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Framework Design for the Protection of Cultivated Land under the Background of Ecological Civilization

Abstract: - Currently, the advancement of ecological civilization necessitates broadening the scope of cultivated land preservation from mere quantity safeguarding to an integrated "trinity" approach encompassing quantity, quality, and ecological considerations. However, the existing research landscape reveals a scarcity of studies delving into the interplay between ecological protection and quantity preservation of cultivated land. Addressing the objectives and mandates of quantity, quality, and ecological safeguards across varying scales, this paper formulates a comprehensive "trinity" framework for the cultivated land protection system, outlining the pivotal aspects and focal points of protection strategies tailored to different scales. Finally, the macro-scale cultivated land quantity, quality and ecological protection in our country were evaluated.

Keywords: cultivated land protection; ecological civilization; basic farmland; ecological quality; frame construction

1. CULTIVATED LAND PROTECTION UNDER THE BACKGROUND OF ECOLOGICAL CIVILIZATION

1.1 Ecological Civilization and Cultivated Land Protection

There are various interpretation of ecological civilization, but its connotation embodied in three aspects. Firstly, human beings should maintain the original characteristics of nature and achieve harmonious coexistence while transforming and utilizing objective nature. Secondly, human activities should be integrated into the ecosystem to achieve a virtuous cycle between human and natural ecosystems. Thirdly, it is necessary to achieve sustainable social, economic and natural development.

Over the years, China has made it clear in its efforts to protect farmland that maintaining stable farmland quantities, enhancing farmland quality, and implementing comprehensive renovation and improvement are core tasks. These endeavors have yielded remarkable results, fortifying a solid defense for the country's farmland security and food supply safety. Currently, a crucial challenge lies in successfully integrating the core principles of ecological civilization into every aspect of farmland protection work, ensuring that the principles of harmonious coexistence and sustainable development are upheld throughout the maintenance, protection, and renovation of farmland. This will serve as the pivotal pathway to promote the harmonious coexistence and sustainable development between humans and farmland.

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1.2 Connotation of Cultivated Land Ecological Protection

Various scholars have articulated diverse interpretations regarding the essence of cultivated land ecological protection[1]. Wang Wanmao, for instance, emphasizes the harmonization of cultivated crops with their surrounding ecological factors as the cornerstone of this protection. At its superficial level, it involves safeguarding the quantity and quality of cultivated land, while at its core, it encompasses preserving the structure and functional integrity of the cultivated land ecosystem[2]. Zhou Liqiu, on the other hand, views cultivated land ecological protection as the preservation of the natural ecosystem that hosts the cultivated land, with improvements in cultivated land quality serving as its primary manifestation[3]. Meanwhile, Zu Jian and Hao Jinmin, among others, have defined the objective of cultivated land ecological protection as maintaining the stability of cultivated land element characteristics within the farmland ecosystem and ensuring a favorable ecological environment[3].

The relationship between quantity, quality, and ecological factors in cultivated land protection varies significantly across different angles and scales. By acknowledging the interdependence among these three elements and aligning with the diverse needs and objectives of cultivated land management at various levels, a hierarchical analysis of the disparities and convergences within these relationships at differing scales is conducted. Subsequently, these relationships are harmoniously integrated to establish a structured and comprehensive cultivated land protection framework. This approach represents the prevailing trend in cultivated land ecological protection amidst the backdrop of ecological civilization.

2. ECOLOGICAL CIVILIZATION UNDER THE BACKGROUND OF THE CULTIVATED LAND PROTECTION SYSTEM OF THE TRINITY

Within the comprehensive framework of cultivated land protection, the stable maintenance of quantity constitutes a prerequisite for quality optimization, while the continuous guarantee of quality ensures the stability of quantity. Meanwhile, the proper protection of ecology lays a solid foundation for the dual guarantee of quantity and quality. Therefore, cultivated land protection is regarded as a highly systematic engineering project, requiring comprehensive consideration and collaborative promotion. Quantity, quality and ecology should be integrated into a whole system when farmland protection is carried out. From the system point of view, the safety and suitability of the three are evaluated, and the relationship between the three is coordinated, so that the trinity protection can be harmonious and sustainable. Cultivated land protection operates on a multi-layered basis, with conservation and utilization objectives varying according to distinct perspectives. Consequently, the interplay between the quantity, quality, and ecological components of cultivated land exhibits disparities across varying scales.

It can be divided into three levels: macro (national and provincial scale), meso (city and county scale) and micro (micro-geomorphology, small watershed, etc.). The contents and objectives of quantity, quality and ecological protection are formulated respectively. The macro level should focus on the coordination of the relationship between the three, the meso level should start from the mutual suitability of the three to protect, and the micro level should improve the security of the three (Table 1).

Table 1 Framework of the Three-in-one Cultivated Land Protection System

Scale	quantity	Quality	Ecological	Trinity
Macro	Overall protection scale	Overall quality	Overall ecological and environmental quality	1. Coordination between the scale of protection and the quality of ecological environment; 2. Coordination between overall quality and ecological environment quality; 3. Coordination of protection scale and overall quality;
Mesoscale	Area protection scale targets	Regional protection quality objectives	Regional eco-environmental carrying capacity	1. The scale target of regional protection is suitable for the ecological and environmental carrying capacity; 2. The quality target of regional protection is

				suitable for the ecological and environmental carrying capacity; 3. The scale target of regional protection is appropriate to the quality target;
Micro	Cultivated land restoration, balance of occupied and replenished	Quality improvement, accounting balance	To build a stable cultivated land ecosystem to ensure product quality and safety	1. Quantity safety: stable utilization mode without loss; 2. Quality and safety: production capacity is stable and does not decrease; 3. Ecological safety: the ecological environment is stable and sustainable, and the product quality meets the ecological standards;

2.1 Macro-scale

（1）At the macro level, China's cultivated land necessitates a general "threefold coordination" between quantity, quality, and ecological relationships. This entails: firstly, harmonizing the scale of protection with ecological environment quality, focusing on balancing the relationship between the protected area's size (i.e., the extent of basic farmland) and varying environmental quality classifications. Ideally, basic farmland should be allocated to regions with superior environmental quality (quantitative-ecological harmony). The degree of this coordination is quantified by comparing the average environmental quality of all cultivated land against that of basic farmland. In theory, the average ecological environment quality of cultivated land in the area with good ecological environment quality can be taken as the upper limit of protection target, and the average ecological environment quality of all cultivated land can be taken as the lower limit of protection target. In order to ensure that the conservation target is in a better ecological environment, the environmental quality of the basic farmland should be at least between the lower limit and the upper limit. The closer to the upper limit, the better the environmental quality of the basic farmland.

The coordination degree of quantity-ecological environment quality can be calculated by the following formula:

$$S_a = \sum_{i=t0}^{U} F_i h_i$$

S_a is the coordination degree between actual quantity of regional basic farmland and ecological environment quality;

F_i is the zoning score of level i environmental quality;

h_i is the percentage of basic farmland area in the total basic farmland area in the environmental quality zone of level i;

U is the highest level environmental quality partition of the region (the higher the level is, the greater the value is);

t0 is the lowest level environmental quality partition of the region;

（2）The coordination between overall quality and eco-environmental quality means that in the same environmental quality classification, the average level of basic farmland should be higher than that of general farmland (quality-ecological coordination). Theoretically, cultivated land boasting relatively superior ecological and environmental quality serves as a prime candidate for protection. By comprehensively evaluating both cultivated land classification and environmental classification, a comprehensive score can be assigned. The addition of the segment of cultivated land with the highest score to the basic farmland area can be deemed the upper limit of coordination, while the total cultivated land's score represents the lower limit. To ensure optimal quality and ecological environment of the protection target, the quality-ecological environment coordination level

of basic farmland should ideally fall within this range, with closer proximity to the upper limit indicating a more "doubly optimal" state in terms of both farmland quality and ecological environment.

The coordination degree of quality-ecological environment quality can be calculated by the following formula:

$$h = \sum_{i=1}^{n} b_i \, (L + 1 - q_i)(n + 1 - i)$$

h is the coordination degree between basic farmland quality and ecological environment quality;

b_i is the percentage of basic farmland area in the total basic farmland in level i environmental quality classification;

q_i is the average grade of basic farmland in level i environmental quality classification;

n is the number of environmental quality classifications, with level 1 being the best and level n the worst.

L is the number of cultivated land quality grades, with grade 1 being the best and grade L the worst.

（3）The coordination between protection scale and overall quality means that the overall average parity of basic farmland should be higher than the average parity of general farmland (quantity-quality coordination). The degree of coordination is derived by comparing the average parity of basic farmland to that of all cultivated land. In theory, the area-weighted parity of the cultivated land segment exhibiting the highest parity can be incorporated into the average parity of basic farmland, setting the upper limit. To guarantee the quality of the protection target, the quantity-quality coordination of basic farmland should ideally lie within the range defined by the lower and upper limits, with a closer approximation to the upper limit indicating superior quality of the basic farmland.

The quantity-quality coordination degree can be calculated by the following formula:

$$P_s = \sum_{i=t0}^{U} (L + 1 - i)h_i$$

P_s is the actual average of regional basic farmland;

L is the national equal number;

h_i is the percentage of the basic farmland area of class i in the total basic farmland area

U is the highest regional rank;

t0 is the lowest level in the region;

In the context of farmland protection, quantity, quality, and ecology are all equally crucial factors. Nevertheless, during the protection process, it is often challenging to achieve a "tripartite comprehensiveness," striking a balance between safeguarding a certain quantity of farmland while optimizing both its quality and ecological environment. Thus, it is imperative to differentiate the relative importance of quantity, quality, and ecology according to the unique characteristics of different regions. Based on the coordination levels of quantity-ecology, quality-ecology, and quantity-quality, improvement indicators for integrated protection encompassing these three dimensions are calculated, ultimately yielding both horizontal and vertical outcomes.

2.2 Mesoscale

The core of the meso-scale protection strategy lies in establishing a harmonious and balanced relationship between the quantity and quality of farmland and the ecological environment of the region in which it is located.

(1) The assessment of quantity and ecological suitability primarily focuses on the impact of cultivated land on the natural ecological environment, as well as the theoretical carrying capacity of the regional natural environment for arable land. It evaluates the region's capacity to sustain a certain amount of cultivated land under conditions that ensure ecological security, and subsequently determines the degree of suitability between the quantity of cultivated land and the surrounding ecological environment.

(2) Ecological suitability for quality pertains to the theoretical capacity of a region's natural ecological environment to support high-quality cultivated land. This assessment gauges the sustainability of cultivated land quality, taking into account the environmental conditions that are conducive to maintaining such quality.

(3) The compatibility of quality and quantity refers to the level of cultivated land quality that can be achieved or maintained under a specific regional farmland protection plan. This process involves evaluating the current average quality of cultivated land and conducting a comparative analysis with the theoretically achievable highest quality of cultivated land, thereby assessing the stability of cultivated land quality in the region and its potential for further improvement.

By conducting the three suitability evaluations, an assessment of the region's capacity to support cultivated land quantity and quality, while ensuring ecological balance, was derived. This ultimately safeguards the stability and long-term sustainability of the region's overall production potential.

2.3 Microscale

At the micro scale, the core objective is to stabilize the area and quality of farmland, and facilitate the smooth circulation of materials and energy between farmland and the natural environment system, thereby ensuring the long-term sustainability of farmland functions.

(1) Quantity safety primarily entails the restoration of damaged farmland and the replenishment of lost cultivated areas through a balanced approach of occupation and compensation, aiming to prevent any net loss of cultivable land.

(2) Quality safety focuses on maintaining the quality of cultivated land to prevent degradation, while also ensuring that the quality of any supplementary farmland meets or exceeds that of the farmland it replaces.

(3) Ecological security mainly includes three aspects: First, to establish a stable cultivated land ecosystem, and to build a complete and stable ecosystem of cultivated land of a certain scale (which can enable the ecosystem to maintain a continuous and stable flow of material and energy, small drainage basins, microgeomorphic units, and contiguous cultivated land that can produce a certain scale of crops). If the scale of arable land is too small (not every piece of land needs to build its own ecosystem), it is difficult to build an ecosystem with good integrity and stability. If the area is too large, it is difficult for the ecosystem to take into account the characteristics of different regions, and the efficiency and function will be reduced. Second, it is necessary to balance the relationship between the cultivated land ecosystem and natural elements such as water resources, forests, and grasslands based on the region's natural conditions, planting techniques, crop growth requirements, and environmental impacts. This ensures the continuous cycle of energy and matter between cultivated land and the ecological environment, maintaining a healthy interaction. Additionally, based on the carrying capacity of the local natural environment for cultivated land production activities, it is possible to persistently guarantee the safety of cultivated land product quality and production efficiency while avoiding adverse effects on the ecosystem.

Through micro protection, the ultimate goal is to stabilize the utilization of micro units, coordinate with the surrounding ecological environment and maintain stable and high-quality food production activities.

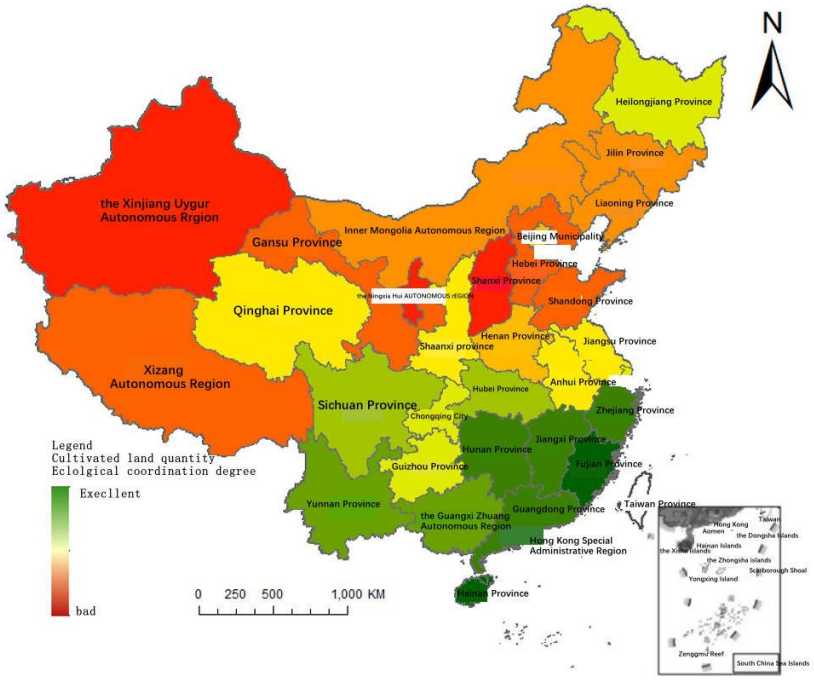
3. MACROSCALE CULTIVATED LAND QUANTITY, QUALITY AND ECOLOGICAL ENVIRONMENT PRESENT SITUATION IN CHINA

The Ministry of Ecology and Environment's "2018 China Ecological Environment Status Bulletin" conducted a preliminary evaluation regarding the distribution patterns of cultivated land and basic farmland across provinces and cities, as well as the interplay between the quality, quantity, and ecological aspects of cultivated land. The results showed that:

3.1 Amount of Cultivated Land - ecological Coordination

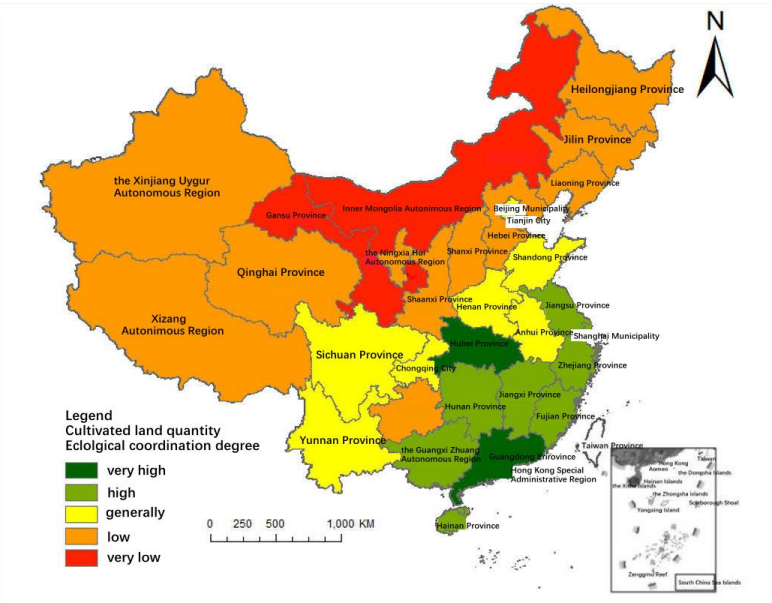
From the perspective of the whole country, Hainan Province and Fujian Province have the highest cultivated land ecological coordination degree. The southeastern provinces of Zhejiang, Jiangxi, Hunan and Guangdong are

higher, indicating that the ecological environment level of cultivated land in these provinces is higher. The provinces with low coordination degree mainly include Xinjiang, Ningxia and Shanxi. The overall coordination degree of quantity and ecology in North China is smaller than that in South China. Through calculation, the quantity-ecological coordination of basic farmland in most provinces is between the upper and lower limits.



3.2 Cultivated Land Quality-ecological Coordination

The coordination degree of cultivated land quality-ecology was the highest in Hubei province and Guangdong Province. The reason is that its ecological quality and cultivated land are high. Although Hainan has the best ecological environment in China, its cultivated land is lower than that of Guangdong, and its quality-ecological coordination level is at a higher level than that of Guangxi, Hunan, Jiangxi, Fujian, Zhejiang, Jiangsu and other provinces. Due to the general level of environmental quality and the low level of cultivated land, the coordination degree between cultivated land quality and ecological environment in Gansu and Inner Mongolia is the worst.



3.3 Quantity-quality Coordination of Cultivated Land

The province with the highest average parity of cultivated land is Hubei Province, and in addition, Henan, Jiangsu,

Jiangxi, and Guangdong provinces have higher average parity. Qinghai, Gansu, Inner Mongolia and other provinces have low average equality between cultivated land and basic farmland. The average value of basic farmland in the central and eastern regions and the three eastern provinces still has a great potential to improve.

3.4 Comprehensive Situation

In conclusion, China's cultivated land exhibits a geographical pattern with higher quantities, quality, and ecological integrity in the southeast, while these factors are comparatively lower in the northwest. Comprehensive environmental quality level, cultivated land, basic farmland proportion and other situation analysis, Guangdong province, Hubei province is China's cultivated land “trinity” realization of the best region. The provinces of Hainan, Jiangxi, Fujian, Zhejiang, Jiangsu, and Anhui in the Southeast also have high levels of protection. The three eastern provinces, central China and Southwest China are at the intermediate level. The regions with the worst comprehensive coordination are Tibet, Xinjiang, Qinghai, Gansu, Inner Mongolia, Shanxi and other northwestern provinces.

4. DISCUSSIONS

4.1 Improving Technical Measures for Ecological Protection of Cultivated Land

At present, the ecological environmental quality assessment in our country is carried out with the standard formulated by the Ministry of Ecology and Environment, which covers a wide range and can reflect the overall regional environmental quality. Due to its limited relevance, it poses challenges in practically showcasing the distinctiveness of cultivated land ecology. As such, crafting technical specifications (or standards) tailored for assessing ecological environment quality, which aligns with the protection of cultivated land, is a prerequisite for an accurate assessment. These specifications should encompass evaluation schemes tailored to macro, meso, and micro-level protection objectives, thereby reflecting the tiered and systematic approach to cultivated land ecological protection.

In the cultivated land protection work, the cultivated land quality is mainly used as the standard for protection and basic farmland delimitation.In the next step, the ecological environmental quality should be added to the hard index of basic farmland delimitation. High-quality cultivated land should be prioritized for designation as basic farmland. Based on the national assessment of cultivated land quality and ecological environment, combined with the natural conditions of different regions, targets for cultivated land quantity, quality, and ecological protection should be set to achieve comprehensive protection.

4.2 Quality and Ecological Risks in the Balance of “East and West”

In China's efforts to balance occupied cultivated land, a common scenario involves replenishing land lost in eastern regions with land from western regions, resulting in a northwestward shift of the center of gravity for cultivated land. While there is a focus on ensuring the quality of cultivated land, the balance of the cultivated land's ecological environment is not currently a requirement. Through the evaluation, it is found that the cultivated land in the southeast of China presents a “double high” situation in terms of quality and ecology, while the northwest presents a “double low” situation, and there is a risk of simultaneously reducing the cultivated land quality and ecological environment in the “east occupies the west”.

4.3 Correctly Understanding the Ecological Function of Cultivated Land

In safeguarding the quantity and quality of cultivated land, it is crucial to gain a deeper understanding of the stability and sustainability inherent in the cultivated land ecosystem, as well as the intricate process of material and energy exchange occurring between cultivated land and other ecological components. The perspective of cultivated land management is promoted from agricultural production to ecological maintenance, and cultivated land is integrated into the ecosystem for management. When managing cultivated land, it is necessary to give consideration to both material production and ecological functions, such as biodiversity conservation, soil and water conservation, and climate regulation.

4.4 Determining Regional Tillage Intensity

China has been improving its cultivated land productivity for a long time, but this process has led to the decline of cultivated land quality and ecological environment. Therefore, based on the evaluation of the quantity and

quality carrying capacity of cultivated land by ecological environment, the cultivation intensity of regional cultivated land can be reasonably determined, and the hidden dangers caused by the high intensity utilization of cultivated land can be alleviated through fallow and crop rotation.

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