementation of these laws, regulations, and policies should be monitored and evaluated. These practices are essential for restoring biodiversity, protecting the carbon-sink capacity of forests, and preventing and controlling disease sources to reduce the risk of future epidemics.

(7) Guide residents' behavior change for a win-win for human and planetary health. Residents' diets and behaviors will affect not only their own nutrition and health but also climate change and environmental sustainability. Therefore, consumers must be guided towards healthy and sustainable diets, including increasing their consumption of whole grains, fruits, and beans and reducing excessive consumption of refined grains and red meat. The research in Chapter 3 of this report shows that shifting the Chinese dietary pattern to be more in line with the recommendations of the Chinese Dietary Guidelines, the EAT-Lancet diet, the Mediterranean diet, and the flexitarian diet would reduce agricultural GHG emissions significantly. Simulation results show that changes in Chinese dietary patterns between now and 2030 could reduce agricultural GHG emissions by 146 million to 202 million metric tons, that is, by 18–25 percent, compared with the benchmark scenario. In addition, reducing food loss and waste is also an important focus for guiding residents' behavior change by promoting a moderate diet, and encouraging people to cherish food and eliminate "waste on the tip of the tongue" (that is, food discarded from the table) in order to reduce both GHG emissions and pressure on water and soil resources. Chapter 2 runs a food loss and waste reduction simulation showing that, compared with the baseline, agricultural GHG emissions can be reduced by 2.0–5.6 percent and 4.0–7.0 percent, respectively, by 2030 and 2060.

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Chapter 2

Transforming Agrifood Systems to Achieve China's 2060 Carbon Neutrality Goal

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Key Findings

● During recent decades, agriculture has developed rapidly in China, ensuring food security and enriching residents' diets. At the same time, greenhouse gas (GHG) emissions from the country's agrifood systems have increased by only 16 percent in the past two decades and fell for two consecutive years in 2017 and 2018. The proportion of GHG emissions in the country's food systems to the total GHG emissions dropped from 18.7 percent in 1997 to 8.2 percent in 2018.

● GHG emissions from the Chinese agrifood systems should not be ignored, neverthless. In 2018, GHG emissions from agrifood systems was still as high as 1.09 billion tons CO_2eq[1].

● While ensuring food security as the national top priority, measures such as improving agricultural technologies, reducing food loss and waste, and shifting dietary patterns must be adopted to reduce GHG emissions from agrifood systems. Improvements in agricultural technologies are the most effective stand-alone measures, but the combined three measures above have the most significant effect on GHG emission reduction. Projections show that the combined three measures can redcue GHG emissions by 47 percent in 2060 from the 2020 level.

● Land use, land use change, and forestry (LULUCF) play a key role as a carbon sink. The carbon sequestration from LULUCF was around 1.1 billion tons CO_2eq in 2014. It can increase to 1.6 billion tons of CO_2eq per year in 2060, thus LULUCF could completely offset GHG emissions from agrifood systems and still have a surplus capacity to sequester nearly 1 billion additional tons of CO_2eq per year, well above the current level of net sequestration,contributing to overall carbon neutrality of China.

[1]Tons refers to metric tons throughout the chapter.

Recommendations

- Comprehensive emission reduction strategies and precise pathways for whole agrifood systems should be formulated while maintaing grain production of more than 650 million tons per year as the top national food security priority. From both supply and consumption sides, specific and more precise measures should be developed for all commodity chains to promote the transformation of agrifood systems to achieve the goals of reducing emissions and increasing the capacity of ecosystems as carbon sinks.
- Optimizing agricultural subsidy policies, increasing investment in agricultural science and technology, and re-prioritizing science and technology innovations should be urgently implemented. A favorable environment must be created for promoting disruptive, integrated and comprehensive technological innovations. In particular, the development and extension of low-carbon green technologies should be strengthened.
- Consumers should be incentivized to become active participants in carbon neutrality actions by inducing their behaviors that reduce food waste and change dietary patterns, for example, reasonably reducing meat consumption for their own health as well as for the environment.
- Land use planning and control should be strengthened in conformity with the red line of 120 million ha (1.8 billion Chinese mu) of arable land, so that the land saved through technological improvement, reduction in food loss and waste, and changes in dietary patterns can be converted into grassland, woodland, and wetland in line with local conditions, increasing the carbon sink capacity of the ecosystem.
- The construction of the carbon market should be accelerated, and farmers should be encouraged to participate, both to reduce their GHG emissions and to increase their income through compensation.

2.1 Introduction

According to the special report Global Warming of 1.5°C issued by the Intergovernmental Panel on Climate Change (IPCC 2018), human being will pay a huge price in terms of the world's ecosystems, food security, water supply, human security, health, and well-being, as well as economic growth, if we fail now to go all out for achieving the 1.5°C temperature control goal. Upholding the concept of a community with a shared future for mankind, the Chinese government is actively participating in global climate governance and utilizing effective measures to formulate emission reduction pathways and push forward a green and low-carbon transformation to safeguard our planet. In September 2020 at the UN General Assembly, the Chinese government pledged to scale up its Intended Nationally Determined Contributions by adopting more vigorous policies and measures to reach the country's peak carbon dioxide emissions before 2030 and achieve carbon neutrality before 2060. In December 2020 at the Climate Ambition Summit, the Chinese government further made specific plans for carbon neutrality and the carbon peak, aiming to reduce CO_2 emissions per unit of GDP by 2030 by more than 65 percent compared with the 2005 level; increase the proportion of non-fossil fuels in primary energy consumption to about 25 percent; increase the forest stock by 6 billion m^3 compared with 2005; and increase the total installed capacity of wind power and solar power to more than 1.2 billion kilowatts.

Many studies that focus on China's emission reduction pathways point out that China is facing various challenges in achieving its goal of carbon neutrality. He and colleagues (2020) showed that China can achieve carbon peak by 2025, reduce CO_2 emissions to 1.72 billion tons per year by 2050, and increase the carbon sink capacity of agroforestry and land use by 780 million tons per year, using a simulation scenario constraining planetary temperature rise to no more than 1.5°C by 2050. They also projected that 880 million tons of CO_2 can be captured each year thanks to carbon-capture technology, achieving almost net zero CO_2 emissions, with 1.33 billion tons of non-CO_2 GHG emissions per year remaining. However, Yu and colleagues (2021) suggest that the 2060 carbon neutrality goal set by the Chinese government cannot be achieved by relying solely on a low-carbon transition of the energy system plus carbon-capture technology, because 0.3 billion to 3.1 billion tons of carbon per year would remain to be sequestrated by forests and oceans.

To achieve the goal of carbon neutrality, emission reductions in agrifood systems must be considered. Globally, GHG emissions from agrifood systems accounted for 21–37 percent of overall GHG emissions from 2007 to 2018, of which agriculture, land use, and the preproduction and postproduction agriculture value chain accounted for 9–14 percent, 5–14 percent, and 5–10 percent, respectively (Rosenzweig et al. 2020). Poore and Nemecek (2018) calculated that GHG emissions generated by the overall food supply chain account for 26 percent of total human GHG emissions, and Crippa and colleagues (2021) asserted that GHG emissions from the global food system account for one-third of total GHG emissions. According to the Food and Agriculture Organization of the United Nations (FAO), GHG emissions from agriculture in China accounted for 11–12 percent of the world's total agricultural emissions. GHG emissions from agricultural activities in China were 710 million tons of CO_2eq in 2018, reflecting an increase of 18 percent compared with 1990 (FAO 2021). With economic development, agricultural mechanization has increased significantly, and the agriculture-related industry value chain has lengthened. Simultaneously, energy consumption and emissions have also significantly increased in the food processing, warehousing, transportation, wholesaling and retailing, and catering.

Agriculture is of particular importance in nitrous oxide (N_2O) and methane (CH_4) emissions, but it also shows great potential for reducing emissions and increasing carbon sinks. CH_4 and N_2O emissions from agricultural production activities in China accounted for more than 40 percent and 50 percent of national CH_4 and N_2O emissions, respectively (PRC 2018a). Ma and colleagues (2019) found that GHG emissions decreased by 7–55 percent, compared with the baseline scenario, in their three simulated scenarios (enhancing production, reducing food loss and waste, and importing more food).

More importantly, China's forest ecosystem is a principal factor in carbon sequestration, contributing roughly 80 percent of the country's total (Fang et al. 2018). Wang and others (2020) found that the average annual CO_2 sequestration of terrestrial ecosystems from 2010 to 2016 reached 1.11 billion tons, accounting for roughly 45 percent of anthropogenic carbon emissions during the same period, largely thanks to China's investment in natural forest vegetation restoration and plantation cultivation over the past four decades. According to a projection from Energy Foundation China, carbon sinks contributed by land use, land use change, and forestry (LULUCF) will reach approximately 1.6 billion tons of CO_2eq per year in 2050 (Energy Foundation China 2020).

Because of the priority placed on reducing emissions in agrifood systems, comprehensive study of the system's carbon emissions status, carbon sink potential, and emission reduction pathways is required to provide a scientific basis for transforming agrifood systems to help achieve the 2060 carbon neutrality goal. This chapter incorporates food processing industries, transportation and storage, wholesale and retail, catering services, and intermediate inputs related to agriculture into a unified analysis framework from the perspective of the industrial chain. In this way, GHG emissions from agrifood systems can be comprehensively evaluated by analyzing GHG emissions from the various agricultural activities and estimating GHG emissions related to energy consumption by agrifood systems. Furthermore, we explore possible pathways for achieving the 2060 carbon neutrality goal, such as improving agricultural emission reduction technologies, reducing food loss and waste, shifting dietary patterns, enhancing energy efficiency, and optimizing the energy structure. Based on simulations of the emission reduction effect of various scenarios, we propose measures and approaches to accelerate the transformation of agrifood systems for achieing carbon neutrality while ensuirng national food security.

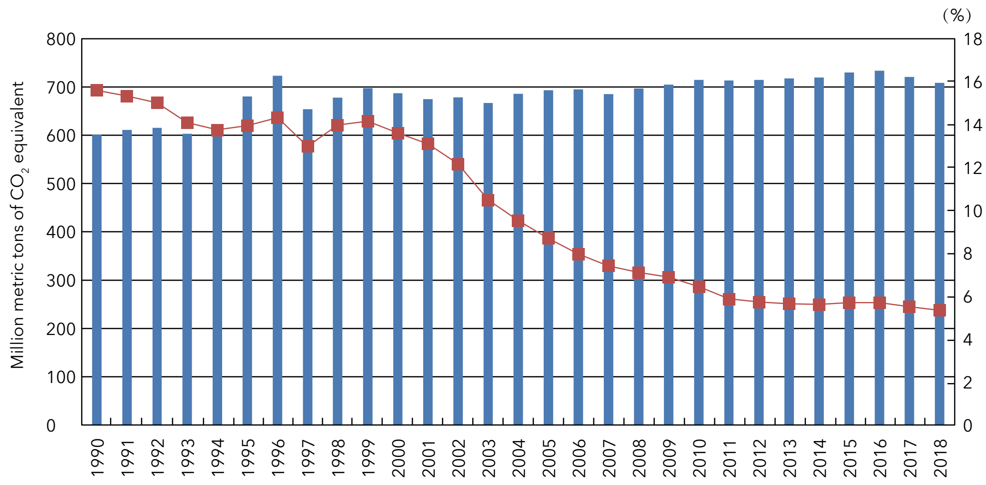
2.2 Greenhouse Gas Emissions from the Agrifood Systems in China

2.2.1 Greenhouse Gas Emissions from Agricultural Activities

Based on FAO data (FAO 2021), GHG emissions of CO_2eq in China increased from 3.85 billion tons in 1990 to 13.23 billion tons[2] in 2018, an increase of 2.4 times, or an average annual growth rate of 4.6 percent. This growth rate is significantly higher than the world average, with China's share of worldwide GHG emissions increasing from 9.5 percent in 1990 to 23.0 percent in 2018. GHG emissions from agriculture in China increased from 600 million tons in 1990 to 710 million tons in 2018, with 18 percent increase in 28 years. Yet the proportion of agriculture-source GHG emissions in total GHG emissions dropped from 15.6 percent to 5.4 percent during the same period, as shown in Figure 2.1. In addition, the use of synthetic fertilizers has experienced

[2]Carbon emissions data in this chapter are all CO_2eq per year; data for 2018 are calculated in the same way as the FAO data for previous years.

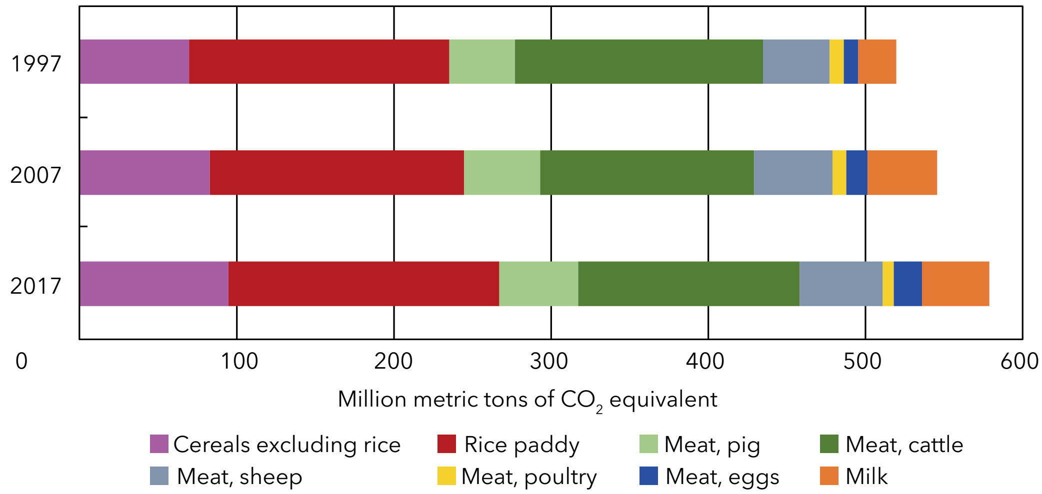
Figure 2.1 **China's greenhouse gas emissions from agricultural activities and its share in the country's total emissions, 1990–2018**



Source: *FAO database (FAO,2021).*

Note: *Data for 2018 are calculated in accordance with the historical data of FAO.*

Figure 2.2 Greenhouse gas emissions from agricultural activities in China, 1997–2017, by commodity



Source: *FAO (2021).*

negative growth since 2016 thanks to the implementation of the Action Plan for Zero Growth of Fertilizer Use by 2020. Thus, GHG emissions from agricultural activities have declined for two consecutive years since 2017, dropping by approximately 4.0 percent in 2018.

GHG emissions of agricultural activities are primarily from farmland emissions, animal enteric fermentation, rice cultivation, manure management, and agricultural residuals, and they are dominated by N_2O and CH_4. Agricultural land emissions and enteric fermentation account for more than 60 percent of GHG emissions from agricultural activities in China. Rice and beef are the primary sources of the country's GHG emissions. In 2017, GHG emissions from rice and beef production reached 170 million tons and 100 million tons, respectively, accounting for 26.4 percent and 16.7 percent of the total agricultural GHG emissions in that year, as shown in Figure 2.2.

2.2.2 Greenhouse Gas Emissions from Land Use, Land Use Change, and Forestry

LULUCF is a considerably cost-effective approach for reducing GHGs through absorbing them in the atmosphere or reducing their emission. According to data from China's Third National Communication on Climate Change (PRC 2018b), net CO_2eq absorption of LULUCF increased from 990 million tons in 2010 to 1.11 billion tons in 2014, an increase of 120 million tons due to the increase in China's forest reserves. Forestland and forest products achieved 840 million tons and 110 million tons, respectively, of carbon sequestration in 2014, accounting for 85 percent of the total net carbon sequestration, whereas farmland, grassland, and wetland achieved 50 million tons, 110 million tons, and 8 million tons of carbon sequestration, respectively, as shown in Table 2.1.

Table 2.1 Net greenhouse gas emissions from land use, land use change, and forestry, 2010 and 2014

Unit:100 million tons

Net GHG emission/sequestration	2010	2014
Forest	-7.79	-8.40
Forest products	-0.96	-1.11
Farmland	-0.66	-0.49
Grassland	-0.45	-1.09
Wetland	-0.09	-0.08
Construction land	0.02	0.03
Total	-9.93	-11.15

Source: *PRC (2018a, 2018b).*

2.2.3 Greenhouse Gas Emissions from Energy Consumption in Agrifood Systems

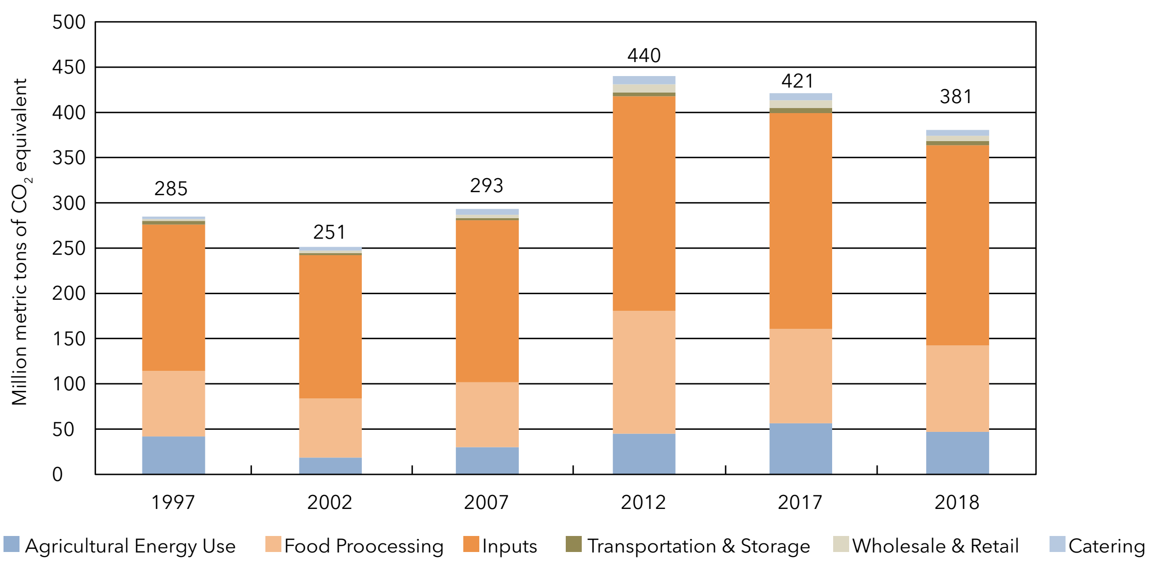
Agriculture's preproduction and posthavest activities also consume energy and generate GHG emissions, in addition to direct GHG emissions from agricultural production activities. This section first presents systematic estimates of GHG emissions from energy consumption in agrifood systems, including agriculture, food processing, and related wholesale and retail, transportation and storage, catering, and intermediate inputs industries. More precisely, the energy consumption and carbon emission coefficients of subsectors are estimated to measure the CO_2 emissions of various sectors. Second, we calculate the proportions of energy consumption by transportation and storage, wholesale and retail, catering, and intermediate inputs in various sectors using the China input-output table (NBS 2021). Next, carbon emissions of related sectors associated with agriculture and the food processing industry are estimated, together with CO_2 emissions of various sectors. Finally, carbon emissions from all sectors of agrifood systems are gathered to estimate the energy-related GHG emissions total agrifood systems, as shown in Figure 2.3. GHG emissions due to energy consumption in agrifood systems increased comparatively fast before 2012, growing from 280 million tons in 1997 to 440 million tons in 2012, an increase of 54 percent. GHG emissions from energy consumption declined to 420 million tons in 2017 and 380 million tons in 2018 because of improved energy efficiency and improved energy composition. GHG emissions from energy use in agriculture and food processing industries are 47 million tons and 95 million tons, respectively, accounting for 12 percent and 25 percent of the energy-related GHG emissions of agrifood systems. GHG emissions from transportation, wholesale and retail, and catering are on a smaller scale, together accounting for 4.5 percent of the GHG emissions from the energy use of agrifood systems. In addition, large GHG emissions (220 million tons) are witnessed from the intermediate inputs used by the agriculture and food processing industries, accounting for 58 percent of GHG emissions from energy use in agrifood systems.

2.2.4 Greenhouse Gas Emissions from Agri-food Systems and from Land Use, Land Use Change, and Forestry

GHG emissions from agrifood systems consist of those generated by agricultural land use, agricultural activities (excluding energy use), and energy use in agrifood systems. A trend of first increasing and then decreasing is observed in GHG emissions from agrifood systems, as shown in Figure 2.4. Specificly, GHG emissions from agrifood systems increased from 940 million tons in 1997 to 1.16 billion tons in 2012 before declining to 1.14 billion tons in 2017 and 1.09 billion tons in 2018. Moreover, agrifood systems' share in nationwide total GHG emissions continuously declined, from 18.7 percent to 8.2 percent, during 1997–2018. Agricultural activities, intermediant inputs, food processing, and agricultural energy use are major sources of emissions from agrifood systems.

Sequestration of carbon from tagrifood systems involves the carbon sink of LULUCF, but not all GHG

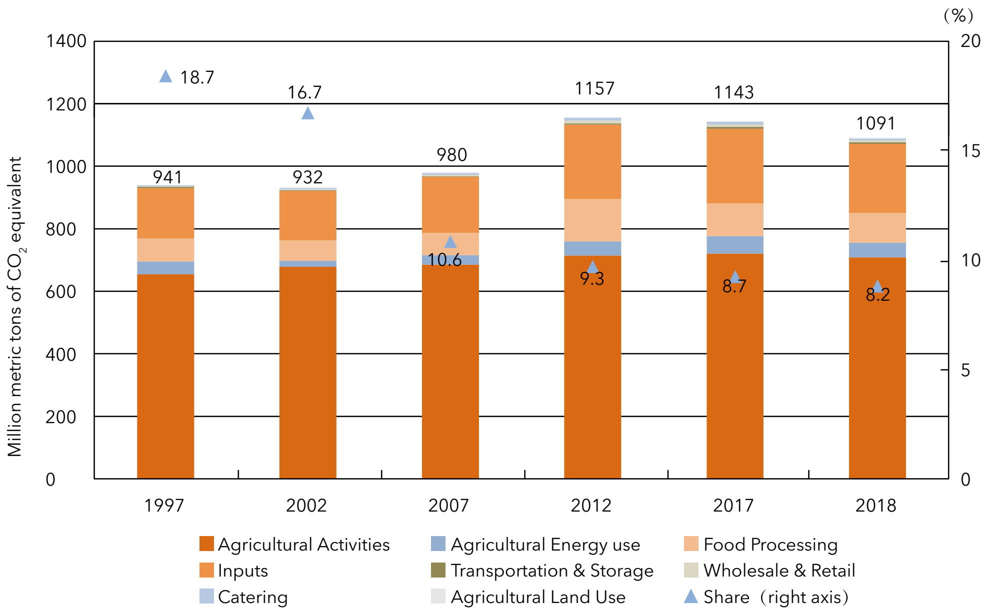
Figure 2.3 Greenhouse gas emissions from energy use in agrifood systems in China, 1997–2018



Source: *Authors' calculation using data from NBS(2021).*

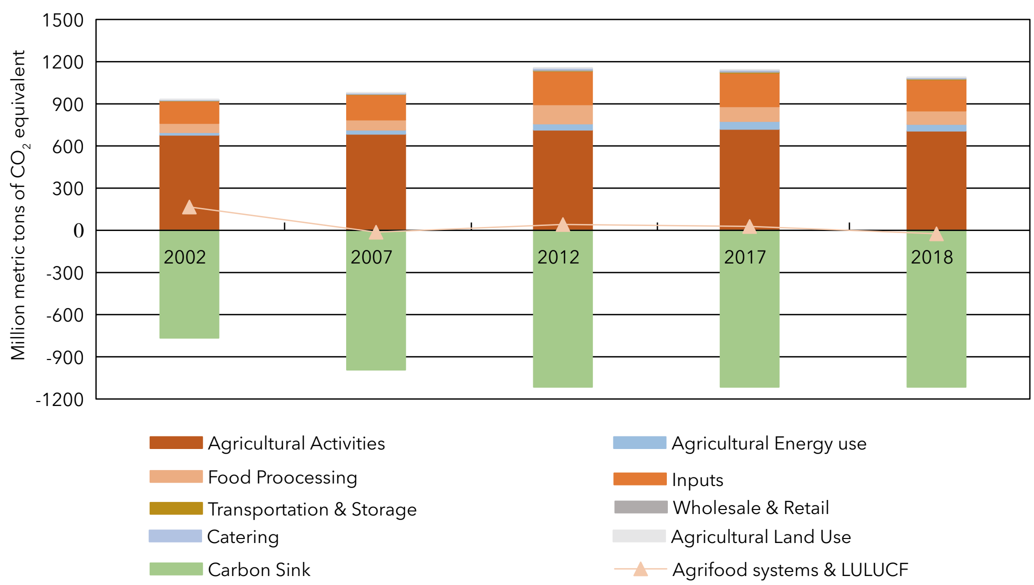
emissions from the agrifood systems are entirely sequestered by LULUCF, and there was a remaining net emission of 165 million tons in 2002. With an increase of the LULUCF carbon sink, however, GHG emissions from agrifood systems since 2007 might have been be entirely sequestered by LULUCF. The net carbon sink of agrifood systems and LULUCF was 24 million tons in 2018, as shown in Figure 2.5.

Figure 2.4 Greenhouse gas emissions from agrifood systems in China, 1997–2018



Source: *Authors' calculation using data from NBS(2021) and FAO(2021)*

Figure 2.5 GHG emissions from agrifood systems and LULUCF in China 2002-2018



Source: *Authors' calculation. LULUCF data are from PRC (2018a, 2018b): 2002 data based on 2018a (data of 2005), 2007 data from 2018b (data of 2010), and 2012, 2017, and 2018 data are from 2018a (data of 2014).*

Note: *LULUCF = land use, land use change, and forestry.*

2.3 Pathways for Transforming Agrifood Systems in China to Achieve the 2060 Carbon Neutrality Goal

2.3.1 Pathways for Reducing Greenhouse Gas Emissions of Agricultural Activities in China

In the context of the goal to ensure food security and grain self-sufficiency in China, we project future changes in the supply of and demand for agricultural products using the China Agricultural Sector Model (CASM), developed by the Institute of Agricultural Economics and Development of the Chinese Academy of Agricultural Sciences together with the International Food Policy Research Institute (CAAS and IFPRI 2018). We added a carbon emission module to this model to estimate GHG emissions. GHG emission coefficients of various agricultural commodities are primarily calculated by referring to the FAO (FAO 2021). Specific model introductions and parameters are presented in Appendix 1[3]. The situation of 2060 is projected recursively, with 2020 as the base year. In the business-as-usual (BAU) scenario, assumptions are made about future social and economic development, such as population, urbanization rate, economic growth, and per capita income, in a normal or usual way. Basic parameter settings are shown in the appendix. To ensure food security and self-sufficiency, the import of agricultural products in the model is controlled at the level of 2020, resulting grain production to reach more than 650 million tons during the 14th Five-Year Plan period (2021–2025). Increases in food consumption due to growth in population and income will be predominantly satisfied by domestic agricultural production, resulting in an increase in agricultural GHG emissions.

To simulate the emission reduction pathway of agricultural activities, future GHG emissions are estimated based on the projected supply of and demand for agricultural products under BAU. The carbon emission coefficients of agricultural production activities decrease year by year due to technological progress. Under BAU, various future change trends of different carbon emission coefficients are set by referring to historical data about the GHG emission coefficients of the relevant agricultural activities. Based on this method, the pathways of emission reduction for agricultural activities are designed with reference to existing research results (see Appendix 2 for details), many of which shows that carbon emissions can be reduced through technological improvements. Increasing the yield of crops, improving the use efficiency of chemical fertilizer, reducing the overall use of chemical fertilizer, and lowering carbon emissions from rice fields through dry-wet alternating measures are major emission reduction measures for crops. Livestock producers will adopt improved livestock and poultry production management and feed quality or added dietary supplements to reduce GHG emissions (Cui et al. 2018; Gathorne-Hardy et al. 2016; Nayak et al. 2015). Moreover, changing residents' behaviors from the demand side to reduce food loss and waste, and change dietary patterns, also contributes to emission reduction (Munesue, Masui, and Fushima 2015; Springmann et al. 2018).

We present five scenarios in addiiton to BAU: crop technology improvement (Tech-CR), livestock technology improvement (Tech-LV), food loss and waste rate reduction (Waste), dietary change (Diets), and combination of all these measures (Comb). Furthermore, considering future uncertainty, all scenarios are considered at high, medium, and low levels, as shown in Table 2.2. The details of scenario design are illustrated in Appendix 3.

The agricultural production will continue to increase as a whole because income levels and therefore per capita consumption will continue to increase, especially the demand for livestock products, and population will also continue to grow and reach its peak around 2030. Specifically, in 2021 and 2022, pork production will return to its normal level from African swine fever. Predictably, the annual average growth will be up to 25 percent, which will result in an increase in GHG emissions. Nevertheless, the GHG emission coefficients of agricultural activities will decline over time due to technological progress. Under BAU, GHG emissions from agricultural production will drop to 652 million tons and 640 million tons by 2030 and 2060, respectively. However, they will still be higher than the level of the base year, 2020, by 4.7 percent and 2.9 percent, respectively (Figure 2.6). In this scenario, future emissions are mainly growing from the growth of livestock production. GHG emissions of pork and beef increase by

[3] all appendices can be found on the AGFEP website (https://agfep.cau.edu.cn).

Table 2.2 Scenario design for modeling greenhouse gas emission reduction of agricultural activities in China, 2020-2060

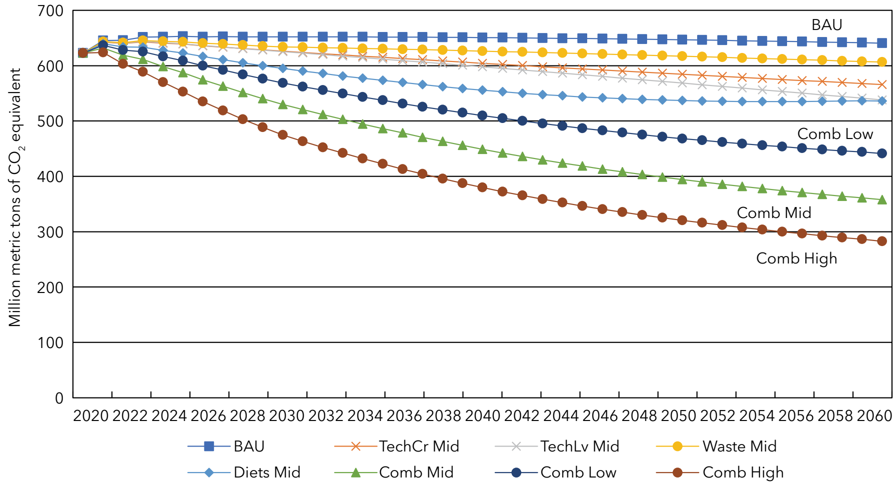
Area	High-level scenario	Medium-level scenario	Low-level scenario
BAU	Yields of rice, wheat, and maize in 2020 were 7, 5.7, and 6.3 tons/ha, respectively, which will be increased by 10%, 15%, and 25% in 2060, reaching 7.7, 6.6, and 7.9 tons/ha, respectively. The loss and waste rate of rice, wheat, and maize is 15%; of vegetables and fruits are 55% and 50%, respectively; and of pork, beef, and mutton are 15%, 10%, and 10%, respectively. Urban and rural residents' per capita consumption of livestock and poultry meat will be 223 grams per day in 2060. In 2060, fertilizer use efficiency will be increased by 20%; the emission coefficient of rice fields will be reduced by 20%; the coefficients of carbon emissions from pork, mutton, and poultry meat will be reduced by 15%, 25%, and 30%, respectively; and the coefficients of carbon emissions from beef, poultry eggs, and milk will be reduced by 10%.		
Tech-CR	Yield of rice, wheat, and maize in 2060 will be increased by 25%, 40%, and 50%, respectively, as compared with 2020; fertilizer use efficiency will be increased by 50%; and the coefficient on emissions from rice fields will be reduced by 50%.	Yield of rice, wheat and maize in 2060 will be increased by 20%, 35% and 45%, respectively, as compared with 2020; fertilizer use efficiency will be increased by 40%; and coefficient of emission from rice fields will be reduced by 40%.	Yield of rice, wheat and maize by 2060 will be increased by 15%, 25%, and 35%, respectively, as compared with 2020; fertilizer use efficiency will be increased by 30%; and coefficient of emission from rice fields will be reduced by 30%.
Tech-LV	The coefficient of emissions from livestock products in 2060 will be reduced by 50%, with the feed conversion rate improved by 30%.	The coefficient of emissions from livestock products in 2060 will be reduced by 40%, with the feed conversion rate improved by 20%.	The coefficient of emissions from livestock products in 2060 will be reduced by 30%, with the feed conversion rate improved by 10%.
Waste	The loss and waste rate of each product in 2060 will be 67% lower than that in 2020.	The loss and waste rate of each product in 2060 will be 50% lower than that in 2020.	The loss and waste rate of each product in 2060 will be 33% lower than that in 2020.
Diets	Per capita consumption of livestock and poultry meat by urban and rural residents in 2060 will be reduced to the lower limit recommended by the dietary guidelines, of 40 grams per day.	Per capita consumption of livestock and poultry meat by urban and rural residents in 2060 will be reduced to the median level recommended by the dietary guidelines, of 60 grams per day.	Per capita consumption of livestock and poultry meat by urban and rural residents in 2060 will be reduced to the upper limit recommended by the dietary guidelines, of 75 grams per day.
Comb	Combination of the above scenarios	Combination of the above scenarios	Combination of the above scenarios

Source: Authors' compilation.

approximately 30 percent in 2060 compared with 2020, whereas emissions from crops decline. In particular, GHG emissions related to rice and wheat production drop by 20 percent and 27 percent in 2060 comparing with 2020 level, respectively (Figure 2.7).

Tech-CR. To produce the same production of agricultural products, the increased crop yields will lead to a decline in the use intensity of farmland. At the same time, the increased use efficiency of fertilizer will reduce the input of chemical fertilizers, and the emission coefficient of rice fields will also be decreased. All of these measures contribute to reducing GHG emissions due to crop production. However, the increase in crop production results in a decrease in the price of feed grains, contributing to more livestock production, resulting in a slight increase in emissions from livestock. GHG emissions from agriculture in 2030 and 2060 under the scenario of Tech-CR are 2–6 percent and 7–16 percent lower, respectively, than emissions under BAU (Figure 2.6). Compared with 2020, emissions in the medium-

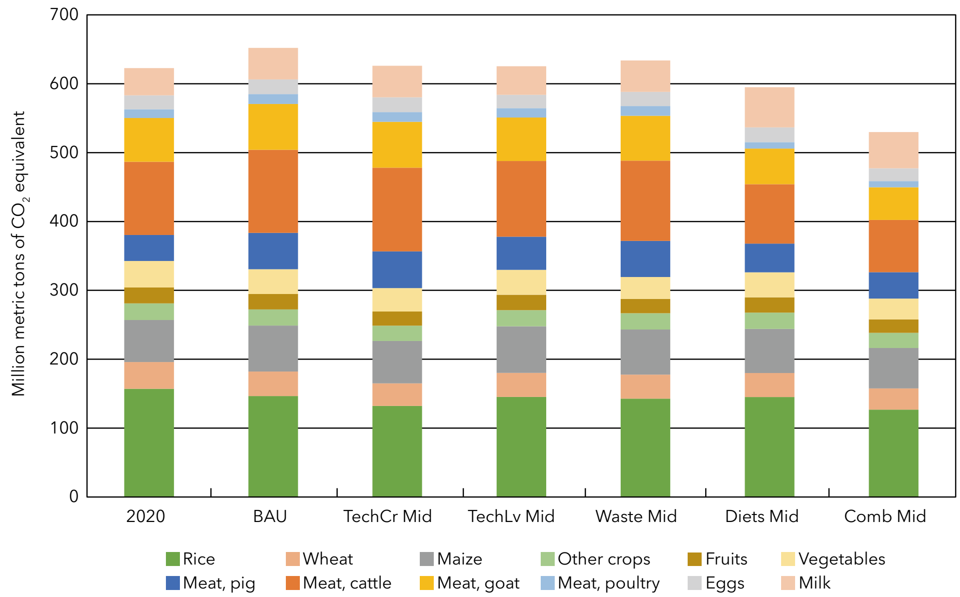
Figure 2.6 **Greenhouse gas emissions from agricultural activities in China under different scenarios, 2020–2060**



Source: *Results of China Agricultural Sector Model*

Note: *BAU = business as usual; Tech-CR = crop technology improvement; Tech-LV = livestock technology improvement.*

Figure 2.7 **Greenhouse gas emissions of agricultural activities in China in 2060 under different scenarios, by commodity**



Source: *Results of China Agricultural Sector Model.*

Note: *BAU = business as usual; Tech-CR = crop technology improvement; Tech-LV = livestock technology improvement.*

level scenario are slightly increased in 2030, at roughly 0.5 percent, 4.2 percentage points less than under BAU. GHG emissions in the medium-level scenario in 2060 are lower than in 2020, with a decline of 9.1 percent. Wheat and rice are major sources of emission reductions. In the medium-level scenario, GHG emissions of wheat and rice in 2060 are reduced by approximately 46 percent compared with 2020.

Tech-LV. The intensity of GHG emissions from livestock production decreases due to various emission reduction technologies used in the livestock sector. Meanwhile, the increased feed conversion rate also reduces the livestock sector's demands for feed grain, thereby reducing GHG emissions from both crops and livestock products. GHG emissions from agriculture in 2030 and 2060 under the scenario of Tech-LV decrease by 2–6 percent and 9–23 percent, respectively, in comparison with BAU. Compared with 2020, GHG emissions from agriculture in the medium-level scenario increase by 0.4 percent; however, this is 4.3 percentage points less than under BAU. GHG emissions in the medium-level scenario in 2060 are significantly lower than in 2020, with a decline of 13.6 percent. Beef is the main source of emission reductions in all livestock products, witnessing a decline of 8 percent in 2060 when compared with 2020. Evidently, the demand for feed grain will be decreased with the improved feed conversion rate. Hence, GHG emissions from rice, wheat, and maize will fall by 20 percent, 29 percent, and 12 percent, respectively.

Reduction of Loss and Waste (Waste). Decreased food loss and waste rates can result in a decline in the overall demand for food and thus in food price. The consequent decline in the production of agricultural products is conducive to reducing GHG emissions. GHG emissions from agriculture in 2030 and 2060 in this scenario are 2.0–5.6 percent and 4.0–7.0 percent lower, respectively, than under BAU. Compared with 2020, GHG emissions from agriculture in the medium-level scenario will also be increased, but much less than under the BAU scenario. GHG emissions in the medium-level scenario in 2030 are up by 1.8 percent, yet decrease by 2.6 percent in 2060, compared with 2020.

Shifting Diets (Diets). A reduction in the consumption of livestock and poultry meat leads to declines in prices and imports. Moreover, there is reduced fertilizer use caused by the reduction in feed demand, which also leads to a decrease in GHG emissions. GHG emissions from agriculture in 2030 and 2060 under this scenario are 7–12 percent and 13–19 percent lower, respectively, than under BAU. After residents change their dietary pattern, GHG emissions from agriculture in the medium-level scenario are lower than they were in 2020. Specifically, they are reduced by 14 percent in 2060. In the medium-level scenario, GHG emissions from beef, pork, and mutton in 2060 are reduced by 65 percent, 51 percent, and 39 percent, respectively, compared with 2020.

Combined Scanario (Comb). Finally, the combined scenario present the largest reduction in GHG emissions, significantly lower than both BAU and the emission levels of 2020. The GHG emission reduction effects of the scenario of Comb is remarkably superior to any of the above four scenarios. In this scenario, GHG emissions from agricultural production activities in 2060 are reduced by 29–55 percent compared with their levels in 2020. In the medium-level scenario, carbon emissions in 2030 will be reduced by 15.0 percent, and they go down by 42.6 percent in 2060, compared with 2020. GHG emissions from both crops and livestock products are significantly decreased, with emissions from beef reduced by approximately 70 percent, emissions from rice and wheat reduced by more than 50 percent, and emissions from other products reduced by more than 30 percent, as shown in Figure 2.7.

2.3.2 Pathways for Reducing Greenhouse Gas Emissions from the Energy Use of Agrifood Systems in China

According to China's Policies and Actions for Addressing Climate Change (2019), CO_2 emissions per unit of GDP had declined cumulatively by 45.8 percent in 2018 as compared with 2005, and non-fossil energy accounted for 14.3 percent of total energy consumption, with an increase of nearly 7 percent in 2018 as compared with 2005 (China, MEE 2019). The Government Work Report in 2021 suggested that the national independent contribution goal for climate change will be implemented in 2030 (Li 2021). Energy consumption per unit of GDP and CO_2 emissions are expected to be reduced by 13.5 percent and 18 percent, respectively, during the 14th Five-Year Plan period (2021-2025). Improving energy efficiency and adjusting the energy consumption structure, especially increasing the proportion of non-fossil energy consumption, are principal pathways for reducing GHG emissions due to energy consumption in agrifood systems, in the same way as emission reduction in the energy industry.

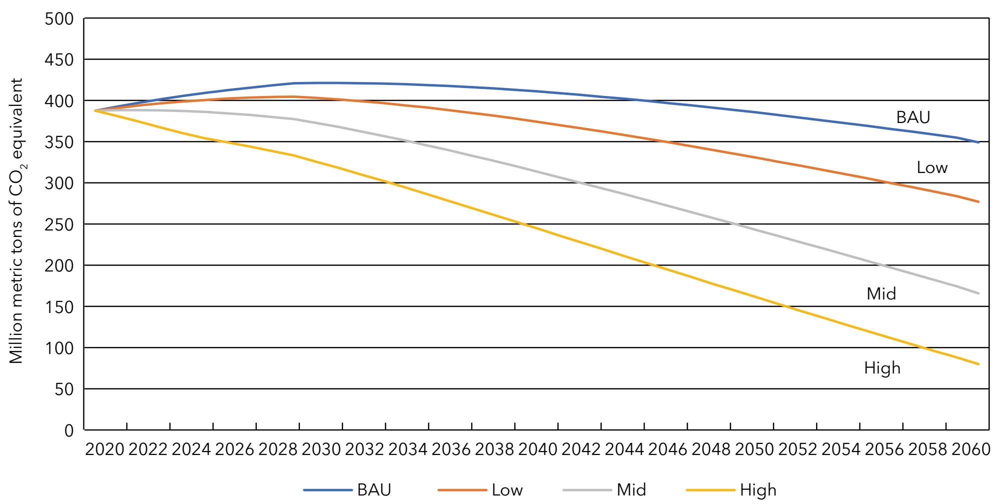
We estimate the energy consumption intensity and energy consumption structure of industries related to agrifood systems using the China input-output table and energy consumption by sector. We find that energy consumption per RMB 10,000 of GDP in the agriculture and food processing industry was relatively low in 2018, about 0.24 tons and 0.56 tons, respectively. Both are lower than the average level of all industries of 0.83 tons/RMB 10,000 of GDP. However, in terms of the energy consumption structure, the proportion of coal in the food processing industry is 63.0 percent, slightly higher than the average level of 56.8 percent of all industries (NBS 2021). Four scenarios are designed for agrifood systems to achieve the future development goals of improving energy consumption efficiency and lowering the non-fossil energy consumption rate, in the context of the actual situations of agriculture and the food processing industry. From 2020 to 2060, energy consumption per RMB 10,000 GDP will decrease by 1.0–2.0 percent annually on average, and the proportion of energy from non-fossil sources will increase by 0.5–1.0 percent annually on average. Specific scenario design is presented in Appendix 4.

Next, we use the China Dynamic General Equilibrium Model to simulate and project the future GDP growth of the agriculture and food processing sectors, using 2017 as the base year and projected population growth, labor growth, and technology progress. It can be observed that the average annual growth rate of agriculture and food processing from 2020 to 2060 are roughly 2 percent and 3 percent, respectively. We estimate changes in GDP of whole agrifood systems according to its components. Total energy consumption is estimated as the projection of GDP and energy consumption per RMB 10,000 GDP of agrifood systems. Further, the GHG emissions of agrifood systems from 2020 to 2060 are estimated by adjusting the energy consumption structure and the GHG emission coefficient of various energy sources, as shown in Figure 2.8. Under the BAU scenario, GHG CO_2eq emissions from energy consumption in agrifood systems will reach 420 million tons by 2030, an increase of 8.7 percent compared with 2020, and 350 million tons by 2060, a decrease of 9.9 percent as compared with 2020 (Figure 2.8). GHG emissions from energy consumption will be significantly reduced if comprehensive emission reduction measures are taken, such as the improvement of energy efficiency and adjustment of the energy consumption structure. To be specific, emission reductions under the low, medium, and high intensity scenarios in 2060 will be 20–77 percent lower than under BAU, and 28–79 percent lower than in 2020. In the medium-level scenario, GHG emissions from agrifood systems will be reduced by 57 percent in 2060 compared with 2018.

2.3.3 Analysis of Greenhouse Gas Emissions from Agrifood Systems in China

Total GHG emissions of future agricultural activities, agricultural land use, and energy consumption by agrifood systems are used to illustrate the future GHG emissions. Because GHG emissions from agricultural land use have been nearly unchanged for the past 10

Figure 2.8 Greenhouse gas emissions from energy use of agrifood systems in China under different scenarios, 2020–2060



Source: *Results of China Dynamic General Equilibrium Model.*

Note: *BAU = business as usual.*

years, they are assumed to be constant from 2020 to 2060, remaining at their 2017 level. Because the CASM does not include all agricultural commodities, the figure for total agricultural GHG emissions is smaller than the total from FAO (FAO 2021). For data consistency, GHG emissions of future agricultural activities are adjusted using the FAO GHG emission data of agricultural activities in 2017. Then the future GHG emissions from agricultural activities are estimated using the growth rate of GHG emissions from agricultural activities calculated by the CASM. The GHG emissions from energy use in agrifood systems are the results projected in the previous section.

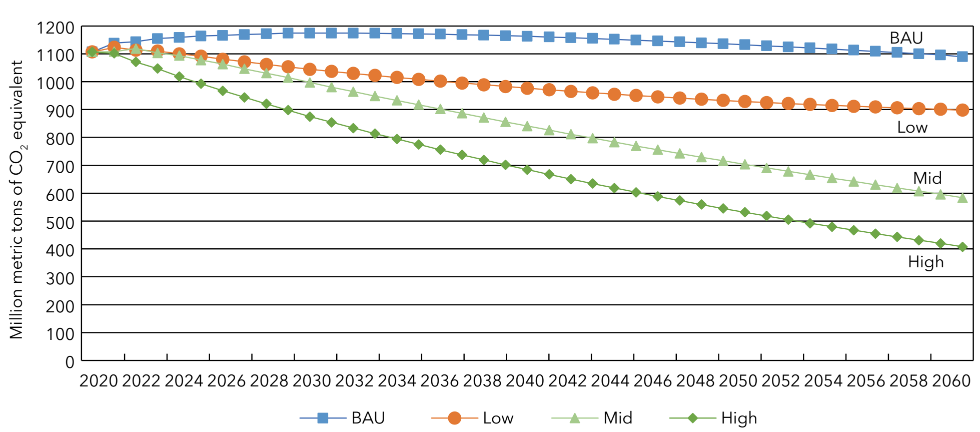
Results on GHG emissions from agrifood systems under various scenarios are presented in Figure 2.9. Under BAU, GHG emissions from agrifood systems reach 1.17 billion tons in 2030, an increase of 7.7 percent compared with 2020, and then they futher decline to 1.09 billion tons in 2060, returning to their level of 2018 (Figure 2.9). Measures such as improving agricultural technology, reducing food loss and waste, shifting dietary patterns, enhancing energy efficiency and optimizing the energy consumption structure, and combining all of these measures substantially reduce GHG emissions from agrifood systems. In the low, medium, and high scenarios, GHG emissions from agrifood systems in 2060 are 17–63 percent lower than under BAU and 19–63 percent lower than in 2020. The medium-level scenario would contribute to a reduction of 47 percent of GHG emissions in agrifood systems in 2060, compared with 2020.

At the 2020 Climate Ambition Summit, the Chinese government announced that forest inventory would be increased by 6 billion m^3 by 2030, compared with 2005, and future forest carbon sink capacity would also increase. In 2014, forests in China sequestered 1.1 billion tons of CO_2eq. According to studies conducted by Energy Foundation China, forest carbon sequestration in China will be increased to 1.6 billion tons by 2050 (Energy Foundation China 2020). If forest carbon sink capacity remained at 1.1 billion tons in 2020, the net carbon sequestration of the agrifood systems and forests would reach about 30 million tons. If forest carbon sink capacity is estimated at 1.6 billion tons in 2060, the country will produce negative net emissions of its agrifood system and forests—that is, 0.7 billion tons to 1.2 billion tons of CO_2eq can be sequestered. Specifically, in the medium-level scenario, 1 billion tons of CO_2eq can be sequestered, making huge contributions to emission reduction, as shown in Figure 2.10.

2.4 Policy Recommendations for Transforming Agrifood Systems to Achieve China's 2060 Carbon Neutrality Goal

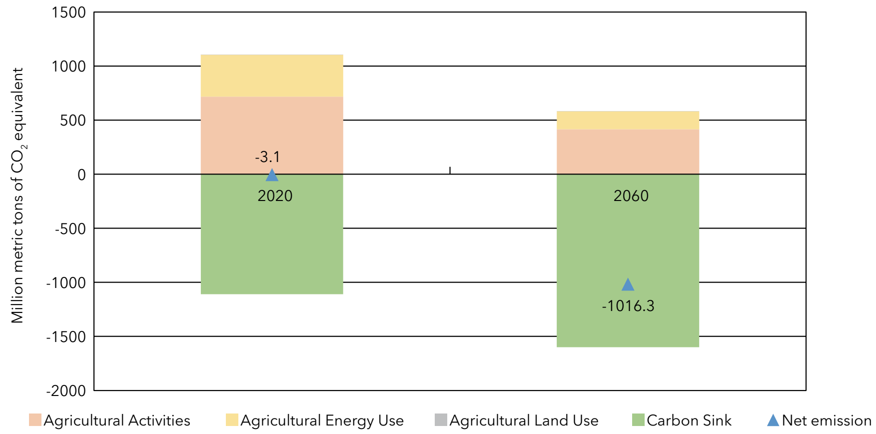
This chapter has systematically estimated the GHG emissions of China's agrifood systems. These emissions have increased by a mere 16 percent in the past two decades despite rapid development of the country's agriculture sector. Moreover, consecutive emission

Figure 2.9 Greenhouse gas emissions from agrifood systems in China under different scenarios, 2020–2060



Source: *Results of China Agricultural Sector Model (CAAS and IFPRI) and China Dynamic General Equilibrium Model*
Note: *BAU = business as usual.*

Figure 2.10 **Greenhouse gas emissions from agrifood systems and from land use, land use change, and forestry in China, 2020 and 2060**



Source: *Results of China Agricultural Sector Model (CAAS and IFPRI 2018) and China Dynamic General Equilibrium Model, Carbon sink data derived from Energy Foundation China (2020).*

declines occurred in 2017 and 2018. The share of the agrifood sector in total GHG emissions dropped from 18.7 percent in 1997 to 8.2 percent in 2018.

However, GHG emissions of agrifood systems cannot be ignored under the 2060 carbon neutrality goal, with their 2018 level still as high as 1.09 billion tons. It is imperative to transform agrifood systems so that it makes more significant contributions to emission reductions. Therefore, this chapter thoroughly analyzed emission reduction pathways for future agrifood systems. Specifically, we used models to analyze the emission reduction effects of various measures, such as improving agricultural technology, reducing food loss and waste, shifting residents' dietary patterns, enhancing energy efficiency, and optimizing the energy consumption structure. The results show that improving crop and animal husbandry technologies, reducing food loss and waste, and changing dietary patterns can have significant emission reduction effects while also ensuring food security and cereal self-sufficiency in China. More importantly, the most significant emission reductions can be obtained by combining the above measures. In 2060, a scenario of medium intensity of such combined measures can reduce the GHG emissions of agrifood systems by 47 percent, compared with 2020. The emission reductions of the agrifood systems and of LULUCF complement each other. In the medium intensity scenario, approximately 1 billion tons of GHG can be sequestered, well above the level of 2020. Thus, the combined measures can make a more significant contribution to achieving the country's carbon neutrality goal.

Based on the above conclusions, we recommend scientifically formulating a comprehensive emission reduction strategy for agrifood systems, and exploring "precise emission reduction" pathways for value chains of agrifood systems as a whole as well as certain specific products, with the multiple goals of safeguarding food security, cereal self-sufficiency, and holding the red line of 1.2 million ha (1.8 billion mu) of arable land. Agrifood systems can be transformed to achieve the 2060 carbon neutrality goal by promoting changes in agricultural production and guiding consumption. First, the government should continue to optimize the agricultural subsidy policy system; increase investment in agricultural science and technology; and encourage research, development, and extension for low-carbon, green technologies. These include technologies that contribute to increasing production as well as reducing emissions, such as green fertilizers, pesticides, and seeds, soil-crop system integrated management technology, biodiversity use technology, high-yield and high-efficiency agricultural machinery and agronomic technologies, green and low-carbon planting and pollution prevention technologies, smart healthy breeding technology, livestock and poultry manure use technology based on a low-carbon cycle, integrated green planting and breeding technologies, and green and healthy food production and processing technologies. Second, the government should encourage consumers to actively participate in carbon neutrality actions, take measures to guide residents' consumption habits, substantially reduce food loss and waste from farm to fork, encourage residents to shift their dietary patterns, and guide them to eat a healthy and sustainable diet in accordance with recommended dietary guidelines. Third, the government should improve energy efficiency, increase the use of non-fossil energy, and promote green and low-carbon transformation. Fourth, it should strengthen landscape planning and control, leading to land save through improving technologies, reducing food loss and waste, and adjusting dietary structures. Such land can be converted into grassland, woodland, and wetland, enhancing ecosystem carbon sinks. Finally, the government should facilitate farmers' active involvement in carbon-sink markets to increase their incomes and reduce their emissions.

Some uncertainties in the simulation results of this chapter are noteworthy. First, it is impossible to predict technological development over the next four decades. The technologies in given scenarios are projected mainly according to existing literature, and therefore the results may be somewhat conservative. Emission reduction potentials, such as biological nitrogen fixation technology, microbial fermentation, and synthetic biology in agricultural activities, should also be considered in the future studies. Second, in the discussion of the potential of emission reduction of various measures, we do not consider issues such as rising producer costs due to the adoption of new technologies, the burden on consumers due to the rise in food prices caused by the application of technologies, or the specific strategies and methods for reducing food loss and waste and changing the dietary patterns. In future studies, more focus should also be placed on considering the cost and availability of various emission reduction technologies to improve agricultural production efficiency and decrease the price of nutritious food. Third, several possible measures are not analyzed due to the limitations of the models. Notably, the land use are not simulated. For one thing, the model does not consider the emission reduction effects of converting the land saved through technological progress into grassland and forestland. In addition, in-depth simulation and analysis are not performed on land use changes, such as the carbon-sink capacity increase from large-scale afforestation programs. Optimizing land use has huge potential to reduce emissions from agrifood systems and achieve carbon neutrality. Moreover, emission reductions in urban agriculture and facility agriculture are not discussed in detail, nor is the contribution of marine fisheries to the "blue carbon sink." These uncertainties need to be studied thoroughly in the future. Nevertheless, they do not influence the main conclusions and suggestions proposed in this chapter.

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Chapter 3

Shifting Chinese Diets for a Win-Win of Health and the Environment

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Key Findings

- With rapid improvements in agricultural productivity and residents' income, China has made remarkable advances in reducing hunger and malnutrition, as well as quality improvements in residents' diets, witnessed by the progressively increasing consumption of fruits, eggs, aquatic products, and milk.
- However, new health and environmental challenges also arise alongside China's dietary transition. Specifically, overweight and obesity have become increasingly prominent, and the incidence of diet-related chronic diseases has been on the rise. Among all these trends, the significant increase in meat consumption not only led to nutrition and health challenges, but also imposed intense pressure on resources and the environment.
- There are significant gaps between the current diet of Chinese residents and the recommended diets of the Chinese Dietary Guidelines and the EAT-Lancet Commission. The current Chinese diet is mainly composed of grains, dominated by refined rice and noodles, insufficient coarse food grains, excessive meat, and insufficient consumption of whole grains, fruits, legumes, and milk.
- Incidence and mortality from diet-related chronic diseases in China would be significantly reduced if the "healthy diet" recommendations of the Chinese Dietary Guidelines, EAT-Lancet, Mediterranean and flexitarian (or low meat) diets were adopted. Deaths in China would be reduced by 1.15 million by 2030 if the population were following the Chinese Dietary Guidelines, or 1.8 million by shifting to the EAT-Lancet diet.
- At the same time, such a shift would significantly lower greenhouse gas emissions. Simulation results show that greenhouse gas emissions from agricultural activities would be reduced by 146-202 million metric tons if residents adopted one of the healthy diets, and by 60-116 million metric tons compared with food consumption at the 2020 level. The flexitarian diet would reduce greenhouse gas emissions the most.

Recommendations

- Guide residents to eat healthy through changing their diet habits. Specifically, mainstream healthy diet knowledge in public education, and implement dietary nutrition interventions in key geographic areas and targeted populations to reverse the trend of rapid increase of overweight and obesity. Provide subsidies for vulnerable groups to improve their dietary quality.
- Promote transformation of the agrifood systems by adjusting the food supply structure as well as encouraging and supporting the development of healthy and environmental friendly food value chains. Enhance technologies to increase the production of highly nutritious food while reducing production costs, thereby increasing the accessibility of nutritious food to residents.
- Incorporate environmental sustainability into national programmatic and guidance documents such as the Chinese Dietary Guidelines, Guidelines for Food and Nutrition Development in China, National Nutrition Program, and Healthy China Initiative, so as to establish a food security strategy oriented toward nutrition, health, and environmental sustainability.
- Scale up investment in research on linking agriculture to nutrition and the environment. Use systemic approaches to holistically analyze food production, environmental sustainability, nutrition, and health (for example, control and preventions of chronic diseases) as a basis for China to formulate major policies.

3.1 Introduction

Since its "reform and opening up," China has witnessed sustained and rapid socioeconomic development. Now China has become the world's second-largest economy and a higher-middle-income country. With improvements in agricultural productivity and residents' income, China has made remarkable advances in mitigating hunger and malnutrition. In 2019, for instance, the prevalence of undernourishment had dropped below 2.5 percent (FAO et al. 2020). Meanwhile, Chinese residents' dietary pattern has undergone tremendous changes. Unhealthy Westernized diets have been introduced, causing steady growth in the consumption of animal-source foods such as red meat, poultry, milk, and eggs, as well as a substantial increase in the consumption of refined grains and edible oils (fats) (Zhao et al. 2018). As a result, China has witnessed greater health and environmental challenges. In the firstplace, overweight and obesity have become increasingly prominent, with more than half of adults overweight or obesity (NHC 2020). The incidence of diet-related chronic diseases is also on the rise. In addition, the increase in meat consumption has caused a rise in total greenhouse gas emissions. According to statistical data from the Food and Agriculture Organization of the United Nations (FAO 2018), greenhouse gas emissions from agricultural activities in China were 720 million tons[4] in 2017, an increase of 20 percent over their 1990 level.

Currently China, like all the other countries in the world, is encountering the challenges of both nutrition and health, and environmental pressure. To cope with the former, many countries and international organizations are formulating a variety of dietary guidelines. For example, China, the United States, and Japan have formulated dietary guidelines according to the health status, food supply, and dietary habits of their residents to improve their residents' dietary patterns and enhance overall nutrition and health. Various countries have also explored solutions to cope with environmental challenges. As indicated by the Paris Agreement on climate in 2015, before taking action to address climate change, all countries should recognize the vital role of sustainable consumption and production patterns in tackling climate change. Accordingly, Brazil, Germany, Qatar, and Sweden have incorporated environmental sustainability into their dietary guidelines (FAO and Food Climate Research Network 2016).

This chapter discusses how to achieve wins for both health and the environment through shifting Chinese diets. First, it reviews the transition of Chinese residents' food consumption and the resulting challenges to health and the environment. On this basis, popular healthy dietary patterns from China and abroad are reviewed and compared with the current dietary pattern of Chinese residents. Next, the impact of Chinese dietary patterns on the environment is further discussed. A simulation assesses whether Chinese residents' adjustment of their dietary pattern as per various healthy diet standards would be conducive to both improved human health and a significant reduction in greenhouse gas emissions from agriculture. Finally, policy recommendations are proposed for guiding Chinese residents to shift their diets.

3.2 The Transition of Chinese Residents' Food Consumption

With economic development and improvement in living standards, Chinese residents' food consumption habits have undergone tremendous changes, including a significant increase in dining out. To better reflect the transition of residents' food consumption, this chapter estimates the country's food consumption conditions, including consumption at home and away from home (see Appendix 5). In general, Chinese food consumption has the following characteristics.

There is a variety of food consumed by Chinese residents. Consumption of nutritious foods such as fruits, vegetables, meat, eggs, milk, and aquatic products has increased. However, the consumption of grains has dropped significantly. The annual overall per capita consumption of grains was 145.8 kg in 2019, representing a decrease of 33.5 percent in comparison with that of 1997. Yet the consumption of refined grains has seen a significant increase (Yu et al. 2020). A prominent increase has also been witnessed in the annual per capita consumption of fruits and poultry, which in 2019 were 58.6 kg and 60.3 kg, respectively, about 1.9 times and 2.9 times their 1997 levels. Although

[4]Tons refers to metric tons throughout the text.

fast growth has been witnessed in the per capita consumption of milk, eggs, and aquatic products, the 2019 levels were still only 19.2 kg, 12.9 kg, and 20.2 kg, respectively, due to starting at a low per capita consumption in 1997.

Trends in the dietary variety of urban and rural residents are similar, and gaps between urban and rural residents' food consumption are gradually narrowed. The grain consumption of rural residents was 169.5 kg in 2019, representing a decrease of 35.5 percent in comparison with 1997. Nevertheless, it was still 27.5 percent higher than that of urban residents. The meat consumption of both urban and rural residents has increased rapidly, reaching 67.1 kg and 53.5 kg, respectively, in 2019, approximately 2.4 times and 3.1 times that of 1997. Fruits, milk, aquatic products, and eggs consumed by urban and rural residents have been on the rise. Rural residents' food consumption has increased faster than that of urban residents, especially aquatic products consumption. However, the aquatic products consumption of rural residents in 2019 was 42.1 percent, lower than that of urban residents due to the low baseline consumption of rural residents (only 3.6 kg per person per year in 1997).

Remarkable regional differences are witnessed in Chinese residents' dietary patterns. High consumption of aquatic products is observed in the southern and eastern coastal areas due to abundant fisheries resources. For example, aquatic products consumed by residents in Fujian, Guangdong, Shanghai, and Zhejiang exceeded 36.5 kg per person in 2019, about twice the national average. In addition, large consumption of beef and mutton is witnessed in western China. Overall, the vegetables, fruits, and animal-source foods consumed by residents of various provinces and cities have increased in recent years. Among these, vegetable consumption has increased the most significantly. More than half of the residents of various provinces consumed more than 109.5 kg of vegetables in 2019.

The dietary patterns of urban and rural residents in China have improved continuously over the past 30 years. Nevertheless, the daily energy intakes of urban and rural residents in China have declined in recent years, dropping from 2,395 kcal in 1992 to 1,940 kcal in 2015 for urban residents, and from 2,294 kcal in 1992 to 2,054 kcal in 2015 for rural people (CNS 2021). We can use the above-mentioned food consumption data and the China Food Composition Tables (Yang 2018) to estimate the variation trends of the three major macronutrients (proteins, carbohydrates, and fats), drawing the following conclusions:

(1) The intake of quality protein has increased significantly, 49.1 percent and 38.5 percent of which in 2019 were from animal-source foods for residents in urban and rural areas, respectively. Particularly fast growth was witnessed for rural residents, 26 percentage points higher in 2019 than in 1997.

(2) The proportion of energy contributed by carbohydrates fell for urban residents from 56.6 percent in 1997 to 50.5 percent in 2019, and for rural residents from 71.5 percent in 1997 to 55.9 percent in 2019.

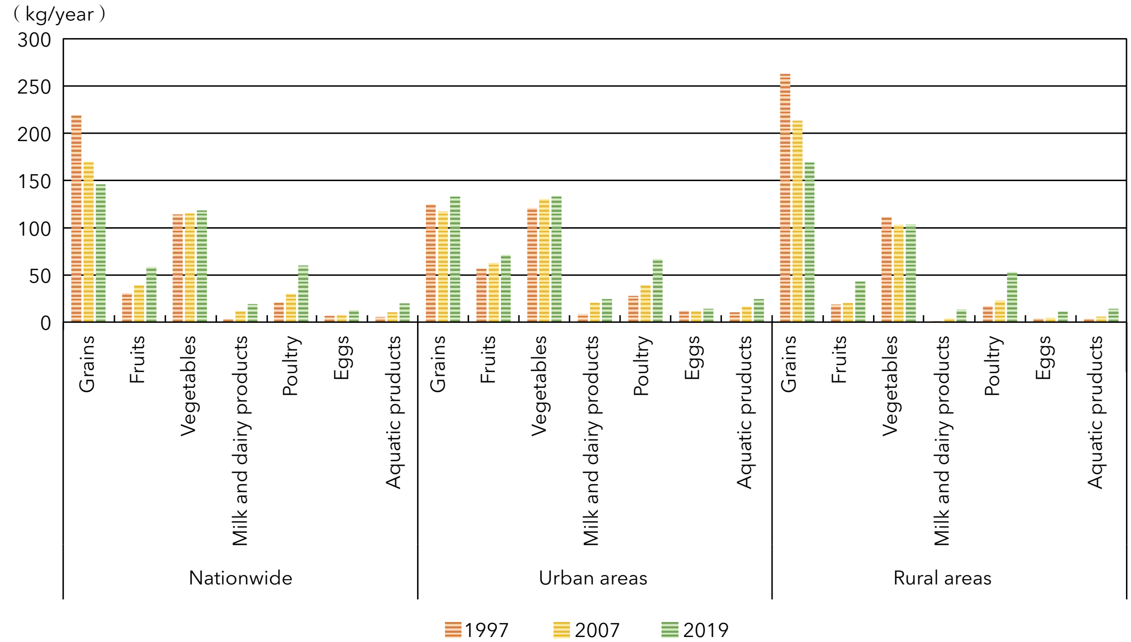
(3) The proportion of energy contributed by fat, however, has been on the rise, exceeding 30 percent of the recommended upper limit for both urban and rural residents.

It is worth noting that excessive energy intake and an imbalance of the three major macronutrients might increase the risk of all-cause mortality and morbidity from chronic diseases such as overweight, obesity, and cardiovascular disease (CNS 2021).

3.3 Health and Environmental Challenges from the Transition in Chinese Residents' Dietary Patterns

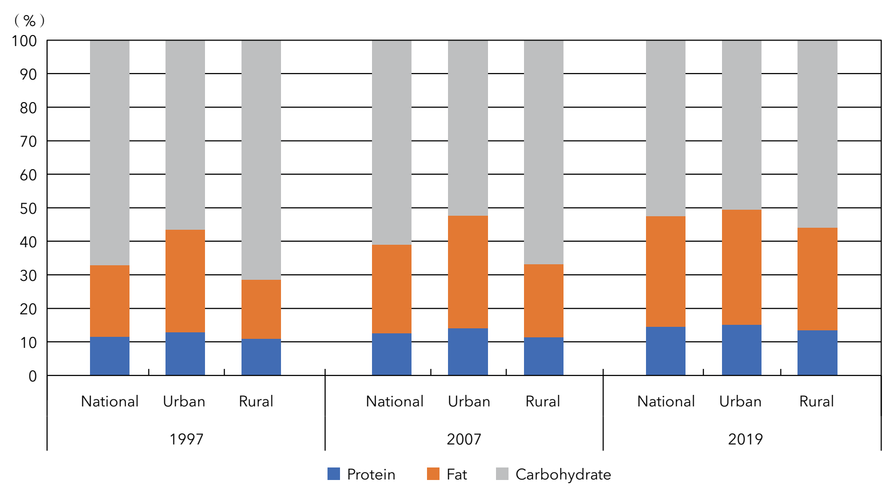
Diet is a bond for connecting human health with the ecological environment. Chinese residents' dietary pattern has undergone dramatic changes in the 21st century. There is an increasingly abundant variety of food consumed by Chinese residents. Consumption of nutritious food such as fruits, vegetables, meat, eggs, milk, and aquatic products has increased. Hence, the situation of malnutrition has fundamentally changed. However, this positive impact on nutrition and health is offset by the substantial consumption of food high in oil (fat) and sugar. Overweight and obesity are new challenges for malnutrition in China. The incidence of overweight and obesity increased dramatically among Chinese residents from 2000 to 2018, with the rate of obesity in adults rising faster than that of overweight, and the rates of overweight and obesity in rural residents increasing faster than those in urban residents (Chinese Nutrition Society 2021). In addition, the problem of

Figure 3.1 Dietary changes from 1997 to 2019 of urban and rural residents in China



Source: *Per capita consumption from China Statistical Yearbook (1998–2020), adjusted by the proportion of out of home consumption (see Appendix 1).*

Figure 3.2 Changes from 1997 to 2019 in the ratio of dietary energy provided by macronutrients for urban and rural residents in China



Source: *Calculated from Chinese Food Composition Table (2018).*

overweight and obesity is more prominent among males. Specifically, the overweight and obesity rates of male adults were 37.6 percent and 16.1 percent in 2018, an increase of 13.2 percent and 10.1 percent, respectively, compared with their rates in 2000 (Chinese Nutrition Society 2021). Overweight and obesity are principal risk factors for chronic diseases such as cardiovascular and cerebrovascular diseases, diabetes, hypertension, and cancers. According to the Global Burden of Disease Study 2017, 590,000 deaths from cardiovascular diseases in China were attributed to high body mass index (BMI). Long-term dietary imbalance is also a major risk factor for chronic diseases. It is estimated that mortality from cardiovascular and metabolic diseases in the Chinese adult population was 20.8 percent due to poor dietary quality in 2012, affecting approximately 1.51 million people (He et al. 2019).

At the same time, changes in Chinese residents' dietary patterns also exacerbate environmental problems. In the context of a substantial increase in the consumption of meat, edible oils, and starchy foods, greenhouse gas emissions, water consumption, and the area of land use by the agrifood systems increased by approximately 1.1 percent, 1.8 percent, and 2.0 percent each year, respectively, from 1997 to 2011. In particular, the growth of meat consumption is the principal factor causing these three environmental pressures (He et al. 2018). Specifically, livestock enteric fermentation and animal waste management are important sources of greenhouse gas emissions from agriculture. According to FAO statistical data, greenhouse gas emissions from agriculture in China increased to 720 million tons in 2017 from 600 million tons in 1990, up by 20 percent. In the meantime, the upgrading of dietary patterns has demanded more lands for food production. And the proportion of animal-source food consumption in the total land demanded per capita for food production increased from 14.0 percent in 1961 to 38.2 percent in 2009 (Zhao et al. 2014). Moreover, the water required by the agrifood systems has also been increasing. The water footprint of food consumption tripled from 1961 to 2003, exacerbating pressure on water resources (Liu et al. 2008).

3.4 Impacts of Different Dietary Patterns on Health

A healthy and sustainable diet is a dietary pattern that can enhance personal health with a small impact on the environment (FAO and WHO 2019). As a matter of fact, a healthy and sustainable diet does not have a single fixed pattern. In practice, healthy and sustainable dietary patterns vary according to local cultural background, food supply, and dietary habits.

The Chinese Dietary Guidelines are essential for advocating and promoting healthy and sustainable diets (UNSCN 2017). China's first dietary guidelines were released in 1989. Since then, they have been revised three times to keep pace with the nutritional and health status of residents and the development requirements of the dietary pattern. The Chinese Dietary Guidelines (2016) are the latest version of dietary guidance in China. The Chinese Food Guide Pyramid (CFGP) shows the types and quantity of food people should eat every day to follow the Chinese Dietary Guidelines. The EAT-Lancet diet, the Mediterranean diet, and the flexitarian diet are healthy dietary patterns recognized worldwide (Willett et al. 2019; Sandro and Berry 2015; Tilman and Clark 2014). The EAT-Lancet diet is a healthy and sustainable diet goal proposed by the EAT-Lancet Commission in 2019 taking into account human health and the ecological environment. The Mediterranean and flexitarian diets are derived from specific regions and particular population groups that have long been proven to be healthy in their dietary patterns. In general, these dietary patterns suggest that people eat less meat and more plant-based food, and reduce their total energy (caloric) intake and food waste. See Table 3.1 for more details.

3.4.1 Gaps between Chinese Residents' Dietary Pattern and Healthy Diets

To analyze the current dietary quality of Chinese residents, their dietary pattern is compared with dietary patterns that are promoted as healthy, to determine the gap between the two. Specifically, this section compares the 2019 self-reported dietary patterns of Chinese residents with, first, the EAT-Lancet healthy dietary pattern and, second, the Chinese Dietary Guidelines. The EAT-Lancet diet is a globally applicable healthy dietary standard, and the Chinese Dietary Guidelines are healthy dietary standards for the Chinese. Both can intuitively guide the shift in residents' dietary patterns through clarifying optimum intakes of various foods in the dietary pattern.

Looking at consumption data for the country as a whole, we find gaps between Chinese residents' dietary pattern and the dietary standards listed in the Chinese Dietary Guidelines (Figure 3.3a) as well as the EAT-Lancet diet (Figure 3.3b), which are represented in excessive consumption of meat and insufficient consumption of whole grains, fruits, nuts, and milk. Currently, Chinese residents' dietary pattern is dominated by grains, and these are primarily composed of refined grains, with insufficient intake of whole grains and miscellaneous

Table 3.1 Healthy dietary patterns

Dietary pattern	Main dietary recommendations	Sources
Chinese Dietary Guidelines	Eat a variety of food, mainly cereal; eat plenty of vegetables, fruits, milk, and soybeans; and eat aquatic products, poultry, eggs, and lean meat moderately, with a limited amount of salt and oil. Intake of meat should be less than 75 grams, and of fruits and vegetables less than 500 grams, per day.	CNS 2016
EAT-Lancet diet	Of total daily energy, 35 percent is derived from whole grains and starchy vegetables, with vegetable protein as the main source of proteins. Daily intake of red meat should be about 14 grams, and the intake of vegetables and fruits should reach 500 grams.	Willett et al. 2019
Mediterranean diet	Eat more vegetables, fruits, aquatic products, legumes, and nuts; use vegetable oil, especially olive oil, instead of animal oil for cooking. The proportion of energy contributed by fat ranges from 25 to 35 percent, with fewer than two servings of red meat per week.	Willett et al. 1995; Bach-Faig et al. 2011
Flexitarian diet	Eat animal-source food moderately as personal circumstances allow, with fewer than four serving per month, on the basis of having a multitude of plant-based food.	Tonstad et al. 2009; Rizzo et al. 2013

grain crops. Only about 20 percent of adults have a daily average consumption of whole grains and miscellaneous grain crops of more than 50 grams (CNS 2021). In 2019, the consumption of meat in urban and rural areas, respectively, was 184 grams per day and 147 grams per day, or about 4.3 times and 3.4 times the amounts recommended by the EAT-Lancet diet, and 3.2 times and 2.5 times the amounts recommended by the CFGP. Chinese residents' consumption of milk has always been low. Urban and rural residents consumed 67 grams per day and 37 grams per day, respectively, in 2019, far below the recommended value. Urban residents' consumption of fruits and vegetables comes closer to the recommended value, whereas rural residents' consumption of fruits is relatively low, 56.5 percent and 40.2 percent lower than the CFGP and EAT-Lancet diet, respectively. Urban residents' consumption of eggs and aquatic products meets the recommended range of the CFGP, whereas rural residents fail to reach the lower limit of this range.

Figure 3.4 again compares consumption with the CFGP and EAT-Lancet recommendations, this time broken out by 31 provinces. We find that residents in various regions of China have the problem of excessive meat consumption and insufficient milk consumption. The milk consumption of residents in Beijing ranks

Figure 3.3a Difference between the 2019 dietary pattern of Chinese residents and the EAT-Lancet dietary standard

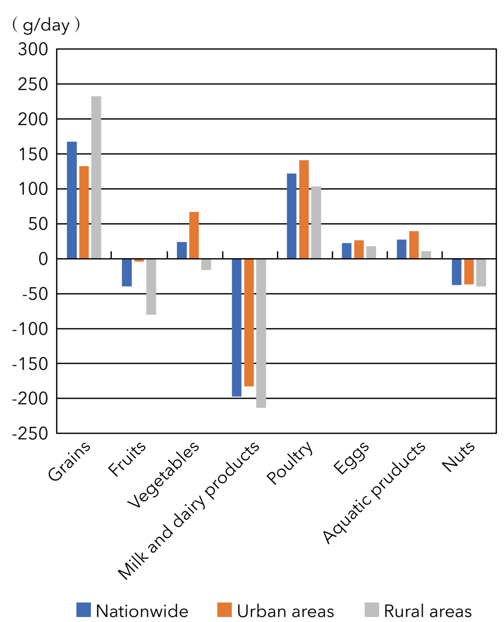
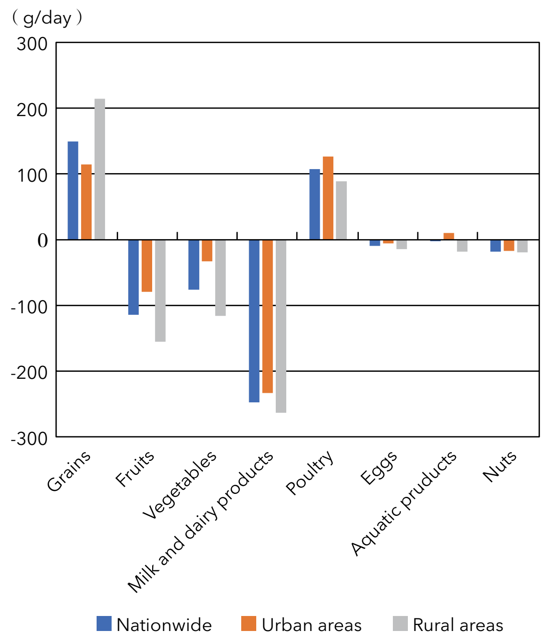


Figure 3.3b Difference between the 2019 dietary pattern of Chinese residents and the Chinese Food Guide Pyramid standard



Source: *Per capita consumption is derived from the China Statistical Yearbook (2020) and adjusted by out of home consumption ratio (see Appendix 1). The EAT-Lancet dietary standard comes from Food in the Anthropocene: the Eat-Lancet Commission on Healthy Diets from Sustainable Food Systems, and the the Chinese Food Guide Pyramid standard comes from the Chinese Nutrition Society.*

at the top nationwide but is still only 102 grams per day, about one-third and two-fifths of the values recommended by the CFGP and the EAT-Lancet diet, respectively. Southwest China witnesses the highest pork consumption, with residents of Chongqing and Sichuan consuming 127 and 126 grams per day, respectively, about 18 times the recommendation of the EAT-Lancet diet. Besides that, a huge gap, ranging from 27 to 281 grams per day, can be observed in the fruit consumption of residents in various provinces (including municipalities and autonomous regions), and only one-third of Chinese residents, whether in the provinces or the cities, can reach the consumption level recommended by the CFGP and the EAT-Lancet diet. Aquatic product consumption in coastal areas, such as Fujian, Shanghai, and Zhejiang, is higher than that in other provinces, exceeding 100 grams per day, which is 1.5 times the upper limit of CFGP and 2.6 times the recommended value of EAT-Lancet. Egg consumption reaches the value recommended in the EAT-Lancet diet (13 grams per day) in all provinces, but in most provinces consumption is far less than what is recommended by the CFGP (40-75 grams per day).

3.4.2 Impacts of Different Dietary Patterns on Health

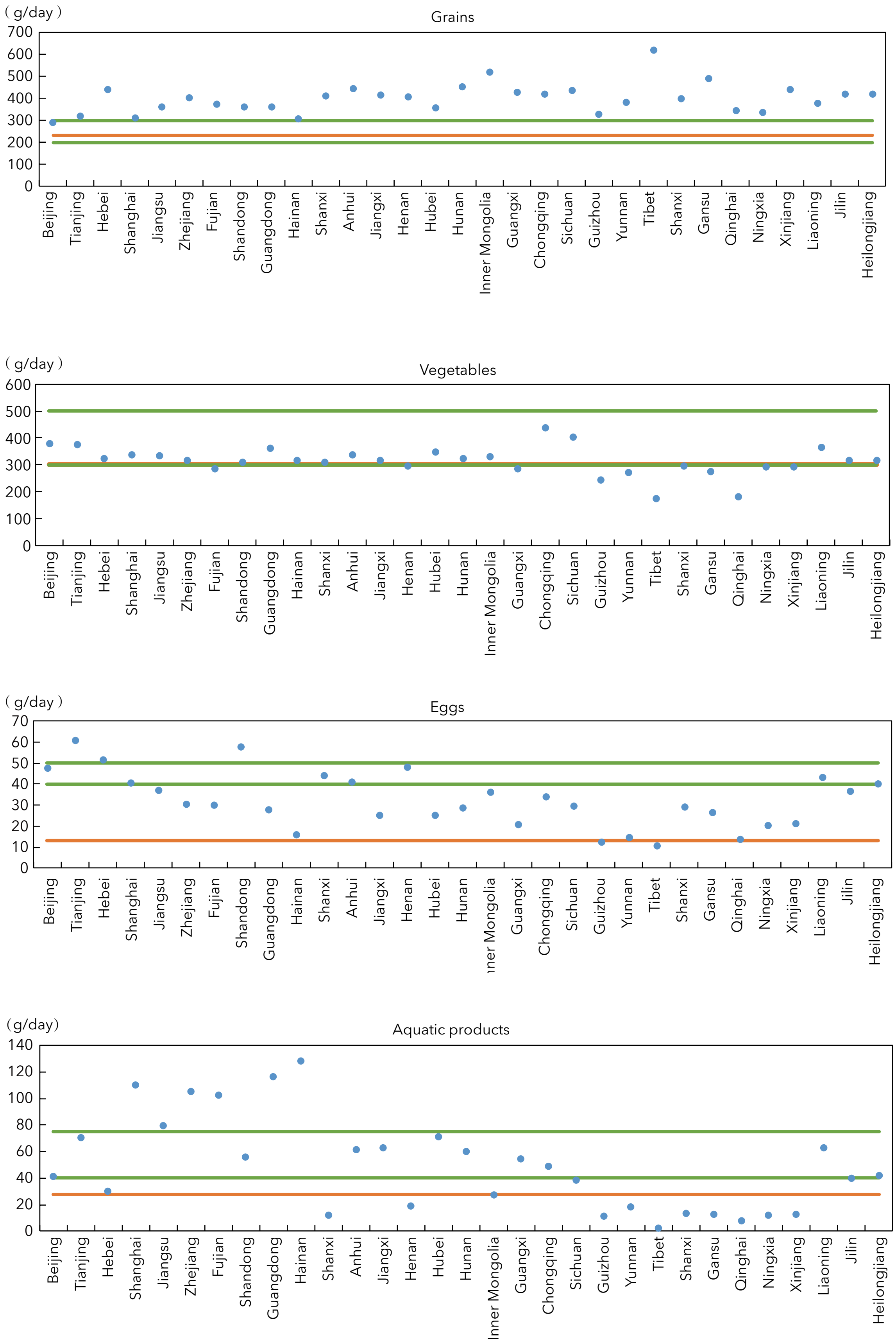
According to extensive studies of the influence of different dietary patterns on health, following the Chinese Dietary Guidelines is significantly positively associated with the overall health of residents (Zang et al. 2018). What's more, the higher a person's score on the CFGP, the lower the chance of mortality from cardiovascular diseases, cancers, and diabetes (Yu et al. 2014; Chen et al. 2018). If Chinese residents followed the Chinese Dietary Guidelines, 1.15 million deaths[5] and 0.43 million premature deaths[6] are predicted to be avoided in China, respectively—representing about 12.2 percent and 12.5 percent fewer deaths than that in 2010, the year we use for reference. Likewise, if Chinese residents conformed to the EAT-Lancet dietary standards, 1.80 million deaths and 0.67 million premature deaths in China are predicted to be avoided—about 19.2 percent and 19.5 percent fewer deaths than that in 2010 (Springmann et al. 2020).

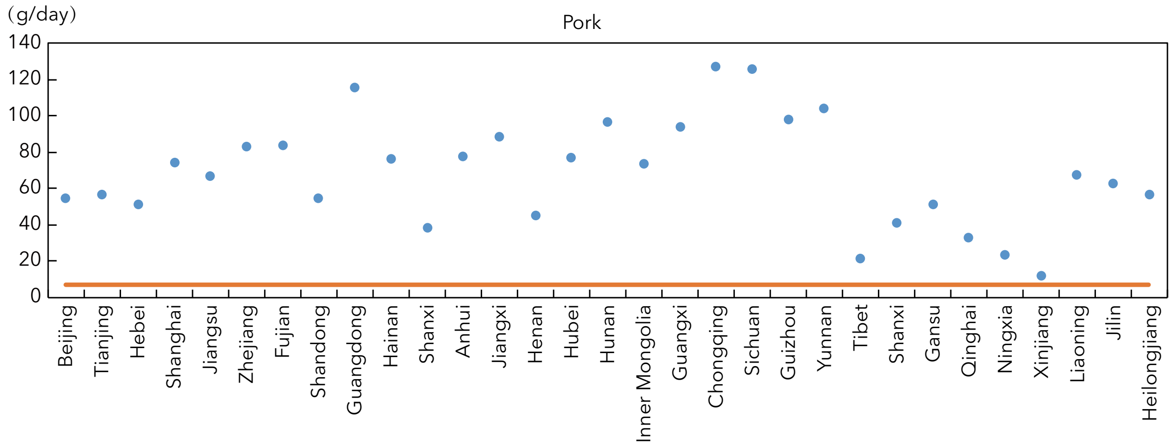
The Mediterranean diet is associated with many health benefits and provides human beings with a potential solution to improve their health and well-being by reducing the prevalence of and mortality from chronic noncommunicable diseases (Trichopoulou et al. 2014). Globally, if the Mediterranean diet was implemented, the prevalence of type 2 diabetes would be reduced by 16 percent, the relative mortality caused by cardiovascular disease would be reduced by 26 percent, and the overall mortality caused by all factors would be reduced by 18 percent (Tilman and Clark 2014). Gao and colleagues (2018) demonstrated the potential impact of the Mediterranean diet on the health of Chinese residents and suggested that the higher the compliance with the Mediterranean diet, the lower the risk of hypertension.

A global study conducted by Springmann and others in 2018 found that as animal-source foods content in the diet decreased, premature mortality declined accordingly. With energy intake held constant, the premature mortality rate globally in 2030 would be 4

[5]Refers to the number of avoided deaths of people ages 20 and older.
[6]Refers to the number of avoided premature deaths of people ages 30 to 69.

Figure 3.4 Comparison of 2019 dietary patterns in 31 provinces in China with Chinese Food Guide Pyramid and EAT-Lancet dietary standards

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Shandong
Guangdong
Hainan
Shanxi
Anhui
Jiangxi
Henan
Hubei
Hunan
Inner Mongolia
Guangxi
Chongqing
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Liaoning
Jilin
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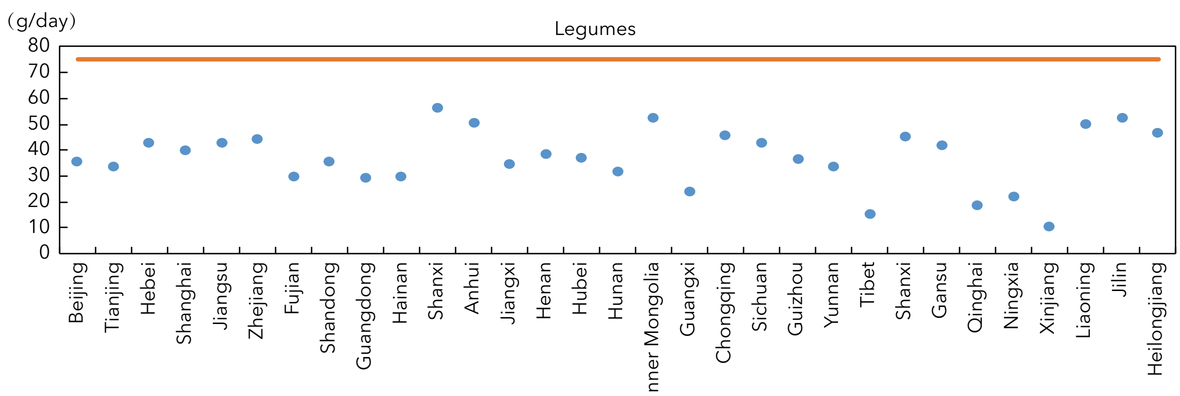
(g/day)
Legumes
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Guangdong
Hainan
Shanxi
Anhui
Jiangxi
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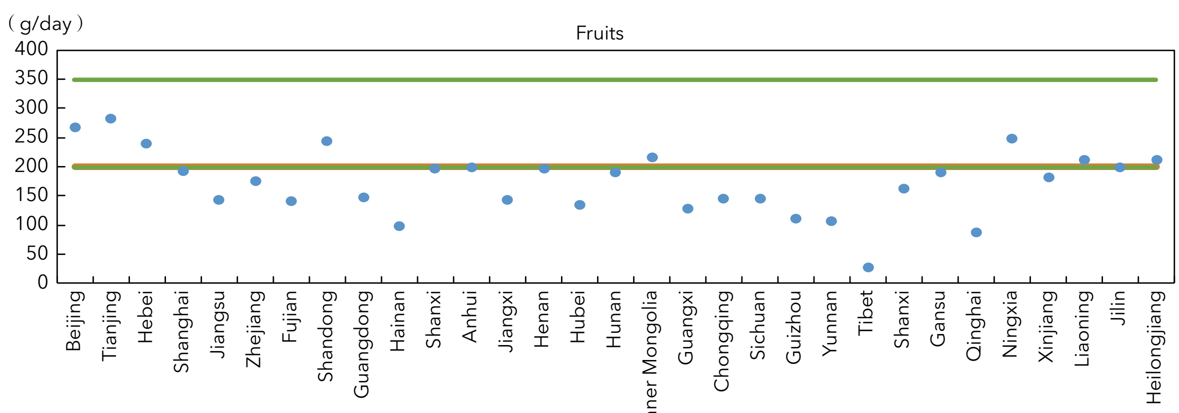
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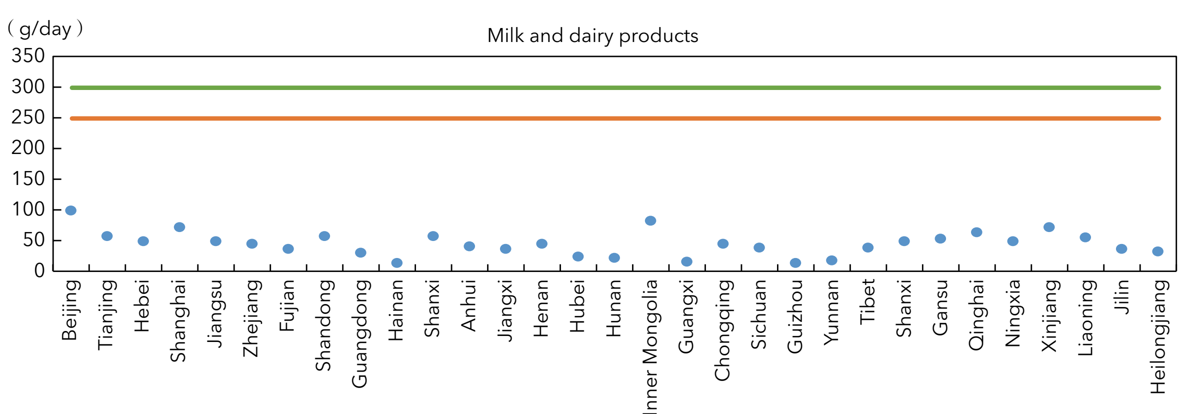
(g/day)
Milk and dairy products
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Zhejiang
Fujian
Shandong
Guangdong
Hainan
Shanxi
Anhui
Jiangxi
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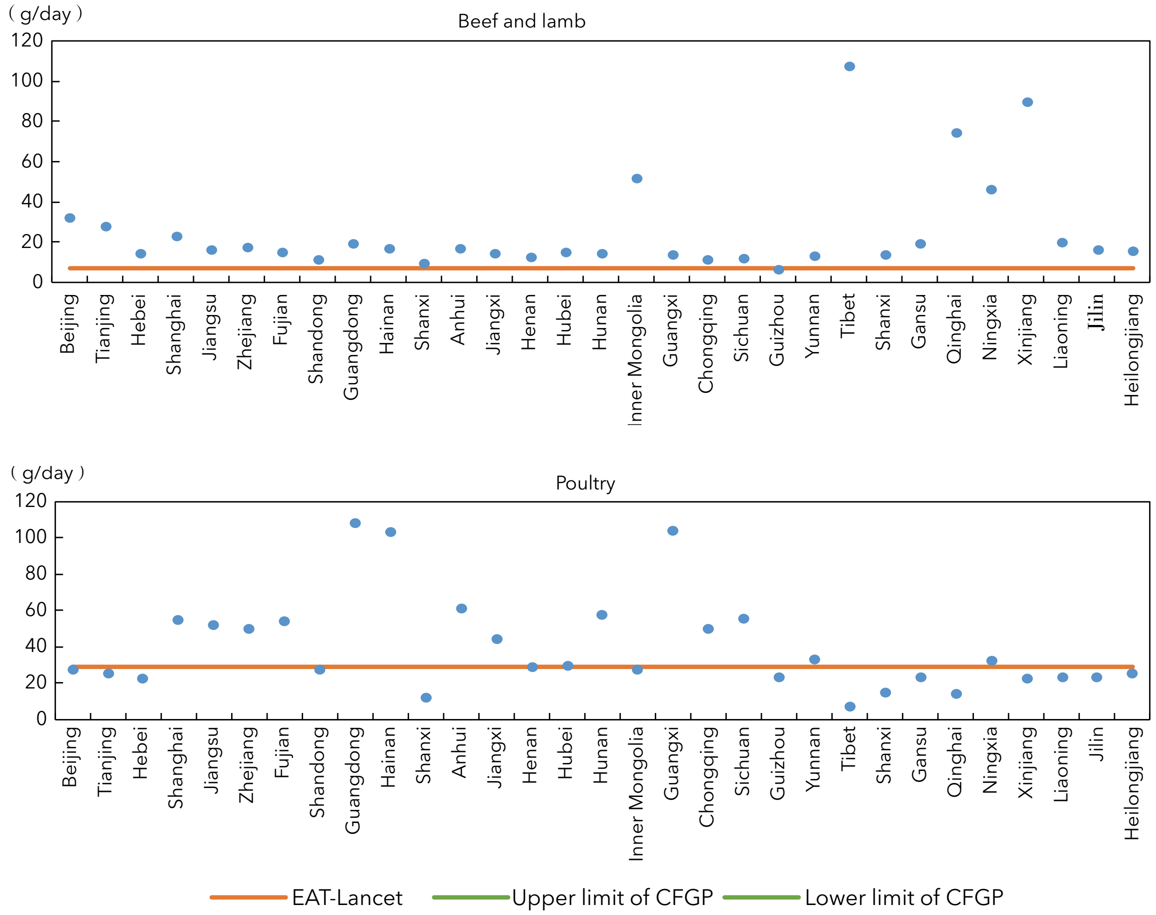


Source: *Per capita consumption is derived from China Statistical Yearbook (2020) and adjusted by out of home consumption ratio (see Appendix 1). The EAT-Lancet dietary standard comes from Food in the Anthropocene: the Eat-Lancet Commission on Healthy Diets from Sustainable Food Systems, and the the Chinese Food Guide Pyramid standard comes from the Chinese Nutrition Society.*

Note: CFGP = Chinese Food Guide Pyramid.

percent to 12 percent lower than the reference standard in 2010 if 25 percent to 100 percent of animal-source food were replaced by plant-based food. However, the largest decline would be witnessed in high-income countries, whereas middle-income and low-income countries would see almost no change by reducing consumption of animal-source food. Note that when plant-based foods are gradually substituted for animal-based foods, the protein content in the dietary structure declines. The protein intake of high-income and middle-income countries would remain sufficient without animal products, but low-income countries would face the problem of insufficient protein intake.

In spite of their ability to contribute toward improving the nutritional and health status of residents, the recommended diets discussed above are confronted with challenges in popularity and application. Part of the problem is that the recommendations do not consider the public's willingness to change traditional food culture. Food selection is significantly affected by the food culture, which is in turn determined by the population, agricultural production, purchasing power, eating habits, and cultural traditions of a country or region—and none of these can be changed easily (Yin et al. 2020). For example, in China, only about 15.3 percent of respondents expressed a willingness to lower their meat intake (Kan 2019). At the same time, many residents cannot afford nutritious food, which is normally high in cost (Dowler et al. 2007). About 230 million Chinese people cannot afford the average US$3.71 per day it would take to reach the dietary standards recommended by the Chinese Dietary Guidelines (Herforth et al. 2020).

3.5 Simulation Analysis of the Effects of Different Dietary Patterns on the Environment

In 2020, China made the 2060 carbon neutrality pledge at the United Nations General Assembly. To reach this goal, not only should technical measures be taken to lower carbon emissions, but also human behavior, such as dietary patterns, needs to be changed. Therefore we investigate whether the shift in Chinese residents' dietary patterns toward following healthy diet guidelines can contribute to carbon emission commitments, and if so, the magnitude of the contribution. We created a scenario for each of the four healthy diet standards discussed previously. Then we used the China Agriculture Sector Model (see section 2 of Appendix 2 for an introduction to the model), jointly developed by the Chinese Academy of Agricultural Sciences' Institute of Agricultural Economics and Development and the International Food Policy Research Institute (IFPRI), to analyze the different influences of adopting the CFGP, the EAT-Lancet diet, the Mediterranean diet, or the flexitarian diet on greenhouse gas emissions from agricultural activities.

3.5.1 Scenario Design

To begin with, we predict changes in food consumption demand by 2030 through recursive dynamics, with 2020 as the base year. For the benchmark scenario, we make a series of assumptions about future social and economic development, including factors such as population, economic development, residents' income, and technological progress. Next we design scenarios based on four dietary patterns: the CFGP, the EAT-Lancet diet, the Mediterranean diet, and the flexitarian diet. Each scenario assumes that between 2020 and 2030, Chinese urban and rural residents will gradually change their dietary habits to the specified dietary pattern. Note that the intakes of energy (calories) and the three major macronutrients (protein, fat, and carbohydrates) in the scenarios are set to satisfy the recommended intake range of the Chinese Dietary Reference Intakes 2013 even though the types and amounts of food consumed vary in the different simulation scenarios. See Appendix 6 for details on the design of the simulation.

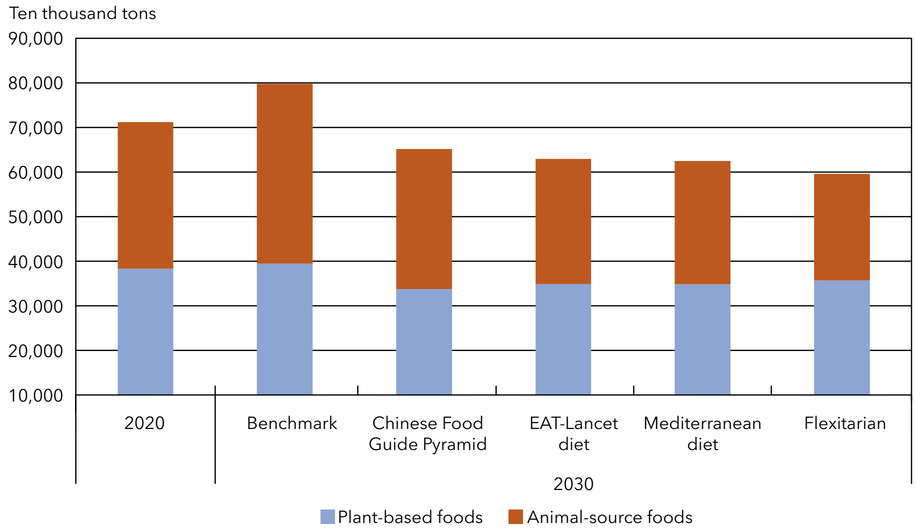
3.5.2 Simulation Results

Under the benchmark scenario, socioeconomic development and growth of income levels, without adoption of any dietary recommendations, will still contribute to changes in dietary patterns in China. By 2030, Chinese residents' grain consumption will have declined to 380 grams per capita per day, a decrease of 7.1 percent from 2020. Consumption of fruits, vegetables, beans, and animal-source foods will continuously increase, with meat and milk increasing to 177 and 67 grams per capita per day, respectively, up by 27.3 and 26.4 percent since 2020. The increased consumption of these foods might result in rising greenhouse gas emissions from agriculture. At the benchmark, therefore, changes in China's dietary pattern in 2030 will lead to an increase of 85.44 million tons of agricultural greenhouse gas emissions, up 12.0 percent in comparison to that of 2020.

In contrast, shifting the Chinese dietary pattern in line with the recommendations of the CFGP or of the EAT-Lancet, Mediterranean, or flexitarian diets would be efficient in reducing agricultural greenhouse gas emissions. The simulation results show that changing Chinese residents' dietary patterns to one of the four recommended diets by 2030 would reduce agricultural greenhouse gas emissions by 146 million to 202 million tons, or 18 percent to 25 percent, compared with the benchmark scenario. Specifically, the flexitarian diet would lead to the largest reduction in agricultural greenhouse gas emissions, about 202 million tons less than the benchmark scenario, followed by the Mediterranean and EAT-Lancet diets, which would reduce emissions by 173 million tons and 168 million tons, respectively. The CFGP would have the least effect on reducing agricultural greenhouse gas emissions but would still eliminate about 146 million tons of such emissions.

Under the healthy diet scenarios, the decline in meat consumption would contribute to a dramatic drop in agricultural greenhouse gas emissions, whereas an increase in milk consumption would offset part of this reduction. According to recommendations of the CFGP and the flexitarian diet, agricultural greenhouse gas emissions would be reduced by 172 million tons and 247 million tons, respectively, by 2030, amounting to 52.9 percent and 75.9 percent less than the benchmark scenario. However, a substantial increase in milk consumption would lead to an increase of 81 million tons

Figure 3.5 Agricultural greenhouse gas emissions under different dietary pattern scenarios



Source: *Author's construction using data from China Agriculture Sector Model results.*

of agricultural greenhouse gas emissions, offsetting part of the reduction from the decline in meat consumption. The results of the EAT-Lancet diet simulation show that agricultural greenhouse gas emissions in 2030 would be reduced by 179 million tons through the reduction of pork, beef, and mutton consumption, whereas the increase in milk consumption would lead to an increase of 59 million tons of emissions. Following the EAT-Lancet and Mediterranean diets, which are substantially similar in their recommendations for animal-source food consumption, would reduce agricultural greenhouse gas emissions by 31.5 percent and 30.3 percent, respectively, from the benchmark scenario.

Changes in the consumption of plant-based food would have less of an impact on agricultural greenhouse gas emissions, mainly due to the decline in such emissions brought about by the reduction in grain consumption. Under the healthy diet scenarios, China's grain consumption by 2030 would be anywhere from 14.5 percent to 31.6 percent less than under the benchmark scenario, causing agricultural greenhouse gas emissions to be reduced by 40.30 million tons to 52.31 million tons. However, due to insufficient baseline (2020) fruit consumption by Chinese residents, the increase in fruit consumption would lead to an increase in agricultural greenhouse gas emissions, of between 0.65 million tons and 5.37 million tons, compared with the benchmark scenario. Changes in the consumption of vegetables and legumes would also exert a small impact on agricultural greenhouse gas emissions.

3.6 Policy Recommendations for Promoting Health and Environmental Sustainability through Improving Chinese Residents' Dietary Pattern

The dietary pattern of the Chinese population has been remarkably improved in recent years, witnessing an increase in intake of animal-source food and quality protein, and a narrowing gap between urban and rural residents' nutrition. However, the transition of Chinese dietary patterns also poses health and environmental challenges. In particular, a tremendous increase in the rate of overweight and obesity has been observed among residents. In response to this challenge, it is urgent to change the Chinese dietary structure. A shift in Chinese dietary patterns based on recommendations of the Chinese Dietary Guidelines, the EAT-Lancet diet, the Mediterranean diet, and the flexitarian diet would not only improve the nutritional health of residents but also contribute to reducing agricultural greenhouse gas emissions. The following policy measures are recommended to promote such a shift in Chinese residents' dietary patterns.

First, residents should be guided to eat a healthy diet by improving their dietary patterns. Specifically, public education should spread knowledge of healthy diets, instructing residents in how to optimize their diets. In addition, dietary nutrition interventions should be implemented in key areas and among target populations to address the prominent problem of the fast growth of overweight and obesity. Moreover, subsidies should be provided for vulnerable groups to help them improve their dietary patterns and enhance their nutritional health levels (Xu et al. 2020).

Second, the agrifood systems should be transformed by adjusting the food supply structure as well as encouraging and supporting the development of a healthy and environmentally friendly food industry chain. Technologies should be enhanced to increase the production of foods rich in nutrition and reduce production costs so that residents can have easy access to nutritious food (Chen et al. 2019). By doing so, the negative impact of the agrifood systems on the ecological environment can be diminished even while ensuring sustainable food security in the context of maintaining nutrition and health.

Third, environmental sustainability should be incorporated into national programmatic and guidance documents, such as the Chinese Dietary Guidelines, Guidelines for Food and Nutrition Development in China, National Nutrition Program, and Healthy China Initiative, to establish a food security strategy steadily oriented toward nutrition, health, and sustainability. Moreover, a valid cooperating mechanism between governmental departments such as health, agriculture, and environmental protection should be proactively explored to jointly push forward food security, nutrition, and health, as well as sustainable development (Chen et al. 2019).

Fourth, investments in research on agriculture, nutrition, and the environment should be strengthened. Systemic studies on sustainability, food production and consumption, the economic benefits of nutrition and health, and the burden, prevention, and control of chronic diseases will provide a basis for China to formulate major policies (Chen et al. 2019).

It should be noted that there are some limitations in this chapter, which should be further studied in the future (see Appendix 7).

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Chapter 4

Nonpoint-Source Pollution Control and Greening of China's Agrifood Systems

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Key Findings

- The unsustainable agricultural production mode of "high input and high output" has imposed a heavy burden on China's ecosystems, and severely restricted the sustainable development of the country's agrifood systems. Taking long-term prevention and control of agricultural nonpoint-source pollution as the key approach can play an important role in upgrading country's agriculture to circular and renewable agriculture-food-ecological system circulation.
- Currently, the five major sources of agricultural nonpoint-source pollution in China are livestock, poultry and aquaculture; chemical fertilizers; pesticides; crop residues; and waste plastic films. The Chinese government has issued corresponding policies and measures to carry out prevention and control at the source and end, which have achieved initial results. Its accurate grasp of policy direction and policy implementation provide lessons for other developing countries.
- Several years of treatments have resulted in remarkable reduction of nitrogen and phosphorus emissions from the livestock and poultry farming, but the pollutant emissions of the aquaculture are increasing, and the utilization rate of chemical fertilizers and pesticides is still relatively low compared with that of developed countries.
- China mainly relies on policies and legal means, and government subsidies to control agricultural nonpoint-source pollution in the short term. However, more emerging options should be explored to establish a long-term mechanism to prevent and control agricultural nonpoint-source pollution and to transform the agrifood systems to become even greener, including property rights arrangements, interprovincial ecological compensation, green finance, and brand building for ecological agricultural products.

- China can learn from developed countries by paying more attention to product quality certification and market cultivation, and guiding the formation of a market premium for "eco-friendly" or "green" agricultural products, thus providing continuous incentives and motivation for the whole agricultural supply chain.

Recommendations

- Based on China's green agriculture development target, measures should be taken to strengthen the supervision of the agricultural ecological environment; to give full play to the important supervisory role of the government, enterprises, and social organizations in the process of environmental governance; and to promote the green transformation of the agrifood systems from the supply side.
- To establish and improve ecological compensation mechanisms, efforts should be made to learn from the interprovincial ecological compensation mechanism used for the Xin'an River, further expand the sources of funds, and establish an ecological compensation mechanism based on ecosystem services.
- An effort should be made to develop the branding of ecological agricultural products, guide the formation of a market premium for eco-friendly or green agricultural products, promote nonpoint-source pollution control from the demand side, and boost the green transformation of the agrifood systems.
- Stakeholders should actively seek funds through other channels to support the development of green agriculture and vigorously explore the application of green finance in the agricultural field.
- To benefit from technological progress, efforts should be made to establish a scientific and technological innovation and promotion system to support the transformation of the agrifood systems. The goal would be to design a model system of cleaner agricultural production technology as well as agricultural nonpoint-source pollution prevention and control technology suitable for China's national circumstances and agricultural conditions.

4.1 Green Transformation of the Agrifood Systems and Nonpoint-Source Pollution Control in China

A green transformation of China's agrifood systems is a crucial part of agricultural modernization with Chinese characteristics, and it is also a dynamic concept. Its connotation and extent are constantly changing with increased socioeconomic development, productivity, and technological progress. At present, an important approach for the green transformation of China's agrifood systems is to prevent and control agricultural nonpoint-source pollution and adopt an environment-friendly agricultural production mode. Severe problems caused by agricultural nonpoint-source pollution, such as degradation of water and soil resources, decline of cultivated land fertility, and heavy-metal pollution, have greatly hindered the sustainable development of China's agrifood systems and seriously threatened the nutrition security and health of urban and rural residents. Therefore, it is of great importance for the transformation of the agrifood systems to promote the development of agricultural green ecology through nonpoint-source pollution control.

Since the country's reform and opening up, China's agricultural production has developed rapidly, and its grain output has increased year by year, making great contributions to ensuring food security in China and the world. However, extensive agricultural production for a long time has exerted a significant impact on resources and the environment, resulting in the loss of water and soil resources, water pollution, heavy-metal pollution of cultivated land resources, and so on. Since the 1970s, China's water pollution problem has become increasingly severe, with important lakes and rivers (such as Taihu Lake, Chaohu Lake, Huaihe River, Haihe River, Three Gorges Reservoir Area, and others) experiencing different degrees of nitrogen and phosphorus eutrophication. The main reason for these effects is agricultural nonpoint-source pollution (Zhang et al. 2004; Chai et al. 2006), which includes pollution with chemicals such as those found in chemical fertilizers, pesticides, and agricultural films; nitrogen and phosphorus nutrients such as those found in crop residues, livestock manure, and domestic sewage; and garbage and other pollutants from agricultural production. Environmental pollution formed by surface runoff and leakage initially manifests as water pollution and then gradually extends to three-dimensional pollution of soil, air, and other media. It involves greater uncertainty and more complicated processes than other types of pollution, making it more difficult to treat (Chai et al. 2006; Li et al. 2010). To address this issue, changing agricultural production behavior is the key.

In this context, China has issued a range of policies to promote green development, among which the prevention and control of agricultural nonpoint-source pollution is the main policy focus. The annual No. 1 Document of the Central Committee clearly pointed out for the first time in 2016 that the green development of agriculture should be promoted from the viewpoints of protection and efficient utilization of agricultural resources, management of outstanding environmental problems, protection and restoration of agricultural ecology, and management of food safety. Since then, the document has put forward relevant opinions on the green development of agriculture every year. The Opinions on Innovating System and Mechanism to Promote Green Development of Agriculture, issued in 2017, provided programmatic guidance for promoting green development of agriculture, among which two goals related to prevention and control of agricultural nonpoint-source pollution (resource conservation and environmental friendliness) were clearly listed. In terms of concrete implementation, in March 2021, the Ministry of Ecology and Environment specially issued the Implementation Plan for Agricultural Non-point Source Pollution Control, Supervision, and Guidance (Trial) on how to control agricultural nonpoint-source pollution, focusing on the reduction of chemical fertilizers and pesticides, as well as the control of pollution from livestock and poultry breeding operations smaller than a designated size, to reduce the impact of agricultural nonpoint-source pollution on the ecological environment of soil and water. Obviously, the prevention and control of agricultural nonpoint-source pollution is a key approach for the green development of agriculture at this stage. After several years of prevention and control, the trend of agricultural nonpoint-source pollution has been curbed, but there remains a problem of low utilization of resources (Chinese Academy of Agricultural Sciences 2020).

4.2 Current Situation of Nonpoint-Source Pollution

As mentioned earlier, agricultural nonpoint-source pollution initially manifests as the pollution of a water body and then gradually extends to the comprehensive pollution of soil, air, and other media. There are five main sources of agricultural nonpoint-source pollution in China, including water pollution caused by livestock and poultry farming and aquaculture; water pollution caused by excessive use of chemical fertilizers; comprehensive pollution of soil, water, and air caused by pesticides; environmental pollution caused by random discarding or burning of crop residues; and soil pollution caused by waste plastic films that have not been recycled in time (China, Ministry of Agriculture 2017).

4.2.1 Discharge of Agricultural Water: Controlled to Some Extent but Still the Main Source of Agricultural Nonpoint-Source Pollution

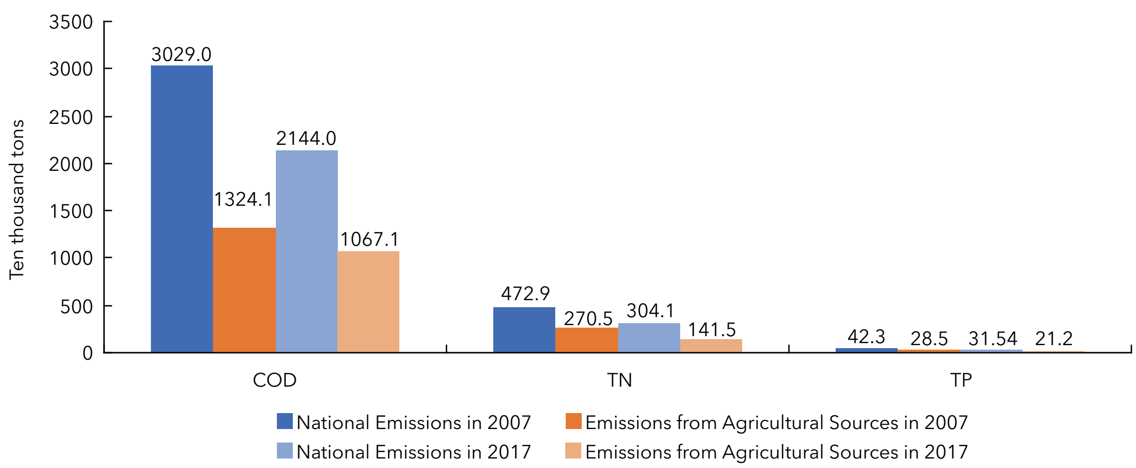
According to the Bulletin of the First National Survey of Pollution Sources, agricultural pollution sources were the main sources of chemical oxygen demand (COD), total nitrogen (TN), and total phosphorus (TP) in China in 2007, accounting for 44 percent, 57 percent, and 67 percent of these total national emissions, respectively (Figure 4.1). In 2012, the 12th Five-Year Plan for Energy Conservation and Emission Reduction, issued by the State Council, clearly required that agricultural COD and ammonia nitrogen emissions drop by 8 percent and 10 percent, respectively, by 2015, compared with 2010 levels. According to the 2020 Bulletin of the Second National Survey of Pollution Sources (Figure 4.1), the emissions of COD, TN, and TP from agricultural pollution sources had decreased by 19 percent, 48 percent, and 26 percent, respectively, by 2017 compared with 2007, but these are still the main pollution sources.

4.2.2 Nitrogen and Phosphorus Emissions from Livestock and Poultry Breeding Significantly Reduced, but Emissions of Aquaculture Increase

Within agriculture, livestock and poultry breeding have contributed the most COD and TP emissions, mainly from livestock and poultry manure. With the continuous development of animal husbandry, from 2007 to 2017, its COD emissions dropped from 12.683 million tons to 10.005 million tons, an emission reduction rate of 21 percent; TN emissions decreased from 1.024 million tons to 596,300 tons, an emission reduction rate of 48.8 percent; and TP emissions were down from 160,400 tons to 119,700 tons[7], an emission reduction rate of 51.4 percent (Figure 4.2).

[7]Tons are metric tons throughout the chapter.

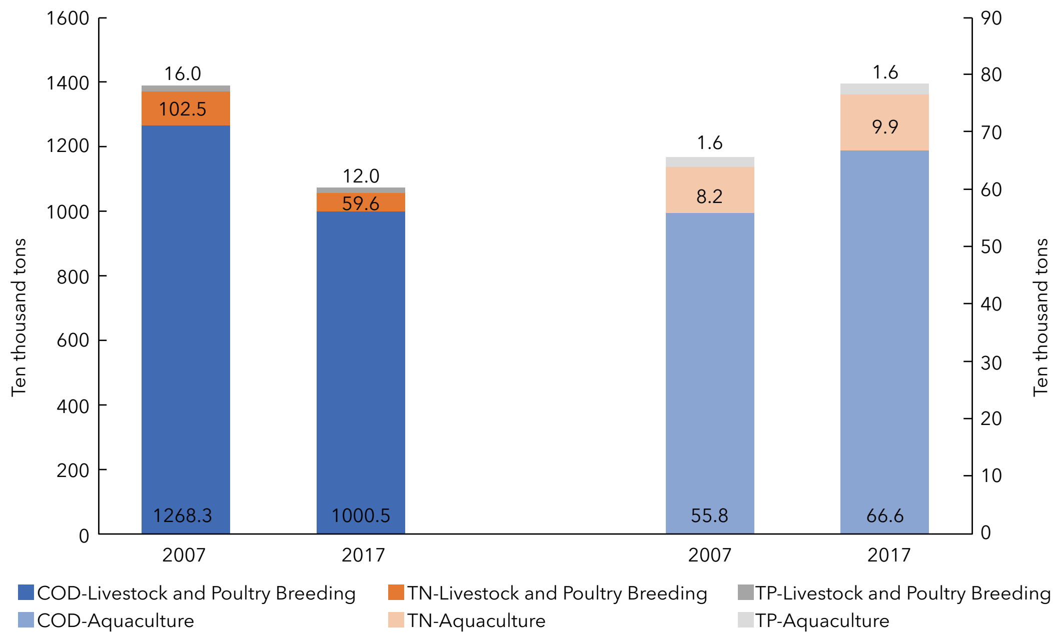
Figure 4.1 Total water pollutant discharge and agricultural-source discharge, 2007 and 2017



Source: *China, Ministry of Agriculture and Rural Affairs, Ministry of Ecology and Environment, and National Bureau of Statistics (2020); China, Ministry of Environmental Protection, State Statistics Bureau, and Ministry of Agriculture (2010).*

Note: *COD = chemical oxygen demand; TN =total nitrogen; TP = total phosphorus.*

Figure 4.2 Pollutant discharge from livestock, poultry, and aquaculture, 2007 and 2017



Source: *China, Ministry of Agriculture and Rural Affairs, Ministry of Ecology and Environment, and National Bureau of Statistics (2020); China, Ministry of Environmental Protection, State Statistics Bureau, and Ministry of Agriculture (2010).*

Note: *COD = chemical oxygen demand; TN =total nitrogen; TP = total phosphorus.*

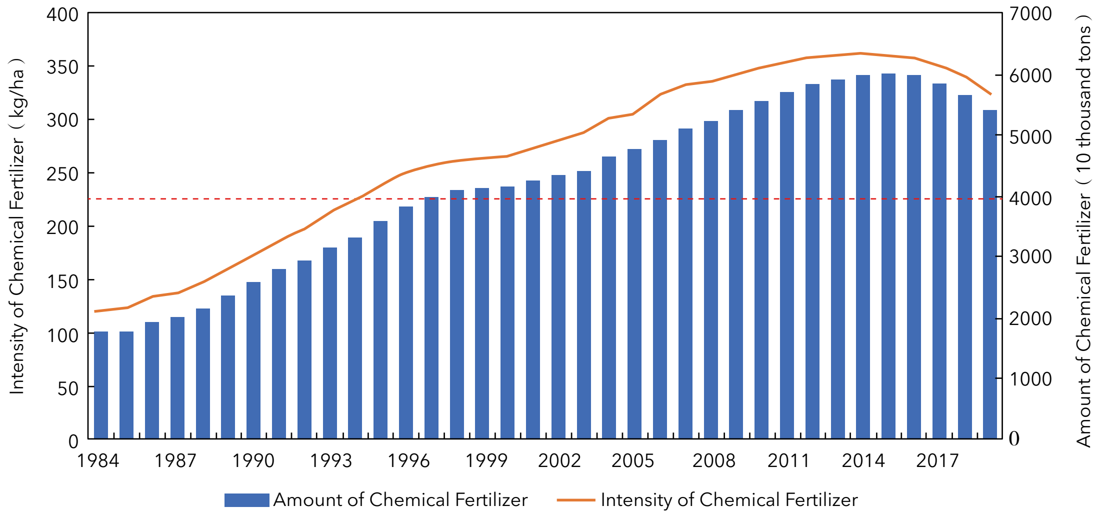
The pollutant emissions from aquaculture are not high in relation to those from agriculture overall, but the absolute amounts of COD, TN, and TP produced by aquaculture have increased (Figure 4.2). From 2007 to 2017, the COD produced by aquaculture rose from 558,500 tons to 666,000 tons, an increase of 19.7 percent; TN increased from 82,100 tons to 99,100 tons, an increase of 20.7 percent; and TP rose from 15,100 tons to 16,100 tons, an increase of 3.2 percent.

4.2.3 Initial Results in Reducing Use of Chemical Fertilizers and Pesticides, but Improvement Still Needed

Chemical inputs causing nonpoint-source pollution mainly include chemical fertilizers and pesticides. Excessive use of chemical fertilizers and pesticides not only increases production costs but also exerts negative impacts on the ecological environment. For this reason, the Ministry of Agriculture proposed the goal to achieve zero growth in the application of chemical fertilizers and pesticides to major crops by 2020. Figure 4.3 shows the application amount and intensity of chemical fertilizer in China from 1984 to 2019. Judging from the total application amount, the amount of chemical fertilizer maintained an increasing trend beginning in 1984, reaching a peak of 60.23 million tons in 2015, and has achieved negative growth for four consecutive years since then. In 2019, the amount of chemical fertilizer applied reached 54.04 million tons, a drop of more than 10 percent compared with the peak. The application intensity of chemical fertilizer (that is, the amount applied per unit of sown area) has continuously increased since 1984, reaching a peak of 363 kg/ha in 2014, far exceeding the 225 kg/ha recommended internationally as the safe application level. In 2019, the intensity of chemical fertilizer application in China was 326 kg/ha, which was 10.3 percent lower than that in 2014. In terms of fertilizer utilization rate by crop, the utilization rate for rice, corn, and wheat in China was 37.8 percent in 2019, 2.6 percentage points higher than that in 2015, but there is still a gap compared with the utilization rate of 50–65 percent of food crops in developed countries in Europe and the United States (China News 2017).

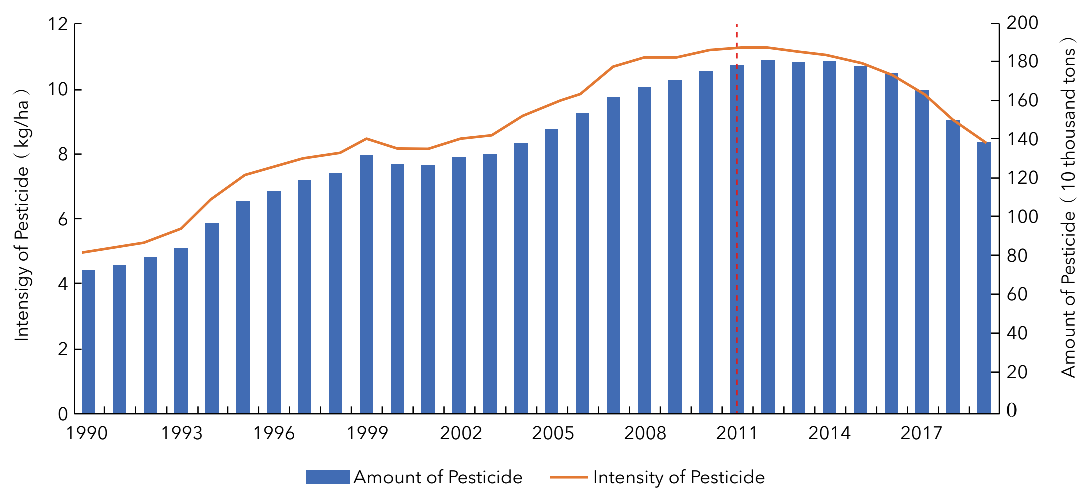
Figure 4.4 shows the use of pesticides in China from 1990 to 2019. In terms of total use, the amount of pesticides increased from 780,000 tons in 1990 to 1.81 million tons in 2014, a growth rate of 147 percent. Since then, however, it has witnessed negative growth for five consecutive years, with usage decreasing to 1.39 million tons in 2019, a decrease of 23 percent compared with the peak in 2014. Use intensity continuously increased until 2011, when it reached a peak of 11.7 kg/ha, and then fell to 8.4 kg/ha in 2019, a drop of 26 percent compared with the peak. In terms of the utilization rate by crop, utilization for rice, corn, and wheat in China reached 39.8 percent in 2019, 3.2 percent higher than that in 2015, but there is still a gap compared with the 50–60 percent pesticide utilization rate on wheat, corn, and other food crops in developed countries in Europe and the United States(China News2017).

Figure 4.3 **Application amount and intensity of chemical fertilizers in China, 1984–2019**



Source: *China Statistics Press (various years).*

Figure 4.4 **Pesticide use and intensity in China, 1990–2019**



Source: *China Statistics Press (various years).*

4.2.4 Improvement in the Recovery and Utilization Rate of Crop Residues

In 2015, the resources of major crop residues in China were 1.04 billion tons, the collectable resources were 900 million tons, 720 million tons could be utilized, and the comprehensive utilization rate of crop residues was 80.1 percent. In 2017, the output of crop residues was 810 million tons, down by 22.1 percent compared with 2015, and the collectable resources of crop residues were 674 million tons, down by 25.6 percent compared with 2015. The comprehensive utilization rate of crop residues in China in 2017 exceeded 82 percent, up by 1.9 percent compared with 2015. Basically, a comprehensive utilization pattern has been formed whereby fertilizer utilization is dominant, feed and fuel utilization are steadily promoted, and base materials and raw materials are auxiliary components.

Table 4.1 Utilization of major crop residues in China, 2015 and 2017

Year	Crop residues production (100 million tons)	Collectable resources (100 million tons)	Crop residues utilization rate (%)
2015	10.4	9.0	80.1
2017	8.1	6.7	82.0
Rate of change	-22.1%	-25.6%	1.9%

Source: *China, Ministry of Agriculture and Rural Affairs, Ministry of Ecology and Environment, and National Bureau of Statistics (2020); China, Central Government Portal (2016).*

4.3 Policy Practices for Green Transformation of the Agrifood Systems and Nonpoint-Source Pollution Control

Green agricultural development is not only a choice for facing objective ecological environment constraints, but also a policy put into practice by the Chinese government. In view of the current sources of agricultural nonpoint-source pollution, the government has issued corresponding policies and measures to prevent and control nonpoint-source pollution at the source and end. According to the public policy theory of environmental economics, China's policies to prevent and control nonpoint-source pollution can be divided into two types: economic incentive policies and encouragement and persuasion policies. Economic incentive policies are the main measures being taken to promote green agricultural development. These subsidies-based policies may reduce the burden on technology adopters and play an important role in the promotion of technologies for reduction of chemical fertilizer and pesticide use, as well as greater utilization of crop residues and manure resources. Encouraging and persuading policies are a crucial support to promote green agricultural development. The promotion of green agricultural technology cannot be separated from training and publicity. Farmers who have received technical training often have greater acceptance of green agricultural technologies. Some policy measures that address specific sources of nonpoint-source pollution and a typical case of institutional arrangement (Box 4.1) are introduced below.

4.3.1 System for Reducing Agricultural Inputs

Formula fertilization by soil testing. The Ministry of Agriculture and the Ministry of Finance started to fund a project for formula fertilization by soil testing in 2005, arranging special subsidy funds to comprehensively promote the development of formula fertilization by soil testing and encourage and support farmers to apply fertilizer scientifically. Subsidies were distributed to agricultural technology promotion agencies that undertake the task of formula fertilization by soil testing and enterprises that process formula fertilizers according to formula so as to facilitate their soil testing, fertilizer formulation and distribution, and other links, as well as project management. In 2019, the fertilizer utilization rate on China's three major grain crops was 39.2 percent, and with more than 3,000 intelligent service outlets for formula fertilization by soil testing nationwide, the technical coverage rate of formula fertilization by soil testing reached 89.3 percent. Although the existing policies have achieved certain results, some studies have shown that the ecological benefits of popularizing multiple-formula fertilizers are greater than those of single-formula fertilizers, but their adoption rate is lower due to cost constraints (Sun et al. 2019). Therefore, when promoting formula fertilization, the agricultural sector should consider the high cost of precision inputs and the negative impact of too many varieties of fertilizer for farmers to choose from.

Substitution of organic fertilizer for chemical fertilizer. In 2017, the Ministry of Agriculture and Rural Affairs formulated the Action Plan for Replacing Chemical Fertilizer with Organic Fertilizer in Fruit, Vegetable, and Tea, and selected a number of key fruit-, vegetable-, and tea-growing cities and districts to carry out demonstrations of replacing chemical fertilizer with organic fertilizer. Subsidies were adopted to encourage farmers to apply more organic fertilizers. Meanwhile, regular technical training on replacing chemical fertilizers with organic fertilizers was held to guide large growers to actively participate in the composting and application of organic fertilizers. In 2020, the application area of organic fertilizer exceeded 37 million ha, an increase of about 50 percent over 2015 (Ministry of Agriculture and Rural Affairs of China 2021). Although the existing policies have achieved some results, government subsidies are more effective at promoting the use of organic fertilizer by farmers. In addition, early data show that farmers have not reduced the amount of chemical fertilizer due to the application of organic fertilizer (He et al. 2006), and academia should still pay attention to the substitution effect of organic fertilizer in reality. Furthermore, organic fertilizer is mainly used in cash crops such as fruits, vegetables, and tea, and the adoption rate of organic fertilizer for field crops is relatively low, so it is necessary to gradually promote the diffusion of organic fertilizer technology to field crops.

Green pest control. In 2011, the Ministry of Agriculture promoted the quality and safety improvement of agricultural products by adopting environment-friendly measures such as ecological regulation, biological control, physical control, and scientific medication to control the harm caused by crop diseases and insect pests. It is required that by 2020, the overall coverage rate of green prevention and control of pests and disease in major crops in China reach more than 60 percent (China, Central Government Portal 2012). The implementation of green prevention and control technology can reduce the applications of chemicals for field crops by about 1–2 times per season and for fruit trees and vegetables by approximately 3–4 times per season, reducing the overall amount of chemical pesticides used by around 20–30 percent (Pesticide Express Information Network 2018). However, the application of green prevention and control technology is widely scattered geographically. Therefore, the government should take socialized service as an important starting point for implementing green prevention and control, build a public service platform, speed up the construction of socialized service bases, and carry out socialized services for green prevention and control of pests and diseases. Besides these actions, the government should establish and improve a subsidy mechanism for biopesticides, and give reasonable subsidies to farmers who adopt this measure (Zhou et al. 2016).

Reduced use of veterinary antibacterial drugs. In 2018, the Ministry of Agriculture and Rural Affairs began a program to achieve "zero growth" in the use of veterinary antibacterial drugs over three years, and effectively control veterinary drug residues and the drug resistance of animal bacteria. Every year, no fewer than 100 large-scale farms have been organized to carry out pilot work and promote different modes to reduce the use of veterinary antibacterial drugs. Farms participating in the pilot work should use veterinary antibacterial drugs in a standardized, reasonable, scientific, and prudent manner; actively explore the use of veterinary antibacterial drugs substitutes; and gradually reduce the variety and amount of growth-promoting veterinary antibacterial drugs. A large number of large-scale farms adopted the contract farming mode of "company + farmer," which encourages contract farmers to adopt antibacterial substitutes through technical training, and has achieved initial positive results in reducing the use of antibacterial drugs.

4.3.2 Utilization of Crop Residues and Livestock Manure Resources

Utilization of crop residues resources. In recent years, the Chinese government has successively issued policies such as Opinions on Accelerating Comprehensive Utilization of Crop Residues(2008), Implementation Plan for Comprehensive Utilization of Crop Residues in the 12th Five-Year Plan (2011), and Guiding Opinions on Compiling Implementation Plan for Comprehensive Utilization of Crop Residues in the 13th Five-Year Plan (2017) to promote comprehensive utilization of crop residues. Since 2016, 2.5 billion RMB[8] has been invested to carry out pilot projects for comprehensive utilization of crop residues. In 2017, a total of RMB 457 million of subsidy funds was arranged for the purchase of crop residues crushing and returning machines, and picking and baling machines to support the work of returning crop residues to the field. Under the active promotion of policies, the comprehensive utilization rate of crop residues in China has exceeded 82 percent. Research shows that long-term land rights can encourage large-scale households to return crop residues to the field, but for small farmers, policies such as subsidies or penalties need to be adopted (Xu et al. 2019).

Utilization of manure resources. In 2017, the General Office of the State Council issued Opinions on Accelerating the Resource Utilization of Livestock and Poultry Breeding Waste, proposing the policy objectives of establishing a resource utilization system of livestock and poultry breeding waste, building a breeding cycle development mechanism, and achieving a comprehensive utilization rate of livestock and poultry manure of more than 75 percent nationwide by 2020. In 2017 and 2018, the Ministry of Agriculture successively formulated specific resource utilization plans for livestock and poultry manure. By 2019, the comprehensive utilization rate of livestock and poultry manure in China had reached 70 percent, and the matching rate of manure treatment facilities and equipment in large-scale farms had reached 63 percent. The government should further establish standards for the storage and treatment of livestock and poultry manure, which can improve the level and combination of planting and breeding, and strengthen the recycling of livestock and poultry manure.

Recycling of waste agricultural film. In 2017, the Ministry of Agriculture formulated the Agricultural Film Recycling Action Plan. In 2019, six ministries and commissions issued the Opinions on Accelerating the Prevention and Control of Agricultural Film Pollution to promote the promulgation and implementation of new national standards for plastic films, improve the thickness standards of plastic films, increase the tensile strength and elongation at break of plastic films, and ensure the recyclability of plastic films from the source. Under these opinions, local governments should promote the mechanization of plastic film picking; increase subsidies for plastic film recycling machines and tools; and demonstrate and promote use of one film for multiple purposes, inter-row covering, and other technologies. In 2020, the recovery rate of agricultural film in key areas of northwestern China was stable at more than 80 percent, and "white pollution" was effectively controlled. Although some government departments have incorporated farmers' compensation measures into the agricultural film recycling policy in recent years, there are still some phenomena such as unreasonable compensation methods and low compensation amounts.

4.3.3 A Healthy Aquaculture System

Opinions on Innovating System and Mechanism to Promote Green Development of Agriculture, issued in 2017, proposed to promote a healthy aquaculture system. In 2018, the Ministry of Agriculture and Rural Affairs launched a national demonstration of healthy aquaculture, promoting the protection and restoration of the aquaculture ecological environment by creating healthy aquaculture demonstration counties and demonstration farms. Subsequently, in 2019, 10 ministries and commissions issued several opinion documents on accelerating the green development of aquaculture, advocating ecological and healthy aquaculture systems to give full play to the ecological service function of aquaculture. Environmental protection facilities and equipment were fully popularized on demonstration farms in demonstration counties, so as to purify water for fishing, realize self-control and self-inspection in key links such as disease prevention and control and aquaculture wastewater treatment, and continuously improve the quality and efficiency of aquaculture. The government provided financial support for the treatment of aquaculture tail water. At present, 1,005 national-level demonstration farms for healthy aquaculture have been built in China, greatly promoting the high-quality development of fisheries.

[8] 1 RMB ≈ 0.15 USD

Box 4.1 Innovative Property Rights Systems and Agricultural Nonpoint-Source Pollution Control

Pollution is a negative externality, and the purpose of pollution control can be achieved by improving the property rights system. The essence of the current system of property rights is to internalize negative externalities and transform public goods into private goods. One goal of perfecting the property right system of resources is to create an environmental protection system. In this respect, Zhejiang Province has taken the lead by piloting useful experiences and practices. This case takes Deqing County of Zhejiang Province as an example for discussion.

Deqing County, Zhejiang Province, focused on the principle of "three rights" for people or households and the idea that these rights to "follow" people or households. Therefore the county comprehensively promoted the certification of contractual management rights, homestead usufructuary rights, and collective assets equity rights to land (including forestland), and established a rural property rights transfer trading center. Of all land in the county, 76 percent was transferred efficiently, promoting the development of modern ecological circular agriculture.

Deqing County took rural property rights reform as an opportunity to accelerate the ban on crop residues burning as well as promote the comprehensive utilization of crop residues; deepen the recycling and disposal of waste packaging of agricultural inputs; vigorously promote the establishment of ecological recycling demonstration areas, demonstration subjects, and demonstration sites; and build a main small cycle and a county large cycle for harmless treatment and resource utilization of waste packaging of crop residues and pesticides. Moreover, it has made great efforts to promote various new farming systems such as water-saving, land-saving, fertilizer-saving, energy-saving, and medicine-saving technologies as well as recycling of agricultural waste resources. It has promoted a number of new, ecological, and efficient planting and breeding modes, such as rice-turtle symbiosis, rice-fish symbiosis, and similar integrated systems of agriculture and animal husbandry for thousands of hectares.

The amount of chemical nitrogen fertilizer applied has been reduced by 6.5 percent and the amount of chemical pesticides by 9.3 percent; moreover, the county reached 100 percent harmless treatment and resource utilization of livestock and poultry manure, 95 percent comprehensive utilization of crop residues, 90 percent recovery of pesticide input packaging materials, and 100 percent proper disposal, basically achieving the goal and task of "one control, two reductions, and three basics."[9]

Source: Zhejiang News (2015).

4.4 International Experiences in Controlling Nonpoint-Source Pollution and Promoting the Green Transformation of the Agrifood Systems

With the escalation of global agricultural nonpoint-source pollution, promoting the sustainable development of agriculture and the welfare of the ecological environment has become the focus of agricultural development in various countries. Countries worldwide have accumulated valuable experiences in chemical fertilizer reduction, moderation in the use of pesticides, management of livestock and poultry manure, monitoring and protection of water resources, and exploration of development modes in sustainable agriculture.

4.4.1 Fertilizer Reduction

Nonpoint-source pollution from agricultural fertilizer leads to eutrophication of water bodies and excessive nitrates in groundwater, posing a grave threat to the water and soil environment and ecosystem. Since 1990, the EU's Common Agricultural Policy has gradually attached importance to the protection of the agricultural environment. In 1991, the EU Nitrate Directive was promulgated, requiring member countries to take actions to reduce the impact on water bodies of nitric acid fertilizer use, and barring farmers who failed to meet the standards in particularly vulnerable areas from receiving relevant subsidies. Compared with the early 1980s, EU countries have reduced the variety and use of agricultural chemical fertilizers by 30 percent and 50 percent, respectively (Fu 2017). Since the 1990s, the Netherlands has successively implemented five nitrate fertilizer action plans, and farmers who fail to meet the standards

[9] Control of total agricultural water consumption, reduction of chemical fertilizers and pesticide applications, and basic utilization of plastic film, straw, and livestock manure.

must pay taxes (Zhang and Jin 2020). According to the principle of farmers' voluntary participation, the British government signed an environmental improvement agreement with farmers, specifying that they would gradually reduce or eliminate the use of chemical fertilizers within five years, and compensation would be given for the losses caused. In the process of fertilizer reduction and agricultural nonpoint-source pollution control, the United States mainly relied on best management practices (BMPs)—that is, any method, measure, or operating procedure that can reduce or prevent water pollution. The US federal government has allocated funds to give certain agricultural subsidies, technical support, or financial concessions to farmers who voluntarily participate in the BMPs system. Several state governments in the United States have also established a sampling inspection system for chemical fertilizers to ensure fertilizer quality. At the same time, the United States vigorously promoted technologies including soil testing and formula fertilization, water and fertilizer integration, replacing chemical fertilizer with organic fertilizer, and so on. After more than 20 years of effective treatment and control, agricultural nonpoint-source pollution in the United States decreased from 66–83 percent of total agricultural pollution in 1990 to 20 percent in 2014 (Fu 2017).

4.4.2 Moderation in the Use of Pesticides

Pesticide application can effectively reduce the loss of world grain output due to diseases, insects, and weeds. Although pesticide application is scattered, it is also continuous, and the environmental pollution it causes is more hidden than pollution from other sources because of the time lag between its use and the appearance of its effects. It has long been a common goal of most countries in the world to reduce their environmental pollution and agricultural product residues. The Dutch government restricts the use of pesticides through legislation and also actively supports the research and development of applicable high-efficient, low-residue pesticides as well as biological pesticides (Zhang and Jin 2020). All states in the United States implement a unified pesticide use management system: Farmers must have written recommendation reports provided by pest control consultants to purchase or apply restricted pesticides, or to carry out professional and socialized pesticide spraying services. Within one week after applying ordinary or restricted pesticides, a farmer must report the specific information about the pesticide application to the county pesticide correspondent. No pesticide application is allowed within approximately 45–60 days before harvest, and all agricultural products or foods must be marked with pesticide residue values (Guo et al. 2015). In 2016, Israel's Ministry of Agriculture Rural Development updated its standards, requiring all veterinary pesticides and disinfectants sold on the market to be registered.

4.4.3 Livestock and Poultry Manure Treatment

Considering the negative effects of livestock manure on the environment, most countries have imposed strict regulations on its recycling and nutrient extraction and application. The EU Nitrates Directive clearly promotes the application of livestock and poultry manure, and EU countries formulate specific standards in line with local conditions (Khoshnevisan et al. 2021). The control of livestock and poultry pollution also involves control of sulfur dioxide, nitrogen oxides, nonmethane volatile organic compounds, and ammonia volatilization (European Parliament and Council of the European Union 2016). The UK has formulated a clean air strategy to reduce ammonia emissions from the storage and treatment of livestock and poultry manure as well as from the application of chemical fertilizers. Countries including Austria, Canada, Estonia, Greece, Malaysia, and others have clearly stipulated the upper limit for heavy metals in organic fertilizers (mainly livestock manure). Sweden's Zero Eutrophication policy clearly states that livestock manure can be applied only during the growing season of crops and that its application is restricted or prohibited near water bodies. The governments of Denmark and Germany support and develop biogas technology for the utilization and recycling of livestock manure.

The Netherlands formulated a national environmental policy plan for livestock and poultry breeding in 1989, which requires controlling the environmental pollution caused by livestock and poultry breeding from three aspects: (1) in terms of total amount control, it is forbidden to build new farms and expand existing scale at will; (2) in terms of structural adjustment, the number of livestock and poultry must be matched with the pasture planting area and land self-purification ability within the region; and (3) in terms of manure discharge treatment, farms and companies must apply for manure discharge permits and pay manure treatment fees if they exceed a threshold. The government assisted in establishing livestock and poultry manure trading markets, and it supports the establishment of large manure treatment plants. After nearly 40 years of treatment, livestock and poultry manure in the Netherlands has been effectively utilized as a resource, and environmental pollution has decreased significantly. At the same time, the country's agriculture maintains outstanding international competitiveness (Zhang and Jin 2020).

The United States requires large-scale farms to comply with the Comprehensive Nutrient Management Plan. Farms should apply for pollution discharge permits, and formulate plans for manure storage, land management practices, nutrient management, and so on to promote the integration of crop planting and livestock breeding (De and Bezuglov 2006).

4.4.4 Monitoring and Protection of Water Resources

Most parts of the world are facing the pressure of water pollution, especially areas with intensive agriculture and high population density. In 2000, the European Union issued the Water Framework Directive, which mainly aimed at nitrogen, phosphorus, and other chemical pollutants from pesticides and fertilizers, as well as heavy metals, and established comprehensive supervision of underground and surface water resources. Members were required to formulate watershed plans and govern them based on geographic and hydrologic boundaries, rather than administrative boundaries (Wiering, Boezeman, and Crabbé 2020). The Dutch government has established a monitoring system for water sources that requires the agricultural sector to enhance its supervision, requires agricultural producers to keep detailed input-output records, and introduces stricter agricultural resource input standards as well as a supervision system (Zhang and Jin 2020). New Zealand has also promoted community collaboration to implement its national policy statement on freshwater management by developing Supervisor® software to measure parameters such as nutrient use and farm profitability. In addition, the Clean Water Act of the United States plays a fundamental role in the prevention and control of pollution from aquaculture.

4.4.5 Exploration on Development Modes to Pursue Sustainable Agriculture

Countries have also actively explored and promoted the sustainable development and transformation of agriculture (Box 4.2). The reform of the EU Common Agricultural Policy in 2003 decoupled agricultural subsidies from output. The condition for farmers to receive income subsidies is to meet the standards of food safety, environmental friendliness, and animal health and welfare. In the 2013 reform, it was proposed that all member states be required to dedicate 30 percent of their direct payments for green direct payments (European Commission 2021; Laborde et al. 2020). The Dutch government launched a sustainable development agenda in 2011, calling for the establishment of a sustainable agricultural industry and food supply system. In 2016, it put forward the Circular Economy 2050 plan, calling for the construction of a large, circular system among the planting, horticulture, animal husbandry, and fishery industries, and the realization of 100 percent recycling of agricultural and food wastes by 2050 (Netherlands, Ministry of Agriculture, Nature and Food Quality 2018).

Japan has vigorously promoted a certification system for organic agricultural products and ecological farmers since 2000. In 2006, it passed the Organic Agriculture Promotion Law and defined the specific standards for environment-friendly agriculture and agricultural products. Since 2007, farmers who have adopted environmentally friendly production methods in Japan can apply for interest-free loans, tax relief, and other policies from the government and the Agricultural Assistance Bank. Since 2011, environment-friendly farmers can also receive direct payment subsidies from the central government. According to the statistics of the Japanese government, there were 51,000 ecological farmers in Japan in 2000 and 210,000 in 2011 (Fu 2017). The United States promulgated the Farm Security and Rural Investment Act in 2002 and the Food, Conservation, and Energy Act in 2008 to subsidize and support organic agriculture and green agricultural development through the implementation of ecological protection subsidy programs. These examples show the ways in which the governments of various countries actively promote the sustainable intensification of agriculture and seek the triple-win goals of yield, efficiency, and environment. Bioagricultural technology, conservation agriculture, ecological agriculture, and organic agriculture can all be used to achieve the goal of sustainable yield increase and high efficiency (Godfray and Garnett 2014).

Box 4.2 Global Synergy between Nature Conservation and Climate Change

In concert with the Paris Agreement, the Global Plan to Conserve Nature was first proposed by researchers in 2017, describing the conditions needed to maintain a livable planet. The plan requires protection and sustainable management of half of the Earth's land and sea by 2030, which means that protection activities in all countries must go hand in hand and strive to limit global warming to 1.5℃ higher than the preindustrial level.

The seventh plenary meeting of the Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services took place in Paris in May 2019. The meeting reviewed and adopted the Global Assessment Report on Biodiversity and Ecosystem Services. The assessment results will also provide an important scientific basis for the formulation of the global biodiversity framework after 2020. The 15th Conference of the Parties to the Convention on Biological Diversity (COP15), to be held in Kunming, China, in 2021, will review the framework and discuss ecological protection goals for the next decade.

Source: Chinese Science News (2019); China, Ministry of Ecology and Environment (2019).

4.4.6 Experiences

The policies and mechanisms involved in controlling agricultural nonpoint-source pollution and promoting a green agricultural transformation in various countries worldwide provides valuable insights for China and other developing countries. The experiences can be summarized as changing farmers' behavior; promoting the research, development, and adoption of agricultural technology; and cultivating markets for ecological agricultural products.

First, through laws and regulations, index standards, policy planning, subsidies, and taxes, countries directly affect farmers' production behavior or impact their inputs and production costs to indirectly affect their decision making. For example, the Netherlands has fully implemented pesticide reduction, ban, and restriction plans through legislation, which regulated and changed farmers' pesticide application behavior. The United States has given certain agricultural subsidies to farmers who participate in a BMPs system, to change their production behavior in relation to agricultural chemical inputs.

Second, efforts should be made to actively support and strengthen the promotion and application of recycling technology. For example, the United States has promoted technologies such as soil testing and formula fertilization, water and fertilizer integration, and organic fertilizer, whereas the Danish and German governments have supported and subsidized biogas technology.

Third, the certification of ecological agricultural products and market cultivation will support a price premium for ecological/green agricultural products, creating a continuous incentive and motivation for the entire agricultural supply chain. Along these lines, the EU provides subsidies for farmers conducting organic production and eco-friendly agriculture, and Japan have has developed a sound certification system for organic agricultural products and ecological farmers.

4.5 Policy Suggestions on Accelerating the Green Transformation of the Agrifood Systems and the Control of Nonpoint-Source Pollution in China

The unsustainable agricultural production mode of "high input and high output" has placed a heavy burden on China's environment, severely restricted the sustainable development of its agrifood systems, and threatened the food, nutrition, and health of its urban and rural residents. Taking long-term prevention and control of agricultural nonpoint-source pollution as the starting point, it will play an important role in promoting an upgrade to circular agriculture, renewable agriculture, and agriculture-food-ecological system circulation.

First, based on China's agricultural green development index, measures should be taken to strengthen agricultural ecological environment supervision and public participation. The involvement of China's agricultural green development index system and the construction of a green development index provide a real and reliable scientific basis for nonpoint-source pollution control and for decision makers to evaluate the effect of agricultural green development policies (Chinese Academy of Agricultural Sciences 2020). Meanwhile, China's environmental governance is based on a task-oriented responsibility system, whereby the central government achieves its purpose of pollution control by assessing the environmental governance of local governments. Local governments, however, may encounter implementation difficulties under the dual pressures of economic growth and environmental assessment. In this process, the investigation and supervision of the higher-level government is of great importance (Zhang, Chen, and Guo 2018). In addition, attention should be paid to supervision from social organizations, private enterprises, and the public. It is necessary to promote the disclosure of environmental information, protect and give full play to the public's right to know and supervise the environment, and enable third-party organizations other than the government and enterprises to play an important role in guiding public supervision in the process of environmental governance (Anderson et al. 2019).

Second, efforts should be made to establish and improve the ecological compensation mechanism. At present, the European Union and others have made useful explorations into ecological service payments, especially through making full use of market mechanisms to form a multi-type ecological compensation system framework including such components as one-to-one transactions, public compensation, and product ecological certification. China has already established relevant laws and regulations on sewage charges and the construction of ecological compensation mechanisms. For example, upstream and downstream financial transfer payment arrangements have been built into the interprovincial ecological compensation pilot projects in Zhejiang and Anhui (Box 4.3). However, China also should learn from foreign experience, expand funding sources, and establish an ecological compensation mechanism for ecosystem services through the direct participation of a wider range of stakeholders and economic actors.

Box 4.3 Interprovincial Ecological Compensation and "Gambling" on Water Conservation between Anhui and Zhejiang

Nonpoint-source pollution has externalities and therefore needs interregional collaborative treatment. In 2012, under the guidance of the central Ministry of Finance and Ministry of Environmental Protection, Anhui Province and Zhejiang Province jointly promoted the implementation of an ecological compensation mechanism in the Xin'an River Basin and set up a compensation fund of RMB 500 million[10] per year, of which RMB 300 million[11] was from the central government and RMB 100 million[12] each was contributed by Anhui and Zhejiang Provinces to assess and improve the quality of the Xin'an River. If the annual water quality meets the assessment standard, the downstream Zhejiang Province allocates RMB 100 million to the upstream Anhui Province; otherwise, the opposite is true. This is the first pilot project of an ecological compensation mechanism in interprovincial watersheds in China. During the first three-year pilot project, the water quality of Xin'an River remained excellent, and the eutrophication challenge of Qiandao Lake in Zhejiang Province was tackled. In 2018, Anhui and Zhejiang Provinces signed the Agreement on Horizontal Ecological Compensation in Upstream and Downstream of Xin'an River Basin, completed the third round of pilot renewal, and explored more compensation methods as well as joint prevention and treatment of upstream and downstream waters on the basis of monetized compensation. Thus the "Xin'an River Model" became normal and sustainable, and was replicated and promoted in six river basins and 10 provinces across the country.

Source: Xinhua News (2020).

[10] It's approximately equal to 77.25 million US dolloars.
[11] It's approximately equal to 46.35 million US dolloars.
[12] It's approximately equal to 15.45 million US dolloars.

Third, efforts should be made to make full use of the market, guiding the formation of a market premium for ecological/green agricultural products through product certification and brand building, thus forming continuous incentives and motivation for the entire agricultural supply chain. The government should help overcome the information asymmetry between producers and consumers, and transform the food supply chain to make it more demand-driven. For example, Lishui City, Zhejiang Province, explored building a regional public agricultural brand, thus mobilizing market forces and increasing the premium for ecological agricultural products (Box 4.4).

Box 4.4 Lishui, Zhejiang Province, Builds a Regional Public Agricultural Brand and Elevates the Value of Ecological Agricultural Products

In recent years, food safety and ecological problems have occurred frequently, and consumers' demand for pollution-free and eco-friendly, or "green," agricultural products is constantly increasing. In 2014, Lishui City, Zhejiang Province, gave full play to the ecological and environmental advantages of having more mountains than water and fields, by integrating local ecological fine agricultural products, such as Jingning Huiming Tea, Qingyuan Mushrooms, and Suichang Chrysanthemum Rice, to create the first regional public brand in a prefecture-level city in China. The Lishui Shangeng brand covers agricultural products in the whole region, category, and industry chain, such as grains, edible fungi, dried bamboo shoots, dried fruits, vegetables, livestock, Camellia oleifera, fishery products, and traditional Chinese medicines. In terms of production, Lishui Shangeng carries out the double control of pesticides and fertilizers, and restricts 105 kinds of pesticides and fertilizers with high toxicity and residue to the European Union standard. In terms of supply chain, Lishui Shangeng has adopted the tenets of direct supply from the base, inspection for access, and full traceability, and it has built a rigorous traceability management system for agricultural product quality and safety.

Agriculture, forestry, fishery, and other departments are responsible for supervising the production process and ensuring the standards of enterprises. Consumers can trace the source and flow information of products by scanning the traceability QR code on products. In terms of brand operation, Lishui Shangeng not only has government endorsement but also attracts production entities to join through unified standards, unified operation, and unified dissemination, reducing the cost and risk for producers entering the market and improving the premium space of products. Guided by the market, the public brands in Lishui Shangeng have achieved remarkable results, and its agricultural products are exported to more than 20 provinces and cities, such as Beijing, Shanghai, and Shenzhen. By 2018, 1,122 cooperative bases had been established, with brand sales reaching RMB 13.52 billion[13] and the average premium rate of products exceeding 30 percent.

Source: China, Ministry of Agriculture and Rural Affairs (2016).

Fourth, all localities should actively seek funds through other channels to support the development of green agriculture and vigorously explore the application of green finance in the agricultural field. For example, in 2020, as the first green development fund of the World Bank in China, the Henan High-Quality Green Agriculture Development Promotion Project received a long-term preferential loan of US$300 million. Huangshan City's Xin'an River Basin Ecological Protection and Green Development Project has built infrastructure, including rural point-source and nonpoint-source pollution control and green finance pilot projects, with loans totaling 140 million euros from the Asian Development Bank and KfW Bankengruppe (Box 4.5).

Finally, relying on technological progress as well as scientific and technological innovation, an extension system to support the green development of agriculture should be established. To this end, around key technologies such as scientific and efficient fertilization and medication, recycling of crop residues and aquaculture waste, and remediation of heavy-metal pollution in cultivated land, China has formed a model and system of cleaner agricultural production technology, as well as agricultural nonpoint-source pollution prevention and control technology, suitable for the country's national and agricultural conditions. In

[13] It's approximately equal to 2 billion US dolloars.

Box 4.5 Huangshan, Anhui Province, Actively Explores Diversified Green Finance and Promotes Green Development

"Green finance" refers to economic activities to support environmental improvement, cope with climate change, and save and utilize resources efficiently. That is, it encompasses financial services provided for project investment and financing, project operation, and risk management in the fields of environmental protection, energy conservation, clean energy, green transportation, and green buildings, which play a huge role in supporting pollution control and rural revitalization (People's Bank of China et al. 2016). Huangshan City, Anhui Province, guides financial institutions to actively explore diversified green financing modes by participating in the green financial system. To help finance comprehensive management of the Xin'an River Basin, Huangshan financial institutions issued RMB 600 million[14] of corporate bonds and RMB 500 million[15] of short-term financing bonds. In addition, China Development Bank Securities set up a RMB 2 billion[16] Xin'an River Green Development Fund to invest in ecological protection, green industry development, and cultural tourism. In 2020, loans of 90.9 million euros from the Asian Development Bank and 50.0 million euros from KfW Bankengruppe were obtained, which will be used for ecological protection and green development projects in the Xin'an River Basin of Huangshan Mountain, so as to enhance the ecological and economic benefits on both sides of the Xin'an River.

Source: Anhui News (2017).

addition, there is a need to interconnect and coordinate, both upstream and downstream, the current research and development innovation in agricultural germplasm resources, agricultural planting technology, production and processing equipment, agricultural machinery and equipment, cold chain logistics networks, intelligent management platforms, and other related technologies. Measures should also be taken to enhance technology application and promotion, and strengthen the promotion of agricultural nonpoint-source pollution prevention services and control technology. An example worthy of emulation is the platform model of the Institute of Science and Technology, initiated by the National Green Development Research Institute of China Agricultural University, which takes scientific research pilots into the front line of agricultural production, carries out scientific research and technology promotion around practical problems, and explores the path of sustainable agricultural development in the future.

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[14] It's approximately equal to 92.7 million US dolloars.
[15] It's approximately equal to 77.25 million US dolloars.
[16] It's approximately equal to 309 million US dolloars.

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Chapter 5

E-commerce and Smallholder Agricultural Transformation: The Chinese Experience

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Key Findings

- The development of e-commerce has greatly boosted the connection between smallholder farmers in China and the larger market. It has become an important way for smallholder farmers to connect to the fast-growing demand of Chinese urban population, which will help promote the transformation of China's agrifood systems into one characterized by safety, nutrition, sustainability, and resilience.
- 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.
- Logistics and communication infrastructure, inclusive digital business platforms for smallholder farmers, and a new generation of farmers are prerequisites for developing rural e-commerce.
- To properly develop further, rural e-commerce needs an ecosystem suitable for the participation of smallholder farmers, composed of network operators, government, and service providers.
- E-commerce may exclude smallholder farmers who cannot participate in the digital economy or lack the required skills. Therefore, the attention must be paid to the regional disparities and inequalities among farmers caused by the digital divide.

Recommendations

- Create an e-commerce ecosystem suitable for the development of smallholder farmers: (1) expand and improve infrastructure, including information and communication infrastructure and other facilities; (2) improve the ability of smallholder farmers to use the internet effectively; (3) support the development of inclusive digital business platforms; and (4) give full play to e-commerce public service providers.
- Train a new generation of farmers with e-commerce insights, knowledge, and skills to help them lead other smallholder farmers to join e-commerce.
- Reconfigure the benefit distribution mechanism to ensure and enhance the profitability of smallholder farmers from participating in e-commerce.
- Pay more attention to vulnerable groups and establish the necessary conditions to improve their awareness of, opportunities for, and profitability from participating in rural e-commerce.

5.1 Introduction

With smallholder farmers representing their primary food production source, many developing countries face the challenges of connecting smallholder farmers with the larger market. First, in most developing countries, farmers encounter many difficulties in accessing markets because of both their own small scale and market imperfections such as inefficient production, slow adoption of new technologies and new ideas, high transaction costs, and the like (Markelova et al. 2009; Poulton, Dorward, and Kydd 2010; Ma and Wang 2020). These challenges limit the trading radius and market profitability of agricultural products, further restricting farmers' sustainable economic growth and welfare improvement. Furthermore, as the main component of the agrifood systems in developing countries, smallholder farmers play an important role in development. Their ability to grow food sustainably almost single-handedly determines the overall development level of the agrifood systems in developing countries. It affects the food production capacity, the sustainability of nutrition security, and the resilience of the agrifood systems.

The emergence and adoption of e-commerce make it possible to build a capable, sustainable, and resilient agrifood systems. E-commerce enables farmers in developing countries to sell their products through the Internet, skip the middlemen and directly reach the consumers, and thus take control of their own marketing links and after-sales service. It helps streamline the supply chain and promotes information collection, market-driven production, and interaction between farmers and consumers. In this way, smallholder farmers in developing countries may break the barriers of under developed traditional markets and, through this new approach, gain access to both domestic and international markets (Jamaluddin 2013; Li et al. 2020; Ma, Zhou, and Liu 2020; Okoli, Mbarika, and McCoy 2010; Yu and Cui 2019).

The development of e-commerce among the rural population of 600 million in China has attracted worldwide attention. The growth of e-commerce is mainly due to the increasingly completed rural road and network infrastructure in China, the rapid growth of Internet penetration and user numbers, the continuous spread and radiation of logistics and distribution systems to rural areas, the rise of third-party e-commerce platforms, and China's vast market with its fast-growing demand for agricultural products. This chapter introduces the current situation and modes of China's rural e-commerce development and analyzes the development experience and challenges. It provides a reference for China and many developing countries to make better use of e-commerce to connect smallholder farmers with large markets in the future and accelerate the transformation of agrifood systems.

5.2 Background and Current Situation of Rural E-commerce Development in China

According to data from the Third China Agricultural Census, there are currently 230 million farmers in China, and 210 million of them operate less than 0.67 ha of cultivated land (National Bureau of Statistics of China 2016). Thus, smallholder farmers are still the primary actors in China's agricultural system. E-commerce of agricultural products is a new mechanism that emerged from the use of modern Internet information technology in agricultural production, circulation, and consumption. It is an important method to promote the connection between smallholder farmers and modern agriculture. The Chinese government has put great emphasis on the importance of rural e-commerce. Since 2004, many policies have been issued to encourage and support the development of rural e-commerce, especially e-commerce of agricultural products. In February 2019, the General Office of the Chinese Communist Party Central Committee and the General Office of the State Council specially issued Opinions on Promoting the Organic Connection between Smallholder Farmers and Modern Agriculture Development.

Since 2014, China's rural e-commerce has ushered in a vigorous and rapid development momentum. From 2014 to 2019, rural online retail sales soared from 180 billion renminbi (RMB) to RMB 1.7 trillion, increasing by 9.4 times[17]. In 2019, there were nearly 13 million rural e-commerce companies in China. The retail sales of the country's entire e-commerce sector reached RMB 3.1 trillion, a year-over-year increase of 23.5 percent; online retail sales in poverty-stricken counties nationwide reached RMB 149 billion, up 18.5 percent year over year. In 2019, online retail transactions for agricultural products in China reached RMB 397.5 billion, up 22 percent year over year (E-Commerce and Information Technology Department 2020). Although no authoritative statistics show the number of farmers participating in online agricultural product sales, data from Pinduoduo, a well-known Chinese e-commerce platform, show that in 2019 alone, the turnover of agricultural and sideline products through this platform reached RMB 136.4 billion, with 240 million active buyers (Zhang 2020). There are various kinds of agricultural products participating in e-commerce, from characteristic local products (such as hairy crabs, miscellaneous grains, and so on) to bulk agricultural products (such as fruits and vegetables, tea, grains, dairy products, edible oil, and the like) (Research Group of International Trade and Economic Cooperation 2019).

5.3 Major Modes of Smallholder Farmers' Participation in E-commerce in China

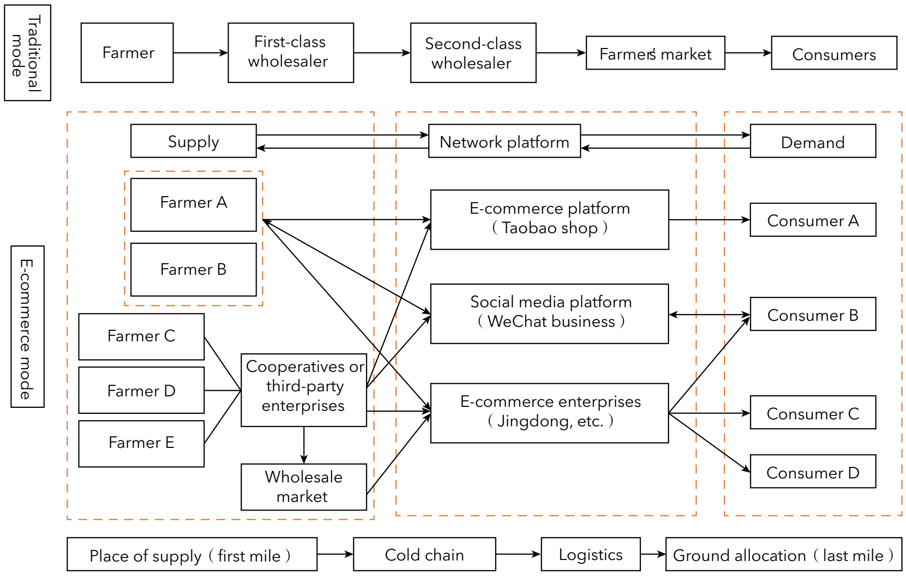
Internet technology provides a virtual platform to realize cross-regional direct dialogue and a high concentration of production and marketing subjects, leaving middlemen less critical in the food supply chain. With the support of the Internet platform and the modern logistics industry, some farmers can directly trade with consumers, some are connected with consumers through cooperative organizations (co-ops), and some connect with consumers indirectly through working with e-commerce enterprises (including platform enterprises and operational service providers). The development of e-commerce has changed the traditional circulation system of agricultural products, and the new circulation system has obvious differences (Figure 5.1).

In light of the different roles and degrees of farmers' participation, e-commerce can boost smallholder farmers' connections with larger markets in the following ways:

First, farmers rely on the e-commerce platform to help them operate independently (Box 5.1). 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 bypass middlemen and sell directly to foreign consumers. This model mainly appears in areas with special agricultural products, convenient infrastructure and logistics, and a vibrant atmosphere of farmers' entrepreneurship and innovation. Third-party e-commerce platforms gather many consumers,

[17] For reference, the average exchange rate of RMB to US dollar in 2019 is 1 US dollar = 6.8985 RMB.

Figure 5.1 Circulation systems of agricultural products, traditional versus e-commerce modes



Source: *Authors' own framework*

bringing both opportunities and challenges to e-commerce farmers. If e-commerce farmers succeed in their operations, they can not only solve the problem of difficulty in selling their own agricultural products and earn higher profits but also have the opportunity to shape their own brands in the online market and buy more agricultural products from other farmers for resale online, thus becoming large online sellers and realizing a substantial income increase. Moreover, with a large number of online stores and the homogenization of competition, the online market is fully competitive and price wars are fierce, placing high requirements on the management ability of e-commerce farmers. Over time, the investment cost in e-shop renovation, client diversion, photography and art design, marketing, and promotion will also increase.

Second, farmers rely on social media platforms to help them operate independently (Box 5.2). 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 online social media such as WeChat,

Box 5.1 An agricultural products "Taobao village": Bainiu

The traditional industry of Bainiu, a village in Zhejiang Province, is hickory planting, processing, and selling. The existing hickory base covers an area of about 107 hectares. Lin'an City, where Bainiu is located, has a 500-year history of hickory cultivation and is the largest hickory-producing area in the country. It is known as the "hometown of hickory in China." In 2007, some returning youths began to set up shops on the online Taobao platform to sell local hickory. They achieved great outcomes and demonstrated proof of the concept, driving more and more villagers to participate in e-commerce entrepreneurship, and earning Bainiu the title of "China's Taobao village." Rural e-commerce breaks the traditional regional restrictions and market scope of agricultural product sales, expands the sales radius of products, and effectively solves the channel problem of selling agricultural products from rural to urban areas. In 2020, e-commerce sales in Bainiu increased to RMB 470 million, and the per capita net income of rural village residents reached RMB 39,020.

Source: Authors' own studies.

Box 5.2 Farmers from Shuyang sell flowers online

Shuyang, Jiangsu Province, is known throughout China for its flowers and trees. Since 2001, farmers have been selling flowers and trees through online yellow pages and bulletin boards, and since 2007 they have used Taobao, Tmall, 1688, and other e-commerce platforms for online marketing. Growers of flowers and trees in Shuyang County have consistently shown the entrepreneurial and innovative spirit of being the first and exploring bravely. This strong spirit of entrepreneurship and innovation enables Shuyang to take the lead in the trend of Internet development. In 2019, the number of online stores in Shuyang County was more than 40,000, and the transaction volume of e-commerce reached RMB 33.6 billion. Total express deliveries in the county reached 291 million pieces, with an average of more than 790,000 pieces per day. Every second, an average of 9.2 packages from Shuyang were sent to all parts of the country.

In addition, of the more than 40,000 e-commerce companies in Shuyang county, about 80 percent are engaged in the sale of flowers, trees, seedlings, and related goods ranging from seeds, saplings, cut flowers, and dried flowers to bonsai, trees, and green houseplants; from flowerpots, fertilizers, and shovels to sunshade nets, watering pots, and plastic wrap. Platforms for these businesses have gradually expanded, including various e-commerce platforms from Taobao and Jingdong to 1688 and Pinduoduo, and social media platforms such as WeChat, TikTok, and Kuaishou. The total number of direct and indirect employees of e-commerce entrepreneurs in Shuyang County reached 280,000 in 2019, and the whole county created a strong and warm atmosphere of innovation and entrepreneurship.

Source: Authors' own studies.

Weibo, and TikTok, thus enhancing their direct connection with consumers. With the help of social media, people as a key actor, and social relations as a link, this new business model based on mobile Internet is called "We Business." Compared with e-commerce platforms, social media platforms feature lower entry barriers, more straightforward operation, richer and more flexible interaction between production and marketing parties, and none of the online shop setup and promotion costs of e-commerce platforms. Farmers get connected with consumers through social media such as WeChat and Weibo; then, by interacting and sharing product information on a regular basis, they earn consumers' trust and loyalty. Using social media platforms, farmers can bring those online customers to offline farmhouse entertainment and agricultural product picking activities, or launch a new business model of customized agriculture (such as fruit tree adoption).

However, this mode of independent operation relying on social media platforms requires certain conditions. In addition to good product quality and convenient logistics conditions, it also requires operators to have a large number of acquaintances and good communication skills. For example, farmers should post pictures, text, or short videos on their social media at the best time to display product information; otherwise, even if social media platforms are used, the sales are still limited. Some areas are rich in rural tourism resources and have a large number of visitors. Farmers can use online social media to establish contact with tourists. Meanwhile, tourists can deepen their understanding, get a better experience of local agriculture, and form positive impressions and trust when visiting the farm, all helping farmers carry out community marketing in the future.

Third, farmers work in cooperation with e-commerce enterprises (Box 5.3). 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 cooperative relationship with an e-commerce platform enterprise or an operational service provider and sharing certain digital dividends. This mode is suitable for farmers and co-ops that can produce a great number of high-quality agricultural products but lack the awareness, access, and abilities to use the Internet to connect with the market directly. Cooperative e-commerce enterprises give full play to their professional advantages. The e-commerce enterprises can analyze information collected from the Internet, big data, and industrial research, and transmit it to the production end. Such research can guide farmers and farmer co-ops to carry out corresponding standardized production, strict quality control processes,

Box 5.3 Market-oriented production: Songxiaocai

Songxiaocai is currently China's largest business-to-business (B2B) vertical e-commerce platform for vegetables. It provides goods collection, distribution, and after-sales service for small and medium-size retailers such as vegetable vendors and fresh food stands in downstream farmers' markets through market-oriented and contract modes. At the same time, it also provides continuous orders for production organizers (farmers) in upstream vegetable-producing areas, guiding their production. After six years of operation, Songxiaocai's upstream has covered 10 core vegetable-producing areas, including Gansu, Inner Mongolia, Shandong, and Yunnan, and its downstream has reached 45 consumer cities including Beijing, Guangzhou, Hangzhou, Shanghai, and Wuhan.

The company's business has gradually expanded from B2B e-commerce matching to supply chain–related services such as logistics, warehousing, processing, data, and finance. Farmers directly connect with the Songxiaocai platform to access information from both the demand side and the production side. One advantage is that vegetable products no longer need to be loaded and unloaded many times in the traditional way. Instead, they can be directly transported from the bazaars or vegetable production sites to the hands of vegetable sellers through the third-party trunk logistics of Songxiaocai, greatly reducing their circulation costs (such as inventory fees, market transaction fees, intermediary fees, labor fees, transportation fees, and so on) and effectively minimizing their loss rate. Under its digital supply chain, Songxiaocai can keep the loss rate of the vegetable supply lower than 0.2 percent, compared with the current average loss in the industry of about 10 to 40 percent, demonstrating the significant advantages of the digital supply chain in improving vegetable supply efficiency.

Source: Authors' own studies.

and unified and standardized product packaging. In this mode, although farmers and farmer co-ops do not have their own Internet channels to directly sell products to consumers, under the guidance of third-party partners, they not only avoid blind production but also improve their production efficiency. As a result, they gain great benefits. Nevertheless, farmers, co-ops, and third-party partners belong to different stakeholder categories, and thus they face problems of uncertain performance and unequal bargaining power. Based on the practice in some places, this mode may also play a transitional role, laying a foundation for some farmers and co-ops eventually to begin using the Internet directly to connect with the market. In the process of cooperation with third parties, farmers and co-ops have not only optimized production and improved product quality and popularity, but also gradually turned their orientation to "Internet thinking."

Basic characteristics of the three main organizational modes whereby farmers currently use e-commerce to connect with the market are shown in Table 5.1. Thanks to the continuous development of social media and e-commerce platforms with inclusive and innovative characteristics, the entry threshold is relatively low for farmers or co-ops to operate independently by relying on e-commerce and social media platforms.

From the perspective of their own interests, farmers can get the maximum digital dividend by relying on the organizational model of cooperation between farmers or farmer co-ops and e-commerce enterprises. In this organizational model, farmers or their cooperatives do not use the Internet to connect with consumers

Table 5.1 Comparison of the main modes of e-commerce that boost the connection between smallholder farmers and large markets

Organizational mode	Entry threshold	Farmers' interests	Online competitive pressure	Scope of applicable farmers	Difficulty of achieving significant income increase
Farmers rely on e-commerce platforms to operate independently	Low	Large	Large	Small	Large
Farmers rely on social media platforms to operate independently	Low	Large	Small	Large	Large
Farmers cooperate with e-commerce enterprises	High	Medium	No	Small	Medium

Source: *Authors' own compilation.*

independently. Instead, they supply goods to e-commerce enterprises and indirectly share in some of the digital dividends. However, as pointed out earlier, farmers, co-ops, and third-party partners are not equal in all respects.

From the perspective of online competitive pressure, farmers face the greatest such pressure when they rely on e-commerce platforms to help them operate independently, with less competitive pressure resulting from reliance on social media platforms. With the latter, farmers do not need to invest in online shop setup and promotional costs, but on the other hand, the circle of acquaintances belongs to each farmer, with specificity and isolation. In contrast, farmers or co-ops that cooperate with e-commerce enterprises need to focus only on offline production links to complete the supply, and thus the online competitive pressure is entirely borne by the e-commerce enterprises.

From the perspective of the scope of application to farmers, although the entry threshold for farmers to operate independently by relying on e-commerce platforms is low, such platforms are difficult to use successfully, and the ultimate investment required and risks faced by farmers are high. Thus this mode is not suitable for adoption by the vast majority of farmers. Judging by the current practice, this mode mainly appears in areas with a locally characteristic agricultural industry, convenient infrastructure and logistics, and an active atmosphere of farmers' entrepreneurship and innovation. The mode of farmers relying on social media platforms to operate independently has a low entry threshold, is simple to operate, and requires no capital investment, so it is suitable for most farmers. The organizational mode of cooperation between farmers or co-ops and e-commerce enterprises is applicable only to a small number of larger-scale farmers.

Based on previous findings, it is still very difficult for farmers to achieve a significant income increase by relying on e-commerce platforms or social media platforms. Although the business mode of relying on social media platforms applies to most farmers, the consumer groups reached by these platforms are not large, and the sales rate is often very low, meaning that such platforms can serve only as an auxiliary or supplement to traditional sales channels because their income effect is not significant. Comparatively, it is less difficult for farmers or co-ops to achieve a substantial income increase by cooperating with e-commerce enterprises. Farmers benefit from the effects of economies of scale and the advantage of concentrating resources toward the same goal, and co-ops benefit from the improvement of production capacity and the expansion of product sales when they work with e-commerce enterprises.

5.4 E-commerce Mechanisms to Boost the Development of Smallholder Farmers

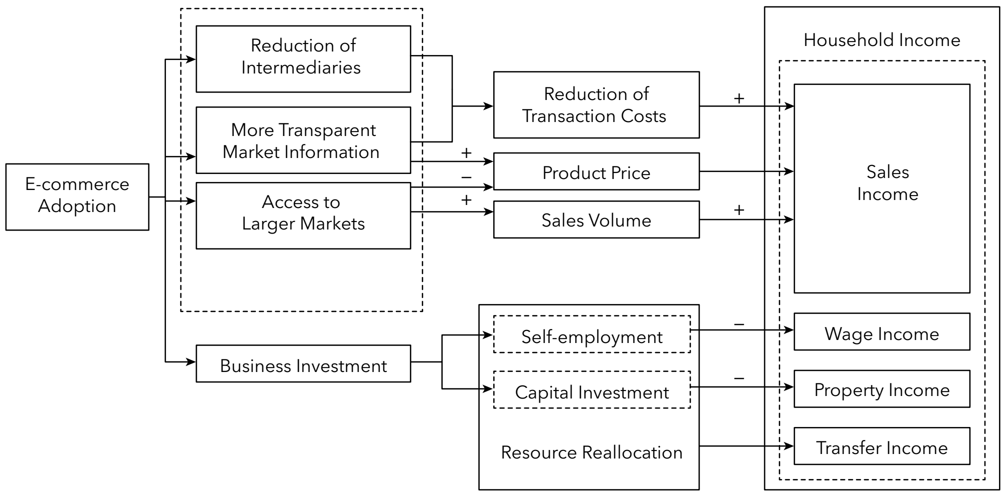
The ways and mechanisms through which e-commerce can promote smallholder farmers' better access to large markets are shown in Figure 5.2.

The first impact pathway is through reduction of intermediaries. By adopting e-commerce, farmers can directly sell their products to consumers through online stores, reducing intermediate trading links. Selling products through the Internet and thereby eliminating some or all of the intermediate links can reduce the relatively high transaction costs faced by smallholder farmers (Poulton, Dorward, and Kydd 2010), allowing them to obtain a higher income by selling the same amount of products.

The second impact pathway is through transparent market information. The adoption of e-commerce can help farmers reduce their information asymmetry in price and technology to a certain extent. Transparent market information reduces arbitrage opportunities, thus improving market efficiency. From the perspective of farmers, however, the impact of e-commerce on prices is inconclusive. On the one hand, due to the reduction of the price squeeze from intermediate links and market information asymmetry, the adoption of e-commerce enables farmers to sell their products at higher prices (Zeng et al. 2017); on the other hand, due to increased competition, market integration may lower product prices (Tang and Zhu 2020).

The third impact pathway is through market size. The adoption of e-commerce can enable farmers to sell their products to a wider customer base, which is perhaps the most important way for e-commerce to promote the welfare growth of farmers. Tang and Zhu (2020) pointed out that e-commerce provides opportunities for farmers to sell local products nationwide. Similarly, Yu and Cui

Figure 5.2 Impact pathways for e-commerce to boost the development of smallholder farmers



Source: *Authors' own framework.*

(2019) suggested that the adoption of e-commerce helps farmers expand their market, gaining access to many customers who are unreachable without e-commerce. Therefore, e-commerce enables farmers to seize the opportunity to produce and sell more products suitable for online sales.

5.5 Empirical Studies on E-commerce as a Boost to the Development of Smallholder Farmers

A great deal of practical evidence has pointed out that e-commerce can increase the income of smallholder farmers and become an important means to promote rural development and reduce poverty (for example, Qi et al. 2019; Yu and Cui 2019; Zeng et al. 2017). According to a rural network business development report based on data from the China Household Financial Survey (Research Group of International Trade and Economic Cooperation 2019), the density of village network business is directly proportional to household income. Under the condition of similar family characteristics, network businesspeople can increase their family income by RMB 20,500 and family wealth by RMB 213,000 (compared with families not adopting e-commerce). Zeng and others (2018) analyzed survey data from 1,009 flower and tree farmers in Shuyang County, Jiangsu Province, and found that the adoption of e-commerce can significantly promote farmers' agricultural income through the mechanisms of an increased profit rate and a higher sales volume. Li and colleagues (2021) used the data of farmers surveyed in Shandong, Jiangsu, and Zhejiang Provinces of China to further find that the adoption of rural e-commerce may lead to a substantial increase in farmers' production of operational income, a slight increase in property income, a slight decrease in wage income, and no significant change in transfer payments. Especially for poor areas, rural e-commerce has played an important role in poverty alleviation and has become an important means to rise out of poverty. Lin and others (2020) found, based on micro-survey data of poor households in Inner Mongolia, that participating in e-commerce can clearly raise the income of poor households. With other conditions unchanged, participating in online sales can increase the income of poor households by 27. 22 percent.

However, some studies have shown that e-commerce of agricultural products may lead to a "digital divide," and indeed there are significant differences in regional and family digital characteristics. The results of Li and colleagues (2021) showed that adoption of rural e-commerce has a greater impact on farmers' income in relatively poor counties (compared with richer districts and counties) and for relatively poor farmers (compared with richer farmers). The younger the head of household, the higher the education level, the smaller the family size, the less the initial income, and the more cultivated land, the higher the income obtained through e-commerce.

There are many reasons for the emergence of the digital divide. Unbalanced regional economic development, which determines the construction speed of information infrastructure in different regions, is the primary cause (Hu and Zhou 2002), resulting in a gap in the adoption time of digital technology in different regions (Zhang and Zhu 2013). At the same time, regional differences are also reflected in residents' education level, which directly determines the ability of farmers to use information. Generally, more capable people benefit more from the digital economy (Clark and Gorski 2002; Mills and Whitacre 2003). Liu and Han (2018) and Zeng (2018) summarized the causes of the digital divide as differences in capital endowments, including material capital, human capital, and social capital.

5.6 The Experience of E-commerce as a Boost to the Development of Smallholder Farmers

The national policies promote the development of e-commerce. The rapid development of e-commerce in China in recent decades cannot be separated from the policy support of the Chinese government. In 2005, the General Office of the State Council issued Opinions on Accelerating the Development of E-commerce, legalizing e-commerce as a national strategy to promote China's economic growth. In addition, new legislation has been adopted to regulate and ensure the security of Internet e-commerce. The state has successively introduced policies and measures to speed up the penetration of e-commerce into rural areas. For six consecutive years since 2014, the annual No. 1 Document of the Communist Party of China's Central Committee has emphasized the importance of promoting rural e-commerce.

Local governments at all levels have also formulated relevant policies and regulations to support and promote the development of rural e-commerce. So far, China's Ministry of Commerce has given financial and policy support for 1,016 counties (737 of which are nationally recognized as poverty-stricken counties) to become comprehensive demonstration counties for bringing e-commerce into rural areas. Local governments have used special funds to carry out e-commerce-related personnel training and set up e-commerce industrial parks with their own characteristics.

In addition, the rapid development of China's e-commerce cannot be separated from the Chinese government's investment in rural e-commerce infrastructure. Since December 2015, when the Ministry of Industry and Information Technology started its pilot work on universal telecommunication service, the proportion of administrative villages in China with optical fiber has risen from less than 70 percent to 96 percent. By the end of June 2019, the proportion of China's administrative villages connected to optical fiber and 4G exceeded 98 percent, and the number of rural netizens reached 225 million, accounting for 26.3 percent of total Internet-connected people in the country (China Internet Network Information Center 2019). At the same time, the coverage rate of rural logistics facilities has been greatly improved. By 2019, 556,000 villages across the country had direct postal service, with more than 30,000 express outlets in rural areas and 63,000 public pickup and delivery points. The coverage rate of township express outlets reached 96.6 percent, and more than 15 billion mail pieces were received and delivered in rural areas in 2019 (E-Commerce and Information Technology Department 2020). The improvement of Internet infrastructure and the narrowing of the overall gap between urban and rural areas have become important parts of the foundation for developing e-commerce for agricultural products.

The digital platforms contribute signifcantly to the growth of e-commerce. Some e-commerce platforms in China also actively make overall plans for rural markets and help local farmers sell agricultural products to metropolises smoothly by establishing e-commerce service stations. For example, Alibaba Group released the One Thousand Counties, Ten Thousand Villages plan in October 2014, proposing to invest RMB 10 billion in three to five years to establish 1,000 county-level operation centers and 10,000 village-level service stations, and to build a rural e-commerce service system at the county/village level. On the one hand, the plan will open up the information flow and logistics channel of consumer goods going to the countryside, and on the other hand, it will explore the channel of agricultural products going to urban areas. In addition, it will establish an e-commerce ecological service center for farmers. Jingdong, Suning, China Post, and others have also implemented similar plans, one after another.

In the past few years, various agriculture-related e-commerce platforms in China have developed rapidly. At present, there are more than 30,000 such platforms, including more than 3,000 for agricultural products. The types of rural e-commerce platforms are constantly enriched, and the forms of rural e-commerce are constantly evolving. China's agricultural products e-commerce has formed business-to-business, business-to-consumer, consumer-to-business, online-to-offline, and other modes, covering comprehensive e-commerce, social e-commerce, fresh e-commerce, agricultural materials e-commerce, bulk agricultural products e-commerce, and a variety of logistics distribution supply chains, with various service e-commerce companies providing financial and information technology support. The agricultural products e-commerce ecosystem has basically taken shape. The development of the e-commerce platform provides abundant opportunities for smallholder farmers to participate in the market.

Some platforms are driven by a new generation of farmers. With the support of public policies, the maturity of the market, the follow-up of relevant supporting measures, and the development of electronic information technology, rural e-commerce has become an industry conducive to rural employment and talents. A large number of college graduates, small and medium-size business owners, migrant workers, returned overseas students, and other people have moved to rural areas to engage in e-commerce entrepreneurship. An open-minded, innovative group of new farmers familiar with both e-commerce and agricultural products, and equipped with marketing skills, and can connect with scattered smallholder farmers. The work of such groups has led to great changes in the labor structure of Chinese farmers. By 2018, 7.8 million innovative entrepreneurs had returned to the countryside, mainly distributed in the fields of e-commerce, leisure agriculture, and rural tourism. In 2017, the number of rural e-commerce online stores reached 9.85 million, with 28 million employees. Returning entrepreneurs were distributed across nearly 500,000 rural e-commerce grassroots sites all over the country in addition to the large e-commerce platforms such as Pinduoduo and Taobao. In 2018, online stores in Taobao Village and Taobao Town provided more than 6.83 million employment opportunities nationwide. A large number of new farmers were active on Weibo, WeChat, and more than 3,000 other e-commerce platforms such as Benlai and Jingdong (Research Group of International Trade and Economic Cooperation 2019). The return of talents to the countryside has also injected a brand-new force that has directly promoted the development of rural e-commerce.

5.7 Conclusions and Policy Implications

(1) E-commerce contributes to the development of smallholder farmers. China's experience shows that e-commerce, as an important application of information and communication technology, can help farmers skip middlemen, directly connect with consumers, and thus take control of their own marketing links and after-sales service. The adoption of e-commerce not only shortens the supply chain but also promotes information collection, market-oriented production, and interaction between farmers and consumers. E-commerce can significantly increase farmers' agricultural income by increasing their profit rate and sales volume. In addition, it can help farmers in poor areas to enter larger markets. Evidence suggests that young farmers are more likely to adopt e-commerce, and female farmers are not discriminated against in the adoption process. The successful practice of e-commerce in rural China shows that e-commerce could be an effective way for smallholder farmers in developing countries to fight poverty, improve market access, and promote employment opportunities.

(2) It is crucial to build an e-commerce ecosystem conducive to the development of smallholder farmers. China's experience shows that an appropriate e-commerce ecosystem could benefit both smallholder farmers and the rural economy. The rural e-commerce ecosystem should consist of three key actors: network operators, the government, and public service providers. Network operators are the main force of e-commerce development and are responsible for the overall operation of the Internet market; the government boosts the development of e-commerce and is responsible for constructing infrastructure such as roads and communications, creating a development atmosphere, and providing policy guidance and overall coordination; service providers offer a set of e-commerce public services, including agency operation, incubation of network operators, talent cultivation, resource integration, and the logistics. In addition to these three important actors, financial institutions, online business associations, talent-training institutions, the logistics industry, e-commerce platforms, and other third-party service providers are indispensable parts of the entire ecosystem. The three important roles interact efficiently, complement each other, and promote each other, forming a friendly and intensive e-commerce environment. This environment, in turn, not only reduces the operating cost of the whole industry but also creates an atmosphere of cooperation and innovation, which is the key to the healthy and sustainable development of rural e-commerce.

(3) E-commerce may cause income inequality and deepen the digital divide for smallholder farmers. Farmers' sharing of digital dividends will not be homogeneous and equal. Farmers with different capital endowments, including material capital, human capital, and social capital, may have heterogeneous benefits from e-commerce. And e-commerce will also aggravate existing income inequality among farmers. Families with younger household heads, higher education levels, smaller size, lower initial income, and more cultivated land can benefit more by adopting e-commerce. Therefore, well-educated young farmers are more likely to adopt and benefit from e-commerce.

In addition to supporting well-educated young farmers to engage in e-commerce, the government should also pay attention to older farmers with lower education levels. It is important to provide them with training and other support, improve their e-commerce literacy and ability, and thus allow more farmers to benefit from rural e-commerce. In order to close the digital divide, it is also a vital policy choice for the government to reduce the cost of farmers' access to the Internet by improving information infrastructure (building base stations, increasing speed, lowering fees, and so on), so that more farmers have the opportunity to use digital technologies, which is especially important in the early stage of development.

With the vigorous construction and popularization of rural informatization, the gaps in information access have gradually begun to shrink. The focus on closing the digital divide has shifted from the problem of "information accessibility" to the problem of how farmers can "effectively use" information (Xu et al. 2013). Therefore, efforts should be made to train new farmers with e-commerce insights, knowledge, and skills, and demonstrate how smallholder farmers can benefit from joining e-commerce. Moreover, it is essential to determine how the benefits from e-commerce are distributed and how they can enhance the profitability of smallholder farmers; pay more attention to the vulnerable groups; establish the necessary conditions in various ways; and improve farmers' awareness of, opportunities for, and profitability through participating in the development of e-commerce.

5.8 Research Prospects

China's e-commerce is growing rapidly overall; however, the development of e-commerce for fresh agricultural products remains relatively slow, and farmers' participation rate is not high enough, due to the large volume of agricultural products, low unit prices, and the high requirements of logistics along the cold chain. How to develop e-commerce for fresh agricultural products remains a problem worth studying. Still, there are various ways and modes for smallholder farmers to participate in e-commerce. In order to provide suitable development modes for these farmers, it is necessary to study the factors that affect their participation choices and the influence of e-commerce adoption on their production, income, and consumption. Finally, for the development of smallholder farmers, it is necessary to study the impact of e-commerce platform monopoly and how to build a conducive e-commerce ecosystem.

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Chapter 6

Agricultural Trade in China's Agrifood Systems: Evolution, Challenges, and Prospects

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Key Findings

- As a critical part of the agrifood systems, China's agricultural trade has seen dramatic changes since the country's accession to the World Trade Organization (WTO) two decades ago. China has shifted from a country with a surplus in agricultural trade to the country with the largest deficit, and the trend of overall net importing of bulk agricultural products remains strong. Agricultural trade plays an increasingly prominent role in supplementing domestic supply and optimizing resource allocation.
- This change in the import and export pattern has also given rise to a range of challenges and pressures, which are manifested in increasing dependence on the import of bulk agricultural commodities, declining competitiveness of traditionally advantageous export products, increasing uncertainty and risk in relation to the external environment, and the like.
- The COVID-19 pandemic has brought great challenges to the global agrifood systems and agricultural trade, especially the rise of trade protectionism, the increase of trade restrictions, and the rise and fluctuation of agricultural prices, all of which have greatly increased the uncertainty of the global agricultural market and trade prospects.
- Affected by the pandemic, the export of China's agricultural products (especially aquatic products) declined slightly, whereas imports did not fall but rose. Agricultural trade was resilient on the whole, laying a foundation for the transformation to a higher level of openness as well as a more efficient and stable agricultural trade system under the new pattern of "double circulation" .

Recommendations

- Under the new development pattern, efforts should be made to promote the transformation of China's agricultural supply and demand guarantee philosophy from a"dual balance"of production and demand to a "ternary balance" of production, consumption, and trade; to incorporate agricultural trade and international market into the strategic framework for medium- and long-term

agricultural and food systematic planning based on a global orientation context.

- In the context of increased competition in global agricultural market, measures should be taken to promote the transformation of China's agricultural development from increasing production to enhancing competitiveness and from market demand–oriented to green and high-quality development–oriented. There should also be efforts to enhance the transformation of the domestic agricultural production through the combination of "lowering cost and price" with "upgrading quality and unique characteristics" .
- Confronted with rising trade risks, efforts should be made to promote the transformation of China's agricultural trade regulation from opening or closing of doors to active risk management and control. Further, it is necessary to strengthen agricultural trade risk monitoring and early warning systems, promot the strategy of diversifying agricultural product imports, participate in building global agricultural supply chains, and enhancing the construction of an agricultural trade promotion and damage relief system.
- Amid an uncertain external environment, China should actively participate in global food and agricultural governance, strengthen construction of the global agricultural trade policy coordination mechanism, improve mutual trust between proponents of agricultural trade opening and those concerned with food security, maintain the stability of the global agricultural market, and ensure the food and nutrition security of China and the world (especially developing countries).

6.1 Introduction

Agricultural trade is an important component of the agrifood systems. For China, during the two decades of opening up after the country's accession to the World Trade Organization (WTO), agricultural trade has developed rapidly and China has become the second-largest agricultural trading country in the world. China's agriculture has reached a considerable scale by utilizing the international market and overseas resources, and has continued to expand the depth and breadth of its integration into the world markets. However, the rapid onset of the COVID-19 pandemic has brought severe pressure to the agrifood and trade systems both in China and the globe.

Under the new pattern of "dual circulation," we should, first, give priority to domestic circulation, promoting the transformation and development of agricultural production methods toward low-carbon, environmentally friendly, green, nutritious, and healthy methods. Second, we should also make use of the international market and promote the high-quality development of agricultural trade by further expanding the opening up of agriculture, deepening international cooperation in agriculture, enhancing the overall utilization efficiency of markets and resources both at home and abroad, pushing or forcing the transformation of China's agrifood systems and the upgrading of the country's capacity to guarantee an adequate supply of agricultural products.

6.2 Twenty Years after China's Accession to the WTO: Development and Evolution of China's Agricultural Trade

Since its accession to the WTO at the end of 2001, China has accelerated the pace of agricultural opening up to the world. With its agricultural opening up occupying a leading position in the world, China becomes one of the countries with the lowest tariff levels and the highest degrees of trade liberalization in the world (Ye 2020; Anderson et al. 2010). China has promoted the integration of its agriculture into the international agricultural system, and agricultural trade has shown a strong and rapid development momentum.

6.2.1 Trade Continues to Expand in Scale, Status, and Influence

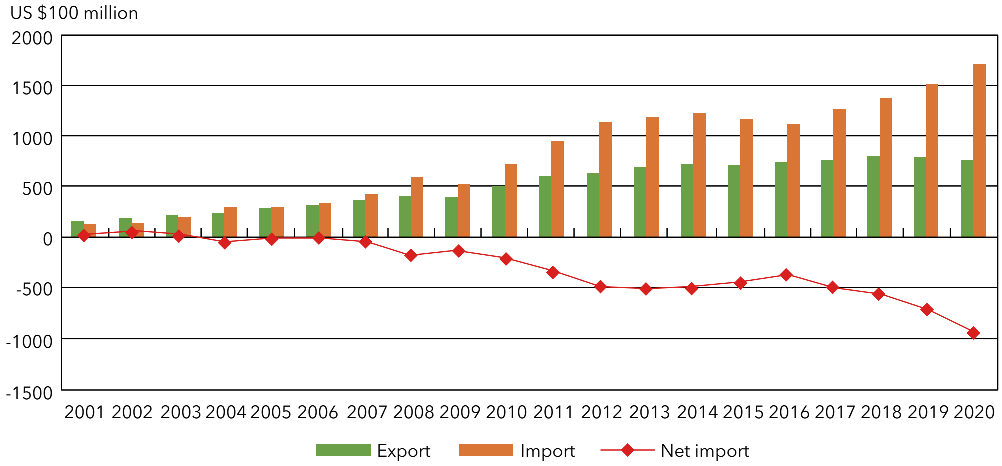
Since China's accession to the WTO, the country's agricultural trade has entered an unprecedented stage of rapid development. From 2001 to 2020, the total trade volume of agricultural products increased rapidly from $27.90 billion to $246.83 billion[18], an increase of nearly eight times, with an average annual growth rate of more than 12.2 percent (China, Ministry of Agriculture 2020). With the rapid growth in the scale of agricultural trade, China's position in the world agricultural trade market has been significantly enhanced, and its proportional share in global agricultural trade has been continuously increasing. In 2001, China's agricultural trade accounted for only 3.6 percent of the global agricultural trade, and this figure rose to 10.1 percent in 2019 (United Nations 2021). Even with the EU countries taken as a whole, China has become the second-largest importer and fifth-largest exporter of agricultural products in the world, and its total trade volume of agricultural products has leaped to second place in the world (Jiao 2020).

6.2.2 Gradual Pattern of Huge Imports and Huge Exports, Unstoppable Trend of Trade Deficit

The continuous increase of China's total agricultural trade volume is the result of the long-standing dual growth of imports and exports (Figure 6.1). From 2001 to 2020, the export value of China's agricultural products rose from $16.05 billion to $76.03 billion, an increase of about 3.7 times and an average annual growth rate of 8.5 percent; the import value of agricultural products increased from $11.85 billion to $170.80 billion, an increase of about 13.4 times and an average annual growth rate of 15.1 percent. Meanwhile, as the growth rate of imports continued to be significantly faster than that of exports, China rapidly changed from a surplus country in agricultural trade at the beginning of its WTO accession to a deficit country, and the scale of that deficit has shown a rapid growth momentum since 2004. From 2004 to 2020, China's agricultural trade deficit increased from $4.73 billion to $94.77 billion, an average annual growth rate of more than 20.0 percent. While China has

[18]Dollar amounts are in US dollars throughout.

Figure 6.1 China's agricultural trade and trade deficit, 2001–2020



Source: *Authors' construction using data from China Ministry of Agriculture (2020) and China General Administration of Customs (2020).*

become an important agricultural trade country in the world, it has also become the world's largest agricultural trade deficit country.

6.2.3 Continued Improvement in the Variety of Traded Products and Increased Diversification in Trade Partners

The variety of products in China's agricultural trade has been continuously increasing since the country's accession to the WTO, and the pattern of trade has developed in response to the country's resource endowment of a large population and limited farmland—that is, mainly exporting labor-intensive agricultural products and importing land-intensive agricultural products (Table 6.1). In terms of exports, from 2001 to 2019, the total exports of labor-intensive agricultural products, such as aquatic products, vegetables, and fruits, rose from $9.61 billion to $48.89 billion and accounted for 59.9 percent to 61.8 percent of the total exports of agricultural products each year. These were the main export varieties and an important channel to facilitate domestic agricultural employment and increase farmers' incomes. Meanwhile, China's imports of land-intensive agricultural products, such as soybeans, vegetable oil, cotton, and grains, continued to grow, with the total import value rising from $4.04 billion in 2001 to $50.47 billion in 2019 and accounting for more than 30 percent of the total imports of agricultural products. Besides these products, China also imports a large number of high-value-added agricultural products, such as pigs, cattle, sheep, poultry, and dairy products, from the international market. These imports of resource-intensive and high-value-added agricultural products not only help to meet the increasingly diversified and quality-conscious consumption demands in China, but also effectively relieve the pressure of water and soil resource shortages and environmental protection constraints. Thus, they are conducive to boosting the strategic adjustment of the domestic agricultural production structure and the optimization of regional layout.

In terms of trading partners, with the continuous expansion in scale of agricultural trade, China's agricultural trade partners have continued to expand, and a diversified pattern has gradually taken shape in the trading market. In the early days of China's accession to the WTO, exports were mainly concentrated in neighboring economies such as Japan, South Korea, and Hong Kong, as well as developed countries in Europe and the North America. In recent years, the proportion of China's agricultural products exported to these traditional markets has obviously declined, and the proportion of exports to emerging trading partners has increased day by day. Especially since 2013, with the deepening of the Belt and Road Initiative (BRI), the proportional share of China's agricultural exports to the BRI countries kept rising from 27.9 percent to 34.1 percent. Meanwhile, China's agricultural import trading partnership has also been widening. Besides for the traditional importing

Table 6.1 China's agricultural import and export structure, 2001–2019

A. Export structure of agricultural products								
Variety	Exports (US$100 million)				Proportion of agricultural exports (%)			
	2001	2007	2013	2019	2001	2007	2013	2019
Aquatic products	41.7	97.5	202.6	206.6	26.0	26.4	29.9	26.1
Vegetables	23.5	62.5	115.8	155.0	14.6	16.9	17.1	19.6
Animal products	26.6	40.5	65.2	65.0	16.6	10.9	9.6	8.2
Edible fruits and nuts	4.3	16.3	41.7	62.3	2.7	4.4	6.2	7.9
Others	64.4	153.1	253.0	302.1	40.1	41.4	37.2	38.2
B. Import structure of agricultural products								
Variety	Imports (US$100 million)				Proportion of agricultural imports (%)			
	2001	2007	2013	2019	2001	2007	2013	2019
Soybeans	28.1	114.7	380.1	353.4	23.7	27.8	32.0	23.4
Edible vegetable oil	4.8	62.4	80.7	63.3	4.1	15.1	6.8	4.2
Cereals and cer1al flour	6.3	5.3	51.0	52.0	5.3	1.3	4.3	3.4
Cotton	1.2	35.8	87.2	36.0	1.0	8.7	7.3	2.4
Dairy products	2.2	7.4	51.9	112.7	1.9	1.8	4.4	7.5
Cattle products	0.4	0.6	16.0	86.9	0.3	0.1	1.3	5.8
Pork products	1.0	4.7	26.6	65.5	0.8	1.1	2.2	4.3
Poultry products	4.6	9.8	10.7	20.6	3.9	2.4	0.9	1.4
Others	69.9	171.3	484.5	719.3	59.0	41.7	40.8	47.6

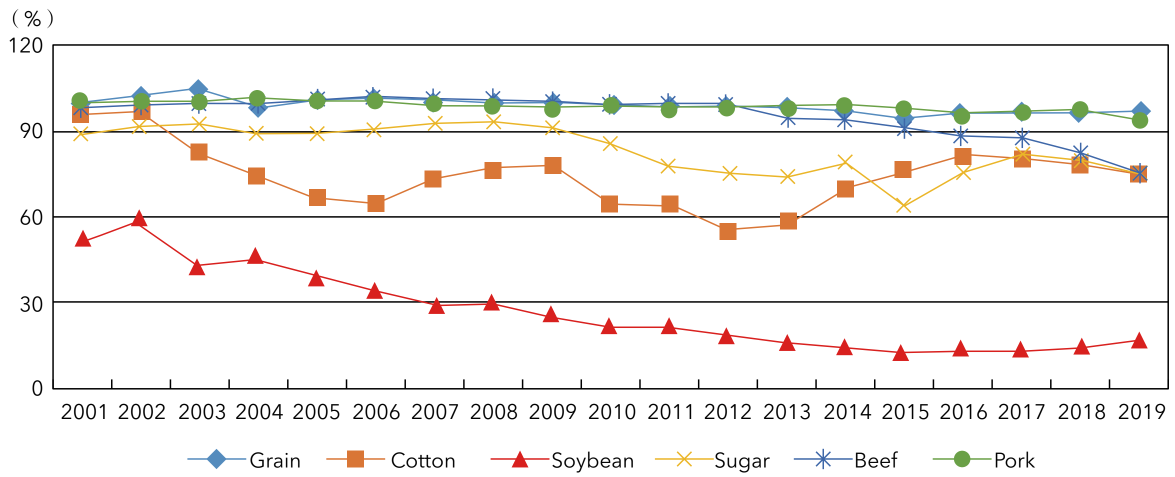
Source: *Calculated by authors using data from Chinese Ministry of Agriculture and Rural Affairs (2020).*

sources, i.e. the European and the North American countries, China's has been importing more and more agricultural products from the South American countries, Australia, New Zealand, and African countries. So far, China has established agricultural trade partnership with 219 countries and regions in the world, and signed 19 free trade agreements with 26 countries, pushing China's agriculture into a new era of "buying from the world and selling to the world" (China Free Trade Service Network 2021).

6.2.4 Net Imports of Bulk Agricultural Products, Declining Competitiveness of Advantageous Export Products

After China's accession to the WTO, especially in recent years, due to the combined effects of rising production costs, consumer demand, and market opening, China's bulk commodities, such as grain, cotton, oil, sugar, and livestock products, began to show a comprehensive net import pattern, and the scale of net imports continued to expand, resulting in a continuous decline in the country's self-sufficiency rate for these products. From 2001 to 2019, the self-sufficiency rates for grains, cotton, soybeans, sugar, pork, and beef dropped from 101.3 percent, 97.5 percent, 53.0 percent, 89.4 percent, 100.4 percent, and 100.7 percent, respectively, to 91.7 percent, 75.5 percent, 17.0 percent, 76.5 percent, 94.8 percent, and 75.6 percent(Figure 6.2). Although China's self-sufficiency rate for major cereal crops is still at a high level, of about 95 percent, if soybeans are included, the broad self-sufficiency rate for grain has been less than 95 percent since 2008, dropped to 90 percent in 2012, and further decreased to 86 percent in 2019. Moreover, in recent years, the export growth rate of China's traditionally advantageous agricultural products has continued to slow down and become sluggish. The export growth rates of vegetables, fruits, and aquatic products have obviously declined since 2012 (Zhu, Li, and Lin 2018). On one hand, the strong import momentum of bulk agricultural commodities indicates that China's dependence on the international agricultural products market is deepening. On the other, the decline of export momentum for advantageous agricultural products highlights the deficiency and further weakening

Figure 6.2 China's self-sufficiency rate for major agricultural products, 2001–2019



Source: *Authors' construction using data from China, Ministry of Agriculture (various years) and China Statistics Press (various years).*
Note: Self-sufficiency rate = output/(output + imports – exports) × 100%.

of China's competitive advantage in agricultural trade.

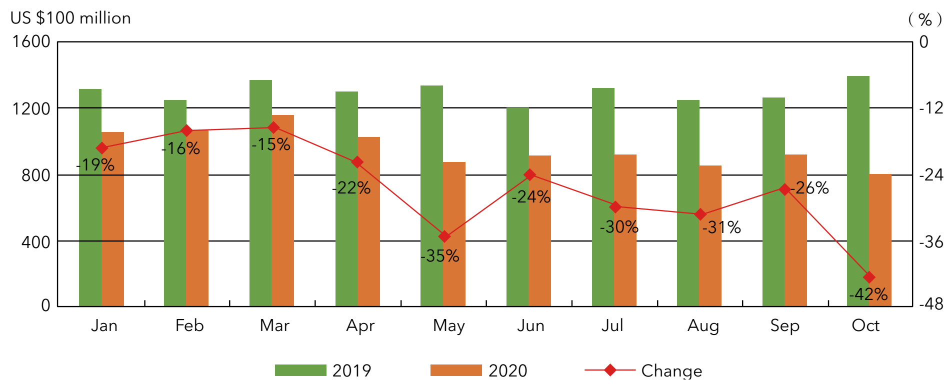
6.3 Impact of the COVID-19 Pandemic on China's Agricultural Trade

The sudden and global spread of COVID-19 has impaired global trade and caused the world economy to fall into a severe contraction. As a vital part of global trade, agricultural trade is also greatly affected by the COVID-19 pandemic. Although China has well contained the spread of the pandemic in a short time, and its economy has stabilized and rebounded rapidly after the pandemic, the increasing severity of the pandemic in other countries, the economic and trade situation, and the escalating trade risks and uncertainties still pose particular challenges to and pressure on China's agricultural trade.

6.3.1 The Pandemic's Impact on the Global Agrifood Systems and Agricultural Trade

Affected by the COVID-19 pandemic, from January to October 2020, the global trade volume of agricultural products dropped by 26.1 percent compared with the same period of the previous year (Figure 6.3). This dip was mainly due to the destruction of agricultural materials and slowdowns in production, processing, transportation, and consumption in the agricultural supply chain. In terms of agricultural supply, whether it is planting or aquaculture, factors such as personnel mobility as well as the logistics of limited transportation have affected the procurement and use of production input factors to a certain extent. In terms of production, due to the restriction of population mobility, the production of labor-intensive products such as fruits and vegetables has been hindered, and the supply of fruits and vegetables in many countries has been interrupted. In terms of processing, the agricultural products processing industry was impaired by the shortage of labor and the closure of factories. This interruption mainly affected factories with high labor intensity, such as fruit and vegetable packaging factories or meat processing factories. Transportation and logistics difficulties also hindered the operation of the agricultural products supply chain. In terms of consumption, the pandemic caused consumers to engage in panic buying or hoarding, which made the demand for key agricultural products (such as rice and wheat) suddenly surge, resulting in short-term shortages. Consumer demand has shifted sharply from restaurants, hotels, coffee shops, and other types of out-of-home consumption to home consumption. Besides these disruptions, the COVID-19 pandemic led to an increase in the number of unemployed people and a decrease in income, which further reduced the demand for agricultural products.

Figure 6.3 Global agricultural trade volume, January–October, 2019 versus 2020



Source: *Authors' compilation using data from the United Nations (2021).*

In addition, the pandemic has intensified trade protectionism in the world, with some countries taking the opportunity to introduce a range of agricultural trade restrictions, which further increased the risk and instability of the international agricultural market and trade (Chen and Mao 2020). Export restriction measures mainly include export bans, export quota management, export tariffs, export licenses, and other categories of restriction. As of December 25, 2020, 38 countries and regions around the world had implemented 1,336 export restriction measures for 196 kinds of agricultural products (ITC 2020). Import restriction measures, widely used by various countries as vital prevention and control measures, mainly include import bans, quarantine requirements, import surtaxes, transportation restrictions, quality certification requirements, and others. Although the scale of agricultural trade accounts for only 8.5 percent of the global trade in goods, it has become the area hardest hit by import restrictions, with the adoption ratio of import restrictions as high as 52 percent. By the end of November 2020, 19 countries and regions around the world had implemented 1,019 import restriction measures against 202 kinds of agricultural products (ITC 2020).

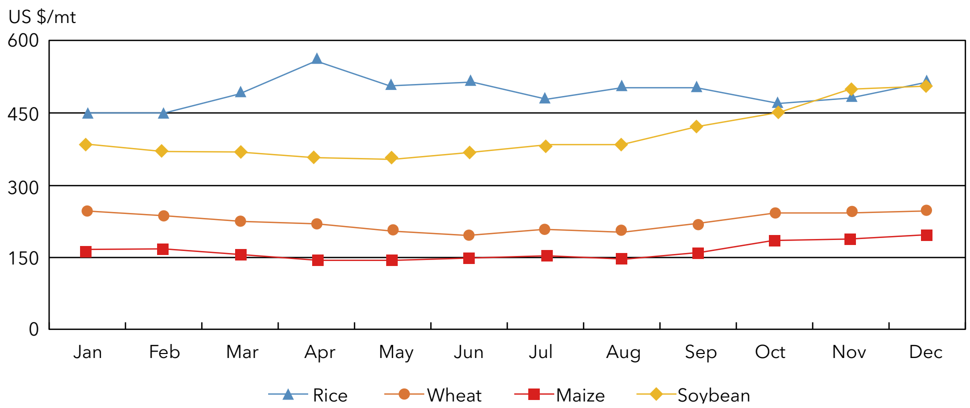
Generally speaking, the COVID-19 pandemic has exerted a great impact on the global agrifood systems and agricultural trade due to its disruption of links in production, consumption, circulation, and distribution. At the same time, the pandemic also induced a series of problems such as a rise in protectionism and an increase in trade restrictions; aggravated the instability of the global agricultural supply chain and trade chain; triggered changes in the global agricultural products market; and pushed the prices of major agricultural products in the world to rise sharply since mid-March 2020, with the price rise in grains and oilseeds particularly significant (Figure 6.4). As a result, the world saw aggravated poverty and hunger, especially in low-income countries, and further deterioration of food security and nutritional status (Fan and Gao 2020). Considering that the current global pandemic has not been effectively controlled, the future prospects of global agricultural trade will still face high uncertainty.

6.3.2 China's Agricultural Product Imports Show Good Resilience under Impact of Pandemic

As the second-largest importer and fifth-largest exporter of agricultural products in the world, China cannot be immune to the impact of the pandemic on its agricultural trade. Nevertheless, the country's imports of agricultural products reached $170.80 billion in 2020, up 13.1 percent year over year. From an overall perspective, the pandemic did not have a significant negative impact on China's agricultural product imports. Except for the year-over-year decrease in January, the import volume in other months rose year over year (Figure 6.5). This sustained growth of agricultural product imports is mainly due to a handful of factors: (1) The pandemic is well contained, and various economic activities in China have been resumed. (2) After the import demand recovered and the pandemic was effectively controlled, the domestic super-large-scale markets provided strong support for expanding imports. (3) The implementation of the first-stage economic and trade agreement between China and the United States has increased the procurement of agricultural products imported from the United States. (4) The tight supply of and demand for some domestic agricultural products (for example, due to the slow recovery of domestic pig production after the African Swine Fever epidemic) has led to an increase in import demand.

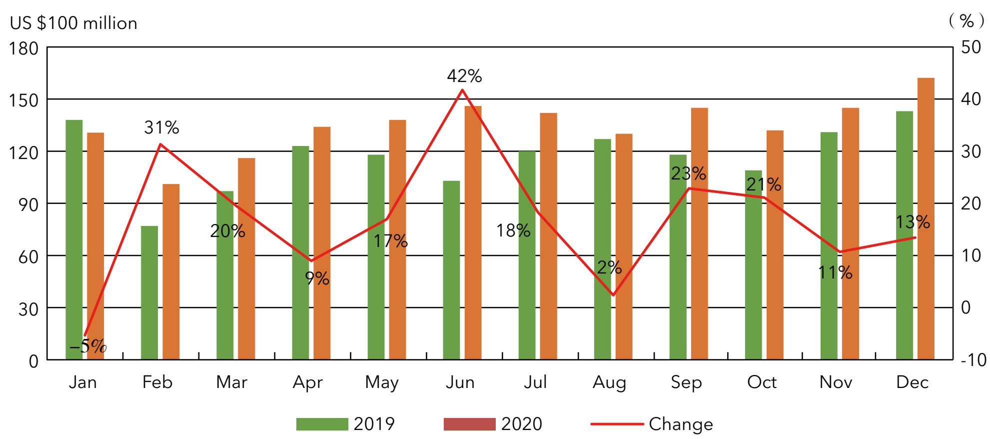
China's major imported agricultural products include oil, meat, aquatic products, fruits, and animal and vegetable fats. In 2020, the total import value of these five types of agricultural products was $110.8 billion, and they accounted for 27.7 percent, 18.7 percent, 7.6 percent, 7.4 percent, and 6.9 percent, respectively, of the total import volume of agricultural products. Since the outbreak of the pandemic, although the import of aquatic products has declined, the import of the other four types of agricultural products has risen, and the import of meat has witnessed the largest increase, reaching 61 percent (Figure 6.6). The main reasons can be summed up as follows: (1) Affected by multiple factors such as African Swine Fever, environmental protection policies, and the COVID-19 pandemic, the number of live pigs in China has been greatly reduced compared with previous years, causing the domestic supply to decline, the gap between pork production and demand to widen, and the price to rise, leading to an increase in import demand. (2) Since the outbreak of the pandemic, the Chinese government has issued a series of policies to expand the import sources and commodity range for livestock products

Figure 6.4 Monthly average price changes of major agricultural products in the world, 2020



Source: *Authors' compilation using data from the World Bank (2021a).*

Figure 6.5 China's agricultural product imports, January–December, 2019 versus 2020



Source: *Authors' compilation using data from China, General Administration of Customs (2020), using Harmonized System (HS) agricultural product codes 1–24.*

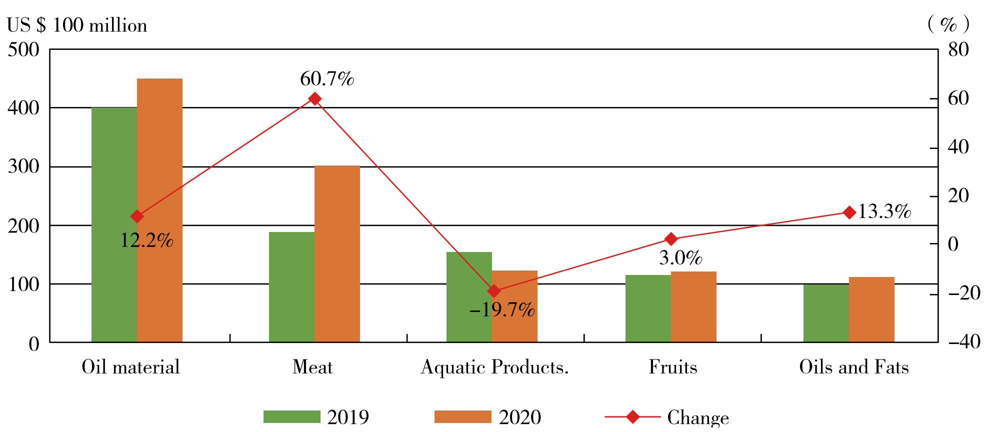
(Cao, Li, Wang, and Zhu 2020), driving the import of livestock products in China to rise sharply. On the other hand, aquatic products have become the agricultural product with the largest decline in China's imports, down nearly 20 percent compared with the same period last year. This is mainly due to the continuous detection of positive novel coronavirus nucleic acid in the outer packaging of imported seafood, seafood processing enterprises, or warehousing and transportation terminals in China, which has made consumers cautious about purchasing imported cold-chain products, resulting in a decline in demand for foreign aquatic products (Liu, Zhang, and Chen 2021).

6.3.3 Increasing Risk of China's Agricultural Exports Being Blocked under the Impact of the Pandemic

Due to the pandemic, the exports of China's agricultural products dropped in 2020, with a year-over-year decrease of 3.9 percent. As can be seen in Figure 6.7, the monthly change in China's agricultural exports in 2020 can be roughly divided into three stages. In the first stage (approximately January and February), the COVID-19 pandemic spread rapidly throughout the country, and the prevention and control situation was extremely severe. Compared with 2019, China's agricultural exports fell sharply year over year, falling by 6.3 percent in January and 21.4 percent in February. In the second stage (from about March to April), domestic pandemic control showed a positive trend. The whole country entered the stage of normalized prevention and control of the pandemic, enterprises resumed work and production in an orderly manner, and orders that had been backlogged in the early stage were delivered centrally, promoting a strong rebound of agricultural product exports (Zhong, Guan, and Huang 2020). In the third stage (May–December), with the rapid spread and continuous escalation of the pandemic in other countries around the world, China's agricultural exports were blocked again. Except for September and November, China's agricultural exports decreased significantly year over year in the third stage.

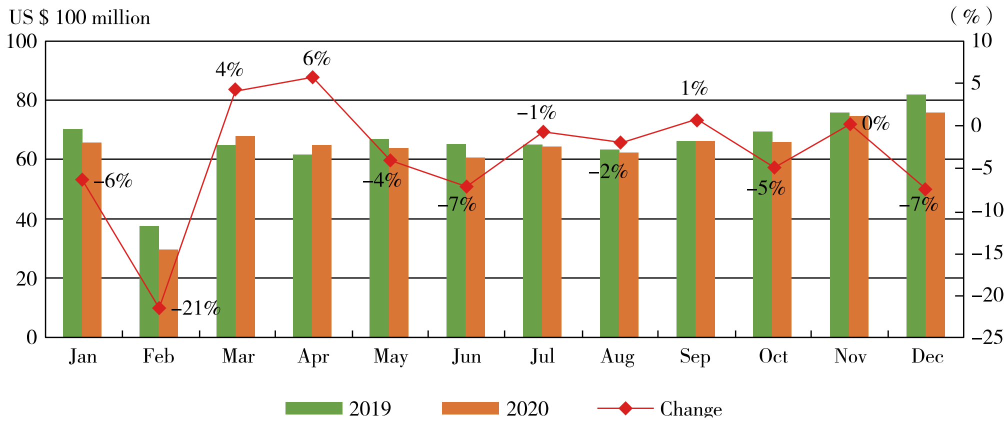
China's major exported agricultural products include aquatic products, vegetables, meat products, fruit and vegetable products, and fruits. Since the outbreak of the pandemic, except for the increase in fruit exports, the exports of the other four types of advantageous agricultural products have all declined, and the exports of aquatic products have seen the biggest drop (Figure 6.8). In 2020, China's aquatic products exports amounted to $10.71 billion, down by $1.76 billion year over year, a decrease of 14 percent; vegetable exports amounted to $9.67 billion, down by $660 million year over year, a decrease of 6 percent; exports of meat products amounted to $9.17 billion, down by $80 million year over year, a decrease of 1 percent; exports of fruit and vegetable products amounted to $7.62 billion, down by $210 million, or 3 percent, year over year.

Figure 6.6 China's import value of major agricultural products, 2019–2020



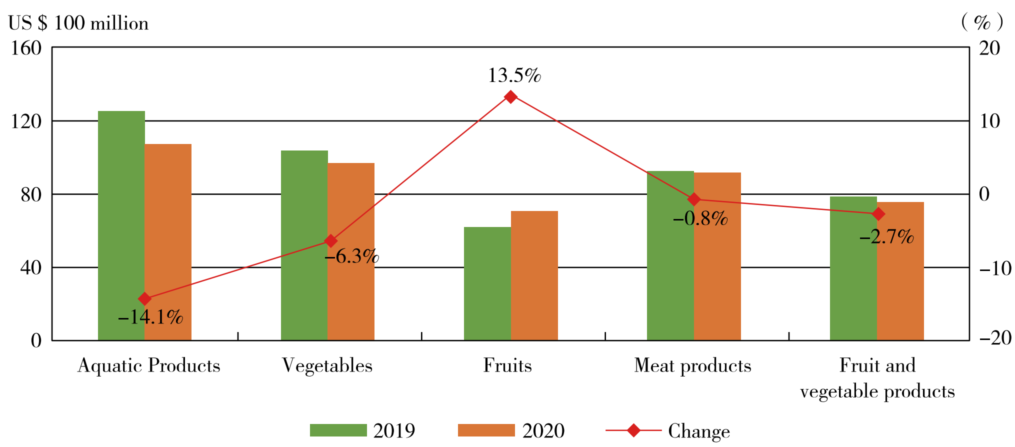
Source: *Authors' compilation using data from China, General Administration of Customs (2020), using Harmonized System (HS) agricultural product codes 1–24.*

Figure 6.7 China's agricultural exports, January–December, 2019 versus 2020



Source: *Authors' compilation using data from China, General Administration of Customs (2020), using Harmonized System (HS) agricultural product codes 1–24.*

Figure 6.8 China's dominant agricultural products export volume, 2019 and 2020



Source: *Authors' compilation using data from China, General Administration of Customs (2020), using Harmonized System (HS) agricultural product codes 1–24.*

The main reasons for the disruption of China's agricultural exports were different in the first stage than in the later stages of 2020. In the first stage, the shortage of personnel, traffic obstruction, and difficulties in resuming work and production caused by strict isolation and prevention measures led to the delay of production progress of some export enterprises, making it difficult to deliver foreign orders and complete planned exports of agricultural products on time. In addition, after the outbreak in China, some countries and regions continuously raised the inspection and quarantine threshold or issued import bans for Chinese agricultural products. Six countries, including Egypt, Georgia, Jordan, Kazakhstan, Mauritius, and Russia, have banned the import of aquatic products, live animals, fruits and vegetables, and plant products from China, a measure that has also reduced the export of Chinese agricultural products to a certain extent. During the outbreak in China, a survey of the country's agricultural export enterprises' response to the pandemic showed that 68.5 percent of enterprises faced rising costs, 63 percent suffered logistics obstruction, 52.4 percent expressed financing difficulties, 48.3 percent faced a lack of labor, and 31.7 percent encountered restrictive measures taken by importing countries or regions (China Rural Network 2020).

In the third stage of 2020, although normal prevention and control were being carried out in China, the pandemic situation abroad continued to escalate, and the weak international market demand once again hit China's agricultural exports. Considering that China's demand elasticity for aquatic products, fruits and vegetables, and other products with export advantages is relatively large, in the context of global economic downturn and declining residents' income, the overseas consumption demand for these products is significantly reduced compared with products that have relatively low demand elasticity, such as grain (Cao, Li, Wang, and Zhu 2021). Moreover, 14 countries, including Australia, Egypt, Georgia, Indonesia, and Vietnam, continued to impose import restrictions on Chinese agricultural products, greatly increasing the difficulty for Chinese agricultural products to enter these markets (ITC 2021).

6.4 Under the New Paradigm of "Dual Circulation" in the Post-pandemic Era: Prospects and Policy Recommendations for China's Agricultural Trade

To sum up, as an important part of the agrifood systems, China's agricultural trade has undergone tremendous changes in the 20 years since the country's accession to the WTO. Trade has played a crucial and positive role in supplementing domestic supply, meeting diversified consumption needs, promoting optimization of the agricultural production structure, and relieving pressure on resources and the environment. In the context of the COVID-19 pandemic, China's agricultural trade has been resilient, and its imports and exports have been barely affected by the pandemic. However, in the long run, the complex internal and external environment, including the unknown evolution of the pandemic and the instability of the international political and economic structure, will still bring a series of severe challenges and pressure to China's agricultural trade, mainly including (1) increasing dependence on the import of bulk agricultural products, (2) declining international competitiveness of advantageous export products, and (3) rising trade protectionism and increasing trade risks and uncertainties. Under the new development paradigm, it is necessary to seize the opportunity of a "dual circulation" transformation, plan ahead, and take the initiative to promote high-quality development of China's agricultural trade and its transformation to a more open, efficient, and stable system. Specifically, China should focus on achieving the following:

6.4.1 Adjust the Supply and Demand Guarantee Philosophy from "Dual Balance" to "Ternary Balance"

At present, China's imports of agricultural products account for one-tenth of the global trade volume of agricultural products; its net import of grain is equivalent to one-fifth of the total domestic grain output; and its import of grain, cotton, oil, sugar, meat, and milk is equivalent to the production of more than 67 million ha of cultivated land and more than 120 billion m^3 of water resources, or the equivalent of 40.0 percent and 30.7 percent of its total sown area of domestic crops and its agricultural water, respectively (Ni 2019; Ali et al. 2017). The international market has become indispensable to ensure the supply of agricultural products and food security. Meanwhile, China's reliance on international markets means that its agriculture will face greater competitive pressure and higher import risks (Zhu, Li, and Lin 2018).

In light of this situation, there is an urgent need to change the traditional view that regards trade as a surplus and that can be adjusted to address any deficiency in the "dual balance" between domestic production and demand. Agricultural product trade and the international market should be incorporated into the strategic framework and systematic planning for the national medium- and long-term balance of supply and demand of important agricultural products. Moreover, a new philosophy that promotes a ternary balance of "production-consumption-trade" should be established, resulting in an open guarantee system for the balance of supply and demand of agricultural products based on a global orientation.

To begin with, it is necessary to systematically consider the interactions between the demand and supply, import and production, and international market and domestic market in relation to important domestic agricultural products. There is also a need to establish and improve a regulatory system and mechanism that is compatible with the "ternary balance" philosophy to ensure that domestic industrial policies are linked with trade policies, that the distribution of domestic productive forces is matched with the utilization of the international market, and that the trend of domestic supply and demand is coordinated with the growth of imports and exports, so as to avoid a negative impact of excessive imports of agricultural products on domestic production and markets.

It is also necessary to continue to make use of the important role of the international market in giving full play to China's comparative advantages and optimizing its allocation of resources. While improving the availability and stability of imports of resource-intensive agricultural products, efforts should be made to fully use the substitution effect of foreign markets on the domestic market to promote structural adjustment and supply capacity improvement for key agricultural products; give full play to China's export advantages in labor-intensive agricultural products, agricultural capital, and technology; and realize structure-based massive imports and exports.

6.4.2 Face the International Competitive Pressure of Agricultural Products and Promote the Transformation of Domestic Agricultural Production Methods and the Upgrading of Competitiveness

As China's trade deficit in agricultural products continues to grow, the overall net import of bulk agricultural products and the decline of export momentum of advantageous agricultural products expose the decline and deficiency of China's agricultural trade competitiveness. When the country first entered into the WTO, China's agriculture maintained strong international competitiveness through abundant labor resources and high land productivity. However, with the advancement of industrialization and urbanization, although agricultural labor productivity has been improving rapidly, it still cannot keep up with the rising opportunity cost of agricultural labor, resulting in the continuous rise of labor cost per unit product in China. Both land-intensive agricultural products and labor-intensive agricultural products have been gradually losing their international competitiveness.

Under the constraints of low border protection and insufficient domestic support, the fundamental way to effectively regulate the import and export of China's agricultural products in the future is to enhance the international competitiveness of the country's agriculture (Zhu, Li, and Zang 2021). On the one hand, it is necessary to focus on the main factors that lead to a rapid rise in the production cost of agricultural products by looking at the principle of "low cost and low price," and to reduce the production cost of agriculture (especially of field crops such as grain) by expanding the scale of agricultural operations, promoting scientific and technological progress, and increasing investment in infrastructure. On the other hand, based on the principle of "high quality and unique characteristics" and considering international competitive pressure and market consumption demand, it is necessary to incorporate concepts such as low carbon footprint, environmental protection, green production, and nutritious and healthful foods; promote the transformation of domestic agriculture from increasing production to improving quality; rely on quality, branding, science, technology, greening, and service to attract markets for export; enhance quality agriculture, green agriculture, and branded agriculture; and continuously improve the quality and safety, brand cultural connotation, and comprehensive competitiveness of the country's agricultural products.

6.4.3 Enhance Control of External Market Utilization, and Transform from Unilateral, Independent Market Opening and Closing to Active Risk Management and Control

The world is undergoing change at a magnitude not seen in a hundred years. A series of nonmarket factors, such as ideology, geopolitics, and challenges to the multilateral trade and investment framework system, may seriously disrupt the global agricultural market and trade order. Other factors, such as food energy, financialization, frequent natural disasters, and epidemic spread, will also complicate the market situation for agricultural products at home and abroad (Zhang et al. 2020; Morton 2020). Facing increasing risks surrounding the international trade of agricultural products, China should strive to improve its ability to control the international agricultural products market and resources, and disperse and resolve import risks and other risks through the construction of an active risk management and control system.

First, efforts should be made to strengthen the construction of an agricultural trade risk monitoring and early warning system; to strengthen the basic work of monitoring, judging, and warning the international market for bulk agricultural products such as grain, cotton, oil, sugar, meat, eggs, and milk; to track the supply, demand, and trade trends of key countries, markets, and products; to enhance public welfare information services; and to effectively improve the ability of domestic agricultural enterprises to cope with fluctuations and risks in the international market.

Second, measures should be taken to further promote the strategy of diversifying agricultural product imports; grasp the scale, rhythm, modes and sources of agricultural imports; strengthen agricultural trade cooperation with Association of Southeast Asian Nations (ASEAN), Central Asia, Africa, South America, and other countries along the Belt and Road Initiative; promote the diversification of agricultural product imports as to varieties, regions, and supply channels; build an efficient, stable, and reliable overseas agricultural products supply chain; and disperse the risks of centralized import.

Third, it is necessary to actively participate in the construction of a global agricultural product industry chain; rely on the Belt and Road Initiative, the Regional Comprehensive Economic Partnership, and other multilateral/regional agreement frameworks; vigorously support advantageous agricultural product brands and enterprises to "going outside"; strengthen investment coverages in the industrial chain and its key links; enhance the control and discourse power over the industrial chain; lay a solid foundation for the establishment of efficient, stable, and reliable import channels; and create conditions for increasing the export of advantageous agricultural products.

Fourth, efforts should be made to strengthen the construction of a domestic agricultural trade promotion system and an industrial damage relief system; to increase support for agricultural export enterprises; and to help industries, regions, and individuals damaged by trade risks to reduce their losses and avoid risks in a timely manner.

6.4.4 Actively Participate in Global Food and Agriculture Governance, and Create a More Stable External Environment and Fair Institutional Arrangements

To ensure rational use of the international market and external resources, China should not only strengthen the controllability of risks but also take the initiative to actively create a stable international agricultural production and trade environment by strengthening cooperation with countries and international institutions around the world. China should actively participate in global food and agriculture governance and promote the establishment of a stable and fair new order. According to estimates from the UN World Food Programme (WFP), the COVID-19 pandemic has increased the number of people facing severe food insecurity in 79 countries, from 149 million in 2019 to 272 million in 2020 (World Bank 2021b). By 2030, there will be 130 million additional extremely poor people in the world (United Nations 2020). In this regard, during the current pandemic period and the future post-pandemic era, China needs to join hands with other countries to fight against the pandemic, promote the building of a community with a shared future for humankind, cooperate to enhance the global capacity to produce and supply agricultural products, and improve global food and nutrition security, especially in developing countries. At the same time, the country should actively maintain the framework arrangement of its multilateral trade and investment system, strengthen the construction of a global coordination mechanism of agricultural trade policy, enhance mutual trust between advocates of global agricultural trade opening and those concerned with food security, and jointly safeguard the stability of the world agricultural products market.

In addition, considering that agricultural trade will play a positive role and have bright prospects in optimizing the allocation of global agricultural resources as well as reducing greenhouse gas emissions and environmental pollution (FAO 2018; OECD and FAO 2020), China should actively use international trade to promote the high-quality development of its agriculture; participate in and lead the agricultural reform under the framework of the WTO and the collaborative governance of international institutions such as the Food and Agriculture Organization of the United Nations, the International Energy Agency, the International Fund for Agricultural Development, and the WFP; effectively promote all-around global cooperation in agricultural development, food security and nutrition, greenhouse gas emissions, and climate change; and assist the transformation and sustainable development of the global agrifood systems.

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