ID 1447 | STUDY ON SUITABLE MODE OF URBAN SPATIAL FORM IN NORTHERN SHAANXI COUPLING WITH FRACTAL LANDFORM OF LOESS PLATEAU

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1 PREFACE

The self-similarity (fractal characteristics) of the unique gully landform of Loess Plateau has been demonstrated adequately. Urban spatial distribution rooted in the landform also has an obvious feature of self-similarity, to forms a relatively stable and harmonious relationship between human being and nature over the past thousands of years. With the rapid development of energy industries and urbanization in Northern Shaanxi, the soil erosion and other ecological problems are getting intense. The contradiction between loess gully landforms, which is a regional and critical ecological factor, and urban spatial development becomes sharper. It brings a tremendous impact on existing relationship between human being and nature. With the help of fractal theory, this research made a coupled correlation study between the topography,which in Northern Shaanxi energy-rich region with fractal characters, and the urban spatial form, so as to explore a realistic way for urban spatial development adapted to landscape environment in Northern Shaanxi . Hopefully, this paper will provide a reference for other research about urban spaces in ecologically sensitive areas.

2 FRACTAL FEATURES OF LANDFORM OF LOESS PLATEAU AND URBAN SPATIAL FORM IN NORTHERN SHAANXI

Loess Plateau in Northern Shaanxi is a typical area of the Loess Plateau in China which located at latitude 34°10 '~ 39°35', longitude 107°30 '~ 111°15', including area among north of Guanzhong Plain, south of the Ordos Plateau, east of Ziwuling, and west of the Yellow River in Northern Shaanxi. Its plateau elevation is about 600 to 1900 meters, its northwest terrain is high and southeast terrain is low. Its total area is about 89,327 square kilometers, accounting for 43.2% of the province's land area and 18.4% of the total area of the Loess Plateau[1].

From the perspective of administrative divisions, Northern Shaanxi includes 1 district and 11 counties of Yulin and 1 district and 12 counties of Yan’an (Table 1). The total population of Yulin City in 2014 was about 3.75 million people, and the total area was about 44,000 square kilometers[2].

city	center city	county
Yulin	Yuyang district	Shenmu, Fugu, Hengshan,Jingbian, Dingbian, Mizhi, Wubu, Qingjian, Zizhou, Jiaxian, Suide
Yan’an	Baota district	Yanchang, Yanchuan, Zichang, Ansai, Zhidan, Fuxian, Ganquan, Luochuan, Yichuan, Huanglong, Huangling, Wuqi

Table 1 -The Scope of Administrative Division in Northern Shaanxi

2.1 FRACTAL FEATURES OF LANDFORM OF LOESS PLATEAU IN NORTHERN SHAANXI

The terrain of Loess Plateau in Northern Shaanxi gradually reduced from northwest to southeast. The forms of the surface are plateau, beam, hilly and ditch, so the features of Loess Plateau in Northern Shaanxi is fractal. Based on literatures of hydrogeology and geography and surface matter composition, the form of Loess Plateau in Northern Shaanxi was divided into six categories which were sand-loess transition area,loess beam and hilly area, loess hilly area, loess long beam area, loess plateau and broken loess plateau (Figure 1). From the intuitive form of view, the form of Loess Plateau in Northern Shaanxi shows self-similar structure which repeated by valley and plateau and valley[3](Figure 2).

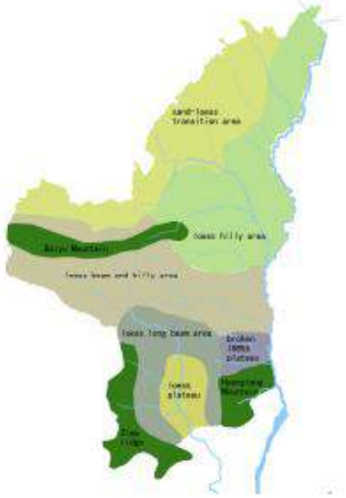


Figure 1 -Six categories of the form of Loess Plateau in Northern Shaanxi

Figure 2 -Luohe in Huangling county of Yan'an, Shaanxi (Image source: http://www.taiwan.cn/taiwan/roll/201409/t20140920_7400890_5.htm)

By using grid algorithm, this paper measured six types of the form of Loess Plateau in Northern Shaanxi which has been characterized by trench lines, and the results are as followings(Table 2) : 1) fractal dimensions of different areas in same type of landform were not exactly the same but pretty close which were in a digital interval. 2) fractal dimensions of different types of landform were with a large difference and the landform can be sorted based on FD from small to large as following: sand-loess transition area＜loess beam and hilly area＜loess hilly area＜loess plateau＜loess long beam area＜broken loess plateau. The reason that caused result above is that different types of landform have different surface roughness. The slope of sand-loess transition area was slow, so the contours were sparse and the fractal dimension was the lowest compared with fractal dimensions of five other types of landform. Loess beam and hilly area and loess long beam area usually have both beam and hilly, so the surfaces are complex and different and the fractal dimension was high. Compared with loess plateau, broken loess has both beam and plateau which are under the erosion at the same time, so the geomorphic fragmentation was greater, fractal dimension was higher.

categories of the form	FD of the landform	Interval of FD
sand-loess transition area	1.0019	1.0-1.2
	1.0241	
	1.0571	
	1.0803	
	1.1847	
loess beam and hilly area	1.3553	1.3-1.7
	1.6153	
	1.6435	
	1.6694	
	1.6977	
loess hilly area	1.4301	1.4-1.6
	1.4458	
	1.451	
	1.4694	
	1.5634	
	1.5831	
	1.6475	
	1.6184	
	1.6335	1.6-1.7

loess plateau	1.616	
	1.6519	
loess long beam area	1.6341	1.6-1.7
broken loess plateau	1.7787	1.7-1.8

Table 2 -Fractal dimensions of six categories of the form of Loess Plateau in Northern Shaanxi

2.2 FRACTAL FEATURES OF URBAN FORM OF CITIES IN NORTHERN SHAANXI

By using grid algorithm, this paper measured fractal dimensions of urban boundary and urban land of 25 cities in Northern Shaanxi.

First of all, based on the form of urban boundary, these 25 cities were divided into five types which were narrow stripes city, branching band city, curved strip city, broken strip city and lumpy city. By using grid algorithm, this paper measured fractal dimensions of urban boundary(Table 3) and sorted the results by ascending sequence(Figure 3).The results showed that with the ever-increasing dimension of fractal dimension, there were corresponding regular changes in the form of urban form. In the lower part of the fractal dimension, the corresponding boundary morphology were mostly long strip and curved strip which indicated that the boundary shape of these two types of towns was relatively simple. In the higher part of the fractal dimension, the corresponding boundary morphology were mostly branched and stripped which indicated that the boundary shape of these two types of towns was more complicated. The fractal dimension of the bunker town was uneven and the rule was weak.

City	Wuqi	Yulin	Huanglong	Hengshan	Yichuan	Shenmu	Zhidan	Wubu	Ansai
FD of urban boundary	1.2	1.216	1.268	1.355	1.362	1.378	1.379	1.387	1.387
City	Luochuan	Qingjian	Yan'an	Zichang	Fuxian	Jingbian	Dingbian	Jiaxian	Fugu
FD of urban boundary	1.399	1.441	1.441	1.445	1.445	1.452	1.462	1.463	1.471
City	Ganquan	Yanchuan	Huangling	Mizhi	Suide	Zizhou	Yanchang	——	——
FD of urban boundary	1.491	1.494	1.501	1.511	1.52	1.576	1.59	——	——

Table 3 -Fractal dimensions of urban boundary of 25 counties

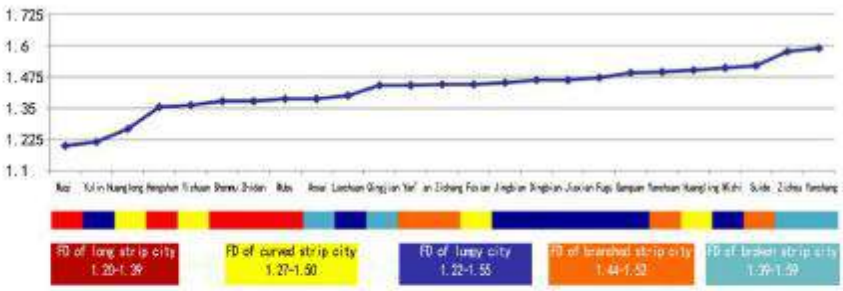


Figure 3 -Correspongding relationship between FD of urban boundary and form type

Secondly, filled the town boundary and measured fractal dimension of urban land. The result showed that the fractal dimensions of the urban land were basically between [1.3-1.6], and a small number of fractal dimensions of the urban land were basically between [1.6-1.85](Table 4). The incremental order of fractal dimensions were as followings: fractal dimensions of long strip city＜branched strip city＜curved strip city＜broken strip city＜lumpy city(Figure 4).

City	Wuqi	Yulin	Huanglong	Hengshan	Yichuan	Shenmu	Zhidan	Wubu	Ansai
FD of urban land	1.3	1.701	1.339	1.398	1.535	1.492	1.425	1.365	1.669
City	Jingbian	Dingbian	Jiaxian	Fugu	Ganquan	Yanchuan	Huangling	Mizhi	——
FD of urban land	1.614	1.847	1.56	1.49	1.618	1.51	1.603	1.605	——
City	Luochuan	Qingjian	Yan'an	Zichang	Zizhou	Yanchang	Fuxian	Suide	——
FD of urban land	1.489	1.68	1.42	1.471	1.685	1.713	1.449	1.46	——

Table 4 -Fractal dimensions of urban land of 25 counties

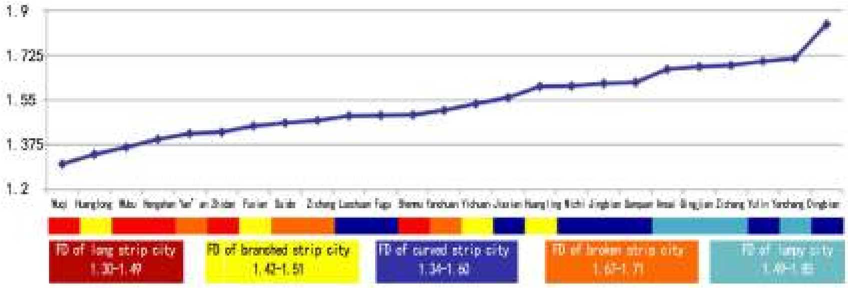


Figure 4 -Comparison between FD of urban land and form type

At last, based on the fractal dimension increment, arrange the fractal dimension of urban land and urban boundary of 25 cites (Figure 5).Increase of fractal dimension of urban boundary(0.39) was slightly smaller than the one of urban land(0.55) which indicated that fractal dimensions of urban land fluctuated greatly. The reason might be that fractal dimension of urban boundary only represented the complexity of the form of boundary, and fractal dimension of urban land represented the complexity not only of the form of boundary but also of the filling with internal land. Thus fractal dimensions of urban boundary may be close, but fractal dimensions of urban land are usually different given that different cities have different layouts of land.

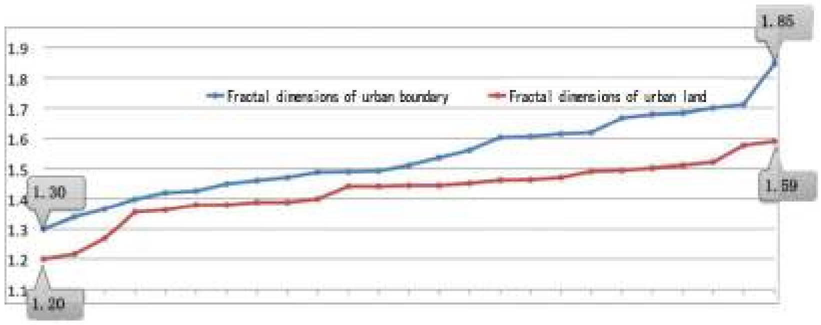


Figure 5 -Comparison between FD of urban land and urban boundary

3 FRACTAL COUPLING RELATIONSHIP BETWEEN URBAN SPATIAL FORM AND LANDFORM

Different from city in the plains, the development of city in gully area is always limited by the ups and downs of the mountain, geomorphic structure and other external space environment.The typical fractal features of the loess plateau in Northern Shaanxi determine the narrow and long characteristics of the landform, valley and the mountain undoubtedly have obvious binding and guidance on the form of urban spatial form. In the typical gully region of the Loess Plateau in Northern Shaanxi, the valley is often very narrow, cities in this area often appear band shape and grow with the river bend or extend along the river valley, so they highly coincide with the characteristics of landform(Figure 6).The urban spatial forms in Northern Shaanxi inherit the morphological characteristics of valley, thus they also form dendritic system with different scales, and the form of urban land and landform have coupling similarity on different scales.

Figure 6 -Coupling relationship between urban land and landform of Ganquan county (left)and Fuxian county (right)

3.1 FRACTAL COUPLING RELATIONSHIP BETWEEN FORM OF URBAN BOUNDARY AND LANDFORM

Land boundary is one of the important characterization elements of urban spatial form, also is an important interface between urban and natural landform. Forms of urban boundary are different because of different types of landform where the cities located. The coupling relationship between boundaries and landform of cities in different sizes is different, even the cities are located in the same type of landform.

Perform a linear fit of fractal dimensions of urban boundary and corresponding landform of the 25 towns(Figure 7). The result showed that correlation trend between fractal dimensions of urban boundary and landform in sand-loess transition area was negative(except Yulin). Correlation trend between fractal dimensions of urban boundary and landformin in three types of hilly areas was discontinuous and in general the former moved up and down around the latter. Correlation trend between those two in loess plateau was basically proportional.

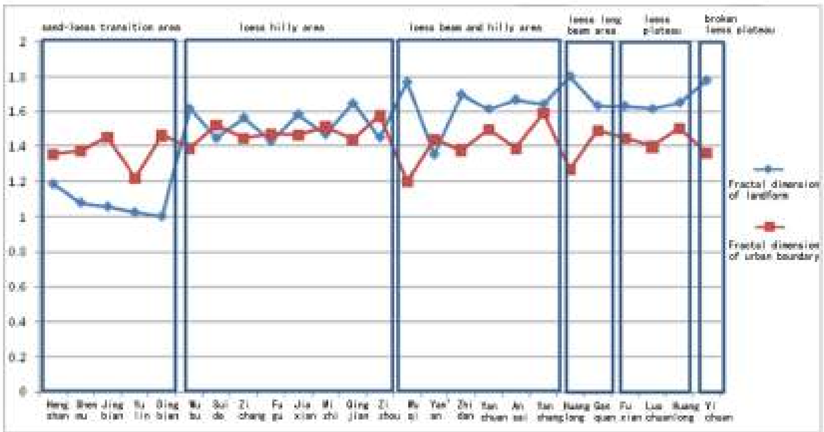


Figure 7 -Comparison between FD of landform and urban boundary

Based on the fractal dimension increment, arrange the fractal dimension of urban boundary and landform. The result showed that when fractal dimensions of urban boundary became larger, distribution of fractal dimensions of landform had no obvious rule(Figure 8). When fractal dimensions of landform became larger, distribution of fractal dimensions of urban boundary showed a downward trend(Figure 9). Judging from those tow results, fractal dimension of urban boundary was influenced by fractal dimension of landform, and the former changed in the subsequent changes.

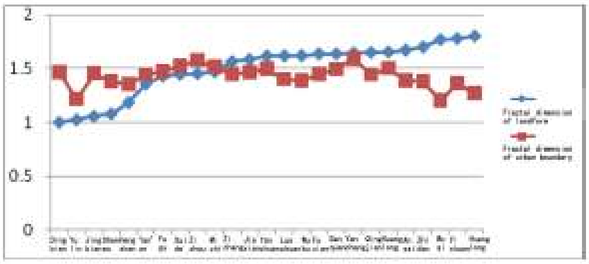


Figure 8 -Comparison between FD of landform and urban boundary based on the former

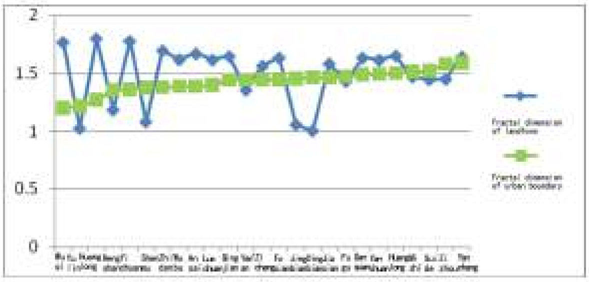


Figure 9 -Comparison between FD of landform and urban boundary based on the latter

Combined with the chart and the actual situation analysis, there are four points in the relationship between the form of urban boundary and landform in Northern Shaanxi: 1)the original construction of the town and the landform were the most closely related. In a certain watershed, the urban boundary along the ditch line showed the fractal characteristics. 2) urban construction land tended to select the water system developed flat valley which showed that water system had restrictions on urban boundary. 3) when the social factors such as traffic weakened, the coupling between urban boundary and landform increased. 4) the relationships between landform and urban boundary of Yan'an and Yulin were relatively weak, mainly due to the influence of various factors such as economy, society and traffic, and the urban boundary gradually deviated from the original form determined by natural factors such as landform in the process of urban development.

3.2 FRACTAL COUPLING RELATIONSHIP BETWEEN FORM OF URBAN LAND AND LANDFORM

Fill urban boundaries of 25 cities and the resulting patterns were the forms of urban land. Measured those forms of urban land by using grid fractal algorithm and compared with fractal dimensions of corresponding landform (Figure 10).

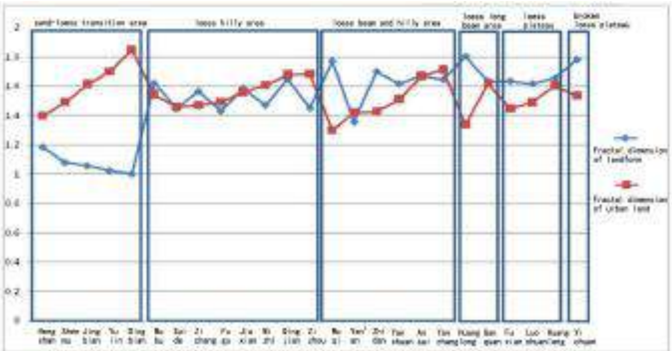


Figure 10 -Comparison between FD of landform and urban land

It can be seen from the figure that there was no obvious linear relationship between fractal dimensions of landform and urban land of 25 cities, whereas corresponding relationship in same type of landforms was obvious: 1) there was a negative correlation between those two in sand-loess transition area. 2) correlation trend between fractal dimensions of urban boundary and landformin in three types of hilly areas was discontinuous and in general the former moved up and down around the latter. 3) correlation trend between those two in loess plateau was basically proportional.

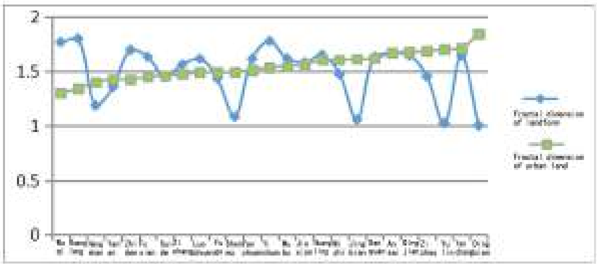


Figure 11 -Comparison between FD of landform and urban land based on the latter

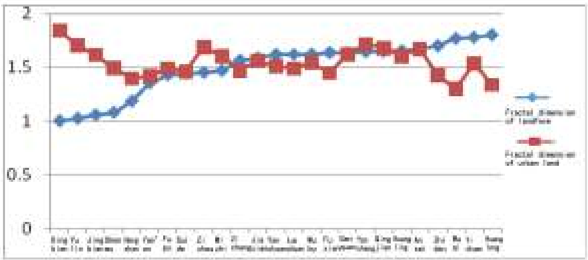


Figure 12 -Comparison between FD of landform and urban land based on the former

Figure 11and 12 can be obtained by increasing the order of urban land fractal dimension and landform fractal dimension respectively. When fractal dimensions of urban boundary became larger, distribution of fractal dimensions of landform had no obvious rule. When fractal dimensions of landform became larger, distribution of fractal dimensions of urban boundary showed a downward trend.

3.3 SUMMARY

In general, most of the towns, except for individual towns, have similar fractal characteristics in land form and boundary morphology, and are negatively correlated with topography in fractal dimension. In addition, there are corresponding relationships between the scale of urban land form and the complexity of landform, that is, the more complex landform broken, the smaller the scale of urban land use, the greater the contrary, which in the sand -loess transition zone and other hilly areas of the performance was very obvious.

4 "GROUP + NETWORK -LIKE" FRACTAL -MIZHI URBAN LAND SUITABLE SHAPE MODEL

4.1 OVERVIEW OF MIZHI COUNTY AND STUDY REGION

Mizhi County is located in the eastern part of Yulin City, Shaanxi Province, the middle reaches of Wuding River, longitude 109o49′-110o29′, latitude 37o39′. East-west length of administrative area is 59km, north-south width is 47km, and the total land area is 1212km2.

The landform of Mizhi county is the area of the transition from sandy beach to loess landform, and it has the characteristics of typical loess hilly and gully landscape.Gully and beam and hilly staggered in this area and the surface fragmented. The area of central Wuding River valley is flat and its agricultural production conditions are better.

Affected by economic development and traffic and other external factors, urban boundary began to break through the original fractal state. River traffic and land conditions and other leading factors became obstacles to growth of urban boundary inheriting fractal landform.

Focusing on the area of Mizhi county as the main study region, and extending the area of 20km square as the "fractal characteristics and performance evaluation of urban and rural spatial form"(Figure 13). The study area extends north to Zhenchuan town of Mizhi county, extending southward to Shilipu township, extending eastward and westward by about 10 km to the end of the subsurface watershed.

Figure 13 -Study region of Mizhi county

Figure 14 -Urban and rural land use status of study region Table 5 -Fractal dimensions of urban land of 25 counties

4.2 FRACTAL CHARACTERISTICS OF CURRENT SITUATION

The land of the study area is composed of the three trenches of valley, sub-ditch and the tributary ditch. This system can be analogous to the tree:valley is the main trunk, sub-ditch for the branch, branch ditch for the tip, thus forming three levels of “trunk -branches -shoot”(Figure 14). The total construction land use situation in the study area is shown in Table 5.

According to the results of radius fractal dimension calculation (Figure 15), the fractal fit degree R2 of the study area was 0.992, and the fractal characteristics were not obvious. The radius dimension D = 0.941, which was much smaller than 2, showed that the density of land use circle in the study area was decreasing from the center to the periphery, which was consistent with the current situation of development along with valley (i.e. "strong backbone and weak branches" form). In addition, the radius dimension 0.941 was low (less than 1), indicating that the construction area of the study area was still concentrated in the county center (i.e. Yinzhou town), the surrounding township construction land proportion was low, therefore the spatial utilization and integration of the outer area of Mizhi county (including sub-ditch and The use of land within the trench) should be strengthened.

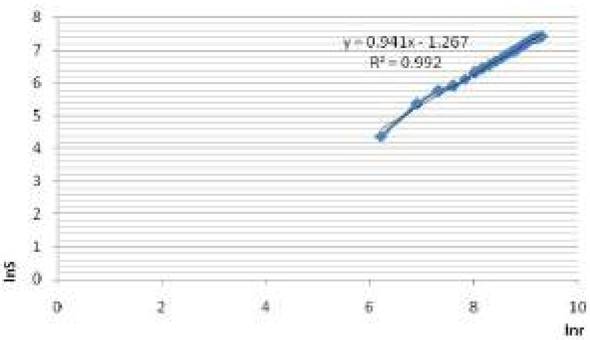


Figure 15 -Radius FD of study region

According to the results of grid fractal dimension, the fractal fit degree R2 of the study area was 0.991, and the fractal characteristics were not obvious. The grid dimension D = 1.501, which was between 1 and 2, belongs to the normal range, but the dimension was low, which indicated that the spatial development in the study area was immature, and the land form did not reach the stable saturation state (Figure 16).

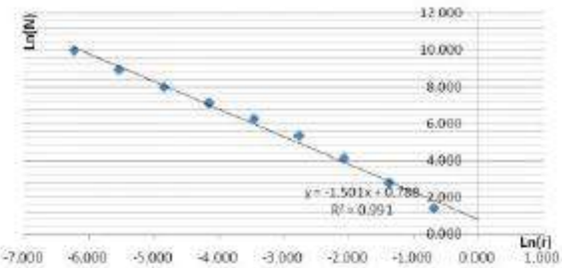


Figure 16 -Grid FD of study region

In summary, due to constraints of the slope, water and a large number of unavailable land, Mizhi urban and rural land tended to spread along the large and loose strip, resulting in the overall land of small scale, discrete layout and weak fractal characteristics of urban and rural space. Therefore, it is necessary to combine the spatial potential and actual situation of the study area, to rationally expand and guide distribution of urban and rural land, and to improve the fractal dimension of urban land, so as to optimize and enhance the overall form of land use .

4.3 SUITABLE FRACTAL PATTERNS OF MIZHI

Based on the research on literature and cases of urban and rural development in the Loess Plateau of Northern Shaanxi, the future development of urban and rural spatial form in the study area should be based on three basic structures: shape and scale of valley, shape and scale of sub -groove, shape and scale of branch ditch. Based on the organization of these three types of structures, this paper summarized eight developmental forms of urban and rural spatial patterns for the study area(Table 6).

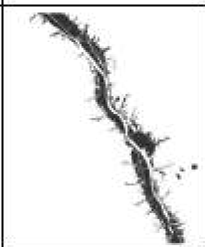
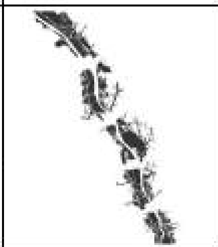
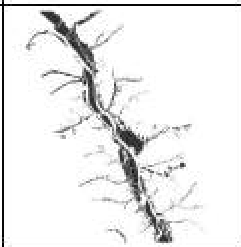
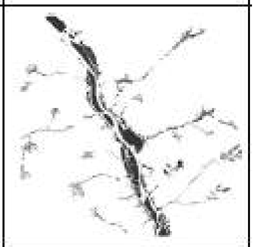
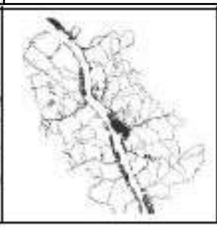
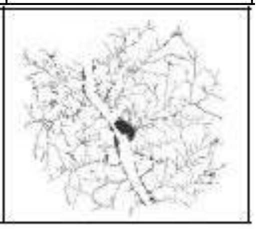
Spatial configuration	①monopodial structure	②linear and crumby structure	③fish-bone structure	④point-axis structure
Land layout				
Spatial configuration	⑤cluster agglomeration structure	⑥linear and leaf-like structure	⑦feathery structure	⑧uniform net-like structure
Land layout				

Table 6 -Spatial configuration of urban and rural land of Mizhi county

Although the above configurations can not cover all the land forms, they represented the main spatial development paths for cities in the loess plateau gully area and had a guiding significance. By comparing the fractal dimensions, three kinds of relatively good spatial configurations ware obtained.

First, the divergent structure of the group presented a better balance and filling because of its high grid fractal dimension: the cluster of patches in the channel ensured the balance of the whole structure and was easy to form a multi-core group pattern. The radius fractal dimension of the configuration did not meet the fractal standard, indicating that the concentration of the center and the periphery of the city was poor: the dilution of the land in the subsurface was not enough, so that the land use efficiency in the small watershed was low and the synergistic effect was insufficient(Figure 17).

Secondly, the branch-like structure exhibited a superior central agglomeration and peripheral diffusivity due to its high radius dimension. The full development of urban space in the subsurface formed a relatively independent dendritic or pinnate small watershed unit, which was organized as a central green axis to ensure the protection of the ecological environment and cultivated land. The end-like dendritic or pinnate space structure was not conducive to the small watershed between the traffic links and functional layout, and was not conducive to building agglomeration centers of urban and rural land. In addition, the point-like configuration and the uniform mesh configuration had similar problems and were more prominent: excessive expansion of the space skeleton and decentralized land layout led to higher infrastructure costs and made it difficult to gather the formation of urban centers (Figure 18).

Thirdly, The zonal vein shape had the advantages of grid fractal dimension and radius fractal dimension, and had more comprehensive spatial occupying effect. The segmental layout in the channel ensured the balance of urban space, and the layout of the network in the limited area was more easily integrated with the gully terrain, thus forming a multi-level space system. This structure not only protected the efficiency of urban space development, but also alleviated the pressure of urban and rural development on the ecological environment of the valley (Figure 19).

Figure 17 -Cluster and divergence structure

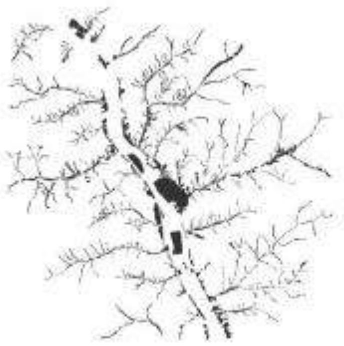


Figure 18 -Feathery structure

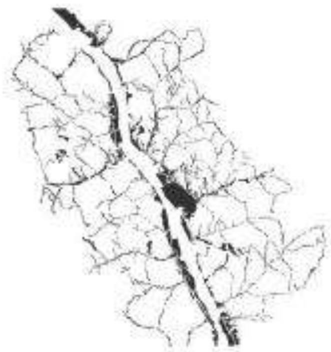


Figure 19 -Linear and leaf-like structure

Based on those three kinds of urban and rural fractal space development strategy, the suitable model and optimal configuration of urban and rural land in Mizhi research area can be outlined. The spatial form of the configuration is "group + veins"(Figure 20), that is, based on the expansion of both the valley and the channel, the urban form continuously expands as the self-similar veins and its scale grows from small to large. Its scale of land can be up to 40km2 and its fractal dimension is 1.673 which is relatively suitable judging form perspective of fractal cities. Besides, this form of urban and rural land will have good spatial filling and equalization and high land use rate.

Figure 20 -Cluster + net-like structure 5

CONCLUSION

With 25 counties as samples, this paper made a coupled correlation study between topography and urban spatial form based on GIS and fractal dimension calculation.The main conclusions are as follows: (1)The higher fractal dimension of land form goes, the lower fractal dimensions of urban spatial boundary and urban land become.Hence the urban spatial form inversely coupled with land form under fractal perspective, which means they are spatially complementary. (2)Based on sample study of Mizhi county, this paper had come up with the suitable urban spatial mode "leaf-like network mode" which requested territory of county and city growing along with main valley and then extending along with sub-valley and finally becoming continuous and dense and netty land use.

The exploration above showed that many ideas and methods in fractal theory have wide application prospect in urban and rural planning and design, and can provide feasible means and ideas for studying the order logic of complex objects. At the same time, fractal planning and design should be guided and supported by the theory and method of urban planning, thus expanding the application and practice of fractal theory in urban and rural planning.

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