Landscape pattern analysis from IKONOS image data by wavelet and semivariogram method

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Abstract: The wavelet and semivariogram analysis method are used to identify the city landscape and farmland landscape pattern on the 1m resolution IKONOS images. The results prove that wavelet method is a potential way for landscape pattern analysis. Compared to semivariogram analysis, Wavelet analysis can not only detect the overall spatial pattern, but also find multi-scale and direction structures. In this experiment, the wavelet analysis results indicate: (1) the city landscape image is mainly composed of three level structures whose spatial pattern characters appear at 2m, 16m, 128m and 256m accordingly; (2) the farmland landscape is mainly two scale spatial patterns appearing at the 2m，128m and 256m. IKONOS Remote sensing, with the high spatial and spectral information, is a powerful tool that can use in many ecological systems research and sustainable management.

Keywords: Landscape pattern analysis, multi-scale structure, IKONOS remote sensing image, wavelet analysis, semivariogram analysis

1. Introduction

Landscape pattern can help to explain and predict the ecology system behaviors through the analysis of interactions between the spatial structure, ecological process and their change. Remote sensing is a powerful tool that can provide information concerning the landscape, such as land use and land cover, and the size, form and patterns of features on the surface of the earth, and the temporal dynamics of the landscape[1]. But paradoxically, the direct implementation of remote sensing in landscape research and its application remains relatively scarce[2]. With appearing the meter-based high spatial remote sensing satellite in 1990s, it provides the fine information on the landscape spatial structures[3].

In this paper, IKONOS PAN remote sensing images are adopted to identify city landscape and farmland landscape pattern to find its potential for landscape pattern analysis. At the same time, the wavelet and semivariogram analysis method are compared for landscape structure analysis to test their ability of identifying landscape pattern.

2. Methods

2.1. Study area and data

The study region belongs to Beijing Fangshan County, locating in Yongding river alluvium plain. The farmland and city landscape is the main landscape type. The remote sensing data is IKONOS one-meter panchromatic image in May, 2001. The representative city landscape and farmland landscape, each has the 1024 row and 1024 column are used to analyze the landscape structure.

2.2. Wavelet and semivariogram method

Wavelet transformation results can be a measure of the intensity of the local variations of the data for the scale under consideration[4]. Hence the results value for a particular location and at any scale can be understood as a characterization of the structures having this scale and present at this geographical position.

Wavelet variance, which is simply the average of the squares of the wavelet transform results at an given scale and direction, are adapt to landscape structure analysis. Higher values of the variance at a given scale and

direction reflect the presence of a greater intensity of the structure. Graphic techniques are adapted to show the relationship between scale, direction and structure in image by the plots of wavelet variance in images as a function of scale. Tap-4 Daubechies wavelet is adopted to wavelet analysis.

semivariogram method, a basic geostatistics tool, has been applied to remotely sensed data to derive the texture character for remote sensing to improve classification accuracy or to quantify the landscape structures[5]. We follow the method used by Sun and Li[6].

3. Results

3.1. Wavelet analysis results of landscape structures

In this experiment, city landscape and farmland landscape was decomposed with scale j from 1 to 9. Fig.1 and Fig.2 is the wavelet variance graph of each directional detail images. The wavelet variance at diagonal direction is very small, which means no dominant feature appeared at this direction. Two distinct peaks centered at 16m and 128m are in city landscape images at horizontal direction, at the same time, there have two distinct peaks centered at 16m and 256m at vertical direction (Fig.1). The city complex landscape is mainly composed of three level structures. By the ground truth survey, the wavelet variance peak centered at 16m appeared at both horizontal and vertical direction mainly detected the building average width character. At this experiment region, the representative buildings group is about 256m lengths in vertical direction and about 128m widths in horizontal direction. Besides this representative combination, there is a small peak at 2m at both directions in the wavelet variance graph of city landscape image. In the experiment region, this usually is the building shade width or small greenbelt width between buildings etc.

At horizontal direction in farmland landscape images, a peak appeared at 128m, meanwhile, one peak centered at 256m at vertical direction (Fig.2). Through the ground truth survey, this rectangle area usually is the farm field size, whose boundary is the field path or the trees. Besides this pattern structure, there is a small peak at 2m at horizontal direction in the wavelet variance graph of farmland landscape image. It is just the planting trees average row spacing.

3.2. Semivariogram analysis results of landscape structures

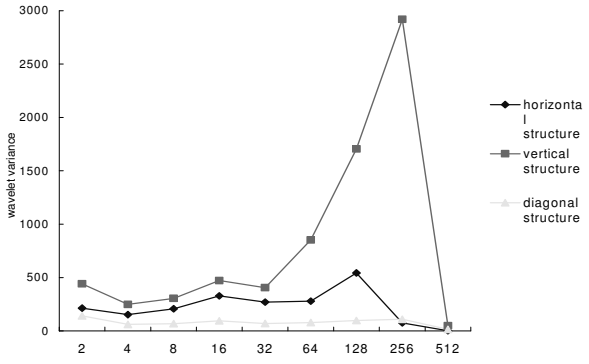

Figure1city landscape direction wavelet

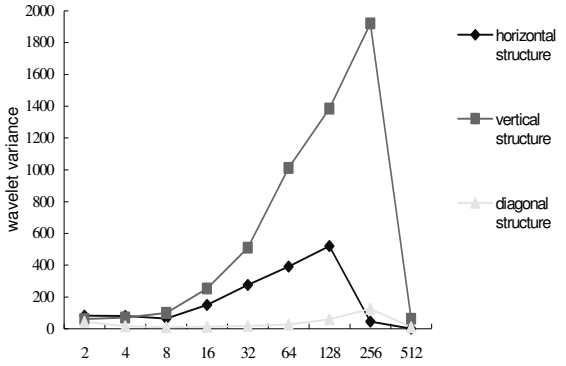

Figure2 farmland landscape direction wavelet variance

Fig.3 and Fig.4 show the intrinsic stationarity hypothesis is not satisfied in city landscape and farmland landscape, but they meet second-order stationarity in the 200m range data. At the same time, the different directional semivariogram graph shape is similar for the two landscape types. So the semivariogram analysis does not discover the multi-scale structure and directional structure. 200m ranges are used to fit an appropriate theoretical model semivariogram, whose parameters of the spherical model are summarized in Table 1. The city landscape overall structure range is reached at about 135.38m. The farmland landscape overall structure range is reached at about 152.65m.

Table1. Parameters of model semivariogram fitted to data for each landscape

Landscape	Nugget	Range（m）	Structure	Sill	Nugget/ Sill（%）
City landscape	461	135.38	367	828	55
Farmland landscape	77	152.65	78	155	49

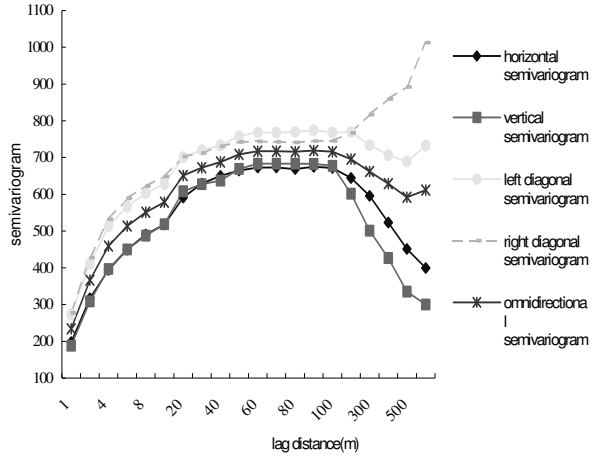

Figure 3 city landscape experimental semivariogram

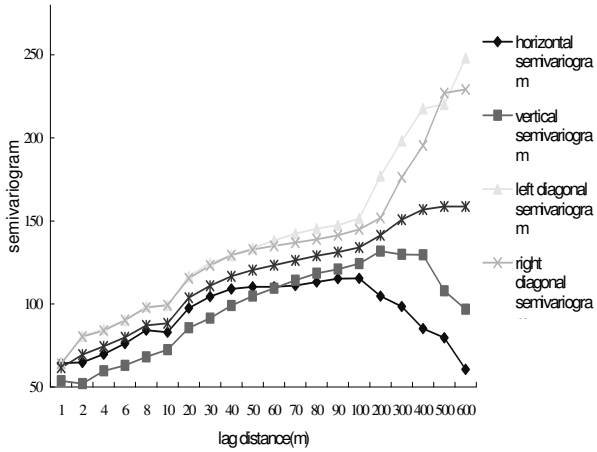

Figure4 farmland landscape experimental semivariogram

4. Conclusion and discussion

Changes in heterogeneity and pattern with scale are common to many ecological systems. With the development of landscape ecology theory and methods, the spatial pattern analysis become more and more important in explaining and predicting the ecology system behaviors. IKONOS Remote sensing, with the high spatial and spectral information, is a powerful tool that can use in many ecological systems research and sustainable management, particular in digital earth and precision agriculture application.

In the experiment area, city landscape and farmland landscape both has multi-scale pattern structure and different in each direction appearing on IKONOS PAN image. They all can be detected by the tap-4 Daubechies wavelet analysis. Semivariogram analysis only can discover the important overall pattern on the experiment area, although it can be used for different direction detection. The results of experimental areas prove the wavelet analysis method is a potential way for landscape pattern research.

Acknowledgements

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