Spatial pattern of channel network in Jiuyuangou drainage basin

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1. Introduction

Scale is a fundamental issue in Digital Terrain Analysis (DTA). Pattern and processes in nature, such as ecosystem distribution and rainfall or runoff series, display complex behavior and often intertwine with scale problems. River basins are the basic natural system of many hydrologic phenomena (I Rodríguez-Iturbe, A Rinaldo, 2001). Structural characteristic and spatial pattern can be explored by analyzing feature point, feature line and feature surface of landform.

At present, spatial scale research of drainage basin mainly focuses on several areas, including:

1) Relationship between orders and parameters of channel. How to description and explanation of drainage form, how to organize it and its function are primary topics in this subject. Fruitful achievements have been achieved, and they are not only the entrance to structural research and but also represent a step change in the drainage basin research. However, this method has an obvious drawback for describing drainage parameters, in that it can only describe one side property of drainage basin. Relationship among these parameters and channel order is partial for fully understanding drainage characteristic. Furthermore, there lack of information for a comprehensive spatial scale extent for channel order.

2) Fractal in river basin. Fractal is a powerful method for quantitatively description for river basin configuration, drainage landform evolution, drainage structure and hydrologic responses(I Rodríguez-Iturbe, A Rinaldo, 2001). But, fractal dimension derived from two different patterns may be the same which is ineffective in interpreting spatial pattern.

3) Researches on influence in drainage properties under different resolutions or different map scales (Wu Xianfeng, 2003, Zhu Yongqing, 2005). It is difficult to interpret structural characteristic under multiple scale for the behaviors of drainage proprieties

Motivated by solving the problems mentioned above, this paper investigates the structural characteristic of channel network under multiple scales and find out accurate critical points of scales. Two kinds of lacunarity algorithms, i.e. gliding box algorithm and 3TLQV are adopted. Experimental results show that this method can effectively interpret multi-scale characteristic of channel network. And it helps us get better understanding of multi-scale structural characteristic, which is the essential to scaling.

2. Material and Method

2.1 Lacunarity Overview

Lacunarity was developed as a general scale-dependent measurement of an object (Plotnicketal, 1996, M. R. T. Dale, 2000). It represents the distribution of gap sizes: low lacunarity geometric objects are homogeneous because all gap sizes are the same, whereas high lacunarity objects are heterogeneous (Dong, 2000). And it is a scale-dependent measurement of spatial complexity or texture of a landscape (Plotnick, Gardner, &ONeill, 1993).

In this paper, two kinds of methods are adopted, which are “gliding box” (Allain and Cloitre (1991) recommended by Plotnick et al. (1996)) and “three-term local quadrat variance” (3TLQV). These two methods provide supplementary and comprehensive spatial information (Guo Qinghua, 2004).

Formulae 1-4 and Fig.1 below are the algorithms for gliding box algorithm and 3TLQV. In which, Formula 1-3 are the gliding box algorithm of Lacunarity, Formula 4 is the algorithm of 3TLQV (M. R. T. Dale, 2000).

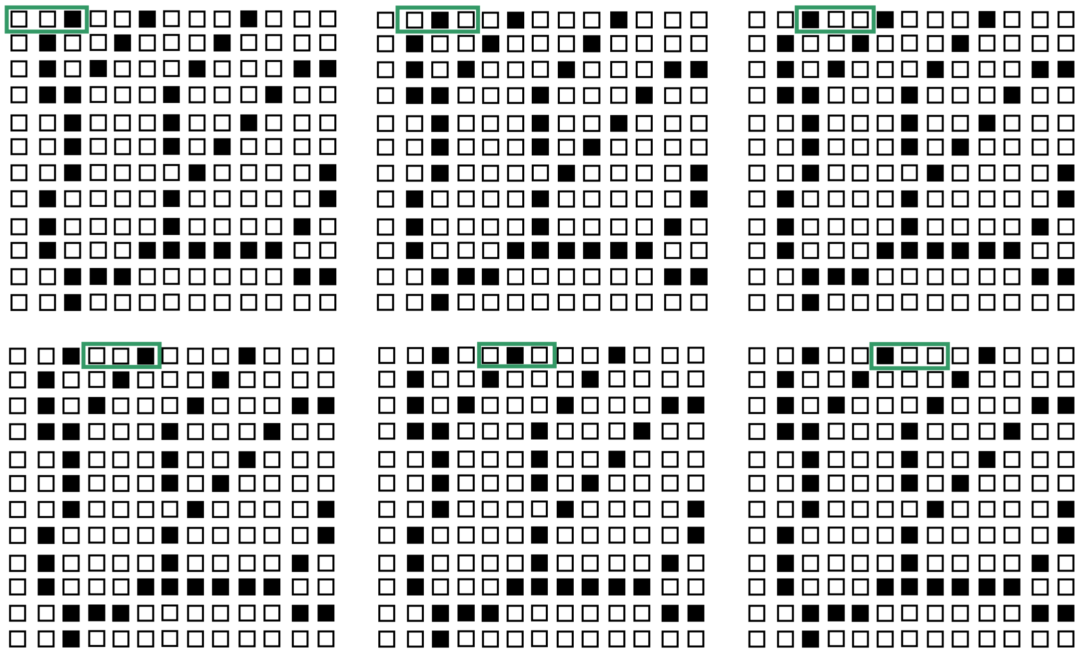
$$m_1(r) = \sum_{i=1}^{n+1-r} \sum_{j=i}^{i+r-1} x_j \Big/ (n+1-r) \tag{1}$$

$$m_2(r) = \sum_{i=1}^{n+1-r} \Big(\sum_{j=i}^{i+r-1} x_j\Big)^2 \Big/ (n+1-r) \tag{2}$$

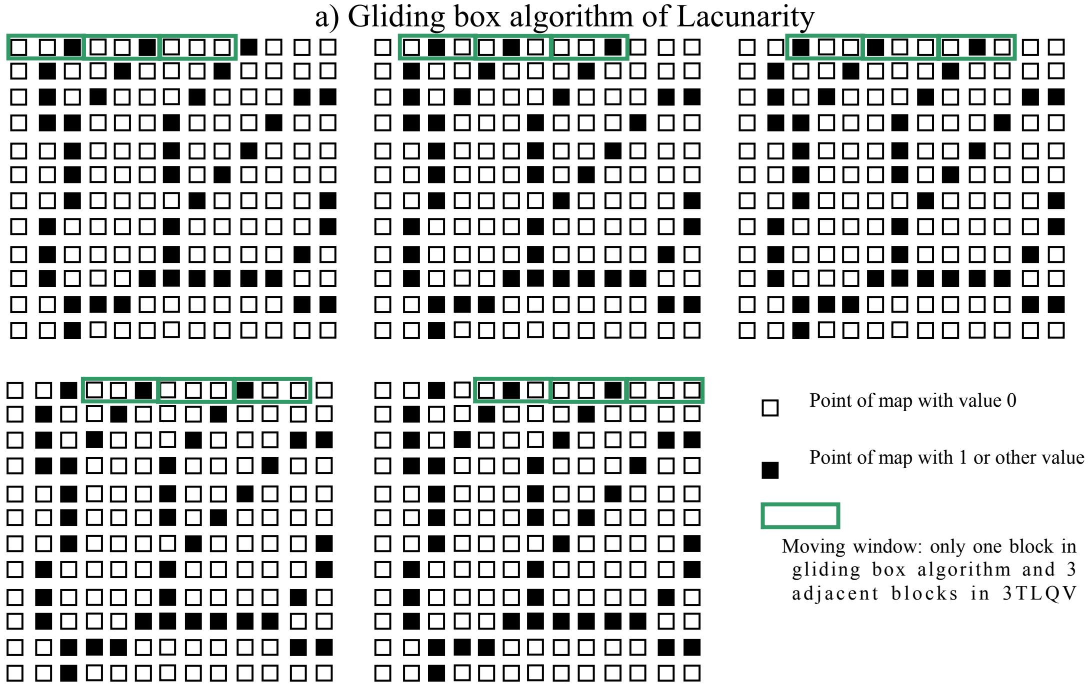
$$\Lambda(r) = m_2(r) \big/ (m_1(r))^2 \tag{3}$$

$$V_3(r) = \sum_{i=1}^{n+1-3r} \Big(\sum_{j=i}^{i+r-1} x_j - 2\sum_{j=i+r}^{i+2r-1} x_j + \sum_{j=i+2r}^{i+3r-1} x_j\Big)^2 \Big/ 8r(n+1-3r) \tag{4}$$

Where r is the length of box size, n refers to the number of points in the map, xi is the ith point in the map, m1(r) and m2(r) are two temporary moments expressing mean and variance for size r, Λ(r) refers to Lacunarity for size r of gliding box algorithm and V3(r) is the 3TLQV result for size r.



a) Gliding box algorithm of Lacunarity



b) 3TLQV algorithm

Fig. 1 Two kinds of algorithm for Lacunarity

2.2 Experimental Samples

The experimental area in this paper is a whole river basin named as Jiu Yuangou drainage, a typical loess gully area located in northern Shaanxi province in the Loess Plateau of China (see Fig.2). There's serious erosion and fragmentary surface. And it is also one of the most important test areas of soil and water conservation. Corresponding DEM with 5m grid cell, produced according to the national standard of China, is the fundamental data. The channel network, which derived from DEM, is converted into Grid DEM with 5m grid cell and expressed with 0, 1 data (squares that contained channel are denoted 1, squares of non-channel 0) and it is the primary data in following work.

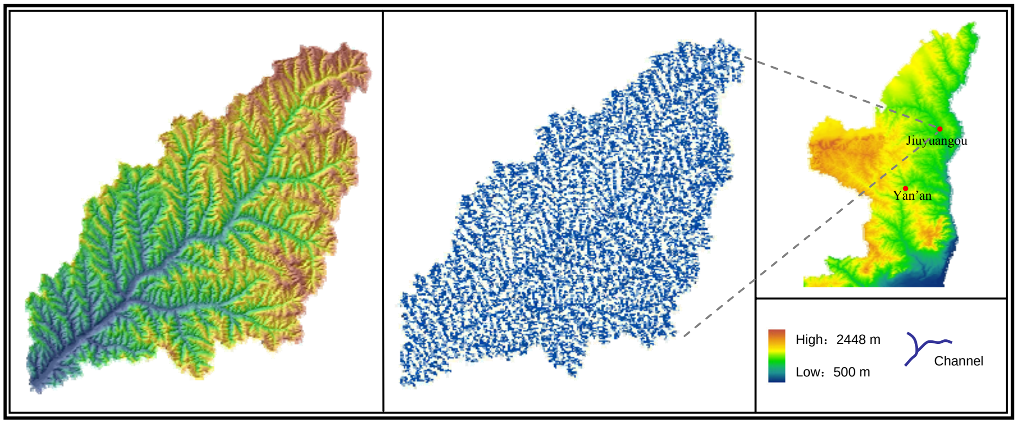


Fig. 2 Experimental data in Jiuyuangou drainage basin

3. Lacunarity analysis

Both gliding box algorithm and 3TLQV are applied in channel network of Jiuyuangou drainage basin. As for anisotropy of channel network, two kinds of rectangle moving window are adopted in following work for two kinds of algorithms. In which, one is a narrow band of r by 1 grid cell (see Fig. 1), i.e. west-east (WE) direction and the other 1 by r, i.e. north-south (NS) direction. Here r refers to the variational window size ranges from 3 to 621 grid cells, increased with 2 grid cells each step.

In results of gliding box algorithm (Fig. 3), two distinct scales pattern in both WE and NS directions are found out although the critical point between two adjacent scales is obscure. And this critical point in WE and NS direction has small shift although lacunarity curves in two directions show similar trend. The small shift expresses anisotropy of channel network in Jiuyuangou drainage basin. For every scale extent, a fractal phenomenon exists and fractal dimensions of these two adjacent scales have little difference. It means landform roughness and structural characteristic of these two scales are different and what we can obtain from these two scales is different. For the first scale we can obtain detailed structural information instead of general structural information in second scale.

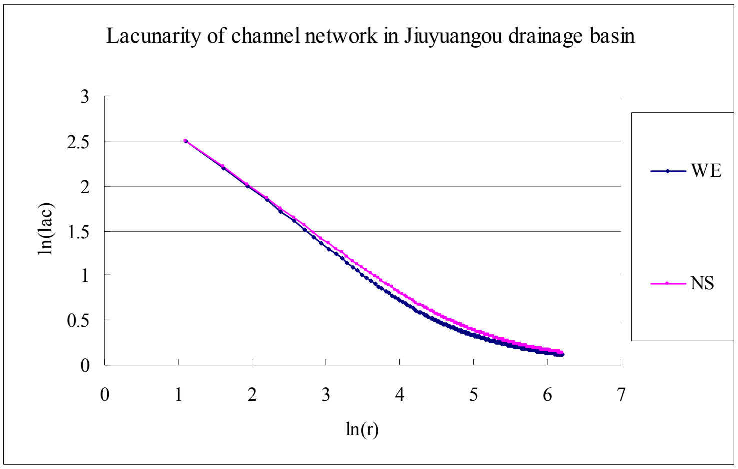


Fig. 3 Gliding algorithm results of stream network with 0, 1 data

It is difficulty for gliding algorithm to acquire accurate position of break points. In order to get better understanding of channel network characteristics, 3TLQV algorithm is carried out. Five break points including three obvious and two tiny ones in WE direction are obtained, whereas two obvious and one tiny break points in NS direction (see Fig. 4 and Table 1). Each break point corresponds to a kind of spatial pattern (see Fig. 5). As is shown in Table 1, Fig.4 and Fig.5, obvious break point indicates a distinct change in spatial pattern, such as scale pattern 4 and scale pattern 5. On the contrary, scale pattern 2 and scale pattern 3 show little differences. Similar as gliding box results, anisotropy exists in 3TLQV results for both WE and NS directions.

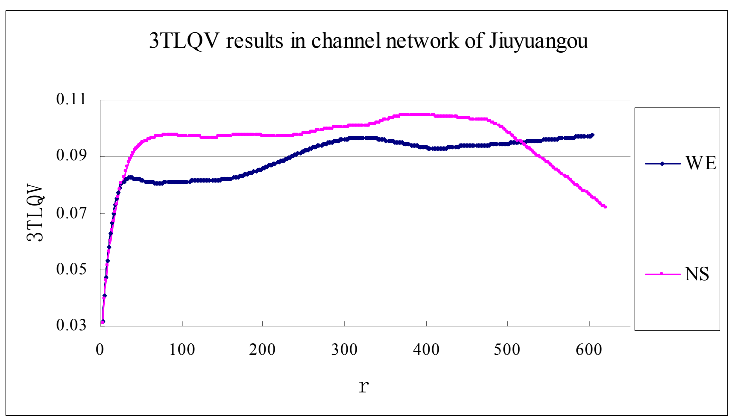


Fig.4 3TLQV results of channel network with 0, 1 data

	Break point (unit: grid cell)	Moving window size (unit: meter)	Variant extent
WE	37	555	obvious
	87	1305	tiny
	129	1935	tiny
	325	4875	obvious
	603	9045	obvious

	87	1305	obvious
NS	183	2745	tiny
	385	5775	obvious

Table 1. Scale pattern results of 3TLQV algorithm in WE and NS directions.

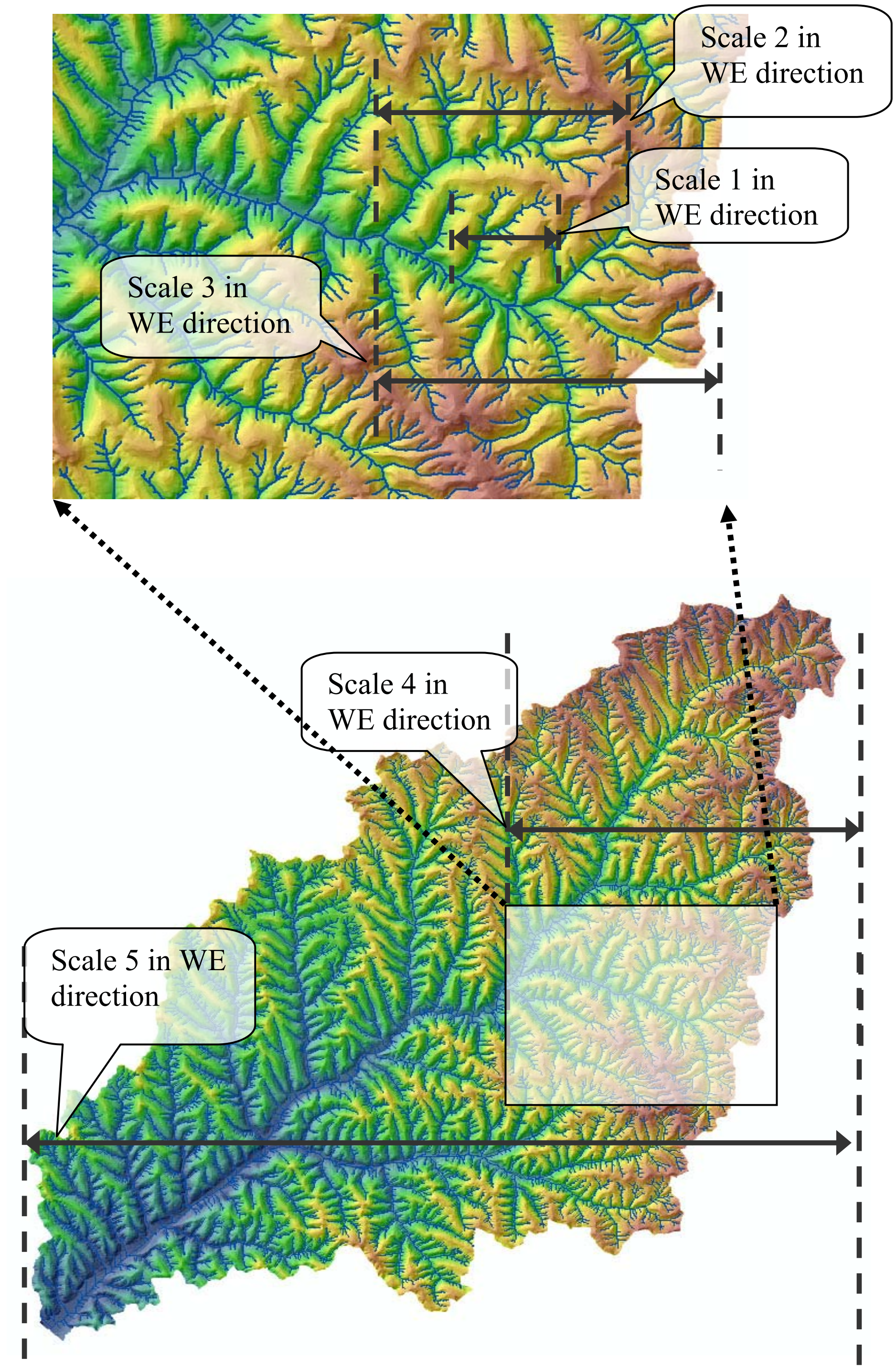


Fig.5 Five different spatial patterns in WE direction of Jiuyuangou drainage basin

We can find that accurate position of break point is easy to obtain from results of 3TLQV. More scale patterns are found out by 3TLQV than they are in gliding box algorithm. The difference between these two algorithms leads to their different results. At each scale examined, gliding box algorithm looks at only one block at a time, therefore losing information on the spatial relationship between blocks of high density and blocks of low density. Therefore, results of scale and its critical points in 3TLQV are more exact than they in gliding box algorithm. But results of gliding box algorithm have discovered what could not be found in 3TLQV, i.e. two scale patterns with different fractal dimensions. In a word, these two algorithms provide supplementary interpretation of channel network structure.

4. Conclusions

This paper provides an effective way for interpreting spatial pattern of channel network. It is the fundamental project of choosing suitable scale for research and scaling topics in drainage basin.

The methodology in this paper is based on two lacunarity algorithms. The gliding box algorithm is used for interpreting spatial pattern at each scale examined, and 3TLQV is used for acquiring accurate critical points of distinct scales.

There are several conclusion can be draw from the experiments. Firstly, there are five scale patterns in WE direction and three scale patterns in NS direction in channel network of Jiuyuangou drainage basin. Secondly, anisotropy is between WE and NS direction in channel network. Thirdly, at each scale examined there's fractal pattern and fractal dimensions in different scales have little difference. Fourthly, an effective way for interpreting spatial pattern under different scales is put forward and it can be used for other network, for example ridgelines.

As for future work, we will investigate the relationship between prosperities of channel network and spatial pattern at distinct scales. Moreover, relationship between spatial pattern of channel network in drainage basin and its evolution process will be a part of future work.

5. References

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