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Sustainable Development for Food Security in Northeast China

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Abstract: Grain is a commodity with strategic significance. The general self-sufficiency of cereal grains is vital to the livelihood of individuals and the national security of China, a country with a population approaching 1.4 billion. In China, the Northeast is the most abundant region in agricultural resources, with a grain industry that is growing faster than any other region of China. Northeast China has the greatest potential for development and contributes the most to China's national food security. Northeast China is presently an important commodity grain and livestock production area. Herein, we sought to describe the state of food security in this region based on internationalization and green development, analyze the trend in food supply and demand in this region, discuss the issues regarding food security, and propose strategic suggestions including acceleration of the supply-side structural reform for agriculture, promotion of the combination of agriculture and animal husbandry, and development of benefit-oriented agriculture. It is hoped that this study will serve as a reference for making decisions related to regional food security and sustainable development.

Keywords: Northeast China; food security; sustainable development

1 The Position of Northeast China in national food security

Geographically, Northeast China (including the Heilongjiang, Liaoning, and Jilin Provinces and four prefectures of eastern Inner Mongolia, namely Chifeng, Tongliao, Hingan, and Hulunbuir) is a fairly complete and relatively independent region. It is also surrounded by mountains in the East, North, and West, which serve as a natural protective barrier for its ecosystem. The fertile vast Northeast Plain—which has the Sanjiang, Songnen, and Liaohe Plains at its center—serves as China's largest plain [1,2].

Northeast China has a temperate continental monsoon climate and its rainy season overlaps with its hot season. In addition to having a self-contained hydrological and climate system, Northeast China has an annual precipitation of 300–1 000 mm. From the East to the West, precipitation gradually decreases and climate gradually changes from wet and semi-wet to semi-arid. Because of favorable natural geographical conditions for comprehensive large-scale agriculture, Northeast China has become one of China's major areas for the production of grains and the rearing of livestock.

During an inspection of Northeast China in 2018, Chinese President Xi Jinping emphasized that the region is one of China's major industrial and agricultural areas, and plays an extremely important strategic role in safeguarding

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China's national security, food security, ecological security, energy security, and industry security. Thus, this region is recognized to be vital to China's national development [3].

Northeast China has 450 million mu (1 mu ≈ 0.0667 hm^2) of farmland, which is mainly comprised of black soil. In recent years, there has been an increase in the region's total food output. According to the statistics of the National Development and Reform Commission, the total food output of the Liaoning, Jilin, and Heilongjiang Provinces was 1.333×10^8 t in 2018, accounting for 20.26% of the total food output of China. Together, this region contributed to one third of the annual increase in China's total food output. More than 60% of the domestic food that is distributed throughout East, South, and North China originates from the Northeast region. Among the grain production regions of China, the Northeast has achieved the fastest growth in food output in recent years, which has contributed to its role as the major granary for safeguarding national food security and stabilizing the food market in China.

2 Status quo of food security in Northeast China

2.1 Food production

2.1.1 Cereal grains and other staples

According to the statistical data published by the National Bureau of Statistics, between 2000 and 2017, the food output of Northeast China increased by 203.1% at an average annual growth rate of 7.1% while grain output increased by 186.1% at an average annual growth rate of 6.6%. Particularly, the output of corn increased at an average annual growth rate of 9.9%, thereby accounting for more than two thirds of the region's total grain output. As a result, corn is the biggest contributor to the region's growth in total grain output. Rice and wheat increased at average annual growth rates of 5.3% and 2.3%, respectively, with the former accounting for more than 90% of grain consumption in Northeast China (Table 1) [4].

Table 1. Production of grains and other staples in Northeast China between 2000 and 2017

Year	Corn		Rice		Wheat		Cereal grains		Staples	
	Output ($\times10^4$ t)	Farming area ($\times10^4$ hm^2)	Output ($\times10^4$ t)	Farming area ($\times10^4$ hm^2)	Output ($\times10^4$ t)	Farming area ($\times10^4$ hm^2)	Output ($\times10^4$ t)	Farming area ($\times10^4$ hm^2)	Output ($\times10^4$ t)	Farming area ($\times10^4$ hm^2)
2000	2335.1	542.1	1794.1	268.0	147.9	78.5	5209.5	1405.0	5323.5	1454.5
2001	2966.6	630.9	1722.7	276.9	120.9	57.6	5850.5	1525.1	5999.5	1589.9
2002	3468.5	629.7	1697.2	278.7	108.8	33.4	6460.2	1455.5	6666.4	1517.4
2003	3353.4	611.6	1512.4	233.3	51.9	27.2	6091.7	1439.0	6270.2	1487.2
2004	3829.2	668.0	1969.1	273.2	95.3	28.7	7098.8	1528.9	7231.0	1567.7
2005	5298.1	810.0	2169.6	293.4	182.2	61.5	7725.8	1248.8	9396.1	1917.6
2006	5444.3	845.9	2404.5	327.7	182.6	60.1	8082.3	1325.1	9630.4	1984.3
2007	5401.8	1010.9	2756.8	365.7	149.1	63.8	8343.2	1525.7	9539.3	2176.3
2008	6066.7	1005.3	2718.1	377.7	152.0	57.4	8970.4	1532.2	10 478.5	2212.5
2009	5442.2	1006.3	2638.4	382.5	186.3	55.0	8298.9	1513.6	9866.1	2278.3
2010	6317.5	1066.1	2914.1	416.3	175.9	55.4	9487.8	1599.3	11 266.8	2307.4
2011	7597.2	1110.0	3258.1	433.8	204.3	57.3	11 111.1	1656.6	12 601.7	2327.0
2012	8269.5	1267.5	3281.8	449.5	193.2	64.9	11 854.4	1852.8	13 189.8	2327.8
2013	9211.0	1339.4	3341.6	460.4	166.0	53.5	12 822.5	1913.3	13 939.4	2348.1
2014	8957.9	1380.6	3339.4	456.9	178.7	54.3	12 575.6	1955.2	13 727.6	2385.3
2015	9550.3	1441.2	3349.8	450.9	160.0	47.0	13 163.1	2004.9	14 230.2	2413.1
2016	9144.0	1370.9	3513.8	473.3	203.6	68.8	13 056.8	1970.7	14 129.5	2411.0
2017	10 438.9	1526.2	4047.9	545.3	215.1	72.1	14 906.8	2197.0	16 135.3	2721.7

Between 2000 and 2017, the farming area used for crop production in Northeast China increased by 87.1% at an annual growth rate of 3.9%, thereby displaying a similar trend to annual grain output. Grain farming area increased by 56.4% at an average annual growth rate of 2.9%. As corn farming area increased by an average annual rate of

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6.5%, it was identified as the primary contributor to the growth in grain output. Rice farming area increased by 103.5% at an average annual growth rate of 4.5%, whereas a negative growth trend was identified for the wheat farming area.

In recent years, the unit yield of staples in Northeast China markedly increased at an average annual rate of 3.5%, while that of grains increased at an average annual rate of 2.9%. Nonetheless, rice was found to have the highest unit yield, followed by corn and wheat.

2.1.2 Vegetables and fruits

Overall, the output of vegetables in Northeast China had an increasing trend between 2000 and 2017; however, a slight decrease has been recognized in recent years. The vegetable production area exhibited a similar trend to vegetable output. The total output of fruits in Northeast China displayed a steady increase; this was despite an 18.1% decrease in the fruit production area at an average annual rate of 1.0% during the period. Thus, the increase in fruit output during the period was mainly due to the increase in unit yield (Table 2).

Table 2. Production of vegetables and fruit in the Northeast China from 2000 to 2017.

	Vegetables		Fruit	
Year	Output ($\times10^4$ t)	Farming area ($\times10^4$ hm^2)	Output ($\times10^4$ t)	Farming area ($\times10^4$ hm^2)
2000	3918.9	112.4	317.7	55.7
2005	4363.8	95.7	1099.1	42.4
2010	5143.7	86.0	1331.5	44.9
2011	5325.2	92.5	1423.8	45.0
2012	5578.0	97.4	1482.1	45.8
2013	5607.8	97.2	1561.1	48.7
2014	5455.6	95.4	1477.2	49.1
2015	5196.0	94.6	1405.6	48.7
2016	4531.2	86.1	1411.1	46.1
2017	4329.6	65.7	1206.8	45.6

2.1.3 Meat, egg, dairy products, and aquatic products

The output of meat products in Northeast China was 1.058×10^7 t in 2017, a value 1.2×10^5 t higher than that in 2005 and 3.26×10^5 t lower than that in 2016. Based on the structure of meat products during the last decade, the proportion of pork output to the total output of all meat products was stabilized in the range, 50%–55%, with a slightly higher pork output in 2017 (by 3.68×10^5 t) than in 2005. According to output, poultry meat ranked second, followed by beef and mutton.

Overall, the output of poultry eggs in Northeast China exhibited a growing trend during the past decade, despite the annual decreases identified in some years. In 2017, poultry egg output was 5.491×10^6 t, a value 19.3% higher than that in 2005 (4.603×10^6 t). Generally, the output of dairy products displayed a gradually increasing trend between 2005 and 2017, despite decreases in some years. Particularly, the output in 2017 was 8.356×10^6 t, a value 18.4% higher than that in 2005 (7.059×10^6 t) and 15.1% lower than that in 2016 (1.489×10^6 t). Taken together, the average annual growth rate during this period was 1.7%.

The output of aquatic products displayed an overall increasing trend between 2005 and 2017, despite decreases in some years. Particularly, the output in 2017 was 5.693×10^6 t, thereby markedly decreasing annually by 10.6%. However, this output was 17.4% higher than that in 2005 (4.85×10^6 t). According to the geographical structure, the output of aquatic products of Liaoning accounted for approximately 85% of the total output of Northeast China.

2.2 Food circulation

2.2.1 Logistics

Since 2008, the food output of Northern China has exceeded that of Southern China, with its food production area and output accounting for 54.8% and 53.4% of the national total, while those of Southern China account for 45.2% and 46.6% of the national total, respectively. This has turned Northern China from a net food importer to a net food exporter. Particularly, Northeast China has become the primary domestic food exporter.

However, domestic food circulation in China faces challenges, including high logistical cost and insufficient logistical capacity. Although Northeast China currently serves as China's largest food production area and domestic food exporter, it has no coastal port, except few ports in Liaoning. As a result, food export mainly relies on railway transportation; however, the capacity of railway transportation is insufficient. As Northeast China is located at the northeastern end of China's railway network, the cost of railway transportation is high. More specifically, the logistical cost accounts for 30%–35% of the total sales cost, while that in developed countries is 20%–25%.

2.2.2 Food purchase

In recent years, corn has served as the primary contributor to the increase in food output and its farming area has markedly increased. Conversely, there has been a continuous decrease in the farming area of beans. This new food production structure of Northeast China does not align well with the consumption structure and has resulted in a significant successive surplus of corn, which poses a challenge that needs to be urgently resolved through agricultural supply-side structural reform. To address the issue of successive corn surplus, since 2016, the Chinese government has been gradually adjusting the food production structure and reforming the system of temporary purchase and stockpiling of corn through a new purchase mechanism that combines market-based purchase and subsidies. Under the new system, food producers sell corn at market price, and market entities freely purchase corn from the market. Thus, this mechanism has been adopted as the main solution for issues such as difficultly in sales and high inventory stockpiles. The cancellation of the minimum corn purchase price is recognized as the official signal of China's launch of the agricultural supply-side structural reform. The reform for corn purchase policy plays a very important role in safeguarding the structural optimization and capacity improvement of grain production in Northeast China.

2.2.3 Food processing

Northeast China is not only China's major granary, but also its traditional industrial base. Owing to agricultural product processing, the following two advantages of Northeast China can be simultaneously utilized: an abundant supply of agricultural raw products, and a solid industrial foundation. However, because of the vulnerable nature of agriculture and the long-standing defects of the agricultural system, the agricultural product processing industry in Northeast China continues to suffer from slow growth, difficult operations, and marked declines in profitability in recent years. The challenge faced by Northeast China's agricultural product processing industry, particularly the food processing industry, is mainly attributed to the following three reasons: (1) the short industrial chain in the agricultural product processing industry, with insufficient precision and depth of processing; (2) the higher prices of agricultural products, which are the raw materials of the agricultural product processing industry, owing to the policy of the government-determined food purchase price implemented in Northeast China; and (3) insufficient market awareness owing to the outdated mindset of a planned economy and long-standing government-determined price mechanism.

2.3 Food consumption

2.3.1 Food consumption structures of rural and urban populations

In 2017, the per-capita consumption of grain and staple by Northeast China's urban population was 117.5 kg and 132.3 kg, respectively, while that of fruit, vegetables, aquatic products, poultry eggs, dairy products, and meat was 68.3 kg, 106.2 kg, 11.5 kg, 12.2 kg, 17.6 kg, and 30.1 kg, respectively. The per-capita consumption of grains and staples in the region's rural population was 143.5 kg and 158.6 kg, respectively, while that of fruit, vegetables, aquatic products, poultry eggs, dairy products, and meat was 35.2 kg, 87.5 kg, 5 kg, 8.5 kg, 7.3 kg, and 23.2 kg, respectively. The urban and rural populations had different food consumption structures (Fig. 1). More specifically, the per-capita consumption of grains and staples for the rural population was higher than that of the urban population. However, the per-capita consumption of meat, dairy products, poultry eggs, aquatic products, vegetables, and fruit of the urban population were higher than those of the rural population.

2.3.2 Overall food consumption structure in Northeast China

In 2017, the total consumption of staples and cereal grains in Northeast China was 1.5369×10^7 t and 1.7167×10^7 t, respectively. Liaoning respectively consumed 5.724×10^6 t and 5.035×10^6 t staples and cereal grains, thereby ranking first among the northeastern provinces. The total consumption of vegetables in Northeast China was

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1.19×10^7 t in 2017 and is, thus, only second to that of staples. The total consumption of fruit, meat, dairy products, poultry eggs, and aquatic products in Northeast China was 6.66×10^6 t, 3.299×10^6 t, 1.635×10^6 t, 1.293×10^6 t, and 1.078×10^6 t, respectively, in 2017. Liaoning ranked first among the northeastern provinces in the consumption of all major food categories (Table 3).

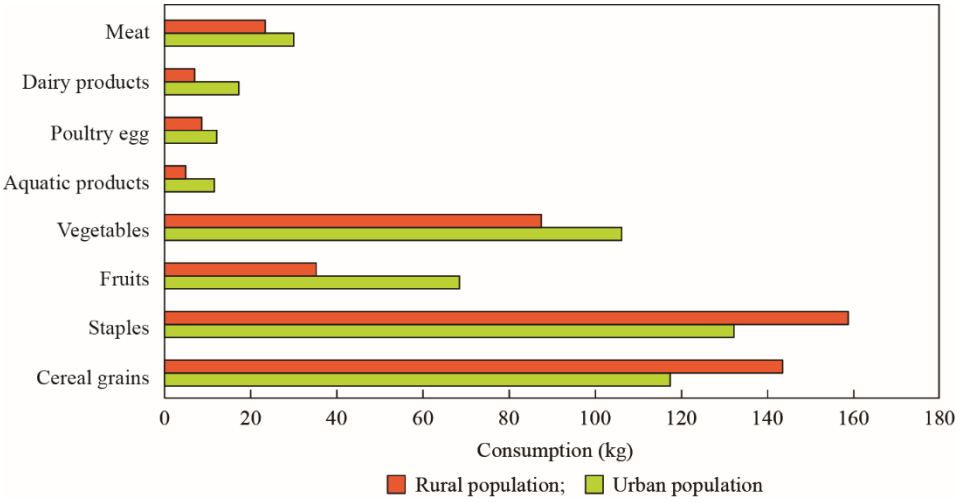

Fig. 1. Food consumption structures for the urban and rural populations of Northeast China in 2017.

Table 3. Provincial food consumption structures for Northeast China in 2017 ($\times10^4$ t).

Region	Cereal grains	Staples	Fruits	Vegetables	Aquatic products	Egg	Dairy products	Meat
Liaoning	503.5	572.4	281.0	483.1	66.5	56.4	65.9	138.2
Jilin	353.1	384.6	139.6	296.7	20.0	29.8	27.2	60.4
Heilongjiang	495.2	545.6	209.2	346.9	33.3	38.7	42.9	85.2
Eastern Inner Mongolia	161.1	182.5	56.6	96.5	5.4	10.1	20.7	38.4
Subtotal	1 536.9	1 716.7	666.0	1 190.2	107.8	129.3	163.5	329.9

3 Analysis of the food supply and demand variation trend in Northeast China

3.1 Staple supply and demand variation trend in Northeast China

Northeast China's output of staples and cereal grains was much higher than its consumption between 2005 and 2017 (Table 4), thereby demonstrating its position as China's major granary. According to the provincial food supply and demand variation, Liaoning had the lowest food self-sufficiency rate among the northeastern provinces. More specifically, its food self-sufficiency rate decreased and then increased between 2005 and 2017, with a rate of ~4.1 times in 2017. In particular, the self-sufficiency rate of cereal grains continued to increase from 3.0 times in 2005 to 4.5 times in 2017. The self-sufficiency rates of the staples and grains of Jilin, Heilongjiang, and eastern Inner Mongolia had insignificant variations between 2005 and 2010, and a rapid increase between 2010 and 2015. More specifically, the rates in 2015 were almost greater than 10 times, with rates as high as 12.1 and 12.4 times for Heilongjiang and eastern Inner Mongolia, respectively. The self-sufficiency rates of the staples and grains of Jilin and eastern Inner Mongolia varied insignificantly between 2015 and 2017. The self-sufficiency rates of staples and grains of Jilin were 10.8 times and 11.5 times, while those of eastern Inner Mongolia were 12.3 times and 12.4 times, respectively. The high staple self-sufficiency rate of Northeast China is due to accelerating efforts within the region to continuously improve its food production capacity. The evolution of the food consumption structure in recent years has also resulted in a decreased demand for staples.

Table 4. Provincial output and demand for staples and grains in Northeast China.

Region	Year	Staples			Grains		
		Output ($\times10^4$ t)	Demand ($\times10^4$ t)	Self-sufficiency rate (times)	Output ($\times10^4$ t)	Demand ($\times10^4$ t)	Self-sufficiency rate (times)
Liaoning	2005	1976.3	567.3	3.5	1763.7	584.8	3.0
	2010	1765.4	663.4	2.7	1611.8	544.3	3.0
	2015	2002.5	574.4	3.5	1873.9	516.0	3.6
	2017	2330.7	572.4	4.1	2261.3	503.5	4.5
Jilin	2005	2581.2	361.5	7.1	2371.5	372.6	6.4
	2010	2842.5	425.0	6.7	2654.1	348.7	7.6
	2015	3647.0	345.3	10.6	3538.9	317.6	11.1
	2017	4154.0	384.6	10.8	4044.0	353.1	11.5
Heilongjiang	2005	3600.0	517.3	7.0	2714.0	533.3	5.1
	2010	5012.8	598.2	8.4	4284.8	490.7	8.7
	2015	6324.0	524.8	12.1	5765.6	475.6	12.1
	2017	7410.3	545.6	13.6	6609.7	495.2	13.3
Eastern Inner Mongolia	2005	1238.5	160.2	7.7	876.6	165.2	5.3
	2010	1646.1	184.3	8.9	937.1	151.2	6.2
	2015	2256.7	181.4	12.4	1984.7	167.3	11.9
	2017	2240.3	182.5	12.3	1991.8	161.1	12.4

3.2 Provincial output and demand for vegetables and fruit in Northeast China

The self-sufficiency rate of vegetables in Northeast China increased and then decreased between 2005 and 2017; this was mainly because of the marked decrease in vegetable production areas in Liaoning and Jilin in 2017. Overall, the self-sufficiency rates of vegetables in Heilongjiang and eastern Inner Mongolia has exhibited increasing trends in recent years. The rates of Heilongjiang and eastern Inner Mongolia increased by 2.8 times and 4.7 times in 2017, respectively. However, owing to population decline, the provincial demand for vegetables in Northeast China has been decreasing. The overall self-sufficiency rate of vegetables in Northeast China is high, with Liaoning being the major vegetable production base of the region (Table 5).

Owing to the marked increase in demand for fruit in recent years, the self-sufficiency rate of fruits in Liaoning increased and then slightly decreased between 2005 and 2017. As the rate was 2.7 times in 2017, it contributed to the establishment of Liaoning as Northeast China's major production region for fruits. The fruit supply-demand gaps in Jilin and Heilongjiang gradually decreased between 2005 and 2017. Particularly, the fruit self-sufficiency rate in Jilin decreased by 40% in 2017; the province has thus lost its status of self-sufficiency for fruits. One of the major reasons contributing to this decline is the adjustments in the fruit production areas of Jilin and Heilongjiang, which declined from 4.8×10^5 hm^2 and 3.39×10^5 hm^2 in 2015 to 1.86×10^5 hm^2 and 2.72×10^5 hm^2 in 2017, respectively. Another major reason is that the local demand for fruit has increased across the region.

Table 5. Provincial output and demand for other major categories of foods in Northeast China.

Year	Vegetable			Fruits			Meat		
	Output ($\times10^4$ t)	Demand ($\times10^4$ t)	Self-sufficiency rate (times)	Output ($\times10^4$ t)	Demand ($\times10^4$ t)	Self-sufficiency rate (times)	Output ($\times10^4$ t)	Demand ($\times10^4$ t)	Self-sufficiency rate (times)
2005	4133.7	1645.5	2.5	1099.2	555.2	2.0	1099.2	263.4	4.2
2010	4867.7	1403.8	3.5	1331.5	520.8	2.6	981.3	227.6	4.3
2015	5196.4	1224.0	4.2	1381.9	647.7	2.1	1057.0	275.4	3.8
2017	4329.6	190.2	3.6	1206.8	666.0	1.8	1058.1	329.9	3.2

Year	Egg			Dairy			Aquatic		
	Output ($\times10^4$ t)	Demand ($\times10^4$ t)	Self-sufficiency rate (times)	Output ($\times10^4$ t)	Demand ($\times10^4$ t)	(times)	Output ($\times10^4$ t)	Demand ($\times10^4$ t)	Self-sufficiency rate (times)
2005	460.3	121.7	3.8	714.4	123.4	5.8	485.0	96.5	5.0
2010	512.2	113.5	4.5	944.7	91.6	10.3	492.0	61.2	8.0
2015	530.9	124.9	4.3	1 017.9	151.0	6.7	606.3	113.0	5.4
2017	549.1	129.3	4.2	835.6	163.5	5.1	569.3	107.8	5.3

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3.3 Provincial output and demand for meat, egg, dairy products, and aquatic products in Northeast China

Northeast China has had a relatively stable output and demand for meat and egg, and has been completely self-sufficient in meat and egg production, with capacities for export. In fact, the provincial self-sufficiency rates of meat and egg have been maintained at approximately 4 times. The provincial output and demands for dairy products have been increasing, with a much higher output of dairy products than the local demand. In 2017, the self-sufficiency rates of dairy products in Liaoning and Jilin were 1.8 times and 1.2 times, respectively. The rates in Heilongjiang and eastern Inner Mongolia were higher than 10 times. Despite growing demand for aquatic products, Northeast China is self-sufficient in aquatic products because of an increase in output. The self-sufficiency rate of aquatic products in Liaoning was once higher than 8 times; however, this has decreased to 7.2 times in 2017. The self-sufficiency rates of aquatic products in Jilin, Heilongjiang, and eastern Inner Mongolia increased by different degrees between 2005 and 2017, with a local output that could satisfy the local demand.

4 Food-security problems in Northeast China

4.1 Unbalanced product structure and uncompetitive agriculture

Owing to the long-standing emphasis on increasing food output, high self-sufficiency rates, and especially the policy influence of government-determined minimum food purchase price, food production in Northeast China is affected by prominent structural problems, such as the disproportion between food production and animal husbandry, and the complete loss of advantages in soybean production.

Northeast China is the largest domestic exporter of staple food and has a surplus of other food categories. Most of the increase in the output of staple food in Southeast China is caused by the increase in corn output, which accounts for more than 60% of the total output of staples. Owing to changes in the mode of production and the increasing cost of production factors, the cost of corn production has continuously increased, thereby weakening its competitiveness in the market. Corn can be used for forage, food, and industrial processing purposes, but the corn produced for a given purpose is usually required to be of the same type or cultivar. In Northeast China, different cultivars of corn are mixed during production, purchase, and stockpiling, thereby directly compromising its quality or grade as a bulk product.

The *keng* rice was previously competitive in the international market but has lost this competitiveness in the North Asia market owing to over-emphasis on its quantity and negligence of its quality. As the production of soybean has been decreasing annually, changing the agricultural development mode from a quantity orientation to a quality orientation and improving the competitiveness of the agricultural products in international markets by carrying out agricultural supply-side structural reform are crucial to drive the coordinated development of crop production and animal husbandry, and accelerate the value-added conversion of foods.

4.2 Stagnant development of the agricultural product processing industry

Most of the local food supply in Northeast China is in a primary form. Furthermore, the food processing industry has had a slow development, which makes it difficult to satisfy consumer demand for diverse and quality foods, and increase rural income. The output of major processed agricultural products has faced a considerable decline. Since 2016, the output of 16 of 19 processed agricultural products, with the exception of sugar, canned food, and wine, has been decreasing yearly. In addition, owing to the general sluggish demand in the international market, export from Northeast China has declined. In 2016, the region's export value decreased by 0.42% annually, with food export being decreased by the largest rate of 10.23%, presenting a grave situation.

4.3 Insufficient and excessively-exploited water resources

Northeast China presently suffers from excessive exploitation and insufficient development of water resources. The degree of water resource exploitation and utilization in the Liao River basin is higher than that in the Songhua River in the north. Furthermore, development in the West Liao River basin has exceeded the bearing capacity of its water resources. More than 80% of the water resources of the Hun and Taizi Rivers has been exploited while only 10% of the water resources of the Heilong, Suifen, Wusuli, and Yalu Rivers has been exploited and utilized. The irrigation water in Northeast China is mainly derived from surface water of rivers and reservoirs, and groundwater

pumped from wells and is mainly used for rice production. Owing to ineffective control of surface water, irrigation water is inefficiently utilized while groundwater in well-irrigation areas is excessively exploited. In particular, the irrigation and drainage facilities are poorly configured and insufficiently equipped. In addition, a low standard of design was adopted during their construction and they are presently outdated and deteriorated.

4.4 Poor conservation and serious soil and water loss of black-soil farmland

4.4.1 Serious soil and water loss

According to the statistical data published by the Songliao Water Resource Commission, Ministry of Water Resources, the thickness of the black-soil layer of farmland on the Northeast Plain has decreased from 80–100 cm to 20–40 cm at the time of reclamation, and the content of organic matter has decreased by nearly 50%. According to the first national water resource survey conducted between 2010 and 2012, the black-soil zones in Northeast China had 295,663 eroded channels, thereby suffering serious soil and water loss. The organic matter in the tilled layer has been decreasing at an average annual rate of 0.1%, resulting in the deterioration of the biological properties of the soil. Such occurrence is extremely undesirable for the production of high-quality foods.

4.4.2 Slow effect and insufficient motivation for black-soil conservation

To accelerate the conservation of black-soil farmland in Northeast China, pilot projects for black-soil farmland conservation were launched in the region's 17 counties and municipalities in 2015. With the wide implementation of measures to reduce the use of fertilizer, pesticide, and herbicide, and the increasingly higher percentages of straw returned to the soil, the black-soil conservation initiative has achieved effects in succession. However, black-soil conservation is a long-term and continuous process, and its effects are difficult to achieve quickly. Although farmers are aware of this drawback, they are unwilling to focus on the long-term benefit. Particularly, owing to the high cost of black-soil conservation, farmers and local governments are inadequately motivated to take the initiative. In pilot zones for black-soil conservation, the major driving force is derived from projects funded at different administrative levels, where the actual implementation largely relies on direct support from project funds. However, the actual mobilization of participation from market forces is rather rare to drive the sustainable implementation of such projects.

5 Strategic recommendations for safeguarding sustainable food security in Northeast China

Northeast China has rich agricultural resources and produces a large volume of agricultural products and foods, including staples, meat, dairy products, and aquatic products. Based on the definition of food security by the Food and Agricultural Organization of the United Nations— "ensuring that all people at all times have both physical and economic access to the basic food that they need"— issues regarding food security are rather minor in Northeast China. However, food security not only requires the production of sufficient amounts of agricultural products, but also the satisfaction of demand for agricultural products that are in short supply, and the demand for green, high-quality products.

Therefore, to achieve sustainability in food security, Northeast China must pursue a sustainable mode of development, with a green and global mindset. Moreover, it is necessary to adopt sustainable agricultural development practices; fully and effectively utilize the region's natural resources; continuously engage in development, despite the current characteristics of the region's agroecological-economic system; learn from the best of technologies for sustainable agricultural development both domestically and internationally; explore the advantages of the region's existing agricultural system while actively modernizing the agricultural sector; adopt reasonable production and organization methods; promote innovative, large-scale, low-carbon, and targeted agricultural technologies; consider ecological and environmental preservation; and increase the productivity of resources to the largest extent, thereby improving the quantity and quality of food supply. Overall, this region should seek to establish a mode of sustainable development and technical system for food security that possesses regional characteristics.

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5.1 Accelerate the structural reform of the agricultural supply-side and pursue well-coordinated production of grain, industrial, and forage crops

The focus of the supply-side structural reform of Northeast China's crop production industry is to reduce the corn production area in non-major corn production areas, particularly the Liandaowan areas, and increase the proportion of production area for forage, soybean, and quality forage. Although corn production has rapidly increased in the Liandaowan areas, crop production in these areas is largely extensive in nature and adopts simple product structures. The corn grains produced in these areas are of low quality and thus, lack competitiveness in the market. An excessive inventory of corn has been established in these areas. Moreover, these areas were originally advantageous for animal husbandry, but this sector is presently under-developed in these areas. Thus, local consumption of corn for forage purposes is limited. To reduce corn production, it is necessary to increase the utilization of crop products for forage purposes, establish a reasonable rotational farming system, combine farmland utilization and conservation, and promote the integration of crop farming, animal husbandry, and agricultural product processing to enable the achievement of value-added conversion of corn locally. Such achievement will enable the use of corn for forage and industrial processing purposes, ultimately resulting in profit maximization.

5.2 Better coordinate crop farming and animal husbandry and develop circular agriculture

Crop production and animal husbandry serve as resources and markets to each other. As a result, there is a close relationship between these sectors, which promote, interact with, and restrict one another. Owing to the good coordination between crop production and animal husbandry, bulk agricultural products, such as crop straw and poultry feces, can be locally converted to forage and fertilizer. Fostering new production and business entities, innovating systems and mechanisms, and promoting industrialized operations are also necessary for the establishment of newer, higher-quality, and more crop and livestock products and their processed derivatives, thereby leading to market consumption and the formation of a benign, large-scale, and circular agricultural industry. To integrate crop production and animal husbandry, the concept of ecological civilization must be considered, and "zero-waste" production should be achieved. Particularly, agricultural byproducts, such as straw and feces, can be converted into resources to improve soil quality and strengthen land capability, thereby minimizing the use of fertilizer, enhancing fertilizer efficiency, and improving the quality of agricultural products. Additionally, the production of high-quality livestock products can be boosted by increasing the output of high-quality green, coarse, and fine fodder, innovating systems and mechanisms, and promoting industrialized operations, thereby improving the market competitiveness of Northeast China's livestock products. Overall, promoting the coordinated development of crop farming and animal husbandry is an effective approach for improving the quality and efficiency of agriculture, increasing rural income, and recognizing steady agricultural development.

5.3 Improve agricultural efficiency and develop an agriculture strategy with regional characteristics

Agricultural modernization forms the foundation and pillars of China's modernization. Northeast China's agriculture is approaching or has reached a level similar to that of advanced countries based on many indicators. The largest gap lies in the proportion of agricultural labor force to the total labor force (~30% in Northeast China). However, the relative abundance in agricultural labor force is advantageous to improve the agricultural efficiency of the region through technology- and labor-intensive means and foster new growth points with regional characteristics. In addition to corn and *keng* rice, Northeast China has other agricultural products with regional characteristics and advantages, such as the soybean and dairy products of Helongjiang, beef of Jilin, meat and dairy products of eastern Inner Mongolia, and aquatic products and vegetables of Liaoning. In particular, the industrialized production of vegetables is a proven effective approach for improving resource conversion efficiency and increasing rural income. With industrialized production, vegetables are now available throughout the year and are competitors in the Northeast Asian market.

5.4 Conserve black-soil farmland and accelerate high-standard farmland construction

The construction of water conservancy projects can increase the area of well-irrigated farmland and boost the production of high-quality *keng* rice. Water conservancy projects facilitate the construction of farmland with good

irrigation and drainage and expand the quality scale of farmland for grain production. R rice production also better facilitates the initiative of returning straw to soil as organic matter decomposes more slowly when immersed in water, and slower decomposition better facilitates the accumulation of organic matter in soil. Thus, increasing rice production is an effective measure for black-soil farmland conservation.

Adapting to the needs of agricultural transformation, implementing reasonable rotational cropping, increasing the use of organic fertilizers, implementing straw-covered cropping, and adopting subsoiling tillage can enable the cultivated soil layer to absorb more water during the rainy season, thereby improving the moisture environment in the cultivated soil layer, and slowing down the decomposition of organic matter. Adopting conservation tillage, planting windbreaking forests, and implementing food-forage rotational cropping on semi-arid or steep-slope farmland (cultivation of legume forages for 2–4 years, and then the cultivation of grains or other crops using conservation tillage) are effective measures for driving the initiative of land management-based crop production.

5.5 Improve water resource utilization rate through control at the supply and consumption ends

In Northeast China, precipitation is relatively low. In addition, it displays an uneven spatiotemporal distribution—abundant precipitation in the northern, eastern, and central areas, and inadequate precipitation in the southern, western, and marginal areas. The water-rich areas are mainly located along the international rivers, while the water-scarce areas are mainly located in the central and southern areas. Owing to inadequate water conservancy and transfer facilities, the Liao River drainage basin has a higher water resource development and utilization rate than the Songhua River drainage basin in the north. As a result, more large-scale water conservancy and transfer projects, together with the support of drainage and irrigation facilities, should be constructed to improve the control of surface water, thereby replacing groundwater with gravity-irrigation water and improving the water utilization rate.

5.6 Foster new business entities and improve social services

First, efforts to develop family farms and farmers' specialized cooperatives should be promoted. Second, a relative increase in the scale of operation through transfer, capitalization, and trusteeship of land contracts should be carried out, thereby facilitating agricultural mechanization and improving labor productivity, land productivity, and resource utilization rate. The agricultural labor force freed because of these means can then be transferred to the third industry or labor-, technology-, or capital-intensive agricultural production with local characteristics and advantages. Third, technological support for agriculture should be increased through collaboration among enterprises, universities, and research institutes. A technical service network consisting of universities, research institutes, agricultural technology extension centers at the county/district and municipality levels, and chief technicians of specialized cooperatives should be established, improving agricultural production through technological innovation. Additionally, information, technology, and circulation services, as well as the supply of the resources for agricultural production should be improved through collaboration with reputable material circulation service providers. Science and technology education should also be strengthened for farmers through various means, thereby attracting new farmers who are well-trained in technology, and can operate a business, contribute as a team player, and protect their own legitimate rights and interests through legal means.

6 Conclusions

Northeast China is rich in agricultural resources, especially its vast ranges of flat, fertile farmland that is suitable for mechanized agricultural production. Moreover, the region has a low rate of pest occurrence because of the cool climate and requires relatively low amounts of fertilizers and pesticides for agricultural production, thereby facilitating green agricultural production.

The region is one of China's major production areas for crop and livestock products (corn, *keng* rice, soybean, pork, beef, and mutton). However, the region's agricultural production is currently a concern for both the regional food security of Northeast China and the national food security of China.

However, as Northeast China has an unbalanced crop production structure, particularly based on the ratio between food, industrial, and forage crops, the region is currently suffering from structural and short-term surpluses of some agricultural products. In particular, the export of massive amounts of food products has caused excessive consumption of agricultural resources and serious deterioration in black-soil farmland. Furthermore, there is a lack

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of water conservancy facilities, with existing facilities being poorly configured and outdated, thereby causing a low rate of water resource utilization and excessive exploitation of groundwater. Currently, this is the major barrier to Northeast China's sustainable food security.

In the process of implementing agricultural supply-side structural reforms, Northeast China should aim to better coordinate crop production and animal husbandry, stabilize corn production, relatively increase *keng* rice production, and significantly increase soybean production, thereby fully utilizing the local advantages, boosting agricultural development with local characteristics through technological innovation, and increasing rural income.

To improve the agricultural infrastructure and safeguard the supply of major agricultural products, policy makers should focus on: establishing and improving mechanisms for subsidizing major grain-producing areas and increasing the subsidies for major grain-producing counties; strengthening high-standard farmland construction and black-soil conservation; strengthening the construction and renovation of water-saving facilities in medium and large irrigation areas to improve the control of water resources; and increasing the support for technological innovation in agricultural crop production, full mechanization, innovative agriculture, and green agriculture. By establishing these goals, a food crop production strategy based on farmland management and technological application will be implemented to safeguard sustainable food security in Northeast China.

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