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China food security assessment

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Abstract. Ensuring food security is a strategic goal of any state, especially in the face of population growth. A review of the academic literature showed the presence of problems in ensuring a high level of food security in China: the rigidity of demand for food, limited land resources, structural contradictions between supply and demand. This study proposes an approach to assessing the level of food security, based on the calculation of an integral index consisting of four units of indicators: the sub-index of provision of crop products, the sub-index of productivity, the sub-index of provision of livestock products, and the sub-index of food import dependence. The results show that, in general, the level of food security in China has increased over the period under review, but there are problems in self-sufficiency in crop and dairy products, as well as in an increase in food import dependence. A forecast of the dynamics of the integral index of the food security level and its sub-indices was constructed, which showed that a decrease in the integral index might occur due to a decrease in self-sufficiency in livestock products and import dependence, while the availability of crop products and yields will increase. The study showed that the measures taken by the Chinese government led to some positive changes, but it is necessary to take a comprehensive approach to this problem, to solve which it is necessary to use the potential of all sectors of the food industry.

Key words: food security, COVID-19 restrictions, food markets, agriculture, import dependence, government support.

INTRODUCTION

Food security is one of the most important conditions for national security. To ensure it, it is necessary to solve a set of issues, including an increase in the area of arable land, an increase in the production of crop and livestock products without environmental damage (Vervoort et al., 2014), lean food production and minimizing food waste

(Kubule et al., 2019; Andersson et al., 2020). Obviously, when food production reaches its technological peak, the lack of arable land will become a key factor limiting its production (Van Dijk & Meijerink, 2014; Põldaru et al., 2018). In recent decades, worldwide, population growth has outpaced food production growth, which has led to a decrease in food availability per capita, has created new risks for a number of countries.

China is the most populous country in the world. China's food production per capita is currently above the world average of about 470 kg per person, facing an increase of 14% over more than 22 years (414 kg per person in 1996). The total food production is growing steadily, in 2018 this figure was about 660 million tons (State Council Information Office of the People's Republic of China, 2019). However, the active growth of production creates threats in the use of land resources (Zhou et al., 2015). More than 20% of the world's population lives in China, with less than 10% of arable land. The availability of food in China is important not only because it affects a large part of the world's population and consumption, but also because rapid industrialization has led to competition for resources between agricultural and non-agricultural sectors, strong income growth, rapid urbanization, and population growth (Zhanga et al., 2018). All this stimulates the demand for agricultural products.

One can agree that in the context of active socio-economic development, China's food security in the future is of increasing concern (Jiang et al., 2019). First, although food production in China has increased, significant year-to-year fluctuations in supply and prices remain. Market stabilization and food price inflation have been among the main goals of government policy since the late 1980s, and the problem has not yet been resolved and is exacerbated by external global trends. Second, food security and access to food are mainly problems of poverty. China's economic growth as a whole is unevenly manifested in its regions. Incomes in the central and eastern regions of China continue to grow at a faster rate than in the western and southwestern regions. Income inequality between regions and between rural and urban areas continues to grow (Mukhopadhyay et al., 2018). Third, the COVID-19 outbreak, which became a global pandemic in early 2020, continues to impact agricultural supply chains. This is mainly reflected in the supply of grain, as many exporting countries have announced export bans. Disruption to supply chains has already driven up global food prices (Marchisio, 2020).

These and other reasons are more and more relevant to the topic of ensuring food security in China. That is why the purpose of this study is to assess food security and justify measures to stabilize it. To do this, the authors studied the current state of the Chinese agricultural industry; identified new trends in its development manifested against the backdrop of the COVID-19 pandemic; analyzed the effectiveness of food security measures taken by the Chinese government at the national and regional levels.

The paper consists of several sections. In the introduction, the authors substantiate the relevance of the issue, determine the purpose and tasks of the research. The literature review considers the concepts of food security, clarifies the difference between the categories of food security and food self-sufficiency, poses the problems of China's food security, and identifies approaches to its assessment. Materials and methods present the authors' approach to assessing food self-sufficiency based on an integral indicator comprising four sub-indices. The results of the study present an assessment of food self-sufficiency based on the proposed approach, as well as an explanation of the revealed import dependence of China based on the self-sufficiency level. The dynamics of the integral index of the food security level and its components are forecasted. The

discussion section compares the results obtained with other studies and analyzes the food self-sufficiency situation. The conclusion contains findings concerning China's food security prospects in the medium term.

LITERATURE REVIEW

Food security is a priority in the political agenda for many countries' governments. Achieving food security supposes that the country's population has stable access from economic, physical, and social perspectives to the volume of safe and nutritious food products that meets their nutritional needs (Food and Agriculture Organization of the United Nations, 2017).

It is important to note that food security is not synonymous with food self-sufficiency. The concept of food security does not consider the origin of food products or the country's ability to produce food products, provided that they are affordable, nutritious, high-quality, and safe. According to FAO's concept, food self-sufficiency is the degree to which a country can meet its food needs through its own domestic production (Food and Agriculture Organization of the United Nations, 1999). This definition concerns a situation when a country practices complete autarky and has closed its borders for international food trade. In FAO's modern interpretation, food self-sufficiency is defined as a country's production of agri-food products satisfying the predominant part of its need for food, which approaches or exceeds 100% of domestic food consumption. This definition does not exclude the possibility of international trade. Countries that are self-sufficient in food may to some extent specialize their food production and import, as well as export, food products (Puma et al., 2015; Clapp, 2017).

Let us discuss the case of China. With the advancement of industrialization, food security in China is facing new challenges, including increased demand for food, resource constraints, and structural contradictions. Despite the measures taken, there are still many unresolved problems. According to Van Meijla et al. (2020), the government should rationally address food security issues, based on such aspects as the establishment of a system for protecting food prices, improving the agricultural business model, increasing food subsidies, etc.

Hasegawa et al. (2018) pointed out that China's food security should focus on agricultural infrastructure, key links in food logistics, food markets, food subsidy policies, and other areas. To protect China's food security, a reproduction reserve system should be developed. That is, food security should enhance the comprehensive potential of food production, as it is based on the organic integration of food production, distribution, and consumption (Godfray & Robinson, 2015).

As one can see, the issue of ensuring food security is very urgent and requires an early solution, which predetermines the importance of assessing its level.

Many indicators have been proposed to identify which countries need to improve their food security status (Melgar-Quinonez et al., 2005; Kuyvenhoven, 2012; Food and Agriculture Organization of the United Nations, 2013; Jones et al., 2013; Pérez-Escamilla, 2013; Kuzmin, 2015). However, the lack of consensus on how to compare and rank countries has prompted international institutions to create composite indices to summarize information. The index building process includes several options that obviously affect the result. This review aims to understand how relevant and discretionary the choice of

algorithms can be for calculating composite food security indices. Table 1 presents a systematization of approaches to assessing the level of food security.

Table 1. Approaches to assessing the level of food security

Method	Description
Anthropometric indices	Initial data: Weight, height, body size and other information on food provision, preparation, food composition and consumption. **Result:** The proportion of the population that is undernourished. Features: Mapping of food security can be done both nationally and locally. It takes a long time to directly measure food security.
Household expenditure survey	Initial data: Household information on spending on food and other necessities. **Result:** Per capita calorie intake. Features: Allows identifying the determinants of consumption. Converting available food to calories involves basic assumptions that can cause measurement errors. Measures the amount of food available (ignores consumption in a given period).
Survival strategy evaluation indices of different levels	Initial data: Respondents' answers (on how households respond to food shortages). **Result:** A vision of how households are responding and/or adapting to the presence or threat of food shortages. Features: Subjective assessment. Household comparisons are problematic.
Scales based on food insecurity experiences	Initial data: A scale containing elements that reflect the conceptual and multidimensional nature of food security. **Result:** Various algorithms for transforming food security assessment scales. Features: Measures food security according to individual experience.
Food intake assessment indices	Initial data: Food consumption by an individual/household over a given period. **Result:** The amount of food consumed. Features: Directly measures consumption, not food availability.

Based on the approaches presented, one can conclude that it is advisable to assess the level of food security taking into account the context of the study. In this case, it is important to assess the dynamics of changes in the level of food security, taking into account the production and imports of food.

The review showed that most researchers agree that ensuring national food security is essential for agricultural sustainability (Fang et al., 2018; Morea & Balzarini, 2018; Raymond et al., 2018; Pakravan-Charvadeh et al., 2020). The they are also concluded that the issues of the sustainability of supply chains, the subject of responsibility, and the area of food security were widely discussed in the literature, but they have not formed a general analytical basis for studying the level of food security, taking into account import dependence, natural conditions, productivity, consumer relations, and other factors (Ray et al., 2013; Valešová et al., 2017; Ceballos et al., 2020; Nicola et al., 2020). As a result, many studies (for example, Ghose, 2014; Wu et al., 2016) treat food security as food self-sufficiency. Zou & Guo (2015) consider food security as self-sufficiency and reduce it to self-sufficiency in grain as the main agricultural crop. Based on this, Zou & Guo have developed an index system for the quantitative assessment of food security.

MATERIALS AND METHODS

To assess food security, the authors propose to use an integral approach through calculating the corresponding food security index, which includes four units of assessment indicators: the sub-index of provision of crop products, the sub-index of productivity, the sub-index of provision of livestock products, and the sub-index of food import dependence. The proposed integral index includes indicators with different dimensions to ensure the commensurability of different indicators, their values swere normalized using the 'maximum-minimum' method.

First, the sub-indices of indicators, the greater value of which characterizes a higher level of food security, were calculated as follows:

$$i_{FSi} = 100 + \frac{i_i - V_{av}}{(V_{max} - V_{min})/2} . \quad (1)$$

Second, the sub-indices of indicators, the greater value of which characterizes a lower level of food security, were calculated using the formula:

$$i_{FSi} = 100 + \frac{V_{av} - i_i}{(V_{max} - V_{min})/2} , \quad (2)$$

where i_{FSi} – the sub-index for the i-th year; V_{av} – the average value of the indicator for the period; V_{max} – the maximum value of the indicator for the period; V_{min} – the minimum value of the indicator for the period.

The integral index of the level of food security I_{FSi} was calculated as follows:

$$I_{FSi} = \frac{\sum_{m=1}^{M} i_{FSi}}{M} , \quad (3)$$

where M – the number of units for assessing the level of food security (in the studied case, $M = 4$, since the assessment examined four units of indicators).

Units of indicators of the integral index of food security:

1. Sub-index of provision of crop products. Production of the most commonly consumed crop products. The production of such crops as corn, rice, green corn, oil palm fruits, soybeans, wheat was assessed per capita.

2. Sub-index of productivity, which includes indicators of the productivity of the most frequently consumed crop products.

3. Sub-index of provision of livestock products. Production of the most commonly consumed livestock products. The production of such types of meat as pork, goat, lamb, poultry, goose/guinea fowl, duck meat per population was assessed.

4. Sub-index of food import dependence, which includes such indicators as the coefficient of dependence on grain imports, the cost of food imports in total exports of goods, the variability of food production per capita, the ratio of food imports to the population, the prevalence of undernourishment (in % of the population).

The advantage of the proposed integral index of the level of food security is wide coverage of various aspects of agriculture. The approach provides a high degree of accuracy and identifies weaknesses in food security.

In the course of the study, a forecast of the dynamics of the integral index and its sub-indices was constructed using the least-squares method. The paper used statistical

data on agriculture and trade in China of the Food and Agriculture Organization of the United Nations (2020) for 1990–2018.

RESULTS

Using the proposed approach for calculating the integral index of food security, the authors calculated all of its components. Fig. 1 presents the data for four sub-indices.

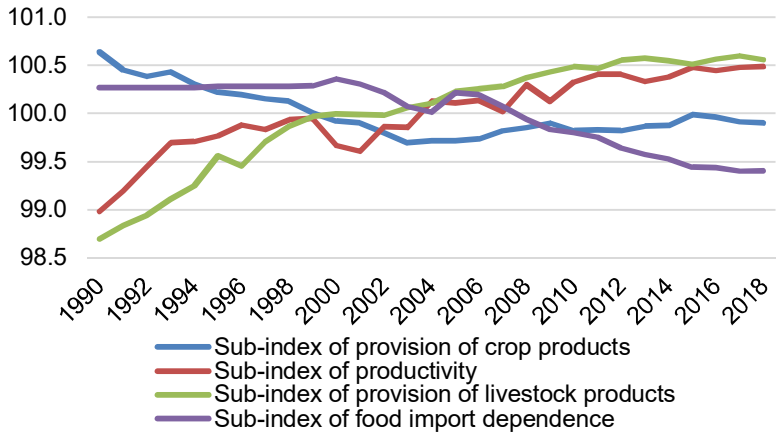

Figure 1. Sub-indices of the level of food security in China in 1990–2018.
Source: (Food and Agriculture Organization of the United Nations, 2020).

The dynamics of the sub-index of provision of livestock products demonstrate steady growth. This indicates the use of innovative technologies in agriculture, which affects the total volume of livestock production. Increased competitiveness becomes a logical consequence of innovation (Batkovskiy et al., 2020). Growth for chicken meat in 1990–2018 was 2.53 times; for pork - 0.51 times; for lamb - 1.16 times, for duck - 1.54 times, for goat and goose/guinea fowl - 1.13 and 1.32 times, respectively (Food and Agriculture Organization of the United Nations, 2020). The results of calculating the productivity index showed an increase in all the products under consideration: the yield of corn increased by 34.9%, rice - by 22.9%, corn - by 27.5%, oilseeds - by 4.9%, soybeans and wheat - by 22.3% and 69.6%, respectively.

Despite the increase in productivity, the indicators of the sub-index of provision of crop products are characterized by unstable trends. According to the data obtained, only the production of corn per capita shows an increase over the period of 1990–2018 by 26.7%, while the production of rice, wheat, soybeans, and oil palm fruits decreased by 41.3%, 49.1%, 32%, and 21.9%, respectively (Food and Agriculture Organization of the United Nations, 2020). A strong decrease is observed in the specific indicator of production of particular crops per capita (with an accompanying increase in the population of China over the period under review).

The sub-index of food import dependence also shows a decrease, which is associated with an increase in imports of particular types of products, primarily, this concerns crop production (wheat, rice, soybeans). Thus, the coefficient of dependence on grain imports increased more than 10-fold, the value of food imports in total exports

increased by 33.3%, the variability of food production per capita increased almost 2-fold (by 96.3%), a positive trend is shown by the index of undernourishment (in % of the population) - it decreased by 52%.

The coefficient of the level of China's dependence on grain imports and the specific cost of food imports in the total exports of goods and services are shown in Fig. 2. The data show that the minimum value of the coefficient of dependence on grain imports was observed in 2001, after which its annual increase began. The value of food imports in the total exports of goods and services show a similar trend: in the early 2000s, this indicator was minimal, after which its value began to grow.

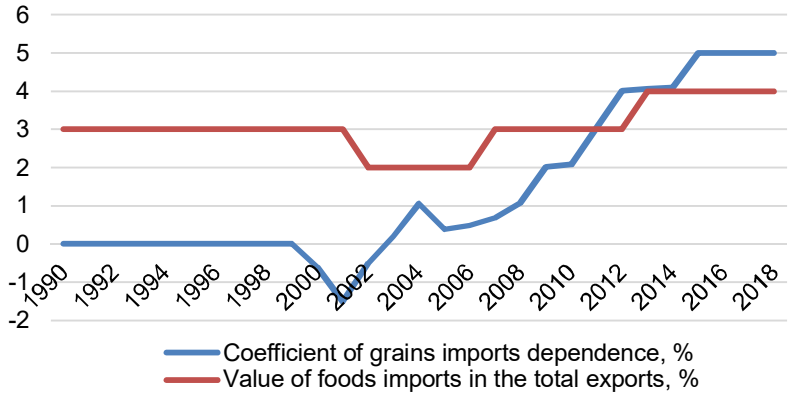

Figure 2. Indicators of China's food import dependence for 1990–2018.
Source: (Food and Agriculture Organization of the United Nations, 2020).

To understand the components of food import dependence, let us consider China's self-sufficiency coefficient for some particular types of food products (Fig. 3). As one can see, the greatest dependence on imports is observed in the production of soybeans (34%), oilseeds (45%).

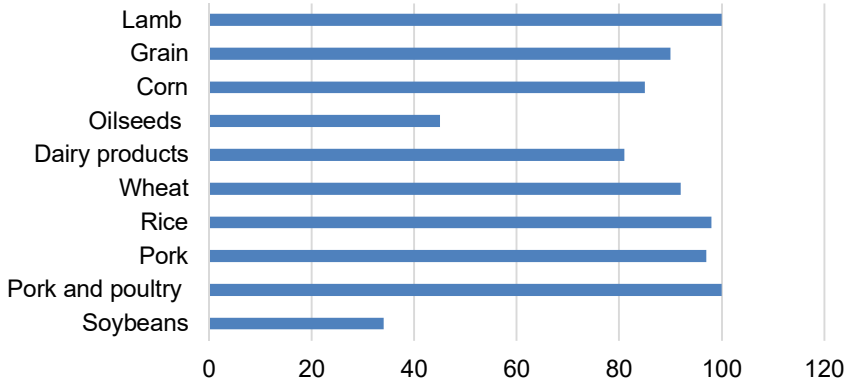

Figure 3. Coefficients of China's self-sufficiency for certain types of agricultural products in 2018, %.
Source: (Food and Agriculture Organization of the United Nations, 2020).

Self-sufficiency data indicate that the lowest values are related to crop and dairy products. The self-sufficiency goal set by the authorities (for a long time China applied the 95% rule: domestic supply must be able to cover at least 95% of domestic demand (Organisation for Economic Co-operation and Development, 2018)) is becoming more difficult to fulfill every year: the main reason is associated with the increasing volume of agricultural products supplied to meet demand, continuing to grow, causing, as a result, a significant increase in imports of grain, as well as soybeans and other staple foods. China's sharply widening trade deficit in agriculture and agri-food is proof of this. Local production of grains (rice (98%), wheat (92%), corn (85%)) met 90% of the national needs in 2018, compared to more than 100% in the early 2000s. Since 2018, rice production in China has shown negative growth for two consecutive years, while consumption and therefore demand has continued to rise, putting pressure on domestic production. China's rice self-sufficiency is relatively high, but the balance between domestic demand and supply is fragile. China also imports 19% of its dairy needs.

These trends are confirmed in the course of this research: the results of calculating the integral index of the level of food security show that in recent years the level of self-sufficiency in China has been declining (Fig. 4).

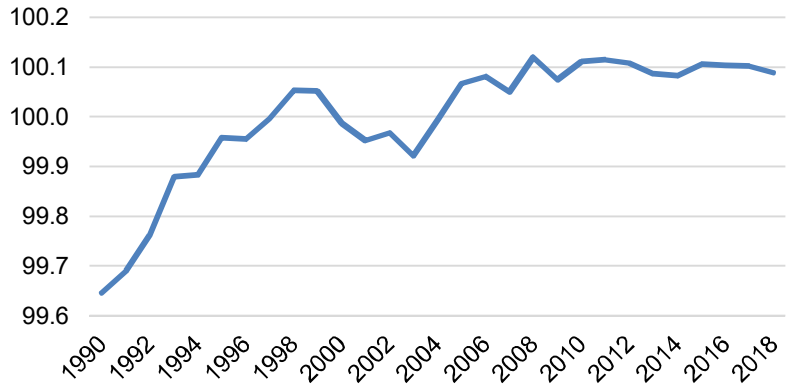

Figure 4. Integral index of the level of food security in China for 1990–2018.
Source: (Food and Agriculture Organization of the United Nations, 2020).

For the period of 1990–2015, the integral index increased by 0.46%, while from 2015 to 2018 it decreased by 0.02%. As mentioned above, the growth in food imports had a significant impact on this dynamics. To avoid overdependence on international markets, China's strategy is to secure its supply, control production in other countries, and limit the number of intermediaries.

To understand the further development of the situation in the field of food self-sufficiency, the authors built a forecast of the dynamics of the integral index of the level of food security and its sub-indices (Fig. 5).

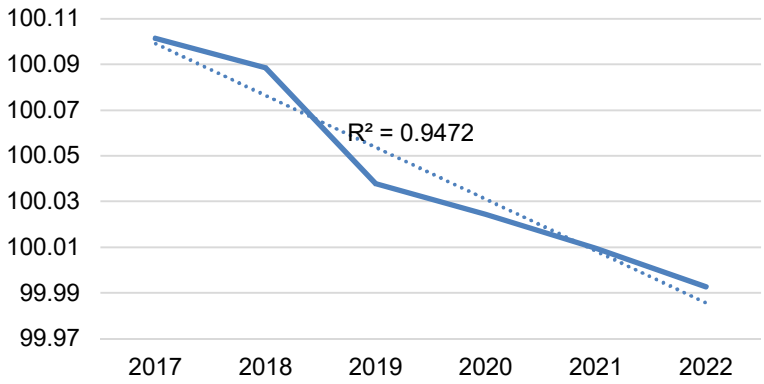

Figure 5. Forecast of the dynamics of the integral index of the level of food security in China.

The integral index is expected to decline by 0.1% over the next three years, suggesting an acceleration in the rate of loss of food security in China. In the medium term, this will be facilitated by a decrease in self-sufficiency in livestock products and import dependence, while the provision of crop products and productivity will increase (Table 2).

Table 2. Forecast of the dynamics of China's food security sub-indices

Sub-indices	Fact		Forecast*			
	2017	2018	2019	2020	2021	2022
Sub-index of provision of crop products	99.92	99.90	100.06	100.11	100.18	100.24
Sub-index of productivity	100.48	100.49	100.46	100.48	100.49	100.50
Sub-index of provision of livestock products	100.60	100.56	100.56	100.54	100.51	100.48
Sub-index of food import dependence	99.41	99.40	99.17	99.08	98.98	98.88

Note: * – taking into account the time lag in the formation of statistics.

The results obtained differ slightly from the common point of view in other studies - that the most negative situation is observed in the field of crop production. As one can see, a one-sided policy in relation to certain sectors of agricultural production can lead to the fact that livestock indicators will decline, which, in turn, will lead to an even greater dependence on food imports.

DISCUSSION

Due to the unprecedented growth of imports in 2020, the key purpose of China's economic policy for 2021–2025 has become to maintain stable food production (Bloomberg News, 2021). For this, the Chinese government has developed the national food security strategy based on self-sufficiency through domestic production, guaranteed food production capacity, moderate imports, and technological support. However, the increasing dependence on imports and the export ban on food grains due to the

COVID-19 pandemic is highly likely to exacerbate the global food crisis and could have serious implications for China. China's food security currently faces three major challenges - severe resource constraints, complex structural contradictions, and supply lags in agricultural logistics.

It should be noted that, on the one hand, China's agricultural policy of the year was not always aimed at meeting the needs of the population for food, at the same time, the rural sector was not always a priority of economic policy. Therefore, the very structure of China's agriculture has changed very little, the share of grains in agricultural land in the added value of agriculture has largely remained. To maintain stable food production, China is going to focus on increasing the yields of rice, wheat, soybeans, and corn to improve national food self-sufficiency. The current production volumes of Chinese grain do not cover the growing demand of animal farming for feed crops. In China's agri-food sector, the consumption of fodder grain exceeds the consumption of cereals for food purposes, which, given the limited growth potential of total grain production, exerts great pressure on China's food supply (Lin et al., 2014). Price volatility and geopolitical tensions have complicated the situation in the global feed grain market and forced China to diversify its import sources (Wang, 2021).

Another limiting factor is population growth: since 1990, the population of China has increased by 60% to 1,401 million people, the average life expectancy over the same period has increased by 11.5%, reaching 77.1 years (Food and Agriculture Organization of the United Nations, 2020). These events lead to a huge increase in the demand for food. It is forecasted that following the intensification of urbanization processes and changing diets, the consumption of main crops per capita will decrease, while demand for meat and fish products will grow (Donley, 2021).

China has about 8% of arable land to feed 19% of the world's population (Food and Agriculture Organization of the United Nations, 2020). However, not only two-thirds of China's territory is located at an altitude of more than 1,000 meters, but urbanization and desertification also limit the possibilities of land cultivation. The Chinese authorities have set a minimum cropping area of 120 million hectares to ensure 95% self-sufficiency in grain. The growth of crop production efficiency in the previous years due to the increased use of fertilizers and pesticides has reached its limit and resulted in a considerable deterioration of the soil condition. The next surge in agricultural production efficiency should be based on scientific innovation.

These demographic, land, and water barriers are limiting production growth, so China is focusing agriculture on strategic products and is looking outside the country for other foods it needs.

In addition, Chinese purchases are based on a limited number of suppliers, further increasing the country's dependence. Three countries - the United States (23%), Brazil (19%), and Australia (7%) - supply half of the agricultural and agri-food products imported by China (Food and Agriculture Organization of the United Nations, 2020). Therefore, one of China's strategies is to diversify supplies.

The implementation of the Household Responsibility System, which provided every rural household with a plot of agricultural land, made an important contribution to improving agricultural efficiency in the early 1980s. The next step was market liberalization. Policies to stimulate the development of rural enterprises have contributed to employment and increased income for rural residents. The share of non-agricultural farmers increased from 15% in 1980 to over 40% in 2018. China has over 200 million

farm households (or rural households with land contracts). Reforms in agricultural technology have also made important contributions, in particular to increased yields.

In addition, during the period of preparation for accession to the WTO, China has weakened access to import and export markets. After accession to the WTO, the aggregate indicator of support for domestic producers fell to less than 8.5% of the value of agricultural products. The most important agricultural policy measures are the minimum purchase price that applies to rice and wheat, the Temporary Storage Program, which was launched in 2008 for maize, soybeans, and rapeseed. Although the aforementioned price support measures have increased crop production, the shortage of some commodities is still high and even increasing.

It is very difficult to predict China's future food import needs. On the one hand, self-sufficiency or near-self-sufficiency in food has always been an important strategic goal of Chinese agricultural policy, especially with respect to staple crops. In recent years, China has maintained an overall food self-sufficiency rate of 95%. If it adheres to the same policy, its food imports are unlikely to change significantly in the future - at least it is certain that they will not increase significantly (according to this study, China's self-sufficiency level will decline slightly in the medium term). However, there is still a risk that the COVID-19 pandemic, poverty, and food insecurity in other countries will lead to increased protectionism and restriction of food exports. Other factors, such as dietary changes (imports of foods such as meat, milk, and sugar may increase) and demographics (consumption may stabilize as China's population approaches a peak), may also determine future levels of food imports.

Despite the strengthened measures aimed at achieving food self-sufficiency, many researchers believe that China's food self-sufficiency will decrease from 94.5% in 2015 to about 91% by 2025. However, this additional volume of imports is not expected to result in serious damage (Huang et al., 2017).

The results obtained by the authors of this paper are in line with other researchers' assessments of China's self-sufficiency. For example, Cui & Shoemaker (2018) showed that China's self-sufficiency in three main crops (wheat, rice, and corn) was about 95%, and even after the pandemic, their imports were less than 10% of domestic consumption (Wang, 2021), while about 80% of the soybean consumed in China was imported. Similar conclusions are drawn in Donley (2021), which states that by 2025, China will be almost entirely self-sufficient in main crops such as rice and wheat, but will remain the largest importer of soybeans.

A factor analysis of food security carried out by Zou & Guo (2015) showed that its level in China was permanently declining. Zou & Guo believe that these changes are caused by the growth of the population's incomes and changes in the structure of food consumption. They conclude that demand for grain is expected to grow in China, but do not specify whether it concerns grain for food or grain for livestock fodder. The main problem of food security is considered to be the gap between the production and consumption of grain.

The analytical report of Hang Seng Bank China (Wang, 2021) states that despite the priority of food self-sufficiency, an increase in the imports of a number of crops is unavoidable. Achieving self-sufficiency comes at a high cost for the Chinese economy. The problems include rising payroll costs, land depletion, and water deficiency in many regions of China. Due to low production efficiency and high production costs, grain cost prices in China are usually higher than in the global market. In the past five years,

average domestic prices for wheat, rice, corn, and soybeans have been higher than world prices.

We believe it would be advisable to adopt a strategy aimed at maintaining a balance between a comfort level of self-sufficiency in basic food products and the share of imported food products. However, the definition of the 'comfort level' ultimately depends on political considerations, in particular, it will be the question of achieving food security in other countries.

CONCLUSION

The study examined China's food security prospects over the medium term. China continues to be the main contributor to global food production and consumption. Food consumption in China will continue to grow in the coming years, driven by economic growth and urbanization. The proposed approach to assessing the level of food security in China, based on the calculation of the integral index, consisting of four units of assessment indicators, made it possible to prove that, in general, the level of food security has increased. However, the forecast for the dynamics of the integral index shows that in the medium term, there will be a reduction due to a decrease in self-sufficiency in livestock products and import dependence. China will remain self-sufficient for rice and wheat, but it will continue to depend on other countries for soybeans and corn. The dynamics will also be influenced by the restrictions associated with the COVID-19 pandemic, the decisions of some countries to restrict food exports, and the rise in food prices. To eliminate the existing restrictions, China needs to take a comprehensive approach to this problem, helping to realize the potential of all sectors of the food industry.

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