Front. Agr. Sci. Eng. 2024, 11(2): 282–291 https://doi.org/10.15302/J-FASE-2023523

RESEARCH ARTICLE

Exploring differentiated improvement strategies of cultivated land quality in China

Wenguang CHEN, Xiangbin KONG (✉), Yubo LIAO

College of Land Science and Technology, China Agricultural University, Beijing 100193, China.

KEYWORDS

China, cultivated land quality, differentiated improvement, food security

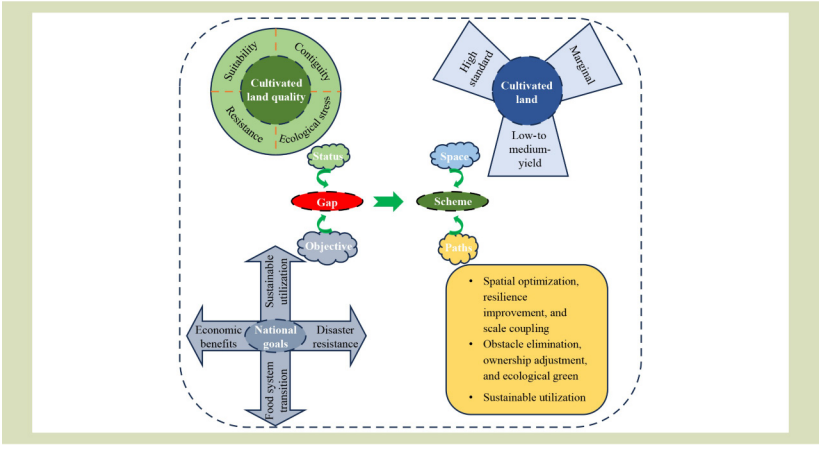
HIGHLIGHTS

- Cultivated land quality can be considered in four dimensions: suitability, contiguity, resistance, and ecological stress.
- China's future goals for construct cultivated land quality include four aspects: promoting the sustainable use of resources, improving the economic benefits of farming, coping with extreme meteorological disasters and meeting the transition of the food system.
- In the future, China should create three major food production spaces: high-standard, low- to medium-yield, and marginal cultivated land.
- Paths for improving cultivated land quality in the three major food production spaces were developed.

Received July 31, 2023;
Accepted September 27, 2023.

Correspondence: kxb@cau.edu.cn

GRAPHICAL ABSTRACT



ABSTRACT

Quality is the core feature of cultivated land. In the face of deteriorating cultivated land quality and growing food demand, improving cultivated land quality is a top priority for guaranteeing the sustainable use of resources and national food security. Cultivated land quality in the new era can be considered in four dimensions: suitability, contiguity, resistance and ecological stress. Cultivated land suitability in China shows a decreasing trend from east to west, cultivated land contiguity is high in the north-east and low in the south-west. In terms of cultivated land resistance, the number of strongly and weakly resistant cropping fields is small and spatially clustered. Cultivated land with ecological stress is mainly located in the northern region. Based on the current situation of cultivated land quality and the strategic needs of national high-quality development, China's future goals for improving cultivated land quality include four aspects: promoting the sustainable use of resources, improving the economic benefits of farming, coping with extreme meteorological disasters and meeting the transition of the food system. Against the backdrop of a volatile international environment and high domestic demand for food, China should guarantee a safe supply of staples, a stable supply of animal feed and a moderate supply of high-nutrient food. In the future, China should create three major food production spaces: high-standard, low- to medium-yield, and marginal cultivated land. China urgently needs to construct three paths to implement the goal of improving cultivated

land quality, namely the development of high-standard cultivated land with the core of spatial optimization, resilience enhancement and scale coupling, the transformation of low- to medium-yield cultivated land with the core of obstacle elimination, tenure adjustment, ecological sustainable, and the conservation development of marginal cultivated land with a focus on sustainable use.

1 Introduction

Cultivated land is the most basic agricultural production resource, cultivated land quality is the core feature of cultivated land and the key to consolidating agricultural production capacity, safeguarding the livelihoods of farming households and regional ecological security[1,2]. To meet the food demand under the continuous increase in population and the optimization of dietary structure, the high-intensity and unreasonable use of cultivated land in China has led to serious degradation of cultivated land quality[3]. For example, the thinning of the tillage layer of black soil, the decrease in soil organic matter content and the increase in soil bulk density on the Northeast China Plain[4,5], the soil salinization of cultivated land on the Huang-Huai-Hai Plain[6], the rocky desertification and soil heavy metal pollution of cultivated land in Southern China[7,8], and the nationwide acidification of soils and agricultural non-point source pollution[9,10] have seriously threatened the sustainable use of cultivated land resources, national food security and human well-being. Chinese-style modernization is the modernization with a huge population and the modernization in which human beings live in harmony with nature, and that it is necessary to comprehensively promote the rural revitalization, build a strong agricultural country and consolidate the foundation of food security in an comprehensive manner. As cultivated land is the foundation of food production, the Chinese government has constantly emphasized the protection of cultivated land quality and proposed making every effort to improve the quality of cultivated land.

To strengthen the improvement of cultivated land quality, the state has undertaken projects such as the transformation of low- to medium-yield cultivated land, improvement of high-standard cultivated land and comprehensive land consolidation[11,12]. The key constraints to soil quality (including slope, organic matter and pH), cultivated land infrastructure (including irrigation and drainage ditches and roads), and the shape and scale of cultivated land have been reformed and repaired, which has effectively improved the soil fertility and grain production capacity of cultivated land[13]. Due to the combined effects of the large total area of cultivated land in China, wide spatial distribution, poor resource endowment and inappropriate use, the quality of cultivated land suffers from a wide variety of constraints: fragmentation, insufficient disaster-resistant and mitigating capacity, and high ecological stress[14]. In the context of frequent occurrence of extreme meteorological events globally[15], low economic benefits of cultivated land for food cultivation[16], upgrading of the dietary structure of urban and rural residents[17], and sustainable use of resources, it is difficult for the current quality of cultivated land to support the national high-quality development and safeguard national food security into the future. Therefore, it is urgent to systematically document the current situation of national cultivated land quality, clarify the objectives of improvement of cultivated land quality under the national macro strategic layout and put forward differentiated control paths based on hierarchical structure of food demand and the endowments of cultivated land, in order to realize the synergy of the improvement of cultivated land quality with the multi-objectives of nation food, resource, ecological and livelihood security.

Currently, a considerable amount of research has been conducted within China and abroad on the protection and improvement of cultivated land quality. The concept of cultivated land quality has been defined based on different stages of economic and social development and management needs[18,19]. The spatial and temporal dynamic succession law and driving mechanism of single factor, single dimension and comprehensive quality of cultivated land has been analyzed[20–24]. The spatial and temporal priorities, key technologies and models for the improvement of cultivated land quality based on the types and degrees of factors that hinder the quality of cultivated land have been discussed[25]. Paths of realization have been proposed from the elimination of constraints, the construction of cultivated land infrastructure, the optimization of spatial scale, and the

adjustment of land tenure[26,27], and a guarantee mechanism for the improvement of cultivated land quality has been formulated around the breakthroughs in major engineering technologies, policies and laws[28–30]. However, a harmonized definition of cultivated land quality, taking into account the needs of the new era, has not yet been established. Cultivated land quality zoning and its enhancement strategies based on the cultivated land quality composite index lack scientific validity because the cultivated land quality composite index masks the actual situation of each element of cultivated land quality, leading to a lack of targeted control of cultivated land quality. There is a lack of systematic analysis of the quality characteristics of cultivated land in the whole region of China, the goal of improvement of cultivated land quality oriented to the high-quality development of the country has not yet been reported, and the zoning and differentiated improvement cultivated land quality based on the enhancement of dietary structure are not clear.

Therefore, this study mostly attempts to meet the following three objectives: (1) to clarify the desired attributes of cultivated land quality in the context of the new era and analyze the current situation of cultivated land quality in China; (2) to propose the goals of improving the quality of cultivated land in the context of national high-quality development and global climate change; and (3) to construct a differentiated path for improving the quality of cultivated land in China under the synergistic goals of food, resource and ecological security.

2 Status of cultivated land quality

The quality of cultivated land is the degree of suitability to satisfy crop growth and the ability to meet human needs for high and stable grain yields, efficient and convenient production, environmentally-sustainable and healthy products, and sustainable use resulting from a combination of natural and anthropogenic factors, and it is a measure of the state of cultivated land and its advantages and disadvantages. The attributes of cultivated land quality can be considered in four dimensions: suitability, contiguity, resilience and ecological stress. Among these, suitability is the natural productivity of cultivated land determined by climatic conditions, topography, soil physicochemical and biological traits; contiguity is the shape of cultivated land parcels and the degree of concentration and contiguity that is determined by the spatial scale of cultivated land and the condition of fragmentation, and characterizes the ability of cultivated land to satisfy the degree of convenience of human cultivation and the mechanization of agriculture; resilience is mainly determined by the conditions of cultivated land infrastructure, which characterizes the ability of cultivated land to resist external disasters and other perturbations in the production of cultivated land; and ecological stress is the extent to which cultivated land is subjected to soil heavy metal pollution, groundwater overexploitation and soil erosion, which characterizes the sustainability of environmentally-sustainable production of cultivated land.

The study found that the suitability of cultivated land in China showed a decreasing trend from east to west. Fifty percent of the cultivated land in China was highly suitable cultivated land, mainly occurring in the Middle-Lower Yangtze Plain, southern and eastern parts of the Huang-Huai-Hai Plain, eastern and north-western parts of the Northeast China Plain, the Sichuan Basin and surrounding regions. Thirty-nine percent of the land was moderately suitable cultivated land, mainly occurring on the central part of the Huang-Huai-Hai Plain and western part of the Northeast China Plain, and in central and eastern parts of Inner Mongolia, south-eastern Gansu and parts of Xinjiang in the northern arid and semiarid region. Only 0.5% was unsuitable cultivated land, mainly occurring in the northern arid and semiarid region and on the Qinghai-Tibet and Loess Plateaux. The contiguity of cultivated land in China showed a decreasing trend from north-east to south-west, with concentrated and contiguous cultivated land, mainly occurring on the Northeast China, Huang-Huai-Hai and Middle-Lower Yangtze Plains and in the northern arid and semiarid region, and Sichuan Basin and surrounding regions. Poor contiguity of cultivated land mainly occurred on the Yunnan-Guizhou Plateau, in Southern China, on the Qinghai-Tibet Plateau, and on the south and north-west of the Loess Plateau. Cultivated land in China was largely (81%) of medium resistance, which widely occurs on the Huang-Huai-Hai and Northeast China Plains, the central and eastern parts of the Middle-Lower Yangtze Plain and in the northern arid and semiarid region. Weakly resistance cultivated land represented 16% of the total area, mainly occurring on the Loess Plateau, in the Sichuan Basin and surrounding areas, on the south-west of the Middle-Lower Yangtze Plain and east of the Yunnan-Guizhou Plateau.

The spatial distribution of ecological stress of cultivated land in China was obtained through the cluster analysis of three ecological factors, namely, soil pollution, groundwater overexploitation and soil erosion. The results showed that cultivated land under ecological stress represented 22.5% of the total cultivated land area in China, widely occurring in various agricultural areas, mostly the Huang-Huai-Hai Plain, the northern arid and semiarid region, the Northeast China Plain,

the Loess Plateau and the Sichuan Basin and surrounding areas. About 3% of cultivated land had moderate and heavy soil pollution, mainly occurring in Hunan and Anhui on the Middle-Lower Yangtze Plain, Henan and Shandong on the Huang-Huai-Hai Plain, and Liaoning ion the Northeast China Plain. While cultivated land with light heavy-metal pollution was scattered over a large area of southern China. About 5% of the cultivated land in China was had moderate and severe overexploitation of groundwater, bine relatively concentrated in Hebei and Henan on the Huang-Huai-Hai Plain, Jilin on the Northeast China Plain and Shaanxi on the Loess Plateau. In addition, some areas such as Heilongjiang and Liaoning in the Northeast China Plain, Gansu and Xinjiang in the northern arid and semiarid region also had a mild degree of overexploitation of groundwater. Just over 15% of the cultivated land in China was affected by moderate and severe soil erosion, mainly occurring in Shaanxi on the Loess Plateau, Ningxia and Gansu in the northern arid and semiarid region, as well as on the Northeast China Plain and Sichuan Basin, and in surrounding areas.

3 Goals of improving the quality of cultivated land

3.1 Promoting the sustainable use of resources

The sustainable use of cultivated land resources is the basis for ensuring national economic and social prosperity. In pursuit of high grain yields, long-term cumulative exploitation and over use have resulted in poor suitability of cultivated land such as soil acidification, compaction and reduction in organic matter content, as well as ecological damage, such as soil erosion, soil heavy metal pollution, groundwater overexploitation and other ecological stress, which threaten the sustainable use of cultivated land resources and ecological security. To this end, the Chinese government formulated the "Plan for the Rest and Recuperation of Cultivated Land, Grassland, Rivers and Lakes (2016–2030)", which proposes that the quality of the national cultivated land will be raised by one grade by 2030, that the quality of cultivated land will have been markedly improved, and that an overall pattern of highly efficient use of cultivated land with stable quality and a the basis for a safe environment will have established in order to advance toward the realization of the perpetual use of resources.

Therefore, it is necessary to conduct a projects for improving the quality of cultivated land according to local conditions, taking comprehensive measures to eliminate the constraints to cultivated land quality (e.g., soil acidification and compaction), reduce the ecological environment risk of cultivated land use (e.g., heavy metal pollution and erosion), explore the road of coordinated development of cultivated land protection and use, and to steadily achieve the transition from a single-focus pursuit of high yields to combination of use and maintenance, and sustainable use, thus improving the suitability of cultivated land, reducing the ecological stress of cultivated land, and realizing the strategic goal of storing grain in land.

3.2 Improving the economic efficiency of food growing

As an important foundation of production, cultivated land is the most basic resource for securing the livelihood of farmers. Affected by the endowment of cultivated land resources and the special land system arrangement in China, cultivated land suffers from the problems of fragmentation of tenure and spatial fragmentation, which to a certain extent increases the input of production factors (e.g., labor, fertilizer, pesticide, water resources and land resources), restricts the efficiency of cultivated land use and reduce the benefit. In the context of rising prices of agricultural production factors and low grain purchase prices, net income of farmers from growing grain has been continuously reduced, with the average net profit per unit area of the three major grain crops (rice, wheat and maize) has been reduced from 3360 yuan in 1995 to 660 yuan in 2019. The "Central Document No. 1" of 2023 notes that it is necessary to further encourage the conversion of small fields into large fields, and explore the gradual solution of fragmentation problems in combination with cultivated land construction and land consolidation under the premise of the willingness of farmers to participate in order to promote the efficiency of agricultural operations. Therefore, one of the important goals of improving the quality of cultivated land is to improve its contiguity, synergize the spatial scale and the scale of farm operations, thereby reducing the input costs and improving economic benefits.

3.3 Responding to extreme meteorological disasters

To guarantee national food security and promote grain storage in the land, China has undertaken the improvement of high-standard cultivated land, the renovation of low- to medium-yield cultivated land and other work on improvement of cultivated land quality. However, before the institutional reform of the State Council, the improvement of high-standard cultivated land was the responsibility of different departments, with limited financial inputs, and simple improvement of cultivated land quality was undertaken only in terms of

departmental construction needs. For example, a considerable part of high-standard cultivated land is only compacted with production roads, and field irrigation and drainage facilities are not coordinated with cultivated land water conservancy projects. The weak infrastructure of cultivated land and the weak ability of disaster prevention and mitigation have not been fundamentally changed, and the foundation of food security is still not fully established. In this regard, the policy, "Opinions of the General Office of the State Council on Effectively Strengthening the Construction of High Standard Farmland to Improve the Ability to Guarantee National Food Security", set the primary goal of enhancing food production capacity, accelerating the mending of the shortcomings of agricultural infrastructure, and effectively enhancing the ability of cultivated land disaster prevention and mitigation, so as to provide a firm foundation for ensuring national food security. Therefore, to improve the quality of cultivated land more attention should be given to the resilience of cultivated land, and effectively improving the ability of cultivated land disaster prevention and mitigation to cope with extreme meteorological disasters.

3.4 Meeting the food system transition

The transformation and upgrading of the food system has placed higher demands for China's improvement of cultivated land quality. Since the reform and opening up, China's population has increased rapidly and the dietary structure has been optimized and upgraded. The total population has increased from 963 million to 1412 million. From 2013 to 2019, the per capita consumption of staples decreased from 149 to 130 kg. From 2013 to 2021, the per capita consumption of meat, poultry, eggs and milk increased from 25.6, 7.2, 8.2 and 11.7 kg to 32.9, 12.3, 13.2 and 14.4 kg, respectively, with a gradually decrease in plant-based foods and a continuous increase in animal-based foods, and a rapid increase in total food demand. The agricultural production demand of residents can be divided into four categories: human food, animal feed, industrial grains and seed grains. According to research, the per capita consumption of human food and animal feed in the peak state of dietary consumption of residents in mainland China is 119 and 336 kg, respectively, and based on the United Nations population projections, the total food demand of China's population peak year will be 769 Mt. In 2022, China's total grain production was 687 Mt, and there will be a huge gap between grain supply and demand.

Affected by the increasing gap in per capita income, the types and quality of food demands of different groups also have great differences. Groups with high income have increased demand for foods with high nutritional value and rich in beneficial micronutrients, such as vegetables and fruits rich in beneficial micronutrients. Also, there is greater consumption of meat and a commensurate demand for more animal feed. Against the backdrop of a complex international environment, it is necessary to ensure that everyone can achieve absolute security for staples and relative security for animal feed, and it is also necessary to guarantee an appropriate supply of food with high nutritional value. Therefore, to improve the quality of cultivated land, it will be necessary to further improve the soil fertility of cultivated land, reduce or even eliminate the risk of soil heavy metal pollution in order to ensure total food security and quality, and promote the transition of the food system.

4 Differentiated program for improvement of cultivated land quality

China is a vast country with large differences in the endowment of cultivated land resources. Combined with the current status of cultivated land resources, the goal of improvement of cultivated land quality, and the structure of food consumption, macro-zonation of cultivated land quality protection and improvement is undertaken, and China's cultivated land is classified into high-standard cultivated land improvement zones, low- to medium-yield cultivated land improvement zones, and marginal cultivated land conservation development zones (Fig. 1). Cultivated land without ecological stress and without poor grades in suitability, contiguity and resilience will be designated as high-standard cultivated land improvement zones. Cultivated land with ecological stress and poor suitability, contiguity and resilience in two or three dimensions, as well as undeveloped land, are designated as marginal land conservation development zones. Designation of the remaining cultivated land as low- to medium-yield cultivated land improvement zones.

4.1 Accelerating the improvement of high-standard cultivated land and building a space for high-yield, stable-yield and efficient grain production

The key to guaranteeing food security lies in the implementation of the strategy of food crop, and focus on solving the issue of cultivated land, while high-standard cultivated land is the best part of cultivated land, it is an important tool to ensure national food security. The document, "The General Rules for the Construction of High Standard Farmland", issued by the Ministry of Agriculture and Rural

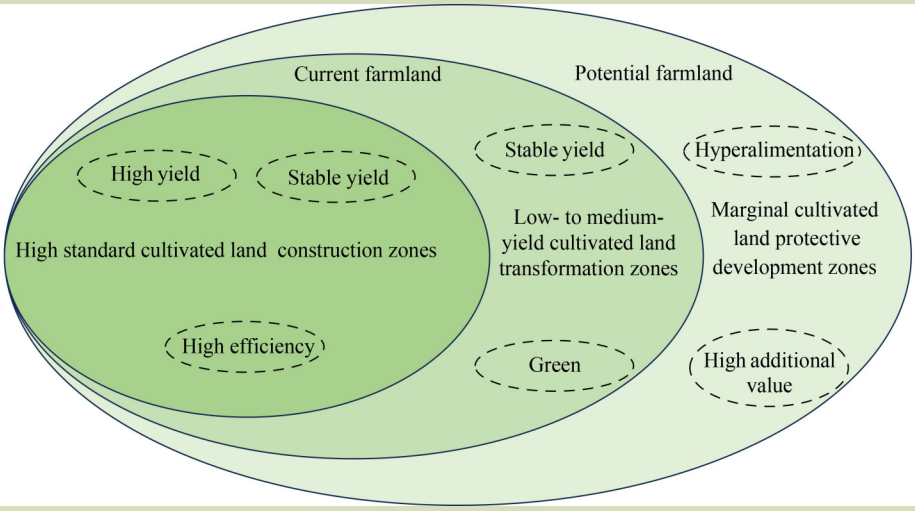


Fig. 1 Concept map of cultivated land quality classification improvement in China.

Affairs of China in 2022 states that high-standard cultivated land refers to cultivated land with level fields, centralized and continuous, perfect facilities, water saving and high efficiency, agricultural power matching, suitable operation, fertile soil, ecological friendliness, strong disaster resistance, and suitable for modern agricultural production and management. In China, high-standard cultivated land is not only high-quality cultivated land, but also the core space for food production. By strengthening the improvement of high-standard cultivated land to create a high-yield, stable-yield and efficient food production space, which in turn guarantees that all Chinese people will be able to obtain basic public goods at a lower price. Guaranteeing the security of China's human food and animal feed requires a focus on upgrading the quality of this part of the cultivated land. Combined with the status of cultivated land quality, it can be seen that it is necessary to take the Northeast China Plain, the Huang-Huai-Hai Plain, the Middle-Lower Yangtze Plain and the Sichuan Basin as the core, improving the quality of cultivated land by upgrading suitability, increasing contiguity, improving resilience and reducing ecological stress in order to ensure the absolute safety of staples and the relative security of animal feed.

4.2 Strengthening the transformation of low- to medium-yield cultivated land and building a space for stable-yield and environmentally sustainable grain production

Medium- to low-yield cultivated land refers to fields with relatively low grain yields, which not only have farming constraints (e.g., shallow soil, and low soil organic matter and high salt contents), but also have problems such as poor field infrastructure and poor farming environments, with low cultivated land production capacity and high ecological and environmental risks of cultivated land use (e.g., soil erosion and agricultural non-point source pollution), mainly occurring in the Yunnan-Guizhou Plateau, Southern China, the Loess Plateau, the Qinghai-Tibet Plateau, and the northern arid and semiarid region. However, the quality of cultivated land is difficult to improve rapidly in the short-term. Therefore, in the context of the national promotion of sustainable development and the construction of ecological civilization, it is necessary to steadily and systematically strengthen the transformation of low- to medium-yield cultivated land, mitigate the key constraints to cultivated land quality through physical, chemical and biological methods, reduce the ecological risk of cultivated land use, and create a stable-yield and environmentally-sustainable grain production space, with a focus on safeguarding the demand for feed grains, grains for seeds and industrial grains.

4.3 Promoting the conservation development of marginal land in a systematic manner and building a space for high-value-added food production

Marginal land refers to land with strong limitations of soil quality, water and heat resource, or topographical constraints, with low agricultural capacity and economic efficiency, and ecologically fragility. The main characteristics of China's marginal land are strong soil constraints, such as shallow soil, high salt content, high acidity or alkalinity, serious wind and/or water erosion, and extreme drought. These characteristics

make it difficult to manage such land, and the ecological risks of development and use are high, but there is still substantial opportunity for capacity enhancement. China's cultivated land is has significant underutilized areas, including saline-alkali land, sandy land, Gobi, bare land and other types. According to "China Soil Census Data" [31], China's non-cultivated saline-alkali land is 29 Mha, mainly in the Northeast China Plain, the northern arid and semiarid region, the Huang-Huai-Hai Plain, and the eastern coastal areas. The area of sandy land in China is about 172 Mha, mainly in the northern arid and semiarid region and the Qinghai-Tibet Plateau. The Gobi is widely distributed in the northern arid and semiarid regions of the north. The light and heat conditions in this region is suitable for crop production, and the soil environment is healthy. Therefore, in the context of improving the dietary structure and pursuing nutritional security among Chinese, it is necessary to moderately promote the conservation development of marginal land, build a space for high-value-added food production, such as vegetables and fruits, and meet the pursuit of high-quality life of the peoples of these areas.

5 Pathways for improving the quality of cultivated land

5.1 Improvement of high-standard cultivated land centered on spatial optimization, resilience improvement and scale coupling

The first strategy for improvement of high-standard cultivated land is spatial optimization. Based on the results of the four-dimensional evaluation of the quality of cultivated land in terms of its suitability, contiguity, resilience and ecological stress, the cultivated land with high suitability, high contiguity, strong resistance and low ecological stress is preferentially included in the scope of improvement of high-standard cultivated land, with a focus on strengthening the protection and improvement of high-quality cultivated land in order to ensure that the high-standard cultivated land that is developed will be high-yield, stable-yield and efficient. The second strategy is improving the resilience of cultivated land. Based on the spatial optimization layout of high-standard cultivated land, combined with the results of cultivated land quality evaluation and targeting the shortcomings of fields in suitability, connectivity, resistance and ecological stress, each agricultural area should undertake improvement of high-standard cultivated land according to local conditions. This should systematically and scientifically improve the resilience of cultivated land, reduce the input cost of production factors for cultivated land use, improve the income of agricultural management entities, and ensure the sustainable and efficient grain production capacity of high-standard cultivated land. The third strategy is coupling the spatial scale of cultivated land and the scale of cultivated land management. Based on the data of regional population density, resource endowment and crop type, to determine the appropriate scale of cultivated land management for different management subjects in the region, develop a reconstruction model for various cultivated land production units covering the reconstruction subject, construction content and implementation process. This should reasonably adjust the spatial scale of cultivated land, realize the coupling of cultivated land spatial scale and operation scale, and improve the efficiency of cultivated land use.

5.2 Rehabilitation of low- to medium-yield cultivated land centered on constraint elimination, tenure adjustment and ecological sustainability

The first strategy for rehabilitation of low- to medium-yield cultivated land is the gradual elimination of the constraints to cultivated land quality. Based on the type and degree of constraints of low- to medium-yield cultivated land in each region, priority is given to the transformation of low- to medium-yield cultivated land with fewer constraints, and to the amelioration of key constraints by adopting physical methods such as restructuring of the constraints to soil structure, water conservation and tillage and cultivation techniques, by adopting chemical methods (e.g., scientific fertilization and the passivation of heavy metals in the soil), and biological methods (e.g., microbial and botanical amelioration). The second strategy is adjusting the ownership of cultivated land to achieve centralization and contiguity. China's special land system has led to the problem of spatial fragmentation of cultivated land tenure, and the cultivated land used by agricultural business entities is sporadically distributed in multiple parcels, so it is necessary to further undertake work on adjusting the tenure of cultivated land by merging small parcels into larger parcels, such as "One Village, One Field" and "One Cooperative, One Field" initiatives. Integration the fragmented cultivated land into one piece through land remediation projects, and convert the shares based on the cultivated land use area of the business entities as the standard in order to realize the large-scale operation of the cultivated land space, improve the efficiency of cultivated land use, reduce the cost of agricultural production, and increase the economic benefits of planting grain. Third, reducing the ecological environment risk of cultivated land use. By gradually mitigating the constraints to the quality of cultivated land, continuous improvement of the quality of cultivated land, reducing the use of pesticides and fertilizers in the process of cultivated land use, such as soil erosion and

greenhouse gas emissions in order to create a stable-yield and environmentally-sustainable space for food production.

5.3 Conservation development of marginal land with the core of sustainable use

Marginal land has a fragile ecological environment, poor basic soil strength, poor soil and water status, and inappropriate development and use of land can easily lead to unsustainable use of resources, and even threaten the sustainable development of the region and the well-being of people. Therefore, the conservation development of marginal land should be based on the strategy of "nature as the mainstay, science and technology as a supplement". In view of the conservation development of saline-alkali land resources, it is necessary to follow the scientific principles of water and salt movement, make sustainable regional development as the goal, scientifically assess the total water resources suitable for development and use in the region, and then determine the area of saline-alkali land for conservation development. Establishment of a nature-based saline-alkaline land development technology model, which is focuses on natural application and is supplemented by engineering development, and selection of differentiated conservation development technology models and agricultural high-efficiency water-use technology in response to the causes of the formation of different saline-alkaline lands, such as cultivating crops tolerant to salinity and alkalinity. For conservation development of sand resources, it is necessary to focus on the research and development of water-saving irrigation technology, the use of soil stabilizers and water-retaining agents to improve the structure of the soil in order to achieve the purpose of sand-fixing. Concurrently, a combination of ecological, agricultural and water management technology is needed to realize the transformation of a single sand remediation model to a governance model with synergistic ecological, resource and economic benefits. For conservation development of Gobi resources, it is necessary to adhere to the principles of water conservation and efficient water use, combine advanced technologies, such as organic matter cultivation, facility planting and efficient water saving, to promote the sustainable development and use of Gobi resources.

6 Conclusions

The quality of cultivated land in the new era can be considered in four dimensions: suitability, contiguity, resistant and ecological stress. The suitability of cultivated land has a decreasing trend from east to west, the contiguity of cultivated land is high in the north-east and low in the south-west. The resistance of cultivated land is generally adequate, and the amount of strongly- and weakly-resistant cultivated land is small and spatially clustered. Cultivated land with ecological stress mainly occurs in the northern region.

Based on the current cultivated land quality and the strategic needs of national high-quality development, China's future goals for improvement of cultivated land quality mainly include these four aspects: promoting the sustainable use of resources, improving the economic benefits of farming, coping with extreme meteorological disasters, and meeting the transition of the food system.

In the context of turbulent international environment and high domestic food demand, China should ensure the secure supply of staples, stable supply of animal feed and appropriate supply of high-nutrient food. In the future, China should create three major food production spaces: high-standard, low- to medium-yield and marginal cultivated land.

China urgently needs to build three strategies: (1) improvement of high-standard cultivated land with spatial optimization, resilience improvement and scale coupling as the focus; (2) low- to medium-yield cultivated land transformation with obstacle elimination, ownership adjustment, and ecological sustainability as the focus; and (3) marginal land conservation development with sustainable use as the focus. These will provide a pathway to realize the goals of national improvement of cultivated land quality.

Acknowledgements

This research was supported by Major Program of the National Social Science Foundation of China (19ZDA096) and National Natural Science Foundation of China (42171289).

Compliance with ethics guidelines

Wenguang Chen, Xiangbin Kong, and Yubo Liao declare that they have no conflicts of interest or financial conflicts to disclose. This article does not contain any studies with human or animal subjects performed by any of the authors.

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