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REVIEW

The prospects for China's food security and imports: Will China starve the world *via* imports?

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Abstract

China's food supply and demand have significant implications for both China's own national food security and that of the world. This study reviews China's food security prospects and their implications, focusing on international trade in the coming decade. The results show that China's policies for ensuring food security will be enhanced and China will move to sustainable agriculture. Most studies anticipate that China will increase its food and feed imports in the coming decade. China's overall food self-sufficiency is likely to fall from 94.5% in 2015 to around 91% by 2025. The greatest increases in imports are likely to be soybean, maize, sugar, and dairy products. However, within the production capacity of the major exporting countries and of many food-importing developing countries, China's additional imports of 3 to 5% of its total food consumption in the coming decade are unlikely to threaten global food security. Indeed, the projected imports of feed and several foods could provide opportunities for many exporting countries to expand their production and save global resources.

Keywords: food security, food supply, import, China, global

1. Introduction

China has made remarkable progress in agricultural production since the economic reform initiated in the late 1970s. The average annual growth of agricultural GDP reached 4.5% from 1980 to 2015, which was about four times China's population growth over the same period (NBSC 2016). The production of nearly every agricultural commodity has increased. The most significant growth has been recorded in horticulture, livestock, and fishery products (NBSC 2016).

In the meantime, food demand has also increased significantly, and consumption patterns have changed. Within the past four decades, after the population growth rate peaked (1.66%) in 1987, it began to decline and fell to less than 0.5% after 2009 (NBSC 2016). The major driving forces of food demand have gradually shifted from population growth to rising income and urbanization, leading to significant changes in food demand and consumption patterns since the late 1980s (Fan *et al.* 1995; Huang and Bouis 1996; Huang *et al.* 2010). Because of these changes,

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the demand for food grain has been falling since the mid-1990s, and demand for horticultural products, edible oils, livestock, and aquatic products, as well as for high-quality and safe foods has increased considerably (Ma *et al.* 2006; Gale and Huang 2007; Bai *et al.* 2010).

The relative changes in food production and demand growth have affected China's position in the global food trade. Amid a continuously increasing food demand, China has shifted from a net food exporter to a net importer over the past decade (see Fig. 1). Among agricultural commodities, China's leaders are particularly concerned about grains[1], but China's self-sufficiency declined from 97% in 2001 to 86% in 2014 (NBSC 2015). The most rapidly rising import is soybean. Its import reached 84 Mt in 2016. Meat imports have also increased in recent years (NBSC 2016).

Given the sheer size of its population (1.375 billion people in 2015), China's food security has attracted great attention during the past several decades. While doom-laden predictions in the early 1990s that China would distort global trade and starve the world in the early 21st century (Brown 1995) have not been realized, the recent increases in food and feed imports have again come under scrutiny both in China and the rest of the world. If China repeats past experiences of significantly rising food imports in similar land-scarce neighboring countries such as Japan and South Korea, it could have huge global implications (McMichael 2000; Otsuka 2013). There is also increasing concerns about the threat of unsustainable agricultural production to China's long-term food security (e.g., soil degradation and groundwater over-exploitation; Zhang *et al.* 2013; Lu *et al.* 2015).

Previous reviews of China's food supply and demand projections have provided some insights into the prospects of China's future food security[2]. For example, a review paper by Lv (2013) focused on studies about China's grain production and demand projections toward 2020/2030. His review showed a wide range of both the production and consumption of grain in China, with both pessimistic and optimistic views on the country's grain imports. However, most of the pessimistic projections were made in the 1990s and early 2000s, and often stemmed from inappropriate assumptions about China's production potential (Alexandratos 1996; Fan and Agcaoili-Sombilla 1997). On the other hand, the optimistic projections of China's food security often underestimated the rising demand for meats and feed (e.g., Li 2005; Ma and Niu 2009). Norse *et al.* (2014) reviewed China's supply and demand projections toward 2020 for grains and other major foods, showing that, on average, China will be close to self-sufficiency in rice and wheat and about 90% self-sufficiency in maize and other coarse grains by the 2020s. While they concluded with an optimistic view that China's food security would not be at risk, they cautioned against the environmental degradation and sustainability of China's agriculture (Norse *et al.* 2014). One of the major points made in the previous review papers is that China's food production and imports will heavily depend on the policies governing domestic production in the future (Lv 2013; Norse *et al.* 2014).

While future food policies are of critical importance in shaping China's food supply and trade, none of the studies reviewed by Lv (2013) and Norse *et al.* (2014) considered the recent changes in China's food policies. As shown by Huang and Yang (2017), policy changes have occurred not only for national food self-sufficiency targets but also

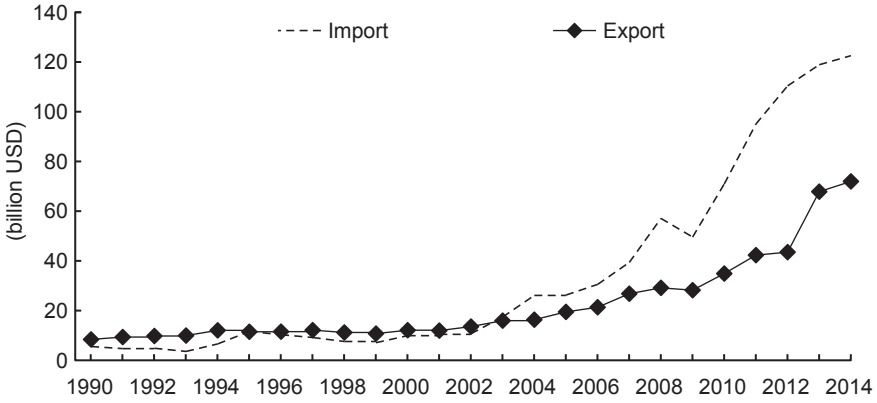

Fig. 1 China's food imports and exports, 1990–2014 (billion USD). Source: FAO (2017).

[1] In China, grains include cereal (rice, wheat, maize, and coarse grains), soybeans, sweet potato, and potato.

[2] Though several papers have reviewed the driving forces of China's agricultural growth in the past decades, such as Zhou (2016), this study mainly focused on the projection of food supply and demand in future.

concerning how China should modernize its agriculture for sustainable growth in the long run. Considering the recent policy changes in food supply and demand projection analysis can improve our understanding of China's future food security.

The overall goal of this paper is to review China's food supply and demand and their implications for food security in China and the rest of the world in the future[3]. To achieve this goal, our paper has the following three specific objectives: (1) synthetizes the major factors that have affected China's food production in the past and the recent policy changes as well as their likely future trends; (2) reviews China's food supply and demand projections for the coming decade; and (3) draws the policy implications of China's food imports for China's future policies and pressures on global food markets and natural resources.

The remainder of this paper is organized as follows. Section 2 summarizes the major driving forces of past food production, recent policies, and likely future trends. Section 3 starts by reviewing the major studies on China's food supply and demand projections published in referred journals between 2005 and 2015 that have not considered recent policy changes and then presents the latest projections toward 2025 that use 2015 data as the base year[4]. Section 4 discusses the likely implications of China's rising food imports. The last section concludes the study by offering implications for both policy and research.

2. Major driving forces of agricultural production in China

2.1. Major driving forces since the late 1970s

After reviewing the literature on China's food production and policy, Huang and Yang (2017) concluded that four major driving forces have fostered China's agricultural growth since the economic reform initiated in 1978. First, institutional changes have been an important source of China's agricultural growth, particularly in the early reform period. For example, it has been well-documented that the household responsibility system that improved farmers' production incentives was the most important factor in increasing agricultural production from 1978 to 1984 (Fan 1991; Lin 1992; Huang and Rozelle 1996; Zhou 2016). Second, technological change has been a key driver of agricultural growth since the mid-1980s. The literature showed that more than half of the agricultural production growth can be attributed to the increasing total factor productivity (TFP), while technological change was a primary source of agricultural TFP growth (Fan and Agcaoili-Sombilla 1997; Jin *et al.* 2010). Third, the gradual market reform and trade liberalization have facilitated China's smooth transformation from a planned economy to a market-oriented one, which contributed to the overall agricultural production growth and the change in commodity structure since the early 1990s (Park *et al.* 2002; Huang and Rozelle 2006). Finally, increasing investment in rural infrastructure, such as irrigation (Wang *et al*. 2017), has contributed to the steady growth of China's agriculture over the past four decades. Besides the above four major factors that have driven agricultural production growth through boosting agricultural productivity, the increases in chemical fertilizer, pesticide uses and mechanization as well as other inputs have also raised agricultural production in China in the past decades.

2.2. Recent policy shifts and prospects for the coming decade

China has been shifting its policy regime from taxing to subsidizing and protecting its agriculture since the early 2000s. Agricultural tax has been completely eliminated since 2006 (Chen 2010). Meantime, the government has begun to implement a variety of subsidies for famers since 2004, including grain direct subsidy, quality seed subsidy, machinery subsidy, and aggregate input subsidy. These policy changes have raised farmers' incomes and production incentives (Chen 2009).

However, the results of government market intervention intended to protect agriculture, particularly grain, implemented since the late-2000s are mixed. While market intervention through minimal price or government procurement raised grain prices and farmers' incomes, it also distorted crop production, hurt the livestock and processing industries, and accumulated huge grain reserves (Hejazi and Marchant 2017; Huang and Yang 2017). The most distorted market is that of maize. For example, with the increasing government maize procurement, the annual growth rate of the maize area increased from 2.0% in 1990 to 2009 to 3.4% in 2009 to 2015 (NBSC 2016). Through the combined area expansion and yield increase, annual growth in maize production reached 5.4% from 2009 to 2015. As a result of oversupply, China held more than 200 Mt of maize stocks at the end of 2016.

The good news is that China restarted its agricultural

[3] It is worth noting that, while the FAO's definition of "food security" covers several dimensions, China's food security has focused on grain self-sufficiency and imports of major food products. While household food security and nutrition are also important components of the nation's food security, they are not covered in this paper.

[4] Using actual production, consumption, and trade data for 2015 as the base year implies that policy changes up to 2015 have been embodied in the data and the projection models.

market and pricing reforms in 2014. Recognizing the difficulty of sustaining its grain market intervention program, China introduced a target price policy for soybean in 2014, reduced rice and wheat procurement in 2015, and phased out maize procurement in 2016 (Hejazi and Marchant 2017; Huang and Yang 2017). Eliminating excessive maize and other grain stocks will affect the growth of not only grain production but also other crop and livestock production in the coming years.

Recognizing the challenges of increasing food imports, China has also introduced several significant new policies. These have further highlighted the importance of the institutional change, technology innovation, and investments designed to boost China's agricultural productivity and enhance its food security in a more sustainable way. For example, the strategic guiding policies for China's food security are outlined in the 13th Five-year Plan (2016–2020) for National Economic and Social Development (CCCPC 2016), which emphasizes the critical roles of agricultural technology and investment for agricultural growth in the long run. Given China's limited land and water resources, the government has also adjusted its national food security priority from a focus on all grains to one on food grains (rice and wheat) in recent years.

Several major efforts have also been initiated to address the challenges of sustainable agricultural growth. These include (1) facilitating institutional reforms to improve land tenure and the rental market so that land can be consolidated[5]; (2) substantially enhancing scientific and technological innovation capacity and implementing the *cang-liang-yu-ji* (or "Storing Food in Technology"), a food production strategy based on technology, to boost agricultural productivity in the long run; (3) increasing investment in land and water infrastructure and implementing the *cang-liang-yu-di* (or "Storing Food in Land"), a food production strategy based on farmland, to improve agricultural production capacity in the long run. Investment in water infrastructure has increased, totaling about 630 billion USD for the period 2012–2020.

3. China's food supply and demand projections

3.1. Review of major food supply and demand studies conducted during 2005–2015

In this sub-section, we review the previous studies on food supply and demand projection toward 2020 that have been conducted between 2005 and 2015. The papers selected for review meet the following two requirements: they were published in refereed journals and used either the general or partial equilibrium model. As they were published between 2005 and 2015, the base years used in the projections range from 2000 to the early 2010s. The above selection criteria produced 12 journal articles, as summarized in Table 1. The commodities included in these studies cover grain and livestock products. Unfortunately, none of these papers examines the supply of and demand for vegetables and fruits, in which China has comparative advantages.

Table 1 shows that China will need to import food to meet its increasing demand, though import projections differ across studies. Except for rice, all products included in these studies are projected to be imported in some amounts from the international market in 2020. The commodities with imports exceeding 10% of domestic consumption include soybean, maize, dairy, and beef. The high imports of dairy and beef are largely due to higher demand growth as incomes rise and to constraints on the expansion of grazing animal production in China. The rising imports of soybean and maize are explained by the increasing demand for meats and therefore feed demand. On the other hand, China is also likely to import moderate amounts of other foods such as wheat, pork, and mutton. Their imports will account for about 2 to 5% of domestic consumption by 2020 (Table 1).

While all studies agree that China will import substantial amounts of soybean, the projected imports in 2020 are all much lower than the actual imports in 2015 (nearly 82 Mt). This implies that these studies have vastly underestimated China's demand for soybean. Interestingly, more recent studies such as Cao and Zhao (2011) and Huang *et al.* (2012) have generally projected more soybean demand for 2020 (ranging from about 88 to 98 Mt) than earlier studies such as Chen (2005, 55 Mt), indicating that researchers' recognition of the rising feed and edible oil demand in China has increased over time.

Maize is another commodity that needs more discussion. While the projections in most studies show rising maize demand and imports and a decline in its self-sufficient rate (SSR), they tend to underestimate production, and some also underestimate demand or overestimate imports. Lu *et al.* (2011) optimistically project near self-sufficiency (97%) for maize by 2020, but their projection is based on a significant underestimation of both demand (180 Mt) and production (174.6 Mt) because China's maize production already reached 224.6 Mt in 2015 (column 1, Table 2). Although the highest import (24.7 Mt) is projected by Chen (2005), this import is also based on a significant underestimation of both production (143 Mt) and demand

[5] Huang and Ding (2016) show that these institutional changes and policy supports for land consolidation have increased the average farm size since 2008.

Table 1 Projections of China's food production, demand, net import (Mt), and self-sufficient rate (SSR, %) for 2020

Food	Production	Demand	Net import	SSR	Reference
Cereal	439.8	505.2	66.0	87	Chen (2005)
Rice	183.5	178.8	–3.3	103	
Wheat	94.5	102.8	8.3	92	
Maize	143.0	168.4	24.7	85	
Soybean	18.8	55.1	36.3	34	
Coarse grain	42.7	46.9	4.2	91	Chen and Liu (2008)
Rice	–	–	–	103	Huang *et al.* (2010)
Wheat	–	–	–	95	
Coarse grains	–	–	–	86	
Oilseeds[1)]	–	–	–	45	
Beef and mutton	–	–	–	94	
Pork and poultry	–	–	–	100	
Dairy	–	–	–	81	
Soybean	18.5	98.1	79.3	19	Cao and Zhao (2011)
Grain	536.2	595.8	59.6	90	Lu *et al.* (2011)
Cereal	478.3	493.1	14.8	97	
Rice	188.3	192.1	3.8	98	
Wheat	115.4	117.8	2.4	98	
Maize	174.6	180.0	5.4	97	
Soybean	17.2	61.4	44.2	28	
Coarse grain	9.2	9.1	–0.1	102	
Grain	575.0	663.0	88.0	87	Huang *et al.* (2012)
Rice	160.7	157.5	–3.2	102	
Wheat	134.8	137.5	2.8	98	
Maize	210.0	230.0	20.0	91	
Soybean	15.8	87.8	72.0	18	
Mutton	5.0	5.3	0.4	94	Ding and Xiao (2014)
Mutton	4.5	4.7	0.2	96	Liu *et al.* (2014)
Rice	201.0	206.5	5.5	97	Ni (2014)
Wheat	121.8	128.0	6.3	95	
Maize	221.6	260.5	38.9	85	
Maize	219.1	245.4	6.5	89	Yang and Wu (2014)
Pork	71.7	73.6	1.9	97	Hu *et al.* (2015)
Beef	6.0	7.2	0.6	83	Shi *et al.* (2015)

[1)] Oilseeds in Huang *et al.* (2010) include soybean and other oilseeds.
–, no data.

Table 2 China's food and feed production in 2015 and projection for 2025 (Mt)

Food	2015 (NBSC 2015)	2025			
		This study	CAAS (2016)	OECD-FAO (2016)	USDA (2016)
Rice	145.8	135.5	144.2	145.2	152.9
Wheat	130.2	116.7	132.8	134.0	139.2
Maize	224.6	235.3	212.3	240.5	248.5
Soybean	11.6	11.3	14.9	14.0	12.5
Oilseed[1)]	35.5	36.7	37.7	35.4	–
Sugar	10.6	12.8	11.2	13.6	–
Beef	7.0 (4.9)[2)] (6.8)[3)]	6.2	8.5	8.5	7.2
Mutton	4.4 (3.7)[2)]	4.5	5.6	5.7	–
Pork	54.6 (47.5)[2)]	58.1	62.5	62.5	62.7
Poultry	18.3 (16.4)[2)] (13.0)[3)]	20.7	21.2	21.2	15.8
Dairy	38.9	51.2	45.0	49.4	–

[1)] Oilseeds do not include soybean.
[2)] Pork, beef, mutton, and poultry production used in base year (2015) in the Chinese Agricultural Policy Simulation Model (CAPSiM).
[3)] Beef and poultry production used in base year (2015) in USDA (2016).
–, no data.

(168.4 Mt). The projections toward 2020 in more recent studies (Huang *et al.* 2012; Ni 2014; Yang and Wu 2014) are on the high side for production, demand, and import. They conclude that maize production will increase to a range of 210 Mt (or 91% of SSR; Huang *et al.* 2012) to 221.6 Mt (or 85% of SSR; Ni 2014) by 2020, however, these levels are still lower than the actual production reached in 2015. The large variations and less successful projections of maize production, demand, and imports in most studies are not surprising because the recent significant shifts in maize procurement policy were not included in their expectations.

Because the studies reviewed above were not able to consider the recent changes in food policies and national strategies for pursuing sustainable agriculture, in the next sub-section, we review below the latest studies that updated their base year to 2015 and projection to 2025 but have not been published in referred journals.

3.2. Review of the latest studies on food supply and demand projection in 2025

Several major organizations have regularly projected China's food supply and demand and delivered updated baseline projections in 2016[6]. They include the Chinese Academy of Agricultural Sciences (CAAS 2016), the Organization for Economic Cooperation and Development and Food and Agricultural Organization of the United Nations (OECD-FAO 2016), and the United States Department of Agriculture (USDA 2016). We also project food supply and demand in China (named as this study or our study in the rest of this paper). Our study is based on a multi-sector partial equilibrium model — the Chinese Agricultural Policy Simulation Model (CAPSiM), developed by the China Center for Agricultural Policy (CCAP). The CAPSiM and the major assumptions used for the baseline scenario are described in Appendix A. Because some commodity categories (e.g., coarse grains, vegetables, and fruits) differ among studies, in this review, we focus on projections of production, demand, and net imports of those commodities that are comparable to those of the above-reviewed studies. These commodities include rice, wheat, maize, soybean, sugar, beef, mutton, pork, poultry, and dairy.

Compared with other projection studies, our projections have improvements in at least three aspects: 1) The demand parameters used in CAPSiM are mostly based on the recent empirical studies conducted by CCAP; 2) We allow our demand elasticities to change over time as income increases; 3) Unlike other projections that impose maize TRQ[7] policy in the future, we also simulate the scenario without imposing TRQ policy.

Production projections Compared with those of most earlier studies, the latest projections generally predict slightly higher productivity growth but lower growth in grain area in the coming decade. The higher productivity (e.g., higher crop yields or higher meat-feed conversion rates) reflects the Chinese leadership's recent commitments to raise agricultural production by increasing investments in agricultural technology and natural resources (i.e., land and water). The lower growth in grain area is due to the reduced grain price protection in the coming years. In the USDA projection (USDA 2016), cereal production (except for rice) is projected to fall. This seems reasonable because China has been phasing out its grain market intervention since 2014 (Huang and Yang 2017). For example, maize production decreased by 2.6% in 2016 (MOA 2017) when maize prices fell because the government's maize procurement was phased out.

The latest production projections are consistent with each other in terms of the rising production of most commodities, but their projections of cereal production differ widely. From 2015 to 2025, a moderate increase in production is projected for rice and wheat by the USDA (2016) and for wheat by the OECD-FAO (2016). Virtually no change in rice and wheat production is projected by the CAAS (2016), but about a 9% decrease in both rice and wheat production is projected by our study (rows 1 and 2, Table 2). We project a decrease in rice and wheat production in 2025 over 2015 because we expect that grain prices will fall with the release of substantial government stocks and that demand will not grow significantly from 2015 to 2020. The recovery of production will be very moderate from 2020 to 2025 because rice and wheat consumption is not projected to increase. For maize production from 2015 to 2025, the CAAS (2016) projects a slight decrease, and the other three studies project an increase of about 5 to 10%. All studies project an increase in soybean production. The higher growth of soybean production projected by the CAAS (2016) is explained by the shift from maize to soybean production, as the price of maize relative to that of soybean will fall.

China's livestock production is projected to grow and largely meet the nation's growing demand (rows 7 to 11 in Tables 2 and 3). From 2015 to 2025, mutton, beef, and dairy production will increase by about 20 to 30%, at an annual growth rate of 2 to 2.5%. Further, poultry and pork production is projected to increase by about 10 to 15% in the coming decade. USDA (2016) and our study projected

[6] Although the changes in food quality demand is also important in projecting future food demand (Huang and Gale 2009; Yu and Abler 2009), all studies reviewed in this paper have not examined this issue.

[7] China's maize import is under a tariff rate quota (TRQ) regime. We assume that China would not impose the above-quota import tariff (65%) for maize import exceeding the import quota (7.2 Mt). Otherwise, maize import will be limited to 7.2 Mt but meat import will rise.

lower poultry and beef production in 2025 than the other two studies because they consider the official production data to be overstated and thus adjust the production level in the base year (2015) in their projections (column 1 in Table 2).

Demand and trade projection Except for a few commodities, all studies show that demand will exceed production and that imports will gradually increase in the coming decade (Table 3). By 2025, rice imports are projected to be 2 to 6 Mt, slightly higher that imports in 2015, while wheat imports will remain at a similar level from 2015 to 2025 (about 2 to 3 Mt). Interestingly, these similar low import levels are associated with wider differences in their projected production (Table 2) and demand (data in Table 2 plus the data in Table 3). In this regard, all analysts seem to have considered the recent policy change to focus on food grain security. Imports of oilseeds will not increase but stay at high levels (5 to 6 Mt; row 5, Table 3).

The commodity showing the greatest demand and import projection differences is maize. With the consideration of recent government's efforts to increase maize use in processing to eliminate excessive stock and updated the feed-meat ratio based on the recent survey data, our study projects that maize demand will rise faster than that of other studies. For example, we project 52% increase of maize used in industrial processing (increase from 56 Mt in 2015 to 85 Mt in 2025), and the other 32% increase in feed demand (increase from 115 Mt in 2015 to 152 Mt in 2025). In our study, maize imports will reach 20.2 Mt in 2025, and other studies project a much lower growth in maize demand and therefore lower imports (only 2 to 6 Mt; row 3, Table 3). However, the projected domestic production and imports of livestock products are similar across studies. We believe that the other studies may underestimate feed demand due to not fully considering the rapid growth of maize used for processing and overestimating the gain from livestock feeding efficiency. While not reported in Tables 2 and 3, we also project that the production and import of livestock products will increase if China does not significantly liberalize its maize market in the coming decade. The heavy protection of domestic maize production will result in higher maize prices and therefore undermine the competitiveness of China's livestock sector and increase its meat imports.

The most significant increase in imports will occur in soybean, sugar, and dairy products, which is similar with the results presented in Section 3.1. Soybean imports are likely to exceed 100 Mt by 2025 (row 4 in Table 3), accounting for more than 80% of domestic consumption. Sugar imports are projected to increase from 4.8 Mt in 2015 to a range of 5.7 to 9.3 Mt in 2025 (row 6 in Table 3). The import of dairy products is projected to increase by half over the next 10 years (the last row in Table 3).

We project a significant increase in both production and demand and a moderate net export of vegetables and fruits in the coming decade (not reported in Tables 2 and 3). However, net exports of vegetables will account for only about 0.4% of the domestic production. As for fruits, both the export of temperate fruits and imports of tropical/sub-tropical fruits will increase, but China will remain a net exporter.

In sum, China is expected to increase its food and feed imports. The rising gap between imports and exports presented in Fig. 1 will continue. If we aggregate the imports and exports of all foods and feeds together based on the latest projections, the overall food self-sufficiency[8] is likely

Table 3 China's food and feed net imports in 2015 and projected net import and total global export in 2025 (Mt)

	Net import in 2015 (NBSC 2016)	Net import in 2025				Global export in 2025	
		This study	CAAS (2016)	OECD-FAO (2016)	USDA (2016)	OECD-FAO (2016)	USDA (2016)
Rice	2.2	2.5	2.0	5.6	3.7	51.4	50.6
Wheat	2.7	1.9	2.5	2.8	0.1	174.5	187.3
Maize	4.7	20.2	2.0	6.1	6.2	141.5	160.7
Soybean	81.7	98.5	88.4	106.1	109.2	161.1	140.0
Oilseeds[1)]	5.8	5.7	6.6	4.6	–	18.8	–
Sugar	4.8	9.3	8.5	5.7	–	70.5	–
Beef	0.5	1.1	1.1	0.8	1.2	13.3	12.6
Mutton	0.2	0.5	0.3	0.3	–	1.2	–
Pork	0.7	0.8	0.9	0.8	0.8	8.4	8.5
Poultry	–0.1	–0.1	–	0.1	–0.1	15.3	14.1[2)]
Dairy	11.1	19.7	18.8	12.1[2)]	–	68.2[2)]	–

[1)] Oilseeds do not include soybean.
[2)] A factor of 7.0 is used to convert butter, cheese, powder, and other dairy products into fresh milk.
–, no data.

[8] The overall food self-sufficiency is defined as the ratio of the total domestic food production to total food consumption in China. All products are measured in values. For easy presentation, this ratio is multiplied by 100.

to fall from 94.5% in 2015 to around 91% by 2025[9].

Comparing the results of the latest projections for 2025 presented in this section with the early projections for 2020 presented in the previous section leads to three general observations. First, except for a few commodities (e.g., soybean, maize, dairy), the increased imports of all foods are moderate. Second, the variations in the projections of production, demand, and trade among the latest studies are much lower than are those among the previous studies. As mentioned, this is explained by the fact that the significant policy changes from 2010 and 2016 could not be considered in the early studies. Finally, wide variations in the projections for maize production, demand, and trade are found in both the early and the latest studies. Our projection results reveal a trade-off between imports of maize and meats.

4. Global implications of China's food imports

4.1. Will China's food imports put pressure on the global markets?

The latest projections of China's food imports for 2025 suggest that the imports of five commodities may exceed 15% of the projected world trade (compared to China's net imports relative to global exports, shown in Table 3). These are soybean, oilseeds, maize, mutton, and dairy. Imports of soybean are expected to account for 55 to 78% of global exports by 2025 (row 4 in Table 3). Oilseed imports are projected to account for 24 to 35% of global exports by 2025 (row 5 in Table 3). The projected maize imports vary widely among the studies, averaging 9 Mt (or about 6% of global exports, shown in Table 3), with the highest import level projected by this study reached in 2025 (20.2 Mt, or about 14% of global exports; row 3 in Table 3). China's imports of mutton and dairy are projected to reach 18 to 42% of global exports by 2025 (compared to the data in the last two columns of Table 3). Will the projected imports of these five commodities exceed the supply capacity of China's traditional trading partners? May other countries expand their production to become potential exporters to China?

Although the highest imports are projected for soybean, increases in imports are expected to be significantly lower than those experienced in the past and to remain within the supply capacity of China's major traditional trade partners (the US, Brazil, and Argentina). Over the past decade, China more than tripled its soybean imports, from 26.6 Mt in 2005 to 86.8 Mt in 2015 (NBSC 2016). The incremental imports were made possible by the expansion of production in only three countries, the US, Brazil, and Argentina, without putting pressure on world market prices. China's incremental imports from 2015 to 2025 are projected to be about 20 Mt, ranging from less than 10 Mt (CAAS 2016) to 28 Mt (USDA 2016; Table 3), much less than the import increases over the previous 10 years (60 Mt). Can these incremental imports in the next 10 years be matched by the production capacity of the current exporters? The answer seems clear. Both the OECD-FAO (2016) and USDA (2016) project that total soybean exports from Brazil and the U.S. can increase by more than 25 Mt from 2015 to 2025. Soybean exports may also increase from several other South American countries (OECD-FAO 2016; USDA 2016).

While the amount of China's maize imports depends on its policy options between importing maize and importing meats, the projected increase in maize imports is also expected to stay well within the supply capacity of the major exporters. For example, maize exports from the US alone are projected to increase by about 12 Mt from 2015 to 2025 without bringing new land under cultivation (USDA 2016). The potential for an expansion of maize production on currently cultivated land in Brazil and other maize-exporting countries is also high (OECD-FAO 2016).

Of course, the potential for simultaneous increases in the imports of soybean and maize in both China and other countries is a concern. As noted by Norse *et al.* (2014), other countries are expected to increase their soybean imports, notably India and several Southeast Asian countries. However, the potential for expanding soybean and maize production in many land-abundant countries is also high. It is reported that there were 14.7 million ha of idle cropland in the U.S. in 2012 (USDA 2013), which could be easily used for soybean and maize production if both China and other importing countries increase their imports. Other countries that could significantly increase their crop production through land expansion include Brazil, Argentina, and several Central Asian nations (OECD-FAO 2016; USDA 2016). For example, FAO (2017) reports that there were 20 million ha of idle cropland in Brazil in 2015. Many countries in Central Asia could also improve their production capacity if infrastructural and technological constraints were overcome. In fact, China has started to explore new exporters in Ukraine and other countries in Eastern Europe where soybean and

[9] Because meat demand is critical important for the demand and supply projections of soybean, maize and livestock products, we conducted a sensitive analysis on meat income elasticities by increase or decrease their values by 30% for both rural and urban consumers. With higher income elasticities, compared with the baseline results reported in Table 3 in 2025, total demand for and net import of meats (pork, poultry, beef and mutton) will increase by 3.3 and 27.6%, respectively; and the net imports of maize and soybean will also increase by 9.2 and 0.3%. In sum, meat and feed imports will be affected by the assumptions on meat demand elasticities, but these impacts will be lower as China's overall self-sufficient rate declines by only about 0.4%.

maize production could be expanded as demand in the international market increases[10].

In addition, with appropriate investment in irrigation, improvement in agricultural technology, and increases in modern inputs, most African nations could become significant exporters of soybean and maize (Fischer and Shah 2010; NEPAD 2013; HLPE 2015). Such opportunities could be important to China's future food security, as they could diversify China's sources of imports both politically and agro-climatically, as well as to global food security, for similar reasons (Norse *et al.* 2014).

While China's shares in global oilseeds, mutton, and dairy imports will remain high, their imports will not be substantial. In the next 10 years, incremental imports of oilseeds will be marginal. Mutton imports will increase about 1 000 to 3 000 tons (Table 3), which can easily be met by Australia and New Zealand alone. While imports of dairy and processed dairy products are likely to double in the coming decade, production and export from New Zealand, Australia, and some countries in Europe and Asia can be increased. With the implementation of China's "One Belt, One Road" initiative, the export capacity of both mutton and dairy from Western Asia and South Asia to China is also expected to increase.

4.2. Will China's food imports put pressure on global land and water resources?

Whether China's rising food and feed imports will deteriorate global natural resources is another concern that has received significant attention. However, according to a recent review paper by Ali *et al.* (2017), China has played a significant role in global water and land saving through its agricultural trade in the past. From 1998 to 2001, China contributed around 24% to global water savings (263 km^3) through its imports and exports (Fader *et al.* 2011). Imports of soybean have been a major contributor, mainly due to increases in China's imports from more efficient producers (the US, Argentina, and Brazil; Dalin *et al.* 2014). China's agricultural trade has also contributed to global land savings. Soybean and edible oil crops are the greatest contributors to land savings because China's yield has been lower than that of major exporting countries. Their imports generated an annual average land savings of 3.27 million ha from 1986 to 2009 (Qiang *et al.* 2013).

Ali *et al.* (2017) suggested that China's increasing food imports will increase both water and land savings at the global level in the future. According to their projection, the global effects of China's food trade on water and land saving will be significantly higher in the future than in the past. For example, they projected that total global savings of water and land in 2030, compared to those in 2015, will increase by 50.5% and 10.5%, respectively. China's future food trade trends suggest that soybean and maize imports will be the major contributors to global savings of water and land in 2030 (Ali *et al.* 2017). The global water and land savings from China's imports are mainly the result of the relatively lower use of water for irrigation and the higher land productivity (or yield) of soybean and maize in the major exporting countries (e.g., the US and Brazil) than those in China.

5. Conclusions and discussion

Despite China's tremendous achievements in increasing its food production to ensure national food security over the past four decades, China's food imports have recently been rising. Given the limited water and land resources and the increasing food demand from wealthier consumers, China's overall food and feed imports have exceeded its exports, and the country's trade deficit has gradually grown since the mid-2000s. The most significant import increase is that of soybean. Moderate increases have occurred in the imports of maize and other coarse grains for feed, as well as in livestock products (e.g., meats, dairy products) and sugar.

On the one hand, given the rising trend in food imports and considering the sustainability of its agriculture, China has strongly committed to increasing its domestic production to improve national food security. On the other hand, China has had to seek appropriate supplies of some products from the international market and may import more in the future. In this context, major studies' projections for China's food production, demand, and trade for 2020 and 2025 are largely consistent with each other in several aspects. They show that China can achieve near self-sufficiency in rice and wheat production. This is not surprising because per capita rice and wheat consumption has been falling and will continue to fall. China's population is also expected to peak in the late 2020s, and China's horticulture continues to have comparative advantages. The key import commodity will continue to be soybean. Imports of sugar and dairy will also increase. The amount of maize imports will depend on which trade-offs between feed and meat imports China's leaders may make in the future.

China's decision about importing feed or meat will affect China's, and the world's, trade in feed and livestock products. If China liberalizes its maize market by expanding

[10] However, the potential for cropland expansion could be limited by political instability, lack of investment, and concerns about the environmental consequences of using new land for crop production.

its import quota (7.2 Mt) or lowering its above-quota import tariff (65%), China will be able to achieve near self-sufficiency in meats, with a significant increase in maize imports. Restricting maize imports through a TRQ policy will increase feed prices, and subsequently, the cost of livestock production. Meat imports will increase. Given the small quantity of meats and large amounts of maize traded in the international market, China may have to decide in favor of importing maize, rather than meats.

Given the projected volume of incremental imports of major foods and feed in the coming decade, it is not very likely that China will starve the world or cause instability in the international food market. The increases in food and feed imports are likely to remain within the production capacity of the current major exporting countries, and the production and export capacities of many developed and developing countries can be increased. China's increased imports of soybean, maize, sugar, and dairy will not only provide export opportunities for all land-rich developing and developed countries but will also contribute to global water and land savings.

The conclusion that China's food imports are unlikely to starve the world is based largely on the assumption that China's agriculture will continue to grow. If the agricultural production growth reflected in the projections reviewed in this paper is not realized, much higher food and feed imports could occur. Indeed, China's national leaders are taking food security issues more seriously now than ever. The Medium- and Long-term Food Security Plan for 2008–2020 and the 13th Five-year Plan for National Agricultural Modernization have highlighted efforts to improve China's food security, particularly the measures for increasing agricultural productivity through investments in technology and resources (e.g., water and land) and institutional innovations in land consolidation.

However, turning the plans into implementation is not without challenges, given the recent slowdown of overall economic growth and the declining growth in national fiscal revenue. Implementation may require much stronger political commitments. Moreover, as China is playing an increasingly important role in the global food trade, active engagement in its governance of the global food trade and improving global food security are also of critical importance to China. We expect that China will play a leading role in forming a more liberalized and open trade environment in the coming years. China has supported African agricultural technology for several decades and has recently intensified this support. China is now the largest bilateral contributor to agricultural development in Sub-Saharan Africa. For China, investing in local agricultural production in Africa and other developing countries is a key pathway to improve both global and national food security.

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Appendix associated with this paper can be available on http://www.ChinaAgriSci.com/V2/En/appendix.htm

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