Ecological Characteristics and Layout Optimization of Rural Landscape for Smart Cities and Ant Colony Algorithms

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Abstract: Studying the spatial pattern of rural settlements and its influencing factors is important for guiding rural economic development, optimizing the living environment of rural residents, effectively using land resources, and accelerating the construction of urban-rural integration. The purpose of this paper is to study the ecological characteristics and layout optimization of rural landscape oriented to smart city and ant colony algorithm, introduce the concept of smart city and rural landscape, propose the ant colony algorithm, take Hengshan District as the research area, and use the method of landscape ecology to analyze the layout pattern and layout of rural settlements in Hengshan District in two periods of 2015 and 2020 under different landforms, different distances from rivers, roads and towns. The landscape characteristics were analyzed. On this basis, nine indicators affecting the layout of settlements were selected. Then, with the suitability of rural settlements as the optimization target, the ACO optimization model was constructed by combining the relevant theories of ant colony algorithm, and the layout of rural settlements in Hengshan District was optimized with the help of GeoSOS geographical optimization simulation system. The experimental results show that after optimization, there are 12,354 rural settlements in Hengshan District, with an average patch area of 0.52 ha and a decrease in the number of patches, while the density of rural settlements PD of patches decreases, indicating that the fragmentation of rural settlements is reduced and the connectivity of settlements is increased.

Keywords: Rural Landscape, Ecological Characteristics, Layout Optimization, Ant Colony Algorithm, Smart City

1. Introduction

Since the reform and opening up, the center of China's construction and development is mostly in the cities, and the development of rural construction is relatively slow. Most rural areas are still in the traditional living mode of the past, with scattered settlements and no detailed land use planning in rural areas, which makes farmers choose arbitrarily according to their own needs, which is not conducive to the protection of arable land and causes a large amount of rural land waste at the same time. Therefore, it is urgent to change the status quo of rural land use, improve the intensive use of rural land and optimize the layout of rural settlements, which has become a hot spot for research in multiple disciplines such as geoinformatics, landscape ecology and land use planning.

Rural settlements serve as the foundation for the social and economic development of rural areas, representing the outcome of social and economic progress up to a certain historical stage. The quantity and structural characteristics of land not only impact the layout and development trends of urban and rural construction land but also influence the overall balance of comprehensive land use structure and the socio-economic development of the region. Owing to its inherent requirements, many cities primarily focused on urban development have, to varying extents, overlooked issues related to rural land use, particularly in rural areas. For an extended period, rural concerns have been crucial matters linked to the overall development of China's economy and society. In comparison to urban areas, the development of China's rural regions has somewhat lagged behind. Therefore, studying the spatial pattern of rural settlements and their influencing factors is significant for guiding rural economic development, enhancing the living environment of rural residents, efficiently utilizing land resources, and expediting the process of urban-rural integration. The innovation of this paper is rooted in the exploration of the ecological characteristics and layout optimization of rural landscapes using the ant colony algorithm for smart cities, representing an innovative and practical approach.

2. Related Work

Based on the theory of sponge city and low-impact development, Duan T explained the origin, development, connotation and construction method of the concept of "sponge city", and took the urban design scheme of Renbei District in Chengdu City as an example. Meng L used nearest neighbor statistics, spatial correlation measurement model and spatial metric model to analyze the spatial variation characteristics of rural settlements in mountainous ecological reserves as an example in Sishui County, Shandong Province [2]. The aim of LIAO is to respond to the government's call to promote the construction of the Yangtze River Economic Belt under an ecological and green strategy, and to seek a coordinated "urban landscape" relationship between urban areas [3]. To improve the existing knowledge in this area, Schwerk A studied beetles in six study sites representing agricultural and post-agricultural areas with different treatments and their surrounding habitats during 2013-2015 [4]. However, the accuracy of the methods used for the layout of rural settlements was not high enough.

In fact, the use of ant colony algorithm has become a hot research topic. Many scholars have used the ACO algorithm in various aspects of research. ma S proposed a UGB division method from the perspective of spatial optimization. Urban processes and planning interventions are incorporated into the ACO model. The improved ACO model is able to retrieve the optimal UGB division pattern [5].Husain N P introduced an optimization approach utilizing the Improved Ant Colony Algorithm (IACA) to determine the optimal parameters for LSSVM diagnostic hepatitis [6]. Zhang X, on the other hand, utilized an improved ant colony algorithm, known as the niche ant colony algorithm (NACA) based on fitness sharing principle, to estimate the equation parameters using the spatial fractional diffusion equation [7]. Kadri O's focus was on proposing a novel fault diagnosis method for complex manufacturing systems, employing artificial neural network (ANN) and ant colony optimization (ACO) algorithms for condition monitoring of cement rotary kilns [8]. Despite these advancements, the studies have been critiqued for their lack of comprehensive considerations to adapt to more complex scenarios and the need for improved accuracy.

3. Ecological Characteristics of Rural Landscape and Related Methods of Layout Optimization

3.1 Theory Related to Smart City and Rural Settlement Layout

(1) Smart City

1) The concept of smart city

IBM considers smart cities as the visualization, analysis and integration of core urban systems using intelligent technologies [9]. It accelerates system responsiveness and promotes effective interaction, cooperation and innovation among participants in city construction and development to create a better life for humanity.

2）Characteristics of smart cities

From its basic connotation, smart city has comprehensive features such as data visualization, deep integration of information networks, collaborative innovation of information services and sustainable development.

(2) Theory related to the layout of rural settlements

1）The concept of rural landscape

"Landscape" (landscape) is divided into natural and human landscapes, where people create a holistic vision of beauty while observing it . From the perspective of geography, landscape is defined as: natural beauty: the integrated features of a region, including landscape, production, economy, history, culture, etc., which constitute an organic whole of harmony and unity of people and the environment [10].

2) Theory of landscape ecology

Landscape ecology, first proposed by the German botanist Troll, is a cross-cutting science that combines scientific ideas such as geography and ecology [11-12]. Its research scope is broad, integrating the interactions between various factors and spatial patterns such as social, economic and ecological. Landscape ecology takes the perspective of the whole landscape, emphasizing spatial variability and different performance at different landscape scales, while the landscape is highly integrative and a synthesis. The core of landscape ecology is the spatial pattern of the landscape, the process of ecological activities and the interactions among subsystems .

With the continuous development and improvement of the theory of landscape ecology, the theory is gradually applied in the research related to land use, and the optimization of rural settlement layout by analyzing the landscape pattern is a practice of landscape ecology in rural land use problems, and the use of landscape ecology theory can better rationalize the planning:planning of land use, scientifically carry out the layout of rural settlements, build a beautiful countryside, and improve the human living environment [13].

a) Location theory

Location theory is a theory about the spatial distribution of human activities and their interrelationships in space [14]. The layout of rural settlements is influenced by the locational theory, and the layout of rural settlements is a problem of optimizing the combination of natural, socio-economic, and human conditions, etc., which affect the layout of rural settlements, and their locational choices are largely influenced by these factors. Therefore, in the process of rural settlement layout optimization, location theory is particularly important.

b) Theory of spatial structure

The spatial structure theory of rural settlements is a crucial aspect of rural settlement research, impacted by both the rural economy and distinct social culture. The spatial layout of rural settlements cannot be separated from the local economic activities, but should be closely related. The optimization of spatial layout of rural settlements is actually a means and process to effectively allocate resources and give full play to comprehensive benefits.

c) Basic GIS theory

A rural settlement is a geospatial entity whose spatial layout and spatial relationships are largely subject to migration over time [15].

3.2 Ant Colony Algorithm

(1) Concept of ant colony algorithm

Ant Colony Optimization (ACO) refers to the process of searching for food by ants in nature. The behavior of one ant is relatively simple, but the colony can always find the shortest food path in different environments because the colony transmits information through some mechanism [16-17].

(2) Principle of algorithm

The principle of the ant colony to find the optimal path is shown in Figure 1 [18].

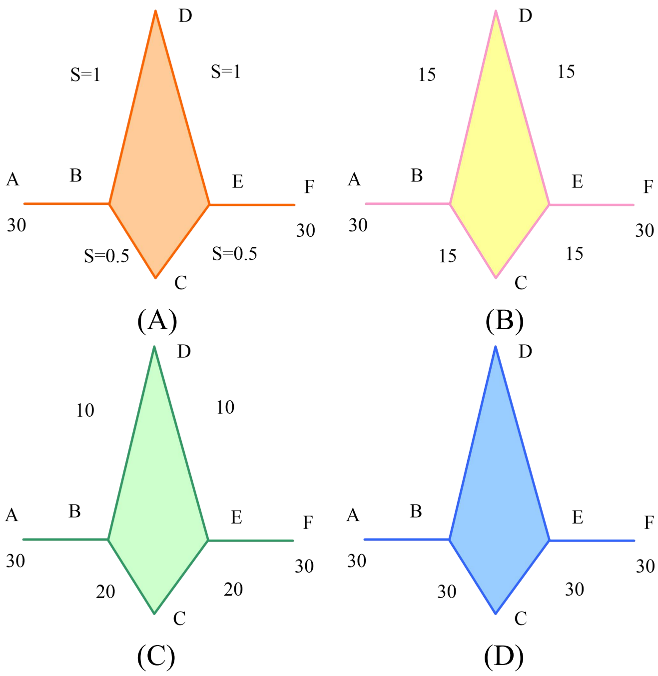

Figure1. Schematic Diagram of the Ant Finding the Optimal Path

Any ant n in the process of moving is deciding the direction of movement based on the amount of pheromone and the path-inspired information. s The probability of path selection for ant n moving from city i to city j at the moment $p_{ij}^n(s)$ is :

$$p_{ij}^n(s)=\begin{cases}\dfrac{[\tau_{ij}(s)^\alpha][\eta_{ij}(s)]^\beta}{\sum_{d\in allowed_n}[\tau_{id}(s)^\alpha][\eta_{id}(s)]^\beta} & \text{if } j\in \text{allowed}_n \\ 0 & else\end{cases} \quad (1)$$

i.e.

$$\eta_{ij}(s)=\frac{1}{g_{ij}} \quad (2)$$

After the ant completes a cycle, that is, it obtains a feasible solution of the traveling salesman problem, it will update the pheromone on the path. The size of the pheromone on the edge (I, J) at the time s+n is updated according to the following rules:

$$\tau(s+n)=(1-\rho)\tau_{ij}(s)+\Delta\tau_{ij} \quad (3)$$

$$\Delta\tau_{ij}=\sum_{n=1}^{u}\Delta\tau_{ij}^n(s) \quad (4)$$

Where, ρ denotes the volatility factor of pheromone, $\rho<1$; corresponding to $1-\rho$ denotes the residual factor of pheromone. $\Delta\tau_{ij}(s)$ denotes the amount of pheromone change on edge (i,j) for the nth ant in that cycle [19].

Depending on the pheromone update rules, there are three different ant colony algorithm models, as follows.

In the anthropomorphic system model:

$$\Delta\tau_{ij}^n(s)=\begin{cases}W & \text{If ant n passes edge ij in this cycle} \\ 0 & \text{otherwise}\end{cases} \quad (5)$$

In the anthropometric system model:

$$\Delta\tau_{ij}^n(s)=\begin{cases}\dfrac{W}{g_{ij}} & \text{If ant n passes edge ij in this cycle} \\ 0 & \text{otherwise}\end{cases} \quad (6)$$

In the peri-antennal system model:

$$\Delta\tau_{ij}^n(s)=\begin{cases}\dfrac{W}{R_n} & \text{If ant n passes edge ij in this cycle} \\ 0 & \text{otherwise}\end{cases} \quad (7)$$

In the above three models, w represents the strength of pheromone; R_n represents the total length of the path passed by the nth ant in this cycle; $\Delta\tau_{ij}^n(s)$ indicates the pheromone released by ant n on path (i,j).

3.3 GIS Spatial Analysis

(1) Directional ellipse analysis

The standard deviation ellipse can be expressed as :

$$SDE_a=\sqrt{\frac{\sum_{i=1}^{n}(a_i-\bar{A})^2}{n}} \quad (8)$$

$$SDE_b=\sqrt{\frac{\sum_{i=1}^{n}(b_i-\bar{B})^2}{n}} \quad (9)$$

where A_i and B_i are the coordinates of element i, $\{\bar{A},\bar{B}\}$ denotes the mean center of the element, and n is the total number of elements.

The elliptical rotation angle is calculated as follows:

$$\tan\theta=\frac{X+Y}{Z} \quad (10)$$

$$X=\left(\sum_{i=1}^{n}\bar{a}_i^2-\sum_{i=1}^{n}\bar{b}_i^2\right) \quad (11)$$

$$Y=\sqrt{\left(\sum_{i=1}^{n}\bar{a}_i^2-\sum_{i=1}^{n}\bar{b}_i^2\right)^2+4\left(\sum_{i=1}^{n}\bar{a}_i\bar{b}_i\right)^2} \quad (12)$$

$$Z=2\sum_{i=1}^{n}\bar{a}_i\bar{b}_i \quad (13)$$

where $\bar{A}_i$ and $\bar{B}_i$ are the deviations of the AB coordinates from the mean center.

The standard deviation of the A-axis from the B-axis is :

$$\sigma_a=\sqrt{\frac{\sum_{i=1}^{n}(\bar{a}_i\cos\theta-\bar{b}_i\sin\theta)^2}{n}} \quad (14)$$

$$\sigma_b=\sqrt{\frac{\sum_{i=1}^{n}(\bar{a}_i\sin\theta-\bar{b}_i\cos\theta)^2}{n}} \quad (15)$$

(2) Average nearest neighbor analysis

The average nearest neighbor analysis is employed to ascertain whether the spatial arrangement of point elements conforms to an agglomeration pattern, dispersion pattern, or random pattern [20]. The calculation formula is as follows:

$$F=\frac{\bar{W}_0}{\bar{W}_E} \quad (16)$$

$$\bar{W}_0=\frac{\sum_{i=1}^{n}w_i}{n} \quad (17)$$

$$\bar{W}_E=\frac{0.5}{\sqrt{n/X}} \quad (18)$$

Here, $\overline{W}_0$ represents the average distance between the observed point gist and its nearest neighboring point gist, while $\overline{W}_E$ denotes the average proximity distance between point gists in the random distribution model. w_i indicates the distance between element i and its nearest neighboring gist, with n representing the total number of gists, and X denoting the area of the smallest polygon that can encompass all elements.

The G-value is calculated as follows:

$$G = \frac{\overline{W}_0 - \overline{W}_E}{SE} \quad (19)$$

$$SE = \frac{0.26136}{\sqrt{n^2/X}} \quad (20)$$

(3) Nuclear density analysis

In ArcGIS, the kernel density analysis tool is used to calculate the density of a point or line element in its surrounding neighborhood [21-22]. Kernel density estimation belongs to a statistical method of nonparametric density estimation with the following equation:

$$k(a,b) = \frac{1}{nh^2}\sum_{i=1}^{n} k\left(\frac{r_i}{n}\right) \quad (21)$$

The formula incorporates k(a,b) as the density estimate at position (a,b); n as the observed value; h as the bandwidth or smoothing parameter; k as the kernel function; and r_i as the distance of position (a,b) from the ith observed position.

4. Experiment and Analysis of Ecological Characteristics and Layout Optimization of Rural Landscape Based on Ant Colony Algorithm

The spatial distribution pattern of size and shape of rural settlements, viewed as landscape spatial units or patches, constitutes the landscape pattern of rural settlements. In this chapter, landscape ecology techniques are employed, and ArcGIS and Fragstats landscape index analysis tools are combined to select suitable landscape pattern indices and quantitatively analyze the calculation results. This analysis helps to identify the size, shape, and layout characteristics of rural settlements in Hengshan District. Additionally, the relationship between the layout of rural settlements and topography, rivers, roads, and towns in Hengshan District is examined for the years 2015 and 2020. The chapter explores the primary issues with the layout of rural settlements in Hengshan District and identifies the possible causes of these problems. Furthermore, the driving forces behind land use changes among rural residents are analyzed, providing a theoretical foundation for improving the layout of rural settlements.

4.1 Analysis of Landscape Pattern *Characteristics in The Trans Mountain Area*

According to Fragstats landscape index analysis software, the landscape pattern index of rural settlements in Yokohama District was obtained, as shown in Table 1.

Table 1. 2015 and 2020 Landscape Pattern Index Analysis in Yokohama District

particular year	2015	2020
$CAhm^2$	6255	6489
PLAND/%	1.43	1.53
PD/km^2	3.85	3.98
NP	16578	17289
$MPShm^2$	0.35	0.35
LPI	1.36	1.44
MPFD	1.25	1.26
MNNm	88.98	87.66

According to Table 1, it is found that the value of the weighted average sub-dimension index AWMPFD of the area of rural settlement sites in Hengshan District from 2015 to 2020 increased from 1.22 to 1.28, indicating that the patch shape of rural settlement sites in Hengshan District is irregular and becomes more complex, although the change is only a small increase, it still indicates that the layout of rural settlement sites in Hengshan District lacks scientific management and reasonable Although the change is only a slight increase, it still shows that the layout of rural settlement sites in Hengshan District lacks scientific management and reasonable planning.

4.2 Characteristics of The Distribution of Rural Settlements in The Hengshan District

(1) The relationship between the distribution of rural settlements and towns

The urban land use data for 2015 and 2020 in Hengshan District were extracted from the urban land use layer. Subsequently, the buffer zone was analyzed at 1 km intervals based on the study area's area. The buffer zone was then divided into five categories: less than 1 km, 1 km-2 km, 2 km-3 km, 3 km-4 km, and 4 km-5 km. The buffer zone of urban land use was analyzed by overlaying it with rural settlements. This process yielded the distribution of rural settlements in Hengshan District at different distances from the town.

From the analysis of the situation, the area of rural settlements within the 1km area from towns increased from 991.31 ha in 2015 to 1284.89 ha in 2020, and the proportion of occupied area increased by about 4 percentage points. In the process of urbanization, rural settlements have a tendency to move closer to the edge of towns, and the average patch area has increased, and the aggregation of rural settlements closer to towns has increased. The rural settlements outside 1km and within 5km from the town have a small increase in area, but the average patch area has decreased, and the fragmentation of rural settlements remains unchanged. Meanwhile, rural settlements outside 5km from towns still account for a large proportion, nearly 30%. With the development of urbanization, rural settlements have a tendency to be built close to towns.

(2) The relationship between the distribution of rural settlements and rivers

The buffer zones were divided into five categories, namely less than 1 km, 1 km-2 km, 2 km-3 km, 3 km-4 km, and 4 km-5 km. The distribution of rural settlements at different distances from rivers in the Heng Shan District can be obtained.

As can be seen from data analysis, the area of rural settlements within the area 1 km from the river exceeds 50% in both 2015 and 2020, and the proportion within 3 km reaches about 86%, and the area of rural settlements within each area does not change much, which indicates that most of the rural settlements in Yokohama District are distributed within the area not far from the water, but according to the change of time, the layout of settlements to the river dependence has not changed much, and there is no large migration.

(3) The relationship between the distribution of rural settlements and roads

The primary road layers in the 2015 and 2020 land use data of Hengshan District were individually extracted, and buffer zones were analyzed at 1 km intervals based on the study area's size. These buffer zones were then categorized into five groups: less than 1 km, 1 km-2 km, 2 km-3 km, 3 km-4 km, and 4 km-5 km. By conducting a superposition analysis, the distribution of rural settlements in Hengshan District at various distances from the road can be obtained.

As can be seen from data analysis, the layout of rural settlements is more influenced by roads, and the proportion of rural settlements within 1 km from roads in 2015 and 2020 has been nearly half, and the area of settlements has increased from 2774.71 ha in 2015 to 2897.91 ha in 2020, with the average map area remaining the same, and people prefer to live in areas close to roads for traffic People tend to live in areas with convenient traffic. Compared with 2015, the proportion of rural settlements located more than 5km away from roads in 2020 decreases to 8.17%. With the increase of urbanization, the transportation infrastructure in Hengshan District is more complete, and the road and railroad network is more sound, so we should make full use of the transportation advantage and lay out the rural settlement sites scientifically and reasonably in the future.

(4) The relationship between the distribution of rural settlements and slope

The slope information in the DEM data of Hengshan District was extracted and the slope was classified into 5 levels, namely 0-2°, 2°-6°, .6°-15%, 15°-25° and greater than 25°. The slope layer was overlaid with the rural settlement layer, and the distribution of rural settlements in Hengshan District under different slopes could be obtained.

As can be seen from the data results, rural settlements in Hengshan District are mainly distributed in areas with slope less than 15°, and the area ratio of the whole district reaches 83.69% and 84.51% in 2015 and 2020, respectively. From the perspective of five years, the distribution of rural settlements in Hengshan District shows a trend of clustering in areas with low slope.

(5) The relationship between the distribution of rural settlements and altitude

The elevation information in the DEM data was extracted in the same way as the slope, and the elevation values of the rural settlements were extracted and analyzed by the "Extract Value to Points" tool of ArcGIS software. 1000m, 1000m < 1100m, 1100m < 1200m, 1200m < 1300m, 1300m < 1400m and greater than 1400m, and the distribution of rural settlements in Heng Shan District at different elevations can be obtained.

From the data results , it can be seen that the rural settlements in Hengshan District are mainly distributed below 1300m above sea level, and the scale accounts for more than 90%, because the area below 1000m above sea level in Hengshan District is not large, mainly concentrated on both sides of the Wuding River, so the proportion of rural settlements is not high, compared with the scale and proportion below 1000m above sea level in 2015, both have increased in 2020, the settlements are mainly distributed between 1000m and 1200m above sea level, mainly in the central and southeastern areas of the Heng Shan District, and the scale of settlements above 1200m above sea level has decreased in 2020, so it is said that the settlements have moved to places with lower altitude, which is beneficial to people's production activities.

(6) Problems with the layout of rural settlements in Yokohama District

Through the landscape pattern index and the quantitative analysis of the layout of rural settlements, combined with the field survey, the following problems are mainly found in the layout of rural settlements in the Hengshan District:

1) The settlement layout is scattered and the clustering degree is low.

In 2020, Hengshan District had a total of 17,277 rural settlement patches, accounting for a relatively small proportion of the study area at approximately 1.5%. The average area of these patches was less than 1 hectare, indicating a large number of small-sized rural settlement patches in the district. Additionally, the average sub-dimension index was 1.28, suggesting that the shape of the rural settlement patches in Hengshan District was complex, with irregular and "star-shaped" distributions being predominant. The density of patches is 3.99/ km^2 , and the average distance of neighbors is 87.64m, which indicates that the landscape fragmentation of rural settlements in Hengshan District is high, the average distance of settlements is large, the clustering degree is low, and there is a lack of scientific integration planning.

2) Low conservation and intensification of settlements and serious land idleness.

In 2020, the per capita area of settlements in the Hengshan district has already exceeded 200 m^2 per person, while the national range of per capita area of rural settlements is 120 m^2 per person-150 m^2 per person, which is far beyond the national range. Most of the farmers move to the areas with convenient transportation such as highways, railroads and rivers, but after building new houses, the old houses are not demolished, resulting in multiple houses for the farmers.

3) Poor infrastructure support inside the settlement, the living environment needs to be improved

With the development of social economy, the layout of rural settlements is also constrained by the surrounding environmental factors. Although the infrastructure of towns in the Hengshan District and the road transportation network are more complete, the rural roads are narrower and difficult for large transport vehicles to pass, while the drainage facilities and domestic garbage recycling systems in villages are not perfect due to the more disorganized settlements, and domestic sewage and garbage have caused a certain impact on the living environment.

4.3 Optimization Model of Rural Settlement Layout Based on Ant Colony Algorithm (ACO)

(1) The relevant parameters of the ant colony algorithm are set

The rural settlement layout optimization is completed using GeoSOS optimization software, and according to the settings of the operating platform, three parameters are initially required, namely, the heuristic weight A, the information weight B, and the pheromone evaporation coefficient C. Different combinations of the three parameters directly affect the convergence speed and accuracy of the ant colony search process. According to the research of related scholars, the convergence speed is kept stable near $A = 3 \pm 1$; near $B = 4 \pm 1$; and the convergence effect is better at $0.15 \le C \le 0.35$. Therefore, 1000 ants are used for 300 iterations, and the best combination of parameters is determined according to the convergence curve of the objective function by the combination scheme of different parameters (Table 2).

From Table 2, it can be seen that the parameter combinations 2, 3, 5, 6, 7, and 8 converge when the number of iterations does not exceed 50, and converge too early, resulting in a low final optimization score; the parameter combinations

1, 4, and 9 converge at a moderate speed, but the optimization score is relatively low; when the ant colony optimization parameter combination with the number 10 is used, it starts to converge gradually after the 250th iteration, and the convergence speed is The optimization score is the highest among the simulation results. Therefore, A=2, B=4, and C=0.35 are chosen as the parameter combinations of the ant colony optimization algorithm in this study.

(2) Analysis of ACO layout optimization results

To conduct a thorough analysis of the layout, a comparison and analysis of the landscape pattern of the spatial distribution of rural settlements was performed, and the measured results are presented in Table 3.

Table 2.Combination Settings of Parameters A, B and C of Ant Colony Algorithm

Serial number		1	2	3	4	5	6	7	8	9	10
Parameter value	A	2	3	3	2	4	2	4	4	2	2
	B	3	5	4	3	5	3	5	5	4	3
	C	0.15	0.25	0.15	0.25	0.25	0.25	0.25	0.35	0.35	0.35

Table 3. Landscape Pattern Analysis Before and after Optimization of Rural Settlements

index	Before optimization	After optimization
$CAhm^2$	6489	6489
PD / km^2	3.98	2.88
NP	17289	12354
$MPShm^2$	0.35	0.52
LPI	1.44	1.62
MPFD	1.26	1.25
MNNm	87.66	95.66

According to Table 3, it can be seen that after optimization, there are 12,354 rural settlements in Heng Shan District, with an average patch area of 0.52 ha and a decrease in the number of patches, while the PD of rural settlement patch density decreases, indicating that the fragmentation of rural settlements has been alleviated and the connectivity of settlements has increased. The maximum patch index LPI increases and the average nearest neighbor distance MNN increases, indicating that the aggregation of rural settlements increases, and the distance between patches will increase because the settlement layout reduces the distribution of sporadic settlements and shows a scale clustering distribution.

5. Conclusions

This study focuses on the layout of rural settlements in Hengshan District, with a specific emphasis on the following three aspects. Firstly, utilizing the principles of landscape ecology and incorporating Fragstats landscape index analysis software, the paper analyzes the layout pattern and landscape characteristics of rural settlements in Hengshan District during the periods of 2015 and 2020, considering different landforms, distances from rivers, roads, and towns. The aim is to explore the landscape pattern characteristics of rural settlements in Hengshan District. Secondly, based on the aforementioned analysis, nine indicators influencing the layout of settlements were identified. Finally, an ACO optimization model was developed by integrating relevant ant colony algorithm theories, with the objective of optimizing the layout of rural settlements in Hengshan District, using the suitability of rural settlements as the optimization objective. This was achieved with the assistance of the GeoSOS geographic optimization simulation system.

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