ID 1500 | STUDY ON THE SPACE GROWTH BOUNDARY DELIMITATION OF MIZHI COUNTY IN CHINA BASED ON THE COMPACT DEVELOPMENT CONCEPT

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1 INTRODUCTION

The loess plateau region in northern Shaanxi province in China is characterized by loess hilly and gully, fragile ecological environment, scarcity of land resources. The delimitation of space growth boundary is critical to the intensive use of land resources and the compact development of space. How to delimit the compact space growth boundary becomes the focus of attention and research.

The urban space growth boundary is one of the earliest urban land management policy tools adopted by the United States under the new urbanism in the West. The concept was presented in 1976 by Salem, Oregon, USA [1]. Its goal is to curb the social, economic and environmental problems brought about by the spread of the city. Urban space growth boundary is not to curb the development of the city, but through the space boundary to limit the development of the city in a clear geographical space. Thus, city's disorder expansion is blocked while meeting the needs of urban development [2]. Once the urban space growth boundary has been put forward, it has become one of the hotspots of urban planning. Many scholars at home and abroad are committed to many aspects of practice and research, such as the concept of its connotation and impact analysis, the formation of mechanism analysis, delineation methods and related management strategies, application in planning [3-7]. In the traditional urban space growth boundary delimitation method, mainly in static analysis, dynamic simulation of two types of methods, the specific technical means, including ecological suitability evaluation, binding CA model, BP neural network, SLEUTH model [8-10]. In the planning practice, planners often use the urban ecological suitability evaluation, and then take the empirical value to delimit the urban space growth boundary. And also some scholars have made a reference to the overall planning of urban construction land to determine the scope, that is, plus 25% of the floating rate on the scale of the construction land in master plan [11]. In general, different demarcation methods have their own strengths. But the association with the goal of urban space growth boundary is weak, which is the intensive use of land. In addition, there is a lack of adaptability research between two elements, regional natural terrain conditions and urban surrounding ecological environment factors, the urban space growth boundary and its urban space development trend adaptability, the urban space growth boundary and urban space development endogenous needs [12]. In this paper, the method of delimiting the boundary space of urban space has made a response to this problem, which is of great significance to the compact growth of urban space.

2 THE TECHNICAL ROUTE OF DELIMITING THE SPACE GROWTH BOUNDARY FROM THE PERSPECTIVE OF COMPACT DEVELOPMENT

In this paper, the technical route is divided into the following steps: boundary development constraint and power interpretation, boundary superposition simulation, boundary comparison and selection, boundary realistic development verification.

Firstly, the paper uses the ecological suitability evaluation to reflect external development constraints, and calculates the construction land area to reflect internal development needs. Secondly, by the superposition analysis of the external development constraints and internal development needs, this paper simulates to generate several possible space growth boundary lines. Thirdly, this paper calculates the fractal dimension to compare the compactness of each possible boundary line, and selects the most compact one as the space growth boundary of Mizhi County. Furthermore, its feasibility and rationality are verified combined with the construction status of Mizhi County to explore the method of delimiting the space growth boundary of Mizhi County. This method which is presented by the technical route effectively improves the compactness of the delineated urban space growth boundary. In the course of the calculation and comparison of fractal dimension, the coincidence check with the present situation of urban construction is also added, which improves the rationality of the urban space growth boundary.

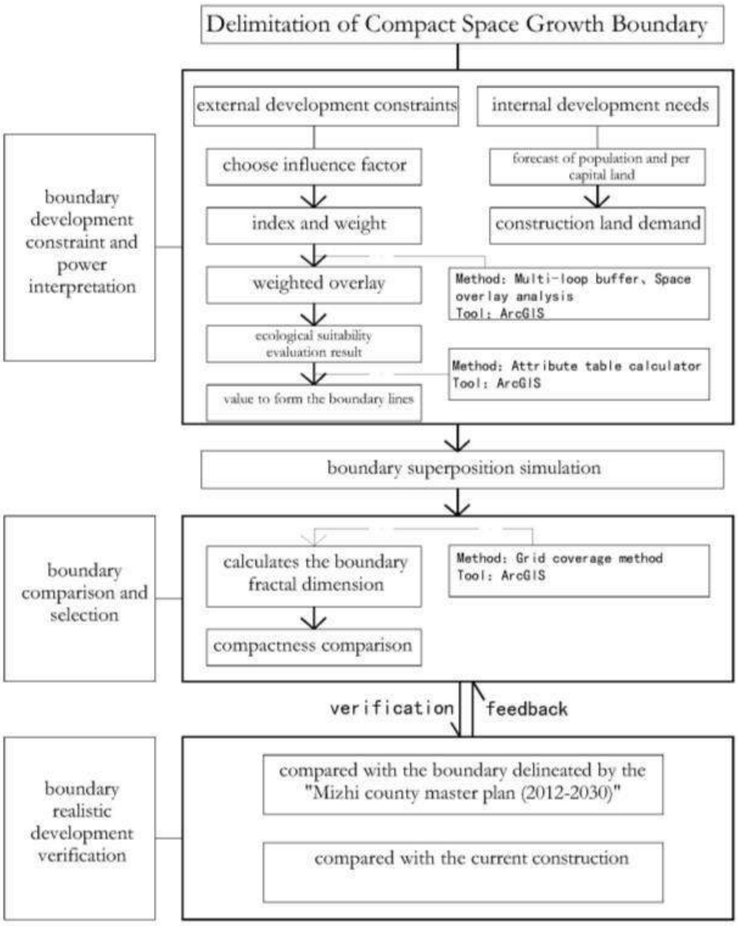


Figure 1 – Technical Route of Compact Space Grwoth Boundary Delimitation (Source: Author self-painted)

2.1 BOUNDARY DEVELOPMENT CONSTRAINT AND POWER INTERPRETATION

The development of urban boundary includes two aspects: external expansion constraint and internal development needs. The external expansion constraints of urban boundaries are mainly based on the evaluation of ecological suitability. First of all, it begins from the selection of influencing factors, and then carries on an evaluation of each individual factors in order to delineate the score. The more conducive to the compact development of urban space, the higher the score is. By using the ArcGIS software (Geographic Information System platform), the database of influencing factors is established. The multi-loop buffer analysis is carried out according to the evaluation score, and the influence of the single factor is given. Furthermore, by using the yaahp analytic hierarchy process software, the weight of each influencing factor is determined by expert scoring method and analytic hierarchy process (AHP). Finally, the paper uses the Rasterization and Raster Calculator function of the ArcGIS software to superimpose the single factor, and obtain the ecological suitability evaluation result. Based on the ecological suitability evaluation results, taking 0.5 as the intermittent value, the ecological suitability evaluation results are taken on the ArcGIS, and a number of space growth boundary lines can be obtained.

The urban internal development needs are measured by the total amount of land for construction based on the forecast population amount and the per capita construction land size at the end of the master plan.

2.2 BOUNDARY SUPERPOSITION SIMULATION

Through the evaluation of ecological suitability, the urban external expansion constraint is obtained. Also the urban internal development needs are obtained by calculating the total amount of construction land. The two are superimposed and simulated to generate several urban space growth boundary lines.

2.3 BOUNDARY COMPARISON AND SELECTION – CALCULATION AND COMPARISON OF FRACTAL DIMENSION

Boundary comparison and merit is based on fractal theory, and it is compared by measuring the boundary fractal dimension of each urban space growth boundary line.

The fractal dimension of the boundary expresses the complexity of the urban space growth boundary, and also reflects the stability of the patch in the urban built area. In general, the greater the boundary dimension, the more complex the urban space growth boundary is. And it also shows the crushing boundary of urban construction land, the poor stability of built area patch. The expansion of urban form is dominated by external expansion. On the contrary, the smaller the fractal dimension, the more compact the urban construction space is. In this situation, the stability of the built area is relatively good, and the expansion of urban form is mainly by the internal filling or promoting along the area [14]. Therefore, by calculating the boundary fractal dimension of each space growth boundary line, the fractal dimension of each space growth boundary line is compared, and the space growth boundary line corresponding to the minimum value of the boundary fractal dimension is taken as the spatial growth compact boundary.

In this process, the calculation and derivation of the boundary fractal dimension is as follows. Taking "L" for Length, "S" for area, "V" for volume, there is the following relationship:

$$L \propto S1/2 \propto V1/3 \quad (1\text{-}1)$$

In the boundary fractal dimension calculation of urban boundary lines, assuming that the circumference of urban boundary is "C", the area of urban construction land is "S", and the boundary dimension of city is "D", then the following relationship is satisfied:

$$C1/D \propto S1/2 \quad (1\text{-}2)$$

That is $C \propto SD/2$ (1-3)

The above formula is rewritten as a general form:

$$C=\varphi Sf(D) \quad (1\text{-}4)$$

Where "φ" is the proportionality constant. If the graph is a square, then constant "φ" = 4. "f(D)" is a function related to the fractal dimension. On both sides with the logarithm, the following formula can be obtained:

$$Ln(C)=Ln(\varphi)+f(D)Ln(S) \quad (1\text{-}5)$$

Obviously, $f(D) = D/2$, so

$$D=2(Ln(C)- Ln(\varphi))/Ln(S) \quad (1\text{-}6)$$ [15]

2.4 BOUNDARY REALISTIC DEVELOPMENT VERIFICATION – VERIFICATION OF SPACE COMPACT BOUNDARY COMPACTNESS

By selecting compact evaluation factors, developing compact factor evaluation criteria, compact fractal comparison, etc., the paper selects a relatively compact urban space growth boundary. The compactness of the border needs to be further validated, including comparisons with the current master plan and current situation of urban land use.

Firstly, the compact space growth boundary is compared with the space growth boundary delineated by the urban master plan. The boundary fractal dimension of the two is measured and compared so as to reflect the compactness of it.

Moreover, the compact space growth boundary is compared with the urban construction land, and the adaptability to the development of urban construction is tested.

3 COMPACT SPACE GROWTH BOUNDARY DELINEATION PRACTICE

3.1 BOUNDARY DEVELOPMENT CONSTRAINT AND POWER INTERPRETATION

3.1.1 EXTERNAL EXPANSION CONSTRAINT – EVALUATION OF ECOLOGICAL SUITABILITY

(1) DETERMINATION OF INFLUENCING FACTORS

The choice of evaluation factors is one of the core problems in the evaluation of ecological suitability of urban land use. The more comprehensive the selected data, the more clear the evaluation target and the more accurate the conclusion is. In view of the difference between the connotation attribute of the urban space growth boundary and the definition of the concept in the traditional planning, the evaluation factor selection process should reflect the combination of the development demand and the ecological suitability, the combination of control and guidance functional properties, and the combination of rigidity and elasticity of the morphological properties [13]. In general, the choice of evaluation factors should reflect the compact characteristics. Evaluation factors should be closely related to land use conditions and ecological environment, and at the same time can have a direct effect on urban development. In the selection of factors should follow the systematic principle, comprehensive principle, dominant principle, operability principle. At the same time, combined with the actual environment and the construction of the city, the ecological environment factors influencing the urban space expansion are analyzed. The evaluation factor intuitively reflects the appropriate construction level of the land, and plays a significant role in the choice of urban land. The influence factors selected in the study can be divided into four categories:

1. Traffic suitability category, including national road, highway, city main road, passenger station, railway;
2. Environmental suitability categories, including rivers, historical units, basic farmland, flood control lines;
3. Urban atmosphere categories, mainly refers to the impact of urban built-up area;
4. Terrain suitability categories, including elevation, slope, slope direction factor.

In this paper, the treatment of these factors is in the construction of the impact factor in the evaluation of the results, excluding the scope of the ban on the construction factors.

In addition, combined with the status of Mizhi county, the single factor for the classification, from high to low were divided into 5,4,3,2,1 five grades. The higher the level, the characterization of the scope of the factors more suitable for the construction are. Taking the grade 5 of the slope factor as an example, it represents the terrain slope in the range of 0-8 degrees. The scope of the land is flat within this area. And it is more suitable for construction relative to other areas (Table 1). In the same way, the paper divides the classification for other factors, including elevation factors, slope factor, river factor, national highway factor, highway factor, urban road primary and secondary factors, passenger station factor, urban built area factor.

Evaluation Factor	Classification	Graded
Slope	0-8 Degree	5
	8-15 Degree	4
	15-25 Degree	3
	25-40 Degree	2
	>40 Degree	1

Table 1 - Slope Factor Evaluation Grading (Source: Author self-painted)

(2) DETERMINATION OF THE WEIGHTS OF THE INFLUENCING FACTORS

Firstly, the paper decomposes each single factor, and scores each factor according to whether it is suitable for urban construction. From the very suitable to unsuitable for construction scores from high to low, that the most suitable for the construction gets 5 points, unsuitable for the construction gets 1 point.

And then the paper puts the results of scoring into the Analytic Hierarchy Process (AHP) to judge the relative importance of each factor, so as to form a matrix to calculate the weight of each single factor. The general steps are as follows.

1. First of all, progressive structure is established according to the attributes of the factors.
2. The paper establishs a judgment matrix, and compares the importance between every two factors. The ecological suitability of urban land use is the criterion C, and the next level of which is dominated by terrain, landform and river system is u1, u2, u3. For criterion C, according to the importance of u1, u2, it is assigned values of points 1-5. Through this step, it establishes the judgments matrix of every two factors:

$$A = (a_{ij})_{m \times n} \; a_{ij} \; (i=1,\ 2\dots m,\ \ j=1,\ 2\dots n)$$

Where aij represents the score represented by the importance of ui and uj relative to C.

3. And then the paper uses the root method to calculate the weight of each factor. Let the weights of the factors u1, u2 ... un be w1, w2 ... wn, for the criterion C. The vector of the columns in A is geometrically averaged and then normalized, and the resulting column vector is the weight of its factor [14]. (Table 2)

Factor Classification	Factor Name	Factor Weight
Terrain Suitability	Elevation	0.0487
	Slope	0.2448
	Aspect	0.0445
Environmental Suitability	River	0.0447
Traffic Suitability	State Road	0.1332
	Highway	0.1120
	City Main Road	0.0938
	City Secondary Road	0.0555
	Passenger Station	0.0500
City Atmosphere	Status Quo Built Area	0.1728

Table 2 - Evaluation of the Impact Factor Weights in Evaluation System (Source: Author self-painted)

(3) WEIGHTED SUPERPOSITION OF INFLUENCE FACTORS

In the ArcGIS software, the weight of each factor is substituted into the vectorized base diagram. According to the different scores, the ecological suitability distribution of each factor is obtained. Finally, the weights of the selected factors are all superimposed on the evaluation base map, and the weight of each factor is summed according to the final evaluation of ecological suitability of urban land (Figure 2).

According to the results obtained by weight superposition method, the evaluation criteria and the evaluation values of urban land in different areas obtained by weight superposition method were used to divide the urban construction land according to the evaluation value. The higher the value of urban land, the more suitable for urban construction is. On the contrary, where the evaluation value is lower, it plays a more important role in the city's ecological security and the natural environment protection.

(4) THE FORMATION OF SPACE GROWTH BOUNDARY LINE

In the ArcGIS, taking 0.5 as the interval value, the paper gets seven boundary lines of which the score are 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0. The two sides of each boundary line show different colors (Figure 3). Among them, the outermost line scores of 1.0 which is the Mizhi county's space growth boundary (UGB). And that is the largest area of construction of the city. On this basis, the paper further seeks the delineation of the compact boundary of Mizhi County. By introducing the fractal theory, the fractal dimension of the boundary line of different scoring land is calculated. The smaller the fractal dimension, the more compact the corresponding boundary line.

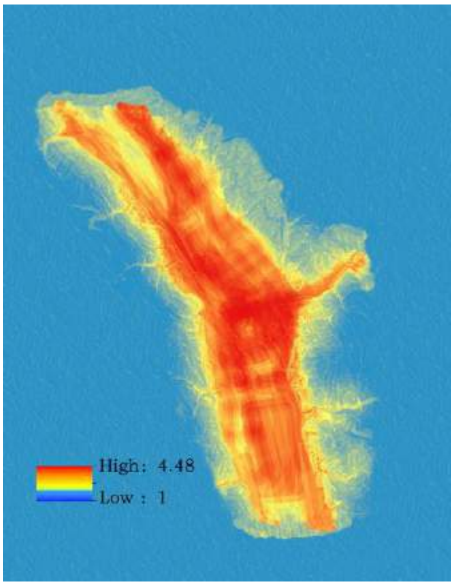


Figure 2 - Ecological Suitability Assessment Results
(Source: Author self-painted)

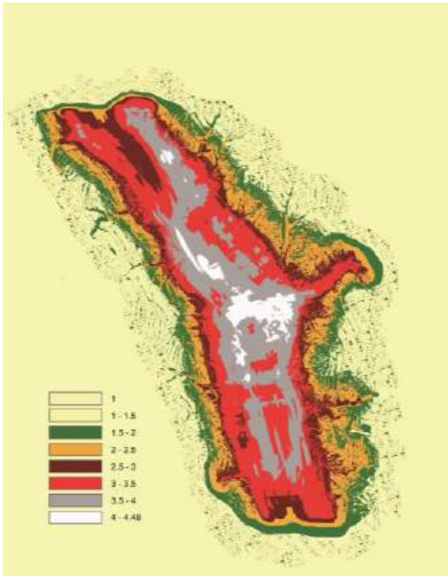


Figure 3 - Spatial Growth Boundary Line
(Source: Author self-painted

3.1.2 INTERNAL DEVELOPMENT NEEDS – FORECAST OF TOTAL CONSTUCTION LAND SIZE

In the "Mizhi county master plan (2014-2030)", it has forecasted population size and per capita construction land size at the end of the plan, so as to estimate the total internal development need of the city. The master plan has determined that the population size of Mizhi county in 2030 controls in 10 million, and per capita urban construction land size of 99.4 square meters. Therefore, the construction land should control in 9.94 square kilometers.

3.2 SPACE GROWTH BOUNDARY SIMULATION

Based on the external expansion constraints and internal development needs of Mizhi County, it can be found that the construction area inside the growth boundary line 4.0 and line 3.5 are respectively 0.74km2 and 4.99km2. The construction area inside these two boundary lines are less than the total forecast of the construction land demand of 9.94km2. So it should be excluded (Table 3).

Evaluation of Land Suitability	4.0	3.5	3.0	2.5
Land Area （km^2）	0.74	4.99	10.81	14.18
Evaluation of Land Suitability	2.0	1.5	1.0	
Land Area （km^2）	18.32	22.71	34.33	

Table 3 - Land Area Statistics for Each Land Boundary Line (Source: Author self-painted)

3.3 SPATIAL GROWTH COMPACT BOUNDARY ESTIMATION AND COMPARISON

Firstly, the boundary fractal dimension of the five boundary lines screened left behind is calculated and compared. Then the degree of compactness of each boundary is compared through the boundary fractal dimension. The smaller the fractal dimension, the more compact the land boundary line.

3.3.1 BOUNDARY FRACTAL DIMENSION CALCULATION OF SPACE GROWTH BOUNDARY

For the boundary fractal dimension calculation of each boundary line, it is necessary to establish a square grid with a side length of 50,100,150,200,250,300,350,400,450,500 meters. The boundary line and the square grid are superimposed separately in the ArcGIS software, and counts the number of square grid coinciding with the space growth boundary lines. And then logarithmic operations are carried on the grid side length, the boundary line of the grid number. After that, the two sets of logarithmic values are plotted and fitted in a straight line in Excel. The absolute value of the coefficients of x in the final fitting equation is the boundary fractal dimension value corresponding to the space growth boundary.

In this case, the space growth boundary line with the ecological suitability evaluation value of 2.5 is taken as an example, and the boundary line is superimposed on the square grids (Table 4).

Grid Side Length (n)	0	100	150	200	250	300	350	400	450	500
Number of Grids (m)	1069	441	276	186	151	119	100	80	71	64
ln(n)	3.912023	4.60517	5.010635	5.298317	5.521461	5.703782	5.857933	5.991465	6.109248	6.214608
ln(m)	6.974479	6.089045	5.620401	5.225747	5.01728	4.779123	4.60517	4.382027	4.26268	4.382027

Table 4 - Boundary Dimension Calculation Table for the Boundary Line of the Ecological Suitability Evaluation Value of 2.5 (Source: Author self-painted)

In Excel, the two sets of logarithmic values are plotted (Figure 4), and fitted linearly to produce a linear equation y=-1.1861x+11.565, R^2=0.9926. It can be seen that R^2> 0.9, indicating that the degree of fitting is high, the boundary line shows fractal characteristics, and the fractal dimension of its boundary corresponds to the absolute value of the x front coefficient, that is 1.1861.

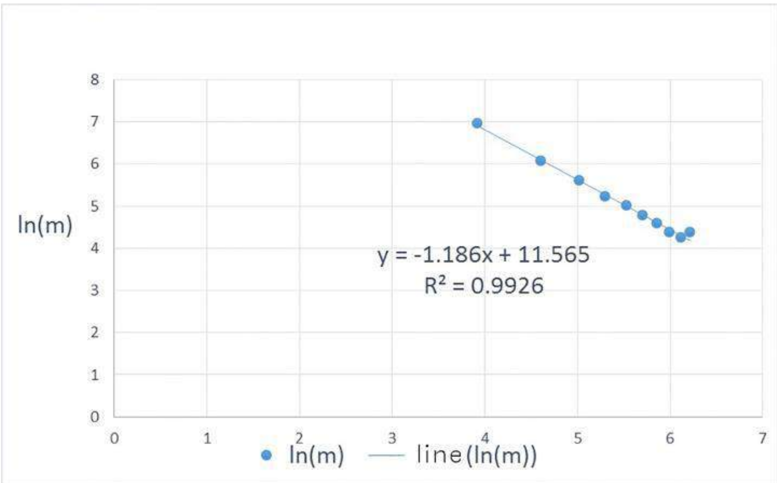


Figure 4 - Boundary Dimension Linear Fitting of Boundary Line with Ecological Suitability Evaluation Value of 2.5 (Source: Author self-painted)

3.3.2 COMPARISON OF BOUNDARY FRACTAL DIMENSION

Similarly, the same method is used to calculate the boundary fractal dimension of the remaining four space growth boundary lines. The final calculation results are obtained in the following table (Table 5).

Ecological Suitability Evaluation Score	3.0	2.5	2.0	1.5	1.0
Boundary Fractal Dimension	1.178	1.186	1.171	1.176	1.183

Table 5 - Fractal Dimension Values of Each Boundary Line (Source: Author self-painted)

The minimal boundary fractal dimension of the five boundary lines can be found to be 1.171, which is correspond to the boundary line with the ecological suitability evaluation score of 2.0. This boundary line is the most compact and intensive of the five boundary lines, which is the compact space growth boundary line of Mizhi county.

3.4 VERIFICATION OF THE COMPACT SPACE GROWTH BOUNDARY

On the basis of the above results, the compact space growth boundary line with the ecological suitability evaluation score of 2.0 is compared with the current construction of Mizhi county. We can find that the current construction is basically included in the compact space growth boundary (Figure 5). It shows that there is a certain realistic feasibility for the compact space growth boundary line of Mizhi county.

Then, the compact space growth boundary and the boundary delineated by the "Mizhi county master plan (2012-2030)" are used to calculate the boundary fractal dimension, so as to discern the compactness of the compact boundary (Table 6). The results show that the boundary fractal dimension curve of the boundary delineated by the "Mizhi county master plan (2012-2030)" is $y = -1.1895x + 10.764$, and the fitting coefficient $R^2 = 0.9988$. So the boundary fractal dimension is 1.1895. It can be found that the fractal dimension of the compact space growth boundary of Mizi county is 1.171, which is minor than 1.1895. This shows that the selected Mizhi County space growth boundary is relatively more compact.

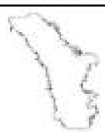
	Mizhi County Compact Space Growth Boundary	Mizhi County Master Plan (2014) Space Growth Boundary
Space Growth Boundary Form		
Linear Fitting Equation	$y=-1.1713x+ 11.595$ $R^2=0.9959$	$y=-1.1895x+ 10.764$ $R^2=0.9988$
Fractal Dimension	1.1762	1.1895

Table 6 - Comparison of the Compactness of the Space Growth Margin of the Mizhi County (Source: Author self-painted)

4 CONCLUSION

With the continuous development of the city and the advancement of the urbanization process, delimiting the urban space growth boundary and setting the scope of urban development is an effective means to curb the random expansion of the city and realize the compact development of the city.

Based on the study of the existing urban space growth boundary delimitation method, this paper takes the Mizi county as the research case, and simulates the urban space growth boundary through the ecological suitability evaluation, and calculates the boundary fractal dimension to the space growth boundary lines. At last, it selects the most compact space growth boundary. At the same time, combined with the status quo of urban construction, the paper verifies its feasibility and rationality.

It is important to emphasize that the ultimate goal of urban space growth boundary delineation is to achieve the sustainable development of the city. The compact development should be based on the necessity of "harmonious relationship between human and nature" idea. The ecological suitability evaluation and the real development check are the responses to it. It still needs to be further studied to join the urban economic and social development considerations in the delimitation of urban space growth boundary.

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