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Original Research

Layout Optimization and Division of Plateau Mountain Arable Land-Based on Cultivated Land Quality Evaluation and Local Spatial Autocorrelation

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Abstract

Mountainous area account for 94% in Yunnan, China. Among them, cultivated land only 16.20%. In order to classify and protect cultivated land contiguous, take Huaping , a typical mountainous area as an example, and integrates the entropy weight method, TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) and spatial autocorrelation method to construct a zoning method based on CLQE (Cultivated Land Quality Evaluation). The results showed that the CLQE was divided into five grades. Class 1 and Class 2 was higher, respectively accounting for 24.98% and 29.98% of the total cultivated land area, Class 3 and Class 4 was accounting for 23.17% and 13.76%, Class 5 was the worst, accounting for 8.11%. In terms of layout, it can be divided into 4 areas, key protected areas are distributed in Class 1 and 2, accounting for 52.52% of the total, suitable adjustment areas are distributed in Class 1, 2 and 3, accounting for 9.02%, key control areas are distributed in Class 3 and 4, accounting for 25.41%, reduce reserved areas are distributed in Class 4 and 5, accounting for 13.05%. The results are consistent with the actual situation, and provide a feasible method for cultivated land classification and zoning protection.

Keywords: cultivated land quality, sustainability, entropy method, local spatial autocorrelation

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Introduction

Cultivated land is the type of land used for planting crops after reclamation. It is the most important resource for agricultural production. According to UNESCO (United Nations Educational Scientific and Cultural Organization) statistics, in 2015, the world's arable land area was 1.73 billion hm^2, and the world's per capita arable land area was only 0.26 hm^2 [1]. It plays an important role in ensuring food security, ecological security and sustainable development [2]. The quality of cultivated land is "the status and conditions of cultivated land", and its connotation extends from the basic land capacity of single goal in the early stage to many aspects, such as suitability, production potential, ecological security, environmental quality and sustainability. CLQE is an important basic work of China's cultivated land protection and one of the essential criteria for the sustainable development of the national economy and society [3-4].

China is a populous country and a large agricultural country. Ensuring food production and security is an urgent matter of the moment. Cultivated land is the foundation for ensuring food production and safety, which are affected directly by cultivated land quality [5-6]. In 2020 and 2021, the Central No. 1 document clearly stated that "ensure food security is the top priority of state governance" and "the bottom line of sticking to the red line of 1.8 billion mu of arable land will not be shaken." Especially since the outbreak of the COVID-19 and the complicated international situation, have deeply realized that protecting high-quality arable land is to firmly hold the job in one's own hands, and the evaluation of arable land quality is the basis for the simultaneous management and protection of the quantity, quality and ecology of arable land. It is also the basic requirement to keep the red line of cultivated land protection and implement the priority of cultivated land protection. In order to reasonably protect arable land resources, effectively improve the quality and strengthen the protection of cultivated land, the quality of cultivated land is evaluated and analyzed, and then its layout is optimized in accordance with the principle of "ensure quantity, improve quality; stable layout, and clarify conditions." It can guarantee regional food security and provide theoretical support for cultivated land protection and management [7-10].

CLQE is a comprehensive evaluation based on a specific purpose, from the research on the natural state of cultivated land such as farmland yield, soil properties, and basic soil fertility, to the “resource value management evaluation of the integration of man and land” that comprehensively considers nature, economy and society [11]. It has always been a hot spot for scholars and government decision-makers [12-14]. Current international scholars' research on the quality of cultivated land mainly focuses on evaluation methods [15-17], the construction of a quality evaluation index system [18-20], and engineering measures to improve the quality of cultivated land [21-22]. For example, Martin et al. [23]conducted a pollution assessment of heavy metal content in the soil of agricultural land in Nimal province, Telangana, India by constructing a pollution index. Grandy et al. [24] compared the effects of microorganisms in different soil types on soil fertility in Nigerian arable land by measuring soil chemical properties and microbial populations. Zhao Jianjun and others used GIS spatial analysis technology and AHP (analytic hierarchy process) to evaluate the quality of cultivated land in Jilin Province [25]; Tan Yongzhong et al. [26] used GIS spatial analysis and multifactor comprehensive evaluation methods to build an evaluation index system which provides a way for the grading, quality improvement and sustainable use of cultivated land in Shengzhou City, Zhejiang Province.To sum up, the understanding, theory and methods of cultivated land quality evaluation are constantly deepening, but there are few studies on the CLQE in plateau mountainous areas, and the establishment of evaluation index system and evaluation model needs to be strengthened [27]. There is an urgent need to explore a CLQE system based on different demand levels to meet the needs of regional development for cultivated land resource management [28].

Yunnan Province is the only province in China completely located in the highland mountains, mountains, and plateaus account for 94% of the province's land area. Subject to geographical conditions, the province's cultivated land mainly slopes cropland, less flat arable land. Huaping County is an important agricultural production county in Yunnan Province, but also a typical representative of slope cropland, which plays an important role in providing food production, improving income, solving the livelihood of households, and other aspects. This paper takes Huaping County, Lijiang City, Yunnan Province as the research area, uses spatial overlay analysis to determine the evaluation unit, entropy method combined with GIS spatial analysis technology to determine the weight of index factors, uses TOPSIS method to establish a CLQE criterion. Finally, on the basis of CLQE, the local spatial autocorrelation method is used to analyze the characteristics of the CLQE layout. The CLQE results and the local spatial autocorrelation analysis results are spatially superposed and analyzed. The cultivated land layout protection zoning plan is proposed, which can provide the theoretical basis for Huaping County to carry out research on CLQE, analyze the characteristics of cultivated land layout, optimize the rational use and protection of resources, and the sustainable development of the grain industry in the plateau and mountainous areas.

Material and Methods

Overview of the Study Area

Huaping County, the study area, is located in the northern section of the middle reaches of the Jinsha River in northwestern Yunnan Province, China(26°21′-26°58′ north latitude, 100°59′-101°31′ east longitude), with a total area of 2,200 square kilometers, an annual average temperature of 19.6ºC, annual average precipitation of 1119.2 mm, an annual average relative humidity of 62%, and a frost-free period throughout 302 days a year, it belongs to the typical subtropical valley climate. The terrain is high in the northwest and low in the southeast, with a prominent three-dimensional distribution. The highest elevation of the county is 3189 meters, and the lowest elevation is 1015 meters. The county is divided into 8 townships, including YongXing, ChuanFang, ZhongXin, XingQuan, TongDa, XinZhuang, RongJiang, and ShiLongBa [20].

Data Sources

This study's spatial data mainly includes the land use database of Huaping County in 2015; the 2015 administrative map, the elevation sampling point data; the irrigation and drainage map; the effective soil thickness map; the 2015 soil nutrient data. The non-spatial data such as annual precipitation and the annual average temperature are obtained through the 2016 Huaping County Yearbook.

GIS Spatial Overlay Method

In this study, four aspects of site conditions, location, spatial form and natural conditions are used as the criterion layer, and 22 evaluation index factors that affect CLQE are screened and subdivided as the index layer. The types of index factors are determined based on statistical principles with reference to relevant literature [25-26]. A negative index means that the index is negatively correlated with the quality of cultivated land, and a positive index means that the index is positively correlated with the quality of cultivated land (Table 1).

Table 1. Index System for CLQE.

Target layer	Criterion layer B	Index layer C	Type of index factors
Cultivated land quality	Site conditions (B1)	Organic matter content	Positive
		Soil PH	Positive
		Tillage depth	Positive
		Available phosphorus	Positive
		Total nitrogen	Positive
		Slowly available potassium	Positive
		Available potassium	Positive
		Available zinc	Positive
		Available nitrogen	Positive
		Water-soluble boron	Positive
		Soil texture	Conceptual
		Irrigation guarantee rate	Positive
		Drainage condition	Conceptual
		Soil parent material	Conceptual
	Location (B2)	Road unobstructed degree	Negative
		Distance to urban construction land	Positive
		Distance to residential area	Negative
	Spatial form (B3)	Farmland Connectivity	Positive
	Natural conditions (B4)	Annual precipitation	Positive
		Accumulated temperature	Positive
		Elevation	Negative
		Gradient	Negative

Based on the determination of the relative indicators, this study uses the GIS spatial overlay method to determine the evaluation unit. First, the data of each evaluation factor selected above are processed by buffer analysis, spatial interpolation, etc., to form a factor spatial distribution layer, and then the spatial distribution layer of each evaluation factor and the cultivated map spot distribution layer are superimposed in pairs. The evaluation data layer is formed with the range of natural patches of cultivated land as the unit, thus forming a total of 16627 evaluation units.

Range and Delphi MeIn the CLQE of Huaping county, the measurement units of each factor are inconsistent. In order to eliminate the dimensional difference between the evaluation factors, this article uses the range method to standardize each index [29]. According to the type of index factors previously divided, the positive index (cost type) is brought into Equation (1), and the negative index (benefit type) is brought into Equation (2). The standardized value of the index is between [0, 1].

For positive indicators:

$$R_{ij} = \frac{r_{ij} - r_{ij\min}}{r_{ij\max} - r_{ij\min}} \quad (1)$$

For negative indicators:

$$R_{ij} = \frac{r_{ij\max} - r_{ij}}{r_{ij\max} - r_{ij\min}} \quad (2)$$

In Equation (1) and (2), R_{ij} represents the standardized value of the index, r_{ij} represents the index value, r_{ijmax} represents the maximum value of the index, and r_{ijmin} represents the minimum value of the index.

For the conceptual index in this study, the main idea comes from reference [20], the membership degree value is determined by the Delphi method. It can also represent the pros and cons of the index value and has the same dimension as the above-mentioned standardized value by the range method, so the membership degree value is used as the standardized value of it (Table 2).

Entropy Method.

In this study, the entropy method is used to determine the weights of index factors, which is a method of objectively determining weights, and it can effectively reflect the information implicit in the index data, improve the difference and resolution of the index, and avoid too small differences in indicators leading to unclear discrimination. The essence of the entropy method is that the greater the difference between the evaluation units on a certain index, the smaller the entropy value presented, indicating the greater the influence of the index; on the contrary, the smaller the difference, the greater the entropy value, and the smaller the influence of the index [30-31]. Proceed as follows:

Step 1. For n samples, m indicators, r_{ij} is the value of the j index of the i sample (i = 1,…,n; j = 1,…,m);

Step 2. Normalization of indicators. Here we use the results of dimensionless processing of index;

Step 3. Calculate the proportion of the i^{th} sample value under the j^{th} index:

Table 2. Standardized Value of Conceptual Index.

Index	Index value	Membership degree
Soil texture	Heavy loam	1.00
	Medium loam	0.90
	Light loam	0.80
Drainage condition	Excellent	1.00
	Good	0.87
	Medium	0.73
	Relatively poor	0.56
	Poor	0.30
Soil parent material	Purple sandstone and shale efflorescence	1.00
	Alluvium, Eluvium of purple sandstone and shale	0.95
	Pelite efflorescence, Efflorescence and slope deposits of quartzite	0.85
	Red soil parent material, Acidified bedrock efflorescence, Alluvial deposit of carbonate rock	0.80
	Slope deposits and eluvium of carbonate rock	0.75

$$P_{ij} = \frac{r_{ij}}{\sum_{i=1}^{n} r_{ij}} (i = 1,...,n; j = 1,...,m) \quad (3)$$

Step 4. Calculate the entropy value of the j[th] index, where k = 1/ln(n):

$$F_j = -k \sum_{i=1}^{n} p_{ij} ln(p_{ij}) \quad (4)$$

Step 5. Calculate information entropy redundancy:

$$D_j = 1 - F_j \quad (5)$$

Step 6. Calculate the entropy weight of each indicator:

$$W_j = \frac{D_j}{\sum_{j=1}^{m} D_j} \quad (6)$$

According to the above analysis steps of the entropy method formula, the weight of each index of CLQE in Huaping County can be obtained (Table 3).

TOPSIS Method

After the weights of each indicator are determined, the comprehensive scores of the cultivated land quality of each evaluation unit can be calculated. The comprehensive evaluation results are measured by the size of the proximity calculated by the TOPSIS method because that the combination of this method and the entropy method has a better effect and has complementary effects. The TOPSIS method is a sorting method that approximates the ideal solution. It sorts by calculating the distance between the evaluation object and the optimal solution and the worst solution. If the evaluation object is closer to the optimal solution and farther away from the worst solution, it means that the evaluation object is better in all schemes. On the contrary, it means that the evaluation object is relatively poor in all schemes [32-33]. The steps are as follows:

Table 3. Weights of Index of CLQE in Huaping County.

Target layer	Criterion layer B	Index layer C	Weight
Cultivated land quality	Site conditions (B1)	Organic matter content	0.053
		Soil PH	0.062
		Tillage depth	0.064
		Available phosphorus	0.045
		Total nitrogen	0.065
		Slowly available potassium	0.063
		Available potassium	0.057
		Available zinc	0.052
		Available nitrogen	0.065
		Water-soluble boron	0.063
		Soil texture	0.025
		Irrigation guarantee rate	0.032
		Drainage condition	0.021
		Soil parent material	0.027
	Location (B2)	Road unobstructed degree	0.012
		Distance to urban construction land	0.024
		Distance to residential area	0.025
	Spatial form (B3)	Farmland Connectivity	0.048
	Natural conditions (B4)	Annual precipitation	0.060
		Accumulated temperature	0.042
		Elevation	0.049
		Gradient	0.046

Step 1. Data standardization processing: use the above results of dimensionless process;

Step 2. Establish a weighted decision-making matrix: index weight determined by entropy method is multiplied with each index of the standardized matrix to obtain the weighted decision-making matrix V_{ij};

Step 3. Determine the positive ideal solution and the negative ideal solution: where V^+ represents the optimal solution and V^- represents the worst solution, where i = 1, ..., m;

$$V^+_i = \max(V_{ij}) \tag{7}$$

$$V^-_i = \min(V_{ij}) \tag{8}$$

Step 4. Calculate the distance from the evaluation object to the positive and negative ideal solutions: the distance from the positive ideal solution (the optimal plan) is recorded as D^+; the distance to the negative ideal solution (the worst plan) is recorded as D^-, where j = 1,...,n;

$$D^+_j = \sqrt{\sum_{i=1}^{m}(V_{ij} - V^+_j)^2} \tag{9}$$

$$D^-_j = \sqrt{\sum_{i=1}^{m}(V_{ij} - V^-_j)^2} \tag{10}$$

Step 5. Calculate the proximity C_j from each plan to the optimal plan: where j = 1,...,n;

$$C_j = \frac{D^-_j}{D^+_j + D^-_j} \tag{11}$$

In Equation (11), the value of C_j is between [0, 1], which means that the closer the value of C_j is to 1, the better the CLQE solution, and vice versa, the worse it is. When it is equal to 1, the CLQE is the best. Combined with the cohesion of the C_j and connective and scale of the cultivated land, the comprehensive quality of the cultivated land was sorted, and by natural breaks classification method, the boundary points of the cultivated land zoning were determined to be 0.80, 0.63, 0.55, 0.46, the level of cultivated land quality is divided into 5 grades (Table 4).

Table 4. Evaluation Criterion of Cultivated Land.

C_j	CLQE grade
≥0.80	Class 1
0.63-0.80	Class 2
0.55-0.63	Class 3
0.46-0.55	Class 4
≤0.46	Class 5

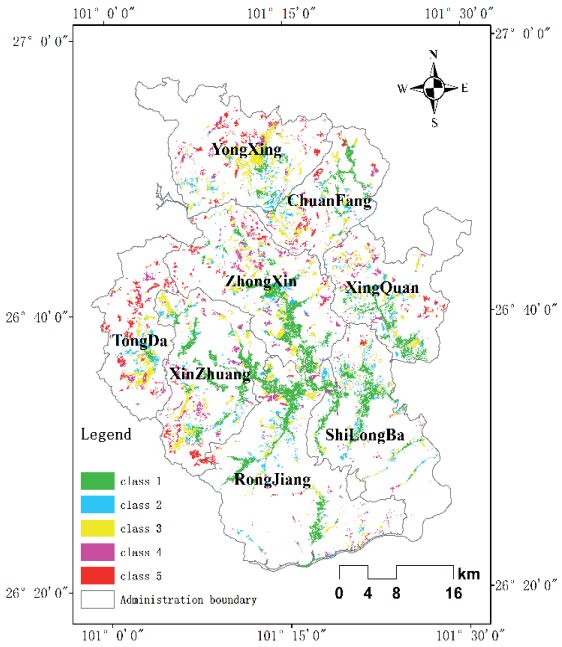

Fig. 1. Spatial distribution of CLQE in Huaping County.

Local Spatial Autocorrelation Analysis Method

In this paper, after reading a large number of relevant literature, the local spatial autocorrelation analysis method is used to analyze the layout of cultivated land [34-36]. Before the autocorrelation analysis, the spatial weight needs to be determined. In order to prevent the spatial weight from being affected by the spatial attribute value and considering factors such as data error, this paper uses the weighted k-nearest neighbor (weighted KNN) method to obtain the spatial weight matrix. By comparing Moran's I index scatter plots obtained by different methods of determining the spatial weight, it is found that when the nearest point k value is 6, the spatial autocorrelation index is the highest.

Local spatial autocorrelation analysis can be used to describe the degree of the autocorrelation of the spatial distribution of cultivated land quality, and it can intuitively represent the spatial aggregation status through graphics. In this study, the cultivated land evaluation unit was used as the basic spatial unit, and the cultivated land quality index was used as the spatial attribute value for spatial autocorrelation analysis, combined with the Moran's I scatter plot for spatial expression. The first and third quadrants are HH (high-high) type and LL (low-low) type, the second and fourth quadrants are LH (low-high) type and HL (high-low) type, respectively. Finally, the spatial distribution of cultivated land quality is divided into HH, HL, LH, LL, and non-significantly correlated type, among

which HH and LL types are positive correlation types, showing a high degree of spatial aggregation; HL and LH types are negative correlation types, showing the spatial dispersion of cultivated land quality, while non-significantly correlated type is no obvious aggregation and dispersion characteristics. The local spatial autocorrelation calculation model is as follows:

$$I_n = Z_n \sum_{m=1}^{m} W_{nb} Z_n \tag{12}$$

$$Z_n = (X_n - X') \Big/ \sqrt{\frac{\sum_{n=1}^{A} (X_n - X')^2}{A}} \tag{13}$$

In Equation (12), I_n represents the local spatial autocorrelation index; Z_n represents the standardized value of spatial unit n; m represents the total number of spatial units adjacent to spatial unit n; W_{nb} represents the space weight between spatial unit n and b. In Equation (13), X_n represents the measured value of a variable on spatial unit n; X' represents the mean value of the variable; A represents the total number of scalar observations.

Results and Discussion

Results and Discussion of CLQE

After the weight of the evaluation index system is determined by the entropy method, the spatial distribution map of the CLQE grade is obtained by the TOPSIS method (Fig. 1). Then Table 5 is obtained by statistical analysis according to the CLQE grade.

Combining the results of CLQE and related statistics, the total cultivated land area of Huaping County in this study is 23830.63 hm^2, and the total number of evaluation units is 16627. The cultivated land is divided into five grades, among which the area of Class 1 cultivated land is 5952.88 hm^2, occupying 24.98% of total arable land area, 4543 evaluation units, 27.32% of total evaluation units; Class 2 cultivated land area is 7143.29 hm^2, accounting for 29.98% of the total, 4915 evaluation units, accounting for 29.56%; Class 3 arable land area is 5521.43 hm^2, accounting for 23.17% of the total, the number of evaluation units is 3636, accounting for 21.87% of total evaluation units; Class 4 cultivated land area is 3280.19 hm^2, accounting for 13.76% of the total, 2133 evaluation units, accounting for 12.83%; Class 5 arable land area is 1,932.84 hm^2, accounting for 8.11%, and 1,400 evaluation units, accounting for 8.42%.

According to the evaluation indicators, the Class 1 cultivated land has a high comprehensive quality level, with good natural conditions, which is represented by relatively low altitude and gentle terrain, good cultivated fertility conditions (high nutrient content, good drainage and irrigation capacity), smooth roads, convenient farming and contiguous cultivated land areas; the Class 2 cultivated land has a higher elevation than Class 1, the ease of farming is a little bit lower, and the other aspects are not much different; the Class 3 cultivated land has a higher altitude and slope and low overall continuity , the level of soil fertility has declined in all aspects; the Class 4 cultivated land is deficient in contiguousness, and the convenience of farming, road access, and soil fertility are relatively low; the Class 5 arable land has the worst performance in all aspects, showing scattered and fragmented cultivated land, the irrigation and drainage capacity of arable land is weak, and poor cultivability and poor soil fertility due to topography and it is far away from roads, residential areas, and towns.

From the perspective of the spatial distribution of cultivated land quality, the high-quality cultivated land in Huaping County is relatively concentrated, with good contiguousness, and scattered distribution occurs only in areas far from towns and higher terrain, and all levels of cultivated land in towns also presents a concentrated distribution. Among them, the Class 1 cultivated land is mainly distributed in RongJiang, ZhongXin, and ShiLongBa, with an area of 3,782.67 hm^2, accounting for 63.54% of the area of Class 1; the Class 2 cultivated land is mainly distributed

Table 5. Statistical Analysis of CLQE.

CLQ Egrade	Area (Hectare)	Area ratio (%)	Number of evaluation units	Percentage of units (%)	Mainly distributed towns	Distribution area (Hectare)	Distribution percentage (%)
Class 1	5952.88	24.98	4543	27.32	RongJiang, ZhongXin, ShiLongBa	3782.67	63.54
Class 2	7143.29	29.98	4915	29.56	RongJiang, ZhongXin, XinZhuang	3616.91	50.63
Class 3	5521.43	23.17	3636	21.87	YongXing, TongDa, XinZhuang	2800.20	50.72
Class 4	3280.19	13.76	2133	12.83	ZhongXin, XinZhuang, TongDa	1643.67	50.10
Class 5	1932.84	8.11	1400	8.42	TongDa, YongXing, ChuanFang, ZhongXin	1466.97	75.90
Total	23830.63	100	16627	100	\	\	\

Table 6. Local Spatial autocorrelation Results.

Autocorrelation type	Area (hm^2)	Area ratio (%)
HH type	13101.17	54.98
HL type	140.38	0.59
LH type	1092.24	4.58
LL type	3110.65	13.05
Non-significantly correlation type	6386.19	26.80
Total	23830.63	100

in RongJiang, ZhongXin, and XinZhuang, whose area is 3616.91 hm^2, accounting for 50.63% of the area of Class 2; the Class 3 cultivated land is mainly distributed in YongXing, TongDa, and XinZhuang, with a distribution area of 2800.2 hm^2, accounting for 50.72% of the area of Class 3; The Class 4 arable land is mainly distributed in ZhongXin, XinZhuang, and TongDa, with an area of 1643.67 hm^2, accounting for 50.1% of the area of Class 4; the Class 5 arable land is distributed in all towns, but mainly distributed in TongDa, YongXing, Xingxiang, ChuanFang and north of ZhongXin, with a distribution area of 1466.97 hm^2, accounting for 75.9% of the area of Class 5.

Discussion of Local Spatial Autocorrelation Results

According to the above method, the local spatial autocorrelation index of cultivated land quality in Huaping County is 0.8094, indicating that the cultivated land quality of Huaping County has a strong positive correlation in the spatial distribution as a whole. The

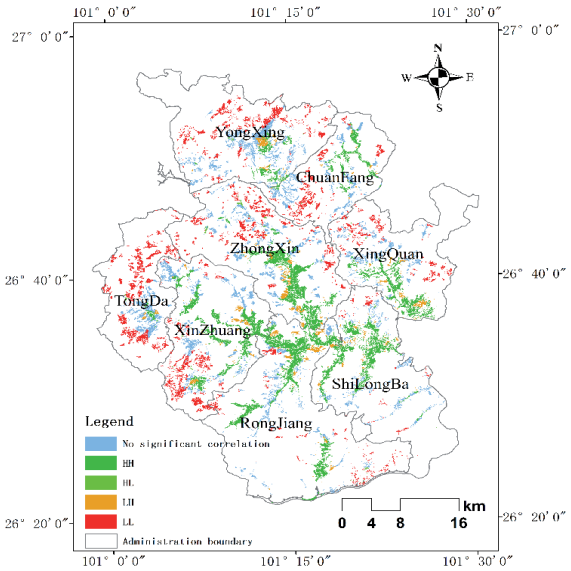

Fig. 2. Local spatial autocorrelation distribution of cultivated land in Huaping county.

areas of positive correlation type HH and LL are 13101.17 hm^2 and 3110.65 hm^2, respectively, accounting for 54.98% and 13.05%; negative correlation type HL and LH have areas of 140.38 hm^2 and 1092.24 hm^2, respectively, accounting for 0.59% and 4.58% of the total cultivated area; the area of non-significant correlation type is 6386.19 hm^2, accounting for 26.8 % of the total cultivated area. It can be seen that the quality of most of the cultivated land conforms to the positive correlation (Table 6).

From the perspective of spatial distribution (Fig. 2), the spatial layout of HH-type cultivated land is consistent with high-quality cultivated land, the coverage is concentrated, and the quality of cultivated land is generally high. It is mainly distributed in RongJiang, ZhongXin, and ShiLongBa, and XinZhuang; ChuanFang and XingQuan also showed local clustering distribution, but the distribution is less than the previous townships; other townships had a small amount of distribution but showed scattered distribution. The HL and LH type areas are mostly distributed in the higher terrain areas in the northwestern central, and the southeast lower terrain areas are less distributed, between the LL and HH types, showing fragmented distribution. As for LL type, there are more distributions in higher terrain areas in the west, north, and northwest, and very few in the southeast. The quality of cultivated land in this area is generally low, and the distribution is relatively discrete.

Comprehensive Analysis of Local Spatial Autocorrelation and CLQE Results

The previous CLQE and the local spatial autocorrelation division results are superimposed and analyzed (Table 7) so that the attribute data of CLQE and the spatial data of the local spatial autocorrelation are combined to obtain the attribute and spatial relationship of the cultivated land quality. The analysis shows that almost all class 1 and class 2 arable landfall into the HH type. Among them, class 1 cultivated land has 5832.38 hm^2, accounting for 97.98% of class 1, and the class 2 cultivated land is 6,682.56 hm^2, accounting for 93.55% of class 2. It shows that the local spatial autocorrelation HH of class 1 and class 2 cultivated land is consistent. A small part of class 2 arable land falls into the HL type, mainly because the terrain of it is high, but it is scattered in small areas. This part is consistent with HL. Class 3 cultivated land occupies 586.23 hm^2, 982.13 hm^2, and 3953.07 hm^2 in the HH, LH, and non-significantly related types, accounting for 10.62%, 17.79%, 71.6%, respectively; class 4 cultivated land falls into LH type, LL type, and no significant correlation type, occupying 110.11 hm^2, 1177.81 hm^2, and 1992.27 hm^2 respectively, accounting for 3.36%, 35.91% and 60.74% of class 4; all of class 5 cultivated land falls into LL type, with an area of 1932.84 hm^2.

Based on the above analysis, it can be seen that the area with high cultivated land quality in Huaping

Table 7. Comparison of CLQE Grade and Autocorrelation Type in Huaping county.

CLQE grade	HH type		HL type		LH type		LL type		Non-significantly correlation type		Arable land area
	Area	Area ratio	Area	Area ratio	Area	Area ratio	Area	Area ratio	Area	Area ratio	
Class 1	5832.38	97.98	0.00	0.00	0.00	0.00	0.00	0.00	120.50	2.02	5952.88
Class 2	6682.56	93.55	140.38	1.97	0.00	0.00	0.00	0.00	320.35	4.48	7143.29
Class 3	586.23	10.62	0.00	0.00	982.13	17.79	0.00	0.00	3953.07	71.60	5521.43
Class 4	0.00	0.00	0.00	0.00	110.11	3.36	1177.81	35.91	1992.27	60.74	3280.19
Class 5	0.00	0.00	0.00	0.00	0.00	0.00	1932.84	100.00	0.00	0.00	1932.84
Total	13101.17	54.98	140.38	0.59	1092.24	4.58	3110.65	13.05	6386.19	26.80	23830.63

County and the local spatial autocorrelation analysis positive correlation type is consistent in distribution. The class 1, 2, and 3 arable lands are consistent with the HH type, and the class 4 and 5 poor quality arable land are consistent with the LL type, both of which are positively correlated, which provide a division basis and data foundation for the optimization of the layout of cultivated land protection later.

Layout Optimization of Arable Land based on CLQE and Local Spatial Autocorrelation

Based on the above-mentioned CLQE and local spatial autocorrelation evaluation results, Huaping County's cultivated land layout is divided into 4 areas: Key protected area, Suitable adjustment area, Key control area, and Reduce reserved area, so as to facilitate the improvement and optimization of cultivated land in Huaping subsequently. The specific division and distribution of each area are shown in Fig. 3 and Table 8.

Key Protected Area

This area mainly falls into cultivated land with positively correlated HH type whose CLQE grade is class 1 and 2, which the total area is 12514.94 hm^2, accounting for 52.52% of the total cultivated land area. The area is relatively large and presents aggregation

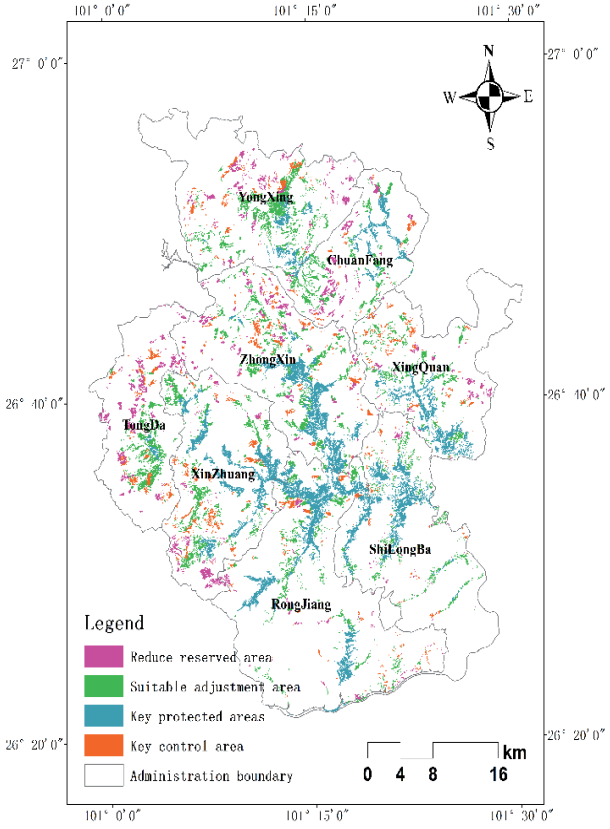

Fig. 3. Layout of Cultivated Land Protection in Huaping County.

Table 8. Division of Arable Land Protection Layout in Huaping County.

Optimization type	Class 1		Class 2		Class 3		Class 4		Class 5		Total	
	Area	Area ratio	Area	Area ratio	Area	Area ratio	Area	Area ratio	Area	Area ratio	Area	Area ratio
Key protected area	5832.38	46.60	6682.56	53.40	0.00	0.00	0.00	0.00	0.00	0.00	12514.94	52.52
Suitable adjustment area	120.50	5.61	460.73	21.43	1568.36	72.96	0.00	0.00	0.00	0.00	2149.59	9.02
Key control area	0.00	0.00	0.00	0.00	3953.07	65.28	2102.38	34.72	0.00	0.00	6055.45	25.41
Reduce reserved area	0.00	0.00	0.00	0.00	0.00	0.00	1177.81	37.86	1932.84	62.14	3110.65	13.05

characteristics in spatial distribution. The overall continuity is good, and the roads are unobstructed. From the analysis of the quality of the cultivated land, the area has a high level of fertility, high nutrient content, fertile soil, flat terrain, good drainage and irrigation conditions, convenient farming, ideal natural conditions, high spatial correlation, and easy to manage. Relying on the characteristics of high quality of cultivated and concentrated distribution, the stability of grain production in this region is relatively high, and it is the ideal region for agricultural development. Therefore, the area should be protected to ensure that the cultivated land isn't abused for other non-agricultural constructions, and fertilization management in this area should be emphasized to keep the quality of cultivated land at a high level.

Suitable Adjustment Area

The suitable adjustment area is relatively small, just 2149.59 hm^2, accounting for 9.02% of the total cultivated land area, and mainly falls into areas with non-significant correlation type of class 1 and class 2 and class 3 arable land in the HH, HL, and LH type areas. Its quality of arable land is also relatively high, which is a little bit worse than that of the key protected areas. Most of this area also has good continuity, mainly distributed in high terrain areas. Only in the border area and the north-central regions, the distribution is discrete, with low contiguousness, but its quality level is generally high, and it is distributed around the HH type. For this area, appropriate adjustments should be made to improve the quality of cultivated land, such as rational fertilization, strengthening irrigation and drainage facilities, carrying out slope transformation, etc.

Key Control Area

The key control area mainly includes class 3 areas of non-significantly type and class 4 cultivated land in the HL and LH type areas, which the total area is 6055.45 hm^2, accounting for 25.41% of the total cultivated land area. The spatial distribution of this area presents discrete characteristics and is located in the edge area of topographic changes, resulting in large slopes and unobvious natural conditions. It is also located between the HH type and the LL type and more difficult to remediate. More workforce, material resources, and financial resources should be invested in reconstruction, strengthen road construction, ensure the convenience of farming, and improve soil fertility. With the long-term investment, there will be the greatest room for improvement in cultivated land quality.

Reduce Reserved Area

The quality of cultivated land in the reduce reserved area is generally low, whose CLQE grade is class 4 and 5, the total area is 3110.65hm^2, accounting for 13.05% of the total cultivated land area, and the local spatial autocorrelation is LL type. This area is mainly distributed in the west, north, and northwest regions and is most affected by topography and geomorphology. Its physical and chemical properties, site conditions, location conditions, and natural conditions are all poor, and the spatial distribution also presents discrete distribution characteristics, with poor continuity, and the distance from roads, residential areas, and towns is relatively long. The rectification is very difficult, and it is not suitable for rectification within a period of time. Most of this area can be withdrawn from the cultivated land plan and can be used for other purposes. However, due to the production of food, some areas with relatively good conditions can be reserved for free farming.

Conclusions

Based on the concept of sustainable development, combing the relevant theories of sustainable utilization of cultivated land, and referring to a large number of relevant literature, this paper decided to conduct CLQE in plateau mountainous areas from the basic situation and characteristics of the utilization of cultivated land resources. And then, suggestions were put forward for the sustainable utilization and layout optimization of cultivated land resources in combination with relevant analysis. The methods used in this article mainly include GIS-related technologies, entropy weight method, TOPSIS method, and local spatial autocorrelation analysis method. After obtaining relevant data, constructing the cultivated land quality evaluation index system, the entropy weight method is used to determine the weights of each index, the TOPSIS method is used to evaluate the cultivated land quality and construct the CLQE criterion, local spatial autocorrelation method is used to perform the spatial autocorrelation analysis based on the CLQE, and finally combine the results of CLQE and the spatial autocorrelation analysis to optimize the layout of arable land and propose a layout optimization plan. In the end, the following conclusions were reached:

(1) Focusing on the evaluation of cultivated land quality, 22 index factors are selected from the four aspects of site conditions, location, spatial form, and natural conditions that affect the quality of cultivated land. Combining index weights and CLQE criterion to obtain CLQE results, the cultivated land in Huaping County is divided into 5 levels, and the attributes and distribution of each grade are analyzed.

(2) Based on the CLQE, the nearest point k = 6 is used to determine the spatial weight. Using ArcGIS 10.2 and GeoDa analysis software to carry out spatial autocorrelation analysis, determine the spatial distribution characteristics of cultivated land quality, and compare it with the results of CLQE. Finally, it

is finally found that the two maintain a good unity in cultivated land quality attributes and spatial attributes.

(3) Combining the results of CLQE and local spatial autocorrelation analysis, the cultivated land of Huaping County is divided into key protection areas, suitable adjustment areas, key control areas, and reduced reserved areas, and each area accounted for 52.52%, 9.02%, 25.41%, and 13.05% of the county's cultivated land area. According to the attributes and spatial differences of each type, based on the principles of rationalization of layout, large-scale arable land, excellent arable land, and unobstructed roads, corresponding improvements were proposed, ensuring that the quantity, quality, and spatial aggregation of cultivated land achieve a better unity.

In a word, compared with other methods, the method proposed in the research is more convenient and provides effective technical support and important practical significance for the study of CLQE and protection layout optimization.

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Conflict of Interest

Yuan Lei and Chen Guoping designed the paper. Zhao Junsan collected and analyzed the data. Chen Guoping revised the paper. All authors have read and agreed to the published version of the manuscript. The authors declare no conflict of interest.

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