Study on Optimization Design of Rural Landscape Layout Based on GIS

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Abstract: With the deepening of rural revitalization strategy, rural landscape planning has become the key to improve the quality of rural environment and promote the sustainable development of rural economy. However, in the current rural landscape design and layout process, there are often many problems, such as the lack of green development concept, unreasonable overall planning, and inconspicuous regional characteristics, which seriously restrict the construction effect of beautiful countryside. In this regard, based on the actual needs of rural landscape design and layout, this paper will put forward a set of implementation plans for rural landscape layout optimization, aiming at analyzing and studying the existing rural green space resources by using GIS technology and landscape ecology principles, and providing scientific digital basis for rural landscape planning. Practice has proved that through the collection of remote sensing images and other related data, and with the help of the spatial analysis ability of GIS software, the current rural landscape index analysis and accessibility analysis are completed, and the optimization suggestions of rural landscape layout are obtained. It not only verifies the effectiveness of the optimization scheme, but also shows the application potential of GIS technology in rural landscape planning.

Keywords: GIS technology; Rural landscape; Landscape ecology; Layout optimization

1 Introduction

China is a big agricultural country, and the rural revitalization strategy, as the core of solving the "three rural issues" in the new period, is of great significance to the realization of socialist modernization. With the deepening of rural revitalization strategy, the importance of rural landscape planning and design has become increasingly prominent, which is not only conducive to protecting the existing ecological stability and establishing a comfortable, convenient and considerable living environment, but also can promote the rational allocation of rural green space resources, fully display the unique regional characteristics and folk culture of the countryside, and lay a good foundation for the realization of rural construction and rural revitalization goals. [1] However, there are still many constraints in the current rural landscape design layout. On the one hand, due to the inherent state of the countryside, the available resources are insufficient and scattered. On the other hand, planning and design schemes often have some problems, such as the lack of green development concept, unreasonable overall planning, and inconspicuous regional characteristics, which further affect the quality and practical effect of rural landscape layout. [2] In view of this, according to the current research status of landscape ecology and urban landscape layout at home and abroad, based on the rural

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landscape planning and design method proposed in reference [3], combined with the results of land cover landscape pattern analysis by Pedzisai Kowe[4] and other people using GIS and remote sensing images, and the explanation and demonstration of landscape ecology application examples by Inger-Lill Eikaas[5], this paper puts forward a set of implementation schemes for optimizing rural landscape layout. It aims to analyze the present situation of rural landscape layout by using GIS technology and landscape ecology principles, and put forward corresponding optimization suggestions, so as to promote the improvement of rural landscape and promote the healthy and sustainable development of rural economy.

2 Related techniques and theories

2.1 Geographic Information System (GIS)

Geographic Information System (GIS) is an application framework for collecting, storing, analyzing and calculating geographic information data. It aims to complete multi-dimensional description and visual expression of analysis and calculation results with the help of computer application systems, and provide effective spatial information services for geographic planning and geographic decision-making. The core application of geographic information system is to establish the mapping relationship between traditional data types and geographic graphics, and its workflow is also called data processing flow. It usually includes five parts: data acquisition and input, data editing and processing, data storage and management, spatial statistics and analysis, and data display and output. [6]

2.2 Landscape ecology

Landscape ecology is a new branch of ecology, which mainly studies the structure, function and dynamics of landscape and its interaction with ecological processes. It emphasizes the study of the spatial pattern and ecological process of ecosystem, the relationship between heterogeneous landscape pattern and process, and the predictability of ecological process on a larger spatial and temporal scale. Among them, the study of landscape layout is the core issue in the whole field of landscape ecology, that is, to analyze the effects of different types of landscape elements in a certain spatial range. The main analysis methods include "patch-corridor-matrix" three elements, landscape index and so on. [7] Based on the theory of "patch-corridor-matrix", the evaluation system of landscape layout can be completed by selecting a certain landscape index. The common index information is shown in Table 1.

Table 1 Landscape index information

Analysis item	Index
Plaque composition analysis	Number of patches (NP), class area (CA), type area (TA), etc.
Patch scale grade analysis	Number of patches (NP), class area (CA)
Spatial structure of metric analysis	Patch Density (PD), largest patch index (LPI), mean patch area (MPS), etc.
Spatial autocorrelation analysis	Moran I's
Spatial isolation analysis	Mean Euclidean Nearest Neighbor Distance (ENN)
Spatial clustering analysis	Aggregation index (AI)

Among them, the number of patches represents the total number of a certain type of patches, and can also represent the total number of all patches in the landscape, which is used to describe the heterogeneity of the landscape and has a significant correlation with patch density, landscape fragmentation and other indicators. The area of patch type is the characteristic of patch size, and the calculation formula is shown in Formula 1, where a_{ij} represents the area of a patch and n is the total number of patches in the landscape. When there is only one landscape type in the landscape, $TA=CA$.

$$CA=\sum_{j=1}^{n} a_{ij}\left(\frac{1}{10000}\right) \tag{1}$$

Patch density represents the ratio of the total number of landscape patches to the total area of landscape patches, or the ratio of the number of patches of a certain type to the total area of patch types. The calculation formula is as shown in Formula 2, where N is the total number and A is the total area.

$$PD=N/A \tag{2}$$

The maximum patch index represents the similarity between a certain type and the whole landscape, and the calculation formula is shown in Formula 3, where a represents the patch area of a certain type, and Max is calculated as the maximum value.

$$LPI=\frac{Max\left(a_1,a_2,a_3,\cdots,a_n\right)}{A}\times 100\% \tag{3}$$

Euclidean nearest neighbor distance represents the distance between patches in the same landscape type to describe the degree of aggregation and dispersion of landscape layout, that is, $ENN=h_{ij}$, and h_{ij} takes the minimum value. The aggregation index represents the aggregation degree between a certain type of patches, and the calculation formula is shown in Formula 4, where g_i is the number of adjacent patches around type i patches, Max is calculated as the maximum, and p_i represents the proportion of type i patches in the landscape. When $AI=0$, it shows that the same type of plaques are scattered; When $AI=100$, it shows that the same type of plaque presents the maximum aggregation state.

$$AI=\left[\sum_{i=1}^{m}\left(\frac{g_i}{Max-g_i}\right)p_i\right]\times 100\% \tag{4}$$

In this study, the above technologies and theories will be fully applied to analyze the layout status of rural landscape, and with the support of GIS, Fragstats and other software, various landscape indexes will be calculated. It will also clarify the distribution law and spatial characteristics of rural landscape, and put forward corresponding layout optimization suggestions in turn, so as to make rural construction and development more in line with ecological significance and help solve problems such as rural resources and environmental pollution.

3 Application example

3.1 Study area

In this paper, a coastal town in East China is selected as the research area. At present, the total area of the whole town is 2731hm^2. As a whole, it belongs to the hilly plain area, and the terrain is inclined from west to south. The northern part is a marine sedimentary plain and the southern part is a hilly area. The overall geological structure is stable and the internal water system is developed. Figure 1 shows the bitmap of the aerial shooting area.

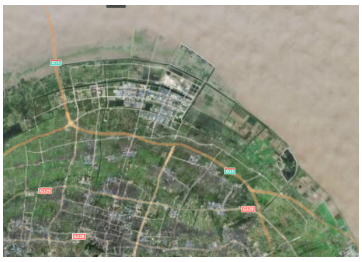

Figure 1 Study area bitmap

3.2 Status analysis

3.2.1Data acquisition and processing

For the existing rural landscape in the study area, remote sensing satellite images will be used as the data source for investigation. In this study, Landsat 8 OLI_TIRS remote sensing image data is used, and the spatial location of data collection is "administrative region", and it is specific to the provincial, municipal and county levels. The time range is April 2022-October 2022, and the cloud cover is less than 5%, and the scale is 1:5000. After the original data is obtained, the remote sensing image processing software (ENVI4.3) will be used to complete the radiation calibration, atmospheric correction, image mosaic and image clipping pretreatment operations to form the final vector image of township administrative boundaries, as shown in Figure 2. [8]

According to the definition of landscape ecology, rural landscape refers to a composite mosaic of different land units in rural areas. [9] According to the actual situation of the study area, the rural landscape is distinguished according to the remote sensing images of villages and towns. In villages and towns, the main landscapes are divided into five categories: park green space, protective green space, production green space, attached green space and other green spaces. With the help of Arc gis9.3 software, the vector images of administrative boundaries of villages and towns are rasterized, and the vector data of different types of rural landscapes are obtained one by one to prepare for the subsequent model analysis and operation, as shown in Figure 3.

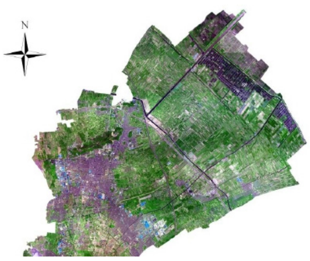

Figure 2 Remote sensing image map of villages and towns

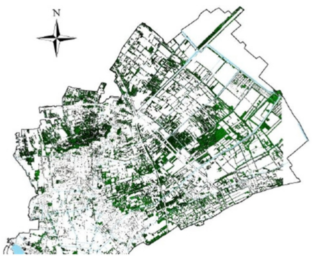

Figure 3 Present situation of rural landscape distribution

3.2.2Index analysis of the rural landscape

Through field investigation and aerial images, the size, shape, location and other data information of various types of landscape green spaces in villages and towns are extracted, and the corresponding GIS database is formed in Arc gis9.3 software. By selecting and calling different types of landscape green space data, combined with the index information in the evaluation system of landscape layout, the corresponding patch composition data, patch scale grade data and spatial index of landscape green space are calculated, as shown in Tables 2, 3 and 4.

Table 2 Landscape patch composition of rural green space

Patch type	NP	Quantity ratio	CA	Area ratio
Park green space	15	0.21%	$3.10hm^2$	0.20%
Protective green space	304	4.80%	$15.52hm^2$	0.95%
Production green space	2025	32.02%	$1360.83hm^2$	88.76%
Attached green space	1950	20.82%	$73.0hm^2$	4.89%
Other green spaces	2035	32.15%	$64.79hm^2$	5.20%

Table 3 Landscape patch size grades of rural green space

Patch type	MPS	The proportion of small patches	The proportion of medium patches	The proportion of medium and large plaques	The proportion of large patches
Park green space	$0.206/hm^2$	40%	26.67%	33.33%	0
Protective green space	$0.051/hm^2$	63.80%	35.87%	0.33%	0
Production green space	$0.672/hm^2$	41.10%	20.55%	16.88%	21.47%
Attached green space	$0.037/hm^2$	84.39%	14.65%	0.81%	0.15%
Other green spaces	$0.031/hm^2$	86.55%	12.27%	1.05%	0.13%

Table 4 Spatial indicators of landscape patches in rural green space

Patch type	PD	LPI	LSI	ENN	AI
Park green space	0.922	0.061	4.402	299.634	96.066
Protective green space	19.970	0.024	56.822	19.501	70.468
Production green space	133.523	0.912	62.347	8.777	96.672
Attached green space	42.841	0.074	44.371	19.706	81.955
Other green spaces	0.073	0.072	73.985	22.840	81.670

The results show that: at present, the production green space accounts for a large proportion with other green spaces in the rural green space landscape, and most of them are medium or large patches, which are dominant in the green space structure. However, the number and proportion of park green space are the lowest, and there is a significant imbalance in quantity ratio and area distribution. In addition, combined with the spatial indicators of landscape patches of rural green space, there are a large number of patches of various types of green space, but the average area is less than $1hm^2$, showing the distribution characteristics of fragmentation and fragmentation, which is directly related to the current numerous water systems, interference and other factors. It is not conducive to the opportunity of communication between green landscape and surrounding materials and energy and its improvement to the surrounding environment. Especially in parks and greenbelts, the patches are the farthest apart, lack certain spatial connectivity, are isolated in distribution, and the overall layout is unreasonable, which affects residents' daily rest.

In addition, in Arc gis9.3 software, park green space and township roads can be abstracted and converted into distance calculation between points, and the accessibility analysis results of park land can be obtained by combining ENN calculation. [10] Figure 4 shows the network data set of the combination of rural park green space and roads, and Figure 5 shows the analysis result of ENN's calculated distance. In the figure, the stars are represented as park green space, and the black dots are road travel points.

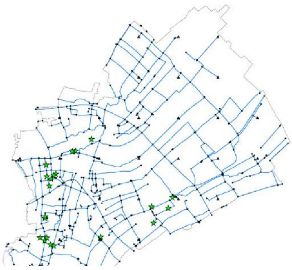

Figure 4 Park green space and road network dataset

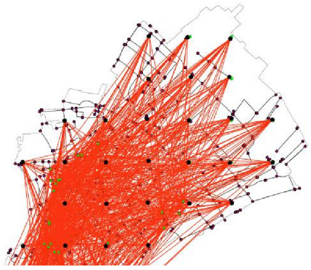

Figure 5 ENN distance analysis results

The calculated results are derived to form accessibility distance cost analysis and time cost analysis. Table 5 shows the time cost analysis data. After averaging the time cost data, it is imported into Arc gis9.3 software again to form the time cost grid division result, as shown in Figure 6. The results show that the current rural park green space is mostly concentrated in the south, and the northernmost starting point of 25, 26, 27 and 28 takes the longest time, with an average time of 30-35min. However, most of the starting points in the central and western regions take 15-20 minutes, which shows that the current layout of parks and green spaces in rural areas is unreasonable, concentrated in the south, and the service scope and service effectiveness to the north and east are low.

Table 5 Time cost analysis of accessibility

	Travel point 1	Travel point 2	Travel point 3	Travel point 4	...
Green space 1	15.80min	13.36min	14.05min	15..64min	...
Green space 2	14.61min	13.23mn	14.94min	18.85min	...
Green space 3	18.79min	13.19min	139.64min	19.74min	...
...	...	...	...	...	...

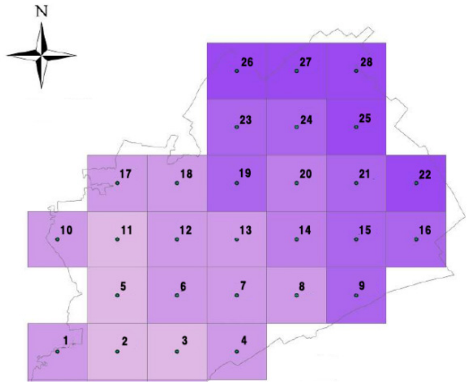

Figure 6 Accessibility analysis results of park green space based on time cost

3.3 Optimization design scheme

According to the analysis results of the present situation of rural landscape layout, we can sum up the problems existing in the current green landscape, and put forward corresponding optimization design suggestions based on this.

(1) Based on the existing superior resources, green landscape forms are innovated. As the absolute core of rural landscape, productive green space can provide great support for rural economic development, and it is also an important basis for the subsequent development of agricultural tourism.

(2) Facing the problem of fragmentation and fragmentation of green landscape patches, it is necessary to speed up the integration and construction of various types of green patches, optimize the road connectivity between patches, and improve the area ratio of finishing green landscape.

(3) For the current distribution pattern of park green space, new construction should be emphasized. Especially in the north and northeast of villages and towns, in order to improve the uneven distribution of parks and green spaces and meet the leisure needs of rural residents.

4 Conclusions

In order to optimize the layout of rural landscape design, this paper puts forward a set of implementation schemes for optimizing the layout of rural landscape in view of many practical problems existing at present, which provides scientific digital basis for the planning of rural landscape. Practice has proved that by using the spatial analysis ability of remote sensing images and GIS technology, suggestions for optimizing rural landscape layout are obtained from landscape index analysis and accessibility analysis, and it is necessary to focus on strengthening the leading role of production green space to pave the way for subsequent agricultural tourism; Strengthen the integrated construction of scattered green patches and improve the area ratio of green landscape; New parks and green spaces will be built to meet the actual needs of residents. In the follow-up research, we will further enrich the application scope of GIS technology, increase the content of spatial analysis, and make an attempt for digital rural landscape planning and design.

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