Delimitation of Priority Areas for Cultivated Land Quality Improvement in Lulong County Based on Restriction Degree Ranking (Postprint)

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Abstract

Cropland is a prerequisite for ensuring national food security and the material foundation for safeguarding social security and sustainable social development. China has a large total quantity of cropland, but the overall quality level is very low. To clarify the direction of cropland remediation and implement remediation with different priorities for different regions, this study, based on the agricultural land classification and grading of Lulong County, Qinhuangdao, constructs a cropland quality evaluation index system, employs the score factor identification method to determine limiting factor combination types, introduces an obstacle degree model to modify the limiting factor combinations, and delineates key areas of limiting factors in Lulong County. The results show that all 15,981 cropland parcels in Lulong County have high limiting factors, with a total of 95 limiting factor combination types summarized, covering a total area of 43,909.71 hm². After modification using the obstacle degree model, the cropland in Lulong County can be divided into five key areas dominated by limiting factors: road accessibility limiting factor dominant area, topographic slope limiting factor dominant area, irrigation guarantee rate limiting factor dominant area, farmland shelterbelt ratio limiting factor dominant area, and effective soil layer thickness limiting factor dominant area; among them, the farmland shelterbelt ratio limiting factor dominant area has the largest remediation area of 37,680.91 hm², accounting for 85.81% of the total cropland area, and is mainly distributed in Lulong Town, Yanheying Town, and Shuangwang Town; followed by the effective soil layer thickness limiting factor dominant area with an area of 3,861.32 hm², mainly distributed in Yinzhuang Township; the road accessibility limiting factor dominant area has a remediation area of 1,876.16 hm², mainly distributed in Shuangwang Town; the irrigation guarantee rate limiting

factor dominant area has a remediation area of 319.44 hm², mainly distributed in Yanheying Town; the topographic slope limiting factor dominant area has the smallest remediation area of 171.87 hm², accounting for 0.39% of the total cropland area, and is mainly distributed in Liutianzhuang Town. Based on the limiting factors in the key areas, it can be seen that the main limiting factors in Lulong County are primarily farmland shelterbelt ratio and effective soil layer thickness, supplemented by irrigation guarantee rate and road accessibility; when conducting cropland remediation, priority should be given to strengthening shelterbelt construction, increasing effective soil layer thickness, improving soil quality, enhancing soil fertility, and strengthening farmland infrastructure and field road construction to ensure steady grain production increases and safeguard regional food security. The research results can provide technical support for remediation planning in hilly and mountainous areas, delineating key areas for cropland quality improvement, and offer a scientific basis for future cropland remediation.

Full Text

Introduction

Food security is a critical global challenge, and to ensure stable growth in grain production, cultivated land consolidation is imperative [1-3]. There are two primary approaches to increasing grain yield: developing reserve cultivated land resources and improving the quality of existing cultivated land. As land development projects progress, reserve cultivated land resources are becoming increasingly scarce, making the improvement of existing cultivated land quality the top priority for future efforts. Land consolidation engineering represents the key measure for enhancing cultivated land quality. While current land consolidation projects have achieved considerable success, they still face issues such as low efficiency, unclear objectives, lack of targeted approaches, and inefficient use of funds. Targeted improvement of major limiting factors constitutes a crucial component of land consolidation engineering.

Currently, most domestic research on cultivated land quality improvement directly utilizes factors from agricultural land classification results as indicators to evaluate quality enhancement, while overlooking the influence of improvable limiting factors in cultivated land consolidation [4-6]. In regional cultivated land consolidation zoning studies, scholars have primarily applied relevant theoretical methods to partition research on cultivated land productivity, land consolidation, sustainable utilization, and cultivated land value. Liu Guoxun et al. [7] employed fuzzy clustering methods to partition the cultivated land production capacity of relevant counties in the Songnen Plain, and later used GIS and mathematical model integration techniques to conduct regional partitioning of cultivated land resource value [8]. Xing Shihe et al. [9] evaluated the sustainable utilization of cultivated land in Fujian Province by constructing 24 identification variables with principal component analysis and fuzzy clustering methods.

Liu Yu et al. [10] divided key consolidation, optimization and enhancement, and core protection zones based on analysis of regional cultivated land use intensity, yield increase potential, and comprehensive production capacity. In land consolidation, landscape ecology analysis methods and zoning approaches based on agricultural land classification data have been particularly representative [11-12]. Research on delimitation methods for prime farmland and high-standard basic farmland construction key areas has primarily been based on land evaluation methods, constructing indicator evaluation systems for prime farmland delimitation [13-16]. In summary, while research on cultivated land quality improvement and land zoning has received considerable attention, studies proposing scientifically effective technical methods for delineating key areas for cultivated land quality improvement remain limited.

In recent years, with industrial development, urban expansion, and intensifying land pollution, cultivated land quality has declined, making its improvement an urgent priority. To ensure grain security at the county level and improve the quality of medium- and low-yield farmland, cultivated land consolidation is imperative in Lulong County, Hebei Province. As Lulong County has a relatively short history of cultivated land consolidation with single funding channels, efforts have primarily focused on improving field road systems, while factors such as effective soil layer thickness remain unimproved, lacking targeted land consolidation measures. This study selects limiting factors for cultivated land quality based on both natural conditions and utilization conditions in Lulong County, constructs a cultivated land quality evaluation index system, introduces a limiting factor obstacle degree analysis model, and partitions key areas dominated by specific limiting factors for cultivated land quality improvement. By clarifying the degree of each limiting factor in consolidation zones, the study proposes targeted improvement measures to provide a theoretical basis for land consolidation in the hilly and mountainous areas of the Yanshan region.

1.1 Study Area Overview

Lulong County is located in the western part of Qinhuangdao City, Hebei Province, between 118°45 54 E~119°08 06 E and 39°43 00 N~40°08 42 N, situated at the northern edge of the North China Plain. The dominant landform type is mountainous hills, with elevations ranging from 22.7 m to 627.0 m and an absolute elevation difference of 599.3 m. In 2014, the county' s total land area was 95,580.24 hm^2, of which cultivated land area was 43,909.71 hm^2, accounting for 45.94% of the total land area. With diverse landforms, this study selects Lulong County in the Yanshan mountainous and hilly region as the research area [Figure 1: see original paper].

1.2 Data Sources

The data required for this study were obtained from the 2014 Lulong County land use change survey database, the 1:10,000 soil map from the Lulong County Soil Gazetteer, 2014 30 m × 30 m DEM imagery (from the Geospatial Data

Cloud website http://www.gscloud.cn), 2012 Lulong County agricultural land classification results (maps, texts, databases, calculation tables, etc.), 2014 Lulong County cultivated land quality update results, and statistical data from the Lulong County forestry department. Among these, data on limiting factors such as effective soil layer thickness, irrigation guarantee rate, and organic matter content for cultivated land quality evaluation were obtained from the agricultural land classification results database; data on field (production) roads, patch morphology, and farmland shelter belts were extracted from the current land use map.

2. Methodology

2.1.1 Cultivated Land Quality Evaluation Index System

Based on the agricultural land classification results for Lulong County, this study analyzes the current status of cultivated land quality and fully considers the connotation and basic characteristics of cultivated land quality. Following the principles of evaluation index system construction, a cultivated land quality evaluation index system was established (Table 1). First, based on previous land consolidation projects in Lulong County, which primarily deployed engineering projects for irrigation guarantee rate, organic matter content, field patch connectivity, field regularity, field planeness, field road accessibility, farming convenience, and farmland shelter belt ratio, 12 evaluation indicators were selected from the 2012 agricultural land classification results: terrain slope, topsoil texture, profile constitution, soil organic matter content, effective soil layer thickness, irrigation guarantee rate, farmland shelter belt ratio, farming convenience degree, road accessibility, field planeness, field regularity degree, and field contiguous degree. Second, using terrain slope and the other 11 limiting factor scores as independent variables and cultivated land quality utilization grade index as the dependent variable, multi-factor regression analysis was conducted on each limiting factor using SPSS to determine the relationship between cultivated land quality impact factors and cultivated land quality. Principal component analysis was then used to determine the weight of each evaluation indicator. Third, in ArcGIS, the current land use map, topographic map, and soil map of Lulong County were overlaid to extract 15,981 cultivated land patches as evaluation units, constructing a cultivated land quality evaluation index system to provide a basis for calculating the restriction degree of cultivated land quality limiting factors.

2.1.2 Evaluation Index Quantification

1) **Field Contiguous Degree [17] (Q)**. This reflects the degree of concentration and connectivity of field patches. The Q value is quantified based on patch area, where a larger Q value indicates higher patch connectivity, and vice versa. The specific calculation is as follows:

$$Q = \frac{a}{A_{th}}$$

where: Q is the field contiguous degree; a is the patch area (hm²), with its threshold obtained using the natural breaks method applied to all cultivated land patch areas in the region.

2) **Field Regularity Degree [18] (FRAC)**. This is expressed using the fractal dimension from landscape ecology (Formula 2). The fractal dimension describes the complexity of patch boundaries, with a theoretical range of [1.0, 2.0]. A smaller value indicates more regular patch shape. The minimum value of 1.0 indicates the evaluation unit is a perfect square, while the maximum value of 2.0 indicates the most complex patch shape. The calculation formula is as follows:

$$FRAC = \frac{2\ln(0.25p)}{\ln(a)}$$

where: FRAC is the field regularity degree, p is the patch perimeter, and a is the patch area.

3) **Field Planeness Calculation [18]**. Field planeness is represented by the relative elevation difference within a patch. Based on DEM data, the maximum and minimum elevation values of each patch were calculated using 3D analysis and spatial analysis tools in the ArcGIS 9.3 software platform to determine the elevation difference.

4) **Field Road Accessibility and Farming Convenience Degree Calculation [19]**. Both location conditions and agricultural production convenience affect cultivated land quality. Therefore, this study uses field road accessibility to represent location conditions and farming convenience degree to represent agricultural production convenience. Both factors are diffusion-type indicators. Road accessibility is measured by the distance from the patch to existing roads, while farming convenience is measured by the distance from the evaluation unit to rural roads. As linear indicators, both are calculated using linear attenuation methods, as shown in Formulas (3)-(5):

$$f_i = \begin{cases} (1 - r_i) \times M_i & \text{if } r_i < d \\ 0 & \text{if } r_i \geq d \end{cases}$$

$$r_i = \frac{d_{ij}}{d}$$

$$d = \sqrt{\frac{S}{\pi L}}$$

where: f_i is the score of the i-th indicator, M_i is the scale index, d_{ij} is the actual distance from the patch to the evaluation factor, r_i is the relative distance, d is the evaluation factor radius, S is the area of Lulong County, and L is the road length.

5) **Farmland Shelter Belt Ratio** [**20**]. Based on 2012 statistical data from the forestry department, the proportion of shelter belt area for each cultivated land patch was calculated using the following formula:

$$H = \frac{S_f}{S_t} \times 100\%$$

where: H is the farmland shelter belt ratio, S_f is the shelter belt area, and S_t is the cultivated land patch area.

2.1.3 Evaluation Index Classification

To standardize the evaluation process and facilitate data processing, each evaluation index factor was quantitatively classified and assigned values according to different grades. The assignment interval was [0, 100], with higher scores indicating better cultivated land quality. The classification standards for grading factors were based on the 2012 Lulong County agricultural land classification results. Supplementary factors were classified according to relevant standards for high-standard basic farmland construction in Lulong County, current conditions in the mountainous and hilly region, and expert opinions combined with farmer survey results. The classification standards for each evaluation indicator are shown in Table 2 .

2.2 Evaluation Unit Limiting Factor Combination Type Design

Before designing the restriction degree combination types for each evaluation unit, it is necessary to first define each limiting factor and determine its restriction degree on cultivated land quality. This study adopts the score factor identification method [21] instead of traditional factor combination types. The factor score identification represents the degree to which growing conditions satisfy crop requirements. A smaller satisfaction degree indicates a greater limiting effect of the factor on cultivated land quality. The factor with the smallest satisfaction degree is designated as the primary limiting factor, the next as the secondary limiting factor, and so on. Based on this principle and the evaluation index classification standards in Table 2, when a score is below 50, the evaluation indicator exhibits obvious limiting effects on crops. The limiting factor scores for each cultivated land patch are detailed in Table 3 .

When soil organic matter content scores below 50 (organic matter content < 15 g · kg ¹), it indicates nutrient poverty. Topsoil texture classified as gravel soil or lack of irrigation conditions also significantly limit crop growth. Therefore, indicators scoring 10-50 are termed high-limiting factors. Gentle slopes below

5°, loam topsoil texture, and irrigation conditions that satisfy crop growth requirements typically score 90-100 and are termed low-limiting factors (factor scores are relative; a score of 100 does not equate to no limitation, as absolutely unlimited factors do not exist, thus factors scoring 100 are also classified as low-limiting). The remaining factors scoring 60-80 are classified as medium-limiting factors.

Different limiting grade factors are then combined using "high-medium-low" codes instead of previous identification codes. High-limiting factors serve as the primary limiting factors, with the final impact factor combination type determined by the number of high-limiting factors present. For example, the code "low-medium-low-high-high-high-medium-high-medium-low-high" yields the final impact factor combination type "6-effective soil thickness + organic matter content + irrigation guarantee rate + field contiguous degree + road accessibility + farmland shelter belt ratio," where "6" indicates the number of high-limiting factors, and "effective soil thickness + organic matter content + irrigation guarantee rate + field contiguous degree + road accessibility + farmland shelter belt ratio" represents the primary high-limiting factor type combination.

2.3 Construction of Obstacle Degree Model

The score factor identification method was used to determine the limiting factor combinations for cultivated land quality in Lulong County, identifying the limiting factors for each patch. To implement the partitioned key areas at the project level, this study employs an obstacle degree model, introducing factor contribution degree, index deviation degree, and obstacle degree to conduct index normalization and obstacle degree calculations. This accurately reveals the ranking of limiting factor restriction degrees within evaluation units, enabling further subdivision of key areas and enhancing theoretical applicability.

2.3.1 Index Normalization The selected indicators in evaluation units have different dimensions and cannot be directly calculated using their corresponding values in obstacle degree analysis. Therefore, all indicators must first be normalized before calculating obstacle degree to place the 12 cultivated land quality limiting factors on the same dimension for global comparability. This study uses the range method [22] for normalization, distributing all limiting factors within [0,1]. The specific normalization process is as follows:

For positive indicators:

$$x'_{ij} = \frac{x_{ij} - x_{\min}}{x_{\max} - x_{\min}}$$

For negative indicators:

$$x'_{ij} = \frac{x_{\max} - x_{ij}}{x_{\max} - x_{\min}}$$

where: x_{ij} is the original score of the i-th indicator in the j-th evaluation unit, and $x_{\max}$ and $x_{\min}$ are the maximum and minimum scores of the i-th indicator in the j-th evaluation unit.

2.3.2 Obstacle Degree Model for Determining Evaluation Unit Limiting Factor Restriction Degree The obstacle degree identification model [13] introduces three indicators: factor contribution degree, index deviation degree, and obstacle degree. By comparing the obstacle degree values of each limiting factor, the ranking of limiting factor restriction degrees within evaluation units can be obtained. The obstacle degree identification model is as follows:

$$P_{ij} = 1 - x'_{ij}$$

$$A_{ij} = \frac{P_{ij} \times R_j}{\sum_{i=1}^{n} (P_{ij} \times R_j)} \times 100\%$$

where: P_{ij} is the deviation degree of the i-th indicator in the j-th evaluation unit, representing the distance between the indicator and its ideal value; A_{ij} is the obstacle degree value of the i-th indicator in the j-th evaluation unit, where a larger value indicates greater limiting effect of the evaluation indicator; and R_j is the contribution degree value of the j-th evaluation indicator, i.e., the weight of each indicator in the cultivated land quality evaluation index system.

3. Results and Analysis

3.1 Limiting Factor Combination Regional Delineation

Analysis of 15,981 cultivated land patches in Lulong County using the score factor identification method revealed that every patch had high-limiting factors. Therefore, this study uses all cultivated land within the county as the research object, ultimately summarizing 95 combination types (Table 4). The area with high-limiting factors totals 43,909.71 hm^2, with the largest area (16,095.53 hm^2, 36.66% of total county cultivated land) having 5 limiting factors, mainly distributed in northern Lulong County. The smallest area (160.43 hm^2, 0.37% of total county cultivated land) had 9 limiting factors, mainly distributed in Xiazhai Township in central Lulong County. The current distribution of limiting factor combination types is shown in Figure 2 [Figure 2: see original paper].

3.2 Dominant Limiting Factor Key Area Delineation Analysis

Limiting factor combination key areas exhibit blindness in land consolidation engineering. To implement these key areas at the project level, enhance theoretical applicability, and truly improve the efficiency and precision of cultivated land consolidation engineering, this study employs the obstacle degree model to revise the limiting factor combinations for each cultivated land quality evaluation unit in Lulong County from largest to smallest. This further subdivides key areas for cultivated land quality improvement into type areas dominated by specific limiting factors, identifying the focus, engineering types, and improvement directions for different key areas to maximize implementation efficiency. The revised factor combination types are shown in Table 5 .

Table 5 shows that Lulong Town' s dominant limiting factor key areas are divided into 5 zones: road accessibility dominated region, terrain slope dominated region, irrigation guarantee rate dominated region, farmland shelter belt ratio dominated region, and effective soil thickness dominated region. The farmland shelter belt ratio dominated region has the largest area (37,680.91 hm^2), accounting for 85.81% of Lulong County' s total dominant limiting factor key area. The smallest is the terrain slope dominated region (171.87 hm^2), accounting for only 0.39% of the total dominant limiting factor key area. The area of each township' s cultivated land quality dominant limiting factor key area in Lulong County is shown in Table 6 , and the distribution is shown in Figure 3 [Figure 3: see original paper].

1) Road Accessibility Dominated Region

The total area of the road accessibility dominated region is 1,876.16 hm^2, accounting for 4.27% of the county' s total cultivated land area, scattered sporadically throughout the county. Shuangwang Town has the largest distribution (413.55 hm^2), accounting for 11.82% of this region' s area. This includes three secondary limiting factor dominated regions, among which the effective soil thickness secondary dominated region has the largest factor combination area: "road accessibility + effective soil thickness + farmland shelter belt ratio" (976.14 hm^2), accounting for 52.03% of this region's total area, mainly distributed in central and northern Shuangwang, Yanheying, Panzhuang, and Yinzhuang Towns. The dominant limiting factor in this region is road accessibility. During consolidation project implementation, priority should be given to strengthening road and field path construction, while also considering secondary limiting factors such as farmland shelter belt ratio, irrigation guarantee rate, and effective soil thickness. This involves enhancing farmland infrastructure construction and actively preventing soil erosion caused by natural disasters.

2) Terrain Slope Dominated Region

The terrain slope dominated region has a total area of only 171.87 hm^2, accounting for 0.39% of the county' s total cultivated land area—the smallest of all limiting factor dominated regions—mainly distributed in Shimen Town and

Chenguantun Township where terrain is relatively high. This region contains two limiting factor combinations: "terrain slope + farmland shelter belt ratio + road accessibility" and "terrain slope + farmland shelter belt ratio + irrigation guarantee rate." Due to high terrain, irrigation and transportation are inconvenient, limiting field road accessibility and irrigation guarantee rate and making improvement difficult. However, since soil layer thickness is suitable and field patches are relatively flat and well-connected, terrace construction can be considered during consolidation.

3) Irrigation Guarantee Rate Dominated Region

The irrigation guarantee rate dominated region has a total area of 319.44 hm^2, accounting for 0.73% of the county' s total cultivated land area—only slightly larger than the terrain slope dominated region—with scattered patches distributed mainly in Yanheying, Shimen, and Yinzhuang Towns. This region includes six limiting factor combinations from four secondary limiting factor dominated regions dominated by road accessibility, farming convenience, farmland shelter belt ratio, and field contiguous degree. The area dominated by irrigation guarantee rate as the secondary limiting factor is largest, accounting for 80.08% of the region, with the factor combination "irrigation guarantee rate + farmland shelter belt ratio + farming convenience degree" having the largest area (255.59 hm^2), accounting for 80.01% of this region' s total area. In this key region, other limiting factors are in relatively good condition (e.g., gentle slopes, stable soil physical and chemical properties). Elevation maps show this region has flat terrain where drilling wells and constructing irrigation canals can secure and improve irrigation guarantee rates, enabling relatively easy and rapid improvement of cultivated land quality to higher levels.

4) Farmland Shelter Belt Ratio Dominated Region

The farmland shelter belt ratio dominated region has a total area of 37,680.91 hm^2, accounting for 85.81% of the county's total cultivated land area—the largest and most widely distributed dominant limiting factor combination region. This region includes 16 limiting factor combinations from four secondary limiting factor dominated regions dominated by road accessibility, terrain slope, irrigation guarantee rate, and effective soil thickness. The area with road accessibility as the secondary limiting factor is largest (15,691.90 hm^2), accounting for 41.64% of this region's total area. The factor combination "farmland shelter belt ratio + effective soil thickness + irrigation guarantee rate"has the largest area (10,991.69 hm^2), accounting for 29.17% of this region' s total area, mainly distributed in Yinzhuang, Panzhuang, and Lulong Towns, each exceeding 1,400 hm^2. The next largest combinations are "farmland shelter belt ratio + road accessibility + irrigation guarantee rate" (7,844.29 hm^2, 20.82% of the region) and "farmland shelter belt ratio + road accessibility + effective soil thickness" (7,273.51 hm^2, 19.30% of the region), distributed mainly in Shuangwang and Lulong Towns (1,514.96 hm^2 and 1,306.94 hm^2 respectively) and in Chenguantun and Shuangwang Towns (1,188.35 hm^2 and 1,084.10 hm^2 respectively). The farmland shelter belt ratio dominated region is distributed throughout the county, with all towns except Shimen, Haibo, Xiazhai, and Liujiaying exceeding 3,000 hm², including Lulong Town with 4,117.74 hm² (10.93% of this region' s total area). In this region, the dominant limiting factor is farmland shelter belt ratio, while road accessibility, terrain slope, irrigation guarantee rate, and effective soil thickness serve as secondary limiting factors. Consolidation should prioritize strengthening farmland shelter belt construction to better protect farmland and prevent soil erosion, followed by improving field road levels, enhancing farmland infrastructure, increasing effective soil thickness, and improving soil fertility to raise the region' s cultivated land quality.

5) Effective Soil Thickness Dominated Region

The effective soil thickness dominated region has a total area of 3,861.32 hm², accounting for 8.79% of the county' s total cultivated land area—the second largest after the farmland shelter belt ratio dominated region—distributed throughout the county but concentrated in Yinzhuang Township (909.00 hm², 23.54% of this region' s area). This region includes six limiting factor combinations from two secondary limiting factor dominated regions (irrigation guarantee rate and farmland shelter belt ratio). The factor combination "effective soil thickness + farmland shelter belt ratio + irrigation guarantee rate" has the largest area (3,533.42 hm²), accounting for 91.51% of this region' s total area, mainly distributed in Yinzhuang, Panzhuang, and Lulong Towns (857.55 hm², 487.89 hm², and 461.33 hm² respectively). In the effective soil thickness dominated region, over 90% of cultivated land has relatively good comprehensive quality. Consolidation should focus on improving effective soil thickness, supplemented by drilling wells or repairing irrigation canals to improve irrigation guarantee rates, strengthening farmland shelter belt construction, and increasing cultivated land input levels to enhance regional cultivated land quality.

4. Conclusion and Discussion

Based on analysis of improvable limiting factors in cultivated land consolidation, this study constructed a cultivated land quality evaluation index system incorporating improvable limiting factors, applied the score factor identification method and introduced the obstacle degree model to research the delineation of regional cultivated land quality improvement key areas, yielding the following conclusions:

1) Using the score factor identification method and considering the actual conditions of the study area, the limiting factor combination types for all cultivated land patches in Lulong County were determined. The region with 5 limiting factors had the largest area, while the region with 9 limiting factors had the smallest area. Areas with more high-limiting factors were mainly distributed in central Lulong County, indicating greater difficulty for improvement in these areas.

2) Introducing the obstacle degree analysis model to revise the 95 limiting factor combinations, the top 3 limiting factors by obstacle degree were

selected and ranked, determining 33 limiting factor combination types and 5 dominant limiting factor key areas, with the farmland shelter belt ratio dominated region having the largest area. Targeted land consolidation should be conducted according to the dominant limiting factors in each key area, combined with other limiting factors within the region, to improve cultivated land quality and ensure grain production.

Previous research has primarily focused on combination types of limiting factors for cultivated land quality improvement, with limited study on restriction degree ranking. This study introduces the obstacle degree model to delineate key areas for cultivated land quality improvement in Lulong County. The obstacle degree model provides more accurate ranking of limiting factors, identifying regional dominant limiting factors to enable targeted cultivated land consolidation. This study only determined key areas for cultivated land quality improvement without analyzing the degree of potential improvement. Future research should explore the improvable degree of these regions. Additionally, establishing a cultivated land resource information system could further understanding of the current distribution and improvable degree of limiting factors, contributing to effective cultivated land resource management.

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