Study on the influence of water systems and roads based on ArcGIS on the layout and morphology of the forest plates in western Sichuan

A J Wan*, Y X Liu, X J Xie, R Q Tu, X L Qi and H L Chen

Institute of Modern Agricultural Science and Engineering, Tongji University, Shanghai 200092, China

*Corresponding authors. E-mail: wanajun@tongji.edu.cn (Ajun Wan); Phone: +86-181-0190-6160

Abstract: The research is about the influence of water source and road traffic conditions on the layout and pattern of the forest plates in western Sichuan, which provides a scientific basis for the quantitative description of the forest plates in western Sichuan. This paper establishes the GIS research platform based on the relevant basic data of the research area provided by the Deyuan Town Government. The buffer zone analysis, neighborhood analysis, fractal analysis and variance analysis were used to study the relationship between the shape and pattern of the forest plates and the water system and the road. The trend model of the forest plates' circular rate and the distance between the road and the water system was constructed respectively. The research results are that the optimal distribution distance of the forest plates from the water system is 10~40m. The optimal distribution distance of the forest plates from the road is less than 50m. In the buffer zone of 0~50m and above, the road has a greater influence on the morphology of the forest plates. The trend model of the forest plates' circular rate and the distance between the road and the water system respectively is nonlinear. Compared with the water system, the forest plates tend to be distributed in places with better road conditions.

1. Introduction

With regard to the study of rural settlements layout optimization, the fractal theory is used to study the morphology of residential areas [1-2] and to analyze the driving factors of its formation. When E Shixuan [3] and other people studied the formation reasons and driving factors of residential area in agricultural production areas, it was concluded that the distribution of residential areas in low hilly areas was more severely restricted by topography, traffic and rivers. When Shen Chenhua [4] and others studied the factors affecting the spatial layout and shape of rural residential areas in Danyang City, the results showed that the main factors affecting the distribution of rural residential areas were roads and rivers. Che Mingliang et al. [5] clarified the fractal characteristics of rural settlements in Pingyi Mountain, and discussed the intrinsic relationship between factors such as roads, water systems, and residents' incomes and fractivities. For agricultural production settlements, the long form of spatial layout makes the distance between farmers and farmland relatively short, which is conducive to improving production efficiency [6]. Most settlements make good use of water resources, roads and tend to be concentrated close to road networks rather than rivers. About half of the study areas are concentrated in rural areas, while others are scattered [7]. The hierarchical road network is the key to affect the spatial shape of residential areas [8-9]. Some scholars have also established a road-oriented residential space optimization pattern [10]. These studies have discussed the impact of water system and traffic road...
conditions on the patterns and layout of rural settlements [11-12], but the mathematical relationship
between them and the influence trend model have not been established.

The western Sichuan forest plate is a special form of rural residential areas, which consists of a few
households and dozens of households and surrounded by tall trees and bamboo forests of up to 20 meters.
Based on the arcgis geographic information platform, this paper studies the influence of roads and water
systems on the layout and pattern of forest plates, and uses sas programming to establish a mathematical
model of the relationship between forest plates morphology and distance from road and water system,
which provides a scientific basis for the quantitative description of forest plates.

2. Research area overview and data platform construction
The research area of this paper is located in the southern part of Deyuan Town, with a total area of 8.87
square kilometers. There are 179 forest plates in the research area of Deyuan Town, with a total area of
1.4 square kilometers. The forest plates are scattered and have different shapes. Most of the forest plates
are distributed in areas with abundant water source conditions and good traffic road conditions. Due to
the distance from the water system and the road, the size of the forest plates is different and the shape is
irregular. This paper uses the concept of circular rate to describe the forest plates’ shape. The distribution
relationship between the water system, roads and forest plate in the study area is shown in Figure 1.

3. Methods

3.1 Buffer area analysis
A buffer zone is a strip-shaped zone of a certain width established around a geographic entity or space
object to identify the influence of its surrounding objects. The size of the neighborhood is determined
by the neighborhood radius R. Therefore the buffer area of object O_i is defined as B_i = \{x | d(x, O_i) \leq R\},
which is the buffer area of the object O_i with radius R. B_i is a set of all points whose distance from O_i
is less than or equal to R. d generally refers to the minimum Euclidean distance, which is path distance
between space objects. For object collection O = \{O_i | i = 1, 2, ..., n\}, the buffer whose radius is R is the
union of each object buffer. That is

\[ B = \bigcup_{i=1}^{n} B_i \] (1)

The neighborhood radius R, which is the buffer distance (width), is the main indicator of the buffer
analysis and can be a constant or a variable. This article sets the buffer distance to be constant.

3.2 Proximity analysis
The proximity analysis process collects features for the analysis object in adjacent objects and calculates
the mutual distance. This article deals with the relationship between lines and points. Figure 2 shows
the closest distance of the forest plates particle to the water system, and the closest distance of the forest
plates particle to the road.
3.3 Fractal theory
Fractal theory treats dimensions as scores. They are based on the area-radius scale relationship (slewing radius method), the geometric measure relationship (circumference and area method), and the grid counting method. If the circular ratio is closer to 1, the shape is closer to a circle and the forest plates are more compact. If the circular ratio is not close to 1, the forest plate is looser, which can explain the complexity of the spatial distribution of rural settlements quantitatively.

\[ C_{\text{ir}} = \frac{4A}{P^2} \]  

Among them, CiR is a circular ratio, A is the area of the shape, and P is the contour circumference of the shape.

3.4 Analysis of variance
Variance analysis is a statistical method for analyzing experimental (or observed) data. Analyze the effects of various factors and interactions on certain index values of the study subjects.

In the analysis of variance, we decompose the total fluctuations of the experimental data (total variable or total variance) into fluctuations (variations of each factor) caused by the factors under consideration and fluctuations caused by random factors (variation of errors), and then analysis and compare these variations to infer which factors have significant impact on the indicators examined and which are not significant. There are three programming statements for variance analysis, ttest, anova, glm. The number of factors is two or more, and anova or glm can be used. Anova designed for the test of equalized data. The equilibrium data refers to the consistent sample size of each factor and level combination. The disequilibrium data uses glm statements. This paper compares the effects of water systems and roads with disequilibrium data.

3.5 Regression analysis
Regression analysis is a statistical method for studying the correlation between variables. The form of linear regression is:

\[ Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \cdots + \beta_pX_p + \varepsilon \]  

For the regression test of the regression equation, whether the statistical difference between each independent variable \( X_j \) and the dependent variable \( Y \) is significant is determined by the P value (the significance value. That is, \( p < 0.05 \), if significant, use \( R^2 \) value, namely the determination coefficient of the regression equation and F test to judge the fitting of the equation. The closer \( R^2 \) value is to 1, the larger F value is, and the higher the fitting degree of regression equation is.

4. Results and discussion

4.1 Buffer area analysis
In this paper, buffer zone analysis is used to divide the water buffer distance. The results are shown in Figure 3.
As can be seen from Figure 3 above, firstly, most of the forest plate settlements in the research area of Deyuan Town are distributed in the range of 0~70m from the water system. And 168 forest plate settlements are distributed within this range which are accounted for 94% of the total number of forest plate; When the distance from the water system is greater than 70m, the growth curve of the forest plate settlements is slowed down and flattened. When the distance from the water system is greater than 70m, the growth rate of the number of forest is less than 10 per 10m, indicating that the suitable distance of the forest plate settlements from the water system is less than or equal to 70m. The distribution of forest plate settlements in the buffer zone range of 10~40m from the water system is the most distributed. It can be seen that the distance from the water system is 10~40m, which is the optimal distribution distance of the forest plate settlement points in the research area of Deyuan Town. In general, the distribution pattern of the water system determines the distribution of the forest plate settlements, and the forest plate settlements is mostly distributed in a stable water supply station. On the contrary, the development potential of forest plate settlements far from the water system is limited.

As can be seen from Figure 4 above, firstly, most of the forest plate settlements in the research area of Deyuan Town are distributed in the range of 0~250m from the road. Secondly, as the distance from the road is more than 250m, the cumulative density basically shows a decreasing trend. It can be seen that the optimal distribution distance of the forest plate settlements in the research area of Deyuan Town is less than 50m from the road. In the range of 50m-150m buffer zone, the average number of forest plates is more than 30, and it can be seen that 50m-150m is the suitable distribution distance of the forest plate residential area. Most of the forest plate settlements are distributed near the highway, with convenient transportation, convenient foreign economic exchange and great development potential.

4.2 Analysis of variance

4.2.1 Two-way analysis of variance of roads and water systems
Analysis 0-50m and above 50m, the distance from the water system and the road and the circular rate
of the forest plate are disequilibrium data, so use glm programming. Through the glm programming of sas, the distance from the road is set to b, the distance from the water system is set to a, and the value of P is judged. Since the test hypothesis is that there is no difference between the respective variables, as long as p<0.05, it means that the null hypothesis is not true, which means that at least one independent variable of the model can predict the value of the dependent variable in a linear relationship. The result show that, P > 0.05, the circularity rate of the forest plate is independent of the order of the data group, indicating that there is no statistical difference between the circular rate of the forest plate and the order of the data group; P <0.05, which is related to the distance from the water system and the road, indicating that the circular rate of the forest plate is statistically different from the distance from the water system and the road. The result show that (a represents the water system and b represents the road) the circular rate of the forest plate is mostly in the range of more than 0.1 to more than 0.2 in the range of 0-50 m from the water system. In the range of 0-50 m from the road, the circularity of the forest plate is mostly in the range of less than 0.1 to less than 0.2. According to the smaller the circular rate, the forest plate shape is more dispersed and the the single forest plate accommodates more people. In the range of 0-50m from the forest plate centroid, the road has a greater influence on the circular rate of the forest plate, and people tend to be more inclined to live in areas with good road traffic conditions. In the range of 50 m or more from the water system, the circular rate of the forest plate is mostly in the range of 0.1-0.2. In the range of 50m and above from the road, the circularity of the forest plate is mostly in the range of more than 0.1 to more than 0.2. According to the smaller the circular rate is, the more dispersed the forest plate is, the larger the circular rate is, and the more compact the forest plate is, the road has greater influence on the circular rate of the forest plate in the range of 50m and above.

4.3 Data fitting and Establishment of regression model

The distance from the water system is divided into every 5m, and the average value of each distance and the average value of the corresponding circular rate are taken to make a trend of the circular rate of the forest plate from the water system (Figure 5). In the same way, the distance from the road is divided into every 10m, and the average of the distances of the segments and the average of the corresponding circular rates are taken to make a trend of the circular rate of the forest plate from the road(Figure 6). The fitting formula of the forest plate particle’s distance from the road and the circular rate is

\[ Y = -1.36 \times 10^{-6}X^2 + 0.22165\log_{10}(X) - 1.17240 \]  (adjusted R square value is 0.645),

where X represents the distance and Y represents the circular rate. The fitting formula of the forest plate particle’s distance from the water system and the circular rate is

\[ Y = -1.566 \times 10^{-5}X^2 + 0.0011X + 0.15287 \] (adjusted R square value is 0.6438), where X represents the distance and Y represents the circular rate.

![Figure 5. Trend analysis of distance from the water system and circular rate.](image)
Conclusion
1) The optimal distribution distance of the forest plate settlements from the water system is 10~40m. The optimal distribution distance of the forest plate settlements from the road is less than 50m.
2) According to the two-way analysis of variance of roads and water systems, in the range of 0~50m, the road has a greater influence on the circular rate of the forest plate, and people are more inclined to live in areas with good road traffic conditions. In the range of 50m and above, the road has a greater influence on the circular rate of the forest plate. The farther away the forest plate settlement is from the traffic road, smaller the population is, the more compact the forest plates are.
3) In this paper, we use the reg function of sas to fit the relationship between distance from the road and circular rate, and the relationship between distance from the water system and circular rate. The fitting formula of the forest plate particle’s distance from the road and the circular rate is \[ \log_{10}(y) = -1.36 \times 10^{-6}x^2 + 0.22165 \log_{10}(X) - 1.17240 \] (adjusted R square value is 0.645), where X represents the distance and Y represents the circular rate. The fitting formula of the forest plate particle’s distance from the water system and the circular rate is \[ y = -1.566 \times 10^{-5}x^2 + 0.0011x + 0.15287 \] (adjusted R square value is 0.6438), where X represents the distance and Y represents the circular rate.

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