Suitability Evaluation of Rural Human Settlements in Pengxi County Based on GIS

Hai Xiao1, *, Lingling Cao2 and Yu Wang2

1 College of Architecture and Urban-Rural Planning, Sichuan Agricultural University, Dujiangyan, China
2 College of Architecture and Urban-Rural Planning, Sichuan Agricultural University, Dujiangyan, China
*Corresponding author’s e-mail: 6178565@qq.com

Abstract. Based on the current hot topic of rural human settlements, this study takes Pengxi county of Suining city as the research object, selects the factors that affect the suitability of rural human settlements, and uses analytic hierarchy process to determine the weight. Based on GIS spatial analysis method, 10m× 10m grid is as the basic evaluation unit, which is divided into four types of areas, including unsuitable, generally suitable, suitable and most suitable. The results show that the suitable and most suitable areas account for 53.12% of the total area, and the general environmental suitability is better. This study provides a reference for the construction and development of rural human settlements at the county level in the Sichuan Basin areas.

1. Introduction

The human living environment is a multi-level surface space system which is closely related to human survival activities [1]. Mr. Wu divided the human environment system into five major systems: natural systems, human systems, social systems, residential systems and supporting systems [2]. The research on human settlements has the characteristics of spatial distribution differences, temporal continuity and research extensiveness [3].

Around these five systems, scholars in different fields have conducted research from different perspectives, and the living environment has increasingly become a hot spot of concern in architecture, planning, geography, and environment [4].

Since the 20th century, the acceleration of urbanization and industrialization has brought mankind superior material civilization and broad living and production space. At the same time, it has also led to a series of problems, such as excessive resource reclamation, climate warming, deterioration of ecological environment and continuous compression of human living space. The continuous expansion of the population has increased the demand for resources and environment, making the problem of human settlements increasingly prominent.

As for the researches on the suitability evaluation of human living environment, Sullivan proposed to conduct governance based on “humanism” in rural areas, and proposed the idea of human settlements from the perspective of humanistic care and human life in 2004. Chen Li [5] et al. (2019) used a variety of research methods of coefficient of variation and Gini coefficient to analyze the regional differences of rural human settlements for China provinces. Huibo Sun [6] et al. (2018) evaluated the quality of China rural human settlements environment from 2010 to 2015. Used nationwide ranges as study area, a model based on the national macro-scale human settlements environment index was set up, and...
analyzed the spatial relationships between various indicators and human settlements across the country. Kangkang Gu [7] et al. (2018) constructed an evaluation system consisting of five major subsystems: living conditions, economic development, infrastructure, public services and ecological environment, and evaluated the rural human settlements in Jianghuai area. Enyuan Zhang [8] (2014) applied a specific mountain area of the northeast Sichuan basin, taking a special geomorphic unit located in the transition zone of Daba Mountain and Sichuan basin, a comprehensive analysis of the five systems of different levels of human settlements construction was carried out. The regional environmental suitability evaluation analysis was also implemented.

However, the natural environment in Sichuan is relatively complicated. The evaluation of human settlements environment based on provincial and municipal levels often masks the characteristics of human settlements in different areas within the study area. Therefore, this study conducts a comprehensive evaluation index system based on county-level rural human settlements. This study combines space vector data, taking Pengxi county road networks and public service facilities as the research object, using the analytic hierarchy process and GIS technology to establish a public service facility buffer zone, and through the grid weighted superposition and spatial analysis method further to excavate the impact of regional urban construction on the comfort of the living environment. The gradual deepening of the description and representation of the appropriateness of the human settlement environment is done.

2. Research area overview, data sources and research methods

2.1. Research area overview
Pengxi county is located in the central part of the Sichuan basin, the eastern bank of the middle reaches of the Minjiang river, and the eastern part of the Suining City. Pengxi county has jurisdiction over 16 towns and 15 townships. It has initially formed a secondary industry dominated by textile and food industries. The three industrial clusters of the upstream industrial park, Jixing industrial park and Jinqiao industrial cluster are formed. The urbanization rate is 44%, the county green area rate is 31.85%, the green coverage rate is 37.83%, and the per capita park green area is 8.42 square meters. The transportation area is formed by the railway, Chengnan expressway and 318 national highway. For the skeleton, the county road is a network, and the rivers and reservoirs are complemented by modern transportation patterns.

2.2. Data sources
County road network data: in order to obtain real-time and updated road network data, the Pengxi County satellite remote sensing image data in 2018 was obtained through an electronic map downloader. The treatment of data rasterization, projection transformation, image cropping, etc., to establish a basic database of human settlements based on roads.

County-wide public service facilities and their attributes: the location and attributes of public service facilities within the county are obtained through the Gaode map (www.amap.com), and they are vectorized by GIS software and stored in human environment base database.

The county's planning indicator data: obtained the township-level administrative division data of the Pengxi county master plan document from the Pengxi county urban and rural planning administration. Among them, include Pengxi County's overall planning documents, township-level administrative division data, and township river vegetation status map.

2.3. Research methods
The analytic hierarchy process (AHP) is a comprehensive and objective evaluation of the development of rural human settlements systems. AHP, referred to as AHP, is a systematic and hierarchical analysis method combining qualitative and quantitative methods. It is a hierarchical weight decision analysis method. Specifically, the Yaahp analytic software will be used, and its steps are as follows:
Firstly, in the hierarchical model page of Yaahp analytic software, the decision target layer is added according to the above evaluation index system, the fifteen evaluation indicators in the next layer are used as the middle layer elements, and the content of the last added option is finally obtained. A hierarchical structure model for evaluating the suitability of rural human settlements in the county is achieved. Secondly, enter the judgment matrix page, refer to other papers for the evaluation index weight setting and field research results, compare the important degree or relative superiority of each evaluation factor, set the important degree of each factor. When the degree is less than 0.1, the judgment matrix can be considered to be consistent and the weight value can be accepted. Thirdly, enter the calculation result page to generate the final score of the weight evaluation of the rural human settlement environment in Pengxi county.

### Table 1. Weight distribution table of evaluation index system.

| Target layer                  | Primary index layer(A) | Secondary index layer(B) | Level 3 index layer                |
|-------------------------------|------------------------|--------------------------|-----------------------------------|
| Comfort                       | (0.2500)               | Rivers and waters(0.0750) | Highway(0.8000)                   |
|                               |                        | Square and green space(0.0250) | Station(0.2000)               |
|                               |                        | Vegetation(0.1500)        |                                   |
| Convenience                   | (0.2500)               | Traffic accessibility (0.1250) | Educational convenience(0.2000)  |
| Environmental suitability     |                        | Convenience of life (0.1250) | Medical convenience(0.4000)      |
| index table of rural village  |                        |                          | Market convenience(0.4000)       |
| residents in Pengxi county    |                        | Noise pollution (0.0714)  | Railway noise(0.3333)            |
|                               |                        |                          | Highway noise(0.6667)            |
| Health                        | (0.5000)               | Chemical pollution (0.4286) | Industrial pollution source(0.3180) |
|                               |                        |                          | Landfill(0.0990)                 |
|                               |                        |                          | Sewage treatment plant(0.0678)  |
|                               |                        |                          | Gas station(0.0621)              |
|                               |                        |                          | Contaminated waters(0.4531)      |

3. Result analysis

3.1. Suitability based on comfort factor

3.1.1. Vegetation. Vegetation plays a leading role in improving the rural living environment and maintaining ecological balance [9]. The vegetation factor is buffered, and the vegetation covered area and the non-vegetation covered area are obtained. The corresponding evaluation values are given to these two areas. Evaluation of Figure 1 was obtained. It can be seen that the impact of vegetation on the living environment in the study area is relatively balanced, and the difference is not obvious.

3.1.2. River and waters. Water resources have the ecological function of regulating climate and nourishing all things. Using the multi-ring buffer analysis method, the river water factor is buffered according to the buffer distance of Table 2. In the attribute table, the field calculator is used to add the evaluation value field for each buffer. The district area gives the evaluation value. The closer to the river waters can provide higher comfort of the human settlement environment and higher corresponding score.
Finally, using the surface-to-grid method to convert the vector data into 10m×10m raster data, the river water area evaluation Figure 2 is obtained. It can be seen that the river waters in the study area are mainly concentrated in the north and south ends and the central area, and the northwest area is relatively small.

| Impact factor     | Buffer level | Buffer distance(m) | Evaluation |
|-------------------|--------------|--------------------|------------|
| Rivers and waters | 3            | <250               | 5          |
|                   | 250-500      | 3                  |
|                   | >500         | 1                  |

3.1.3. Park square. The park squares in the county were extracted and referenced to the relevant literature to determine the buffer distance, and then do multi-ring buffer analysis. After the buffer analysis is completed, the evaluation is done by the field calculator, as shown in Table 3. The area with higher scores is much closer to the park square with higher comfort of the living environment. Finally, using the face-to-grid method to convert the vector data into 10m×10m raster data, the evaluation is shown in Figure 3. It can be seen that the influence of the park square is obvious, and the northern part is the best, concentrated in the vicinity of the county town of Chicheng. Second in the south, adjacent to the sub-center of Pengnan Town, the middle is the worst.

| Impact factor     | Buffer level | Buffer distance(m) | Evaluation |
|-------------------|--------------|--------------------|------------|
| Parks and squares | 4            | <500               | 5          |
|                   | 500-1000     | 4                  |
|                   | 1000-1500    | 2                  |
|                   | >1500        | 1                  |

3.2. Suitability based on convenience factor

3.2.1. Traffic accessibility. The extraction of traffic accessibility indicators mainly includes the two most influential factors of road and station. The distance from the station site shows the convenience of the villagers to travel across towns and towns. The extraction of factors is mainly for the passenger stations and call stations with fixed locations. Road elements include all village road grades and above within the county. According to the ways of travel of the villagers and the time cost required to arrive at the station, the buffer distance of station and road are determined. The buffer distance value represents the accessibility of the station and the road, and the evaluation value is assigned to the buffer area, as shown in Table 4. It can be seen that the traffic accessibility of the study area is relatively balanced, and the difference is not obvious.
Table 4. Traffic accessibility impact factor buffer distance table.

| Impact factor | Buffer level | Buffer distance (m) | Evaluation |
|---------------|--------------|---------------------|------------|
| Highway       | 4            | <500                | 5          |
|               |              | 500-1000            | 4          |
|               |              | 1000-1500           | 2          |
|               |              | >1500               | 1          |
| Station       | 4            | <1000               | 5          |
|               |              | 1000-2000           | 4          |
|               |              | 2000-4000           | 2          |
|               |              | >4000               | 1          |

3.2.2. Convenience of life. This study extracts educational facilities in the study area, including various primary and high schools, secondary technical colleges. Medical facilities include township central hospitals, county hospitals and major private hospitals. The market scope is the area where villagers go to market.

The buffer distance is used to indicate the convenience of education, medical care and market. The educational facility buffer distance is determined by the service radius, and the second convenient area is determined by the walking distance of around 30 minutes. Medical convenience and market convenience are determined by walking and driving distance for a certain period of time [10]. After the buffer distance is determined, the evaluation is evaluated by the field calculator, as shown in Table 5.

Table 5. Life convenience impact factor buffer distance table.

| Impact factor          | Buffer level | Buffer distance (m) | Evaluation |
|------------------------|--------------|---------------------|------------|
| Educational convenience| 3            | <1000               | 5          |
|                        |              | 1000-2000           | 3          |
|                        |              | >2000               | 1          |
| Medical convenience    | 3            | <2000               | 5          |
|                        |              | 2000-5000           | 4          |
|                        |              | >5000               | 2          |
| Market convenience     | 4            | <1000               | 5          |
|                        |              | 1000-2000           | 4          |
|                        |              | 2000-4000           | 2          |
|                        |              | >4000               | 1          |

In this study, the raster layers of three factors affecting the convenience of life are compared with the weight values in Table 1, and the weighted sum method is used for superposition analysis to obtain a life convenience evaluation chart with a grid of 10m×10m. According to Figure 10, the convenience of living in the study area is close to the county town and the area adjacent to Suining city center, its daily
life is the most convenient. The second is the southern part of the Pengxi county Sub-center, and its central convenience is relatively poor.

3.3. Suitability based on health factors

3.3.1. Noise pollution. According to field investigations and inquiries the villagers about two largest noise sources along the railway and expressway, this study extracted Dachen railway and Miansui expressway, Chengnan expressway, Suixi expressway and Suiguang expressway, which have the most serious impact on rural noise pollution.

This study will be evaluated in accordance with the provisions of the "Regulations on the Administration of Railway Technology" Figure 11-12.

Table 6. Noise pollution impact factor buffer distance table.

| Impact factor     | Buffer level | Buffer distance(m) | Evaluation |
|-------------------|--------------|--------------------|------------|
| Railway noise     | 4            | <50                | 0          |
|                   |              | 50-500             | 1          |
|                   |              | 500-1000           | 3          |
|                   |              | >1000              | 5          |
| Highway noise     | 4            | <100               | 0          |
|                   |              | 100-300            | 1          |
|                   |              | 300-1000           | 3          |
|                   |              | >1000              | 5          |

As shown in Figure 13, Chengda railway and Chengnan expressway along the north of the study area are affected by both highway and railway noise, and the noise pollution is the most serious. The central region has the best acoustic environment as there is no highway and railway influence.

Figure 13. Noise pollution score chart.
3.3.2. Chemical pollution. The chemical pollution involved in this study mainly includes five indicators of industry, polluted waters, sewage treatment plants, gas stations and landfills. Extracts three industrial clusters and scattered factories in the territory, and eutrophic waters. Three sewage treatment plants in the county towns, the major gas stations and the landfills in Dashi Town have been built and used.

Table 7. Buffer distance table of chemical pollution impact factors.

| Impact factor       | Buffer level | Buffer distance(m) | Evaluation |
|---------------------|--------------|--------------------|------------|
| Industrial          | 4            | <500               | 1          |
|                     |              | 500-1000           | 2          |
|                     |              | 1000-2000          | 4          |
|                     |              | >2000              | 5          |
| Contaminated waters | 3            | <500               | 1          |
|                     |              | 500-1000           | 3          |
|                     |              | >1000              | 5          |
| Sewage treatment plant | 4          | <100               | 0          |
|                     |              | 100-300            | 1          |
|                     |              | 300-1000           | 3          |
|                     |              | >1000              | 5          |
| Gas station         | 3            | <2000              | 0          |
|                     |              | 2000-5000          | 3          |
|                     |              | >5000              | 5          |
| Landfill            | 3            | <800               | 0          |
|                     |              | 800-2000           | 3          |
|                     |              | >2000              | 5          |

This study refers to the relevant papers and the safety distance regulations of major facilities to determine the buffer distance, which is evaluated in Figure 14-18.

According to Figure 19, the distribution of chemical pollution in the study area is uneven and there are certain differences. The north area near the center of Suining is seriously polluted, followed by the southern part of Pengxi county and the sub-center, and the middle area is relatively good.

3.4. Comprehensive suitability
Using the buffered analysis of each factor raster layer, the weighted summation method is used to perform weighted superposition analysis according to the weight ratio set in Table 1, and the suitability evaluation profile of rural human settlement environment in Pengxi county is obtained.
According to Figure 20, the maximum value of suitability of rural human settlements in Pengxi county is 4.9, the minimum value is 1.97, and the average value is 3.57. The proportion of the suitability of human settlements beyond the average is 48.03%, which is less than half of the whole area. It shows that the overall adaptability of rural living environment is general. In order to respond to the rural revitalization strategy, the rural areas will be better and faster, and it is imperative to further improve the rural living environment.

Table 8. Comprehensive factor suitability analysis.

| Types of suitable areas      | Target | Percentage |
|------------------------------|--------|------------|
| Unsuitable area              | Area   | 7.14%      |
|                              | Population | 5.34%    |
| General suitable area        | Area   | 39.73%     |
|                              | Population | 35.43%    |
| Suitable area                | Area   | 44.45%     |
|                              | Population | 46.51%    |
| Most suitable area           | Area   | 8.67%      |
|                              | Population | 12.72%    |

4. Conclusion and suggestion

Based on GIS technology, this study refers to the conditions that meet the requirements of human basic living conditions summarized by the World Health Organization [11], selects multiple indicators of comfort, convenience and safety evaluation factors, and proposes the basic research ideas of residential environment suitability evaluation. Quantitative evaluation of the suitability and restriction of the natural environment of human settlements in Pengxi county, the evaluation results reflect the characteristics of spatial suitability and spatial differentiation of the middle area of Pengxi county, and coordinate development and scientific planning of regional human settlements construction to provide evidence and decision support. The results show:

The unsuitable area accounts for 7.14% of the total area, mainly distributed in the northwest and southwest areas near the ship-mountain area of Suining city. This area mainly has the large number of factories and three large-scale industrial parks, which are seriously affected by industrial pollution. In addition, due to fewer river waters, traffic noise pollution and other factors, the overall suitability of rural human settlements is relatively poor.

Generally, the proportion of suitable areas is 39.73%, mainly distributed in south and northwest regions. It accounts for a relatively large proportion in four categories. This area is located at the edge of the industrial area. The river water conditions are general, the living facilities are limited, and the living environment is relatively general. Therefore, the overall rural habitat environment is generally suitable.

The proportion of suitable areas is 44.45%, which is the largest, and its distribution is relatively scattered, mainly in the vicinity of the old town of the county. The area was developed earlier. Although
its living service package is superior, its vegetation conditions are relatively poor, and river water conditions are not optimal. In summary, its convenience is relatively good, but due to the limitations of comfort, its overall rural habitat environment suitability cannot be the best in this study area.

The most suitable area is relatively small, accounting for only 8.67%, mostly concentrated in the central and northern regions. These areas have good river waters and vegetation conditions, superior natural conditions, excellent living services, and are far away from chemical pollution and noise pollution. Their comfort, convenience and especially health are better than other areas, which is the most living environment in this study area.

References
[1] Liangyong Wu. (2001) Introduction to Sciences of Human Settlements. China Architecture & Building Publishing, Beijing.
[2] Jiangang Wen, Meng Gao, Jianfeng Zhao, et al. (2013) Research on the evolution and improvement of rural living environment in Suzhou. Ecological Economy, 5: 175–179.
[3] Yonghua Zou. (2002) A preliminary study on the influence of the thought of "human settlement environment science" on architectural design discipline. Planners, 10: 50–52.
[4] Zhen Huo, YaGuang Li. (2010) Research on Suitability Evaluation of Human Settlements in Dianchi Lake Basin Based on GIS. Soil and water conservation study, 17: 159–162.
[5] Chen Li, Rui Zhao, Qingyuan Tang. (2019) Temporal and spatial differences of rural living environment in China based on provincial data. Journal of ecology, 31: 1–13.
[6] Huibo Sun, Xia Zhao. (2018) Evaluation of the quality of Chinese rural living environment and differentiated governance strategies. Journal of Xi'an Jiaotong University, 1:10–11.
[7] Enyuan Zhang. (2018) A study on the human settlement environment of the basin surrounding mountainous areas in northeast Sichuan -- a study on the sustainability of urbanization and urban-rural integration process. Southwest University of Science and Technology, Mianyang
[8] Kang-Kang Gu, Xuexia Liu. (2018) Study on the quality evaluation and spatial differentiation of rural residential environment in Jianghuai area, Anhui province. Journal of ecology and rural environment, 34: 385–392.
[9] Bingming Shen, Yan Jin. (2006) Comprehensive evaluation of natural elements of mountain dwelling environment based on GIS -- a case study of Xianju county, Zhejiang province. Economic geography, S1: 305–311.
[10] Wan Min Zhao, Mao Feng, YaLan Li. (2017) Cooperative sharing and allocation method of public service facilities in villages and towns. Planners, 33: 78–83.
[11] Yang Chou. (2012) Study on the suitability of living environment in Baoan district of Shenzhen city based on GIS. Southwest University, Chongqing.