# Analysis on Spatial Pattern of Land Use Based on Fractal Theory: A Case Study of a Southwest Town

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**Abstract** Based on GIS, RS technology and fractal theory, this paper analyzes land use type of a southwest town in 2010. It obtains fractal model, fractal dimension and stability index of land use types, which will provide favorable reference for healthy social and economic development of this town and scientific decision making for rational control of land resource.

**Key words** Fractal, Dimensional, Land use type, Stability index

The Fractal Theory, set up by American scholar Mandelbrot in the 1970s, is a world-wide popular theory and it involves natural science, social science and noetic science[1-2]. Compared with traditional Euclidean Geometry, the Fractal Theory has more advantages in describing true things in nature. Land use type is the product of nature and human. Its characteristics are relatively complex and can be studied by fractal method[1]. With the aid of the fractal model and GIS and RS technologies, we take a quantitative analysis of stability and distribution characteristics of regional land use types, in the hope of providing reference for optimum allocation of land resource in this town.

## 1 General information about the study area

This study area is a northeastern town in southwest of China. Beside Jialing River, the town has a total area of 33 $km^2$, with cultivated land up to 8.3 $km^2$ and forest coverage up to 22%. Low hill is the major land form, and the average height above sea level is about 500 meters. With subtropical monsoon humid climate, this town is warm in four seasons, and the average temperature of the whole year is 15.6 ℃, and the annual precipitation is about 200 mm. In the whole town, there are 16 villages, 1 residents' committee, 113 village communities, 4 306 households, and the total population reaches 17 109 (containing only 3 600 non-agricultural people).

## 2 Research method

**2.1 Material and processing method** Using TM remote sensing data of this area collected in August, 2010, we conduct preliminary processing of images with the aid of ERDAS remote sensing image processing software. Also, we use geographical information system software to conduct vectorization and data integration of images (including splicing of vector data, attribute connecting, alteration and deletion), and finally form the land use distribution map of this town in 2010. Using GIS, we precisely calculate patch area, perimeter and number of land use types. According to perimeter and area of each patch in the study area, on the basis of fractal model, with the aid of SPSS Statistics17.0 software, we calculate fractal dimension of land use types[3].

**2.2 Division and selection of land use types** In this study, land use types are divided with reference to *Technical Rules of Land Use Survey*. Taking land use purpose, land use method, and coverage characteristics as basis, we classify the study area into 7 land use types: cultivated land, forest land, garden area, grass land, water area, construction land, and others (as shown in the following map).

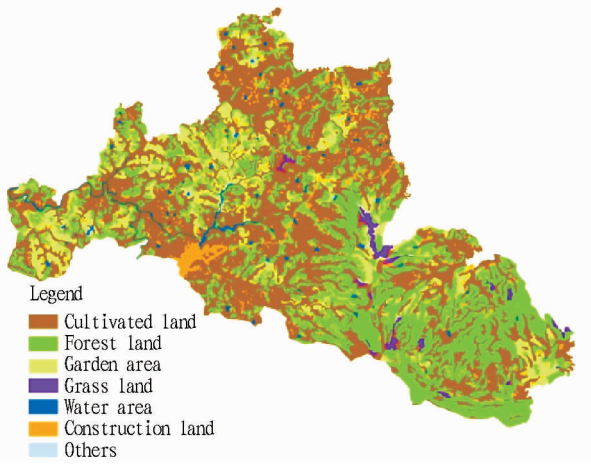


**Fig. 1 Map of current land use of this town in 2010**

**2.3 Fractal study method** There are many estimation methods for fractal dimension of land use patches, and the most widely used one is the method that calculates fractal dimension in accordance with the relationship between patch perimeter and area. The relational expression is as follows[3]:

$$\ln A(r) = \frac{2}{D}\ln[P(r)] + C$$

where $A(r)$ is the patch area, $P(r)$ is patch perimeter, $C$ refers

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to constant (intercept), and $D$ stands for fractal dimension of two-dimensional Euclidean space[1]. For a patch of any land use type, through measuring its area and perimeter, we can plot a point in plane coordinate system, and get a series of points corresponding to all patches, and finally fit a straight line representing the relationship between $\ln A(r)$ and $\ln[P(r)]$. Then, we can calculate the fractal dimension D according to the value of the slope 2/D. The value of D shows complexity of land use types. The range of D value is 1.0 to 2.0. As to land use types, the higher the D value, the more complex of the land use type, and the more irregular of the land boundary. When D is the minimum (1.0), it indicates that the element shape is round, and its boundary is regular; on the contrary, if D is the maximum (2.0), it means the element shape is most complex, and its boundary is the most irregular. When D is 1.5, the element will be in random status, similar to Brownian movement. The closer to this value, the lower the stability. Therefore, we can define the stability index (SI) of each land use type as $SI = 1.5 - D$. The theoretical value of SI is 0.0 to 0.5. The higher SI value means the higher stability of the corresponding land use type[1-2,5].

## 3 Results and analyses

**3.1 Analysis of land use spatial pattern** We take statistical analysis with the aid of SPSS software and according to the above formula. Take the logarithm of area and perimeter of land use types that need calculation of fractal dimension. Then, input into SPPS and take regression analysis. Finally, we get the fractal dimension. Table 1 lists statistical value of perimeter and area of land use types. Table 2 lists fractal model, judgment coefficient $R^2$, number of patch samples, fractal dimension and stability index of land use types in this town in 2010.

**Table 1 Statistical value of perimeter and area of land use types**

| Name of land use type | Number of patches | Patch perimeter// m | Total area of patches// $m^2$ | Percentage into the whole area// % |
|---|---|---|---|---|
| Garden area | 138 | 181 868 | 3 597 560 | 11.78 |
| Water area | 26 | 41 374 | 459 869 | 1.51 |
| Other land | 6 | 434 | 4 346 | 0.01 |
| Forest land | 545 | 467 776 | 8 654 185 | 28.35 |
| Construction land | 440 | 190 094 | 1 847 678 | 6.05 |
| Cultivated land | 11 559 | 507 261 | 15 639 645 | 51.23 |
| Grass land | 10 | 14 908 | 326 996 | 1.07 |

**Table 2 Fractal model, fractal dimension and stability index of land use types**

| Name of land use type | Model | $R^2$ | Number of samples | Fractal dimension | Stability index |
|---|---|---|---|---|---|
| Garden area | $\ln A(r) = 1.252\,6\ln P(r) - 0.075$ | 0.945 | 836 | 1.217 4 | 0.282 6 |
| Water area | $\ln A(r) = 1.232\,5\ln P(r) - 0.063$ | 0.965 | 658 | 1.611 4 | 0.111 4 |
| Other land | $\ln A(r) = 1.323\,6\ln P(r) + 0.339$ | 0.901 | 46 | 1.432 5 | 0.067 5 |
| Forest land | $\ln A(r) = 1.165\,6\ln P(r) + 0.756$ | 0.916 | 2135 | 1.311 2 | 0.188 8 |
| Construction land | $\ln A(r) = 1.158\,4\ln P(r) + 0.349$ | 0.923 | 1612 | 1.267 4 | 0.232 6 |
| Cultivated land | $\ln A(r) = 1.249\,9\ln P(r) + 0.146$ | 0.915 | 3245 | 1.259 0 | 0.241 0 |
| Grass land | $\ln A(r) = 1.3509\ln P(r) - 0.284$ | 0.910 | 58 | 1.248 6 | 0.251 4 |

**3.2 Stability analysis of land use types** Compare fractal dimension D of land use types in Table 2. The fractal value of land use types in the study area is 1.200 to 1.620. From the high to low value, it is water area, construction land, other land, forest land, cultivated land, grass land, and garden area. The high value of water area is resulted from influence of natural environment and climatic conditions in Jialing River. Construction land, cultivated land, grass land and garden area have low fractal values, indicating that the structure of land use types is most simple because of most human intervention. Other land also has high fractal dimension, because other land is distributed separately. The fractal dimension of forest land is at the middle level because of human intervention and natural environment. This shows that the patch shape of natural landscape is relatively complex, while that of artificial landscape is comparatively regular and simple. From the stability index of land use types, the high to low stability is garden area, grass land, cultivated land, construction land, forest land, water area, and other land. Garden area, grass land, cultivated land and construction area have the highest stability index, because these land areas are influenced by human planning activities, and their structure is not stable. Forest land has the medium stability index and so its structure is relatively stable.

## 4 Conclusions

Fractal Theory is a very helpful method for revealing stability of land patches, proper use of land resource and sustainable use of land. Using this method to analyze land use structure of this town, we can reach following conclusions:

(1) Through establishing fractal model of various land types, it can obtain complexity degree of land use types: water area > construction land > other land > forest land > cultivated land > grass land > garden area. The stability degree is garden area > grass land > cultivated land > construction land > forest land > water area > other land.

(2) Garden area, grass land, cultivated land and construction land have special social function, so land structure is relatively stable, patch edges are regular. Thus, these types of land have high ability of resisting against external interference and maintaining their original forms. In the map of current land use situation, other land has minimum stability index and weak ability of resisting external interference and maintaining its original form.

(3) As to the entire study area, the average fractal dimension value of land use types is 1.335 4, highly deviating Brownian random movement value (1.500). The area of land use types that have the stability index of 0.2 to 0.3 accounts for 70.13% of the total land area of this town. This indicates that along with further development of urban construction and under the influence of human activities, the land use spatial pattern of this town gradually becomes stable. However, in the future land use planning, it still needs considering rationality of artificial interference measures, to guarantee more scientific and reasonable of land use in this town.

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