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Suitability Evaluation and Zoning of Construction Land for Suburban Villages and Towns Based on ESP and MCE Model: A Case Study in Qunfeng Town, Zhuzhou City, China

Suifeng Zhang[1,2], Difei Jiang[1*], Yu'an Liu[2],Hongduo Yu[2]
[1]Dept. of Architecture and Art, Central South University, Changsha, China
[2]Dept. of Urban and Environment, Hunan University of Technology, Zhuzhou, China
*Corresponding Author.

Abstract:

As a result of the booming city development in china, the recurring problem of "overdevelopment and ecosystem damage" reflects the inadequate understanding of sustainable environment. The suitability evaluation and zoning of construction land in suburban villages and towns is an important way to guide the coordinated development of space expansion and ecological environment protection. To better understand the suitable uses and the development direction of land based on the security protection of ecology. This study proposes a method of suitability evaluation and zoning based on the model of minimum cumulative resistance (MCR) and ecological security pattern (ESP). First, ecological security pattern shows a stepped spatial trend, and the high-level area accounts for a large proportion, in which traffic location and land use mode are the key factors; Second, the most suitable and suitable types of construction land account for more than 1/2 of the total area, with obvious advantages in economic activities; Third, the gap of 0.52km2 protection gap is identified, indicating that there is a spatial conflict between land development and ecological security; Finally, there are three types of zoning based on the suitability evaluation: Economic development zone, Agricultural safety zone and Ecological safety zone. This study indicates that the suitability and zoning of construction land can effectively optimize and regulate the spatial governance of land use, and provide a theoretical basis for the preparation of land spatial planning of suburban villages and towns.

Keywords: *Suburban villages and towns, Construction land, Suitability evaluation, Zoning, Qunfeng town*

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I. INTRODUCTION

Land suitability refers to the chain effect of coordinate the suitability of land use function in a specific area into human activities, which directly affects land resources, land structure and ecological environment [1]. Land suitability evaluation and zoning is the core of land spatial pattern optimization and land spatial planning [2]. The ecological succession process of the interaction between human activities and natural (soil, forest, water, etc.) is the leading factor for the sustainable development of land use space [3]. From the perspective of maintaining the ecological security pattern of suburban villages and towns [4], the establishment of a planning mechanism of "ecological protection land use development" will scientifically plan the appropriate development and utilization of land resources. It is an important path to respond to the spatial planning of suburban villages and towns and coordinate ecological environment.

Land suitability was originated in the late 19th century and the early 20th century when the United States used manual overlay images to evaluate land suitability [5]; Mcharg believes that rational land use should be combined with nature, and puts forward the evaluation model of "thousand layer cake" [6]; Haber believes that land use has the characteristics of spatial differentiation, and agricultural land development should be effectively combined with nature protection, and puts forward DLU (differentiated land use) system. In the 1970s, China began to learn from foreign ideas to form a series of land use evaluation methods and theories [7]. However, with the rapid growth of urbanization and the sprawling expansion of land space [8], the contradiction between man and land has become increasingly prominent. In addition, ecosystem functions and biodiversity protection have been increasingly squeezed, which directly affects the level of national security and has become a serious obstacle to regional sustainable development [9]. Therefore, the study is carried on land suitability, which has gradually become a hot issue concerned by domestic scholars. The study mainly includes: one focuses on different types of land suitability evaluation systems [10]; The other is the identification of land suitability under the concept of ecological protection [11-12], and the geographical process simulation of land spatial pattern under the support of new technology [13-14]. The study mainly focuses on meso urban scale and micro residential space due to the diversity and complexity of ecological and geographical environment, and the evaluation framework and index system of ecological coordination mechanism have not yet formed systematic standardization. Suburban villages and towns are obviously affected by urban function spillover, with the characteristics of active land use transformation and staggered urban and rural land use [15]. With the deepening of space planning, the study on coupling the ecological security pattern can effectively avoid the risk of land overdevelopment and guide the orderly development of space, which is from the micro dimension of construction land in suburban villages and towns.

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In response to the above questions, the study proposes a method base on MCR and MCE to coordinate ecological security protection with land spatial development, and takes Qunfeng town of Zhuzhou City as an example, the land suitability evaluation results are obtained and the spatial conflict test is carried out by constructing the land suitability evaluation index system and the two-dimensional matrix of "ecological resistance development power" to abtain the land suitability evaluation; Finally, the functional zoning is defined through the degree of land suitability, which provides reliable guidance for suburban villages and towns.

II. MATERIAL AND METHOD

2.1 Study Area

Qunfeng town is located in the south of Tianyuan District, Zhuzhou City and the West Bank of Xiangjiang River, a modern industrial city with rapid development. It governs 15 communities and is 6km away from the county. It relys on rail transit and new energy vehicles, and is a typical suburban villages and towns. Zhuzhou is one of the old industrial basis in southern China. Qunfeng town covers a total area of 59.06 km^2. It is a major gathering area for smelting, powder metallurgy machinery, brick making, tea making and other industries, with 29 industrial enterprises. The area is close to the ecological protection area of Xiangjiang River and the ecological green space of Chang Zhu Tan. The rapid development of industrial economy poses a certain threat to ecological environment. Therefore, it is the practical demand of spatial planning to reasonably adjust the relationship between human disturbance and natural ecology, and then delimit land development zoning.

2.2 Data Source and Processing

The basic data of the sample area mainly includes lantsat 8 oli satellite remote sensing image (30M resolution, from geospatial data cloud), land use status map. With the aid of high-precision remote sensing images, this study is carried out on basic farmland, industrial and mining enterprises and ecological protection areas, and predicts the possible areas of land expansion.

The preliminary interpretation of remote sensing images is carried out with the help of ENVI5.2, and the manual proofreading and interpretation results are combined with field survey, Google maps and topographic map. The land use classification and normalized vegetation index (NDVI) data are obtained through comprehensive classification, and the GDEMV2 digital elevation map (DEM) data of are extracted by projection conversion and mask to establish the land use spatial database of Qunfeng town.

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2.3 Methods

2.3.1 Evaluation indicators selection of ecological security

The construction of ecological security pattern (ESP) is a means of ecosystem and biodiversity protection, and a state in which human production and life adapt to the ecological environment without threat. Kongjian Yu constructs the landscape ecological security pattern and keming Ma puts forward the regional ecological security pattern [16-17]. Due to the different contents of ecological security evaluation, there is no unified standard for the evaluation index system. In view of the existing research and data accessibility [18], this study selects 9 indexes that can fully reflect the ecological security status of the sample area, which is constructed mainly from ecological attribute and interference to establish a comprehensive evaluation index system. Land use type, elevation, slope, slope direction and vegetation coverage are ecological attributes, which are ecological pattern status indicators. Distance from transportation, water body, residential area and industrial and mining area are ecological interference attributes, which are human activity indicators.

The principal component analysis (PCA) is used to determine the weight value of the ecological security evaluation index of suburban villages and towns. The "ecological security index" of Qunfeng town is taken as the overall target layer and the ecological resistance is taken as the criterion layer. Finally, the weighted sum is obtained to evaluate the spatial distribution of the ecological security level of Qunfeng town [19].

$$E = \sum_{j=1}^{m} P_{ij}\, w_j \qquad (1)$$

e is the ecological security index of Qunfeng town; w_j is the weight of each index.

2.3.2 Identification of ecological sources based on MSPA model

Ecological source is the zone of biological and ecosystem diffusion. This study proposes a method based on MSPA (morphological spatial pattern analysis) model, which is proposed by Soille and Vogt. It is used to identify the ecological source [20-21]. This method emphasizes the structural connection of the landscape, and then identifies the landscape types that maintain the connectivity through a series of image processing methods. Seven types of landscape spatial forms are generated with the help of guidos software. Natural ecological elements such as forest land, garden, grassland and water area are taken as the prospect in land use reclassification. Based on the existing studies and the patch fragmentation in the core area of the sample Landscape [22], the area in the pixel is greater than 0.1km^2. Habitat patches such as

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landscape core area, edge area and connecting bridge area are defined as the source of ecological corridor connection.

2.3.3 Extraction of ecological corridor and construction of ecological resistance surface

Forman believes that the ecological pattern is an overall system connected by various patches through corridors [23]. MCR model refers to the evaluation method of "node/chain" to simulate the minimum cost path of each spatial unit from the nearest source, so as to measure the spatial connectivity trend and carry out different spatial interaction feedback [24].The linkage mapper1.1.0 plug-in is used to obtain the minimum cumulative consumption path of the ecological corridor in Qunfeng town. The calculation formula of the minimum cumulative resistance model is:

$$R_{MC} = f_{min} \sum_{j=n}^{i=m} (D_{ij} \times R_i) \quad (2)$$

R_{MC} is the minimum cumulative resistance value of ecological corridor in Qunfeng town; f_{min} represents positive correlation function; D_{ij} is the spatial distance; R_i is the resistance coefficient.

2.3.4 Construction of evaluation index system

The reasonable selection of index factors is the key link of land suitability evaluation. The suitability evaluation index system of rural construction land is constructed from the perspective of "ecological resistance - development power", and the factors are divided into ecological resistance factors and land development factors [25]. The main factors of human activities are determined from the intensity of space distance radiation, which affect land development power. The comprehensive evaluation is carried out from four aspects: the distance from the central urban area, the distance from the high-speed railway station, the population density and the proportion of the built-up area. AHP analytic hierarchy process and principal component analysis are carried out to obtain Table I and Table II. It can be seen that the classification and weight of each single factor from them. The consistency test of AHP methodCR $= 0.044$ (CR ≤ 0.1), and the fuzzy two-dimensional judgment matrix has consistency; In addition, it is found that the distance from the principal component characteristic value > the distance from the high-speed railway station > population density > the proportion of built-up areas, indicating that the strength of traffic distance has a high impact on the development of suburban villages and towns; Population density is the direct condition that determines the expansion of land; The proportion of built-up areas is the basis for supporting the expansion of land and the policy factor for the development of agglomeration areas.

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2.3.5 Multi-factor superposition comprehensive evaluation (MCE) model

Multi criteria evaluation is used to make mathematical statistics on the relevant data of each element to determine the factor weight value through the constructed suitability evaluation index system of rural construction land. The grid distribution maps of various factors are weighted and superimposed with the help of ArcGIS, and the fine patches are merged, and the "natural breaks" method is used for reclassification to obtain the spatial results of construction land suitability evaluation in Qunfeng Town, that is, the most suitable, suitable, unsuitable and prohibited construction land. The calculation formula of the evaluation model is:

$$Suit=\sum_{i=1}^{n} Wi * Pi \quad (3)$$

Suit is the comprehensive evaluation value and *Wi* is the weight value; *Pi* is the score of the *i* single indicator, and *n* is the total number of indicators.

Table I. Two dimensional incidence matrix of "ecological resistance - development power" of construction land in suburban villages and towns

Suitability evaluation	Resistance factor	Development factor	Port Vector	Priority
Resistance factor	1	3	0.25	
Development factor	1/3	1	0.75	

Table II. Principal component characteristics and contribution rate of sample area

Principal Component	Characteristic Value	Contribution rate /%	Cumulative contribution rate /%
1 Ecological security pattern	2.92847	56.6481	56.6481
2 Distance from central urban area	1.15139	22.2723	78.9204
3 Distance from high speed railway station	0.60955	11.7910	90.7114
4 Population density	0.28026	5.4213	96.1327
5 Proportion of built-up area	0.19992	3.8673	100.0000

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III. RESULTS AND ANALYSIS

3.1 Analysis of Ecological Security Pattern in Qunfeng Town

3.1.1 Ecological security assessment in Qunfeng town

To affect the level of regional ecological security, it is found that the closer the sample area is to the water body, the stronger the anti-interference ability is, and the higher the ecological security level is; The closer it is to residential areas, roads, industries and mines, the more frequent human activities and the more serious habitat fragmentation according to the ecological security distribution of each index. In addition, 43 ecological sources are selected from the landscape spatial classification based on MSPA method. Figure 1 shows that the ecological sources in Qunfeng town are concentrated as a whole and scattered locally, mainly concentrated in the ecological core area of Chang Zhu Tan in the southwest region, with a total area of 48.89km^2. Patches provide important habitats for species diffusion, but due to the relative dispersion of ecological sources, ecological corridors need to be constructed to ensure the safety of ecosystem.

3.1.2 Classification of ecological security pattern in Qunfeng town

The ecological security assessment in Table III shows that the ecological security level has a strong correlation with natural environmental factors. Elevation and slope direction covers an area of 12.87km^2, accounting for 23.84%, and it is mainly distributed on the constructed land; Medium level security area is 13.71km^2, which is the direction of future construction land expansion on the basis of improving ecosystem service function; The areas of lower safety and low safety are 12.47km^2 and 11.42km^2 respectively. The trend of ecological environment protection is not obvious, indicating that human activities have strong interference. It can be seen from Figure 2 that it is mainly distributed in the green heart area of Chang Zhu Tan in the southwest, which is the core area of ecological protection, and all kinds of construction activities should be prohibited. The construction of ecological security pattern can scientifically delimit the ecological resistance area for the development of construction land in suburban villages and towns, and better control the interference of ecosystem. It is an important way of land spatial planning under the construction of ecological civilization.

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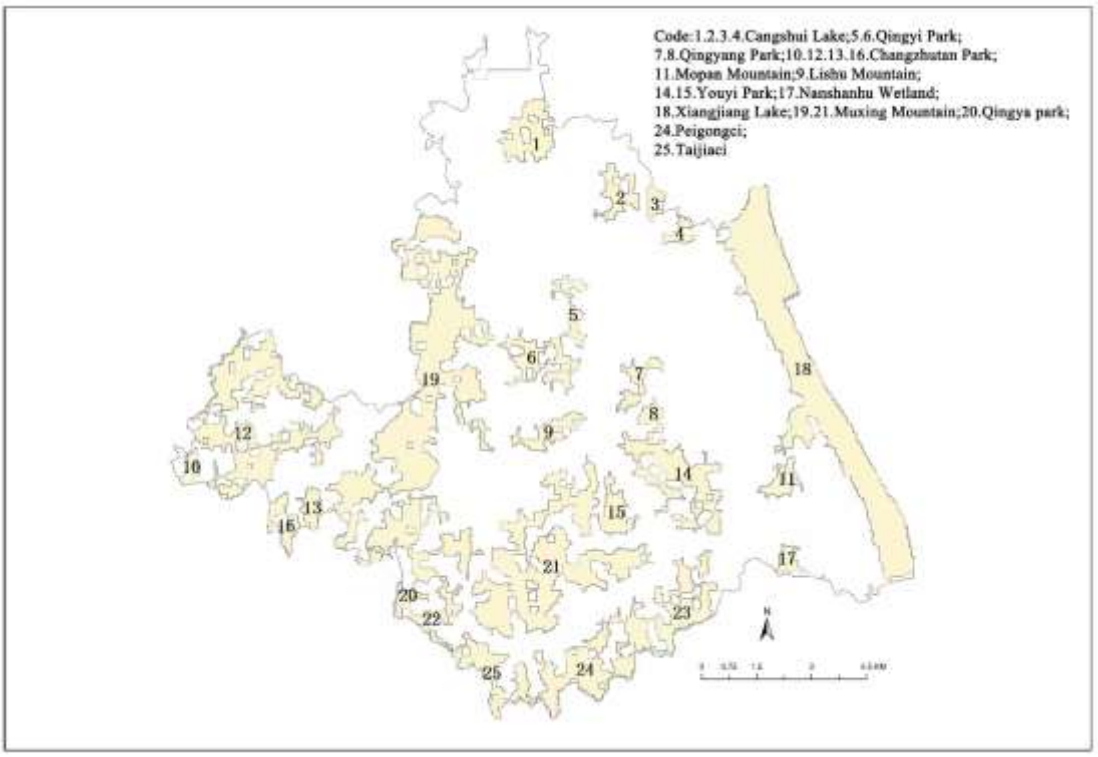

Fig 1: Dentification of ecological sources in Qunfeng town

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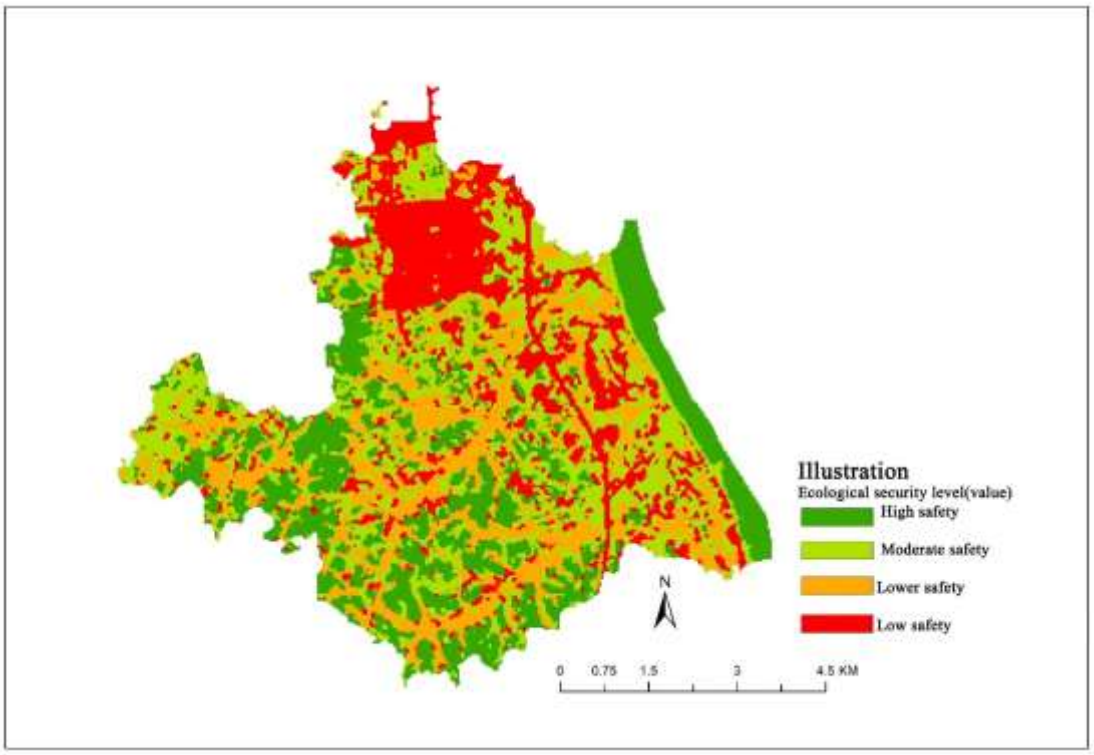

Fig 2: Distribution of ecological security levels in Qunfeng town

3.2 Zoning Results of Construction Land

3.2.1 Quantitative structure of comprehensive evaluation results

According to the principal component analysis and multi-level analysis, Table IV is obtained, which shows that the potential factors of ecological security constraints and distance from the central area account for the largest weight. Further through the multi factor weighted evaluation results (MCE), the most suitable area has the largest value, with an area of 16.5km^2, accounting for 30.56%, indicating that the industrial connection between Qunfeng town and the high tech Zone provides the location advantage of construction land development and is the key driving factor for the allocation of economic activities. The land area suitable for construction is 14.5km^2, accounting for 26.8%; The land area unsuitable for expansion is 11.5km^2, accounting for 21.3%; The land area of the forbidden construction area is 11.5 km^2, accounting for 21.3%. Among them, the area of the most suitable and suitable development zone is slightly larger, accounting for more than half of the total area, and presents the spatial structure characteristics of “core edge”. The trend of regional transformation in suburban villages and towns is obvious.

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Table III. Ecological security index and grade division of sample area

Type	Resistance factor	Grading index	Safety level	Resistance value	Weight
Ecological attribute	Land use type	Cultivated land	5	25	0.383
		woodland	1	1	
		grassland	3	20	
		waters	1	40	
		land used for building	7	100	
		Other land	7	70	
	Altitude(m)	≤0	1	1	0.048
		0~40	3	20	
		>40~80	5	40	
		>80	7	60	
	Slope	≤80	1	1	0.024
		80~160	3	20	
		160~240	5	40	
		> 240	7	60	
	Slope direction	Flat land / South Slope / Southeast Slope / Southwest slope	1	1	0.098
		East / West Slope	3	20	
		Northeast slope / West north slope	5	40	
		north slope	7	60	
	Vegetation coverage	≤0.5	7	1	0.198
		0.5~0.7	5	20	
		0.7~0.9	3	40	
		> 0.9	1	60	
Ecological disturbance	Distance from traffic trunk road leave(m)	≤200m	7	1	0.140
		200~400m	5	20	
		400~800m	3	40	
		> 800m	1	60	
	Distance from water body(m)	L≤100	1	1	0.066
		100~500	3	20	
		500~1000	5	40	
		> 1000	7	60	
	Distance from	≤200	7	1	0.030

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	residential area(m)	200~400	5	20	
		400~600	3	40	
		> 600	1	60	
	Distance from mining site(m)	≤100	7	1	0.013
		100~300	5	20	
		300~500	3	40	
		> 500	1	60	

3.2.2 Spatial distribution of comprehensive evaluation

Figure 3 shows that the most suitable construction areas are mainly distributed along the traffic line in a belt shape through the comprehensive evaluation of spatial visualization results, and this area is close to good riverside landscape resources, which has become a breakthrough point in the development of leisure tourism and ecological residence transformation, specifically in Xiangtang, Hehua, Bailian communities; Suitable construction areas are mainly distributed in the buffer zone of Urban Development Zone, specifically in Qiyun, gaotailing, Changling, Xinwen community and other areas; Unsuitable construction areas are distributed in low mountain and hilly areas that maintain ecosystem services and urban-rural areas with large-area vegetation coverage. The site selection of construction land should not be occupied such as Shitang, Zhuxi, Jianghuang, Lishan, Xintang and miaoquan communities; The prohibited construction areas mainly include the regional ecological security protection area, some areas within the green heart and the infrastructure corridor supporting regional development, which are distributed in the southwest of cities and scattered areas.

Table IV. Weight and grade results of land suitability evaluation in sample area

						Quantitative description of factors			
Evaluation objectives	**Primary index**	**Secondary index**	**second level weight**	**Principal component**	**AHP**	**Most suitable**	**Suitable**	**Unsuitable**	**No construction area**
						Suitability value =7	**Suitability value =5**	**Suitability value =3**	**Suitability value =1**
Suitability evaluation	Resistance factor	Ecological security protection pattern	0.278	0.32	0.25	Low security pattern	Medium security pattern	Higher security pattern	High security pattern

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Development factor	Dista-nce from central urban area(m)	0.360	0.27	0.42	≤5000	5000~8000	8000~10000	> 10000
	Dista-nce from high speed railw-ay station(m)	0.174	0.30	0.09	≤2500	2500~5000	5000~8500	> 8500
	Popu-lation densi-ty (peop-le) /Km²)	0.046	0.04	0.05	> 457	384~457	168~384	≤168
	Proportion of built-up area %	0.142	0.07	0.19	> 19	16~19	12~16	≤9

The final weight value is obtained by 40% of the weight of principal component analysis and 60% of the weight of analytic hierarchy process.

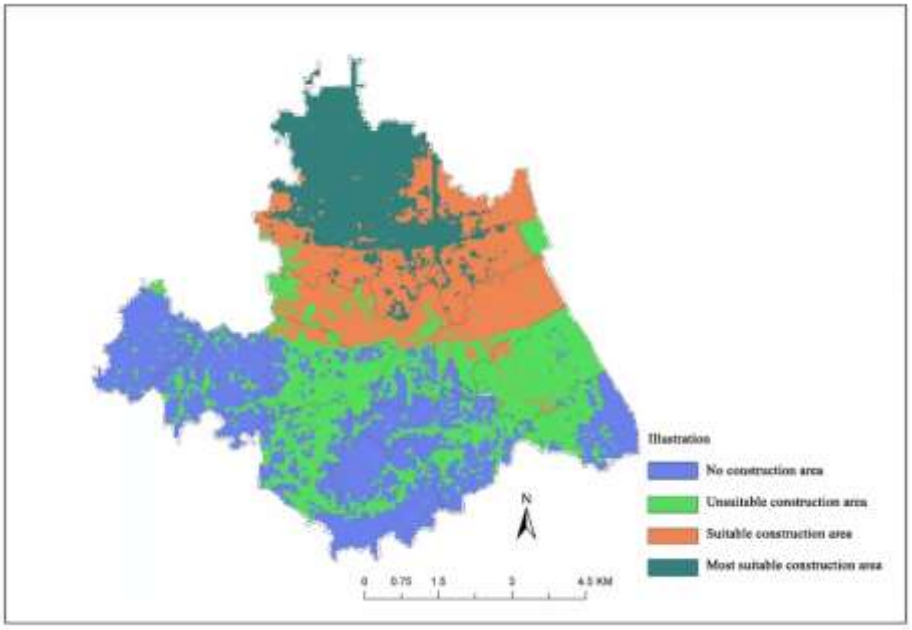

Fig 3: Spatial division type of construction land in Qunfeng town

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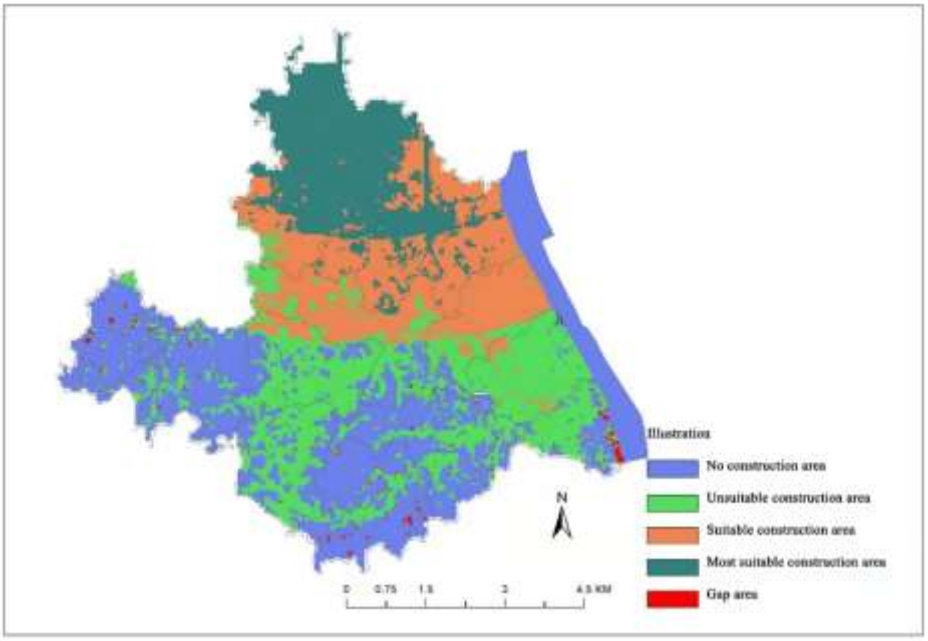

Fig 3: Spatial governance of construction land in Qunfeng town

3.3 Gap Analysis of Rural Construction Land Development

Gap analysis can be used to provide spatial information for reserve design and land demand planning. It is a scientific method to predict the future construction land area, which originates from the conservation gap theory first proposed by Burley [26].The gap analysis method is used to abtain the results and the current land property map. They are also superimposed to obtain the eco-environmental patches with protection value, that is, the vacancy existing in the spatial control of construction land in Qunfeng Town, with a total of 0.52 km2. Figure 4 shows that it is mainly concentrated in the green center of Chang Zhu Tan, Rixing mountain and other areas, which are scattered. Therefore, the importance of ecological security should be increased in land use spatial planning and corresponding ecological compensation measures should be put forward for gap area.

3.4 Zoning Results of Construction Land Development

Qunfeng town is divided into three zones based on the above comprehensive evaluation results of land suitability, and the principle of giving priority to ecological protection and following the regional development concept of current industry city integration [27].

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Economic Development Zone: it is mainly based on the principle of low, medium and low ecological security level and the integration area of the most suitable and suitable area, so that it can undertake high-intensity economic activities such as manufacturing industry, warehousing and logistics center. Compared with the current data of existing construction land, the most suitable area and suitable construction area, in addition to the existing construction land, the exploitable land area is 22.88km^2. The most suitable construction area is the core area for the development of villages and towns. It is adjacent to Zhuzhou Urban Area in the north, radar stone town in the south, Xiangjiang River in the East, Beijing Hong Kong Macao Expressway and Wuhan Guangzhou high-speed railway. It has certain natural environment advantages, good traffic accessibility and perfect social infrastructure. Suitable construction area is the most suitable buffer zone for land use. It promotes the spatial expansion of urban and rural land and regional linkage development through the "core edge" effect of urban development.

Agricultural safety zone: the agricultural planting type of Qunfeng town is mainly rice and vegetables, the animal husbandry production and breeding is mainly pigs and poultry, and various agricultural and sideline industries are booming. It is mainly based on the division principle of unsuitable construction land and medium and high ecological safety level zone, and undertakes the function of combining ecological quality maintenance and green economic development. The agricultural safety zone in Qunfeng town mainly involves areas with obvious characteristics such as poor traffic accessibility, immature infrastructure and diversification of ecological sources. It is mainly agricultural residential areas. Therefore, it should focus on protecting the safety of agricultural products such as grain, vegetables and tea, and scientifically guide the structural adjustment and optimal layout of land use.

Ecological security zone: it is mainly divided according to the principle of high ecological security level and integration area of prohibited construction land, so that it mainly undertakes the function of ecosystem balance and strictly controls the land development intensity of land space. Based on the analysis of the current situation, the ecological security zone in the study area is specifically the southwest minister Zhutan Lvxin and the designated nature reserve (mainly the mountains with a slope of more than 30 degrees and a height difference of more than 50m). The development potential is low. No more rural construction and development land should be added to minimize the ecological environment interference of human activities.

IV. DISCUSSION AND CONCLUSIONS

4.1 Discussion

Firstly, suburban villages and towns is a transitional space form between urban and rural

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areas, and it bears the environmental pressure due to the limited space resources and the market contradiction of multiple stakeholders, which is brought by urban expansion. To construct ecological security indicators, this study will approach the impact of ecological disturbance through comprehensively research on ecological attributes, location conditions and industrial characteristics; The land suitability evaluation takes the ecological constraints as the conditions, the location conditions of the activated land as the benchmark. There are four aspects to construct the evaluation system: the distance from the central area, the distance from the high-speed railway station, the population density and the proportion of the built-up area. In addition, due to the lack of unified and standardized index classification at present, the element selection and objective assignment of the participating factors should be strengthened in the next research to improve the accuracy of the result data.

Secondly, the study divides the land suitability into four categories based on the subjective guidance of significant industrial characteristics and relevant development objectives in the sample area: most suitable, suitable, unsuitable and prohibited construction, so as to meet the operational needs of land management in the study area. It can better guide the spatial differentiation and allocation of land based on the land suitability evaluation, combined with the three zone concept of existing functional zoning and spatial planning, the spatial governance is divided into core development zone, agricultural safety zone and ecological safety zone. Different spatial zoning will bring significant spatial benefits to the region, and can effectively coordinate the optimal development mode and time sequence of land use.

Thirdly, it is found that there is a spatial conflict between the research results and the current construction spatial layout through gap analysis. It is concluded that there is a conflict area between 0.54km^2 land and ecological patches. New concrete and other industries in the study area are scattered in agricultural and ecological security areas. It shows that this phenomenon is the contradiction of land layout brought by the industrial economic development of suburban villages and towns, and further verifies the effectiveness and necessity of land suitability evaluation and zoning under ecological constraints.

Finally, morphological spatial pattern analysis is used to make up for the vacancy of resistance elements; The resistance and dynamic indexes were fitted by the combination of analytic hierarchy process and subjective analysis, and then the mutual exclusion discrimination matrix was used to fit the ecological security pattern level and suitability level; The spatial conflict is used to calculate the mismatch of developed land, which improves the practicability of suitability evaluation. It can be seen that multi method integration effectively enhances the accuracy and reliability of land suitability evaluation.

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4.2 Conclusions

There are five main suitability evaluation indexes of construction land for suburban villages and towns based on the "ecology land". Combined with the two-dimensional discrimination matrix of "ecological resistance development power", the evaluation process of land type division and regional function division is discussed. In addition, the comprehensive calculation of integrated multi method and model, which is to obtain the land suitability evaluation. The study mainly focuses on the division and zoning of land suitability types for the space of suburban villages and towns. We should further analyze the differentiation connotation of different geographical types of suburban villages and towns, and solve the problem path of the difference of land suitability grade and zoning types. To promote the balanced development of population, resources and environment in land space, we also should use dynamic spatio-temporal scenario simulation as a means to build a research framework for the coupling of ecological security pattern and land development of various regional types.

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