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China's food security situation and key questions in the new era:
A perspective of farmland protection

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Abstract: As the world's largest developing country, the ability of China's agricultural resource utilization to effectively support the current and future food security goals has been affected by a variety of factors (e.g., transformed supply channels, tightening international situation and frequent emergencies) in recent years and has attracted extensive attention from the academic community subject to multiple factors. This study uses literature review, statistical analysis, and spatial analysis methods to systematically explore China's food security situation in the context of farmland resource constraints. It is found that the demand-side pressures such as demographic changes, social class differentiation, and dietary structure adjustments derived from economic growth and rapid urbanization have placed extremely high expectations on food supply. However, the quantitative restrictions, utilization ways, and health risks of farmland resources on the supply side constitute a huge hidden concern that affects the stability of food production. Although China's farmland protection system is undergoing a transition from focusing on quantity management to sustainable use, the matching and coordinating demand pressure and supply capacity for food security is unbalanced. Therefore, facing uncertain future development scenarios, policymakers should focus on building a resilient space for China's farmland protection to withstand the interference of major emergencies. The existing farmland protection space policy can be integrated by establishing a national farmland strategic reserve system (based on resilient space), and further development of targeted use control measures for zoning, grading, and classification will help realize sustainable China's farmland resources use.

Keywords: food security; systematical analysis; key questions; farmland protection; resilient space; China

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1 Introduction

As a hot issue of general concern to the international community, food security is an important cornerstone of national security and the key to achieving global sustainable development goals. Food security is defined as allowing all people to have material and economic access to sufficient, safe and nutritious food at all times to meet their dietary needs and food preferences for an active and healthy life (FAO *et al*., 2013). Its complexity is reflected in multiple levels and multiple aspects (Wheeler and Braun, 2013). Food supply and demand should ensure that food is available to meet survival and development needs, including the quantity, quality, structure, price (FAO, 2019). However, food security is facing increasingly uneven supply-side and demand-side pressures. The key to this is climate change, urbanization, globalization, population growth, disease and other factors changing food consumption patterns (Misselhorn *et al*., 2012; Wheeler and Braun, 2013). Effectively addressing the food insecurity challenge mainly focuses on environmental pressures in larger developing countries dominated by smallholder farmers (Misselhorn *et al*., 2012; Tscharntke *et al*., 2012).

China is the world's largest developing country, and the success of its agricultural production has an important impact on the world's food supply and resources utilization (Fan *et al*., 2012; Alexander *et al*., 2015). Since the reform and opening-up in 1978, China's grain production had increased from 304 million t in 1978 to 660 million t in 2018, and 20% of the world's population has achieved a well-off life with 9% of the world's farmland (State Council Information Office, 2019). The fluctuations in food production in recent years have stabilized within a reasonable range (±6%). Nevertheless, China's food security still faces multiple challenges: farmland resources reduction, poor soil-water combination, climate change influence, weakening of employees, and consumption structure upgrading (Ma *et al*., 2020). Moreover, in the new stage of food supply-demand diversification (2015–2050), China is approaching the limits of its domestic agricultural resource exploitation potential (Xie *et al*., 2017). Meanwhile, the supply and demand of global food resources are tight, and the volatility of the food market has intensified. As a result, there is limited space for China's food adjustment (Han *et al*., 2012). Furthermore, evidence shows that if the current rice cultivation system structure remains stable, global warming will reduce China's total rice production by 5% in 2060; if the double-season rice cultivation area continues to decline, China's rice production in 2060 may decrease by 13.5% (Chen *et al*., 2020). Therefore, how to ensure future food system's stability and realize sustainable agricultural resources use (especially farmland) has become the top priority of the country's survival and development issues (Song and Ouyang, 2012; Huang and Yang, 2016; Han and Chen, 2018; Li *et al*., 2018).

China is currently in important urbanization and ecological civilization construction period. The imbalance between supply and demand between people's pursuit of high-quality life and the constraints of limited available resources is more complicated due to changes in external environmental conditions (e.g., climate, trade situation, natural hazards, and public health emergencies). These environmental conditions make it more difficult to analyze food security issues in many regions, including China, and difficult to evaluate and predict (Garnett, 2014; Liu *et al*., 2014). As a basic indicator to measure comprehensive productivity, farmland is also the most fundamental constraint on effective food supply (Jin *et al*., 2017). On the one hand, the spatial mismatch between food production and farmland resources, water and soil elements will lead to a series of problems affecting food security, such as regional structural imbalance, ecological risks, agricultural production risks, and food price fluctuations (Li *et al.*, 2017). On the other hand, unsustainable land management has caused farmland degradation and seriously threatens food security and sustainable development (Song and Liu, 2017). Furthermore, farmland supply capacity continues to evolve with changes in human demand (Ma *et al.*, 2020). Existing studies are generally optimistic that the grain produced in China can meet the needs of its growing population. However, major challenges that may arise in the future, especially high-intensity competition for land resources between food production, urban expansion, and energy production, will pose a serious threat to farmland use (Deng *et al.*, 2006). For example, the change in eating habits from crop-based to animal-based diets caused by economic income growth (Fukase and Martin, 2016); a negative impact on food production, transportation, and storage affected by the weakening of rural labour force and the ageing of the population in the urbanization process (Oeser *et al.*, 2018). Consequently, achieving a dynamic balance between the demand for food consumption and the supply of farmland resources in the context of resource and environmental constraints is the foundation for implementing sustainable development goals.

Summarily, the compound effect of unbalanced supply-demand conditions and external negative impact is bound to affect China's future food security. What is the current situation of farmland resources' utilization, management and protection in China? Is it sufficient to match the current and future food security goals? How does the direction of subsequent policy formulation match China's food security target framework? This paper systematically explores the key issues facing China's food security from the perspective of farmland protection based on literature review, statistical analysis, and other methods to answer the above questions. Furthermore, we proposed future China's farmland protection countermeasures to provide ideas for China's food security, sustainable agricultural resources use, and farmland protection system transformation.

2 Materials and methods

This research comprehensively applies literature review, statistical analysis, geographic information spatial analysis technology, and other multi-source paths to study the characteristics of farmland resource supply under China's food demands and propose policy recommendations accordingly. The databases used for literature review include Web of Science (WoS), China National Knowledge Internet (CNKI), taking into account databases' standardization, availability, and recognition. The search time ranges are 1990–2019 in WoS 1979–2019 in CNKI. Due to the differences in the search fields of different databases, the search rules are slightly different. For WoS, when the literature title is "food security" or "farmland protection" and the subject is "China", it can be included in the review scope. Judging from the publication year of the literature (Figure 1), the research on China's food security and farmland protection was first published in international journals after Brown's Question (Who will feed China?) in 1995. Then the number of regional literature in China has gradually soared. After 2010, the advantages of regional literature publishing have gradually shifted to international literature, which shows that Chinese scholars are striving to explain the importance of China's food security issues to the international community.

The literature collection process mainly extracts the previous research's key conclusions and valuable points to facilitate the summary and induction. Moreover, China's official statistics and land use data at a scale of 1:100,000 are used for simple statistical and geographic analysis. The statistical data at the national level comes from the 1991–2019 China Statistical Yearbook (http://www.stats.gov.cn/), including population, labour force, food output, food trade, planting area, fertilizer and pesticide application, affected crops area, etc. The land use data comes from China's land-use remote sensing monitoring database, supplemented by the second national land use survey results for verification. Land use data is used to analyze farmland resources' spatial characteristics, and the analysis indicators include fragmentation degree, infrastructure completeness, scale rate, and multiple-crop index (Table 1).

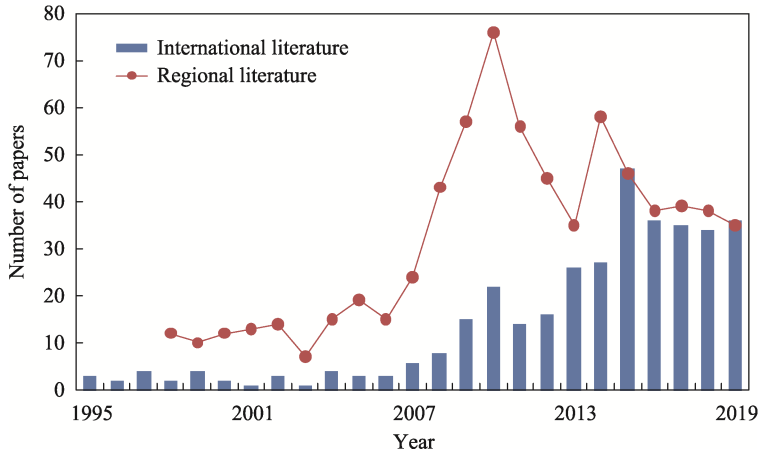

Figure 1 Number of international and regional papers

Table 1 Brief Introduction to farmland resources' spatial analysis method

Analytic index	Unit	Index interpretation	Calculation method
Fragmentation degree	Dimensionless	The index is used to characterize farmland dispersion and irregularity degree and reflect farmland resource distribution patterns.	A comprehensive measurement of farmland patch density, patch aggregation degree, and patch area index, respectively (Liu *et al.*, 2019)
Infrastructure completeness	m/m²	The index is used to characterize the supporting conditions of agricultural infrastructure, mainly including field roads and agricultural power and water conservancy construction projects.	Length of field roads and irrigation ditches per unit area
Scaling rate	%	The index indicates the farmland proportion that has reached large-scale operations based on high-standard farmland construction standards, reflecting intensive farmland management.	The farmland proportion that reaches large-scale operations according to the high-standard farmland construction standards of the Ministry of Agriculture of the PRC
Multiple-crop index	Dimensionless	This index represents the number of consecutive crops planted on the same plot in a year, reflecting the changes in crop maturity.	The ratio of total crops sown area to farmland area in the whole year

3 China's food demand characteristics and changing trends

3.1 Dependence on international trade threatens food supply stability

With economic development and consumption concepts transition, China's food security has gradually been adjusted to a pattern that relies mainly on domestic production and is supplemented by imported food. Changes in world food production areas and yields have also significantly impacted China's food security and food import strategies (Wang *et al.*, 2015; Liu *et al.*, 2017). The food distribution in China is not balanced. On the one hand, China's crops types vary greatly, and most of them focus on cereals cultivation. On the other hand, the huge country's territories span leads to great differences in the spatial distribution of non-cereal crops, which increases the economic cost of domestic food transportation. Therefore, it is necessary to use the international market to ensure residents' diversified dietary needs are in a state of self-sufficiency (Huang and Zou, 2018). Generally, China's food trade mainly depends on the international environment and the country's economic capacity to pay for food imports (Doelman *et al.*, 2019). As a result, China's food import and export trade has fluctuated (Wang *et al.*, 2018a). Take the main cereals as an example, China's grain imports and exports have mainly been soybeans, maize, wheat, and rice since 1990; The proportion of soybean imports is the highest, and the import volume continues to rise. The proportion of maize and rice exports is relatively large, and the export volume shows a trend of first increasing and then decreasing (Figure 2).

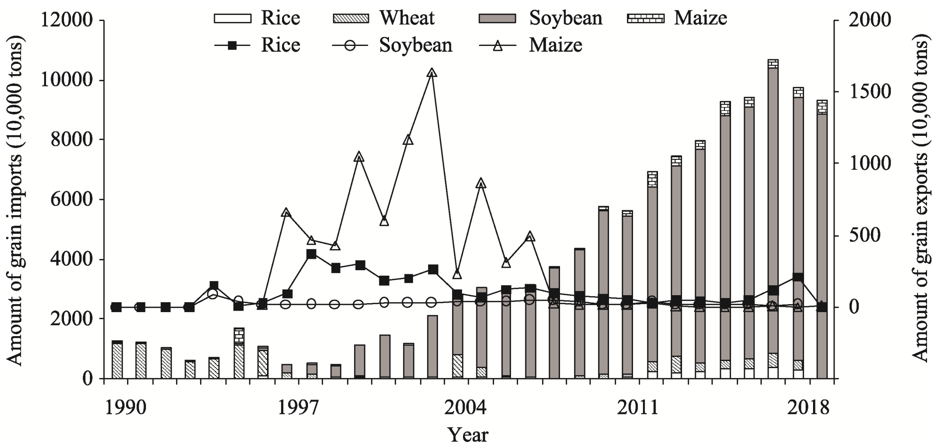

Figure 2 International trade statistics on grain imports/exports from 1990 to 2019. The histogram is the import volume, and the line chart is the export volume.

The expansion of China's food imports promotes foreign trade balance, develops bilateral trade relations with relevant countries, and drives total global food and other agricultural products. Overall, China is still a major food importer globally, and the discursive power in the food trade is relatively weak (Zhang *et al.*, 2021). The main reason is the combined effects of the foreign dependence on soybeans and the increasing demand for corn. However, soybeans are generally used for squeezing oil or as feed grains, which will not affect the safety of China's rations and grains; although the demand for corn has increased, the self-sufficiency rate is still guaranteed. The current challenge for China's grain trade is concentrated grain imports source, and the concentration and simplification of source countries have led to increased risks and uncertainties in the overseas grain trade. The resulting multinational grain merchants' control risks on the industrial chain are worthwhile alert.

3.2 Changes in the domestic market increase food demand pressure

Food consumption is an important part of China residents' consumption. Changes in its quantity and structure can directly reflect residents' living standards (Cao *et al*., 2012) and indirectly reflect the pressure that may be faced on the food supply side. The current increase in food consumption in China is mainly caused by economic income increase and continuous urbanization advancement to promote dietary nutrition structure promotion and other demand factors (Mi *et al*., 2013). China's food security connotation has undergone an "amount-purchase-nutrition" transition along with the "food-deficient, money-deficient, nutrition-demand" change on the food consumption problem (Wang and Wang, 2012). Accelerated urbanization has also led to major changes in food consumption levels and patterns, as well as food purchase behavior, shifting from primary products (e.g., grains, roots, and beans) to secondary foods (e.g., meat, fish, and milk) (Wang, 2019). Calorie demand related to income growth has increased significantly (Gouel and Guimbard, 2019).

It is important to note that the urbanized rural population has changed from the original food producers to the net purchasers. The lack of labour in rural areas has caused major changes in the agricultural planting structure. Migrant farmers have an increased demand for meat, eggs, milk, and other animal products due to heavy physical labour (Li and Wu, 2020), negatively impacting China's food consumption market. Recently, except for beans and tubers, China's total food output has maintained a steady growth. However, non-grain foods consumption will show a rigid growth trend due to population increase, age structure change, and social class differentiation. Official statistics show that fruit production increased significantly from 2000 to 2019, and meat, milk, poultry, eggs, and aquatic products showed a fluctuating growth trend (Figure 3). The transition trend of food demand structure is irreversible constrained by food consumption factors such as income level, dietary structure, and urbanization. In this context, it is not clear whether China's existing farmland resource supply can meet the increasing food demand pressure.

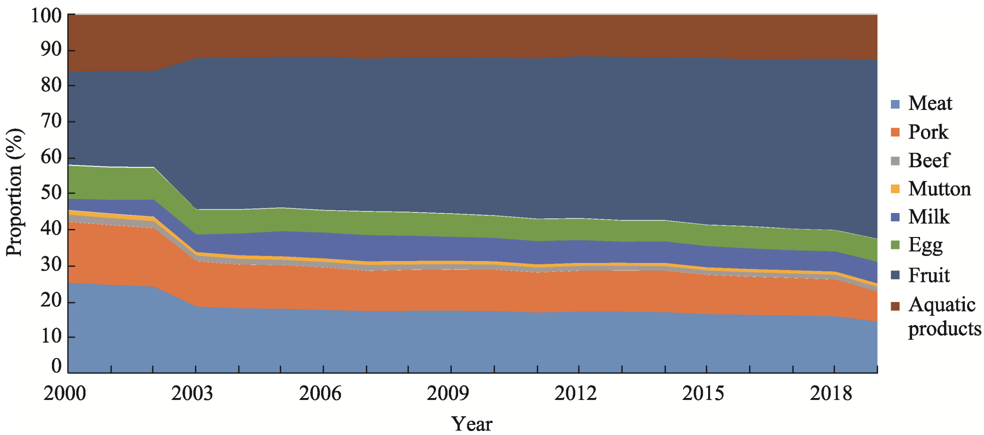

Figure 3 Changes in China's dietary structure from 2000 to 2019

4 China's farmland resource supply and guarantee capacity

4.1 Farmland resource endowment faces a series of problems

As the most basic and most important supply material in the food production system, farmland is the most critical strategic resource to ensure food security (Fu *et al*., 2001; Yu and Hu, 2003). Farmland quantity and quality strongly restrict food production and profoundly affect national food security and sustainable socio-economic development (Ma *et al*., 2020). With rapid industrialization and urbanization, China's farmland is decreasing year by year, and the quality of farmland is seriously degraded (Liang *et al*., 2020). As a result, the farmland resources face unprecedented pressure on food production (Zhang *et al*., 2018; Yun *et al*., 2019). Since 1990, the national farmland area had increased from 95.67 million ha to 134.88 million ha in 2017. Although the grain sown area has declined in a fluctuation in recent years, the increased investment in agricultural technology (especially pesticides and fertilizers) has kept grain output per unit area on a steady upward trend (Figure 4). Nevertheless, extensive pesticide and fertilizers use has led to a decline in farmland quality, affecting agricultural sustainability and healthy development. It is estimated that by 2030–2050, the loss of farmland caused by further urbanization and soil degradation may cause China's food production capacity to drop by 13%–18% compared to 2005 (Gong *et al*., 2011). The high-intensity farmland utilization process has led to the lack of internal functions, structural chaos, system degradation, soil acidification, and increasingly serious farmland pollution in the farmland ecosystem. Overall, the groundwater level in northern China continues to fall (Kong *et al*., 2016), the farmland heavy metal pollution in the southeast is increasing (Gong

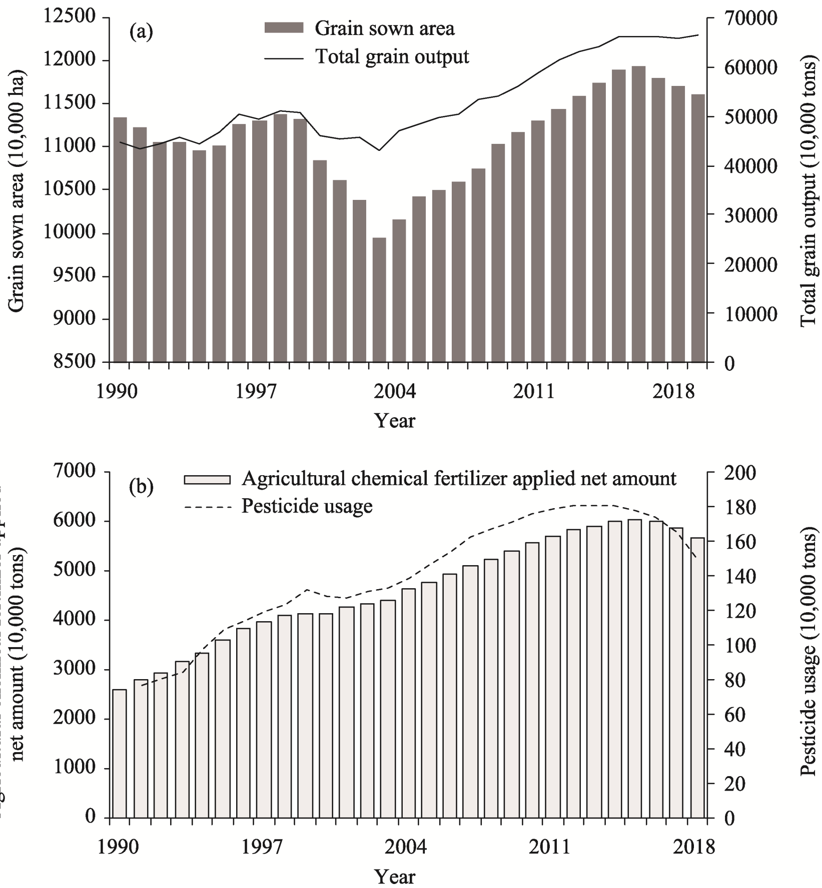

Figure 4 Grain sown area, grain yield and pesticide application

et al., 2011), the soil degradation in the black soil area of the northeast is severe (Niu *et al*., 2011), and the mulch film pollution and soil erosion in the northwest have deteriorated (Bai *et al*., 2015; Zhao *et al*., 2017). These phenomena constrained sustainable farmland resources utilization and continued food security stability.

4.2 Farmland production potential needs to be improved

The rational development and utilization of agricultural resources is a key process factor to ensure food security. Due to the huge population base and unique land-use system, China's farmland fragmentation is significant, and it is mainly concentrated in the economically developed areas of the flat southeast (Figure 5a). Studies have shown that farmland fragmentation in China wastes about 3%–10% of the effective farmland area, increasing labour cost by 115 yuan/t and reducing land productivity by 15.3% (Liu *et al*., 2019). Hence, China has stimulated farmland acquisition by lease for large-scale farming by increasing the farmland rent (Kung, 2002). Large-scale agriculture development has promoted the adoption of mechanized rice transplanting technology. Although China has implemented a series of agricultural land improvement measures to improve farming convenience (Jin *et al*., 2017), the regional differences in infrastructure construction are prominent restricted by per capita farmland area. Besides, large-scale farmland is mostly distributed in high-altitude areas that are not suitable for planting crops (Figures 5b and 5c), and there is a huge potential for improving resources utilization. Presently, more than 65% of China's population feeds on rice as the staple food. The rotation of double-cropping rice and single-cropping rice with wheat, rape, etc. have become the main intensive rice cultivation system (Huang and Zou, 2018). However, the multiple cropping index in major food production areas such as the Northeast and Middle and Lower Yangtze Plain, where rice and wheat are mainly planted, is in the low-level range (Figure 5d). As a result, China has shifted food production to marginal areas with low land productivity and high natural risks to increase production capacity. The excessively intensive agricultural land-use model requires a substantial increase in chemical fertilizers and agricultural machinery input, which will cause serious damage to the farm and the agricultural sector's upstream and downstream environment (Shen *et al*., 2017), threatening sustainable production. Farmland abandonment is also one of the key factors restricting food security. The formation of China's abandonment pattern is synchronized with agricultural labour precipitation under the background of regional economic development and industrial structure adjustment (Zhang *et al*., 2019). Summarily, although China's food production continues to grow, the farmland system it relies on is more fragile than before (Wang *et al*., 2018b).

4.3 Farmland use anti-interference ability needs to be enhanced

Emergencies often have a massive impact on the food production supply and demand chain in a short period (Bhopal *et al*., 2018). Emergencies can be divided into political events, natural disasters, public health events, extreme diplomatic events, etc., and summarized as short-term and long-term effect events (Bhopal *et al*., 2018; Cook *et al*., 2019). Short-term effect events will lead to the suppression of food production supply or demand expansion in the short term, causing a food shortage crisis. Yet, it will gradually return to the original steady-state in the later period, such as natural disasters leading to stagnation of food pro

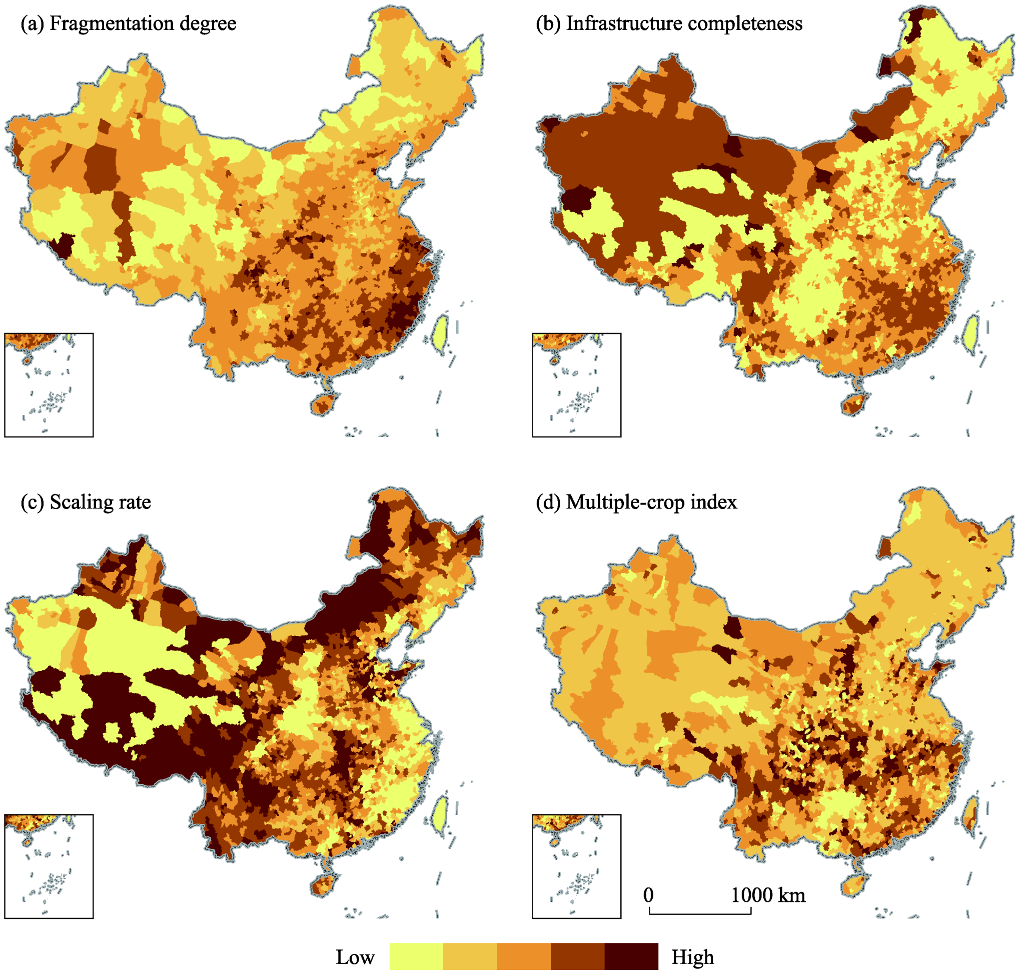

Figure 5 Farmland utilization status in China in 2015

duction activities (Klomp and Hoogezand, 2018), changes in national relations leading to food embargoes (Dithmer and Abdulai, 2017). Long-term effect events will lead to the transformation of food production and reach a new balance point, such as China's accession to the World Trade Organization (WTO) and the Sino-US trade war. Such incidents are transmitted to food supply and demand through economic, political, social, cultural, and policy channels, resulting in irreversible changes in the food security situation (Martin-Shields and Stojetz, 2019). These changes include passive changes directly caused by emergencies and ongoing feedback optimization of the food supply and demand structure from the management system after the events. The occurrence probability and frequency of short-term effect events are relatively high, but the intensity is relatively controllable. Taking natural disasters as an example (Figure 6), the average area affected by floods in China was 12.22 million ha per year during 1990–2018; the average area affected by drought was 20.63 million ha during 1990–2018; the average area affected by typhoons was 18.89 million ha during 2001–2018, and the average annual direct economic loss reached 46.024 billion yuan. The crop damage caused by short-term natural disasters can increase the production capacity recovery rate through economic compensation. Long-term effect events are often more sudden, more extensive in scope, and more rooted in impact. Accordingly, it is necessary to improve social governance capabilities and general management levels through multiple channels to reasonably control external disturbances in the food supply and demand chain and ensure food security (Filippini *et al.*, 2019).

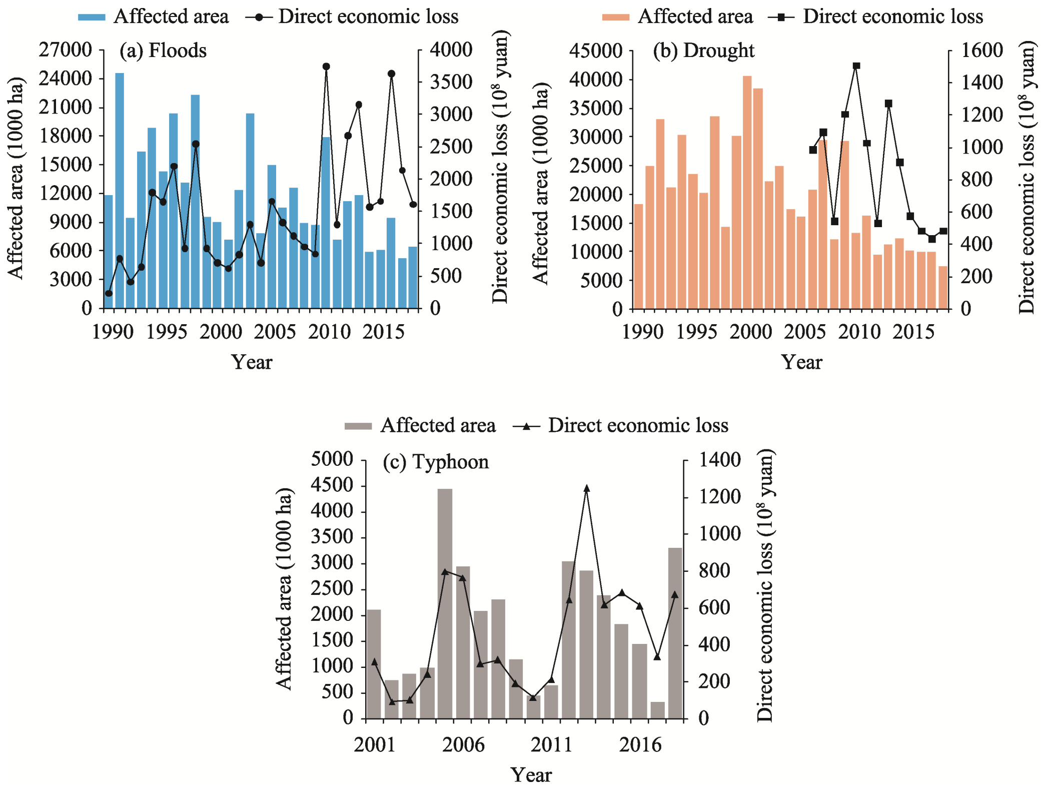

Figure 6 Partial natural disasters in China in the past three decades

4.4 Farmland protection system is in transition

Implementing farmland protection policies is crucial to ensure food supply capacity and maintain food security (Lichtenberg and Ding, 2008; Ge *et al.*, 2018; Wang *et al.*, 2018c). Some scholars believe that inappropriate farmland policies may lead to a decline in food supply capacity (Song and Liu, 2017). Nonetheless, a more general view is that controlling the quantity and quality of farmland is essential for stabilizing social livelihoods, resisting extreme disasters or events, and maintaining food sovereignty before understanding the internal impact of farmland protection on ecology and socioeconomics (Long *et al.*, 2018; Keovilignavong and Suhardiman, 2020; Liu *et al.*, 2020). In China, farmland protection has gone through five stages from the reform and opening-up and formed a farmland protection policy system with one foundation and three main lines (Figure 7). One foundation is the legal foundation. Three main lines are (1) planning control line: the bottom line of quantity control and the target line of quality construction are clarified through planning means; (2) permanent protection line: basic farmland is always the core and key of protection policy; (3) quality construction line: agricultural land improvement projects implemented at all levels play an essential role in enhancing farmland productivity and improving production conditions (Tang *et al.*, 2019). Holistically, China's farmland protection policy is undergoing two shifts. The first is the shift from short-term goals to long-term goals. Farmland protection goal has gradually shifted from production capacity obtained by highly intensive utilization to sustainable intensification represented by rotation fallow. The second is the shift from administrative to economic. Long-term practice shows that strengthening the objective of protecting farmland with administrative will easily lead to conflicts between different stakeholders and further weaken protecting effects (Zhong *et al.*, 2018). Thereby, the economic approach represented by the balance and transaction of occupation and compensation will become a new motivation to enhance the willingness and effect of farmland protection (Shen *et al.*, 2017).

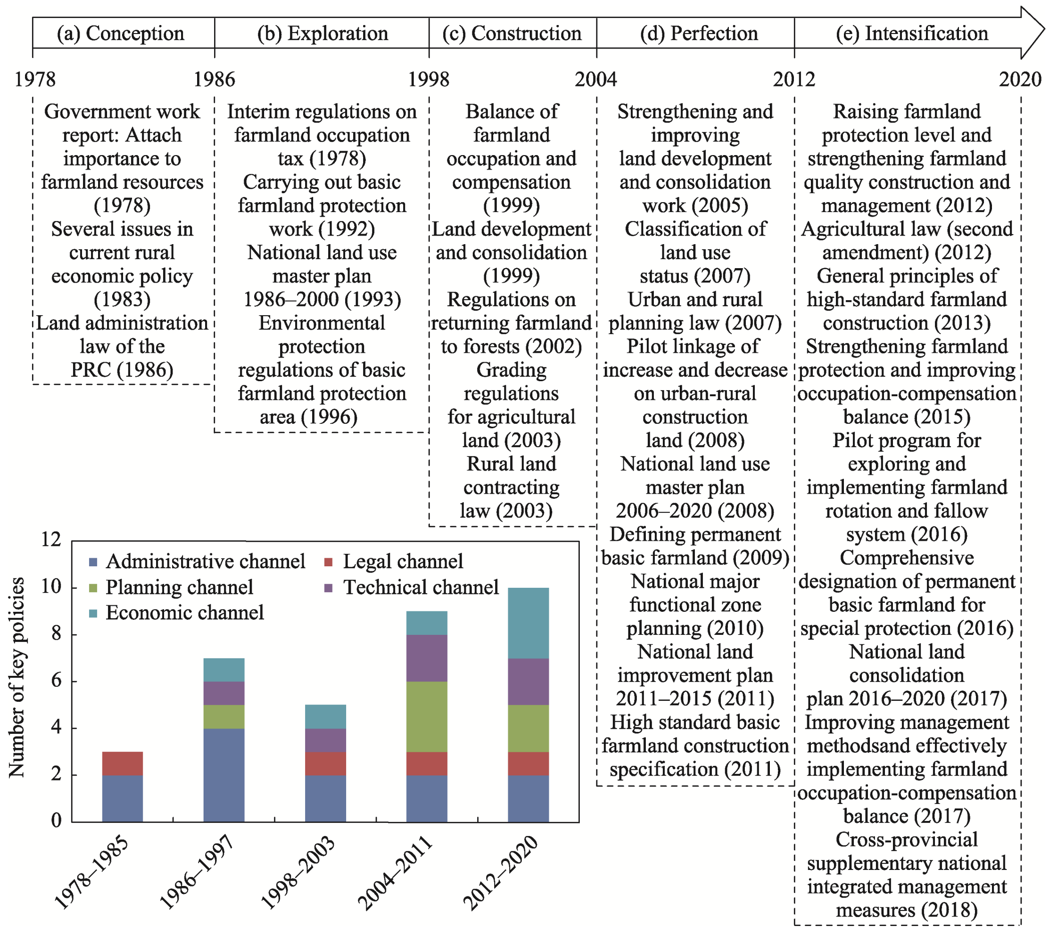

Figure 7 Key policies development on China's farmland protection since reform and opening-up in 1978

5 Strategies for key issues in China's farmland protection

5.1 Thinking on farmland protection resilient space

The global farmland area has only increased by 9% since 1961 (Pretty, 2008). There will be little room for a further increase without causing irreparable damage to critical natural ecosystems (e.g., tropical forests or permanent grasslands that support biodiversity and mitigate climate change by storing carbon) (Young, 1999). Unsustainable utilization of agricultural production resources is a considerable risk of China's food production to ensure food security under the new situation (Li, 2014). However, the long-term cultivation history and a large population have led to China's farmland reserves depletion. China uses almost every available land for agriculture, which leads to limited potential for increasing the food area in the future. The same (or even less) land will need to produce more food (Fan *et al*., 2012; Song and Ouyang, 2012). Agriculture needs to become more productive, stable, and resilient while minimizing its impact on the environment to meet future climate, economic, and social challenges (Foley *et al*., 2005).

Resilience is defined as the ability of a system to maintain its normal function, structure, characteristics and feedback after undergoing changes, absorbing disturbances, and reorganizing behaviors (Holling, 1973). Resilience thinking is a comprehensive concept based on ecological theory; it also reflects the dynamic perspective of complexity theory and combines hierarchy and scale concepts (Sellberg *et al*., 2018). Traditional land resource management usually does not consider interactions between landscapes, medium, and long-term sustainability, or appropriate time and space scale combinations. Moreover, sudden external event interference and internal dynamic changes are difficult to predict and foresee. Hence, traditional environmental and natural resource management methods have limited ability to deal with the complex dynamics of the social-ecological coupling system and the uncertainties of future change scenarios (Li, 2020). Thereupon, resilience thinking is considered an alternative to traditional natural resource management (Sellberg *et al*., 2018). Land-use planning must strive to cope with and adapt to technological knowledge innovations and rapid changes in human values, thereby maximizing flexibility and increasing multiple options for the future (Agudelo *et al*., 2020). The concept of resilient space can provide ideas for the adaptation and sustainable development of land use and management.

With the continuous improvement of cognitive ability, the food security problem no longer establishes a quantitative goal and standard but gradually becomes a process variable composed of trials, errors, intertwined administrative powers, and other uncertainties (Yang *et al*., 2019). Long-term food demand scenarios have become an important tool for studying food security and analyzing agricultural environment impacts to clarify such uncertain variables (Bodirsky *et al*., 2015). Usually, the range between the high-expectation and low-expectation worlds in different scenarios jointly determines the simulation results uncertainty (Verburg *et al*., 2013b). Therefore, exploring the resilience space for farmland resource optimization under uncertain conditions based on the bottom line of food security can reduce future farmland management risks and improve policy effectiveness (Yang *et al*., 2019).

Accordingly, this paper proposes a preliminary idea for constructing a resilience space for farmland protection in China to meet the complex and ever-changing food security situation (Figure 8). Firstly, a mathematical model needs to be constructed to simulate complex scenarios. The superposition and simulation of different scenarios can be achieved based on the principles of system science, namely, to combine or optimize existing mature models by constructing a system dynamics model. Secondly, the minimum and maximum farmland reserves can be estimated by accommodating all the challenges faced by the food demand side, relying on possible future development scenarios such as climate change, international trade, emergencies, etc. Finally, multi-dimensional elements evaluation and scoring are carried out on the farmland plot scale, and the farmland resource reserve range under the composite scenario can be obtained. The rigid space is the minimum range of the food security threshold, and the resilience space is the threshold difference between the maximum and the minimum reserves. The resilient space for farmland protection pays attention to the multi-dimensional comprehensive protection value of farmland space and its differences under long-term sequence scenarios. It is different from the past methods on assessing the fallow scale from natural conditions, human activities, farming quality, and other land vulnerability, or unilaterally measuring the farmland amount on a fixed time and space scale. Official data show that China has achieved a 95% grain self-sufficiency rate. Notwithstanding, considering the trade dependence risks in the context of a diversified dietary structure, there is still a large gap in China's current food demand. Besides, the existing research has not systematically analyzed China's food security resilience after being affected by major incidents, resulting in a lack of long-term planning for government decision-making. Consequently, China's future farmland protection should constrain the rigid space, adopt refined management around the farmland in the resilience space, and realize resilience construction through diversified consolidation and restoration measures.

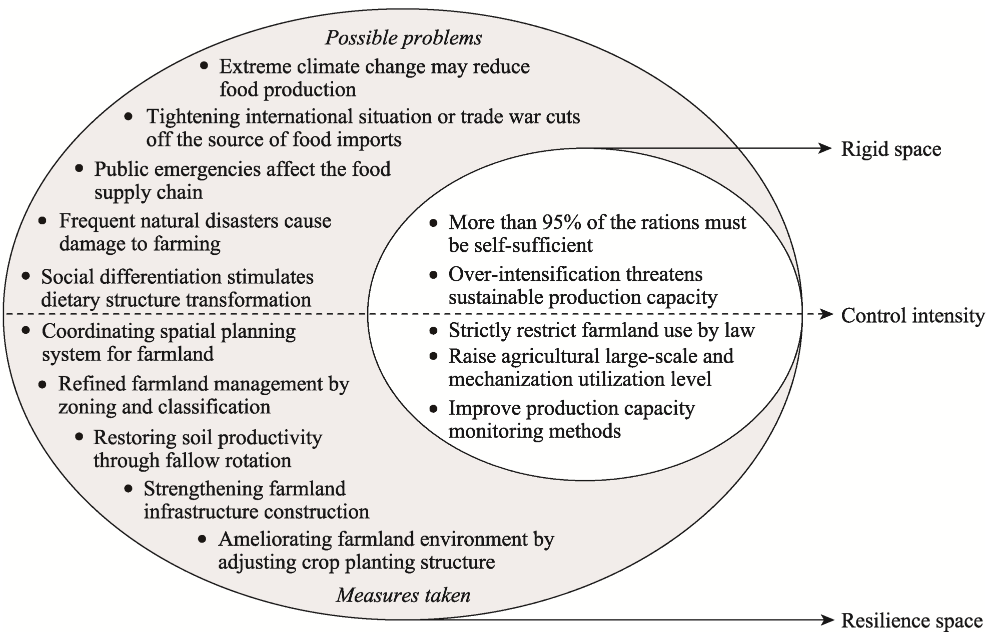

Figure 8 Solutions on resilience space management and control

5.2 Countermeasures for farmland protection in China

Land system change, namely, spatiotemporal changes in social and ecological interaction systems that affect land use and cover, is the core of food security assessment (Verburg *et al.*, 2013a). Land systems science can contribute to sustainable solutions by comprehensively analyzing land availability and assessing trade-offs related to agricultural expansion and land-use intensification (Verburg *et al*., 2013a). The scarcity of farmland per capita has always constrained China's food production. Thus, the government should further strengthen and regularly reiterate the importance of the national farmland protection strategy (Ye and Ranst, 2009). In 2016, the Chinese government formulated a pilot program to explore cropland rotation and fallow systems in some areas. The guiding ideology is to implement the strategy of storing food on land and soil, adhere to ecological priority and comprehensive governance, with rotation as the primary and supplementary fallow. Thoughts focus on ecological restoration of agricultural resources and farmland environments to improve farmland resilience have gradually received widespread attention and a high degree of consensus in academic communities and society (Cheng *et al*., 2018). Nevertheless, China's farmland recuperation is still in the institutionalized practice stage (Yang *et al*., 2018). There is an urgent need to explore related scientific farmland protection and regulation policies and paths. Accordingly, this paper proposes the following countermeasures and suggestions:

(1) Fallow systems should be improved at the legal level and the path of sustainable agricultural intensification combining macro management and micro practice should be explored. Existing food systems focus on short-term production and profits, not long-term environmental sustainability (UN, 2017). Therefore, food security and environmental sustainability issues and the trade-off between multiple ecosystem services in the agricultural landscape need to be more comprehensively solved (West *et al*., 2014). The national scale should improve farmland protection and regulation mechanisms, encourage farmers to promote farmland use further, cultivate ecological environment awareness through benefit-agricultural policy, and achieve multi-scale decision-making coordination.

(2) Fallow farming will inevitably reduce food output, and the fallow scale cannot reach the bottom line of food security. Hence, a regional food system with resilience needs to be established (Ma *et al*., 2020). Clarifying the resilience space of farmland quantity can integrate and improve the spatial linkage between existing farmland protection policies. We suggest that the spatial control planning zones (e.g., rest zones, development reserves, exceptional protection zones, etc.) can be divided from fallow urgency and protection necessary to implement corresponding farmland protection policies for different zones. The spatial configuration relationship between farmland protection and recuperation should be the focus of later research.

(3) Managers should consider the scale effect, coupling mechanism, and regional differences of farmland protection transformation strategy in a multidisciplinary system that integrates resource geography, rural geography, land science, and system science. Normally, studies in a large scale range easily ignore the differences in food supply and demand within the region, which is not conducive to the macro-control realization of food supply and demand at the national level (Hu *et al*., 2016). Thus, multi-functional farmland protection zoning and its policy support should be clarified by strengthening the food system's multi-factor and multi-scale coupling analysis (Liu *et al*., 2018). Ultimately, a food security system assessment and prediction model with a farmer-local-national-global coupling perspective should be constructed to regulate and further form a balanced food supply and demand pattern sufficient to resist external environmental interference.

Regarding the specific policy of resilient farmland protection, we suggest that a strategic farmland reserve system be established at the national level. The state should coordinate high-standard farmland, permanent basic farmland, two agricultural areas (food production functional areas and important agricultural production protection areas), and cultivated land protection red lines to form a national farmland protection map. The departments' objectives (e.g., use, protection, and governance) of different spatial policies can be further coordinated by clarifying the relevant department's responsibilities such as Ministry of Natural Resources, Ministry of Agriculture and Rural Affairs, Ministry of Ecology and Environment, etc. According to the national farmland protection map combined with resilient space, the targeted management control measures are formulated, and legal means are used to regulate farmland use strictly. For example, non-agriculturalization is strictly prohibited in main grain-producing areas, non-grain conversion is prohibited in areas suitable for arable, and economic-food crop rotation is allowed in fallow areas. Concurrently, a special fund for farmland protection and restoration should be established, and the central-local relationship should be regulated to implement the local government's farmland protection responsibility system. A top-down farmland protection and control system can be formed further by drawing lessons from the "five levels and three categories" system of spatial land planning. In response to low farmland utilization efficiency and farmers' farming enthusiasm, the state can deploy major agricultural land consolidation projects and improve agricultural subsidy policies to promote farmland transfer and enhance large-scale operation levels. Additionally, facing low anti-interference ability for farmland, a disaster prevention mechanism should be established to improve the disaster survey and control system while strengthening production capacity monitoring. On this basis, the farmland in areas prone to natural disasters should be identified, and infrastructure construction can be carried out in advance. Ultimately, the synergy between farmland protection, restoration, consolidation, monitoring, and dynamic social development can be realized through a multi-scale-multi-level-multi-type comprehensive and multidimensional approach.

6 Conclusions

China's food security is facing increasingly uneven supply-side and demand-side pressures. Under the background of accelerated urbanization, the pressure on demand-side key factors has a significant negative impact on China's food consumption market. Particularly, the food consumption structure in the domestic market has been continuously upgraded, per capita consumption of rations has fallen, and feed and industrial food consumption has continued to increase. In contrast, the risk of international market trade dependence is relatively high, and uncertainties have gradually increased. However, China's farmland supply and guarantee characteristics do not show the ability to match the food demand trend. Overall, farmland resources supply faces the following characteristics: tightening resource and environmental constraints, weak agricultural infrastructure, slightly low disaster mitigation and resilience, etc. Accordingly, it is necessary to build a resilient space for China's farmland protection to cope with the ever-changing external disturbances. The national farmland strategic reserve system with the concept of resilient space at the core can provide ideas for farmland protection and restoration and help achieve sustainable food security.

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