THE FRACTAL THEORY IN ANALYSIS DESERTIFICATION OF GRASSLANDS IN XILIN GOL LEAGUE (INNER MONGOLIA, CHINA)

Li Chunlan, Yin Shan, Bao Yuha, Ts. Z. Dorzhiev, V. Batsaikhan

© **Li Chunlan**
PhD student, East China Normal University
Shanghai 200241, China

© **Yin Shan**
PhD, Prof., Inner Mongolia Normal University
Huhhot 010022, China

© **Bao Yuha**
PhD, Prof., Inner Mongolia Normal University
Huhhot 010022, China

© **Dorzhiev Tsydypzhap Zayatuevich**
Dr. Sci. (Biol.), Prof., Buryat State University
Russia, 67000, Ulan-Ude, Smolin st., 24a
E-mail: tsydypdor@mail.ru

© **Vanchindorj Batsaikhan**
PhD, Mongolian Law Enforcement University
Ulaanbaatar, Mongolia
E-mail: vbatsaikhan@yahoo.com

Today desertification is one of main natural disturbing process for human lives and livelihoods, especially in the typical steppe grassland in Valley of Xilin Gol River. The analysis of desertification change is an important step toward mitigating the impact of desertification on human life and property. In this paper, we applied fractal theory and remote sensing-based methods to analyze comprehensively the spatial pattern change at Xilin GOL League.
Keywords: desertification; fractal; land use; typical steppe; grassland; Xilin GOL League.

1. INTRODUCTION

The United Nations Convention to Combat Desertification is the only convention stemming from a direct recommendation of the Rio Conference's Agenda 21, was adopted in Paris on 17 June 1994 and entered into force in December 1996. It is the first and only internationally legally binding framework set up to address the problem of desertification. And Desertification is an ecologically inverse land succession due to changes in climate andhuman activities in arid and semi-arid zones [1]. Xilin GOL League in the north of

China, is a place of typical steppe grassland in the Inner Mongolia. It was said that with serious of desertification increasing, the grassland ecological function was under destruction deeply, which resulted in much losses and damaged from such extensive desertification have direct impact on human lives and livelihoods and also critical to the economy. Thus, it would be worthwhile to study how the desertification changed in order to reduce the losses caused by the desertification and develop appropriate steppe eco-system management strategies. As a result, select a scientific method to study the trend of this change is of great necessity and importance to ensure the steppe of Xilin GOL League's long-term sustainability.

Mandelbrot B B [2] proposed the concept of fractional and dimension in 1967. The fractal theory, based on fractal geometry, is a new branch of nonlinear science and is widely applied in different Geographic fields, such as geomorphology [3], [4], Soil geography [5], Natural disasters [6], Climatology [7], Human geography [8], et al. Fractal phenomena exist everywhere, land use patch obviously has the fractal characteristics. Land use research, with the difficulty of the spatial heterogeneity, is an important part of land science while the fractal theory has the advantage in spatial structure analysis. So, applying fractal theory to land use research is very helpful for us to precisely model and comprehensively study the spatial pattern change of land use. In this paper taken Xilin GOL League in Inner Mongolia as a study case.

With the support of remote sensing and GIS as well as related techniques, the process of desertification was studied comprehensively. Then building up monitoring and forecasting danger system of desertification disasters have an important significance for ecological construction in Xilin GOL League.

2. STUDY AREA

Xilin GOL League, the middle part of Inner Mongolia in China, is considered as the study area, which lies between $115°13'–117°06'$E latitude and $43°02'–44°52'$N longitude and covers an area of 202,580 km^2, including (Fig. 1). Topographically, the study area is variable in the range 800–1,800 m above the mean sea level and having a general increasing trend from north-east to southwest. Climatically, the study area experiences relative cold (mean annual temperature varies in the range 0 to 3℃) and dry (i. e., mean annual precipitation varies in the range 140–400 mm) conditions.
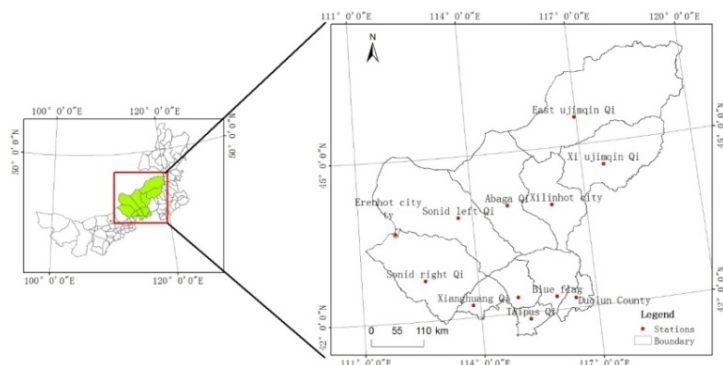
Fig. 1. Study area and the spatial distribution of stations

3. DATA AND METHODS

3.1. Data requirements

Remote sensing data available of TM Image were used in this study. The TM images in 1990, 2000 and 2010 were used to study the land use of desertification spatial change in Xilin GOL League during the past two decades. The data acquired the growing seasons [i. e., July–September] in 1990, 2000 and 2010 at 30-m resolution.

3.2. Methods

In order to understand the complexity of desertification dynamic in Xilin GOL League, China, this paper conducted an integrative approach combining GIS, Area — Perimeter fractal and classical statistics. Their brief descriptions can be found in the following subsections.

3.2.1. Generating Desertification variable

With the remote image process technique, the better image adapting to artificial interpretation was obtained by GIS. Based on the field survey, we established the characteristics of desertification for interpretation, measured Area and Perimeter of each kind of desertification land use through the interpretation, and ascertained the types and actual Area and Perimeter of all types of desertification. Then we classified the land use into six categories, such as No desertification, Slight desertification, Middle desertification, Severe desertification, Waters and Building land.

3.2.2. Fractal

Fractal theory offered methods for describing the inherent irregularity of natural objects. In fractal analysis, the Euclidean concept of 'length' is viewed as a process. This process is characterize by a constant parameter D known as the fractal dimension. There are many methods to measure the fractal dimension of natural objects. In this paper, we used perimeter dimension model of area-perimeter method [9]. Other methods include dividers (compass), grid

(box-counting), etc. It is important to note that not all types of dimension measurement will give the same answer to a single problem.

The perimeter-area method algorithm was as follows:

$$lnA(r)=2/D*lnP(r)+C(1)$$

Where, A and P are the area and perimeter of desertification, respectively, D is the fractal dimension value, and C is a constant parameter.

The fractal dimension D presents the complexity of the land use. For a certain land, the larger the value of D, the more complex of the land shape structure; As D is equal to 1.5, it takes on a characteristic similar to the Brownian motion with the least stability, and the closer to 1. 5 of the fractal dimension, the littler the stability of land use. So the Stability index (S) was defined as following [10]:

$$S= |1.5 –D|(2)$$

3.2.3. Correlation Analysis and Linear Regression Analysis

Correlation and regression analyses [11] are the two commonly useful methods in various disciplines of geography, which were used to check the correlation between area and perimeter of desertification land use in this study. The correlation analysis is one of the most useful classical statistics, which is a statistical measurement of the correlationship between two variables. The positive linear relationship between Area and Perimeter can be expressed as the following equation:

$$Y = a+ bX+ \varepsilon(3)$$

Where, *Y* is dependent variable (i. e. logarithm of the area) and *X*is the independent variable (i.e. logarithm of the perimeter), a and b are linear regression parameters, is the residual.

4. RESULTS AND DISCUSSION

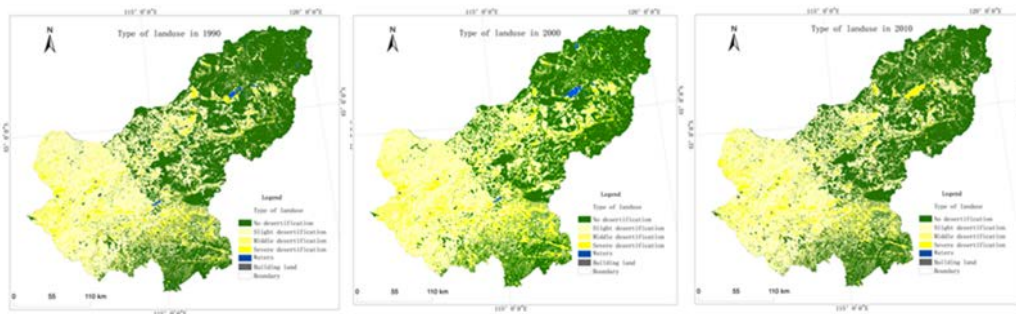*4.1 The spatial pattern change of desertification*

Fig. 2. Land use of desertification in Xilin GOL League during different periods

The use of remote sensing-based methods forclassifying the desertification land use isnot new though limited, and the results are showing here (see

Fig. 2 for details). Comparing with desertification land use of the three periods in 1990, 2000 and 2010, we can find out that desertification in Xilin GOL League had a significant regional feature, and from south-west to north-east the degree of desertification was from high to low transitional. We can also find out that the desertification of land use turn to be improved. Even though some certain area may deteriorate, for example, the middle of East Ujimqin Qi in north-east part of Xilin GOL League, the waters turned into severe desertification from 1990 to 2010 and Southwest appeared the deterioration serious phenomenon, and in Sonid Left Qi, Erenhot City and Sonid Right Qi the Slight desertification area was changed into Middle desertification.

4.2 Analysis fractal and stability feature of desertification in different periods

Tab. 1

Perimeter-Area model, Fractal dimension (D), Stability index (S) and Determination coefficient (R^2) of all land use type in 1990

Land use type	Perimeter-Area model	D	S	R^2
No desertification	ln(A)=1.4045*ln(P)+1.2567	1.423994	0.076006	0.9244
Slight desertification	ln(A)=1.4025*ln(P)+1.1991	1.667918	0.167918	0.9338
Middle desertification	ln(A)=1.4352*ln(P)+0.9528	1.393534	0.106466	0.9391
Severe desertification	ln(A)=1.4512*ln(P)+0.8461	1.378177	0.12183	0.9392
Waters	ln(A)=1.6349*ln(P)-0.3294	1.223316	0.276684	0.9432
Building land	ln(A)=1.6659*ln(P)-0.4687	1.200552	0.299448	0.9598

Upon applying Area — Perimeter dimension model, the fractal dimension ofeach desertification land use can be calculated. The lnA- lnP scatter plot can be plotted and its line arregression function can be calculated by software SPSS. Tab. 1 shown the composition of Perimeter-Area model, Fractal dimension (D), Stability index (S) and Determination coefficient (R^2) for different types of desertification land use in 1990. The values of R^2 for Perimeter-Area model all were greater than 0.9, which indicated that there were strong agreement between the natural logarithm between area and perimeter of all types of desertification land use. And the values of D in 1990 were : Slight desertification >No desertification>Middle desertification>Severe desertification>Waters >Building land, which implied that Slight desertification was the highest value of D and it's shape changed complexly, while the Building land had a lowest D value and it had an simple shape mostly because of the impacts of individuals' operation. Then comparing with the Tab. 3 and Tab. 4, we can realize that the values of D ranking trend in 2000 (except No desertification >Slight desertification) and 2010 were similar with that of values of D in 1990.

While the values of S for No desertification, Slight desertification, Middle desertification, Severe desertification, Waters and Building land in 1990 were 0.076006, 0.167918, 0.106466, 0.12183, 0.276684 and 0.299448, respectively. It was obviously that the highest value of S was Building land, which suggested that Building land was the most stability because of the Building structure desired by human may closer to the rules. Comparing with the Tab. 2 and Tab. 3, we can also conclude that the values of S ranking trend had the same change as that of D value in 2000 and 2010.

Tab. 2

Perimeter-Area model, Fractal dimension (D), Stability index (S)
and Determination coefficient (R^2) of all land use type in 2000

Land use type	Perimeter-Area model	D	S	R^2
No desertification	ln(A)=1.398*ln(P)+1.3381	1.430615	0.069385	0.9021
Slight desertification	ln(A)=1.4027*ln(P)+1.2336	1.425822	0.074178	0.9313
Middle desertification	ln(A)=1.4362*ln(P)+0.9565	1.392564	0.107436	0.9331
Severe desertification	ln(A)=1.4386*ln(P)+0.986	1.390241	0.109759	0.9441
Waters	ln(A)=1.6418*ln(P)-0.3729	1.218175	0.281825	0.9441
Building land	ln(A)=1.6566*ln(P)-0.3987	1.207292	0.292708	0.9565

Tab. 3

Perimeter-Area model, Fractal dimension (D), Stability index (S)
and Determination coefficient (R^2) of all land use type in 2010

Land use type	Perimeter-Area model	D	S	R^2
No desertification	ln(A)=1.4093*ln(P)+1.2351	1.419144	0.080856	0.9362
Slight desertification	ln(A)=1.3927*ln(P)+1.3094	1.436059	0.063941	0.9362
Middle desertification	ln(A)=1.4396*ln(P)+0.9527	1.389275	0.110725	0.9352
Severe desertification	ln(A)=1.4568*ln(P)+0.8353	1.372872	0.127128	0.9398
Waters	ln(A)=1.6257*ln(P)-0.2578	1.230769	0.269231	0.9422
Building land	ln(A)=1.6421*ln(P)-0.2997	1.217953	0.282047	0.9577

4.3 Analysis fractal and stability trend of desertification in recent years

In some extent, D value of different periods can react the change trend of desertification of land use, and with value of D increasing, the area of land use expanding, or change the opposite illustrated in Bao anming et al. [12] (2009).What Fig.3 shown were the Scatterplot of double logarithm of the mean area-perimeter of desertification land use with regressive line and its

Determination coefficient (R^2) in 1990, 2000 and 2010, respectively. From Fig.3, we can calculate out the mean D value was 1.405383 in1990, next was 1.404890 in 2000, and last was 1.402525 in 2010 and mean S value 0.094617(1990)<0.095111(2000) < 0.097475 (2010).With the change of time, the mean D value of desertification land use was decreasing, and it implied that the area of desertification was decreasing and it became much better, and that maybe result from the climate of abundant precipitation and high temperature in recent years and Li Yuwei et al concluded the same result in her study [13]. While the mean S value of desertification was increasing, which suggested that there was a stable change trend of desertification mostly because of the protection policy of desertification land use by the local department and the eco-environment of here turn to be more stability.
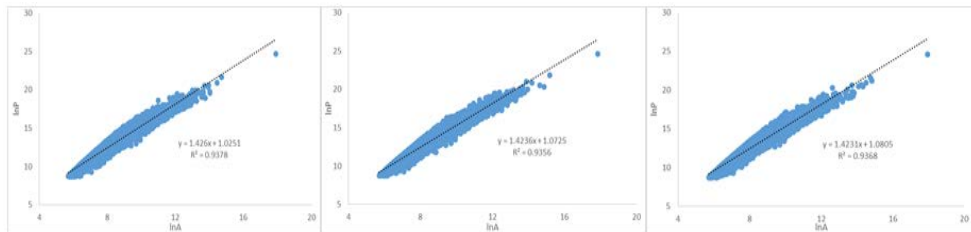

Fig. 3 Scatterplot of double logarithm of desertification mean area-perimeter in 1990, 2000 and 2010

5. CONCLUSION

In this paper, we applied fractal theory to analyze the spatial pattern change at Xilin GOL League comprehensively. By comparing the results we can get following conclusions: Generally the desertification of land use in Xilin GOL League turn to be improved, even though some area may appear deterioration in an extent.

The D value and S value of different kind of desertification land use fluctuating had the similar situation in 1990, 2000 and 2010. And with the change of time, the mean D value of desertification was decreasing from 1.405383 to 1.402525, and it implied that the area of desertification was decreasing, and that maybe result from the climate of abundant precipitation and high temperature in recent years. While the mean S value of desertification was increasing from 0.094617 to 0.097475, which suggested that there was a stable change trend of desertification mostly because of the protection policy of desertification by the local department and the eco-environment of here turn to be more stability.

Reference

1. *Yearbook of World Knowledge: United Nations Convention to Combat Desertification — UNCCD* [J]. The World Knowledge Publishing House, 2011–2012.

2. Mandelbrot B B. How long is the coast of Britain? Statistical self-similarity and fractional dimension [J]. *Science.* 1967. No. 156. Pp. 636–638.

3. Lisi Bi, Honglin He. *A Study on Geomorphologic Indexes in Active Tectonics Based on DEM Data* [D] / Institute of Geology. China Earthquake Administration, 2011.

4. Cai Lingyan, Tang Guoan, Xiong Liyang et al. An Analysis on Fractal Characteristics of Typical Landform Patterns in Northern Shannxi Loess Plateau Based on DEM [J]. *Bulletin of Soil and Water Conservation.* 2014. No. 6. No. 34(3). Pp. 141–145.

5. LI Yiling, QAO Mu, YANG Xiaolin et al. Fractal Characteristics of Land Use and Land Cover Change in a Watershed of Arid Zone in Last 30 years: A Case of the Manas River Watershed [J]. *Arid Land Geography.* 2008. No. 1, 31(1). Pp. 75–81.

6. Song Xinshan, Wang Yuhui, Yan Denghua et al. Fractal and Wavelet Analysis on the 59 Years Time Series of Drought Disaster Ratio in China [J]. *Systems Engineering-Theory & Practice.* 2013. No. 11, 33 (11). Pp. 2986– 2992.

7. Ling Hongbo, Xu Hailiang, Shi Wei et al. Nonliner Characteristics of Climatic Factors in Oasis of Arid Northwest China: A Case Study of Shihezi, Xinjing [J]. *Journal of Desert Research.* 2010. No. 7, 30(4). Pp. 968–975.

8. Liu Jisheng, Chen Yanguang. The Location Process of Population Dynamics and Fractal from of Cities: a Theoretical Approach to a Mathematical Model for Urban Growth. *Human Geography.* 2002. Pp. 17(4). Pp. 24–28.

9. Yu Wangjun,Wu Cifang,Guan Tao et al. Spatial Pattern Change of Land Use in Tunliu County, Shannxi Province Based on GIS and Fractal Theory [J]. *Transactions of the CSAE.* 2005. No. 10, 21(10). Pp. 64–69.

10. Xu Jianhua, Ai Nanshan, Jin Jiong et al. A Fractal Study on the Mosaic Structure of the Landscape of Northwest China: Taking the Drainage Area of Heihe River as an Example [J]. *Arid Zone Research.* 2001. No. 18(1). Pp. 35–39.

11. Jianhua Xu, Yaning Chen,Weihong Li et al. Understanding the Complexity of Temperature Dynamics in Xinjiang, China, from Multitemporal Scale and Spatial Perspectives [J]. *The ScientificWorld Journal.* No. 2013. Pp. 1–9.

12. Bao Anming, Chen Yunhao, Shi Jiangkang et al. Study on the Temporal and Spatial Characteristics of Fractal of Land Use Types in Arid Area [J]. *Arid Land Geography.* 2009. N. 9, 32(5). Pp. 761–768.

13. Luwei Li, Chunlan Li, Jing Liu et al. Research on the Dynamic Change Characteristics of Land Desertification in Xilinguole League [A]. *Proceeding of the 6th Annual Meeting of Risk Analysis Council of China Association for Disaster Prevention* [C]. 2014. No. 529–534.

ИСПОЛЬЗОВАНИЕ ТЕОРИИ ФРАКТАЛОВ В АНАЛИЗЕ ПРОЦЕССОВ ОПУСТЫНИВАНИЯ ПАСТБИЩ ШИЛИНГОЛЬСКОГО АЙМАКА (ВНУТРЕННЯЯ МОНГОЛИЯ, КИТАЙ)

© Ли Чунлан
докторант, Восточно-Китайский педагогический университет
Китай, 200241, Шанхай

© Юин Шан
доктор, профессор, Педагогический университет Внутренней Монголии
Китай, 010022, г. Хух-Хото

© Бао Юхай
доктор, профессор, Педагогический университет Внутренней Монголии
 Китай, 010022, г. Хух-Хото

© Доржиев Цыдыпжап Заятуевич
доктор биологических наук, профессор, Бурятский государственный
университет
Россия, 67000, г. Улан-Удэ, ул. Смолина, 24а
E-mail: tsydypdor@mail.ru

© Ванчиндорж Батсайхан
доктор, Университет правоохранительной службы Монголии
Монголия, Улан-Батор
E-mail: vbatsaikhan@yahoo.com

На сегодняшний день опустынивание является одним из основных процессов, нарушающих жизнедеятельность человека особенно в условиях типичных степей долины р. Шилин-Гол. Анализ процессов опустынивания является важным элементом в нивелировании последствий опустынивания на жизнедеятельность человека.

В статье использованы теория фракталов и данные дистанционного зондирования для анализа всестороннего изменения пространственной структуры земель Шилингольского аймака Внутренней Монголии (Китай).

Ключевые слова: опустынивание, фрактал, землепользование, типичные степные пастбища, Шилингольский аймак.